OCEAN

METEOROLOGY.

12/-

Frontispiece

R.H. LAURIE 53, FLEET STREET LONDON

Alexr Findlay

A

TEXT-BOOK

OF

OCEAN METEOROLOGY,

COMPILED

FROM THE SAILING DIRECTORIES FOR THE OCEANS OF THE WORLD,

BY

ALEX. GEO. FINDLAY, F.R.G.S.

EDITED BY

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PREFACE.

In the course of delivering my annual series of Lectures on Ocean Meteorology, at the Royal Naval College, I have frequently been asked to recommend some Text-Book on the subject which would give a comprehensive view of the various Winds and Currents of the Ocean, and which—without, on the one hand, giving the details necessary for Sailing Directions, or, on the other hand, being a mere cram-book for examinations—should form a fitting introduction to this highly interesting and very important part of a Sailor's education.

Finding that the information in the Admiralty Sailing Directions was scattered through too many volumes for easy reference, and that the information in Findlay's Directories was too voluminous to answer the purpose, I proposed to the Proprietors of the latter well-known Works that they should issue, in a small volume, certain selected portions of those larger Works, and to these I have added various Notes from my own Lectures.

I have omitted almost all theoretical questions, and merely brought together material to illustrate what is the practical issue of the subject—the Art of making Passages from Port to Port.

I hope that this Book may prove useful for the purpose designed—of attracting more attention towards a somewhat neglected but highly useful branch of Naval education.

W. R. MARTIN.

Royal Naval College,
Greenwich.
September 30th, 1887.

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ERRATA.

Page	3,	line	4,	for	"moist" read "saturated."
	11,	,,	16,	,,	"diurnal circles" read "parallels of latitude."
	41,	,,	18,	,,	"diagram" read "Wind charts at end of book."
	42,	,,	3,	,,	"diagram adjoining" read "charts at end of book."
	51,	,,	1,	,,	"section" read "book."
	75,	,,	19,	,,	"diagram" read "charts at end of book."
	102,	,,	33,	,,	"chapter" read "book."
	177—186			,,	"The South Pacific Ocean—Passages," in headings of pages, read "PACIFIC OCEAN—PASSAGES."

OCEAN METEOROLOGY.

CHAPTER I.

THE ATMOSPHERE.

Introductory Remarks.

THE subject of Ocean Meteorology, or an examination of the prevailing Winds and Currents of the Ocean in their relation to Passages made from port to port, has always been one of the highest interest to the practical sailor; nor did that interest lessen with the introduction of steam-vessels of great speed, for though navigation became then less dependent on Winds and Currents, yet the competition at the same time introduced led to a closer examination of those circumstances under which the length of voyages could be shortened, even by a very small amount.

In the Royal Navy, in times of peace, most vessels-of-war, partly from their construction and partly from a necessary economy of coal consumption, can neither be classed with sailing vessels nor swift steamers; but, in time of war, circumstances will doubtless arise when passages will have to be made under conditions, similar to the Mercantile Marine.

The following pages are designed as a general introduction to the subject, in the hope that a sketch of the leading Phenomena of Ocean Meteorology may stimulate readers to pursue the study further, and add much-needed contributions to our stock of information on the points touched upon.

These points are very fully enlarged on in the various Directories for the different Oceans, to which the general reader desiring fuller information is referred.

As these larger Directories will be in the hands of those actually navigating a ship, the question of making Passages (which is the practical outcome of Ocean Meteorology) will here be illustrated by a description of only a few typical, and a few peculiar Passages over each of the Oceans.

As a science, based on well-established facts, Ocean Meteorology could hardly exist before the intelligent use of Barometers and Thermometers at sea,[1] or before the invention of the Chronometer and the consequent improvement in ascertaining a ship's position. In fact, it is only since the Brussels Conference of 1853, and the investigations of Maury, that really rapid progress has been made in assigning limits to Ocean Winds and Currents at different seasons of the year.

Before entering on the detailed description of these, a few pages will be devoted to noting some of the *general* characteristics of the Atmosphere, and of the Ocean.

THE ATMOSPHERE.

The Atmosphere, considered as an Aerial Ocean at the bottom of which we live, must be regarded as consisting of dry air and aqueous vapour intimately mixed, and both generally existing as invisible gases. Theoretically, this Atmosphere extends to a height of several hundred miles, but, practically, almost all Meteorological Phenomena occur below a height of about 10 miles.[2]

Weight.

In round numbers, 13 cubic feet of dry air weigh 1 lb. Av.,[3] and in all respects air follows the same laws as ordinary gases, the density being greatest near the surface of the earth, and decreasing upwards, so that at an elevation of 7 miles it is reduced to one-quarter, at 14 miles to one-sixteenth, and at 21 miles to one-sixty-fourth of what it is at the surface.[4]

Aqueous Vapour.

Aqueous Vapour also follows precisely the same laws, so long as it exists in the *gaseous* form. It is constantly given off from the surface of water at *all* temperatures, and even from snow and ice, mixing with the dry air in a proportion depending upon the temperature. Thus dry air at 32° F. can sustain, in an invisible form, a one-hundred-and-sixtieth part of its own weight of aqueous vapour, at 59° F. one-

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[1] The Barometer was invented in 1643, but not used at sea until 50 years later. The Thermometer appears to have been first used at sea in Anson's voyage.

[2] If a globe 16 inches in diameter be taken to represent the earth, the greatest known depth of the ocean and height of the highest mountain would be represented by a one-hundredth part of an inch, and the height of the Atmosphere, on a similar scale, by about one-fiftieth part of an inch.

[3] More accurately, 1 cubic foot at 32° F. weighs 563 grains, and at 90° F. 502 grains.

[4] In the celebrated balloon ascent by Glaisher, in 1862, at an elevation of 37,000 feet, the Barometer had fallen to 11·53 inches.

eightieth, and at 86° F. one-fortieth, its capacity being thus doubled every 27° F.[1]

It is important to observe that dry air is heavier than aqueous vapour, in the proportion of 8 to 5, and hence a cubic foot of *moist* air weighs less than a cubic foot of *dry* air at the same temperature.

Saturation.

The dry air of the Atmosphere must be regarded as constantly endeavouring to evaporate from any water-surface as much aqueous vapour as it can contain,[2] Saturation being defined as that point at which a volume of air contains the greatest possible quantity of aqueous vapour, and the Dew Point as that temperature at which the Aqueous Vapour begins to be precipitated as water.[3]

Dew Point.

In the *gaseous* form, aqueous vapour occupies about 2,000 times the space it does when condensed to *water*, and the frequent change from one form to another is a probable cause of many great atmospheric disturbances.

A *decrease* of temperature renders aqueous vapour visible as fog, clouds, or rain; but while present in the *gaseous* form, it only becomes *indirectly* apparent through the increased visibility of distant objects.

NOTE.—Careful analyses of the air show that out of every 100 parts by *measure*, Nitrogen forms 77·5 parts, Oxygen 21, Aqueous vapour 1·42 (on an average), and Carbonic Acid 0·08.

Evaporation.

Maury says:—The mean annual fall of rain on the entire surface of the earth is estimated at about 5 feet. To evaporate water enough annually from the ocean to cover the earth, on the average, 5 feet deep with rain; to transport it from one zone to another; and to precipitate it in the right places, at suitable times, and in the proportions due, is one of the offices of the grand atmospherical machine. This water is evaporated principally from the torrid zone. Supposing it all to come thence, we shall have, encircling the earth, a belt of ocean three thousand miles in breadth, from which this atmosphere evaporates a layer of water annually 16 feet in depth. And to hoist up as high as the clouds, and lower down again all the water in a lake 16 feet deep, and three thousand miles broad, and twenty-four thousand long, is the yearly business of this invisible machinery. What a powerful engine is the atmosphere! and how nicely adjusted must be all the cogs, and wheels, and springs, and *compensations* of this exquisite piece of machinery, that it never wears out nor breaks down, nor fails to do its work at the right time, and in the right way!

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[1] Hence it follows that in July there is more actual moisture in the air than in December.

[2] The annual evaporation at Greenwich is about 24 inches, but at the head of the Red Sea it is nearly half an inch *daily*.

[3] One cubic mile of air, at 95° F., containing as much aqueous vapour as possible, deposits 140,000 tons of water on being cooled to 32° F. It is estimated that if *all* the moisture in the Atmosphere were condensed, it would form a layer round the world about 5 inches deep.

THE BAROMETER.

The height of the Barometer affords a measure of the pressure on the surface of the earth exerted by the Atmosphere, such pressure being principally caused by the weight of the dry air.[1]

Barometers in general use at sea are either Mercurial or Aneroid, the former being the more accurate, and the latter the more sensitive.

Corrections.

Ordinary mercurial Barometers require four corrections to be made to their readings: (1) for *Capacity*, owing to the change of level in the cistern as the mercury rises or falls; (2) for *Capillarity*, owing to the depression of the mercurial column, caused by a *small* glass tube; (3) for *Temperature*, since all observations are reduced for comparison to a common temperature of 32° F.; and (4) for *Height* above sea-level.

In those supplied by the Meteorological Office, the first two corrections are made in the graduation of the instrument itself, and (3) is the only correction which practically requires consideration.[2]

Water Barometer.

Barometers are made with mercury as a fluid, since it does not give off sensible vapour at any ordinary temperature. A water Barometer would show atmospheric changes on a much larger scale, but at a temperature of 75° F. the pressure of the vapour in the tube above the water would depress its level one foot.[3]

Daily Changes.

Besides irregular changes caused by atmospheric disturbances, the height of the Barometer is subject to perfectly regular *daily* and *yearly* variations.

Within the Tropics the daily change is very marked, the Barometer rising, as a rule, from 4 a.m. to about 10 a.m., falling from 10 a.m. to 4 p.m., rising again until 10 p.m., and then again falling.

This curious movement is probably owing partly to changes of temperature and partly to different conditions of the moisture of the air. Though the *amount* of this daily change differs much in different localities, yet its regularity is such within the Tropics, that Humboldt observed that at any one

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[1] A pressure represented by a height of the Barometer of 30 inches may be considered made up as follows:—The pressure due to Nitrogen 23·36 inches, to Oxygen 6·18 inches, to Aqueous Vapour 0·44 inches, and to Carbonic Acid 0·02 inch.

[2] At 80° F. this correction is — ·138 inch, so that with this temperature at a place where the Wind and Current Charts showed a barometric pressure of 29·90, a Barometer on board would read 30·038. The mercury in a *Barometer* of course expands and contracts under the influence of change of temperature in the same way as in a *Thermometer.*

[3] At the South Kensington Museum there is a *glycerine* Barometer, 28 feet in length, the rise or fall of 1 inch in a *mercurial* column being represented by about 10 inches of the glycerine column.

place the time of day within 20 minutes could always be told from the height of the Barometer.

The daily change from highest to lowest may, within the Tropics (at sea), be considered as averaging ·08 inch.

Annual Change.

The annual variation in barometric pressure is much greater, and is probably due to the same two causes as the *daily* changes. The pressure is *less* in summer and *more* in winter, averaging ·10 inch over tropical seas, but over Central Asia causing the winter pressure to be as much as ·80 inch higher than the summer pressure.[1]

Permanent High and Low Pressures.

Apart from daily and yearly fluctuations, there are localities where barometric pressure is *permanently* higher and lower than in adjoining localities. Thus, at all seasons, low pressures are found over the Equatorial and Antarctic regions, and high pressures at the Tropics, especially in the middle of the great Oceans.

The value of the Barometer as an indication of Wind in high Southern latitudes has been the subject of much controversy. By many it has been considered as useless, but, as will be seen, this opinion is based on a comparison with its indications in the Northern Hemisphere. The mean of all observations of the height of the Barometer between the parallels of 55° and 60° *North* latitude is 29·85 inches, while in the same latitude in the South it is only 29·24 inches, a difference of six-tenths,—so low, that its fine weather monition in the South would be taken for a forerunner of a gale in the North. The mean height of the Barometer for the year, at Greenwich, is 29·956 inches, as reduced to the sea-level.

The low Barometer, especially in the Austral winter off Cape Horn, and in high South latitudes, had been the subject of universal remark, and this anomaly led the late Admiral FitzRoy to institute an inquiry into the actual condition of the Atmosphere by a wide comparison of the observations made. The results were not attained until after his death, and their main features are here given, as published by the Meteorological Department.

It has long been a well-known established fact that the average height of the Barometer diminishes from the Tropics towards the Poles, and the importance of obtaining Normal Barometric Heights for different parallels of latitude, pointed

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[1] The *mean barometric height* for the year at Greenwich is 29·956 inches, the highest recorded at that Observatory 30·790 inches, and the lowest 28·104 inches; two of the lowest records for the United Kingdom were 27·32 inches at Kilcreggan, near Glasgow, during a very heavy gale in January, 1884, and 27·41 inches at Barrow-in Furness on December 8, 1886.

In comparing the range of the Barometer for different *months*, it may be considered in lat. 50° N. to average 1 inch in summer, and 1¼ inch in winter; a range of 3 inches has been recorded in London, and 3½ inches at St. Petersburg; while at Christiansborg, near the Equator, during five years, the difference between the highest and lowest reading was only 0·47 inches.

out long ago by the Royal Society, has since been insisted on by many eminent meteorologists, more especially by the distinguished chief of the Meteorological Institute of Utrecht; but until the publication, in 1861, of Captain Maury's results, it was not supposed that the diminution of average barometric pressure in high Southern latitudes was so rapid or so uniform as it then appeared.

From nearly 7,000 observations of the Barometer, South of the parallel of 40°, Maury obtained the following average heights :—

						In.
Between 40° and 43° S.,	from	1,703	observations,	Barometer	=	29·88
Between 43° and 45° S.,	from	1,130	„	„	=	29·78
Between 45° and 48° S.,	from	1,174	„	„	=	29·63
Between 48° and 50° S.,	from	672	„	„	=	29·62
Between 50° and 53° S.,	from	665	„	„	=	29·48
Between 53° and 55° S.,	from	475	„	„	=	29·36
In 56½° S.,	from	1,126	„	„	=	29·29

To the Southward of 56° 30′, Capt. Maury appears to have had no observations, but he assumes that the average barometric pressure diminishes in higher latitudes in the same proportion, and concludes that at the South pole it is as low as about 28·14.

The low average height of the Barometer in high Southern latitudes was noticed by Sir J. C. Ross during his Antarctic expedition, and the low barometric pressure in the neighbourhood of Cape Horn has frequently been remarked.

Comparisons are made between the barometric heights at various places, by connecting on a chart by curved lines termed *Isobars* those having the same value at the period considered.

Direction of Wind.

The direction in which the wind blows is determined by the relative positions of regions of high and low pressure, the law governing such directions being known as Buijs Ballot's Law, from its discoverer, a distinguished Dutch Meteorologist. This law is as follows :—

For the Northern Hemisphere.	For the Southern Hemisphere.
Stand with your back to the wind, and the Barometer will be lower on your left hand than on your right.	Stand with your back to the wind, and the Barometer will be lower on your right hand than on your left.

In the Northern Hemisphere, whenever we are within or on the borders of an area of low barometrical readings, the wind blows round it *against watch hands*, and whenever we are within or on the border of an area of high readings, the wind blows round it *with watch hands*. In the Southern Hemisphere the converse is true in both cases.

Those Winds blowing round centres of *low* pressure are termed Cyclonic, and those round centres of *high* pressure anti-Cyclonic. In the former the wind generally curves *inwards*, and in the latter *outwards*, from these centres.

Cyclones and anti-Cyclones.

The *force* with which the wind blows is the chief consideration of the sailor, in connection with the study of the subject. This force is readily measured in a fixed Observatory, or on board a ship at anchor; but not so when she is under sail, as it is manifest that she is then apparently feeling more or less wind than is actually blowing, being drifted before it, or driven against it. We have some singular accounts of fine clipper ships scudding at an immense rate before a gale, which has been marked as of no extraordinary violence; while other ships, dull sailers, have been dismasted or disabled by the fury of the same gale, from their not being able to bear away before its great velocity. Therefore, the *recorded* force of such winds met with at sea should be subject to this qualification—what are the sailing powers of the ship which has recorded them? It is manifest that a vessel, and especially a steam-vessel, will estimate the force of the wind acting on her in exact proportion to the direction she is meeting it, or running before it. Thus, to a vessel of good sailing power going before a wind, which, while stationary, she would estimate as having the force of 4, if running 5 or 6 knots before it, it will appear only to have the force of a light breeze; while if a steamer went 10 knots against it, it would appear to blow with a force of 7, or as a fresh treble-reef topsail wind. We have no *standard* of sea-rates for the wind as yet. Perhaps it would add to the value of such observations, if the sailing powers of all ships engaged in adding to our knowledge were tested, when both close-hauled and running free with a wind of known velocity.

Wind Force.

The velocity or force with which the wind blows is measured at Meteorological Observatories by *Anemometers*, which are instruments generally constructed either on the principle of recording the revolutions made by horizontal vanes carrying hemispherical cups (such as Robinson's Anemometer), or by registering the *pressure* on a flat surface of known area (as in Osler's Anemometer), which is kept pointed to the wind.

Anemometers.

The average velocity of the wind at Greenwich is 10 miles an hour, corresponding to a pressure of about ½ lb. per square foot,[1] and it is considered that the average velocity over the open ocean is about 18 miles an hour.

[1] During a gale on October 14th, 1881, the velocity per hour registered at Greenwich was 61 miles, and the pressure 53 lbs. per square foot.

In Meteorological Observatories a *continuous* record of the direction, velocity, and pressure of the wind is obtained by adapting a pencil to the spindle of Robinson's Anemometer, or to the sensitive spring at the back of the pressure board in Osler's, which pencil presses against graduated paper rolled round a drum, caused by clockwork to make a complete rotation in 24 hours.

Beaufort Scale.

In former times the vague terms Breeze, Gale, Hurricane, &c., sufficed to describe the relative character of the wind. The late Sir Francis Beaufort devised a system of simple notation which more exactly defined these forces, and which is now in universal use at sea. The figures prefixed indicate the estimated character of the wind:—

(Beaufort Notation.)[1]

0. Calm.
1. Steerage way.
2. Clean-full from 1 to 2 knots.
3. ,, 3 to 4 knots.
4. ,, 5 to 6 knots.
5. With royals ("close-hauled").
6. Topgallant sails over single reefs.
7. Two reefs in topsails.
8. Three reefs in topsails.
9. Close reefed topsails and courses.
10. Close reefed maintopsail and reefed foresail.
11. Storm staysails.
12. Hurricane.

From 2 to 9 being supposed close hauled.

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Glaisher Scale.

The wind over the land is found to be generally of much less force and velocity than at sea, so that the Beaufort notation was found inconvenient for land purposes; Mr. Glaisher, therefore, has proposed another notation for this use, which is now adopted at Greenwich, Liverpool, and indeed at most of the principal Observatories. It divides the force into the numbers 1 to 6, which have been proportioned to the Beaufort Scale as follows:—

(Glaisher Notation.)

1. Moderate	(Beaufort Scale .... 1—2)	4. Heavy	(Beaufort Scale .... 7—8)
2. Fresh	(,, ... 3—4)	5. Violent	(,, ... 9—10)
3. Strong	(,, ... 5—6)	6. Tremendous	(,, ...11—12)

The relation between the force and velocity of the wind has been calculated by Sir W. Snow Harris, with an improvement of Lind's Anemometer; he found air moving 20 feet in a second presses on 1 square foot with a force of about 13 oz. avoirdupois, or at 50 feet per second it would support a column of water 1 inch high, the pressure force increasing very nearly with the square of the velocity. With these data the following table has been calculated:—

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[1] In addition to the *figures*, showing the force of the wind, the state of the weather is to be understood by *letters*, as follows:—

Letters indicating the State of the Weather (Beaufort Notation).

b	Blue Sky.	m	Misty.	u	Ugly (threatening) appearance of Weather.
c	Clouds (detached).	o	Overcast.	v	Visibility. Objects at a distance are unusually visible.
d	Drizzling rain.	p	Passing Showers.	w	Wet (Dew).
f	Foggy.	q	Squally.		
g	Gloom.	r	Rain.		
h	Hail.	s	Snow.		
l	Lightning.	t	Thunder.		

NOTE.—A bar (—) or dot (.) under any letter augments its signification:—thus $\underline{f}$ very foggy, $\underline{r}$ heavy rain, $\underset{\odot}{\underline{r}}$ heavy and continuing rain, &c., &c.

TABLE,

Showing the Force and Velocity of the Wind from light Airs to heavy Gales and Tempests.

Pressure in lbs. on Square Foot.	Velocity.		Popular Descriptions.
	Feet per Second.	Miles per Hour.	
0 002	1	0.68	Gentle airs (unappreciable by guage). (*Beaufort Scale*, 1.)
0.004	1.47	1	
0.019	3	2	Light airs (just appreciable by guage); would fill the lightest sail of a yacht (2).
0.032	3.9	2.66	
0.043	4.5	3	
0.065	5.28	3.8	Light breezes, such as would fill tho lightest sails of a large ship (3).
0.071	5.87	4	
0.090	6.6	4.5	
0.100	6.98	4.75	
0.112	7.34	5	
0.130	7.89	5.38	
0.162	8.8	6	
0.228	10.4	7	
0.260	11	7.6	
0.291	11.8	8	Moderate breezes, in which ships can carry all sail (4).
0.364	13.2	9	
0.390	13.6	9.27	
0.452	14.7	10	
0.521	15.8	10.77	
0.551	16.2	11	
0.650	17.66	12	
0.780	19.3	13	Fresh breezes,—topgallant sails and royals (5).
0.830	20	13.6	
0.884	20.6	14	
0.910	20.9	14.25	
1.042	22	15	
1.170	23.6	16	
1.250	24.2	16.5	
1.302	25	17	Fresh winds; reefs (6).
1.470	26.5	18	
1.563	27.39	18.67	Strong winds; treble-reefed topsails (7).
1.630	28	19	
1.790	29.35	20	
2.084	31.15	21.47	Gales; close-reefed topsails and reefed courses (8).
2.600	35.32	24	
3.126	38.73	26.40	Strong gales; close-reefed topsails and stay sails (9).
3.647	41.83	28.52	
4.168	44.83	30.56	
4.689	47.44	32.34	
5.200	50	34	
7.800	61.18	41	Heavy gales and storms (10).
10.400	70.72	48.2	
13.000	79.07	53.91	
20.800	100	68.18	Very heavy gales; great storms; tem pests (11).
26.000	111.74	76.18	
31.200	122.62	83.6	
41.600	141.30	90.34	Tornadoes; cyclones; hurricanes (12).
52.000	157.98	107.7	
62.400	173.06	120	

NOTE.—Such different results are obtained, especially in high winds, with different forms of Anemometers, that they are at present regarded as only giving *approximate* results.

Law of Gyration.

The wind decidedly *veers* round the compass according to the sun's motion, *i.e.*, in Northern latitudes, from North through N.E., East, S.E., to South, and so on, often making a complete circuit in that direction, or more than one in succession (perhaps occupying many days in so doing), but it rarely *backs*, and very rarely, or never, makes a complete circuit in the contrary direction. This has been shown by Professor Dové to be the direct consequence of the rotation of the earth; and, although the observation was recorded by Lord Bacon, in 1600, it is now known as *Dové's Law of Gyration.*

For similar reasons, in Southern latitudes the natural shifts of wind are from North through N.W. and West to South and so on.

This veering and backing of the wind is however, in the case of Cyclonic and anti-Cyclonic winds, dependent upon the position of an observer with regard to the *centre* of disturbance.

GENERAL WIND SYSTEMS.

The principal *general* Winds of the world may be classified as Trade Winds, anti-Trades or Passage Winds, Monsoons, and Land and Sea Breezes.

Trade Winds.

The region of the Trade Winds occupies nearly one-half of the entire surface of the globe. From their constancy and regularity they form by far the most important part of the circulatory system of the atmosphere, although generally their strength is inferior to many of those smaller but compensating currents which are experienced in extra-Tropical regions.

In the year 1686, Edmund Halley proposed the theory of the Trade Winds and Monsoons, which is now generally received as an approximation to the true solution. He afterwards modified his views, which were revised and extended by George Hadley, in 1735. The following is a brief summary of them:—

The sun is constantly vertical over some part of the earth between the Tropics, and this zone is consequently maintained at a much higher temperature than the regions nearer the Poles. This heat on the earth's surface is imparted to the air, which is, therefore, displaced and buoyed up from the surface,[1] and the colder, and therefore heavier air from without glides in on

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[1] 491 cubic feet of air at 32° F. expand to 492 feet at 33° F., and contract to 490 feet at 31° F.

both sides along the surface; while the displaced air, thus raised above its due level, and unsustained by any lateral pressure, flows over, as it were, and forms an upper current in the contrary direction, or towards the Poles; this being cooled in its course, and also sucked down to supply the deficiency in the extra-Tropical regions, keeps up thus a continual circulation.

Since the Equator revolves much more rapidly than the portions nearer the Poles, it follows, that a mass of air flowing towards the Equator must be deficient in rotary velocity, and, therefore, unable to keep up with the speed of the new surface over which it is brought. Hence these currents from the North and South must, as they glide along the surface, at the same time lag or hang back, and *drag upon* it in the direction *opposite* to the earth's rotation, *i.e.*, from East to West. Thus, from simple Northerly and Southerly winds, they become permanent *North-easterly* and *South-easterly winds*.

The velocity of rotation of the earth is 1,036 miles an hour at the Equator, 897 miles in lat. 30°, and 518 miles an hour in lat. 60°.

The lengths of the diurnal circles increase very slowly near to the Equator, and for several degrees on each side of it hardly change at all. It follows from this, that as these winds approach the Equator, their Easterly tendency must diminish, and at the Equator they must be expected to lose their Easterly character altogether. And not only this, but the Northern and Southern currents, here meeting and opposing, will mutually destroy each other, leaving only the actions of local causes, which may lie in one region in one way, and in another in a different one.

The result of this, then, is the production of two great Tropical Belts of North-easterly and South-easterly winds, while the winds in the Equatorial Belt which separate the two should be free from any steady prevalence of an Easterly character, and should also be comparatively calm. All these consequences are agreeable to observed fact, and constitute the system of the regular *Trade Winds*.

The constant friction of the earth upon the air near the Equator, it may be objected, would, by degrees, destroy the rotation of the whole mass; but it is compensated in this manner: the heated Equatorial air, rising and flowing off toward the Poles, carries with it a rotatory velocity much greater than that of the surface over which it passes in its Northward and Southward progress. Hence it will gain more and more on the surface of the earth, and assume more and more a *Westerly* relative direction; and when, at length, it necessarily returns to the surface in its circulation, which it must do, more or less, in all its course, it will act on it by its friction as a powerful S.W. wind in the Northern Hemisphere, and as a N.W. wind in the Southern, and thus restore the equilibrium. This is the origin of the S.W. and Westerly gales so prevalent in our latitudes, and of the almost universal Westerly winds in the North Atlantic.

The existence of this upper return current of air is manifested by the frequent movement in the Tropics of the upper clouds in an opposite direction to that of the surface wind, and also by the records of travellers who, having ascended such mountains as Tenerife and Mauna Loa, have actually risen *above* the Trade Wind region, and entered that of the return current.

Upper Currents.

Well-authenticated cases are also extant of volcanic eruptions in Tropical countries having projected the ashes above the limits of the Trade Wind to fall again on the surface of the earth, at places very far to windward of where the eruption occurred.

On the Polar sides of these Trade Winds are found, as before remarked, broad belts extending to the limits of navigation, where in the Northern Hemisphere the prevailing wind is from S.W., and in the Southern Hemisphere from N.W.; the larger proportion of land in Northern latitudes prevents these winds (known as the anti-Trade or Passage Winds) from being so well developed there as in Southern latitudes.

Anti-Trades.

Separating the Trade Wind and anti-Trade Wind regions are narrow Belts of Calms known as the Calms of Cancer and Capricorn.

Tropical Calms.

The N.E. and S.E. Trades blowing towards each other, meet and are neutralized near the Equator. This neutral line of Calms and varying winds is sometimes known by the name of the "Doldrums," an uncouth term, which, we think, has had unmerited notoriety given to it. It is, perhaps, a corruption of the Spanish *doloroso*, or old Portuguese *doloris*, "tormenting."

Doldrums.

If the surface of the earth were evenly covered with land or water, or a combination of both, the phenomena of the Trade and anti-Trade Winds would form symmetrical zones around the globe; but the relative proportions are very different in the two Hemispheres, being 100 land to 150 water in the Northern, and 100 to 628 in the Southern.[1] There is a still greater contrast, if we take the rational horizon of London as a great circle dividing the earth into two Hemispheres. It will be then seen that London is in the centre of that half which includes all the land, except Australia; and the other half includes almost all the water of the globe. From this cause the line of meeting between the N.E. and S.E. Trades is in all seasons *Northward* of the Equator.

Maury says, "This region of Doldrums has a mean average breadth (around the globe) of about 6 degrees of latitude. In this region, the air which is

[1] The dry land of the whole world, as far as it is known, is estimated to occupy 49,806,000 square statute miles. If this is increased to 51,000,000 for the unknown Polar regions, it will allow 146,000,000 of square miles to be covered by the ocean.—*Sir J. Herschel.*

brought to the Equator by the N.E. and S.E. Trades ascends. This Belt of Calms always separates these two Trade Wind zones, and travels up and down with them. If we liken this Belt of Equatorial Calms to an immense atmospherical trough, extending as it does entirely around the earth; and if we liken the N.E. and S.E. Trade Winds to two streams discharging themselves into it, we shall see that we have two currents perpetually running in at the bottom, and that, therefore, we must have as much air as the two currents bring in at the bottom to flow out at the top. That which flows out of the top is carried back North and South by these upper currents, which are thus seen to flow counter to the Trade Winds."

This Belt of Calms follows the sun in his annual course, though the limits do not range so much in latitude as the sun does in declination; and generally, they pass from one extreme of latitude to another in about three months. The whole system of Wind and Calm Belts moves Northward from the latter part of May till some time in August; they then remain almost stationary till the approach of winter, when they commence to go Southward, and proceed in that direction from December to February or March.

"The great '*sun swing*' of this Calm Belt," says Capt. Maury, "is annual in its occurrence; it marks the seasons, and divides the year into wet and dry for all those places within the arc of its majestic sweep. But there are other subordinate and minor influences which are continually taking place in the atmosphere, and which are also calculated to alter the place of this Calm Belt, and to produce changes in the thermal status of the air which the Trade Winds move. These are unusually severe winters or hot summers; remarkable spells of weather, such as long continuous rains or droughts, over areas of considerable extent. Either within or near the Trade Wind Belts it is tremblingly alive to all such influences, and they keep it in continual agitation; accordingly we find that such is its state, that, within certain boundaries, it is continually changing place and limits. This fact is abundantly proved by the speed of ships, whose log-books show that it is by no means a rare occurrence for one vessel, after she has been dallying in the Doldrums for days, in the vain effort to cross that Calm Belt, to see another coming up to her 'hand over fist,' with fair winds, and crossing the belt after a delay in it of only a few hours instead of days."

These remarks of Capt. Maury, coupled with the experience of most sailors who cross the Line, will demonstrate that the limits of this Calm Belt cannot be very exactly defined, and it is to a great extent uncertain when any particular ship will lose the Trades, and encounter these Doldrums, although of late years this subject has been considerably elucidated by the labours of Captain Toynbee.

A consideration of the chart and the shifting of this Belt will explain how it is that some places have two rainy seasons and others only one, by the passing of the cloud ring over them.

"This ring is broader than the Belt of Calms out of which it arises. As the air with its vapours rises up in this Calm Belt and ascends, these vapours are condensed into clouds, which overflow the Calm Belt as it veers both to the North and South. The air, flowing off in the same direction, assumes the character of the winds which form the upper currents counter to the Trade Winds. These currents carry the clouds still farther to the North and South, and thus make the cloud ring broader. At least, we infer such to be the case, for the rains are found to extend into the Trade Winds, and often to a considerable distance North and South of the Calm Belt."

This oppressive region, most tedious to navigators, is, however, not at all times subject to this great amount of deposition, which has procured for it the appellation of "*The Rains;*" and especially during the winter months, when its extent is more limited, it may be crossed without encountering either those torrents of rain, or almost unbearable calms. This compensating belt to the evaporation of the Trades, of course, is subject to squalls, and especially to thunder-storms, the natural result of the conflicting elements. Altogether, its effect on the health and spirits, its enervating influences, its oppressive and damp heat, make it one of the most unpleasant parts of the surface of the globe.

The Monsoons.

The alternating winds which are met with to the Northward of the parallel of 10° South in the Indian Ocean have one general tendency. They blow toward the vertical sun. When the sun is North of the Equator, and is vertical over the plains of Asia and Africa, which are thus heated, the currents of air move Northwards, to compensate for the upward currents which are put in motion by this increased heat of the surface of the earth. Another cause is also to be traced by the effects. In the passage of these Southerly Winds over an expanse of ocean they become charged with vapours, which, when encountering the opposing forces of the Northerly winds which recede before them, deposit their vapours in that copious Tropical Rain, well known to occur in most places at the change of the Monsoons. This process has been well argued out by Mr. Hopkins, of Manchester, as occurring in many parts of the globe, and this theory, combined with other considerations, will well account for the constancy and regularity of these changing winds which, for six months alternately, blow first in one direction, and then in the opposite, with more distinct characteristics in the Indian Ocean than in any other part of the world.

It must not be supposed, however, that this rule of a Southerly or Northerly wind is universally applicable. There are many modifications of this simplicity, and the disturbances occasioned by the heated land cause many variations from it.

Generally the different winds adapt themselves to the direction of the coasts along which they blow, and the mountain chains which interfere with a straight-forward course either extinguish them entirely, or divert them into a fresh channel.

The Change of the Monsoons takes place at the Equinoxes, or at the period when the sun crosses the Equator, but is not exactly coincident. Like other natural phenomena, as with the Tides, to which these six months Aerial Tides may be compared, some interval elapses between the cause of action and the appearance of the effect.

The principal regions where Monsoons are experienced are:—The Indian Ocean, China Sea, West Coast of Africa, Brasil, and Mexico.

Land and Sea Breezes.

The Alternation of the Sea and Land Breezes in warm latitudes is an important feature in coast navigation, and its cause is generally well understood. It is owing to the different powers of radiation and absorption of heat possessed by land and water, so that, generally, when the day temperature is highest on the land, the stronger will be the alternating breezes. During the day the radiation of the sun's heat on the land causes the air to expand and rise from the surface, and then the sea air rushes in to fill the void. It frequently occurs that the surface of the soil will show a temperature of 120° under the meridian sun, and sink to 50° or 60° during the night; while the sea, rarely having a higher temperature than 80°, and from being a bad radiator fluctuating but very little, it follows that it is alternately warmer and colder than the land, and hence the phenomena in question. The minimum temperature of the twenty-four hours occurring at a little before sunrise, and the maximum about 2 p.m., the change of these breezes comes generally at some little time after those hours.

Note.—The above theory of Land and Sea Breezes does not satisfactorily account for the known fact that the Sea Breeze always sets in first in the offing, and not on the coast.

Professor Laughton accounts for the Sea Breeze by the excess of barometric pressure seaward owing to evaporation, and for the Land Breeze by the descent of the column of air forced up by the Sea Breeze.

It is to be remarked that *both* Land and Sea Breezes are only well developed on coasts backed by hills.

MOISTURE OF THE ATMOSPHERE.

The Moisture of the Atmosphere, or Aqueous Vapour contained in it, has already been alluded to (pp. 2, 3). Under certain circumstances this becomes apparent as Dew, Fog, Cloud, or Rain, all of which are different manifestations of the same phenomenon. The principal source of this moisture is the Ocean, the air immediately over which is, almost always, nearly saturated.

The *sensations* of dampness and dryness depend not upon the *absolute* but *relative* amounts of aqueous vapour in the air. Thus, as before stated, there is absolutely more in the air in July than in December; but if the number 100 represents saturation (which depends upon the temperature), then at Greenwich, in July, the *relative* amount of moisture is 72, and in December 88.

Relative and Absolute Humidity.

At Observatories the condition of moisture of the air is tested by an instrument termed the Hygrometer, but at sea it is more usual to obtain this from the Wet and Dry Bulb Thermometer, which really gives the rate of *evaporation* at the time, from which the relative humidity is easily found.[1]

Hygrometer.

Dew is an effect of the more or less rapid chilling of the surface of the earth after sunset, causing the air immediately above it to be cooled to that temperature when it can no longer support the same amount of aqueous vapour as before. This temperature has been previously defined as the Dew Point.

Dew.

In England, during ordinary fine weather, the difference between the temperature of the air and dew point is from 10° to 15° F., a difference of 20° being rare. In the dry parts of India a difference of 61° F. has been observed, and as much as 78° F. in parts of California.

Fog is produced wherever masses of saturated air are chilled. Thus, the early winter Fogs over the Thames are caused by the fact that the river is then at a much higher temperature than the adjoining land, which colder surface chills the saturated and warm air drifting over it.

Fog.

The effect of the *cold* air lying over many Alpine rivers acts in the same way, in chilling warmer air lying over the land through which they pass, when, if that air is sufficiently laden with moisture, Fog ensues.

On a more extended scale we find in the North Atlantic Ocean that the air resting over the cold Arctic Current, flowing over the Newfoundland Banks, often differs 30° F. in temperature from that over the contiguous Gulf Stream, the result being that the warm vapour-laden air over the latter is condensed into the well-known Newfoundland Fogs.[2]

Clouds may be regarded as Aqueous Vapour existing in a greater state of condensation than is exhibited in Fogs.

Clouds.

Since the discovery of Buijs Ballot's Law (page 6), and of

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[1] The temperature shown by the *wet* bulb will be intermediate between that of the air and the Dew Point. At 53° F. (by the wet bulb) the Dew Point is as much *below* the wet bulb as that is below the dry bulb; at *higher* temperatures the Dew Point is nearer the wet bulb than that is to the dry bulb, and vice versâ for *lower* temperatures.

In Dines' Hygrometer, which is much employed at Observatories, a surface of glass is gradually cooled by means of a stream of water running under it, and the temperature is taken when dew forms on its surface.

[2] Instances are known of Fogs over the South Coast of Newfoundland never having even lifted for six weeks together.

the Cyclonic and anti-Cyclonic gales of extra-Tropical latitudes, the study of the Clouds has assumed a new importance.

The following remarks were made at a lecture delivered in November, 1878, by the Rev. W. Clement Ley, M.A., F.M.S., who has for many years devoted his spare time to the study of this subject. "In the first place it requires a practised eye for Cloud observations, and this no person has a better chance of acquiring than the seaman. There is at present not enough known of the subject to lay down any very reliable rules, but in the case of storms which pass over the British Isles it is observed that the advancing half of the storm first shows a band of *Cirro-stratus* around its semi-diameter; this is followed by a bank of *Nimbus* or rain Cloud; *Cumulus*, accompanied by showers, follows with the succeeding half of the storm, and behind this, *Cirrus* and *Stratus*. Outside the area of high wind, on the left side of the advancing storm, the weather is dry and hazy. Another remarkable feature is the direction taken by the higher Clouds: for instance, with the wind in one of these storms blowing on the observer's back, the Clouds high in the Atmosphere indicate that the direction of the wind is from left to right of the observer, which would seem to show a rising of the wind in a spiral form."

"The researches of Mohn, Hildebrandsson, Buchan, Clement Ley, and others, seem to prove that in all cases which they have investigated by means of wind direction and the motion of *cirri*, the air flows spirally into an area of low pressure at the surface of the earth, and to some extent out from it in the upper regions of the air; whilst the order is reversed with areas of high pressure, the lower air flowing *out from*, and the upper air *in towards*, their centres. It remains to be proved whether the same law holds good with regard to the area of high pressure in the centre of the Atlantic. . . . It must be remembered that there are upper currents of air which (owing to the absence of moisture) do not carry Clouds along with them, and that they need some other means than Cloud motion to detect them."—*Capt. Henry Toynbee.*

Mr. Ley also considers that the classification of the late Mr. Luke Howard, which has been in use for many years, is not suitable for the present state of weather knowledge. Without materially altering the old nomenclature, Mr. Ley is of opinion that the Clouds may be divided into Upper and Lower Clouds, or those high in the Atmosphere, such as *Cirrus*, *Cirro-cumulus*, and *Cirro-stratus*, and those nearer the earth's surface, including *Stratus*, *Cumulus*, *Cumulo-stratus*, and *Nimbus*.[1]

Clouds are seen at all levels between the highest *Cirrus* and the lowest *Stratus*, so that it is often difficult to determine whether a particular sheet or

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[1] In abbreviating these names the following system is used by the Meteorological Office, as others have been found to mislead:—Cir.; Cir. c.; Cir. s.; Str.; Cum.; Cum. s.; Nim. The amount of Cloud is registered from 0, "Blue sky," to 10, "Entirely overcast."

layer of Cloud belongs to the upper or the lower system. In such cases the observer will be greatly assisted by remembering how the Clouds have become formed, whether by the gradual subsidence of the highest forms, or by the ascent of the Lower Clouds.

In the Trade Wind region, by observing the direction of the Upper Clouds, it would appear that an opinion may be formed of the probable direction of the squalls in unsettled weather.

Upper Clouds.

The Upper Clouds are considered by a good authority to be composed of particles of Ice, inasmuch as the phenomena of halos, &c., are produced by them, and these can only be explained by the refraction of the rays of light through ice crystals.

The *Cirrus* is often seen after a continuance of fine light weather, as a thin whitish line of Cloud, stretched across the sky at a great height, the ends seeming lost in the horizon. This is often the first indication of a change to wet weather; to this line of Cirrus others are added laterally, and at times Clouds of the same sort seem to proceed from the sides of the line, and are sent off in an oblique or transverse direction, so that the whole may have the appearance of net-work.

At other times the lines of Cirrus become denser, descend lower in the Atmosphere, and, by uniting with others below, produce rain. The line alluded to above is called the *Linear Cirrus*, and the transverse lines produce the *Reticulated* or *Curl Cloud.*

The *Comoid* or *Hairy Cirrus*, commonly called *Mare's Tail*, is the proper Cirrus; it resembles, in appearance, a long lock of white hair, or a bunch of wool pulled out into fine pointed ends. The appearance of Cirrus in the Atmosphere often indicates wind and rain; and when the fine tails have a constant direction towards any one point of the compass, it has been frequently observed that the gale has sprung up from that quarter to which they previously pointed. It is often difficult to ascertain the direction of the *Cirrus*, owing to its slowness of motion, but as indicating the difference between the direction of the wind at the earth's surface, and that of the higher regions, it is very important.

Lower Clouds.

The Lower Clouds are usually composed of particles of condensed vapour or "bubble-steam," *i.e.*, of water, not of ice; when they are interposed between the sun and the moon, they dim or intercept the light entirely, without giving rise to *halos* or *coronæ.* They may be described as follows:—

The *Cirro-cumulus* (Cirrus and Cumulus) is an assemblage of *Nubeculæ*, or small roundish Clouds, either detached from, or in contact with, each other, and frequently reaching, apparently, into the azure sky, commonly attended by an increased temperature, and found to accord with a rising Barometer. The most striking feature is observed in summer, before or about the time of thunder-storms. The component nubeculæ are then very dense, round in form, and in closer apposition than usual. This kind of Cloud is so commonly a forerunner of storms, that it has been assumed by some as a tempestuous prognostic. In rainy and variable weather another variety of this Cloud appears, contrasted very strikingly with that above mentioned, being of a light fleecy texture, without any regular form in its nubeculæ. Sometimes the latter are so small as scarcely to be discernible, but the sky seems speckled with innumerable little white transparent spots.

The Cirro-cumulus of fair summer weather is of a medium nature, not so dense as the stormy variety, nor so light as the variable one. Its nubeculæ vary in size and proximity. In fine dry weather, with light gales of North and Easterly winds, small detachments rapidly form and subside again, generally in a horizontal arrangement.

When the Cirro-cumulus prevails, we may anticipate an increase of temperature in summer; and in winter the breaking up of a frost, or warmer and wet weather. In the summer time, extensive beds of this Cloud, viewed by moonlight, have a very beautiful appearance, which has been compared to a flock of sheep at rest. The Cirro-cumuli subside either slowly, as if by evaporation, or change into some other modification.

The *Cirro-stratus* (Cirrus and Stratus) or *Wane Cloud*, is composed of horizontal or slightly inclined masses of small Clouds, attenuated towards a part or the whole of their exterior, bent downward or undulated, separate or in groups, and generally with a sinking Barometer, indicating a decrease in temperature, with wind and rain, or snow.

The Cirro-stratus is characterised by great horizontal extent in proportion to vertical breadth ; so that when any other Cloud begins to assume that form, it generally ends in Cirro-stratus. The Cirrus more commonly becomes a Cirro-stratus than any other Cloud; the Cirro-cumulus next; and then the Cumulus. The Cirro-stratus, once formed, sometimes resumes the modification from which it originated, but more frequently it gradually evaporates or conjoins with some other modification. It seldom remains long in one form, but seems to be constantly declining, and hence the term of *Wane Cloud*. It is sometimes composed of wavy bars or streaks, connected in the centre and confused, but the streaks more defined at the edges; this is common in variable weather in summer. The *Mackerel Sky*, as it is termed, is a variety of this ; another variety consists of one long and plain streak, thick in the middle, and wasting away at its edges ; and a third, consisting of small rows of little Clouds, curved in a peculiar manner, and a sure indication of stormy weather; this is more or less regularly formed, and the irregular formation is often produced when a large Cumulus passes under a long line of Cirro-stratus, which is also a sign of stormy weather.

The last variety of Cirro-stratus is a large shallow veil of Cloud, which extensively overspreads the sky, particularly in the evening and during the night, and through which the sun and moon appear dimly. It is in this Cloud that those peculiar refractions of light, of the sun and moon, called *halos, mock suns*, &c., usually appear, and which are tolerably certain prognostics of rain or snow. There are minor varieties which may frequently be observed.

The Cirro-stratus usually terminates in forming an intimate union with some other Cloud, to produce rain; but at times it evaporates or changes into some other modification.

The *Stratus* comprehends fogs and all those creeping mists which in summer evenings fill the valleys, but disappear in the mornings. The best time for observing its formation is on a fine evening, after a hot summer's day; we shall then observe that, as the Cumuli of the day decrease, a white mist forms near the ground; this Cloud, as the Cumuli evaporate, by degrees arrives at its greatest density. In autumn it remains longer in the morning. In winter it often puts on a still denser appearance, and remains during the day, and even for many days successively.

The *Nimbus* always precedes a fall of snow, rain, or hail, and has received its name from a notion of the ancients, who distinguished between the *Imber*, or shower, and the *Nimbus*, or Cloud, from which the rain comes.

The *Cumulus* (plural *Cumuli*).—The progressive formation of the Cumulus is seen in fine settled weather. If we then observe the sky soon after sunrise, we shall see small Clouds here and there in the Atmosphere, which appear to be the result of small gatherings, or concentrated parts of the evening mist, which, rising in the morning, grow into small masses of Cloud, and the Atmosphere becomes clear. As the sun rises, these Clouds become larger, by adjacent ones coalescing, and at length a large Cloud is formed, assuming a cumulated irregular hemispherical shape; this usually subsides in the evening as it is formed in the morning, breaking into small masses, then fragments, and evaporating, when it is succeeded by the Stratus, to the formation of which it may have contributed. In fine weather these Clouds form soon after sunrise, increase during the day, and subside with more regularity, and have a more hemispherical form than in changeable weather. When well-formed Cumuli prevail for three or four days, the weather is settled. These Cumuli reflect a strong silvery light when opposed to the sun, like Alpine mountains covered with snow.

The Cumulus sometimes takes a cylindrical shape, forming itself into long horizontal rolls, between which gleams of light are seen, but which are often so closely packed as to hide the blue sky. These are called *Roll-cumulus*. This variety of Cumulus is an addition to Howard's nomenclature. It is inserted owing to the frequency of this appearance at sea. It is necessary to observe that the effect is simply one of perspective.

The *Cumulo-stratus* designates the Cirro-stratus blended with the Cumulus, and either appearing intermixed with the heaps of the latter, or super-adding a wide structure to its base. The Cumulo-stratus is most frequent during a changeable state of the Barometer, when the wind blows from the West with occasional deviations from the North and South.

This Cloud may be always regarded as a preliminary to the production of rain, and it frequently forms in the following manner:—the Cumulus, which in common passes along in the current of the wind, seems retarded in its progress, increases its density, spreads out laterally, and at length overhangs the base, in dark and irregular protuberances. The change to the Cumulo-stratus often takes place at once in all the Cumuli which are near to each other; and, their bases uniting, the superstructure rises up with mountain-like or ragged summits. The change from Cumulus to Cumulo-stratus is often preceded by Cirro-stratus.

Cumulo-strati vary in appearance; those in which hail showers and thunderstorms form look extremely black before the change to rain, and have a menacing aspect, as they are seen coming slowly up with the wind. The Cumulo-stratus sometimes evaporates or changes again into Cumulus; but in general it ends in the Nimbus, and fall of rain or snow. Sometimes only one part forms a Nimbus, the other remaining a Cumulo stratus.

Nimbus.—Any of the modifications above described may increase so much as to obscure the sky, without ending in rain; before which the peculiar characteristic of the rain-cloud may always be distinguished. In order to get a clear idea of its formation, you may observe a distinct shower in profile, from its formation to its fall in rain. You may then observe the Cumulus first arrested, then the Cirro-stratus or Cirrus may appear to alight on its top; the change to Cumulo-stratus then goes on rapidly, and this Cloud, increasing in density, assumes that black and threatening appearance known as an indication of rain. Presently this blackness is changed to a grey obscurity, and this is the criterion of the actual formation of water, which now begins to fall, and constitutes the Cloud a *Nimbus*, while a Cirriform crown of fibres extends from the upper part of the Clouds, and small Cumuli enter into the lower part. After the shower has spent itself, the Cloud resumes its character of Cumulo-stratus, and thence probably changes into a different modification; if Cumulo-strati appear again, they indicate a return to rain.

Rain.

Rain occurs when the Aqueous Vapour in the Atmosphere is condensed into actual water. This result is brought about in various ways, but generally either (1) as in the Doldrum Region, where volumes of hot saturated air are daily raised by the warmth of the sun into the colder upper regions of the Atmosphere; or, (2) where a high range of mountains lies across the direction in which warm saturated air is being driven by the wind, and causes it to be similarly forced into upper, and therefore colder, regions.[1]

[1] This is well illustrated by the Rainfall at Cherrapunji, in Assam, about 300 miles

Rainy Regions.

The principal Rainy Regions of the globe are :—The Doldrums; Norway; the West Coast of Patagonia; both Coasts of India; and the West Coast of New Zealand.

Rain Guage.

The amount of Rainfall is measured at Observatories by the Rain Guage, where the depth of water falling over the known area of the instrument is carefully measured.[1]

One day's heavy continuous rain in England represents about one inch of uniform depth of water, or a fall of 60,000 tons on a square mile.

About 10 inches depth of snow is equivalent to 1 inch of rainfall.

Rainless Regions.

Rainless Regions occur either (1) where no large expanse of water is near, from which the air can obtain moisture, as in deserts; (2) where the prevailing direction of the wind is *along* a coast, and not at right angles to it, as illustrated on the Coast of Peru; or, (3) in the open Ocean, where the air as it is saturated is borne along by the wind, and succeeded by other and drier portions: this is illustrated by the Trade Wind regions.

The chief Rainless Districts of the world are :—Egypt; Central North Africa; Arabia; Central Asia; Central Australia; Peru[2]; and the Trade Wind regions.

Rainfall in Great Britain.

The average annual Rainfall (mean of 40 years) at Greenwich is 25 inches, of which the maximum average monthly fall (2·94 inches) occurs in October, and the minimum (1·45 inch) in March.

The average number of rainy days[3] in the year is 152, of which fewest (12) occur in June, and most (18) in July, August, or December.

The Rainfall on the West Coasts of Ireland and Scotland is from 60 to 80 inches (Saltash gives 54 inches), compared with an average of 20 inches on the East Coast of England.

Thirty per cent. of our rainy days are coincident with S.W. winds.

The maximum Rainfall in Great Britain occurs at Scaithwaite, in Borrowdale, Cumberland, where, at an elevation of 422 feet, the annual Rainfall is 154 inches.

N.E. of Calcutta, where the S.W. Monsoon, laden with moisture, strikes at right angles against mountains 4,000 feet high, the result being an *average* annual rainfall of 493 inches, of which 325 inches fall in June, July, and August. In 1861, 905 inches of rain fell, and during the single *month* of August, 1841, 264 inches fell, on each of five successive days in that month 30 inches fell; the *greatest daily* rainfall was 41 inches on June 14th, 1876. This is the place of greatest known rainfall.

[1] The Rain Guages used by the Meteorological Office are funnel-shaped, circular, and 8 inches in diameter, the rain falling over this surface being collected in a graduated bottle underneath.

[2] At Lima it is said that rain fell only four times during the 18th *century*.

[3] Days on which $\frac{1}{100}$th inch of rain fell.

The experiments of Tyndall prove the very great effect of the Aqueous Vapour of the Atmosphere on the Climate of a place. Perfectly dry air allows the heat of the sun to pass through it without practically absorbing any, and similarly affords, after sunset, an equally ready passage into space of the heat radiated from the earth's surface. This accounts for the extremes of night and day temperatures in very dry regions, such as the plains of Central Asia and America.

Effect of Aqueous Vapour on Climate.

Aqueous Vapour acts as a screen, absorbing on an average 30 per cent. of the sun's heat when it is in the zenith, and 75 per cent. when on the horizon. It is still more powerful after sunset in preventing the escape of heat from the earth's surface.

In the Northern Hemisphere, the *Barometer* falls during E.S.E. and East winds, passing from falling to rising during S.W., rises with W.N.W. and North, and has its maximum rise with N.E. winds.

Barometer and Thermometer.

The *Thermometer* rises with E.S.E. and South winds, has its maximum with S.W., falls with W.N.W. and North, and has its minimum at N.E.

The *Elasticity of Vapour* increases with E.S.E. and South winds, has its maximum at S.W., and diminishes during the wind's progress by West and N.W. to North; at N.E. it has a minimum.

CHAPTER II.

THE OCEAN.

Composition.

THE Composition of Sea Water is much more complex than that of Air, as at least 27 chemical components are known, the various salts forming on an average 34 parts out of every 1,000.

Freezing Point.

This affects both the freezing point and the temperature at which it is most dense. Thus with *fresh* water the freezing point is 32° F., and that of maximum density 39° F.,[1] while those temperatures for ocean water are on an average 28° F. and 26° F. respectively.

Depth.

The mean Depth of the Ocean may be considered about 2,500 fathoms. The *greatest* known depth being 4,655 fathoms, in the North Pacific Ocean, in lat. 44° 55′ N., long. 152° 30′ E.

Effect of Heat.

The effect of heat received from the sun is very different over a surface of *land* and one of *water*. In the former the heat is arrested within a few feet of the surface, which near the Equator at times attains a temperature of 160° F.; while since the effects of heat penetrate some 600 feet below a surface of *water*, that surface is nowhere known to rise above a temperature of 94° F. (near Aden), and except in some particular localities the temperature of the surface of the sea is not *very* dissimilar to that of the air above it.[2]

Surface Temperature.

A knowledge of the Surface Temperature of the Ocean is often of great value in determining the probable direction of the Surface Current. To facilitate this a valuable series of Charts, giving these temperatures for the various Oceans, for different seasons, have been published by the Meteorological Office.

Observations made at Greenwich and Paris for a long series of years show,

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[1] Hence deep fresh-water lakes seldom freeze over, since this cannot take place until all the water in them has been cooled down to 39° F.

[2] The highest surface temperature observed in the *Challenger* was 88° F. in the Sea of Celebes.

that at an average depth (depending upon the soil) of from 50 to 80 feet below the earth's surface, the effect of the sun's heat is inappreciable. A Thermometer in a vault 90 feet deep, under the Observatory at Paris, only varied half a degree from a temperature of 53° F. in 75 years.

A Thermometer sunk 24 feet below the ground at Greenwich indicates its maximum temperature (52·3° F.) in November, and its minimum (48·7° F.) in May, the mean annual temperature at that depth being 50·5° F., and that of the air at the surface 49·3° F.

Below the layer of constant temperature a Thermometer rises 1° F. for about every 50 feet of increased depth.

OF THE CURRENTS.

General Remarks.

A *Current* is understood to be a Stream on, or a particular set in the direction of, the surface of the sea, occasioned by Winds and other impulses, exclusive of (but which *may be influenced by*) the causes of the Tides. It is an observation of *Dampier*, that *Currents* are scarcely ever felt but at sea, and *Tides* but upon the coasts; and it is certainly an established fact that Currents prevail mostly in those parts where the tides are weak and scarcely perceptible, or where the sea, apparently little influenced by the causes of the tides, is disposed to a quiescent state. This will be obvious by an attentive consideration of the following descriptions. The necessity of attention to the silent, imperceptible, and therefore dangerous operation of the Currents, will be equally apparent.

The usual method of estimating the existence, direction, and velocity of a Current, as is well known, is the comparison between the observed position of a ship and that obtained by dead-reckoning. It may be as well to observe in the outset, that this only method of observation involves some amount of fallacy, as a Current will be the general receiver of all errors or imperfections of observation, and beyond doubt the strength of Currents has been frequently exaggerated from this very cause. Now, as the latitude is ascertained far more easily and accurately than the longitude, it follows that this exaggeration has been chiefly shown in those Currents supposed to move to East and West. Still, by combining a large number of observations, we may safely conclude that they will neutralize each other's errors, and afford something like an accurate conclusion.

That the Waters of the Ocean do circulate over and intermingle with every portion of the water-surface of the globe is certain. Its composition and character is everywhere, in every region, exactly the same. This universality of character can only be accounted for by inferring that the Ocean waters are continually being intermingled, as is the case with the Atmosphere.

It may be objected that the specific gravity of the *surface* water varies considerably in different regions, and that it is therefore an argument against this intermingling of the sea waters. But it will be found that there are local causes which affect the saltness of the surface water. In the Arctic regions, where it is frequently found of great density or increased saltness, it is doubtless caused by the formation of ice, subtracting the fresh water from the surface. Again, in the Equatorial regions, it is usually found of low specific gravity, or containing less salt, which may also be accounted for by the great rainfall which, by intermingling the light fresh water with the surface, lowers its density.

Very much speculation has been used on this variation in the surface density and on its dynamic effects, in producing Currents and other phenomena, but it is deferentially urged against this reasoning, that almost all the experiments made upon the density of the water at any considerable depth, (above 20 or 30 fathoms), show a remarkable uniformity in the density in all regions (1·027), as will be shown in a later part of this book, and that, therefore, the real character of sea water, *below* local influences, is everywhere nearly the same.

Current Bottles.

It has been a well-known practice for many years to utilise floating messengers as indicators of Currents. In 1843, Captain A. B. Becher, R.N., drew up a very interesting chart of the North Atlantic, with the points of "despatch and arrival" of a large number of these Current Bottles. The practice and the accuracy of the teaching of these Bottles led to a long controversy, which, however, certainly did not tend to overturn their authority, so it need not be further adverted to here, than to say that the principal objection to them was, that they were rather impelled by the prevailing Wind than drifted in the Current. But this is also a demonstration of what can be otherwise proved, that the Wind and Surface Currents of the Atlantic and other Oceans obey the same law, and move very much in the same circuits. These Bottles, then, will form an important part of the subsequent demonstrations of the direction and rate of Currents. The chart of Capt. Becher's alluded to, bears intrinsic evidence of its trustworthy character, as in each region the Bottles obey precisely the law which would, *à priori*, be laid down for them.

Of Currents there are two distinctions:—1. The *Drift Current;* 2. The *Stream Current.*

Drift Currents.

The *Drift, or Drift Current,* is the mere effect of a *constant* or *very prevalent* wind on the surface water, impelling it to leeward until it meets with some obstacle which stops it, and occasions an accumulation and consequent *stream* of current. It matters not whether the obstacle be *land* or *banks*, or a *stream of current* already formed. The Drift Current is generally shallow, and has a mean rate, perhaps, of not more than half a mile an hour, when the wind is constant and a good breeze. Such a Current, from a predominance of Westerly winds, occupies the Northern region of the Atlantic, setting from the N.W. and West to the E.N.E. and S.E.; and so, likewise, is the central portion of the Ocean under the influence of the Trade Wind.

Stream Currents.

The *Stream Current* is formed by the accumulated waters of a *Drift Current*. It is more limited, but it may be of any bulk, or depth, or velocity. Of such is the temporary stream setting at times from the Bay of Biscay to the West of Ireland; and of such is the *Florida* or *Gulf Stream*, setting from the Mexican Sea to the Banks of Newfoundland, and terminating to the West of the Azores.

In some parts the Current is compounded of *Drift* and *Stream;* for a *Stream*, already formed, may pass through the region of a prevalent wind, in a direction according with that of its Drift Current, and receive an acceleration of motion from it accordingly. Of such are the Equatorial Currents, which will be presently noticed.

ICEBERGS, ICE ISLANDS, AND DRIFT ICE.

It may not be inapposite, to recall to the seaman's mind the necessity of guarding against these tremendous and dangerous objects—more dangerous than permanent rocks, because unfixed, and more to be dreaded, because frequently obscured in snow and fog.

The Ice which is thus met with is of two descriptions: that which is formed on the surface of the sea during the Polar winter—the Field and Floe-ice; and that which is formed in the course probably of many years upon land, and is periodically launched into the sea in the form of gigantic Bergs of enormous height and dimensions.

Of the first description of Ice no special mention is necessary, as its production and presence in the regions under consideration is very readily comprehended.

Icebergs are a much more interesting subject, and their majestic proportions at once attract attention and invite enquiry as to their formation; consequently we may find accounts and speculations have been advanced to account for them, and various localities pointed out as their birth-place.

Captain (afterwards Dr.) Scoresby, whose opinion is invaluable, observes, "that, however dependent the Ice may have been on land, from the time of its first appearance to its gaining an ascendency over the waves of the Ocean, sufficient to resist their utmost ravages, and to arrest the progress of maritime discovery at a distance of, perhaps, from 600 to 1,000 miles from the Pole, it is now evident that the proximity of land is not essential, either for its existence, its formation, or its increase."

Dr. Scoresby's acquaintance with Icebergs in progress of formation was confined to Spitzbergen and portions of Greenland, where they do not form so marked a feature as has been found in other parts. It is to Dr. Rink, a resident in Greenland, that we are indebted for the most complete account of these marvellous phenomena, and in making a few extracts from his work,[1] we may draw attention to the parallel condition of the South Pole in producing these Icebergs on a far more stupendous scale than is found in the Northern region; for while in the North their dimensions are confined to a few hundred yards, in the South they are very frequently miles in extent, and from 2,000 to 3,000 feet in thickness—a magnitude owing to the vast extent of country in which they are produced. Their protrusion into the sea involves the same considerations as the "glacier theory" of the land, so very interesting and important in geological questions.

The larger Icebergs in the Northern regions rise above the surface of the sea to the height of from 100 to 150 ft. and upwards, and some are 4,000 ft. in circumference. The part *above* can scarcely be considered more than one-eighth of that *below* the surface of the water, so that the cubic contents of the Iceberg may amount to about 66,000,000 cubic yards—a fragment of Ice which, if we suppose it to be wholly landed, would form a mountain about 1,000 ft. in height. All agree that the Icebergs of these Arctic Seas are originally formed on *terra firma*, from the snow and rains which, from the severity of the climate, are never able to reach the Ocean in a fluid state, but which, in the course of years, are transformed into a mass of Ice, and are then, through some physical agency, thrust forward into the sea.[2]

The Ice thrust forth into the sea, in the form of massive mountains, is originally formed over an enormous extent of country, from whence, by an agency similar to that by which the progress of glaciers is effected, it is thrust forward and brought to a point at a place from which the Icebergs proceed. For the formation of Icebergs accordingly a tract of land of a certain extent is

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[1] Dr. Rink "On the Origin of Icebergs," &c., Journal of the Royal Geographical Society, vol. xxiii., 1853, p. 143, *et seq.*

[2] It is a well known fact that all the ice formed from snow upon the surface of land, where the heat of summer is incapable of melting and preventing its gradual increase, has a tendency to extend and move downward, as water should do, according to the same laws, in the ease of rain instead of snow having fallen upon the surface. Those masses of snow accumulated in high regions of mountain chains, even in the hottest parts of the globe, gather in the valleys, which thus form the natural drainage for the highlands, and being congealed into a compact body of ice, move slowly down into lower and warmer regions, till the increasing heat, by thawing them, sets a limit to their further spread. These masses of compact ice spreading down through the valleys or clefts, and constantly furnished with further supplies by the snow accumulated in the surrounding highlands, are, in Europe, seen on the largest scale upon the Alps, where they are known under the name of "Gletscher," or Glaciers.

necessary, in which the sea forms so few and small creeks or inlets, that rivers or watercourses of some magnitude must necessarily be present.

Where the above-mentioned condition exists, in conjunction with the necessary temperature of the climate, the formation of Ice does not proceed from certain mountain heights, but *the whole country is covered with ice to a certain elevation; mountains and valleys are levelled to a uniform plane; the river beds are concealed, as well as every vestige of the original form of the country.* A movement, commencing *far inland*, thrusts the outer edge of this mass of Ice forward toward the sea; and when it reaches the Frith it may be seen to sink, and to diverge and even extend out several miles. There the agency of the *obliterated Rivers* may be observed, in the greater or lesser rapidity with which the matter in a solid state is carried forward to the Ocean. The massive crust, *still preserving its continuity*, proceeds from the shore, borne by the sea, until some circumstance or other destroys the equilibrium, and breaks some fragments off the outer edge, which is again thrust forward, and again detaches new fragments, thus continually renewing the supplies from the interior.

A tract or body of land of the requisite size is, in the Northern Hemisphere, only to be found in Greenland, and more especially in that part which lies to the North of the Arctic Circle, where in the interior, beyond the inlets of the sea, the country increases in breadth from East to West, and affords space for the original birth-place of these large Icebergs. Neither Spitzbergen, nor the narrower parts of Greenland, nor the Peninsula of Scandinavia, nor the islands which surround it, are adequate in size to produce such an effect. The yearly excess of indissoluble Ice, which *is very slowly protruded* from the Western, and, as it seems, in a lesser degree, from the Eastern shores of Greenland, forms the Icebergs which are driven past Cape Farewell, the greatest quantity going to the West, into Baffin's Bay. The friths or fiords which, piercing far into the country, receive and transmit the Icebergs, are called *Ice Friths*.

From November to June the water, in which the Icebergs are to proceed to the Ocean, is so covered by the ocean ice, that they are shut up in the inner Ice Friths; but in July, and especially in August, they are carried by the current to the open sea. This is called *the shooting out of the Ice Friths*, which lasts till late in the autumn, when the continual Easterly storms finally clear out the inner waters, unless the Icebergs are intercepted by certain banks, on which they sometimes remain long aground.

Icebergs consist mostly of hard, brittle ice, of which the white colour originates from very fine lineal pores, uniformly divided through the whole mass, all being of the same size, equi-distant, and parallel throughout the whole Iceberg. This uniform structure may have arisen at the time it was formed in the interior of the country from corned snow—perhaps repeatedly thawed and frozen. The *white* Iceberg is in many directions crossed by broad stripes of intense blue-coloured ice, which is quite clear, and either contains no air bubbles, or, at all events, very irregular ones. These blue stripes are several feet in breadth, and in them are generally found "dirt bands" of foreign matters, such as stone, gravel, and clay, which the Icebergs carry off embodied in them. The *blue* ice is, by thawing, dissolved into regular large grains, which is not the case with the *white* ice which forms the main mass of the Icebergs. It seems probable that these blue stripes are formed by a filling up of the fissures in the *inland* ice with water—perhaps mixed with snow, gravel, and stones; and such a refrigeration of the water in the fissures may be supposed to be an important agency in setting in motion these great mountains of ice.[1]

It would be out of place to enter into detail upon this subject, but from the above-mentioned notice, as well as the works of Dr. Scoresby, Sir George Nares and others, much interesting matter may be gleaned. We must, therefore, consider them here as only affecting navigation.

Mr. W. C. Redfield, to whom the world is so largely indebted for his researches in Meteorology and Physical Geography, published a pamphlet, accompanied by a chart, upon the Ice of the North Atlantic. In this he has clearly shown that the Gulf Stream *passes over* the cold Arctic Current, which transports the deeply immersed Icebergs into and across it. "No impulsion but that of a vast current, setting in a South-westerly direction, and passing beneath the Gulf Stream, could have carried these immense bodies to their observed positions, on routes which cross the Gulf Current, in a region where its average breadth has been found to be about 250 miles." Other observations on this subject are given in the section on the Gulf Stream. The same influence will also cause the presence of floating Ice in the Gulf of St. Lawrence, by carrying it through the Straits of Belle Isle; but the depth of this would prevent the progress of the larger Icebergs.

It need scarcely be mentioned, that greater circumspection is necessary in passing near the regions where these dangers may reasonably be expected.

Southern Ice.

The whole of the Southern Icy Barrier is formed of *Land-ice*, and owes nothing of its enormous magnitude to the sea. The perfectly wall-faced cliffs forming its outer margin, are usually from 150 to 210 feet above the water level, indicating a thickness of over 1,000 feet, and these cliffs extend uninterruptedly for many hundred miles, being approachable in the summer to its foot. "The upper surface of

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[1] Transparent ice, free from interior spaces or bubbles, is one of the purest substances in nature, and it is not possible to detect the presence of the minutest portion of air, or any substance that may have been held in solution by the water from which it is formed. The strongest poisons or colouring matter of any description, are most effectually separated from water by the process of freezing it.

these tabular barriers," says Sir James Ross, "is like an immense plain of frosted silver; gigantic icicles depended from every projected point of its perpendicular cliffs, proving that it sometimes thaws, which otherwise we could not have believed. In the North, in August, the equivalent month to February, streams of water constantly pour from every Iceberg."

This regularity of figure must be owing to its being undisturbed by ocean influence during its formation, and to its being free, or comparatively free, from those changes which alternate thawing and freezing would create. These fields of Ice must then be formed by deposition on their upper surfaces only; and as rain is almost or quite unknown, the fogs and snows are the sources of their increase. These depositions are formed on the land, which at a very considerable distance from its outer edge rises into lofty mountains; possibly, or in some cases probably, they consist altogether of ice, and thus, from the weight of their upper strata, form continuous Glaciers, thrusting forward those parts which have been formed on and beyond the foot of these mountains, which then being brought within the disruptive powers of the sea are detached, and form the Floating Bergs. The thickness and density of the Antarctic Ice will allow of the supposition that they are bodily thrust forward toward the sea, even if the inclination down which they move be very gradual, and that the interior portions of the land have by continual accretion obtained sufficient elevation, however vast it may be, to form a seaward slope of sufficient inclination.

The period required for the deposition of such a mass of Ice is a very interesting question. These Tabular Bergs are all *stratified horizontally*, in some cases very completely so, by layers of dense, and porous, or snow-ice. These layers, according to Captain Wilkes, vary from 6 inches to 4 feet in thickness. Respecting the fall of snow, supposing it to be 1 inch per diem, it would take 30 years to form a mass of the usual thickness. Fogs are also a very efficient aid to their increase, for the same voyager states that his ship and rigging were covered with ice, one-fourth of an inch thick, in a few hours during a fog.

It is stated that there is no *Pack-ice* on the Antarctic coast. It would seem that all the vast quantities of floating Ice are derived from the degradation of those wall-faced cliffs. This is a very important distinction from the Arctic Ice, where the "pack" formed on the surface of the sea during winter, forms by far the largest portion. In the North, when it is broken up, it is in pieces many miles in diameter; in the South these masses are not a mile in circuit.

These Tabular Icebergs, rising 200 ft. and upwards from the surface, are submerged 800 or 1,000 ft. in the open sea. Drifted by the Northerly (subsurface) set, they are brought into warmer water, which dissolves their deeply seated bases, which at first are generally covered with boulders and earth, eroding them into every variety of fantastic form, and thus they ultimately lose their original line of flotation, and roll over in every direction, till at last they disappear as field ice.

Their proximity is said to be invariably announced by a fall in the temperature of the sea and air, and it is to this monition chiefly that the sailor must trust for safety during the night or foggy weather, which too often accompanies their presence. But it is not always that this indication is correct, for when the Ice is to leeward both of wind and current, it is manifest that this indication cannot be so well depended on until in close proximity to the danger.[1]

The late Mr. Towson, so well known for his useful labours in the service of navigation, drew up, in 1859, the most perfect account of the Southern Ice, and from his paper we extract the following results of his investigations, which later and more extensive inquiries have not impugned.

From the consideration of the facts collected, Mr. Towson draws the following practical conclusions:—

Firstly.—That the period comprising the months of November and December, 1854, and January, February, March, and April, 1855, was a most extraordinary season for Icebergs. In every part of the Southern Hemisphere, South of the fortieth parallel, the number of Icebergs met with during these six months was beyond all recorded precedent. During that period, a far greater number were reported than the total of every other season from the time of Captain Cook down to the present year. Whether such phenomena are periodical, or that of 1854—55 is an exceptional one, we cannot decide; but from the reports of those who have been engaged in the seal trade, we believe that for 50 years previously there had been no season bearing the least comparison with the one under consideration. It has been observed that Meteorological Cycles exist in the Southern Hemisphere. If there exists a cycle in which such seasons return, the period must be secular. One individual cannot therefore determine this point.

Secondly.—That by far the greatest number of Icebergs is met with in the Southern Hemisphere during the six months of November, December, January, February, March, and April. There is not the record of a single Iceberg having been sighted in the midwinter months of June and July, and they have been seldom reported in the months of May and August. And further, that Eastward of the Horn there is a space bordering on both the outward and homeward track, which may be regarded as dangerous from Ice.

As far, however, as the homeward passage from Australia is affected by the consideration of this locality, it tends only to confirm our previous convictions, and we have more abundant reasons than ever to impress on the mariner the propriety of sighting the Horn and the Falkland Islands on his homeward

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[1] It is said that this fall of sea temperature is more reliable in Southern latitudes than among Northern Icebergs.

passage. He has every inducement to follow this track. It is favourable for making a short passage, and it will keep the ship clear from the only locality, adjacent to the passage either out or home, in which real danger exists on account of the Ice. I think great sacrifices should be made to follow this part of the route home rigidly, for I have not met with any very extraordinary voyage home made by a ship that has given to the Horn or the Falkland Islands a wide berth. In all cases where no danger has been experienced from Ice, delays have been occasioned, and the passage has been spoiled; nor have I a case on record in which any mariner, following this advice, has met with Ice after arriving East of the meridian of 75° W.

It will be observed that few reports of Ice are recorded, save near the usual tracks of ships. It would be wrong to infer from this, that the regions South of the usual route are comparatively free from Ice; the fact being that we have not sufficient information on the subject to speak positively, although in certain seasons more Icebergs seem to be met with in the lower latitudes than in the higher, in the Pacific. A remarkable instance of this, mentioned by Mr. Towson, occurred in November, 1854, when the *Great Britain* passed 280 Icebergs in 56° S. latitude, between 112° and 92° W., while the *Golden Era*, passing the same meridians at the unusually high latitude of 63° S., never met an Iceberg, nor, until reaching 72° W., when she was surrounded by pack Ice, and narrowly escaped being wrecked, did she experience any inconvenience from Ice.

One thing is quite evident, that there is far greater danger from Ice during the summer months, in the Southern Hemisphere, than during the winter. Of about 550 reports of Ice sighted, nearly half occurred in November, December, and January, while there are only five reports of Ice having been seen in June, and only three in July. One-fifth of the reports relate to Ice sighted in December, and the Ice seen in June and July together is to that met with in December alone, rather less than as 1 to 13.

The decrease from January to April is less rapid than the increase from August to November, and the probability of falling in with Ice in the autumn months of March and April is as 5 to 3 nearly, compared with the chance of sighting it during the spring months of September and October, although more Ice has been seen in December than in any other month.

Many of the Icebergs which have been reported were of immense size. The Dutch ship *General Baron Von Geen*, on the 16th of August, 1840, passed one about 1,000 ft. high, in 37° 32′ S., 14° 10′ E.; another, 960 ft. in height, was sighted by the *Agneta*, in lat. 53° 14′ S., long. 14° 41′ E., on the 23rd of March, 1855; an Iceberg, as large as Tristan d'Acunha, in lat. 53° 40′ S., long. 123° 17′ W., on the 15th of May, 1859, was reported by the *Bosworth;* and the *Queen of Nations* fell in with one as high as 720 ft., in lat. 53° 45′ S., long. 170° 0′ W., on December 25th, 1861.

Several Icebergs, 3 miles long, and about 300 ft. high, were passed on February 12th, 1858, in lat. 50° 54′ S., long. 45° 22′ W., by the *Light of the Age*, and another of about the same dimensions by the *Silistria*, not far from Cape Horn, in lat. 56° 50′ S., long. 63° 0′ W., on the 29th of September, 1860.

The extraordinary mass of Ice which, though not exceeding 300 ft. in height, was reported to be 60 miles long by 40 miles wide, and was seen by many ships during the five months of December, 1854, and January, February, March, and April, 1855, is fully described in Mr. Towson's pamphlet, quoted hereafter. This mass of Ice is supposed to have consisted of numerous connected Icebergs. During the time mentioned it floated from about 44° S. and 28° W. to about 40° S. and 20° W. No report of this Ice having been seen after April, 1855, was received, so that it probably broke up and dispersed shortly after that time, or else turned Southward, and drifted out of the usual track of ships.

In September, 1865, an immense Ice Island was found by Captain John Jones, in the *Alice Davies*, lat. 45° 30′ S., long. 38° 40′ W. The extent of this Ice Island, which appeared to be flat-topped and "level looking," was about 25 miles in a North and South direction, and extended farther than the eye could reach to the N.W.

A very large Iceberg, about 580 ft. in height, and nearly 3 miles long, was seen by Capt. Smithers, of the *Edmond*, in lat. 50° 52′ S., long. 43° 58′ W., on the 1st of December, 1859. So strongly did this Iceberg resemble land, that Capt. Smithers believed it to be an island, and reported it as such; but there is little or no doubt that it was in reality an Iceberg. There were pieces of drift ice under its lee.

It was near the same place, in 50° 50′ S., 45° 0′ W., that another Iceberg was passed by the *Gleaner*, only a fortnight earlier, about 200 ft. high, and resembling an island very strongly until the ship was within about a mile of it, the deception being aided by a vapour which ascended from the base of the Iceberg, and hung about one side of it.

In December, 1861, the *Queen of Nations* passed an Iceberg, apparently very old, and having the appearance of earth sticking to it, in 57° S., 146° W. This Berg may possibly have grounded, and subsequently floated again, and turned over.

The temperature of the water does not seem to be an infallible guide as to the vicinity of Ice, although generally on approaching it there is a marked diminution in the temperature of air and water, but especially the latter.

Capt. Clark, of the *Lightning*, in February, 1860, when in lat. 55° 20′ S., long. 125° 45′ W., found the surface temperature as high as 45°, although there was Ice at a distance of only 2 miles and on both sides of the ship (one Berg being 500 ft. high, and 3 miles long), while a few days later, in lat. 56° 0′ S., long. 90° 54′ W., there was a sudden (but only temporary) fall of the surface temperature to 38°, though there was no Ice, nor any appearance of it.

Mr. Towson remarks: Most of the reported Bergs appear insignificant when compared with a body of Ice reported to have been passed by twenty-one ships during the five months of December, 1854, and January, February, March, and April, 1855, floating from lat. 44° S., long. 28° W., to lat. 40° S., long. 20° W.

This mass has received the various denominations of an immense Iceberg, an Ice-island, "Groote Ijs Eiland," and a connected mass of Icebergs. Its elevation in no case exceeded 300 ft.; but its horizontal dimensions were 60 miles by 40 miles. It was of the form of a hook, the longer shank of which was 60 miles, the shorter 40 miles, and embayed between these mountains of ice was a space of water 40 miles across. The first account of it was received from the *Great Britain*, which, in December, 1854, was reported to have steamed 50 miles along the outer side of the longer shank. This longest range of ice then bore N.E. and S.W., the bay before alluded to being open to the N.E. Whilst in this position it exposed ships to but little danger, since the bay could only be entered on the opposite course to that of ships on their homeward passage from Australia. But during the next three months it swung round 90° to the left, and drifted E.N.E. about 100 miles, which brought it very near to the route of outward-bound ships, with the bay open to their track. We can scarcely imagine any mass of Ice in an equally dangerous form, and I regret to add that one emigrant ship, the *Guiding Star*, was embayed and lost on it with all hands. The *Cambridge* and *Salem* were also embayed in March and April, 1855, but through the skill of their commanders they were extricated from the most perilous position in which we can conceive a ship to be placed by Ice in any form. Beyond doubt this was an extraordinary phenomenon, there being no record of any other mass of Ice bearing even approximate horizontal proportions to those now described.

Mr. Towson says: In tracing some remarkable masses of Southern Ice, I was able to determine the direction of their drift, and their rate of progress. With the exception of one locality, the course of an Iceberg is E. by N., rate 10 miles per diem. The only exception is, after it has passed Eastward of the Horn, when its course bends to the N.E., veering round to the East as it approaches the latitude of 40° S., on which parallel, from the meridian of 25° W. to 15° W., its progress is scarcely one mile daily, direction nearly East. This course is afterwards bent towards the South, crossing the meridian of Greenwich on the S.E. rhumb. I have been unable to determine whether it again changes its course to E. by N., or returns by a circular current to the neighbourhood of the Horn. There are facts tending to support both of these hypotheses; but since near the meridian of Greenwich, few ships go higher than lat. 50° S., we have not a sufficient number of observations to enable me to decide this question.

It may be inferred that the line of perpetual congelation exists in a lower latitude in some parts of the Southern Hemisphere than in others. The Icy

Barrier retreats several degrees Southward of the Antarctic Circle, to the West of Cape Horn, while to the Eastward it advances Northward of that Circle, which is no doubt owing to the situation of the land. The limited experience of the navigators who have penetrated to the land, would however lead to the inference that the line of the Icy Barrier itself does not change much in its position. From the great quantities of Ice drifting in all parts of the Ocean, in high Southern latitudes, it is probable that the formation of Ice Islands is much more rapid than is generally supposed.

The manner of their formation is easily explained. In the first place the Ice seems to require a nucleus, whereon the fogs, snow, and rain, may congeal and accumulate: this the land affords. Accident then separates part of this mass from the land, when it drifts off and is broken into many pieces, and part of this may again join that which is in process of formation.

From the accumulation of snow, such a mass speedily assumes a flatter table-topped shape, gradually increasing in thickness and weight by the congelation of rain, snow, and fogs, which last have no small influence in contributing to the accumulation, as may be supposed, when a few hours suffice to give the rigging and spars of a ship a coating of Ice a quarter of an inch thick. Thus masses of a thousand feet in thickness might require but a few years to form. When the Icebergs are fully formed they have a tabular and stratified appearance, and are perfectly wall-sided, varying from 180 to 210 ft. in height. Sir James Ross followed the line of these enormous Ice-cliffs for 450 miles and upwards, with one unvarying height and character, from which the calculation was made that the Ice must be upwards of 1,000 ft. in thickness. In some places the United States' Expedition sailed, for more than 50 miles together, along a straight and perpendicular wall, from 150 to 200 ft. in height. This enormous envelope, constantly but gradually increasing in thickness by the deposition on its upper surface, slides down the declivities of the land it rests upon, as is inferred by the analogous process well observed in the Northern regions, protruding its margin into the sea, when the stability of the mass and its buoyancy in the sea become neutralized, and its margin then breaks off, or *calves*, as it is termed, forming those tremendous wall-sided, flat-topped Bergs, so characteristic of the Southern regions. These Icebergs afloat are from a quarter of a mile to 5 miles in length.

The peculiar distinction of the Tabular Iceberg of the Southern Hemisphere, and the pinnacled and irregular Bergs met with in the Arctic Ice, is due to their origin. In the North they are formed on a limited space of land, chiefly Greenland, and here the land ice reaches the sea down narrow fiords in the form of Glaciers, literally Rivers of Ice, whose outlet into the sea is constantly disrupted, and in the spring masses drift Southwards in every variety of size and figure, except the tabular.

In the South, on the contrary, the whole of the South Pole appears to be encircled with land covered with this tremendous icy mantle, without any inlet into its interior, as is the case with the Arctic regions, unless there should be such in the lands South of Cape Horn, and thus there is no influx of warmer water, which can penetrate into the rear of the Icy Barrier (as is the case in Baffin's Bay and around Spitzbergen) to dissolve and drift it out in a similar way. Therefore the only feasible theory is that the whole mass of Ice is gradually protruding its margin into warmer latitudes, aad is disrupted when it loses its equilibrium.

When first separated they are all flat-topped and nearly level, from 100 to 200 ft. above the sea, and probably 800 or 1,000 ft. beneath it. They begin to dissolve at the base, generally irregularly, and then become tilted or presenting a bluff end, with a sloping face in the opposite direction. This is varied in every conceivable manner.

The Icebergs met during the cruise of H.M.S. *Challenger* in the Antarctic seas, were usually from a quarter to a half mile in diameter, and about 200 ft. high; the highest was about 248 ft. The largest Berg was seen when farthest South, in lat. 66° 40°; it was certainly 3 miles in length, and accompanied by several others nearly as long.

Observations show that they can be but little changed by the melting process before they reach the parallel of 60°; and here the remarks of Captain Sir James Ross as to the zone of equal temperature (39·5°) become important, as it must be after approaching this in their Northward course that the warmer surface waters act powerfully on their submerged bases.

During their drift to the Northward, on reaching lower latitudes, and as their distance from the land increases, they are found in all stages of decay; some forming obelisks, others towers and Gothic arches, and all more or less perforated; some exhibit lofty columns, with a natural bridge resting on them of a lightness and beauty inconceivable in any other material. Some apparently retain their original tabular form entire, until they reach a lower latitude, while others have entirely lost it, and have evidently upset or overturned. The sight of one of these immense masses upsetting is a truly grand but exceedingly dangerous spectacle to witness. The noise of the huge mass rending is as loud as thunder or volleys of artillery, and Captain Boulton, who witnessed one overturning, says, that as soon as the mist occasioned by its fall cleared away, the enormous body rose out of the water in a totally different shape, its original appearance having been very high and square, but was then fully twice its former length, besides being low and smooth.

Mr. Towson says:—Generally Drift Ice is not to be met with in the Southern Oceans at a lower latitude than 58°, and, in that region, only in the Austral winter months, from April to September inclusive. In one region, it has been found as low as 55°, and, in some cases brash ice has been reported in lower latitudes. But in these last instances, from the numerous Icebergs adjacent, and from the very irregular sizes and forms of the Ice, I am inclined to believe that it consisted of the débris of Icebergs, and was not brash ice properly so called.

A Berg sighted by the *Lightning* on the 10th of September, 1856, in lat. 55° 33′ S., long. 140° W., was 420 feet high; and one of our most celebrated and talented Naval Surveyors stated that he had seen Icebergs in Southern regions 800 feet high.

There appears to be a great difference in the movements of these vast masses; in some years great numbers of them have floated North from the Antarctic Circle, and at times obstructed the navigation about the Capes. The year 1832 was remarkable in this respect; many vessels bound round Cape Horn from the Pacific, were obliged to put back to Chile, in consequence of the dangers arising from Ice; while during the preceding and following years, little or none was seen. This would lead to the belief that great changes must take place in the higher latitudes, or the prevalence of some cause to detach the Ice Islands from the Barrier in such great quantities as to cover almost the entire section of the Ocean South of lat. 50°. Taking the early part of the (Southern) spring as the time of separation, we are enabled to estimate the velocity with which they move, as they have been met with 600 or 700 miles from the Barrier, from sixty to eighty days after that period.

CHAPTER III.

THE NORTH ATLANTIC OCEAN.

WINDS.

General Wind Systems.

The *Wind Regions* of the North Atlantic may be thus defined:—To the North of the Tropic of Cancer are the *anti-Trades*, or *Passage Winds*, which, though variable, have a general tendency from S.W. to N.E. South of these is a Belt of Calms and Variable Winds, distinguished by a high Barometer, called by Maury the "*Calms of Cancer*," and known to sailors as the "Horse Latitudes." This Belt varies between 30° and 35° North, according to the season. South of this, and extending to about 8° to 5° North, but varying in its Southern as in its Northern limits, is the great region of the *N.E. Trades*. In the space between the Equator and this region of Trades are the "*Doldrums*," or Calms of the Equator; and upon the African coast there is a regular alternation of the winds, similar to the Monsoons in other parts. Each of these regions will be treated of separately.

In the spaces which separate these wind systems those Hurricanes or Cyclones occur, which are caused by the action of currents of air moving in opposite directions; their phenomena are further controlled by the influence of the land they approach or pass over. This important branch of the present subject is fully considered hereafter, but the occurrence of storms is an exceptional case in the vast system of atmospheric circulation we are about to consider.

Anti-Trades.

It is impossible, in a Work of this description, to give more than a very general idea of the anti-Trade or Westerly Winds, the direction of which is so varied in different localities, and at different seasons. There appears to be some tendency, with the sun North, for them to blow from S.W. and W.S.W., and, with the sun South, from W.N.W. and N.W.

General Wind Table *for the North Atlantic, between lat.* 55°—40°, *in the Yearly Period, and referred to Eight Points of the Compass.*

Long. W.	Lat. N.	No. of Observations.	Variable.	Calm.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	N.
° °	° °											
	55—50	4,244	45	140	250	364	443	558	712	828	562	322
5—35			1 *p. c.*	3 *p. c.*	6 *p. c.*	9 *p. c.*	10 *p. c.*	13 *p. c.*	17 *p. c.*	20 *p. c.*	13 *p. c.*	8 *p. c.*
	50—45	25,454	134	1,078	2,328	2,495	2,283	2,906	3,909	4,220	3,650	2,451
			1 *p. c.*	4 *p. c.*	9 *p. c.*	10 *p. c.*	9 *p. c.*	11 *p. c.*	15 *p. c.*	17 *p. c.*	14 *p. c.*	10 *p. c.*
	,,	5,384	86	187	337	379	302	622	917	1,067	864	623
35—55			2 *p. c.*	3 *p. c.*	6 *p. c.*	7 *p. c.*	6 *p. c.*	11 *p. c.*	17 *p. c.*	20 *p. c.*	16 *p. c.*	12 *p.*
	45—40	8,007	54	376	611	583	721	1,047	1,284	1,399	1,082	850
			1 *p. c.*	5 *p. c.*	8 *p. c.*	7 *p. c.*	9 *p. c.*	13 *p. c.*	16 *p. c.*	17 *p. c.*	13 *p. c.*	11 *p. c.*
55—74	,,	12,641	180	555	1,093	1,124	914	1,550	1,900	2,221	1,744	1,360
			1 *p. c.*	4 *p. c.*	9 *p. c.*	9 *p. c.*	7 *p. c.*	12 *p. c.*	15 *p. c.*	18 *p. c.*	14 *p. c.*	11 *p. c.*
Total - -		55,730	499	2,336	4,619	4,945	4,663	6,683	8,722	9,735	7,902	5,606
			1 *p. c.*	4 *p. c.*	8 *p. c.*	9 *p. c.*	8 *p. c.*	12 *p. c.*	16 *p. c.*	18 *p. c.*	14 *p. c.*	10 *p. c.*

By adding one-half of the intermediate quadrants to each of the four adjacent cardinal points (W. = W. to S.W. and to N.W.), we find that—

Westerly winds are 33 per cent.
Southerly ,, 23 ,,
Northerly ,, 22 ,,
Easterly ,, 17 ,,
Calms and Variables 5 ,,

The general tendency of the wind to blow from a Westerly direction over the locality under consideration, is strikingly illustrated by comparing the duration of Passages made, in both directions, by the clipper sailing vessels formerly employed in the Packet Service. Thus, the average of passages, out and home, between Liverpool and New York, extending over a period of six years, gave the following results :—Liverpool to New York 40 days, and New York to Liverpool 23 days.

Calms of Cancer.

Between the N.E. Trades, and the Westerly Winds which prevail more or less to the Northward of them, there is a Belt of Variable and Light Winds, called, perhaps somewhat vaguely, the *Calms of Cancer*—a term which will not express its characteristics.

It is called, also, the *Horse Latitudes*, from the fact that vessels in former years, employed in carrying horses to the West Indies, were frequently obliged to throw them overboard during the embarrassment caused by its continual changes, sudden gusts and calms, rains, thunder and lightning.

This zone is caused by the uniting, or interchanging, of those upper but contrary currents which pass Northward over the N.E. Trades (in consequence of the heat acquired under the Tropical sun) having reached the Northern extreme of this superheating influence. They here meet the currents passing

Southward to feed the Trades from the Polar regions, and thus pressing against them cause the high Barometer peculiar to this Belt, standing as it does at a higher level than either to the North or South of it. Maury infers that the mean height of the mercury in this Belt is 30·21 inches, and at the Equator 29·93 inches. Admiral FitzRoy states the mean height of the Barometer in the latitude of England to be 29·95. This greater height of the mercury, showing increased pressure, will be an index to the sailor that he has reached this intervening Belt between the Passage and Trade Winds.

From the lower part of this zone pass out two currents of air, one to feed the N.E. Trades, and the other to form the anti-Trades or Passage Winds; and it is fed by the Polar and Tropical counter-Currents which flow over these different wind systems.

The mean latitude of this Belt is from 30° to 35° N., but varying with the motion of the sun in declination, as explained in page 13. In fact, the Northern edge of the Trade Wind may be taken as the axis over which this Belt moves, sometimes being of great breadth, as 10°; at others not felt at all. The mean position of these Tropical Calms, &c., will be best comprehended by an inspection of the diagram. As is well known, this Belt is the line upon which the dreaded Cyclones turn; they pass to the W.N.W., when South of it; and to the E.N.E., when North of it: showing the origin of the struggle between the Polar and Tropical Currents, which is evident in their tremendous phenomena.

The range over which the Northern limits of the N.E. Trade are met with, seems to be, from Maury's chart, about 10°; but as this chart is apparently not quite perfect, or, at least, is not derived from sufficient data to pronounce absolutely upon, it may be said that the mean position of the Tropical Calms in the various seasons cannot with certainty be predicted; but, as it does not offer the same obstacles to navigation as those of the Equatorial regions, it is of less importance to the sailor, who, by sagacity and prudence, may guard against the squalls, thunder-storms, and calms, which characterize it.

Westward of the meridian 50° W.—that is, over the Western half of the N.E. Trade in the North Atlantic—the Trade is very light during the months of September and October, and perhaps at other times of the summer and autumn. They will be most felt between the parallels of 15° and 25°; but not with any certainty near the American coast. This region may therefore be added to the Tropical Calms during these months.

North-East Trade.

The N.E. Trade Wind blows over the Tropical region between lat. 36° N. and the Equator, seldom, however, reaching these extremes. When uninterrupted by Gales or Hurricanes, caused by the disturbing influences of land or rain, it is a fair weather region which procured for itself the term "The Lady's Gulf," by the old Spaniards.

The N.E., like the S.E. Trade Wind, blows over a wider area in the Eastern part of the Atlantic than on the American side, as at the meridian of 10° W. they together extend from 35° or 38° N. to 25° or 28° S.; while on the American side the limit is 28° or 30° N. to 23° or 25° S.; but on the Eastern side the intervening space of Calms is much wider. The extent and limits will be best comprehended by an inspection of the diagram adjoining, which is formed from the tabular statements drawn up by Maury and by the Dutch Meteorological Institute, and for the Equatorial region by Captain Toynbee. This will explain better the various lines and fluctuations than would be done by a long series of words.

The *Northern limit* of the N.E. Trade Wind, as will be seen, extends on the Eastern side of the Atlantic, that is off the coast of Africa, to lat. 35° as a mean, in August and September, being then at its greatest Northern extent; but it is frequently encountered when in lat. 38°, or sometimes even at 40°. To the Westward of the meridian of 30° the Northern edge seldom extends Northward of 33° or 34°, while toward the Bahamas the Northern limit is 30° N. This extreme Northern limit appears to be attained in August and September, and following the sun in its Southward course it reaches its Southern limit in March or April. In January its mean limit on the Eastern side is about the Canaries; over the Eastern half of the Atlantic, in about 25° N.; in the centre, about 22° N.; and over the Bahamas it seldom vibrates to any great extent throughout the year.

The extent of variation between the Northern edge of the Trade Winds when first encountered, as shown by Maury's Trade Wind Charts, seems to be as much as 10 degrees of latitude—a wide range of probability—and in many cases there appears from these charts to be as much chance of meeting them in one latitude as another. Of course this is taking into account the Belt of Calms and Variable Winds usually (but not always) found on the edge of the Trades.

The *Southern edge of the N.E. Trade Wind* is limited in the Eastern part by that broad region so embarrassing to the sailor, known as the "Doldrums," or (especially during the Northern summer months) by winds blowing towards the coast of Africa, known of old as the West African S.W. Monsoon. This wedge-shaped area, whose apex reaches in July to 40° or 45° W., extends on the African coast, at that period, from 5° N. to 16° or 17° N. To the West of this there is still a belt of almost constant rain "under the Equatorial cloud ring," called the Equatorial Calms, which, however, is much narrower, and perhaps at times may not be encountered. The Trade Wind is at its Southerly limit in March and April, reaching in mid-ocean sometimes to 3° S., but seldom so far as 3° N. on the East side. It remains there for two or three months, and then advances Northward till August and September, when it is seldom found South of lat. 9° N.; indeed, this parallel may be taken as the mean Southern limit of the N.E. Trades. This Northern division of the Trade Wind is owing to the unequal distribution of land in the two Hemispheres.

The following useful Table is that drawn up by the late Captain Horsburgh, as the limits usually found in the track generally pursued by the East Indiamen, at the commencement of the present century:—

TABLE, *showing the Limits of the N.E. and S.E. Trade Winds, between the Meridians of* 18 *and* 26 *degrees West.*

N.E. TRADE WIND.			S.E. TRADE WIND.		INTERVAL BETWEEN.
CEASES.	General Extremes.	Probable Mean.	General Extremes.	Probable Mean.	Mean Breadth.
	° °	°	° °	°	
In January at	3 to 10 N.	5 N.	$0\frac{1}{2}$ to 4 N.	$2\frac{3}{4}$ N.	$2\frac{1}{4}$ degrees.
February	2 to 10 —	4 —	$0\frac{1}{2}$ to 3 —	$1\frac{1}{4}$ —	$3\frac{1}{3}$,,
March	2 to 8 —	$4\frac{3}{4}$ —	$0\frac{1}{2}$ to $2\frac{1}{2}$ —	$1\frac{1}{4}$ —	$3\frac{1}{2}$,,
April	$2\frac{1}{2}$ to 9 —	5 —	0 to $2\frac{1}{2}$ —	$1\frac{1}{4}$ —	$3\frac{3}{4}$,,
May	4 to 10 —	$6\frac{1}{2}$ —	0 to 4 —	$3\frac{1}{2}$ —	4 ,,
June	$6\frac{1}{2}$ to 13 —	$8\frac{1}{2}$ —	0 to 5 —	3 —	$5\frac{1}{2}$,,
July	$8\frac{1}{2}$ to 14 —	11 —	1 to 6 —	$3\frac{1}{2}$ —	$7\frac{1}{2}$,,
August	11 to 15 —	13 —	1 to 5 —	$3\frac{1}{4}$ —	$9\frac{3}{4}$,,
September..........	9 to 14 —	$11\frac{1}{2}$ —	1 to 5 —	3 —	$8\frac{1}{2}$,,
October	$7\frac{1}{2}$ to 14 —	10 —	1 to 5 —	3 —	7 ,,
November	6 to 11 —	8 —	1 to 5 —	3 —	$4\frac{1}{4}$,,
December	3 to 7 —	$5\frac{1}{2}$ —	1 to $4\frac{1}{2}$ —	$3\frac{1}{2}$ —	$2\frac{1}{4}$,,

Direction.

The *Direction of the N.E. Trade Wind* is an important nautical consideration. Its mean direction in the circuit of the earth is estimated at N. 47° E., but it varies considerably under the influence of the land, and especially so in the North Atlantic. The Trade Wind blows much more from the Northward to the Eastward of long. 25°—that is, within 400 or 500 miles of the African coast—than it does in the open ocean. Between the Canaries and Cape Verde, during the Northern summer months, it blows from N.N.E. and N.E. for 55 days out of every 100.

Doldrums.

A ship from England, bound across the Equator, finds the wind to draw more Northerly as she approaches the Southern verge of the N.E. Trades; whilst, after passing through the Equatorial Calms, the S.E. Trades commence at South. It is also found that as this zone of Doldrums is approached, the Barometer falls: it is an area of low pressure; and the zone of Equatorial Doldrums travels with it between the Equator and 10° or 12° N. during the year.

Into this zone the air seems to blow from both North and South, whilst the pressure still remains lower than on either side; we have, therefore, reason to suppose that here, on the border line of the two Hemispheres, the air is drawn directly towards the lowest pressure. It will be remembered that, at a certain distance from the Equator in the Northern Hemisphere, the air draws round an area of low pressure, keeping the lowest pressure to its left, whilst at a certain distance from the Equator in the Southern Hemisphere, this order is reversed, and the lowest pressure is to the right of a person standing with his back to the wind. Hence it is reasonable to expect that the air will move directly for the area of lowest pressure in a part where the two Hemispheres meet.

The influence of the land upon the Trade Winds, and the intervening Calms, is very powerful on the Eastern side of the Atlantic; and the peculiar configuration of the coast of Guinea, trending as it does along the very axis or line of division of the Northern and Southern Wind Systems, causes a different set of phenomena to arise. During that part of the year when the sun is in the Southern Hemisphere, the Trades and Calms follow the normal or usual course, as it is then exerting its maximum for ceon the sea, which has low absorptive and radiative powers; but when, during the Northern summer, it is raising the temperature of the land of the Guinea coast, a new phase arises from the heated Atmosphere over the land drawing the wind towards it; and instead of a S.E. or N.E. wind, we have a South and S.W. wind occurring with great regularity. Major Rennell says, "In the space lengthwise, between Cape Verde and Cape Mesurado, and in certain places to the extent of 70 leagues off shore (50 leagues off Sierra Leone), a regular change of winds and currents takes place, according to the seasons; that is to say, a N.E. or North wind and S.E. current, from September to June; and in the rest of the year, a S.W. wind and N.E. or Northerly current, in effect a *Monsoon*; and this extends, in respect of the *wind*, nearly through the whole space between the two continents.

African Monsoons.

In Dampier's Discourse on the Trade Winds, and his illustrative Chart (1697), we find a solution of the origin of these S.W. winds, which is that still held to be most feasible. It is, that they are derived from the S.E. Trades, and not from a diversion of the N.E. Trades. This also was suggested in the "Mercantile Marine Magazine," of 1856, the data being derived from Maury's charts. An important element in determining the reality or otherwise of this suggestion is the position of the Calms. Are they interposed between the N.E. Trade and Monsoon, or between the Monsoon and S.E. Trade? This consideration may not, however, have great weight in this region of Calms, but the probability of this origin is increased by the data for the direction of the S.E. Trade, which is shown not to blow with regularity to the East of a line joining Cape Palmas and Angola.

There is another conclusive evidence of the Westerly extension of the Monsoons in the *Easterly* Currents that are met with almost constantly during the seasons of their prevalence. These are very persistent as far as long. 40° W., and are at times encountered as far North as lat. 16°, but more usually between lats. 6° and 11° N. This origin of the anomalous Guinea Current was indicated in our chart of the Atlantic, published in 1858. A similar current is shown to exist in the Pacific Ocean, West of Panama Bay. This feature will be further dilated on when we come to the Chapter on Currents.

These South, S.S.W., and S.W. winds prevail, according to Maury's Pilot Charts, chiefly during the months of July, August, September, and October, and are then felt as far to the Westward as 35° or 40° W., between the parallels of 5° and 8° N. In the Western tract of this area they diminish in frequency as the sun proceeds to the South, and are scarcely felt in the North

Atlantic during the months of December, January, and February. The chances of encountering this adverse wind must have an important bearing on the choice of a route for crossing the Equator during these months, but we leave this subject to be discussed under the heading of "Crossing the Equator," in the Chapter on Passages, given hereafter.

From a description of the *General Winds* of the North Atlantic, we proceed to describe those of a few special localities more or less frequented by shipping.

English Channel.

The following are the results of fifteen consecutive years observations upon the wind, taken by M. Nell de Bréauté, at the Chapelle, near Dieppe, at an elevation of 410 feet above the sea :—

Direction of the Wind.	Mean Number of Days.	Maximum.	Minimum.
South.	37	In 1828— 54 days.	1820 and 1825—28 days.
S.W.	93	1823—121 „	1831—67 „
West.	48	1830— 72 „	1829—31 „
N.W.	52	1825— 72 „	1832—38 „
North.	36	1819— 56 „	1821—21 „
N.E.	41	1826— 54 „	1828—22 „
East.	23	1820— 41 „	1821—12 „
S.E.	31	1818— 46 „	1827—19 „
	Total, 361 days.		

From this table the following conclusions may be drawn :—

In the 365 days of the year there are about 361 of wind, and 4 or 5 of dead calm.

If the horizon is divided into four equal parts, there will be—

135 days with the wind between South and West,*
94 „ „ between West and North,
71 „ „ between North and East,
61 „ „ between East and South.

The maximum of winds between S. and W. takes place in November and Dec.
The minimum „ „ May and June.
The maximum of winds between W. and N. takes place in July and August.
The minimum „ „ October and December
The maximum of winds between N. and E. takes place in May and June.
The minimum „ „ October and November.
The maximum of winds between E. and S. takes place in December and June.
The minimum „ „ June and January.

Moderate winds from North and N.E. are those which bring fine weather. In summer the N.E. wind blows more particularly in the afternoon ; in the morning the wind is S.E., a slight breeze, and towards noon it changes quickly to N.E.; then it freshens, and towards the evening it sinks ; at night it is calm, and the coolness condenses the vapours. When this condensation does not take place, it is a sign of a change of wind.

Dead calms are of rare occurrence, and do not last long, except during summer. When they occur in winter, it is regarded as a precursor of bad weather. It is always, in reality, an indication of a change in the direction of the wind.

Bay of Biscay.

The winds in the Northern part of the Bay of Biscay do not differ greatly from those experienced in the entrance of the English Channel, and therefore the same remarks are applicable to each. As we approach the head of the bight, however, it is necessary to use great caution, and observe all indications of the change of the wind.

In summer, the prevalent winds on the coast at the head or S.E. angle of the Bay, are those from N.E. and East, which become North and N.N.W. in the Gulf of Bilbao. These alternate with N.W. and West winds, which generally drop at night, during which they are replaced by the land breeze. In autumn Southerly winds prevail, and are usually very violent. They generally last for two or three days, and sometimes for eight or nine, the weather being clear; but as soon as they shift to S.S.W., the sky becomes covered with heavy Clouds, and almost immediately the "Vendavale" or dirty weather from S.W. and West comes on. These, after some days' duration, shift to N.W., with heavy rains and a rougher sea. This wind is much dreaded by seamen, from the heavy surf which it sends in; it also debars entrance to the few harbours on the Biscayan coast, and is very lasting. It is not uncommon to find it continue for fifteen days consecutively, with only two or three days of even moderate weather. With this N.W. wind there is, however, no fear of being drifted on to the coast, as it is never entirely hidden, and there are sufficiently clear intervals to allow you to make out the land.

It is not so with North and N.N.E. winds; they blow perpendicularly to the coast, and will not allow ships embayed to clear off shore. They completely hide the land, and are accompanied by much rain and hail, which follow each other almost without interruption. They generally last but a short time, and occur between the middle of December and the end of February, or the beginning of March.

The N.E. wind is not frequent in summer, but is often accompanied by thick fogs, in which case it blows heavily for two or three days, and is then called *Nord-este pardo* (the dirty North-easter). When it shifts to the S.E. by the East, you should as far as possible keep in with the coast, because the wind will shortly come from South. When the South wind, after lasting two or three days, shifts to S.W., either get off the land or else enter some harbour, because the N.W. wind will soon come on.

In the spring the winds are generally very light, and nearly always from N.W. or S.W., accompanied by rain. In some years these winds last until July.

African Coast.

On the whole extent of the African coast there are but two Seasons, namely, the *Rainy* and *Dry Seasons*. The division of the two is connected with the periods when the sun crosses from one Hemisphere to the other, and is modified as he advances to, or recedes from, the Equator.

The *Rainy Season* commences at each place on the coast to the Northward of the Equator, at the time when the sun passes the zenith of that place in his course to the Northward. It is, usually, during the month following this event that the change of weather takes place. It may, therefore, be calculated that, at the Isles de Los, the first point exposed to the Rainy Season, and which lie in 9½° N., the first violent squalls do not occur before the 10th or 15th of May. Their arrival seems to be affected by the moon; for they almost always commence, and are most violent, on the days of the new and full.

Tornadoes.

The Rainy Season ends in very violent squalls, with intervals of calm, of which there are at least two, and frequently more, during the twenty-four hours; and it has been remarked that they generally happen on the rising or setting of the sun or moon. In the country, these squalls are generally called *Tornadoes;* but, according to the best information, the Tornado, properly speaking, is to be met with only to the Southward of Cape Verga. They generally begin to form themselves in the N.E. or E.N.E. quarter of the horizon, which seems completely on fire during an hour or more. The storm then gradually shifts round to East and E.S.E., becoming darker in the horizon. Having arrived at S.E., it attains its full vigour, when thunder and lightning become incessant. A moment of absolute calm then takes place, which is caused by the obstruction which the usual winds meet with from this immense mass of Clouds. Shortly after, a small arch is formed at the horizon, which increases and rises rapidly. The more defined the edge of this arch appears, the more violent will be the storm, as it is a proof that the column of air has divided much heavier Clouds, and is more confined. When the summit of this arch has attained an altitude of about 45°, the Tornado bursts forth, and torrents of rain immediately follow. The crisis of its greatest violence generally lasts from 15 to 20 minutes; it afterwards gradually becomes weaker; and finally nothing remains but rain, attended with very little wind. It then shifts round from S.E. to W.S.W., then to the quarter from which the usual winds blow, to exhaust itself to the Northward in another squall from the S.E.

The *Rainy Season*, at any place, continues from four to six months, according to its proximity to the Equator, and the Tornadoes continue to decrease, both in frequency and violence, during the two latter months of the season. In ten days or a fortnight after the sun has passed the zenith of any place on his way to the South, it is considered as free from bad weather. On the 15th of November a gun is fired at Goree, which announces the return of the *Fine Season.*

The Squalls here spoken of, and the Winds which precede or follow them, generally occupying so very small a portion of the year, may be considered as momentary convulsions in a state of climate almost unchangeable; a sky nearly always serene, and generally clear.

On the greater part of the African coast, from Cape Bojador to the Isles de Los, regular winds blow, and no rain ever falls during eight months. The prevailing winds in this country blow from N.E. to N.W.; it may, therefore, be said that they follow the direction of the coast from North to South, and that they seldom vary from the limits here assigned.

The *Dry Season* commences in the latter part of October at Senegal; a little later at Goree; and at each intermediate place towards the Equator it becomes gradually later. It is not till the beginning of December that its return is observed in the parallel of the Isles de Los.

The *Rainy Season* continues for four months, from May to September; but the *Tornadoes*, which invariably accompany its commencement and termination, generally cease between those periods. They blow from the E.S.E., and with great fury; but they seldom last more than three hours. The prevalent winds, during the rest of the Rainy Season, are from the Southward and Westward, and are usually so light as to give way in the afternoon to the N.W. sea-breeze.

The Harmattan.

On the Gold Coast, as well as the Windward Coast, an Easterly wind, called the *Harmattan*, prevails during the months of December, January, and February. This Wind comes on indiscriminately, at any hour of the day, at any time of the tide, or at any period of the moon, and continues sometimes only a day or two, sometimes five or six days, and it has been known to last fifteen or sixteen days. There are, generally, three or four returns of it in every season; it blows with a moderate force, not quite so strong as the sea-breeze, which every day sets in, during the fair season, from the West, W.S.W., and S.W.; but somewhat stronger than the land-wind from the North and N.N.W. at night. In the "Philosophical Transactions," vol. lxxi., for the year 1781, an account of the *Harmattan* was first given by Matthew Dobson, M.D., F.R.S., from the enquiries and observations of Mr. Norris, of which the following is the substance:—

On that part of the Coast of Africa which lies between Cape Verde and Cape Lopez, a singular periodical Easterly wind, named, by the natives, *Harmattan*, prevails during the months of December, January, and February. At the Isles de Los, which lie to the Northward of Sierra Leone, this wind blows from the S.S.E.; on the Gold Coast, from the N.E.; and at Cape Lopez and the River Gaboon, from the N.N.E.

The Harmattan comes on as above described. A fog, or haze, always accompanies it, and the gloom is sometimes so great as to render near objects obscure. The sun is thus concealed the greater part of the day, and appears only for a few hours about noon, and is then of a mild red colour. At 2 or 3 miles from shore the fog is not so thick as on the beach; and at 4 or 5 leagues distance it is entirely lost, though the Harmattan is felt for 10 or 12 leagues, and blows fresh enough to alter the course of the current.

Extreme dryness is a property of this wind. No dew falls during its continuance, nor is there the least appearance of moisture in the Atmosphere. All vegetables are much injured, and many destroyed. The seams in the sides and decks of ships become very leaky, though the planks are 2 to 3 inches thick. Iron-bound casks require the hoops to be frequently driven tighter, and a cask of rum or brandy can scarcely be preserved; for, unless kept constantly moistened, the hoops fly off. The Harmattan has, likewise, very disagreeable effects on the skin, lips, and nose, which become sore.

The effects of the Harmattan on evaporation are great, as will appear by the following comparative statement:—At Liverpool, the annual evaporation is about 36 inches; at Whydah, 64 inches; but, under the influence of the Harmattan, it increases there to the rate of 133 inches.

West Indies.

The following description of the Winds prevailing over the West Indies, in the different seasons, has been extracted chiefly from Captain Livingstone's translation of the "Derrotero de las Antillas," or Spanish Directory for the West Indies.

On the Eastern coasts of America, and among its islands, the course of the general Easterly or Trade Wind is uninterrupted, though subject to some modifications in direction and force. At a short distance from the land the sea-breeze calms at night, and is replaced by the land-breeze. This variation happens every day, unless a strong wind prevails from the Northward or Southward; the first of these being experienced from October to May, and the second in July, August, and September.

The general Easterly Wind, of the Tropical regions, is felt on the coast of Guayana, and on the coasts of the Colombian and Mexican Seas, but with variations which may be denominated *diurnal* and *annual*. The diurnal variation is that caused by the sea-breeze, which strikes the coast usually at an angle of two points, less or more, according to the locality and other circumstances, followed by the land-wind, which, coming from the interior, always blows off shore. The sea-breeze comes on at about 9 or 10 in the forenoon, and continues while the sun is above the horizon, increasing its force as the sun augments its altitude, and diminishing in a similar proportion as that altitude decreases. Thus, when the sun is on the meridian, the sea-breeze is at the maximum of its strength; and at the time that it reaches the horizon this breeze has ceased. The land-breeze commences before midnight, and continues until the rising of the sun, sometimes longer. A space of some hours intervenes between the land-breeze ceasing and the sea-breeze coming on, during which there is a perfect calm.

The *Annual Period* of the Trade Wind here is produced by the proximity or distance of the sun, which occasions the only two seasons known in the Tropics, the *Rainy* and *Dry Seasons*. The first is when the sun is in the Tropic of Cancer, and heavy rains with loud thunder are prevalent. In this season the wind is generally to the Southward of East, but interrupted by frequent calms, yet it occasionally blows with force.

When the sun removes to the Tropic of Capricorn, the Dry Season commences, and then the Trade Wind, which is steady at N.E., is cool and agreeable. At this season, North and N.W. winds are sometimes found blowing with much force; and, indeed, in some degree, they regularly alternate with the general wind, being more frequent in November and December than in February and March.

Although in the Mexican Sea it cannot be said that there is any other constant wind than the general Easterly breeze, yet, from September to March, the North winds interrupt the general course, and in some degree divide the year into two seasons, *Wet* and *Dry*, or the *Breezes* and *Norths;* the first, in which the breezes are settled, is from March to September; and the other, in which the Norths blow, is from September to March.

The Norths.

The first of the Norths is regularly felt in the month of September; but in this month and the following one, October, the Norths do not blow with much force. Sometimes it happens that they do not appear; but, in that case, the breeze is interrupted by heavy rains and Tornadoes. In November the Norths are established, blow with much strength, and continue a length of time during December, January, and February. In these months, after they begin, they increase fast; and in four hours, or a little more, attain their utmost strength, with which they continue blowing for forty-eight hours; but afterward, though they do not cease for some days, they are moderate. In these months the Norths are North-Westerly in direction, and bring cloudy weather; they come on so frequently that there is, in general, not more than four or six days between them. In March and April they are neither so frequent, nor last so long, and are clearer, but yet they are more fierce for the first twenty-four hours, and have less North-Westing. In the interval before November, in which, as we have said, the Norths are established, the weather is beautiful, and the general breeze blows with great regularity by day; the land-breeze as regularly by night.

Examples are not wanting of Norths happening in May, June, July, and August, at which times they are most furious, and are called *Nortes del Hueso Colorado;* the more moderate are called *Chocolateros,* but these are rather uncommon.

CURRENTS.

General System of Currents.

The illustrative chart to be found at the end of this section, will best explain the general Current System of the North Atlantic. Although this gives the mean of all observations throughout the year, and therefore would require considerable modification in various parts, if it were made to show what is to be expected at any special time or season, yet it will correctly represent that circulatory system which is found to be common to all the Oceans.

Around a central area, crossed by the parallel of 30° N. latitude, and termed the Sargasso Sea, the whole of the water between lats. 10° N. and 42° or 43° N. (limits varying with the seasons), revolves against the apparent course of the sun. To the North of this a portion of the water is deflected to to the N.E., and, it is presumed, after circulating around the Arctic Basin re-enters the area on the West. As the Meteorological Equator, or the division between the phenomena of the Northern and Southern Hemispheres, lies to the *North* of the Terrestrial Equator, we find that a reverse Current, of varying magnitude and force, runs from West to East on this division, or from 2° or 3° to 8° N., across nearly the whole breadth of the Ocean and along the African coast, while South of it the Westerly Current of the South Atlantic runs strongly across the Ocean and along the Northern face of the South American continent, a portion thus entering the Northern circulatory system.

There is then some difficulty in assigning a separate designation for each part of what is almost a continuous stream, and in former times when the subject was much less understood, some inappropriate terms were applied to various portions which have become recognised and followed throughout. For the present, therefore, we are compelled to use a somewhat confused nomenclature, but it will be sufficiently explanatory till a general revision of the science may impose a new terminology.

Of the Currents of the Atlantic, the first in order, from the Land's End of England, is *Rennell's Current*, a temporary but extensive stream, which sets at times from the Bay of Biscay to the Westward and N.W., athwart the entrance of the English and St. George's Channels, and to the Westward of Cape Clear.

Second.—The Easterly and S.E. Currents to the coasts of Europe and Africa, and Southerly to the Coast of Guinea, where it may be termed the *North African Current*, flowing to the Westward of South and merging into the Westerly Drift.

Third.—The *Guinea Current*, an *Easterly* stream across the Atlantic between 5° and 8° N., and continuing along the coast of Africa, into the Bights of Benin and Biafra.

Fourth.—The *Sargasso Sea* or Central Area, between the Azores, Canaries, and Bermudas, &c., in which it seems that there is no particular set, or only very various and slight currents; it is covered with the well-known Sargasso or Gulf Weed.

Fifth.—The *North and South Equatorial Currents*, the vast streams caused by the Trade Winds. That of the N.E. Trade running from between the Tropic and Cape Verde, on the Eastern side, towards the Caribbee Islands, having a general Westward tendency, and that from the S.E. Trade, which is usually found to the North of the Equator, passing strongly to the Westward, South of the counter or Easterly Current (number three above), and then strongly to the W.N.W. along the Colombian coast, joining the N.E. Trade Current in the Caribbean Sea.

Sixth.—The *Currents* of the *Colombian* or *Caribbean Sea*, and the *Mexican Stream*, a continuation of the Great Equatorial Streams into the Mexican Sea, from the South-Eastward and Eastward.

Seventh.—The *Florida* or *Gulf Stream*, an outset from the Mexican Sea, setting thence to the North-Eastward, through the Strait of Florida, and then Eastward toward the Newfoundland Banks, &c.

Eighth.—The *North East Drift* which passes over the Eastern side of the Atlantic, from the area East and South of the Newfoundland Banks, towards and past the N.W. Coast of Europe and into the Arctic Basin.

Ninth.—The *Arctic* or *Labrador Current*, passing Southwards from Davis Strait down the coast of Labrador, round Newfoundland, and thence South-Westward past Nova Scotia and the coast of the United States, inside the Gulf Stream.

Rennell's Current.

Rennell's Current, which is occasionally of considerable breadth and strength, frequently sets athwart the entrance of the English Channel, to the N.W. and W.N.W., at some distance to the Westward of the Isles of Ushant and Scilly. As it apparently depends on temporary circumstances, it is considered as a temporary stream; and, although a certain quantity of Northerly indraught is always to be allowed for, with the tide of flood, on approaching the Scilly Islands, the Current, unless with particular winds, will be scarcely, if at all, perceptible.

The common causes of Currents, so far as they depend upon the state of the Winds, &c., are generally known to seamen; and that a long-continued wind, in one particular direction, will either produce a stream where no obstruction exists, or cause an accumulation of the water against an opposing coast, until a reverberation takes place, needs no demonstration. The latter appears to be the case in the present instance. A long and continual prevalence of Westerly and South-Westerly winds, in combination with a Current which commonly sets into the Southern parts of the Bay of Biscay, occasions an accumulation of water in the Bay, which seeks an escape, by setting to the

N.W. or W.N.W., within the limits described by half-arrows in the accompanying chart.

Easterly and S.E. Current.

It may be taken for granted that the whole surface of that part of the Atlantic Ocean between the parallels of 40° and 30° N., and from a distance of 100 miles from the shore to 500 miles West of it, is in motion towards the Strait of Gibraltar and the African coast. This direction of Current is experienced when 50 miles West of Madeira, Westward of which position it sets to the South-Westward.

From Cape Finisterre the Current (termed at this part the *Portugal Current*) generally flows to S.E. and South along the coast of Portugal as far as Cape St. Vincent, when it runs Easterly toward the Strait of Gibraltar.

From the Strait of Gibraltar to the Canary Islands the Current within 100 miles from the coast flows to the Westward, following the bends of the shore; among the Canary Islands it is irregular.

From the Canaries to the the Cape Verde Islands it generally sets from S.S.W. to S.W., with a velocity of from 6 to 24 miles a day, being variable according to the direction, duration, and force of the wind.

This part of the Current is known as the *North African Current.*

Guinea Current.

In the description of the Winds, and in the diagram illustrating the Best Monthly Routes across the Equator, it is shown, that between the N.E. and S.E. Trade Winds there is a Belt of Calms and Variable Winds, which, on the African coast, assume the character of Monsoons; during the summer months especially, the wind blows more or less toward the African coast.

In the Currents there appears to be an analogous system, as there is in this locality an *Easterly* Current flowing, with considerable velocity, in an opposite direction to the great Equatorial Drifts on either side of it. Its existence and character along the Guinea Coast has long been known. It was formerly thought to be a continuation of that Current which we have just described as passing Southward from Western Europe, but later investigations seem to point to the fact that it is a flowing back of the waters heaped up to the Westward by the prevalent winds. In tracing the Currents of the Pacific Ocean, we find that there exists a precisely similar Current in that great ocean setting into the Bay of Panama, in the same latitude. This Current in the Pacific is traced very far to the Westward—in fact, nearly across the ocean.

The Easterly Current passing across the Atlantic strikes the coast of Africa about Sierra Leone and the coast of Liberia. When near the shore, it assumes its direction to the S.E., and runs with great velocity. As is shown by the Chart of the Currents, its mean annual velocity is between 14·1 miles and 26·5 miles per day, being strongest in the summer months.

Its mean direction off Cape Palmas and Cape Coast Castle is E. 12° N., and its calculated velocity from Major Rennell's and Maury's observations is—for

January, 17·4 miles to 27·6 miles; February, 26 miles to 32 miles; April, 11·5 miles to 33·7 miles; May, 22·7 miles to 36 miles; June, 30 miles; July, 18·2 miles; August, 15·7 miles to 26·4 miles per day. These are from the records of 75 observations.

Its Southern edge appears to be in about lat. 2½° to 2° N., up to the head of the Bight.

The Temperature of the Guinea Current is high, which demonstrates its Equatorial origin, although the branch of it which comes from the Northward past Cape Verde has probably a lower temperature as coming from a higher latitude. The Equatorial Current to the Southward of the Guinea Current is also of a lower temperature, coming direct along the African coast from the Southern Polar regions. The mean summer temperature is about 78°, but in our winter and autumn months it is higher, being from 82·6° to 83° as a mean, and sometimes it is found higher than this.

H.M.S. *Challenger*, in crossing this Current, made the following observations on the Temperature of the sea at different depths. From the Cape Verde Islands, 300 miles West of Cape Verde, her track was in a general South-Easterly direction for 88 miles to a position 150 miles S.S.W. of Sierra Leone; thence, in the next two days, she proceeded to a position 160 miles to the S.S.W., or 310 miles from Sierra Leone. The date of this passage was August 10th to 21st.

Temperature Observations, in degrees (Fahrenheit), by H.M.S. Challenger, while crossing the Guinea Current in August, 1873.

Position of Ship.	19° N. 24° W.	18° N. 24¾° W.	13½° N. 22¾° W.	12¾° N. 22½° W.	10½° N. 20½° W.	9¼° N. 18½° W.	8° N. 17½° W.	7° N. 16° W.	5¾° N. 14¼° W.	3° N. 15° W.
At the Surface ..	74	74	79	79	78	78	78	79	79	78
25 fathoms	—	—	—	60	69	65½	—	—	72	—
50 ,,	—	68	—	54	59	59	63	61	62½	65
75 ,,	—	—	—	53	55	55	—	—	59	61
100 ,,	57½	62	52	51	53	54	56	55	56	57
200 ,,	54½	52	50	48½	48½	47	50	49½	53	51
300 ,,	50	47	46	46	43	45	45	43	43	42
400 ,,	46	43	42	42	42	41	41	41	40	40
500 ,,	43	42	40	40	40	41	41	40	40	39
1000 ,,	38	38	38	—	38	—	—	38	—	—
1500 ,,	—	36	36	—	—	—	—	37	—	36

The above table, it must be remembered, refers to the time of year at which the Guinea Current is at its greatest power. Subsequently, in returning home, the *Challenger*, in the passage from Ascension to the Cape Verde Islands, in April, 1876, found the Surface Temperature in lat. 2° 30′ S. to be 82½°; in 0° 15′ S., 81½°. In lat. 3° N., long. 15° W., 300 miles S.W. of Cape Mesurado, the Temperature was 83° on the surface, in the same position in which a Temperature of 78° only was found in August, but the warm water did not penetrate to so great a depth. At 50 fathoms, 65° was found in August, but only 59° in April. Sir Wyville Thomson remarks—"Where the rate of the Current is highest, we have as usual a rapid fall in the Temperature below the surface. This is caused by the cooler water rising to supply the place of the hot surface water, which is being rapidly drifted and evaporated away."

At the distance of about 59 leagues South of Cape Palmas (long. 7¾° W.) the outer border of the Guinea Current sets to the East; and continues to a similar distance South of Cape Three Points (long. 2° W.); we thence, at 2° North of the Line, find it take a more Northerly course, toward the Bight of Benin and the Bight of Biafra; in the latter it mixes with the water of the *South African Current*, which, coming from the South, sets thence to the North and N.W., and both, uniting, form a head in the bight. From this bight, and Southward of the Equator, the Currents thus blended set to the S.W., W.N.W., and N.W., in one expanding and united stream, which greatly facilitates the passage of ships from Fernando Po to Sierra Leone.

The prevalence of the Harmattan Wind, which has been described (pp. 48-9), must interrupt the course of this Current; but its existence, at other times, nearly as described, has long been confirmed, and is incontestable.

It thus appears that the Guinea Current has its maximum extent in August, reaching to 45° W., and occupying 11° of latitude on the meridian of 20° W.; and has its minimum extent in December, attaining long. 23° W., with a width of only 7° on the meridian of 20° W. From December to August it is extending its longitude Westward and widening Northward; and from August to February it is losing its extension Westward, and its Northern limit is retreating Southward again.

The Sargasso Sea.

The central portion of the Atlantic, which is comprised between the Trade Wind and anti-Trade Wind systems, also bounded on the South by the Westerly Drifts of the Trade Winds, and to the North by the Easterly Current, presently described, appears to be in a different physical condition to the other portions of the Atlantic Ocean, and indeed from any other portion of the globe.

Its chief apparent characteristic is well expressed by the name now usually applied to it—the *Sargasso*, or *Weedy Sea*. The well-known gulf-weed, which is found more or less over its whole area, seems to be quite peculiar to it. There may be a somewhat analogous physical condition in the North Pacific, but this is not so easily defined. The gulf-weed is constantly found, in greater or less quantity, scattered over its whole area, and when it is found in places not its usual habitat, it may be safely inferred that it has drifted out of this extensive area by the action of the Current.

It is very difficult to define the limits within which this gulf-weed is found. It is more than probable that the fluctuation of the seasons greatly affects them, as it does the limits of the Trade Winds and intervening Calms, the more particularly as it is owing to the varying currents caused by these winds that the weed is retained in its locality. Consequently we may look for its North and South boundaries more to the Southward during the Northern winter months, and the reverse during the summer. The Tropic, or about the parallel of 23° N., may be its Southern edge in the longitude of the Azores, from whence this limit extends to the Virgin Islands and the Bahamas. Its Northern edge runs from the Azores to the outer edge of the Gulf Stream off Cape Hatteras. It is not so abundant to the Westward of the meridian of the Azores. This will give a breadth of 1,000 miles in its Eastern part, and a length of 3,000 miles from East to West. As before stated, its limits may change greatly at different times, but it may always be looked for within this area, that is between the Southern edge of the Gulf Stream and the Northern limit of the Equatorial Current.

North Equatorial Current.

The name usually given to the great Drifts of the Trade Winds, having as wide a range of latitude as 50° or 60°, is scarcely expressive. The *Equatorial* Current, strictly speaking, is the Guinea or counter-Current we have just described. However, the Drift which is intended passes to the S.W. and W. of the Azores and Canaries, and from the Coast of Africa to the Gulf of Mexico, Northward of the Easterly counter-Current in the North Atlantic; while the great Drift of the S.E. Trade Wind, crossing the Equator Southward of the counter-Current, and running strongly to the N.N.W., along the coast of Guayana, joins its strength to the Northern portion, and thus, together, they pass through the Caribbean Sea.

The Drift of the N.E. Trade is not so powerful as that of the S.E. Trade, as the interference of the land causes such a great change in the regularity of the winds which certainly must be taken as the greatest cause in the production of the Currents. In general it is a very feeble Current, and the mean rate has been over-estimated in former times by many observers. In its Northern limits in the open Ocean its annual average, from a careful calculation, amounts to from 8·2 miles to 11·6 miles per day; in its Southern and stronger portion it is from 16 to 22·4 miles per day. Westward of the Cape Verde Islands, its mean direction is nearly due West, which is remarkable, considering the Northing of the Trade Wind.

South Equatorial Current.

The South Equatorial Current, which passes over the Equator in its Northern portion, in its direction is, like that of the Northern Equatorial Current, nearly due West. Setting upon the Northern coast of South America, it runs with great velocity close in-shore at times, sometimes attaining 100 miles per day, and not unusually 60 miles. It is scarcely necessary to dilate on this part of the Current, as it appears regular and constantly met with. Its progress through the Caribbean Sea, &c., will be dealt with in a following paragraph. For an idea of its strength and direction in the Equatorial region, between the longitudes of 10° and 40° W., the reader is referred to the diagrams illustrating the Best Monthly Routes Across the Equator.

It will be seen that, throughout the breadth of this Ocean, the set of the stream is not to S.W. or N.W., as might be expected from the direction of the Trade Winds, which may be taken as the prime mover of these mighty drifts, but *Westward.*

This fact would seem to indicate that the rotation of the earth on its axis has more to do with this motion than has usually been attributed to it. But our present knowledge of the subject is not sufficiently extensive or accurate to define what amount of action is due to that source, or how much to the Wind, Lunar Influences, or Temperature, all of which combine to produce the phenomena we are considering. Theoretical speculations, however, are not necessary in a practical work, although they may be interesting.

Arrived at the barrier formed by the line of the Antilles, a large portion of the stream is necessarily arrested, the remainder pouring through the openings, which, between Barbuda and Trinidad, are not in the aggregate 230 miles in width, or not one-half of the range. From this, or other causes, the Westerly Drift through the Caribbean Sea is not so persistent, probably, as it is in the Ocean to the Eastward.

On this Current the following is extracted from Mr. R. Strachan's remarks in the Meteorological Report, 1872 :—

The South Equatorial Current commences on the African coast, and seems to extend at times as far as to 3° N. lat., though more commonly here it is not found beyond 1° N. To the first meridian its rate is from 12 to 17 miles. It now extends generally to lat. 3° N., and maintains this limit to long. 25° W., during a course nearly West of over 1,500 miles, at rates changing from 26 to 12 miles per day. It now has a tendency to the N.W., and attains lat. 6° or 7° N., and as a general result, maintains this limit until it reaches the coast of Brazil. Near the Equator the mean rate is less than 24 miles per day, and this becomes lower as the latitude increases, so that in lat. 5° N. its velocity is less than 18 miles. For nearly 300 miles from the coast of Brasil and Guiana the direction of the Current is affected by the land. Off Brasil, the rate is from 62 to 37 miles per day; off Guiana, it is from 31 to 24 miles. Having passed the 50th meridian, the Northern edge of the Equatorial merges with the Westerly Drift, though in some months this is effected in longitudes more to the Eastward, even so far as the meridian of 25° W.

The Westerly Current, which enters the Caribbean Sea, has a rate of 37 to 46 miles North of Trinidad, but the rate decreases as the latitude increases, and in lat. 17° N. it is only 12 miles a day. In this sea the Westerly Current averages about 20 miles a day. The mean velocity of the Yucatan Current is 34 miles, but it flows into the Gulf of Mexico, towards N.W. by N., with a velocity of 41 miles; and at times the Current seems to be carried right across the Gulf. To the North and East there is no escape for it, owing to the Gulf Stream; hence the check felt in issuing from the Yucatan Channel bears it off to the Westward, but not until it has attained its maximum strength in about lat. 23° N., long. 86° W.

There are times, probably, when the Yucatan Current is weaker than the Gulf Stream; then a counter-Current, an overflow from the Gulf Stream, flows round Cape Antonio towards the Isla de Pinos.

The waters of the Equatorial find a passage Westward and Northward round the Gulf of Mexico, and they keep up a well-defined movement of its water. Probably, in about lat. 27° N., long. 90° W., a considerable portion of the Equatorial Current which passed through the Yucatan Channel finds its way into the Gulf Stream. Hereabouts it would appear that the Currents are intricate, and difficult to ascertain, from their conflicting influence upon the ship's course during a day's run.

The Gulf Stream.

The Florida or Gulf Stream has received more attention—has been the subject of more speculation—and has served as the basis of more theories than all the other Currents of the Ocean collectively. Although modern research, conducted with all refinement, in contra-distinction to the imperfect observation of the passing seaman in former years, has shorn it of much of the grandeur and magnitude it was formerly invested with, still it is a mighty and majestic Current, well worthy of all the laborious investigation which the philosopher and mariner have bestowed upon it.

The investigations which the United States Government surveyors have carried on in the narrower portion at the commencement of the Stream, have dissipated all pre-conceived notions of its enormous magnitude; these were only commenced in 1855, and when subsequently published they were so startling as to be received almost with incredulity. But the subsequent most careful measurement of its Depth, Velocity, Temperature, and other collateral features in many parts, down to 1866, have entirely confirmed this first statement, made by Commander Craven, in 1855, that the narrowest was the *shallowest* part of its course. From these and from the other numerous sections which have been examined on lines transverse to its course between Florida and Nantucket, we are enabled to calculate with some approach to exactness, what is the Amount, Rate, and Temperature of the volume of water which is transported by it into colder latitudes.

In the preceding pages we have traced the course of the waters from the shores of Europe down to the Great Set or Tropical Drift, and thence through the Channel of Yucatan to the entrance of the narrow channel between the North shore of Cuba and the Florida Cays. Here may be said to be the commencement of the Gulf Stream as an independent Current, since it flows swiftly hence to the Eastward in opposition to its previous course, and then Northward through the Narrows between Cape Florida and the Bemini Isles. Keeping this direction with its high velocity and temperature, it is deflected to the N.E. by the form of the American coast, and assuming a more Easterly direction, and gradually spreading its warmer waters over a broader area through an immense region of perpetual fogs rising from its tepid waters, it pursues its course with a gradually decreasing rate and temperature, until it reaches the Southern part of the Banks of Newfoundland. At this part it encounters the Arctic Current, which, crossing its track and importing into it the influences of an Arctic temperature, and the counteracting effects of an adverse Current upon its diminished forcé and much decreased volume, causes it to cease to maintain its character as a Gulf Stream or an independent Current.

History.

The Gulf Stream was known by its present name, and in its now known limits, from very early times. The Northern Equatorial Drift was noticed by Columbus, September 13, 1492, when in lat. 27° N., long. 40° W., and this is the first Ocean Current observation. In the subsequent voyages, in 1502-3, he observed the strength of the streams in the Caribbean Sea. The first voyage through the Gulf of Florida was that by Poncé de Leon, in 1512 or 1513, who gave the first account of the Stream itself; he named the present Cape Cañaveral *el Cabo de Corrientes*, from the circumstance. Several other Spanish voyagers, about this period, also experienced its effects, especially the pilot Antonio de Alaminos, who sailed through it in 1519.

The Gulf Stream has had, from early times, a very bad reputation among ship-masters for its dangerous character, and the hundreds of wrecks and millions of property which have bestrewed its margin have given good occasion for such a character. For not only is it to be dreaded for its stormy character, but also its violent Stream renders a ship quite unmanageable during a calm. At these times should any hazy weather occur, and the sameness of the shores mislead the stranger, he is liable to many difficulties and dangers. But the excellent system of beaconage along the Florida Reefs, and the important lights which direct by night, have very much reduced its bad character, and diminished the employment of that enterprising race, the wreckers of Kay West and the Florida Reefs.

Characteristics.

The Indications of the Stream are the *Appearance* and the *Temperature* of the Water. The Stream in its lower latitudes and usual course, where it flows uninterrupted, may be known in fair weather by its smooth and clear deep blue surface; for, outside the line formed by a ripple on its edge, the water in some places appears like boiling water of a lighter blue colour; and, in other places, it foams like the waters of a cataract, even in dead calms, and in deep water.

On the outer edge of the Stream, especially in fair weather, there are great ripplings, which are very perceptible. The appearance of the seaweed, by day, is an indication of this edge of the stream; this weed being, *commonly*, on the edge without the Stream, in greater quantity and larger clusters than within it.

Extent.

The Gulf Stream commences its great career between the Tortugas Bank and the coast of Cuba, therefore the line joining the Dry Tortugas and Havana may be taken as its starting point. It is here 95 miles wide. At the channel between the Kay Sal Bank and Sombrero Kay it is only 48 miles wide; off Cape Florida, its narrowest and shallowest part, it is 45 miles. Between the edge of soundings off Jupiter Inlet and the Matanilla Reefs it is 50 miles. This part of the Gulf Stream, confined on either side by reefs and islands, before it shoots off uncontrolled into the Atlantic, is 330 miles long.

Pursuing its way Northward, its warmest waters and strongest Current keep near to the edge of the Bank of Soundings which fronts the coasts of Georgia and the Carolinas, following the general curve very strictly, and in its main strength keeping 50 miles off Cape Hatteras, where the whole breadth occupied by the three or more warm bands is included in a breadth of 200 miles; the breadth of the bands themselves may not be more than 120 miles. This portion of its course from the channel within the Matanilla is about 590 miles further.

To the Northward of this, its N.W. edge still follows the edge of the Banks of Soundings, and being diverted by the coast and by the obstacles lying off it, gradually winds more to the Eastward towards the parallel of 40°, where on a line transverse to its course trending S.E. from Cape Cod, which will be about 430 or 450 miles beyond the Cape Hatteras section, it is from 250 to 300 miles broad. Beyond this it pursues an Easterly course for 1,250 miles to the meridian of 40° W., which is 350 miles East of the Great Newfoundland Bank, after having skirted the Southern edge of those Banks with diminished velocity and temperature. From the meridian of 40° West just named, its further drift to the Eastward cannot be distinguished from that of the whole surface of the Ocean to the North and South of it. The total distance we have thus gone over will be about 3,500 miles, throughout the whole of which its characteristics may be distinctly traced, although its lateral boundaries are not so easily defined.

It has been usual to extend its independent existence some 1,200 or 1,500 miles further to the shores of Western Europe, as before stated, but when its volume in the outset, or in its *narrowest* part, is considered, it will be no great sacrifice of previously formed opinions to curtail it of its more extended features.

Throughout its latter course the left-hand margin carries the greatest strength. In the Gulf of Florida its Southern side is the most powerful.

Northward of the Gulf its Eastern and South-Eastern edge is difficult to define, as it is found that the Gulf Stream may be said to consist of several longitudinal bands of water, as presently described. To the Southward of British North America its force gradually disappears, till it is lost in the central still water of the Sargasso Sea. The diagram of the Currents which elucidates this section will give a clearer idea of its relation to the great circulatory system, than any long description can do.

The general plan of exploration of the Gulf Stream, laid down in 1845, was to observe the phenomena on sections perpendicular to its axis from well-determined points on the coast. In pursuance of this design, sections were run from near Montauk Point, Sandy Hook, Cape Henlopen, Cape Henry, and Cape Hatteras, previous to 1848. Lieut.-Commander Craven was directed in 1853, in returning from the Florida Reef, to run four sections across the Stream from near Cape Cañaveral, St. Augustine, St. Simons, and Charleston; and Lieut.-Comg. Maffit, after closing his work at Georgetown, South Carolina, to run three sections respectively from Charleston, Cape Fear, and Cape Hatteras.

On the Charleston section, bottom was carried from 10 fathoms, 38 nautical miles S.E. from Charleston Light, to 100 fathoms, 65 miles S.E. from the light. The bottom was not reached at 500 fathoms, nor in 600 fathoms in the Stream. At 97 miles from Charleston Light, after crossing the warmest water of the Gulf Stream, bottom was struck in 300 fathoms in the main strength of the Current, and variable depths from 500 to 370 fathoms were found to 207 miles from the coast, or 80 miles beyond the outer limit of the Stream. The bottom was brought up in every case, and has been preserved, showing some very interesting results.

After crossing the Gulf Stream on the Cañaveral section, Lieut.-Commanding Craven struck soundings of 400 fathoms, at 69 miles from the coast. It appears thus that the existence of soundings of from 300 to 400 fathoms, after crossing the Gulf Stream at these two points of the coast, was discovered independently by the two officers nearly at the same time. In the subsequent sections run by the *Corwin*, soundings were struck 125 miles off St. Simon's in 500 fathoms, and off Charleston in 480 fathoms.

The form of the bottom on the Charleston and Cañaveral sections slopes gradually from the shore to 53 and 36 miles respectively, then suddenly falls off to more than 600 fathoms. On the Charleston section of the bottom, 96 miles off shore, is a range of submarine hills, steep on the Western side, with a height of 1,800 ft., and a base of about 11 miles on the Eastward side; a second range lies 136 miles from the coast, 1,500 ft. high, and 28 miles base towards the shore, and 600 feet high, with a base of about 17 miles, on the outer side. Beyond this is a more gradual rise. On the Cañaveral section the inner range is 68 miles from the coast. In fact, on the Cañaveral section, after sounding at the depth of 1,060 fathoms, the steamer drifting a mile and a quarter, the line showed bottom at 460 fathoms. Both are stated to have been good up and down casts. These first observations, while they are merely a foundation to build upon, are undoubtedly in the highest degree interesting and important in their connection with the phenomena of the Gulf Stream.

On the sections from Cape Fear and Cape Hatteras, after leaving the shoals near the shore, the depths increase very rapidly.

Lieut.-Comg. Craven noticed ripples in connection with the irregularities of the bottom on the Charleston section. Similar ripples were observed on the Sandy Hook section and on the Montauk section in 1845, and were compared to the "rips" on the Nantucket Shoals. These are probably a secondary effect of the irregularities of the bottom, causing changes of the surface current.

As far, then, as Cape Hatteras the bed of the Gulf Stream has been found not to exceed 600 fathoms in depth, and is, in many parts, very irregular. To the Northward of this, the Ocean is very deep. At 200 miles Eastward of Cape Hatteras the depth is 2,500 fathoms; at 150 miles Eastward of Cape Henlopen, 1,500 fathoms; at 180 miles E.S.E. of Nantucket, off the S.E. point of George Shoal, 1,350 fathoms; at 230 miles Eastward of Nantucket, off the Eastern edge of George Shoal, 1,340 fathoms; and at 180 miles Southward of Halifax, and 40 or 50 miles S.S.E. of Le Have Bank, 1,250 fathoms. Between this latter sounding and Bermuda the depths vary between 2,000 and 3,000 fathoms. These are depths at which the Gulf Stream has little or no influence, as is shown by the temperatures taken by H.M.S. *Challenger*.

Although thus deprived of a large portion of the magnitude with which it was formerly believed to be invested, it is not the less a wonderful stream, as it is able, so expanded and thinned out, to maintain its course and character unimpaired, over the counter-Currents of a totally different origin and nature which flow beneath it.

Breadth.

As stated before, it is difficult to define the exact boundaries of the Gulf Stream, which is, in fact, but one out of a series of several. But whilst the more minute examination which has been made has added something to our knowledge of its features, it has not hitherto been sufficiently extensive to fix its limits, either by an average, or, if it is more exactly defined, to give us the position of its margin in different seasons. However, as numerous observations have been given on its drifts, we may give a rude approximation to its extent from the positions where the drift has been found to be appreciable. In the narrowest part it is about 40 miles broad—a breadth it maintains to abreast of Cañaveral. Off Charleston it is about 70 miles; off Cape Look-out, 100 miles; off Cape Hatteras, 120 miles; while off Nantucket, it is probably expanded to 300 miles, so that it has widened to more than seven times the extent it commenced with. That the Southern side of the Gulf Stream to the Northward of Bermuda is very ill-defined will be best understood by studying the Temperatures taken by H.M.S. *Challenger* in April and May, 1873 (see *North Atlantic Memoir*, p. 412). The temperature was higher at Bermuda than at most stations to the Northward, both at the surface and below. Only in two observations between Bermuda and Halifax was the surface temperature found to exceed that at Bermuda, and then only by 1°. The directions of the Currents in the passage between Halifax and Bermuda (May 20—28) also indicate that the Stream here was weak in power. As far as 37½° N. the Current was observed to flow in a Southerly direction between S.W. and S.E., at rates varying from 10 to 26 miles in the twenty-four hours. In 37° N. the Current flowed strong to the Eastward 32 miles; in 36½° N., only 7 miles N.E.; in 35° N., 7 miles E. by N.; and at 60 miles North of Bermuda a weak current of 3 miles flowed to the N.W. The Wind in this passage, Southward of 40° N., was generally from the N.E., and varied in force from 3 to 7 Beaufort Scale (page 8), between 40° N. and 36° N.; Southward of this it was very light.

Velocity.

We abandon the calculation which we made in 1856, of the Velocity of the Stream, as derived from the data given by Rennell, Maury, and numerous other authorities. Generally—perhaps it may be said always—these observations gave a higher rate of motion than subsequent and more carefully corrected observations have shown to be the case. The work of the Meteorological Office, before quoted, on the Currents of the North Atlantic between the Equator and 40° N., as drawn up by Mr. Strachan, at first under the direction of the late excellent Admiral Robert FitzRoy, and afterwards by his successor Robert H. Scott, Esq., M.A., must now be taken as the standard authority, and from it we take the following general observations on the Gulf Stream, as far as the parallel of 40° N., above mentioned.

Origin.

The Gulf Stream may be considered to commence near the Delta of the Mississippi. A Current setting N.E. by N., averaging 20 miles a day, in lat. 26° to 28° N., long. 95° to 90° W., appears to cross the 90th meridian, and unite with the Gulf Stream, which takes a direct course to the Florida Reefs, setting S.E., its rate increasing from 9 to 29 miles per day, in a distance of about 500 miles. On the right it has the Yucatan Current, which it forces Westward. At times part of this S.E. Current finds its way round the West end of Cuba into the Caribbean Sea. On the left there appears to be an off-flow towards the E.N.E.; and North of the Florida Isles, about lat. 26° N., long. 83° W., the configuration of the land occasions a sort of eddy, and the currents experienced there are extremely variable in direction. There being no outlet for the waters towards the N.E., and the Yucatan Current confining it on the S.W., the main part of the Stream is forced into the Straits of Florida, turning to the N.E. by E. in its passage between the Florida Reefs and Cuba at a mean rate of 39 miles. About lat. 25° N. the straits between Florida and the Bahama Banks become contracted, part being known as the Narrows. Here the set becomes almost due North, and its rate greater, averaging 48 miles. This rate and set is maintained to lat. 30° N. Thence to lat. 32° or 33° N., the direction of the set is

N.E. by N., while the rate has decreased to 40 miles. Now the set changes to N.E., and is maintained to lat. 38° N., long. 70° W., the mean rate of the main stream being from 48 to 43 miles. The Stream is strongest towards the land side, being pressed upon by the Arctic Current, which probably causes the very high velocities sometimes experienced about lat. 36° to 38° N., long. 74° to 70° W. On the right side the Stream is free to spread out, being only resisted by a feeble Westerly drift. Here accordingly we find the Current weaker, even down to 10 to 20 miles a day. It must be remarked, however, that the observations made on the right edge of the Stream must frequently be in part due to the influence of the Westerly, or rather South-Westerly drift, upon the ship's run in twenty-four hours, the final result depending on the preponderance of one or the other current during the interval. Whenever this has been suspected, the observations have been separated from those believed to have been made entirely in the Gulf Stream, and averaged by themselves. In long. 70° W., the width of the Stream averages about 120 miles, extending from lat. 36° to 38° N. Thence its set becomes E.N.E., and its main portion seems to pass North of lat. 40° N., the limit of the Chart, near long. 60° W. Between 70° and 60° W. the rate is from 37 to 27 miles per day. The Southern edge of the Stream can be traced to long. 45° W., about lat. 38° N., but the rate is feeble and the set variable.

Temperature.

The Temperature of the Caribbean Sea is above 80° from July to October, during the rest of the year it is below 80°; the minimum, about 75°, occurs in February and March. In the same latitudes, nearly 10° to 20° N., off the African coast, the lowest temperature occurs in January, and the highest in July, when it rises to above 80°, as in the Caribbean Sea; but, with this exception, these Eastern waters are always from 3° to 7° colder than the Western.

It will be noticed that the maximum and the minimum temperatures take place later in the year in the Caribbean Sea than off the African coast. This circumstance is probably due to the prevalent Currents.

The Gulf Stream keeps the sea, off the Southern shores of the United States, from the Mississippi to Cape Hatteras, at a temperature above 80°, from June to October; above 70° during January, February, and March; and above 75° during the intervening months, April and May, November and December.

In striking contrast to this high and equable temperature of the seas of the Southern States, is the low and variable temperature of the seaboard of the Northern States, from lat. 40° to 36° N., due to the presence of the cold Arctic Current. Here in January, February, and March, the temperature of the sea falls below 50°; in April and May, and also in November and December, it is below 60°; in June and October it is below 70°; and in July, August, and September, it attains to 75°. Where the warm waters of the Gulf Stream intermingle with, or flow side by side with the cold Arctic Current, the changes in the temperature of the sea are large and sudden, and are noticed by all navigators of that region. If we contrast these extreme differences of temperature off the American Coast with the slow change observed off the Coast of Africa, the influence of Currents in modifying the temperature of the sea, and determining climatic peculiarities, becomes strikingly evident. With this view, the following tabular statement has been compiled from the Charts, from which it appears that on the meridian of 74° W., the change of temperature from lat. 40° to 35° N., or in 300 miles, is on an average 18°; while on the meridian of 20° W., from lat. 40° to 10° N., a distance six times as great, the average change in the temperature of the sea is but 15°.

Months.	Sea Temperature in Lon. 74° W.		Change in 300 Miles.	Sea Temperature in Lon. 20° W.		Change in 1,800 Miles.
	Lat. 40° N.	Lat. 35° N.		Lat. 40° N.	Lat. 10° N.	
	°	°	°	°	°	°
January ..	49	68	19	60	70	10
February..	39	67	28	57	73	14
March....	45	70	25	58	78	20
April	50	70	20	57	78	21
May......	54	77	23	58	76	18
June	62	79	17	62	80	18
July	69	82	13	66	76	10
August ..	72	78	6	70	80	10
September	65	78	13	71	81	10
October ..	62	75	13	69	82	13
November.	56	72	16	65	80	15
December.	50	71	21	60	80	20
Average ..	56	74	18	63	78	15

It has been found that the temperature of the Stream varies in a greater degree than can be accounted for by the Climates it passes through, being sometimes warmer to the North, and cooler to the South, of any particular position. This seems to be accounted for by the variability at the source of the Stream in the Gulf of Mexico and elsewhere, which it would be very difficult to follow up to any specific determination.

Warm Bands.

The Gulf Stream was found, in the course of its investigation in 1845-48, to consist of alternations of cold and warm water, a fact which was very surprising at the time, but the results of the later explorations in 1853 entirely confirmed the former ones in this respect. In fact, the Gulf Stream is merely a number of bands of warm water separated by cold water. The observations on the Hatteras, Cape Fear, and Charleston sections, show a *counter-Current* where the cold streaks are found; and as these observations and those for temperature are entirely independent of each other, the coincidence in result is very striking. This fact is of too great importance not to be carefully followed up. It would also appear, from general reasoning, that such was not unlikely to be the case.

On the land side, the division between the cool and warm water is very distinct. It is now concluded that this separation into distinct belts is owing to the form of the bottom, as they appear to be strongest North of the section off Cape Cañaveral, where the range of submarine hills and dales is found very much to coincide with the position of those cool and warm belts; and this conclusion is strengthened by the fact, that South of Cape Florida, where the bottom is even, they disappear altogether.

The Cold Wall.

The separation between the warm, deep blue waters of the Gulf Stream and the inner cold counter-Current is sometimes so well marked, that "one end of a ship is seen in the one, and the other end in the other Current." Although this line of demarcation is not so distinct as Captain Maury says, yet a remarkable feature has been always elucidated by the United States' Coast Survey. It is, that the separation between the two Currents is so well marked beneath the surface, and to the greatest depths, as to have obtained for it the title of the "Cold Wall," being, in fact, an upright division between them. This peculiarity has been found to exist along almost the whole Coast of the United States, where the Stream skirts the Bank of Soundings. Without diagrams the features cannot be made quite intelligible; but the main fact, so interesting to the physical geographer, is as above stated—that there appears to be a marked non-affinity between the waters flowing in opposite directions.

It was at first supposed that the Cold Wall was cut off at Cape Hatteras, but subsequent researches have qualified this supposition. The cold water has been traced as far as the Tortugas. Off Sombrero Kay the Cold Wall was strongly marked at depths from 70 to 100 fathoms, while everywhere in that locality the warm water overflows the Cold Wall, and reaches quite to the shore.

The shallowness of the Stream in the Strait of Florida, connected with the fact that the bottom falls off rapidly to the North and South, afforded an excellent opportunity for testing the question whether the cold water of the under Polar Current is forced upwards by the change in depth—as, should this be the case, the cold water would appear in the shallow part of the Strait; and this has actually been found to be the case, as the warm surface water of the temperature of 80° and the cold water of the bottom of the temperature of 49° nearly approach each other. It does not follow from this that the "waters run up-hill," as stated.

Recapitulation.

We have thus described this famous Stream, perhaps at greater length than is needed, from its origin in the Mexican Gulf to the offings of Cape Cod and Nantucket, a portion of its course much better known than any other, and easy of definition, which is not the case with its further progress.

It has been shown that, between the Tortugas and Havana, it is only about 40 miles wide, and not 1,200 feet deep, travelling with a mean annual velocity on the surface of 32·7 miles per day, as was previously estimated in the North

Atlantic Memoir, or of 30·7 miles, as calculated from the Board of Trade charts, which will always be preferred.

Passing onwards to the Narrows of the Gulf between the Bemini Islands and Cape Florida, distant 330 miles from the first section, we come to that part which, beyond contradiction, decides the whole character of the Gulf Stream, as the *whole of it* passes over this OUTFALL. It is here 39½ miles wide, and the water above the temperature of 60° is about 1,200 feet deep in the centre of the Stream. The *sectional area* of the Stream in this part is, therefore, about 6·64 square miles.

Its *Velocity* here was formerly calculated at about 65·4 miles per day on an annual mean; but the much more exact data of the Meteorological Department (1872) gives an annual mean of 48·0 miles per day. In *Spring*, 43·6 miles; *Summer*, 45·1 miles; *Autumn*, 46·8 miles; and *Winter*, 53·4 miles per day; which is contrary to previous calculations. These figures accord very well with those which result from the calculations made for the Tortuga-Havana section.

Now, as the inference is that the cold substratum of the Gulf Stream is moving in a direction opposite to its course, that is, *Southwardly*, there is some point where there is no movement. Making all possible allowance for the decrease in velocity from 48·0 miles on the surface to 0·0 at the bottom (and this must be done in an empirical manner, and may be *much* overrated), the Mean Velocity of the whole mass will not exceed 36·25 miles per day. The sectional area of the Stream not exceeding 6·64 square miles, it follows that there are not more than 240·7 cubic miles of water passing per day over a given line in this part of its course.

Its mean rate of progress, when passing Cape Hatteras, is given as nearly the same as in the Narrows, 47·2 miles per day, though this is in excess of the velocities given at intermediate points. The surface water will take 13½ days to pass from Cape Florida to Cape Hatteras, 630 miles apart; but if the whole mass maintains the same rate, it will not pass in less than 17 days, and will be at the annual mean, only 4·2° Fahrenheit cooler (varying from 10° to 1·2°). Off New York it will be 10° cooler (varying from 17° in winter to 3·9° in August). Off Cape Hatteras the breadth of the Stream is 120 miles, therefore it has expanded to a breadth of more than three times (3·3) its width at the Outfall, and its whole mass will make a bed of water 366 feet thick.

From this line to that of the section running S.E. of Nantucket, the distance is about 480 miles. On and near this section, temperature soundings were taken by the U. S. Coast Surveyors, Commander Craven in 1854, Davis in 1845, and Bache in 1846, and their observations place us in a difficulty; for the warmer waters were not found to exist Northward of the parallel of 38° N.; the "Cold Wall" showed itself to the North of this, and then two less warm beds as far as 40° N. But the observations for Current motion show its Eastern progress much further than this: in fact, up to 41° N. If we accept the lower estimate of its rate, made by the Meteorological Office (as should be done), it will take 16 days to move the whole mass from Hatteras to Nantucket, or 33 days from the Outfall. Its temperature has only fallen about 12° or 18° since it left the Gulf of Florida. It is this rapid course, and consequent preservation of its original warmth, that has made it so remarkable in all ages.

But while it has thus carried the Tropical heat so near to, and amidst the Arctic cold, its volume must be spread over a very much wider space, for its somewhat undefined breadth off Nantucket may be assumed at 300 miles, or seven times its original breadth; and if its velocity throughout were equal, it could only be 170 ft. deep, but, as its rate has somewhat diminished, it may be taken as 200 feet. Its surface has, however, much cooled down, and the body of *warm* water cannot be assumed even as deep as this calculation makes it.

Arrived at the Grand Bank of Newfoundland, we meet with a totally new feature in its condition. It here encounters the full force of the Labrador Current, which, setting Southward over the Banks with nearly equal velocity and bulk, cuts off the Eastward course of the Gulf Stream in all that part of the Current which runs North of 42° or 43° N. The Isotherms, derived from the immense mass of figures in Maury's Thermal Charts, show, as Dr. Petermann says, that the Polar waters set against and penetrate it like an immense wedge. This cold water gulf penetrates Southward for 150 to 200 miles; and in July, which is the period when the Arctic Ice drifts down in the greatest quantities, this is most evident, as the temperature of the Arctic water is not more than 48°, while that of the Gulf Stream, to the Southward, is 68° and upwards. In January, the period when the Arctic regions are entirely frozen, and no Icebergs descend into these Southern latitudes, the effects on the surface are not quite so manifest, but are nevertheless evident as far South as lat. 38° N.

Now, this "Cold Water Gulf" is no surface interference of a temporary nature. It is a strong permanent current, flowing to a greater depth than the Gulf Stream at all seasons of the year. That it entirely cuts off all the lower beds of the warmer water is demonstrated by the fact that Icebergs, 80 and 100 ft. high, have been seen as far South as lat. 36° 10′ N. in April, 1829, and 38° 40′ in June, 1842. This shows that the more powerful Southern Arctic Drift, of which many evidences are constantly met with in the summer months, by the Ice-drifts, and in the winter by the cold water, must cut off the Eastward progress of this Northern portion of the Gulf Stream waters. But it is very probable that a small portion of the warm water does get over to the Eastward of this in "hot streaks" which are so remarkable; because, although the Thermometer on the surface shows that there is no continuity in the waters on the East side of long. 48° with those to the West of that meridian, yet the current observations show that the drift is still, generally, to the Eastward.

Arctic or Labrador Current.

The last section treated of the warmer Tropical waters which passed into the Northern regions, carrying with them the ameliorating influence on the Arctic climate. The present deals with the same waters as they emerge at a minimum temperature from these frozen regions, and bring their Ice and cold into the grand system of circulation and compensation.

The limits of the N.E. Drift about Iceland have been mentioned previously. To the West of this, then, we may place the great Drift which comes down from beyond Spitzbergen, and transports the immense quantities of Ice upon the Eastern shores of Greenland, which has generally rendered this, one of the most inclement regions of the world, unapproachable by ships. Several instances of this Drift could be recited, but, as they are not interesting to navigation, they need not be dilated on. The Ice this Current brings into the low latitudes is an important consideration in the navigation of the Atlantic, as is well known. This branch of the Arctic Drift, however, does not probably furnish many of those gigantic Icebergs, which, drifting down Davis Straits, float over the Newfoundland Banks, and far into the Northern margin of the Gulf Stream.

The estimated rate of this Drift from Spitzbergen, calculated from the rate of vessels drifting in the pack-ice, is from 8 to 14 miles per day.

It was formerly considered that this S.W. stream, after passing Cape Farewell, the South point of Greenland, made direct for the coast of Labrador, and thence over the Newfoundland Banks; but Commodore Irminger, of the Royal Danish Navy, has demonstrated that it does not do so, but that it passes around Cape Farewell to the Westward, and thence Northward along the shores of West Greenland.

If the Current existed, which the before-named writers state to run in a direct line from East Greenland to the Banks of Newfoundland, then the Ice would likewise be carried with that Current from East Greenland; if it were a submarine current, the deeply-immersed Icebergs would be transported by it; if it were only a surface-current, the immense extent of field-ice would indicate its course, and vessels would consequently cross these Ice-drifts at whatever distance they passed to the Southward of Cape Farewell. *But this is not the case;* experience has taught that vessels coming from the Eastward, steering their course about 2° (120 nautical miles) to the Southward of Cape Farewell, seldom or never fall in with Ice before they have rounded Cape Farewell and got into Davis Strait, *which is a certain proof that there does not exist even a branch of the Arctic Current which runs directly from East Greenland towards the Banks of Newfoundland.*

The limits of this Spitzbergen Current, as it may be termed, is therefore indicated by the distance to which the Ice it transports is found to extend, and may be taken as extending to a distance of 120 miles South of Cape Farewell, and to 150 miles off the Danish settlements of S.W. Greenland.

In the space of Ocean between the Southern limits of this Current and the known South-Easterly Drift down the Labrador Coast, an anomalous condition seems to exist. We have no notice of the set of the streams, if any within it, but its characteristics seem to be the *drift-wood* within its area. These floating relics have evidently a Southern origin, and point also to the truth of the statement that a warm current sets toward and past Iceland.

" From the foregoing it seems to be demonstrated that the Current from the Ocean around Spitzbergen, which carries such considerable masses of Ice, after it has passed along the East Coast of Greenland, turns Westward and Northward round Cape Farewell, *without detaching any branch* to the South-Westward, directly towards the Banks of Newfoundland.

" It afterwards runs Northward along the S.W. Coast of Greenland until about lat. 64° N., and at times even up to Holsteinborg, which is in about 67° N."—*Admiral Irminger.*

This Current, then, after drifting over the Atlantic, passes up the Eastern shore of Davis Strait to and beyond the entrance of Baffin's Bay, between Cape Walsingham and Holsteinborg. It here encounters the *Southern* set which passes down Baffin's Bay, especially on its Western side, transporting those immense Icebergs which are annually launched from the glaciers of West Greenland and other parts, as described by Dr. Rink. This Current, which enters Baffin's Bay, especially by Lancaster Sound, is the grand outlet of the waters which run from West to East through the Labyrinthine Archipelago, once the scene of the exciting search for the Expedition of Sir John Franklin, and is unquestionably the continuation of that Drift past Spitzbergen, described previously.

It thus brings into warmer latitudes all the Ice which remains from the melting influences of the Arctic summer, and also is continually floating Southwards that which collects in Baffin's Bay and its inlets. Its Southward Drift is constant, winter and summer, as has been demonstrated by the drift of several vessels of the Arctic searching squadrons—as the Grinnell Expedition, Sir James Ross, H.M.S. *Resolute*, Sir L. M'Clintock in the *Fox*, &c.

About 10 miles per day may be taken as the Drift down Baffin's Bay, as estimated by the author in the " Journal of the Royal Geographical Society," vol. xxvi., 1856.

The Baffin's Bay Current and the Spitzbergen Current, having united, set with great force down the Coast of Labrador, the Westward tendency being probably owing to the earth's rotation, which here rapidly increases as the Current flows Southwardly in these parallels. It is probable that it sets at from $1\frac{1}{2}$ to 2 miles per hour, close in shore on the Labrador Coasts. But its chief interest to the sailor are the masses of drift Ice and tremendous Icebergs which it floats Southward across his track, constituting one of the most formidable dangers of the Transatlantic navigation. The limits within which these Ice-drifts are encountered are also the limits of the Current now being discussed.

These *Ice-drifts* are seldom met with to the Eastward of the meridian of 49°, that is, about 300 miles beyond the limits of the Grand Bank. Near to the Banks they become more numerous, and in some years the sea appears to be covered with them, and vast numbers of Bergs ground on the Banks.

To the Southward the extent of this Ice-drift is uncertain, as it depends upon two causes: the one, the force and extent of the Arctic Current from the Northward; and the other, the depth to which the Icebergs are immersed. As before mentioned, there appears to be a perpetual struggle between the opposing forces of the Arctic Current and Gulf Stream to the Southward of the Banks. This process, invisible at other seasons, is made apparent during the season of the Ice-drifts by the deeply-immersed Bergs passing quite into the course of the Gulf Stream under the influence of which they rapidly disappear. As we have seen, the view now accepted of this phenomenon is that the Gulf Stream overruns the cool waters proceeding Southward and South-Westward; and although the Northern edge of the warm waters of the Stream are met with in the summer months over the Southern end of the Newfoundland Banks, or as high as 45° N., yet these Bergs are found drifting as far South as 39°, and even to 36° 10′, or 420 miles Southward of the Banks, and beyond the limits of the Gulf Stream.

THE MEDITERRANEAN SEA.

WINDS.

The Mediterranean Sea, though lying between those parallels of latitude where in the open ocean Westerly winds would be found, has its Wind and Current systems materially influenced by the differences of temperature of the masses of land which lie on its borders. Speaking generally, the Prevalent Winds for nine months of the year are those from West through North to N.E., but in February, March, and April, S.E. and S.W. winds prevail.

Gales are experienced from November to April, usually from N.E. or N.W.[1] At this season however Easterly and S.E. gales are sometimes known to blow from one extremity to the other; Southerly gales in the Western part are very rare.

The movement of the Barometer is small; but it always gives warning of approaching bad weather from the Westward. Its indications are not so reliable with Easterly gales.

Western and Eastern Basins.

It is usual to consider the Mediterranean Sea as forming two Basins, connected by the channel between Cape Bon and Sicily. Over the Western Basin there is a general prevalence of Northerly winds, especially in summer, at which season land and sea breezes are well developed near the shores, particularly near the coast of Spain. Over the Eastern Basin the prevailing summer wind is from N.W., while in winter variable breezes are found, with gales from S.W. to S.E., and from N.E.

Gibraltar Strait.

The Prevailing Winds in the Strait of Gibraltar are from East or West (*Levante* and *Ponente*), and they are about evenly distributed throughout the year; occasionally, however, in January, February, and March, gales from S.E. and S.W. (the latter known as *Vendivales*) are experienced.

It is a curious fact that at Cadiz and Gibraltar, separated by a distance of only about 50 miles, winds from opposite directions are often blowing at the same time.

The directions of the usual winds in this Strait are caused by the configuration of the land, for a West wind is found, when Westward of the

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[1] A N.E. gale at Malta is locally known as the *Gregale*, while winter gales from the Northward are generally known in the Mediterranean as *Tramontana*.

entrance, to blow as a N.W. wind on the Coast of Spain, and as a S.W. wind on the African Coast; while an East wind, when within the Strait, blows from N.E. on the Spanish shore, and from S.E. on the African side.

In summer it not unfrequently happens that the wind on the Northern side of the Strait is blowing in an opposite direction to that on the Southern side, such opposite winds being locally known as *Contrastes.* This peculiarity is also often observed near many of the prominent capes of the Western Basin.

The Levanter in the Strait is always associated with moisture in the air, mists over the hills being a certain prognostic; while the disappearance of such mists is equally a sign of approaching West winds.

Gulf of Lyons.

The Gulf of Lyons is remarkable for the suddenness with which gales of wind spring up, and for the unusually heavy sea which accompanies them. The ordinary winds are very variable, but those from N.W. (known both here and on the coasts of Italy and Sardinia as the *Mistral*), are the most frequent. These blow with great violence during the winter and spring months.

Over the sheltered space between Corsica and Sardinia and the Coast of Italy, fine weather is generally experienced, with occasional gales from S.E. in winter.

African Coast.

Off the African Coast, Easterly winds (*Levanters*) prevail in summer, with land and sea breezes near the shore; in winter, West and S.W. winds are often of long continuance.

Adriatic Sea.

In the Adriatic the winds mostly experienced are from N.E. to E.N.E., and from S.E. to South, but at the entrance they are very variable, and in summer frequent calms are common over the whole sea. The N.E. wind is known as the *Bora;* it rises very suddenly, and blows with extreme violence, especially in winter.

The Bora is supposed to be caused by the cold air in the mountain valleys rushing down to the warmer regions over the Adriatic, and it is especially dangerous, as it blows *across* that sea.

The S.E. wind, or *Sirocco,* is accompanied by much moisture, fog, and a heavy sea, blowing with violence during the winter months. The S.W. wind in the Adriatic is known as the *Siffanto,* and is often violent. The N.W. wind is frequent in summer, and is locally known as the *Maestro.*

Ægean Sea.

Among the islands of the Grecian Archipelago the Prevailing Winds are from N.W. to N.E.; heavy gales from S.E. and S.S.E. are experienced in the winter months. The N.E. winds which blow in summer are known as *Etesian* winds; and at this season regular land and sea breezes blow in the different gulfs on the mainland, the sea breeze being locally known as the *Imbat.*

CURRENTS.

From Cape Finisterre the Current flows S.E. to Cape St. Vincent, and then East through the Strait of Gibraltar, where it is much influenced by the Tidal Streams.

On entering the Mediterranean, one branch flows to the N.E. as far as the Balearic Islands, while another branch flows Eastward at from one to two knots an hour, at a distance of from 20 to 30 miles from the African Coast, and appears to skirt the whole Southern shore of the Mediterranean, being augmented off the coast of Egypt by the outflow from the River Nile.

Within a distance of from 20 to 30 miles from the African Coast in the Western Basin, a counter-Current to the Westward is often found.

Gibraltar Strait.

The Tidal Streams in this Strait materially affect the Easterly Current. The ebb stream sets to the Eastward, so that when the water is falling at Gibraltar the whole Strait is occupied by an Easterly Current, which sometimes runs at five knots an hour round prominent points.

When the water is rising at Gibraltar, the flood stream setting to the Westward checks the Easterly Current, which then forms a narrow stream in the middle of the Strait, running at about two to three knots an hour; while near the shores on either side a Westerly Current is felt. During strong Easterly winds this Easterly stream in mid-channel is checked, and even a Westerly set experienced.

Near prominent points in the Strait strong counter or eddy Currents are found, with turbulent tide races.

Beneath the surface Currents the whole body of water moves Eastward, while the tide is falling at Gibraltar, and Westward while it is rising.

Bosphorus and Dardanelles.

At all times a strong Current sets from the Black Sea into the Mediterranean through the Bosphorus and Dardanelles. This Current is probably owing partly to the general prevalence of Northerly winds in the Black Sea, and partly to the discharge into it of several large rivers.

The under-Current in these Straits was found to set in the opposite direction to that on the surface.

THE SOUTH ATLANTIC OCEAN.

WINDS.

The general Winds of the South Atlantic Ocean may be classified as the South-East Trade, the Westerly Winds, and the Brazilian Monsoons.

South-East Trade Wind.

The area occupied by the S.E. Trade Wind is of larger extent than that over which the N.E. Trade blows, for the reason that the intervening Calms occupy a space North of the Equator, while the Polar limits are found on about the same parallel in each case. But from this space must be deducted that portion on the Eastern side which lies East of a line joining the Cape of Good Hope and Cape Verde, over which the Winds blow toward the land from the Southward throughout the year, a deflection of the Trade Wind, which thus assumes the character of a Monsoon. On the Western side also, the American Continent so far deflects it from its normal course, that it blows from the Northward of East. In the S.W. portion, besides that Eastward of Rio Janeiro, the Trade is very variable and uncertain.

In the central part of the area of the S.E. Trade the wind is remarkably steady, and of great force, so that for homeward-bound ships passing the Cape of Good Hope there is a long stretch of favourable wind that can always be reckoned on as far as the Equator. This will be well exemplified by the diagram, which will explain the relation of this true Trade Wind with those deflections previously alluded to on either side of it.

The relative strength of the N.E. and S.E. Trades has been the subject of some controversy. Captain Maury contends that, from the difference of 0·055 inch in the mean barometric pressure, as observed by the Dutch between the parallels of 5° and 20° in the N.E. and S.E. Trades, being 29·968 for the former, and 30·023 for the latter, the S.E. Trades are proportionately stronger. The homeward-bound vessels (2,235 in number), with the wind abeam in the N.E. Trades, have an average rate of 5·6 knots an hour, while in the S.E. Trades, with the wind generally dead aft, their rate is 6 knots. He contends that if the wind were abeam instead of dead aft, this rate of sailing would be increased 2 or 2½ knots, which would make the difference still more manifest.

In mid-ocean, or between the meridians 0° and 30° (or 35°) W. of Greenwich, and between the Equator and 30° S., the portion of the Ocean most free from land influences, it will be seen that the S.E. Trade Wind blows with great regularity, as before noticed. But there is this feature which is much exaggerated on either side of the meridians named—that on the Eastern or African side, the wind blows much more from the Southward, and on the Brasilian side much more from the Eastward than the normal direction of the Trade Wind, and at its outer limits this S.E. Trade Wind is so drawn from its course that it blows at a right angle to its ordinary direction, becoming a S.S.W. and S.W. wind against the African Coast, and a N.E. wind on that of Brasil. In mid-ocean also there are much fewer calms and light airs, than where the wind is so much interfered with by the heated continents on either side.

A steady Trade may therefore be reckoned on with much certainty in crossing its area, and it is only when the land on either side is approached, as it must be in crossing the Equator, that the difficulties of contending with varying and adverse breezes have to be met. In the ensuing paragraphs some notices of these peculiarities are given.

Extent.

The limits of the S.E. Trade Wind are very difficult to define verbally. The illustrative diagrams will be far more efficient in giving an idea of its varying extent and borders. On the North side it is separated from the N.E. Trade Wind by the Belt of Equatorial Calms or Doldrums and side Monsoons; but a few words have been already given on this part in connection with the changing winds on the African Coast.

Further to the Westward, the Northern limit of the S.E. Trade is found further to the Northward than is marked in the foregoing, the line of separation running across the Ocean in a diagonal direction, usually from W. by N. to E. by S. It would also appear that the Calms do not generally pass South of the Equator, but this is not always the case, for at times the S.E. Trade fails in lat. 6° S. off the Brasilian coast in the months of February, March, and April, when the full effect of the vertical sun is limited to the Southern Hemisphere. During the rest of the year it is seldom or never lost South of the Equator.

The Southern limits are also very indefinite, and much more so on the Western than on the Eastern side of the Ocean. "The Calms of Capricorn," as they have been termed, are also very vague in their extent and limits, but they are much narrower on the Eastern than on the Western side. Here again the diagrams will be more expressive than a verbal description. It may be observed, that while the Belt of Calms or Varying Winds is, or may be, only 4 or 5 degrees of latitude in breadth on the Eastern meridians, it is seldom less than two or three times that breadth on the American side. The lines given on the chart are chiefly derived from Capt. Maury's observations, but these are so far imperfect that it is very difficult to define a mean where the data are so vague. The wavy boundaries thus shown are rather the effects of this uncertainty of where the Trade Wind absolutely fails, and the Calms or Variations set in.

The S.E. Trade Wind is separated from the anti-Trade Winds by a Belt, the character of which is difficult to define. The analogous Belt in the North Atlantic is sometimes called the "Horse Latitudes," from the bad weather encountered in it formerly causing the necessity of throwing overboard horses which were being carried to the West Indies. This character will be hardly borne out by the term *Calms* of Capricorn or Cancer, applied to them.

Calms of Capricorn.

In the South Atlantic there is this important distinction in the amount of our knowledge respecting it,—that while, in the North Atlantic, it is traversed frequently by vessels throughout its whole extent, in the numerous passages made between the Northern and Southern ports of Europe and America and the West Indies, in the South Atlantic it is only well known on the two sides of the Ocean, or those traversed on the outward and homeward passages around the Cape of Good Hope or Cape Horn. There is no direct traffic across the South Atlantic. Our information as to the Central Portion is therefore less complete, but also of less importance.

In a former page (13) is given the opinion of Capt. Maury, that this Belt is the line of junction of the upper but contrary Currents which pass over the Trade and anti-Trade Winds, and here descend to the surface and feed those winds by continuing their course as lower strata. This reasoning is borne out in some degree by the observations of Capt. Toynbee.

From its nature, it can scarcely be termed a Region of Calms, and this is more especially the case on its Eastern side.

On the American side this Belt of uncertain winds is broader, and its limits are more variable than on the Eastern side of the South Atlantic. It is in this respect analogous to what has been observed in the Indian and Pacific Oceans. In January and February, when it is at its Northernmost limit, it may be encountered when near Trinidad and the Abrolhos, lat. 20°, and if going round the Horn, the true Westerly anti-Trades may not be met with till in lat. 35°. In August these limits may be respectively 15° and 30°. But, as has been said before, the land influences are very powerful here, and therefore the remarks on the Winds on the Brasilian Coast must be considered to relate to what occurs more or less in the open Ocean. Further than this the illustration must give the required information. Of course, the lines there given as defining the boundaries of the Calm and Wind Regions are necessarily very vague, in many cases derived from very insufficient data, and in reality fix a limit to what cannot be bounded except by opinion.

On the Eastern Coast of Brasil, between the months of September and March, the Winds generally prevail from N. by E. to N.E. by E.; between March and September, the prevailing winds are from E. by N. to E.S.E.

Winds on the Coast of Brasil.

The former of these are generally termed the NORTHERLY MONSOON, and the latter the *Southerly* one; although there appears, in fact, to be no direct and opposite change in them on or about the Equinoxes, as is generally the case with the winds so called. These winds are simply a continuation of the S.E. Trade, *which changes its direction* as above described, and is influenced by the land on its approach thereto.

The influence of the land, or rather of its *Temperature*, is more or less dependent on the position of the sun at the particular seasons of the year. When the sun is to the Northward, no particular difference is observed in the S.E. Trade, but it may be carried within sight of the coast, with scarcely any deviation; nevertheless, about both Equinoxes, but more especially when the sun is advancing to the Northward, Calms and very light winds, from apparently no settled quarter, will prevail near the coast; and this may be said to be more particularly the case on that part of it between the Abrolhos and Cape Frio. As the sun advances to the Southward, the Trade Wind will gradually come round to the North-Eastward, and will have its retrograde movement with the return of the sun to the Equinox. At this latter season ships, on approaching the coast, will begin to observe this Northerly inclination of the S.E. Trade when within 250 or 300 miles of it, and they will find this gradually to increase as they incline to the Westward.

Within a few miles of the coast, and in the different roadsteads and harbours, the Wind generally blows directly upon it; and in the deep harbours, and upon the shore, this is generally superseded by a Land Breeze, which sometimes lasts the greater part of the night.

The Seasons of Brasil may be considered as two only—the *Dry* and the *Rainy*. On all the Eastern Coast the Dry Season commences near the end of September, and continues until February, and during the five months of its continuance Thunder-storms frequently occur, but it seldom rains.

The rest of the year includes the Rainy Season; though the rains are not so constant as fully to justify the name. On the Eastern Coast the only months which may be thus considered are May, June, July, August, and sometimes a part of September. On the North Coast the periods vary, for the heavy rains there commonly begin in December; although, as on the Eastern Coast, they include May, June, July, and August.

The *local* winds experienced near the Rio de la Plata and Cape of Good Hope, appear of sufficient importance to justify the following descriptions.

Rio de la Plata.

Captain Heywood gives the following remarks concerning the Winds, Weather, &c., in the River Plata:—At the entrance of the River Plata the Prevailing Winds during the summer months, from September to March, are North-Easterly, with tolerably clear weather overhead, but a dense atmosphere near the horizon. These winds haul gradually to the Eastward as you advance up the river; and at about the full and change of the moon, strong breezes from the South-Eastward are common at this season, accompanied with rain and foul weather.

At Buenos Ayres, during the summer months, the S.E. winds are generally fresh in the daytime, hauling round to the Northward in the night.

During the winter months, from March to September, the Prevailing Winds, at the entrance of the Rio de la Plata, are S.W., or more Westerly; but up the river they are more generally from the Northward than from the Southward of West.

The winter season is the best, in point of weather, in Buenos Ayres; for the winds being chiefly from N.W. to S.W., the water is smooth, and the communication can be kept up between the shore and the shipping with more facility. The weather is sometimes, but not frequently, foggy. Fogs are most common in the months of July, August, and September, and prevail more at the entrance of the river, as far up as the S.E. tail of the Ortiz Bank, than above the Banks.

Pamperos.

Violent gales are common at all seasons of the year, attended frequently with Thunder-storms, but these are most severe during summer and autumn. Sometimes the Thunder-storms are accompanied by hailstones of considerable size, which not only break windows, but kill poultry; they often terminate in a *Pampero*, the well-known Hurricane of the country. It is said that, in a Pampero, sand and small gravel has been blown on board the ships in the roads, a distance of 7 or 8 miles from shore.

Mr. Webster (Naturalist of H.M.S. *Chanticleer*, 1822) has described the indications of a Pampero, from his own observations, as follows:—The weather is sultry during a few days, with a light breeze from East or N.E., ending in a calm. A cool light wind then sets in from the South or S.E., but this is confined entirely to the lower strata of the Atmosphere, while the Clouds above it are moving in the opposite direction from N.W. to S.E. The Northern horizon, as night advances, becomes dark with heavy lowering Clouds, accompanied with lightning from East or N.E. The Southern wind now ceases, and is followed by variable winds from the Northward. Heavy Clouds are thus brought over; and lightning, accompanied by thunder, follows in a most terrific manner. The wind veers gradually to the Westward in violent gusts, the lightning becomes more vivid, and the thunder more awful; a gale of wind follows from the S.W. more violent, but of short duration, and fine weather ensues.

These Pamperos are very destructive to shipping, and frequently occasion wrecks and the loss of boats. The lightning is beautifully coloured, presenting the hues of orange, violet, and pink. Mr. Webster adds, "I have also witnessed at Monte Video very remarkable instances of electric light, playing like the *aurora borealis*, at an altitude of 20° above the horizon. One evening, October 4th, I observed an arc of light which remained permanent, with a tremulous motion, for the space of twenty minutes; a strong gale of wind was blowing at the time; it was of a pale yellow colour, and flashes of lightning frequently appeared beneath it."

During a visit to the River Plata by Captain King, in the *Adventure*, a Pampero of unusual violence occurred. "On the 30th January, 1829, after some intensely hot and sultry weather, we experienced a severe Pampero. It was preceded by the Barometer falling to 29·50, and by a strong N.W. wind, which suddenly veered round to S.W., when the Pampero burst upon us. Our ship and boats fortunately escaped any bad effects from the violence of the squall, which was so strong as to lay the former, at anchor, upon her broadside. The spray was carried up by whirlwinds, threatening complete destruction to everything that opposed them. In less than half an hour it had diminished to a strong S.W. gale, which lasted during the night." "On the night of the 2nd of February we experienced another very severe Pampero, during which one of the *Beagle's* boats, hauled up on shore, was blown to atoms. The Barometer had previously fallen to 29·39."

Cape of Good Hope.

The division of the year at the Cape may be said to consist of four parts, as in Europe; thus dividing it, the *Spring*, which commences at the beginning of September, and continues to the beginning of December, is indisputably the most agreeable season. The *Summer*, from December to March, is sultry, and would be intolerable, if the heat were not mitigated by the winds which blow from the Southern Ocean. The *Autumn*, from March to June, is distinguished by a variety of weather, though generally pleasant toward the end; and the *Winter*, from June to September, is usually cold, rainy, and stormy.

The Seasons are also divided into Dry and Wet; the latter from September to March. The greatest heat is in January and February, when the Thermometer sometimes rises to 100°. In the stormy or winter months, June, July, and August, it falls at times to 40°.

On the summit of the Table Mountain the temperature of the air is considerably lower in the clear weather of winter than in Cape Town; and in summer the difference is still greater, when the head of the mountain is enveloped in the fleecy Cloud called the *Table Cloth*. The approach of winter is generally indicated by the subsidence of the winds and the disappearance of the Cloud. These tokens are succeeded by heavy dews, thick fogs, and cold North-Westerly winds, accompanied by violent storms of thunder, lightning, and rain. At the expiration of three days the Atmosphere begins to brighten, and then the mountains on the Continent appear with their summits covered with snow.

The Prevailing Winds here are from S.E. and N.W.; others seldom last longer than a few hours. East and N.E. winds are rarer than any. North and N.W. winds commonly blow in hurricanes, and bring foul weather. The S.E. winds blow, more or less, in almost all the months of the year, but chiefly in the fair weather season, from October to April; then you generally have, in the mornings, regular Sea-Breezes from S.W. and West, which last till noon, and sometimes longer. They are followed by a S.E. and E.S.E. wind, coming off the land; this mostly blows fresh the remaining part of the day, and frequently all night, when the Sea-Breeze comes off again. In the months of May, June, July, and August, the West and S.W. winds blow strong, being frequently accompanied by fogs and cloudy weather, but they are soon over. Sometimes violent N.W. winds prevail for several days together, and by fits in the other months; the sky at this time is constantly clouded, and they generally end in rain.

During the Southern winter, the great Westerly aerial Current reaches the Southern point of the African Continent, and attains its greatest force, on account of the obstacle that the land presents. It divides near the Cape into two branches: the one turning to the left blows up the Western Coast of Africa; the other turns to the right, and follows the Southern Coast to the East of Cape Agulhas.

By supposing this current blowing from the W.S.W. to E.N.E., and the line of division being some distance to the North of the Cape, it will explain how that strong N.W. winds will occur in Table Bay, and at the same time that a fresh breeze from the S.E. is blowing at only 180 miles to the N.W. of the Cape. The oscillations of this parting line will also explain the sudden shifts of winds encountered in its neighbourhood.

The varying winds, then, in the neighbourhood of the Cape of Good Hope, will be a good guide as to the Southern limit of the Trade Wind, and of the position of the Belt separating it from the anti-Trades, which vibrates in latitude with the progress of the sun in declination. But it by no means follows that the space in question should be occupied by viaarble or light winds, for it has been argued and demonstrated, that at times the Westerly winds gradually assume a S.W., then South, and at last a S.E. direction, without much diminution of force. And this is especially the case near the Cape, for it is frequently found that on gaining a good offing to the Westward, the steady S.E. wind is encountered, and may be carried up to the Line on the usual homeward route.

CURRENTS.

The Prevalent Currents of the South Atlantic Ocean may be briefly enumerated. That remarkable feature of the Ocean, the *Agulhas Current*, which is generated by the great drifts of the Indian Ocean, both Eastward and Westward of Madagascar, flows Westward, and sets over the edge of the great Bank of Agulhas; whence it passes the meridian of the Cape of Good Hope, and is there stopped, but a branch or set-off rounds partially to the S.W., South, S.E., and East, as shown hereafter.

The *South African Current*, a cold stream, called by Major Rennell the *South Atlantic Current*, sets Northward and North-Westward, though, as will be seen, of different origin from the Agulhas Current. It sets in the direction of the African Coast, and nearly parallel thereto, until it has passed the latitude of the River Congo (about 6° South), beyond which it has a decided North-Westerly course, until it blends and unites with the *South Equatorial Current*, between the parallels of 1° and 5° South; and this united stream sets to the West, W.N.W., and N.N.W. (with a great set-off or drift to the North, N.N.E., &c., during the African S.W. Monsoon), as described in the North Atlantic Memoir.

When this South African Current has followed the direction of the coast to the Northward (in a reverse direction to the stream which is found on the same parallels on the East side of Africa), and having attained the latitude of the islands in the Bight of Biafra, it turns to the Westward, and joins the great Tropical Drift.

To the North of this, between it and the Guinea Coast, is the *Guinea* or *Equatorial counter-Current*, or the *African Current*, which presents the singular phenomenon of a current running in a reverse or Eastward direction, between the regions of the N.E. and S.E. Trade Winds, and this is found at times, as will be seen, to extend Westerly nearly across the Ocean, and as far Eastward as Fernando Po.

The Central Part of the Ocean, North of the Tropic of Capricorn, is under the immediate influence of the S.E. Trade Wind, which impels its surface waters to the Westward. This immense drift sometimes reaches nearly home to the Brasilian Coast; but on approaching those shores it appears more frequently to form a Current, setting in a counter direction along shore to the *Southward*, and which is said to have been traced nearly from Pernambuco to Tierra del Fuego; but circumstances prove that it is variable, and always modified by the prevailing winds.

From the River Plate there is commonly a great outfall of fresh water, which has been traced many leagues to the Eastward, and which is lost in the variable currents found between the Westerly or Central Drift, on the North, and a wide *Easterly* Current commonly prevailing between the parallels of 30°

and 35° to 40° S. The last, which has been denominated the *Southern Connecting Current*, greatly facilitates the passage of ships bound to Australia and to ports of the Indian Ocean, and is a portion of that great Eastward Drift of the Antarctic Current.

On the parallels South of the Connecting Current the great Drift of the Antarctic waters, when not disturbed by local winds, appears to be in a North-Easterly or E.N.E. direction. We find it thus at a certain distance from the S.E. Coasts of Tierra del Fuego and of the Falkland Islands, a consequence of the more prevalent winds, which are Westerly. As in the Arctic or Northern Icy Ocean, the great flux of water is from the N.E., so in the Antarctic it is from the S.W. or W.S.W., setting to the N.E. and E.N.E. to the meridian of 60° E., and probably much farther in that direction.

The South African Current.

The *South African Current* sets, as already noticed, along the Western Coast of Africa toward the Equator, where it is connected with the Equatorial Stream. On the parallels of Angola and the River Congo it exists as a powerful and very extensive stream, setting to the North-Westward and Westward, along the Equator, whilst the *Guinea Current*, from the North Atlantic, meeting it, passes *within*, and nearly brushes it in its way to the Bight of Biafra, where it terminates, being barred up by the lands to the Eastward.

The South African Current is analogous to the Peruvian or Humboldt's Current, which runs to the Northward along the West Coast of South America. The Peruvian Current is a prolongation of the Antarctic Easterly Drift (the equivalent to the Southern Connecting Current in the South Atlantic), but which is there more completely intercepted by the greater Southerly projection of the American Continent. With this exception, the features of the two Currents are similar, and they supply similar places in the circulation of the two Oceans.

Captain Toynbee writes :—

The water on the Agulhas Bank and in Table Bay is remarkably cold, showing that its source is not the Mozambique Current. Lying at anchor in Table Bay, in February (the corresponding month to our August), we found the water down to 51° (the same temperature as we found at the entrance of the English Channel in March), when the day before we entered the Bay, in lat. 35° 16′ S., long. 22° 54′ E., it was 70·5°; and four days before, in lat. 33° 15′ S., long. 30° 40′ E., it was 78·3°. Again, after running 90 miles due West from Table Bay, the temperature of the sea rose 19°. We may naturally conclude that Table Bay gets cold water from this ice-bearing sea, and that the same water runs Northward along the West Coast of Africa, and forms the South Equatorial Current, and is also one of the causes of the dampness from which the West Coast of Africa suffers. No doubt the inhabitants of Cape Town are benefited by the cold water of Table Bay in several ways; one may leave the town overcome with heat, and find the temperature of an English March on board a ship at anchor in the Bay. They may also thank it for the abundance of fish which may be had just for the taking. When lying there in February this year, my crew were hauling in large crawfish almost as quickly as they chose, and the fishermen of the place beating about were catching snook *(Thyrsites Atun)* in the same profusion, making the whole Bay a scene of most picturesque and enlivening interest.

One can scarcely avoid contrasting the Climates of Natal and Cape Town. The former abounds in Tropical productions which will not grow at all in the latter. No doubt the cause of this is, that Natal has a current of a temperature of 78° running by it all the year round, while Cape Town is surrounded with a cushion of cold water down to 51° in the height of summer.

The South Equatorial Current.

The great Tropical Drift, caused chiefly by the S.E. Trade Wind, is not well distinguished by the usual term of the "Equatorial Current," which more properly belongs to the Guinea Current as lying on the (Meteorological) Equator. According to the usual definition, it is that great moving mass of waters which is limited on the North by the Guinea Current, and on the South by the Antarctic Drift Current, having in fact the same area as that occupied by the S.E. Trade Wind, and in some degree obeying the same laws.

On the Eastern side it commences with the South African Current, the Northern stream which sets up the West Coast of Africa as far as Cape Lopez and the Bight of Biafra, the Western edge of which is not well defined, but merges gradually from its North and N.N.W. direction to a more Westerly course.

In mid-ocean, where its rate and persistence are the most marked, it may be always reckoned on, and its mean velocity will be found varying from 10 to 15 or 20 miles per diem. Sometimes it is more than this. In its Northern part its rate is greater, sometimes attaining 1½ to 2 knots per hour. Its Southern limit is very undefined in mid-ocean, both from want of collected observations and from its uncertainty, but more will be said on this when the Antarctic Currents are treated of.

Arrived on the American side, this great Drift becomes subject to the modifications caused by the winds of the coasts it impinges on. In the Northern part it sets strongly past the N.E. point of Brasil, and along its Northern Coast, and is considerably altered, varying with the seasons, as it passes down the Eastern Coast.

Brasil Current.

Captain Mouchez, who surveyed and examined the coast between Bahia and the River Plate, from his observations gives the following summary of this Current:—

At 120 or 150 miles off the coast of Brasil the Current generally descends, parallel with the coast, from N.N.E. to S.S.W., and is the Southern branch of the great South Equatorial Current which bifurcates on Cape San Roque. It has a mean velocity of 20 to 15 miles in the 24 hours, and loses its force as it progresses Southward, varying with the seasons and force of the wind. It is scarcely sensible beyond the Tropic, or the parallel of Rio Janeiro. Combined with the Drift of the S.E. Trade Wind, it frequently sets towards the land to the S.W. or W.S.W.

Between this Current and the land, the movement of the surface-waters is entirely dependent on the wind; if it blows twenty-four hours in the same direction, either N.E. or S.W., the Current sets in with proportionate strength. Thus, during the N.E. winds, especially between October and January, the Current sets to the S.W. with a velocity frequently reaching 25 or 30 miles per day. The velocity is greatest near the projecting points, such as Cape St. Augustin, the Rio Doce, Capes San Thomé and Frio, &c. Vessels at this season, making the land at Pernambuco or Bahia, should reckon on a drift of one mile an hour, and act accordingly. Many ships have been drifted 36 to 40 miles to the S.W. in the twenty-four hours.

But these Currents cease with the cause which produces them, and do not offer that permanent obstacle that is met with on the Northern coast, from the continued drift to the Westward that is encountered there. With the exception of the three or four months of summer, November, December, and January, when the N.E. winds are in full strength, the Currents are weak and variable. During the S.W. Monsooon they are equally feeble to the Northward, being strongest in June and July.

Near the land, and under the lee of some of the headlands, as to the Southward of Capes San Thomó and Frio, there are counter-Currents in the Northerly Monsoon to the N.E., although at a few leagues outside they run strongly to the S.W. This is sufficiently explained by the relative direction and form of the land. Along the Coast of Pernambuco near the land there is frequently a strong Northerly counter-Current, which makes it difficult for a vessel to hold her own, if overtaken by calm when nearing the land.

It is therefore manifest that, with few exceptions, the Currents do not offer any very serious difficulties to navigating in any direction on these portions of the Brasilian Coasts.

At *Cape San Roque*, and along the North Coast of Brasil in its vicinity, the Current sets to the N.W. and West, at from 20 to 60 miles per day, between March and September, but during the other part of the year with much less velocity.

The Southern Connecting Current.

After the Brasilian Current has reached the parallel of the Tropic of Capricorn in its Southward course, it is influenced by the Variable and Westerly Winds, which have been termed the "Calms" of Capricorn; and the waters, obedient to their impulse, gradually assume a more Easterly direction, and, blending on their Southern edge with the Antarctic Drift, they form that connecting link in the circulation of the surface waters of the South Atlantic, which is in some degree analogous to that which is seen in the other Oceans, especially in the North Atlantic and North Pacific, where the waters pass gradually around the area, leaving a space in the centre of comparatively still waters. This Southern branch of the circulation in the South Atlantic was termed by Major Rennell, from this cause, the Southern Connecting Current. But this is, perhaps, scarcely definite, for the Westerly Drift of the Antarctic waters unites to form this compensative movement of the water.

This Current flows Eastward over the Ocean between the Variable Drifts, &c., in the parallel of 40° S., and the Trade Wind, commencing in that of 25°. Major Rennell accounts for it thus:—" From between 20° and 25° S. to the verge of the Trade Wind, the Drift Current on the West side of the Atlantic takes a bend to the Southward through the whole space, generally, from the Coast of Brasil to 17° of longitude East from it, or about 300 leagues, which may probably be accounted for from the quantity of drift impelled to the Westward by the Trade Wind, and which cannot reach the coast from want of room, and can escape by no other way. This accumulated water, passing to the South beyond the limits of the Trade Wind, and consequently of the Western Drift, runs off to the Eastward, and is augmented in its way by the prevailing *Westerly* winds, and by drift to the Southward, becoming a large stream before its arrival at the neighbourhood of the Cape of Good Hope."

PASSAGES OVER THE ATLANTIC.

GENERAL REMARKS.

In the preceding pages we have described those natural phenomena of Winds, Currents, &c., which govern the track of a ship across the Atlantic Ocean.

The object of the present Section is to apply these principles to the seaman's practice; but, previous to entering upon this portion of the task, we will make a few general observations upon Great Circle Sailing, which has been revived as a new subject, when, in fact, it is one which was among the earliest principles recognised in navigation.

Great Circle Sailing.

Great Circle Sailing was known and acted on very early in the history of navigation. Cabot, Columbus, Magalhaens, and all the first great navigators were probably acquainted with the subject;[1] but this was prior to the knowledge of the principles of finding the longitude. When Gerard Mercator, in 1569, published "A Universal Map," on the projection now known by his name, a new era commenced in navigation; Edward Wright, however, was the first to correctly describe its true principles, which he did in 1599. In this projection, as is well known, the meridians being parallel to each other, and straight lines, the latitude is distorted and increased in proportion as these meridians are more distant from each other than the correct difference of longitude would give for that latitude. Consequently, a straight line drawn between any two points on such a chart, will give the correct bearing, which, if maintained throughout the course by a ship, will lead her from one point to the other. This course is well known as the rhumb course, and is that in universal use from its simplicity. But it is *not the shortest course*, except it be due East or West on the Equator, or

[1] It is alluded to directly in a work by Pedro Nunez, in 1537; again, by Pedro de Medina, in 1545; but his system was erroneous, and was corrected by Martine Cortes (or Curtis), whose work, "The Arte of Navigation," was soon after, in 1561, translated out of the Spanish into English, by Richard Eden, and was long the text book of British seamen. Numerous other works, in which it is correctly and distinctly described, afterwards appeared, as one by Michael Coignet, of Antwerp, in 1561; an excellent work by Roderick Zamarano, in 1585, &c. That by this time it was thoroughly recognised is evident by John Davis's Book, published in August, 1594, called the "Seaman's Secrets; wherein is Taught the *Three* Kinds of Sayling—Horizontall, Paradoxall, and *Sayling upon a Great Circle*." It is also described in Richard Polter's "Pathway to Perfect Sayling," about the same time. After this it is found in most of the old works on Navigation.

North or South on a meridian, which are great circles. This rhumb course, developed on a sphere, is found to be a *spiral*, and is considerably removed from a Great Circle or shortest distance if a great extent of longitude is traversed by it. We need not pursue this subject, but an example will explain its application.

From a point off the Lizard, in lat. 50° N., long. 5° 30′ W., to Cape St. John in the Bay of Notre Dame, in Newfoundland, also in lat. 50° N., and 55° 30′ W., the rhumb course, *true*, is of course *West*, and the distance on this parallel is 1,928 miles. But if a ship were to quit the Lizard on a *N.* 70° 20′ *W.* (*true*) course, and then gradually bear more to the Westward, attaining the latitude of 52° 45′ N., in long. 30° 30′ W., thence bearing more Southward, and approach Cape St. John on a similar angle to the parallel that she had left the Lizard, she will have sailed over 1,893 miles, or 35 less than on the parallel; but, in her greatest separation, she will have been 165 miles distant from the rhumb course. Therefore, if she were to take any course between this Great Circle and the parallel of 50°, she would have a less distance to traverse than if she followed the rhumb course; and this is the great advantage which Great Circle Sailing offers—that of a wide range of choice (in a higher latitude) without increasing the distance.

Further, if she were to assume a course as much higher in latitude as the Great Circle course is above the rhumb, she will find that it will be of the same length as the latter. Thus, in the example cited, if on leaving the Lizard she were to bear away for a point in lat 55° 30′ N., long. 30° 30′, and then approach Cape St. John, such a curve will be found to be exactly 1,928 miles in length, and yet be at its maximum separation, 330 miles apart from the parallel. The advantage of such a range of choice will appear subsequently in the remarks upon the Transatlantic Passages.

The great difficulties in application of the principle of Great Circle Sailing to practice are, the laborious nature of the calculations, now, however, much reduced, and the inference as to how a course so much at variance with that which the chart will apparently dictate as the most direct, will place a ship in respect to favourable Winds and Currents. Still, the scope it allows to the navigator must be considered as no mean advantage, even if its shorter distance may not be an inducement to rigorously follow out its principles.

In making use of general sailing directions, the application of the facts in Physical Geography which have been described in the preceding sections of this work, must be left to the discretion of the commander in most cases. In fine weather, and with fair winds, the estimation of the various influences which affect the ship's course are not difficult to make. But it is the adverse circumstances of a voyage that call for the seamen's skill and intelligence, and what has been said will help him to form a judgment of what is going on and how best to proceed.

There is an infinite variety of circumstances which render it impossible to lay down any fixed rule which may be implicitly followed to advantage at all times. Therefore, in cases where a definite course is pointed out as the best to be pursued, and a vessel should be driven out of her intended route, it does not follow that it is right to endeavour to regain that course to pursue it afresh, but rather it should be considered that a fresh voyage has to be commenced, and the course shaped from the latest point as if it were a starting point.

A vessel under steam only is considered in the light of a sailing vessel with a fair wind. In a certain sense this is true, as it enables her to be independent of wind or current. But it should be remembered that the same contrarieties which affect and hinder a sailing vessel from pursuing a direct course, will also, in a degree, be adverse to the progress of a steamer; and, therefore, if a moderate deviation from the shortest route will lead her into more favouring winds or currents, that course will be most advantageous to the vessel under steam, as it is to the sailing ship.

There is one circumstance which may be mentioned respecting a ship under steam, as to how she is affected by the direction and strength of the wind. If a vessel be steaming before a fresh breeze, strength No. 8, at the rate of 13 or 13 knots, she will experience a perfect calm, while the sailing vessel will be only able to carry her top-gallant sails and royals. If she steams in the teeth of the wind, she will seem to have a strong gale, under which a sailing ship could only carry close-reefed topsails. This will be made apparent by consulting the table of the Velocity of the Wind on page 9. Now, a vessel steaming with the wind otherwise than directly fore and aft, will not feel the wind in its true direction; for it will appear to blow from that direction and with that force which is a combination of the rate and direction of the ship's course with that of the velocity and direction of the wind itself. Its apparent and real course and velocity may be found by constructing a parallelogram of forces—a well-known problem. It is for this reason that the wind as registered on board a steam-vessel does not give the correct bearing of its direction, and it is much more disguised than it is in a sailing ship when close-hauled, as alluded to on page 7.

As the steam-vessel then may be considered in a great measure independent of wind and current, the great object of the past and succeeding remarks is mainly applicable to sailing vessels.

It has been well observed that the Wind Systems of our globe naturally govern the tracks of ships crossing the Oceans, the Trade Winds carrying them from East to West within the Tropics, while the anti-Trade or Passage Winds will bring them back again Eastward beyond the Tropics. If it were not for the intervening Belt of Calms, sailing directions for vessels going into opposite Hemispheres would be of the simplest kind; but the well-known Equatorial embarrassments—"the Doldrums"—often make a very different matter of it, and also cause many considerations to enter into the problem of shaping a course. In the North Atlantic, these obstacles of the intervening Calms seem to be at their maximum, and in the future remarks one chief point, now still argued, will be found to be that which has engaged attention almost ever since over-sea voyages commenced—where is the best place to avoid these Calms and contrarieties of the Equator.

Steam Lanes. to America.

The continually increasing number of collisions, which have advanced much beyond the ratio of the use of steam, has led to many plans for averting them, but apparently without a corresponding success in adopting them. The terrors of this danger in the open sea are manifest, and many sad examples are too well known not to induce caution—one, that of the U.S. mail-steamer *Arctic* striking the French steamer *Vesta*, near Cape Race, in October, 1854, led our American friends to consider whether some means could not be employed to lessen the danger. Accordingly, R. B. Forbes, Esq., of Boston, proposed one track for steamers *going to*, and another for those *coming from*, America. This problem was worked out by Capt. Maury, and we give here the result in his own words:[1]—

The shortest distance possible for a steamer between Liverpool and Sandy Hook is 3,009 miles; the average distance actually accomplished is 3,069 miles; and the distance by the middle of the Lane coming is 3,038. There is also another recommendation in favour of this Lane to the West, which is this: it lies along the Northern edge of the Gulf Stream, where there is an eddy setting Westward often at the rate of a knot an hour. On the average, I assume that the set of this eddy will amount to 12 miles a day for 3½ days, or say 40 miles. This makes the distance by the Lane coming practically about 2,998 miles; or, allowing 20 miles for détour, we shall have 3,018 miles, which will shorten the average time of the passage this way three or four hours, with less risk of collision, and less danger from Cape Race by the way.

It may be urged against this Lane that it cannot always be followed on account of the Ice, and that, inasmuch as it crosses the Grand Banks, the steamers that ply in it may now and then run down a fishing-vessel. The reply is that, as far as the fishermen are concerned, they are now liable to be run down by the steamers both going and coming. Whereas, with the Lane, that liability is incident to the steamers alone that are Westwardly bound, and the fishermen will have the advantage of knowing pretty nearly where the steamer will pass, and which way she will be coming. And as for its being obstructed by Ice, so as to compel the steamers, as it occasionally will, especially in May or June, to turn out of it now and then, the Erie Canal, of New York, is obstructed by Ice the whole of every winter, but that does not prove it to be of no value; it only shows that it, like this Lane, would be of more value to commerce if it were never obstructed by Ice, or anything at all.

[1] See Chart of Atlantic Routes.

The Grand Banks afford a pretty good indication of position, which can be used in the thickest weather; the water temperature is found to fall as soon as you near these Banks, and it is generally a good warning for them. The Eastern edge runs North and South, and, therefore, affords an excellent correction for longitude. Having ascertained by the lead when the vessel first strikes this edge, then noting the soundings and the distance run before clearing the Grand Banks, the latitude will also be known with accuracy sufficient to enable the navigator to decide whether he is in or out of the Lane, and, if out, on which side. The Lane crosses the Banks near their greatest width, 275 miles. If a steamer be crossing there in a fog, and in doubt as to her position, she can judge, by their breadth and the soundings, pretty nearly as to latitude. For instance, if the breadth of the Banks, where crossed, be less than 275 miles, but the soundings not less than 40 fathoms, the vessel has crossed the Bank to the North of the Lane; but if she finds herself in less than 30 fathoms, then she has crossed to the South of it. Should she, however, find herself in water that suddenly shoals to less than 20 fathoms, and as suddenly deepens again, then she is near the Virgin Rocks, or the Rock and Nine-fathoms Bank to the East of them, and her position is immediately known.

It should be recollected, however, that these Lanes are not channel-ways in which steamers must keep or be lost. Gales of wind, Ice, and other things will now and then force a steamer out of them, and in such cases she will actually be where she is now, for she will then be in no more danger than she is now; only when she gets back into the Lane she will be in less.

You will doubtless observe the advantageous position of the fork to Halifax, in the Lane from Europe. As this Lane approaches Newfoundland, it edges off to the South in such a manner as to render it impossible for a vessel so to miss her way as to get ashore. Suppose a steamer attempting this Lane to be, when she nears the Grand Banks, 100 miles out in position (a most extravagant case), and that she be out on the Newfoundland side, she would, if behaving properly, be steered parallel with the Lane, and if bound to New York, she would go clear of Cape Race. But she might be bound for Halifax, and by steering West too soon, might run upon the land; but recollect that the Lane to Halifax turns off *on soundings*, and a West course from where the Lane from England strikes soundings on the Grand Banks will take you clear of everything. So without the most gross neglect of the lead and all the proper precautions, which it is the duty of the shipmaster to take, it would seem impossible for him to run his steamer into danger here.

In the longitude of the Grand Banks, the Lane to Europe is 200 miles South of the Lane to America. As a rule, this Lane for the Eastern-bound steamers can be followed always, admitting that an exception now and then in practice will make the rule general. It will be observed that this Lane runs E. 15° S. from Sandy Hook to the meridian of 70°, where it takes a course E. 12° N.

towards its junction with the arc of a Great Circle, South of the Grand Banks. Though the distance by this Lane, from Sandy Hook to this junction, is a few miles longer than the direct line, yet on account of the Gulf Stream it is in *time* the shortest distance that a steamer can take. From the Capes of Delaware it is obviously the shortest.[1]

Vessels of war proceeding under sail from England to Halifax usually take what is known as the Southern route.

Sailing Route from England to Halifax.

Passing close Westward of Madeira and keeping to the Southward until well within the edge of the N.E. Trade, the course is then altered to the Westward and afterwards to the N.W., so as to pass about 200 miles East of Bermuda.

Across the Equator.

It is probable that there has been more discussion upon the Route from the British Isles to the Equator, and on the best meridian for crossing the Line, than upon any other passage. And yet the results of these inquiries as to this, the great highway of the Ocean, have served to confirm in a great degree the opinions published in the early days of navigation, before any of the modern improvements and appliances had been brought to bear upon it.

The directions which were given by *M. D'Aprés de Mannevillette*, in his great "Neptune Orientale," published early in the last century, might be followed now without losing much of the advantages which deep study and extensive inquiry into data lately acquired, would give to the shipmaster.

Captain Maury at the time of the publication of his "Wind and Current Charts," in 1849, first advocated a more Westerly crossing of the Equator than had been before pursued. This arose from looking at the voyage from the opposite side of the Atlantic to that on which all previous sailing directions had been composed. The configuration of the land about the Equatorial portion of the Atlantic is peculiar, and causes the difficulties of a trans-Equatorial voyage. The Eastern point of the Continent of South America, Cape San Roque, the "great bugbear" as Maury calls it, and the land about Pernambuco, lying in the strength of the S.E. Trade, and the consequent strong current to leeward which runs past it, were constantly the dread of the older mariners whose ships made so much leeway, and were incapable of sailing on a wind as our modern clippers do. But from the improvements in ships and their rig and management, much that was formerly insuperable is now quite practicable, and many of the difficulties of clearing Cape San Roque have vanished upon later inquiry.

The other difficulty, which also combines with Captain Maury's argument, is the intervening Belt of Calms and Monsoons (extending nearly across the

[1] The quickest passages on record across the Atlantic have been made by the Cunard steamers *Umbria* and *Etruria*, the times being:—Liverpool to New York 6 days 6 hours; New York to Queenstown 6 days 5¼ hours, thus *averaging* more than 19 miles an hour.

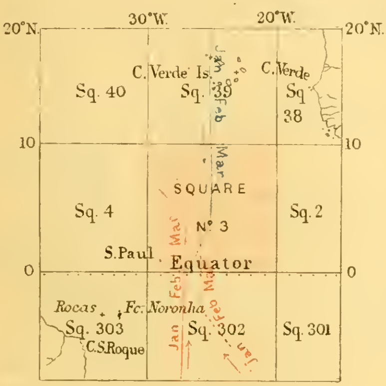
ROUTES

By Captain Henry Toynbee F. R. G. S.

Outward Tracks *are coloured* blue _

Homeward Tracks *coloured* red { *from the Westward thus* ——— / 〃 *Eastward* ....

JAN. _ FEB. _ MAR.



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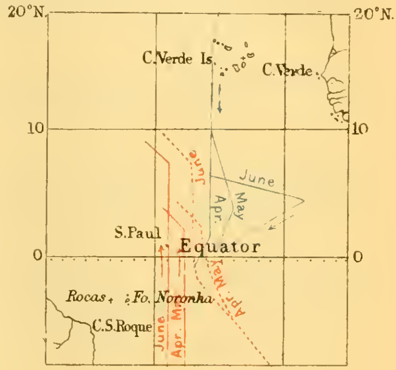

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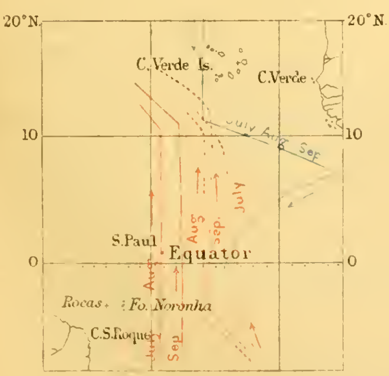

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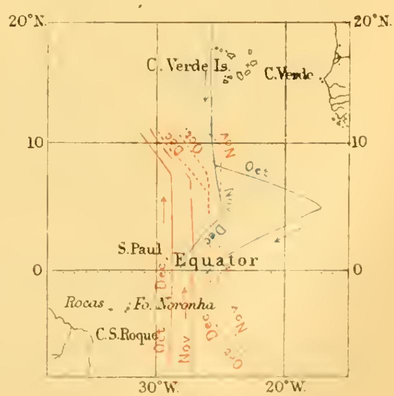

R. H. LAURIE. 53. FLEET STREET. LONDON.

Ocean between the Trade Winds), which has a triangular form, the base lying upon the African Coast, between Cape Verde and the Equator, and gradually getting narrower to the Westward, and therefore by crossing it well to the Westward is traversed in a shorter distance, and its detaining effects are much less experienced.

The work of Captain Maury, although it has done good service, must now give place to those of Captain Toynbee, more recently published by our own Meteorological Office.[1] In these the information is more reliable than that afforded by Captain Maury, not only by reason of the larger number of the observations from which they are compiled, but also because of the greater accuracy of the observations, all having been made with instruments tested and owned by the Meteorological Office. The period over which the observations extend, is mainly between the years 1855 and 1870. They were nearly all collected by the late Admiral Fitzroy from British ships of the Mercantile Marine.

Monthly Routes Across the Equator.

Vessels crossing the Equator from North to South are recommended to pursue the following routes, varying according to the season of the year.

In January, though exceptionally good sailing vessels make good passages by crossing in 30° W., or even West of that meridian, it is not generally advisable to cross the Equator West of 26° or 27° W.

In February, March, and April, after passing the Cape Verde Islands, vessels should stand to the Southward in 26° W., and when Southerly winds are met they should keep on the tack which gives most Southing, endeavouring to cross the Equator not West of 28° W.

In May it is recommended to cross not West of 25° W.

In June, after meeting with Southerly winds (probably in lat. 6° N.), it is advisable to keep on the starboard tack, if any Southing can be made, until a sufficient amount of Easting has been made to admit of crossing the Equator in 25° W.

In July vessels are recommended to cross not Westward of from 25° to 28° W. longitude.

In August the requisite Easting should be made when Southerly winds are first met, and the Equator crossed in about 23° W.

In September it is recommended to cross not West of 26° W.

In October the longitude of 28° W. is recommended as the extreme Westerly limit in crossing.

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[1] (1) Charts of Meteorological Data for Square 3. Lat. 0-10° N., long. 20-30° W., and Remarks to accompany the Monthly Charts, which show the Best Routes across the Equator for each Month, &c. 1874.

(2) Charts of Meteorological Data for the Nine 10° Squares of the Atlantic, which lie between 20° N. and 10° S., and extend from 10° to 40° W., with accompanying Remarks, ending with the Best Routes across the Equator. 1876.

In November and December, after passing the Cape Verde Islands, it is advisable to haul somewhat to the Eastward, so as to be in 25° W. longitude when in 6° N. latitude, and endeavour to cross the Equator not West of 29° W.

When proceeding across the Equator from South to North, at all seasons of the year, vessels are recommended to keep between the meridians of 25° and 30° W., except in July, when those approaching from the South-Eastward should cross between the meridians of 20° and 25° W. In July and August those approaching from the South-Eastward should endeavour to cross the parallel of 10° N. in 25° W.

In July, vessels approaching the Equator from the South-Westward, are advised to cross in 30° W.

England to the Cape of Good Hope.

A sailing vessel on leaving the English Channel should at once make Westing, as the prevailing winds are those from that direction. From the Lizard, with a fair wind, a W.S.W. course should be steered to gain an offing in long. 10° or 12° W., so as to be able to weather Ushant should the wind become adverse. If the wind veers to the Westward, the vessel should be hauled to the wind on the tack which will best enable her to approach the proper course, without being drawn into the Bay of Biscay, which is especially to be avoided. Rather than run any risk of this, it will be better to make a long board to the Westward, in which a vessel may be assisted by Rennell's Current; and since Westerly winds generally veer to N.W., if a good offing has been made, the course can afterwards be pursued a point or two free, making allowance for a South-Easterly set.[1]

From long. 10° or 12° W. a course should be shaped to pass Madeira at any convenient distance. In the winter months it is preferable to pass Westward of it, for the strong Westerly gales which occur in November, December, and January produce eddy winds and heavy squalls Eastward of the island. From Madeira the track recommended is to pass to the Westward (and just in sight of), the Cape Verde Islands, as the winds are stronger and steadier to the Westward than to the Eastward of them. The Equator should be crossed at points varying according to the season of the year.

When the S.E. Trade Wind is met with, it is advisable to keep on the port tack, even should the vessel fall off to W. by S., for the wind will draw more to the Eastward as the vessel advances. During the greater part of the year the S.E. Trade fails on a line drawn from the Cape of Good Hope to the islands of Trinidad and Martin Vaz.

A vessel, when to the Southward of the S.E. Trade, will meet with fresh winds variable in direction. After passing Trinidad Island a course should be shaped to the South-Eastward, to cross the parallel of 30° S. in about long.

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[1] From the Africa Pilot, Part I.

22° W., and the meridian of Greenwich in about lat. 35° to 37° S., whence to the Cape of Good Hope winds from the Westward and Southward usually prevail. A strong Northerly current will frequently be experienced on nearing Table Bay. If bound to Simon's Bay, it will be better to make the land about Cape Hangklip, as a strong current sets during the summer across the entrance of False Bay towards Cape Point.

Cape of Good Hope to St. Helena.

On leaving the Cape of Good Hope with a steady Southerly wind, a N.W. by N. course should be made for some time, as squalls from N.W. and W.N.W. are not unfrequent when near the coast, and have been experienced in both seasons. Having obtained a moderate distance from the coast, the course may be shaped for St. Helena.

St. Helena to England.

From St. Helena, a direct course may be steered for Ascension, as on this passage the S.E. Trade Wind is generally steady, and a Westerly current is experienced. The Island of Ascension may be passed at a convenient distance on either side, but vessels usually pass Westward of it, at a distance of about 10 or 20 miles. After passing the Equator, which should not be crossed Eastward of 25° W., except in July, a Northerly course may be made, in order to reach the N.E. Trade as soon as possible. Having entered the N.E. Trade, the vessel should be kept well full, so as to get quickly across it to the North-Westward.

When the Northern limit of the N.E. Trade Wind is reached, the vessel will probably be in about 26° or 28° North latitude, and from 38° to 40° West longitude, where Westerly winds may be expected.

It is seldom advisable to pass Eastward of the Azores; the better course is to pass Westward of them, or, should the wind draw to the N.W. when near the islands, the most convenient channel through them may be selected.

If Easterly winds are experienced after passing the Azores, it will be more advantageous to keep on the starboard tack, and make Northing, as Westerly winds will probably sooner be found.

Steam Routes.

The course adopted by steam-vessels carrying mails from England to the Cape of Good Hope is to make a direct passage, as described in the next paragraph. Some have succeeded in accomplishing the voyage in less than 20 days.[1]

Outward Passage.

Ushant is, if possible, sighted and passed within 10 miles, and Cape Finisterre is passed at about the same distance; from thence a direct course is steered for Madeira, passing generally East of Porto Santo.

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[1] In December, 1875, the *America* made the passage from Table Bay to Plymouth in 22 days 6 hours, and in March, 1876, the return voyage was accomplished by the same vessel in 22 days 3 hours. The Union Royal Mail S.S. *Moor* has made the shortest passage from Plymouth to Table Bay in 18 days 10 hours; and the same ship made the shortest passage on record from Table Bay to Plymouth in 17 days 21 hours.

From Madeira the track lies West of Salvage Islands, through the Canary Group, between Gomera and Tenerife. A course is then shaped to skirt, as nearly as circumstances will permit, the shoals off Cape Blanco, and parallel to the coast to Cape Verde, continuing to the Southward along the land, passing Bijouga Islands and St. Ann Shoals at a prudent distance. The Equator is crossed in about 9° W., whence the passage is made to the Cape of Good Hope direct, or calling at Ascension and St. Helena.

During the season when S.E. gales occur (January to March), vessels of moderate power make the land to the Southward of Table Bay.

Homeward Passage.

The route followed when proceeding from the Cape of Good Hope to England is nearly the reverse of the above. When among the Canary Islands, if the N.E. Trade blows strongly between Tenerife and Palma, it is desirable in a vessel of moderate power to stand Westward of Palma under fore and aft sails; and when nearing the English Channel, Ushant should be sighted.

New York to the Cape of Good Hope.

The Great Circle Route from New York to the Cape of Good Hope is a good route for steam-ships out or home. It cuts the Equator in 22° W., passing through Ascension and just Westward of St. Helena, the distance being 6,877 miles.

Equator to Cape Horn.

There is but little choice in making this passage. The most direct course is almost the only one that can be taken. The land of South America on the one hand, and the S.E. Trade Wind on the other, leave little scope for variety, as far as the latter is encountered. The Great Circle, which passes through the Lizard and Cape Horn, cuts the Equator in $31\frac{3}{4}$° W., and passes near to Pernambuco and near to Rio Janeiro, towards the Strait of Le Maire. Although this is too far West on the Equator, the track of this corrected would be the best which could be followed to the South American ports and around Cape Horn.

"The sum and substance of the best sailing directions from the 'fair way' off St. Roque, round Cape Horn to the Pacific, amounts simply to this: from the parallel of St. Roque make the best of your way South, keeping a good offing from the coast; always pass inside of the Falkland Islands; and, when the wind will allow, go through the Straits of Le Maire, and hug close around the Cape, aiming to get to the West as fast and as soon as possible. Occasionally Ice is met with East of the Falklands, and that is another reason why outward-bound vessels should prefer to go inside of these islands."—*Maury.*

Ships bound from the Atlantic to any of the ports in the Pacific will find it advantageous to keep within 100 miles of the Coast of Eastern Patagonia, as well to avoid the heavy sea that is raised by the Westerly gales which prevail to the Eastward, and increase in strength according to the distance from the land, as to profit by the variableness of the wind when it is in the Western board. Near the coast, from April to September, when the sun has North declination, the winds prevail more from the W.N.W. to N.N.W. than from any other quarter. Easterly gales are of rare occurrence; but even when they do blow, the direction being obliquely upon the coast, it is not considered at all hazardous to keep the land on board. In the opposite season, when the sun has South declination, the winds will incline Southward of West, and frequently blow hard, but as the coast is a weather shore, the sea goes down immediately after the gale. In this season, although the winds are generally against a ship's making quick progress, yet, as they seldom remain fixed in one point, and frequently shift backward and forward six or eight points in as many hours, advantage may be taken of the change, so as to keep close in with the coast.

Having once made the land, which should be done to the Southward of Cape Blanco, it will be beneficial to keep it topping on the horizon, until the entrance of the Strait of Magalhaens be passed.

For *Steam-ships* the Great Circle Route from the Lizard to Cape Horn is probably nearly the best that could be followed, even if it were not the mathematical course. It passes near to the West end of Madeira and the Cape Verde Islands, as directed for sailing ships, and then crosses the Equator in longitude 31¾° W. It almost touches Pernambuco, and passes close to Rio de Janeiro towards the Strait of Le Maire, the total distance being 6,988½ miles.

To and From the West Indies.

Captain George Cheveley, of Liverpool, remarks, that he would recommend to ships clearing the English Channel, *if bound to the West Indies*, to make a S.W. course, *true*, so as to pass nearly at an equal distance between Madeira and St. Mary's. Capt. Cheveley adds, that, by pursuing this track, he has invariably held a steadier breeze, and got much quicker into the Trades than when he proceeded farther to the Eastward, and so endeavoured to make more Southing. He is aware that the latter is the *general practice*, of which he entirely disapproves, so far as concerns a West India passage.

Ships for Jamaica generally pass to the Southward of the Island Montserrat, and thence proceed for the high rock called Alta Vela, off the Southern point of St. Domingo, whence they take a departure for the Eastern end of Jamaica. When homeward bound, they pass either through the Windward Channel or the Strait of Florida, as the wind and other circumstances may prevail or dictate.

Between the months of October and March, Northerly winds prevail over the Mexican Sea and the adjacent regions; and when Northerly winds prevail in the Strait of Florida, the Windward Channel must, of course, be preferred; but, at all other times—at least, generally at other times—the quickest, and, therefore, most eligible, passage is through the Channel of Yucatan, and thence, with the Florida Stream in your favour, through the Strait of Florida.

Although the Windward Channel appears, by the chart, to be the shorter and readier passage, yet ships are frequently opposed here, both by Wind and Current. For instance:—"After the defeat of the French fleet, commanded by Count de Grasse, in April, 1782, and the British had arrived at Port Royal, in Jamaica, a squadron was detached to gain the Windward Passage, run down the Bahama Old Channel, and cruise to the Eastward of the Havana, to prevent a Spanish squadron, in the harbour, from effecting a junction with the French ships that had escaped into Cape François [*Cape Haytien*]. For six weeks did the English squadron beat against fresh sea breezes and a lee current; and, during that time, never advanced further to the Eastward than off Morant Harbour, though the ships were much strained by carrying a press of sail to attain their object; but, after struggling so long, they were compelled to return, baffled, into port."

From the West Indies to the English Channel.

After having cleared the Strait of Florida or Windward Passages, vessels may pass either to the Northward or Southward of the Bermudas, giving the islands a good offing, and attending to the preceding remarks on Currents, &c. In summer, the track to the Northward of these isles has been recommended, passing thence to the Northward of the Azores. In winter, the track to the Southward of the Bermudas is to be preferred; because, in this season, North-Westerly gales may be expected to arrive from the Coast of America; and, therefore, vessels should continue a little to the Southward of lat. 30°, or in about lat. 29° 40′, if wind permits, until certain of being to the Eastward of the Bermudas; nor should they run to the Northward of lat. 35° or lat. 36°, until within a few degrees of the Azores. Thus will the heavy gales be avoided, which frequently rage more to the Northward.

In shaping a course at any season, it should be remembered that the Great Circle Course from Cape Florida to the Lizard follows the outer edge of the Gulf Stream in its earlier course, and passing about midway between the Bermudas and Cape Hatteras, it bears away North-Eastward over the tail of the Newfoundland Banks, and reaches the parallel of Scilly on a due Easterly course. The vertex of the Great Circle being in lat. 50°, long. 13° 48′ W., of course its direction is nearly East and West for several degrees on either side of this point. The shortest distance between the Lizard and Cape Florida is 3,671 miles. It leaves the Strait of Florida on a nearly *true* N.E. course, (N. 45° 35′ E.), and reaches the Channel on an E. ½ S. *true* course.

During a great portion of the year, it is probable that this course could be strictly followed to advantage. Of course, the consideration of meeting with Cyclones which follow very nearly this Great Circle Course towards the N.E. is important, and, therefore, during their season, July to October, a more Easterly route had better be pursued, that is, if the Florida Channel be taken;

but if, as is more probable, the Windward Passage is taken in this season, the Great Circle Course thence will be the most advantageous.

Passages on the Coast of Brasil.

Captain Mouchez has given the following remarks:—There is no difficulty in running down the coast from Bahia to Rio Janeiro; it is only in the months of May, June, July, and August, that any contrarieties occur, and gales from the South are encountered; it is, however, at this season that the winds hold most Southerly, being not usually more than E.S.E. or E. by S. Advantage should be taken of the S.W. squalls, which frequently occur, to get off the land, if you should be too close in. You may either pass through the Abrolhos Channel, or outside the group, according to the position from which they are approached. The greatest chance of meeting with contrary winds from the S.W. is on the parallel of Cape San Thomé, and this is most probable in June. At 250 or 300 miles off the capes, the chance of these adverse winds is not more than half of that near the land. Nevertheless, Cape Frio should be closed with, because no benefit can be gained by keeping off the shore thereabout. In all other seasons the wind is fair for running down the coast.

The greatest difficulties on running up from Rio to Bahia are encountered in November, December, January, and February, for during these months the N.E. winds blow very fresh along the coast, especially about Cape San Thomé. The Wind Charts show that the Trade Wind has less Northing in the offing than on the coast. It is, therefore, advisable to take the port tacks aboard, and make a stretch of 450 to 600 miles to the E.S.E. before coming round on the starboard tack. The winds will then be found less adverse, and the Northerly current much less rapid, for when the Trades blow strong the current runs at 1 to 1½ mile an hour along the coast, but this velocity is much less close inshore. November, and especially December, are the most unfavourable, and, therefore, it is necessary to prolong this Eastern board to the utmost that may be considered necessary. In the other months of the N.E. Monsoon—or October, January, and February—it is not necessary to go farther East than to gain the Abrolhos on the other tack; for the Wind Observations show that beyond the parallel of these islets the direction of the Trade Wind, being from East or E. by S., is always favourable for going to Bahia.

During the rest of the year, that is from March to October, in running up the coast keep as close as possible to the shore, not more than 30 to 60 miles off, and do not run off to the East, unless compelled to do so by strong N.E. winds off Cape Frio or San Thomé. This frequently occurs in the S.W. Monsoon, but then it only lasts two or three days, and gives way to calms and quiet weather, with variable winds from S.W. to S.E. By manœuvring thus, and taking advantage of these slight shifts of wind, more frequent near the land than off it, you may make all possible way by means of the Trade Wind, which comes from E. by N. to E. by S. The distance is also shorter, for instead of running Eastward for 600 miles to gain a point 600 miles to North, you have only the direct distance to work, and it is also uncertain whether favourable winds will be met with outside.

Between Bahia and Cape San Thomé the variations from the land and sea breezes must not be reckoned on; they are not met with, especially in the bad seasons; the land in general is too low and too wet to affect the direction of the wind.

Brasil to Europe.

As the Land Breezes of Brasil are nearly the same along the whole of the coast, and during the greater part of the year, the day and hour of departure may be always fixed. It has been noticed that these Breezes rise during the night, and are generally very fresh during the early part of the day; as they continue for nine or ten hours, you have consequently every advantage for preparation, and for standing off to a distance from the coast, free from all local obstacles.

The Baron Roussin has treated rather copiously on the routes to be adopted in sailing from the different ports; but his rules appear to be such as will naturally suggest themselves to the mind of a seaman, on the consideration of the prevalent Winds, Currents, &c.

The strength of the N.E. winds often forces vessels when bound from ports South of *Cape Frio*, on their return to Europe, to keep close on the port tack for 12 or 15 days, and descend to the S.E. or S.S.E. to the parallel of 28°, or even of 32°. In advancing from the Southward, you ought to attain the meridian of, and sight the Island of Trinidad, in 20° 31′ S. and 29° 19′ W.; then tack about and leave the island on the starboard side, as you cannot always double the projecting points on the Eastern shore. On proceeding hence, Northward, the winds will be found nearly approaching East and S.E., and so facilitate the proper route. By acting in this way, it will rarely happen that you cannot pass to windward of the Isle Fernando Noronha, and cross the Line between the 28th and 36th degrees of longitude (West of Greenwich), or, if circumstances require it, one or two degrees more to the West.

On quitting Pernambuco, or the points in its vicinity, you may not always be able to get to the Northward on the starboard tack. The direction of this coast inclines from the North to the West, and the winds are mostly from the Eastward; but, at the same time, you may gain a good offing in directing your course to the Northward. Should, however, the winds not permit you to proceed freely on this route, it will be preferable to make a long board to the S.E., and then act according to circumstances.

CHAPTER IV.

THE INDIAN OCEAN.

WINDS.

General Description.

The navigation of the Indian Ocean is influenced by a much more complicated system of Winds and Currents than is found in other parts of the globe, and it will be necessary, in order to fully comprehend their nature, to give a general outline of the Winds and Monsoons as experienced in the different seasons.

The Indian Ocean, it will be seen, while open to the South Pole, has its Northern head within the region of a shifting Calm Belt, which at a mean lies between lat. 5° and 10° N. The area to the North of this, which in a more open Ocean would have the regular N.E. Trade Wind blowing over it, is by the influence of the land subjected, alternately, to Southerly and Northerly Monsoons, the latter being in fact the true Trade Wind which blows while the sun is in the Southern Hemisphere. There are many local variations from this arrangement, which will be presently alluded to. In this preliminary section the General Wind Systems will be described, as they modify or influence the voyages across the Ocean from one part to another.

These may be divided into:—1. The region of the anti-Trades or Passage Winds, South of 25° or 30° S.; 2. The region of the South-East Trade Winds, between lats. 10° and 25° or 30° S.; 3. The Belt of Calms to the North and N.W. of the Trades; 4. The area of the South-*East* and North-*West* Monsoons, between the Equator and 10° S.; and 5. The part North of the Equator, where the Monsoons alternately blow in opposite seasons from Northward or Southward.

The Southern Anti-Trades or Passage Winds.

We have adopted the term *anti-Trade* Winds, used by Sir John Herschel, in the "Memoir on the North Atlantic Ocean," as being expressive and appropriate. They have also been termed the counter-Trades, which designation may be more exactly applied to those upper currents of air *over* the Trade Winds. They have also sometimes been vaguely called the "Variables," from their want of steadiness; but this term is best applied to the Belts of shifting Winds and Calms about the Tropics.

This region of "Brave West Winds" is of great importance to the navigator in his voyage around the Cape of Good Hope.

Although the number of observations recorded in the Southern Indian Ocean is very much inferior to those attainable for the Atlantic, still they are sufficient to enable us to lay down a general law as to their character. There can be no doubt but that there is an immense current of air, varying in its direction between S.W. and N.W., the mean direction of which is probably about West, extending from lats. 25° or 35° S., according to the season, to probably the lat. of 55° or 65° S., all round the globe, and which is most persistent about the parallel of 45°; the position in latitude of this zone, and its breadth, being dependent on the position of the sun, whether North or South of the Equator, shifting its limits with the progress of the seasons.

The South-East Trade Wind.

From the geographical configuration of the Indian Ocean, and the great interference with the regularity of the aerial current, caused by the land of Australia on the one hand, and that of Madagascar and Africa on the other, this perennial Wind, of great extent in other Oceans, becomes much circumscribed in the Indian Ocean; so that it is only felt between lats. 10° and 35° S. (limits varying with the seasons) from the Coast of Australia on the East to Madagascar on the West; within this area there are also many variations. In addition to the Pilot Charts of Capt. Maury, we have an excellent series of Wind and Current Charts of the Indian Ocean, one for each month of the year, drawn up by Lieut. Fergusson, I.N., from well-kept logs, 1853—54, and to these authorities we are chiefly indebted for the brief remarks which follow.

The *Southern Limit* of the S.E. Trade Wind, which of course shifts with the season, attains its maximum Southing apparently in November, when it may be looked for on the parallels of 33° to 35° S. In the opposite season it does not reach lower than 26° or 28° in July and August. These boundaries, with its other features as to extent, &c., will be best explained by the illustrations at the end of this Chapter.

There is some peculiarity in the Western part of the Ocean, Westward of the meridian of 70° E., which interrupts its regularity in some seasons.

Its *Northern Limits* are much more difficult of definition, and without a long discussion, which would be out of place here, it would not be easy to explain the physical reasons of the variations and apparent anomalies encountered between lat. 10° and the Equator. Moreover, we are not in a position to do justice to such a wide subject; the observations attainable are far too few, and, probably, of not sufficient accuracy whereon to base a theory. Although many have written on these topics, no very satisfactory conclusion is arrived at. But this in a sailor's practice is of less importance than it is to the Meteorologist.

Taking the months of January, February, and March, we find that there is a wedge-shaped area of Calms, and Variable Winds chiefly from Northern and Western quarters, which projects from the coast of Sumatra, not on a parallel across the Ocean, with the symmetry of a normal zone, as would perhaps be the case theoretically, but in a *diagonal* curve to the South-West, the point or apex reaching, in January, the parallel of the Mauritius, about 500 miles to the Eastward of that island. In February, the longer absence of the vertical sun increases the breadth of this area, which extends to the Mauritius from the Equator on the Sumatran coast. This arrangement continues till March, when this diagonal Calm Belt is well marked, but which, in the ensuing months, when the Monsoons set in, becomes less apparent, and the Trade Wind begins to blow to the parallel of 10° S., and up to the African Coast, gradually extending to the Northward, but seldom reaching the Equator till September, when this area of Calms again appears to the South of the Equator, and stretches across again to the East of the Mauritius in December.

This peculiar arrangement, or division between the Wind Systems, not known in other parts of the World, is owing to land interferences, and the geographical configuration of the North part of the Indian Ocean, which is that part where all the peculiar modifications in the aerial currents occur as dependent on the seasons. This will be best understood by reference to the Wind Charts.

Now, when it is remembered, that the greater part of the land of the whole world is comprised within the rational horizon of London, and that this horizon will pass diagonally, N.E. and S.W., near the Mauritius, or generally coincident with this zone or line of division between the aerial currents, it may be fairly argued that the influences of the great mass of land lying to the N.W. of it, is exerted in thus interrupting the steady progress of the S.E. Trade, by distorting the otherwise symmetrical Belts of Calms and Variable Winds. However this may be caused, the fact remains for the mariner's service, and is given in the illustrations.

To the Southward and Eastward of this Calm Belt, within the limits indicated, the S.E. Trade blows with considerable regularity, with a mean direction of S.E. ½ E., blowing with the greatest force from the East or S.E., and lightest when from the South, being most constant between East and S.E.

To the Eastward of 60° the Trade Wind blows more from the Eastward on to the Coast of Madagascar, which may be said to stop its progress towards the Mozambique Channel, which has quite a different wind system, and is not subject to the Trades. The mountains of Madagascar, like those of the Indian Peninsula, have thus a very marked influence on the winds on either side of them, and this demonstrates that the main strength of these belts of wind lies within a very few thousand feet of the level of the sea.

In the earlier months of the year, January and February, as well as in November and December, the S.E. Trade blows as an East or E.N.E. wind past the South end of Madagascar towards the Natal Coast; and in general it is nearly East between 10° and 20° S., West of long. 60°, that is, it blows directly on to Madagascar. In mid-ocean its force is generally about a fresh or strong breeze.

Calms near the Equator.

When the sun is South of the Equator, during the Austral summer, the general direction of the winds in the Northern part of the Indian Ocean is to the Southward. They are thus derived from those aerial currents which come from the land, and are liable to all those vicissitudes and fluctuations which distinguish the land winds from the more regular winds over the Ocean, and besides this they have not the force that the latter exhibit.

It is manifest that these Northerly winds cannot have the same force or regularity when it is considered that, generally, their utmost range is limited by the lofty Himalayas and the mountain chains separating India from China. Much speculation has been entered into on these topics, but as the sailor only wants to know how the wind arrives and passes over the Ocean, this must be left to the works of Romme, Kämtz, Dové, Capper, and others.

The S.E. Trade seldom blows beyond the latitude of 10° S. during the months between October and March, and we have before said (page 102), that its Northern limits are very difficult to define with certainty. In the opposite season its effects are felt more to the North, but seldom up to the Equator, and then much altered in its character, so that in a general way it may be said that the zone between 0° and 10° S. is the region of peculiar Winds and Calms.

But, as before stated (page 103), this space between the winds of the Northern Hemisphere and those of the South, or the S.E. Trades, does not lie on a parallel while the sun is South of the Equator, in January, February, and March, but occupies a diagonal belt from Sumatra to the Mauritius, in a form which is best explained by the illustrative diagrams. In April the winds are very light, as a rule, and uncertain, over the whole of the Indian Ocean, Northward of 10° S., though this is the period when the great change in the seasons occurs, and consequently there are many struggles between the opposing currents of air, each striving for the mastery. In May and June, Calms are encountered near the Equator, but in the latter and following months to September or October, the intervening Calm Belts are not very manifest, and the Monsoons are well established.

Although these spaces are here designated Calms, or "Doldrums," they are not entirely so, and in lieu of absolute quiet, as the term might indicate, their area is occupied by winds blowing in a reverse direction to the normal aerial currents, or from Westward quarters, as will be hereafter alluded to.

In the Atlantic Ocean this space of Calms and Monsoons is almost entirely North of the Equator; but, as said in the outset, the configuration of the land totally alters the Meteorological conditions; and the line of separation, in the

Indian Ocean, between the phenomena of the Northern and Southern Hemispheres, is *South* of the Equator.

The Monsoons.

To clearly describe these Monsoons (a term well known to be derived from a Persian word, signifying "season"), it will be better to divide them into their separate areas and seasons.

Commencing from the Southward, we have :—

Sect. I.—The *North-West Monsoon*, a belt of Westerly winds occupying the space between the Equator and 10° S., in the Southern summer months of November to February or March.

In this space is found at other times those Calms and Variable Winds before alluded to on page 104.

During the opposite season the S.E. Trade blows over it, and is here called the S.E. Monsoon, but is clearly an extension of the regular Trade Wind.

Sect. II.—The *South-West Monsoon*, blowing towards the Asiatic Continent, but in different directions, in the months from April to October. This brings fair weather on the African Coast, but is the *bad weather* Monsoon in the Northern part of its course.

Sect. III.—The *North-East Monsoon*, which may be considered as the regular Trade Wind blowing in a reverse direction to the last, but varying to the N.N.W. on the West Coast of India, and also much modified on other coasts. This is felt from November to March, and is the fair weather Monsoon in the North.

Like the winds South of the Tropic of Capricorn, there is a considerable interference with the regularity of these Monsoons to the Westward of the meridian of 65° E., as before remarked.

The North-West Monsoon.

This peculiar wind, occupying the central space between the Northern and Southern systems, has been called the *Line*, or *Equatorial Westerly Monsoon ;* or the *Middle* or *Cross Monsoon*. It was first really distinguished by the latter name by Capt. Thomas Forrest, in his little treatise, in 1782. He says :—" As the N.W. wind which blows from the Line to eight or ten degrees of South latitude in winter, blows in a direction across the N.E. Monsoon, I have called it the *Cross Monsoon*, it being bounded to the South by the S.E. Trade Wind. I call it also the *Middle Monsoon*, it lying, as it were, inclosed between the N.E. Monsoon to the Northward, and the S.E. Trade to the Southward.

" But the S.E. Trade in (the Northern) summer produced, or continued, from where it blows perpetually, into a region to which it has not access in winter, and so blowing in a direction that crosses the S.W. Monsoon, may, with as much propriety as the other, be called a Cross Monsoon. This being allowed, the one may be called the *Cross Middle Winter Monsoon*, and the other the

Cross Summer Monsoon; the word *middle* not belonging to this last with propriety, as it is not enclosed on each side. It may be said that, in winter, N.E., N.W., and S.E. winds blow in three respective regions; and in summer, the S.W. and S.E. only. In winter three different winds blow; in summer only two."

This definition of a current of air, important to navigation, must be accepted with some limitation. A more intimate knowledge has confined its existence to the months between November and March, in the first and last of which periods it blows in squalls, with much uncertainty, but in December, January, and February, it is tolerably regular in the central part of the Ocean, though at times much varied by calms and baffling winds. As was said above, this area does not extend to the Westward of long. 55° or 65° E., and towards the Coast of Sumatra it also becomes much altered and very variable in its direction.

The South-West Monsoon.

Like the periodical current of air last mentioned, the remarkable wind now to be described is an exceptional phenomenon, in direct opposition to the normal aerial system, and which, by the forces which call it into existence, is made one of the most formidable manifestations of the power of the Wind that can be adduced in any part of the globe.

Owing to the influence of the heated plains of Asia, this Southerly Monsoon drives before it with great fury and violent storms the quieter N.E. Trade Wind, or Monsoon, which occupies its position during the period when the sun, being South of the Equator, is not exerting the power of its vertical rays on the Northern Continent. But as soon as the change of seasons brings these forces into action, the S.W. wind gathers its strength, and gradually replaces that from the opposite direction, carrying with it much rain, derived from the evaporation during its passage over the sea; and from the great force that is developed in the conflict, causing an abundant and frequently terrific display of electric phenomena.

At the breaking up of this S.W. Monsoon, which, after the first few weeks, gradually subsides in its power and peculiarities, the sun having once more crossed the Equator, the N.E. wind again usurps its sway, and this struggle is also usually marked with much stormy and violent weather, though less so than the opposite season, on account of the more moderate nature of the forces in action.

In a general way, then, it may be said that the Northern summer months, April to November, are the season of the S.W. Monsoon; but, as before stated, these limits do not apply to the whole area of its action, as the change is gradual on its proceeding to the Northward, and there is usually some interval between the changes of the Monsoons. Besides this, the action of the wind does not immediately follow on that of the sun, but some interval occurs between them, while the cause is gathering strength to be made manifest in its effect.

Commencing at the S.W., or the limit of the S.W. Monsoon, in its Southernmost part, we find that it reaches beyond the Equator on the African Coast—that is, in that area of the Indian Ocean, which has been found to be exceptional in many of its phenomena. Captain R. F. Burton, the well-known African traveller, says, that the S.W. Monsoon sets in at Zanzibar, between the latter end of March and the early part of April; later in the Northern, earlier in the Southern, parts of the coast. There is much uncertainty about the winds in this district; but it may be stated, in a general way, that the Northern end of the Mozambique Channel may be regarded as the Southernmost limit of the S.W. Monsoon, which afterwards reaches to the West Coast of India.

From the above remarks, the origin of the S.W. Monsoon on the Coast of Africa, to the North of Madagascar, appears to be the S.E. Trade Wind, which thus blows continuously from the Southern Hemisphere across the Equator into the Northern. This view, as far as concerns the setting in of the S.W. Monsoon, was propounded by Professor Dové, in the "Annalen der Physik," in 1831, and that this Southerly Monsoon was caused by the rarefaction created by the heated plains of the Asiatic and African deserts, drawing the S.E. Trade over its boundary. Subsequent researches by Captain Maury, Lieutenant Fergusson, and Lieutenant Taylor, confirm this, and place it in a clearer view for the use of the sailor; it is important, as it shows where the intervening Calms between the two Winds may be calculated on in certain months, and, consequently, their vicinity avoided; and also where one wind passes at once into the other without any calm interval. This will be better understood by the illustrative diagram, than by verbal explanations.

In order more fully to place these matters clearly before the reader, at the risk of being prolix, we quote Capt. Maury. He says:—"The Desert of Gobi and the arid wastes of Asia are the cause of the Monsoons. When the sun is North of the Equator, the force of his rays, beating down upon these wide and thirsty plains, is such as to cause the vast super-incumbent body of air to expand and ascend. Consequently, there is an indraught of air from the surrounding regions to supply the ascending column. The air that is going to feed the N.E. Trades is thus arrested, drawn in, heated, and caused to ascend; and so the N.E. Trade Winds are first weakened, then 'killed,' and afterwards drawn into the vortex of ascending air over the burning sands of the deserts; on the other hand, the S.E. Trades failing, when they arrive at the place where the Equatorial Doldrums were wont to be, to meet with them or any opposing force from the N.E. Trades, are drawn over into the Northern Hemisphere. Going now from the Equator towards the Poles, their tendency is to obey the forces of diurnal rotation, as well as those of the indraught for the heated plains, and thus the S.E. Trade becomes the S.W. Monsoon. From this view, the

'Equatorial Doldrums' of the Indian Ocean are transferred, as it were, during the S.W. Monsoon, to the deserts of Central Asia."

It must be observed here, that this feature of the S.E. Trade passing at once into the S.W. Monsoon is only met with during the period when that Monsoon is well established, as in the months of June, July, and August. At other periods, during the struggle which occurs between the opposing winds of the two Hemispheres, they are separated by spaces of Calms, Squalls, and Shifting Winds, common to other regions, as will be seen by the diagrams of the Winds.

On the *Eastern Coast of Africa* the wind blows very strong from the S.S.W., and continues with full force from that quarter through the channel between the Island of Sokotra and Ras Asir (Cape Guardafui), and thence across the Gulf of Aden to Ras Rehmat (which signifies in Arabic, Cape of the Wind's Death), a cape South and West of Makalleh. On the line between these capes a vessel generally enters the Monsoon when proceeding from the Red Sea to the Eastward.

Within the *Gulf of Aden*, that is, between the meridians of Ras Asir and Bab-el-Mandeb, the winds, during the season, are very variable; as a general rule, they are freshest by day and lightest by night. In April and May they vary from E.N.E. to S.E. and South, with clear sky, but hazy weather is sometimes experienced; close inshore land winds are occasionally felt from 4 to 8 a.m. June is a very unsettled month, the wind uncertain, weather at times clear, but generally hazy; in the morning it is either calm, or there are very light airs, which sometimes increase towards noon to a fresh breeze from South, occasioning a long swell on the Arabian Coast. Towards the middle of the month, and in July and August, between Meyet or Burnt Island and the Straits of Bab-el-Mandeb, strong Westerly and South-Westerly winds may be expected, blowing through the Straits with violence, and sometimes enabling a vessel bound to India to reach the Monsoon; but, as a general rule, a vessel will lose the wind before reaching Ras Rehmat, and will not fall in with it again until it bursts from the Southward, through the channel between Sokotra and the mainland of Africa.

Moderate Southerly winds may also be expected during these months, blowing only during the day, and declining into a light air at night. In the evening, after the Southerly wind dies away, severe land squalls are not unfrequent on the Arabian Coast, which, rising in a thick cloud of dust, give ample warning to the seaman. There is always a long Southerly swell on the Arabian Coast at this season.

The S.W. Monsoon is felt in the *Arabian Sea* earlier in the Southern parts than in the Northern: that is, it advances to the Northward with the progress of the sun in declination. It sets in at Cape Comorin between the middle of April and the end of May, but it is not felt at Bombay till a month later. It commences and ceases earlier nearer the coasts than in the open sea.

It is different in the *Bay of Bengal*, where the S.W. Monsoon sets in earlier in the Northern part, and comes Southward at the rate of 10 or 20 miles a day—"backing down," as it is termed by Capt. Maury. It comes on the Coast of Orissa about the beginning of March; and 15 or 20 days later on that of Golconda; it does not reach the Coromandel Coast till the end of that month; and at Ceylon it arrives about the middle or end of April. At the end of May it is established all over the Bay of Bengal as far as the Equator.

The *Island of Ceylon* is somewhat peculiarly placed, for its Southern part reaches towards the limits of the Monsoons, and it participates in the characteristics of the winds of the Arabian Sea. The West Coast has the nature of that of the Malabar Coast, where the S.W. Monsoon, passing over the Ocean, brings bad weather; while the N.E. Monsoon is the fine weather wind. This is reversed on the opposite or Eastern Coast, which has a similar climate to that of the Coromandel Coast, the N.E. Monsoon bringing storms, a heavy sea, and dark foggy weather. The S.W. Monsoon is here the fair weather season.

There are many local variations from the regularity of the S.W. Monsoon, occasioned by the nature and direction of the coasts, but in general it seems that the S.W. winds are first felt more particularly on the African side; and during the months of April and May, the winds come from the Westward of North on the Indian Coast of the Arabian Sea. In June, when the Monsoon is fairly established, it blows home over its whole extent.

The North-East Monsoon.

The N.E. Monsoon is the usual N.E. Trade Wind, which blows over the area North of the Equator, as in most other parts of the globe, during that period when the sun is not exerting its most powerful effects on the plains of Asia and Africa. As this wind is generally of a much more gentle nature than the stormy S.W. Monsoon, it will not require so many words to describe its effects, and therefore it will be dismissed with sufficient description to enable the mariner to judge of its usual direction and force in the various parts of the Indian Ocean, North of the Equator. In this the geographical order that has been followed in the notes on the S.W. Monsoon will be here repeated.

The N.E. Monsoon commences in the *Arabian Sea*, about the middle of October, and prevails during the months of November, December, January, and February, after which the winds become light and variable, until the setting in of the other Monsoon. It blows a steady moderate breeze from the North-Eastward, in the open Ocean, with fine settled clear weather, and a smooth sea; but on the East Coast of Arabia, and the coasts within the limits of the Gulf of Aden, the wind is very variable.

In the *Gulf of Aden* the N.E. Monsoon commences early in November, the prevailing winds being East and E.N.E., blowing fresh at the full and change of the moon. At the end of December, or early in January, it frequently blows a moderate gale with heavy rain. In January, February, and March, Easterly and East-North-Easterly winds are common, increasing in strength towards the Straits of Bab-el-Mandeb. The weather is generally clear and pleasant; the Thermometer ranging from 68° to 80° Fahrenheit; rain may sometimes fall, but not in any great quantity. These three months are the principal for trade.

On the *S.E. Coast of Arabia*, light and variable winds are experienced during the month of October. In November, between the island of Masírah and Rás-al-Hed, light land winds of short duration, and sea breezes from S.E. to South, generally prevail; but to the Southward and Westward of Masírah, land winds are rare. A strong breeze from N.E., with a short chopping sea, is by no means unusual during this month and early in December; it is always looked for by the native navigators.

During the months of December, January, February, and part of March, the N.E. Monsoon blows along the whole line of coast, varying with the direction of the coast line. At a distance from the shore it blows from N.E. to E. by S., with clear pleasant weather, and free from squalls and rain; but near the coast the atmosphere is generally hazy, particularly when land winds are blowing. Fogs are also prevalent in the vicinity of Ghubbet Hashish and the Gulf of Masírah.

Strong land winds, called by the natives *Belát*, may be expected from the middle of December till the middle of March, between Rás Seger and the island of Masírah; they blow from North to N.N.W., and last from one to three days, and at times even as long as seven days. Indication of their approach is generally given by a faint hazy arch over the land the previous evening, or by the wind veering towards the land, sometimes in sudden gusts, early in the night. They nearly always set in between midnight and 4 a.m., commencing with a light breeze, and increasing to a moderate gale in about an hour, blowing hardest between 9 p.m. and 9 a.m., and usually ceasing about noon, as suddenly as they commenced.

The N.E. Monsoon is much affected by the mountains of the Indian Peninsula, and hence the well-marked appearances of the Sea Breeze, which, during the day, overcomes this North-Easterly wind, almost along the entire *Western Coast of India*. But abreast of Paniany (10° 45′ N.), or 40 miles South of Calicut, there is a remarkable break, about 16 miles wide, in the continuity of the Ghauts. It is generally said that, in passing near this parallel, ships experience a much stronger N.E. wind than at any other part, and which sometimes lasts throughout the entire day. It may be attributed to this opening, which thus allows the N.E. wind to pass uninterruptedly to the West Coast.

The N.E. Monsoon should commence in October in the *Bay of Bengal*, but it rarely blows in this month in the Southern portion of the Bay. Between Ceylon and the Strait of Malacca, from the Equator to the parallels of 8° or 10° N. lat., Westerly winds, strong, and lasting several days without intermission, occur. Near the Equator these winds blow more frequently from

N.W. and N.N.W.; on the line joining Ceylon and Achin Head, they vary between W.S.W. and W.N.W.; while in the Northern part of the Bay they are from S.W. or S.S.W.

From a description of the *general* Winds of the Indian Ocean, we proceed to a short description of a few of the more important *local* Winds.

Mozambique Channel.

The *Mozambique Channel* would be in the strength of the S.E. Trade, were it not, as before stated, for the protecting effects of Madagascar, which entirely intercepts it, and gives to the winds of the channel to leeward of it a Monsoon character, with great peculiarities. These require a special notice, the more so as the channel itself is a great highway for Indian commerce, between April and September.

Soon after the change in the seasons, when the vertical sun enters the Southern Hemisphere, the Southern limit of the S.E. Trade reaches the South point of Madagascar; and this wind, therefore, blows more directly on to the Coast of Natal and Sofala, by which it is diverted to the Northward, and then, about May, forms the commencement of the S.W. Monsoon, which is the *fair weather* wind of the Mozambique. When this wind acquires its full force to the North of the Equator, as is well known, it is highly charged with electricity, and is accompanied by heavy falls of rain, caused by the evaporation of the Ocean over which it passes in its Northern course. This continues till about September, when the effects of the Southerly Monsoon are waning, and the S.E. Trade is intercepted by the South extreme of Madagascar.

The division between the winds which come from the North end of the channel, and those which enter the South, is usually found about Cape St. Andrew; and calms, squalls, and overcast weather, result from this meeting of the opposing aerial currents. Still this general outline, as may be supposed, does not exactly represent the winds of this channel, which are liable to many changes and interruptions to their continuity, arising from the want of stability in the origin of the winds blowing towards it. The winds near the shores, too, are much influenced by the land and seasons, and differ from those met with in mid-channel.

The Red Sea.

The *Red Sea*, from its geographical configuration, has only two general winds, those blowing up or down it. The N.E. Monsoon in it becomes a South-Easterly wind, thus turning at a right angle up the Red Sea, and the S.W. Monsoon becomes a North-West wind, also at right angles to its normal course.

"The N.E. Monsoon entering the Red Sea, becomes a S.E. wind, and, being repelled by the high land of Africa into a narrow strait, blows with considerable force, rather inclining towards the Arabian Coast; for it is probable that the winds are stronger there than on the Abyssinian side, even in the most Southern part of the sea. These winds generally begin to decrease in force after passing the Hánish and Zukur Islands in lat. 14°; and as they approach the wider part of the sea, they are gradually lost in light breezes along the outer reefs on the Arabian side, or turn to the Westward amongst the banks and islands on the African side, and gradually unite with the prevailing Northerly winds in that part.

"The Southerly winds commence in October, and subside in the latter part of May, or beginning of June. They blow with most force from October to the end of January, and in some months extend as far as Suez, but most commonly do not reach Jiddah; they are frequently succeeded by light, variable, or Northerly winds in the 18th degree of latitude. From February to the end of May they do not always blow so strong as in the preceding months, and are frequently succeeded by Northerly winds for several days, particularly in the month of February, at which time the native boatmen avail themselves of the opportunity to reach the Southern parts of the sea.

"From October to January, in the Southern part of the sea, the weather is generally thick and hazy, obscuring objects until pretty near; and along the outer reefs squalls and rain are frequently experienced in November and December. From February to May the weather is unsettled—in April and May particularly. Below the 15th degree of latitude we experienced fresh squalls from the Eastward, with heavy clouds of sand, and sometimes rain."—*Commander T. Elwon, I.N.*

In the beginning of June the Southerly Monsoon is succeeded by North-Westerly winds, which, in the Southern part of the sea, seldom blow with great force. They continue pretty regular in June and July, and in August and September are frequently light and variable; in the latter month there are sometimes light Southerly winds or calms. During this season the weather is frequently very thick and hazy, particularly on the Arabian side; and the Abyssinian shore is consequently much the most pleasant, and is considered the most healthy.—*Capt. Moresby.*

The Persian Gulf.

There is great diversity of opinion among the different writers on the Winds of the Gulf of Persia. Some state that there is a N.W. Monsoon from September or October till May or June, and a S.E. Monsoon during the other months. Others, with more probability, insist that the N.W. winds prevail during the greater part of the year, and that only in November, December, and January, are Southerly winds either strong or lasting. With the exception of these three months, during which heavy squalls from S.S.W. to S.W. sometimes occur, Southerly winds are rarely encountered. Should they last for two or three days with any strength, it is almost certain that the N.W. winds will bear down on them with greater violence. And it often occurs that vessels going up with these South winds are driven back by the stronger Northerly gusts.

These Northerly winds are called *Shemaal.* Those which last forty days in June and July are called the Great Shemaal, and it is useless endeavouring to beat up against them to go North. There is also in March and April the Little Shemaal, lasting only twenty days without varying its force or direction.

The Winds of the Persian Gulf are neither so steady nor of such duration as those met with in the Red Sea. In the Southern part they are still more irregular ; and any other winds than those from N.W. or S.E. are light and variable. During the winter months, Southerly winds are accompanied by rain.

Sumatra

The *West Coast of Sumatra* lies in a peculiar geographical position. Being intersected by the Equator, it partakes of the Meteorological features of both Hemispheres.

North of the Equator.—From October to April the winds are variable, with land and sea breezes and fair weather.

From May to September, the period of the S.W. Monsoon in the Bay of Bengal, the winds inshore of the outlying islands are from N.W., light with calms, rain, and bad weather. N.W. winds cause a considerable sea in the various roadsteads. Westward of the outlying islands the winds are from S.S.E. to S.W. The rainy season ends in August.

South of the Equator.—From October to April the N.W. Monsoon of the Indian Ocean prevails on the West Coast of Sumatra South of the Equator, and is ushered in by thunderstorms and heavy rain. Land and sea breezes are occasionally experienced, and bad weather with rain and heavy squalls occur at night. Near the Equator the winds are variable, with frequent calms.

During the period from May to September the S.E. Trade Wind prevails on the West Coast, South of the Equator, and blows from S.S.E. to S.S.W. with fine weather. In this season N.W. winds with bad weather are occasionally experienced at full and change of the moon. Land and sea breezes occasionally blow in May and September.

CURRENTS.

The *permanent* Currents of the Indian Ocean are the Agulhas and Equatorial Streams; those of a more variable character are found within the limits of the Monsoon regions.

Agulhas Current.

The Agulhas Current is one of the most remarkable in the world; and, after the Gulf Stream, was the first that attracted investigation by scientific data. It was owing to the hint given by Captain Waghorn to Major Rennell, in 1764, that this first inquiry took place. Major Rennell's essay appeared in the year 1777, and was the precursor of those many useful treatises on Ocean Currents, which have proved of such service to navigation, and which in their main features have not since been contradicted. We give the following, therefore, from Major Rennell's summary, as found in his last work.

The two Streams of Current from the Indian Ocean, the one from the Channel of Mozambique, down the S.E. Coast of Africa, and the other from the Ocean at large, both running South-Westward, join nearly opposite Point Padrone, or longitude $26\frac{1}{2}°$ E., and probably near the edge of the Agulhas Bank, about 40 miles from the shore.

These Currents united, between the meridians of 25° and 29° E., form one Stream, of 20 to 100 miles in breadth, which acquires a moderate velocity on the side toward the Agulhas Bank. Near the meridian of 29° it has been found to set South-Westward, more than 4 miles an hour, but more frequently $3\frac{1}{2}$, 3, and $2\frac{1}{2}$ miles.

From the meridian of $25\frac{1}{2}°$ the Stream gradually turns to the West; its main body continuing to the border of the Bank, which extends 150 miles, in a direction W. by S. $\frac{1}{2}$ S., whence it changes to S.S.W. The main body, or central part of the Stream, appears to strike on the Bank, nearly W. by S., about latitude $35\frac{1}{2}°$, and longitude 23°, and is immediately deflected Southward to S.W. by W., and, by the time it arrives on the parallel of 36°, to S.W. It becomes S.S.W. before it reaches 37°. In $37\frac{1}{2}°$ it sets due South, on the meridian of 22° E.

On the S.W. quarter of the Bank, between $36\frac{1}{2}°$ and 37° S., and between the meridians of 19° 40′ and 21°, the Current appears to form eddies, or a kind of whirl; and hereabout the Easterly or *Connecting Current*, from the South Atlantic, passes at no great distance from it. The latter appears often to disturb, and absolutely impede, the opposite Current, which sets round the Bank, being by far the more powerful of the two in this place, and it is apparently the cause of turning the Agulhas Current to the Eastward, after the Eastern side of the Bank has already turned it from a Westerly to a Southerly direction.

Although the main body of the Stream is turned aside, on coming upon the

Bank, from its general Western course to one more Southerly, a large portion of it comes over the edge, in some parts to 20 miles or more within the border, in 100 to 120 fathoms water, and with a velocity of about 45 miles in the 24 hours.

The check given to the Current by the Eastern edge of the Bank does not turn it aside at once, but it acquires the new direction by degrees, and a considerable portion of the main stream passes over, and to some distance within, the edge of the Bank, more particularly going Southward, where the water on the Bank becomes deeper.

From what is known, it has been concluded that the Bank, with the depth of about 100 fathoms, actually turns the Stream as the strong current advances; whence it must be inferred that its main body is at least 100 fathoms in depth. No other reason appears why it does not pass directly across the Bank, in the line of a slow Westerly current, where the shallowest depths are from 40 to 50 fathoms.

Captain Henry Toynbee has remarked that the water on the Agulhas Bank and in Table Bay is remarkably cold, showing that its source is not the Mozambique Current. In Table Bay, in February, the water was down to 51°, while the day before, on the Eastern edge of the Agulhas Bank, it was 70·5°, and to the N.E. of this 78·3°. Again at 90 miles due West from Table Bay the temperature rose 19°. This water, therefore, comes from the ice-bearing sea, and is one of the causes of dampness from which West Africa suffers; and the inhabitants of Cape Town, overcome with heat on shore, may find the temperature of an English March on board a ship at anchor in the bay. There is a great contrast in the climates of Natal and Cape Town from this cause, Natal abounding in Tropical vegetation, which will not grow at all at the latter. Again the drift ice travelling North-Eastward is repelled by this down-bearing warm water, and is fended off to the S.E.

The Velocity of the Agulhas Current is to the sailor an important element in its condition. Yet it cannot be given with any certainty, owing to its very variable nature. At times when the wind is favourable, and the frequent opposing winds have not been active, the rate attained is very great near the shore, sometimes reaching nearly 4 knots an hour; under exceptional cases a higher rate than this has been recorded. Capt. Henry Ponsonby gave a series of useful tables, in 1849, of his experience of thirteen passages to the Westward, over the Bank, which gave a mean rate for those made during the Southern summer of 37 miles in the 24 hours, and in winter of 41 miles. These rates varied very considerably on consecutive days; from no current whatever, up to a maximum of 105 miles in September, and 85 miles in June; but in no instance was a reverse current experienced.

It is this strong Current which, running dead to windward, occasions that heavy turbulent sea, for which the neighbourhood of the Cape has gained such a dreaded celebrity. The effect of this adverse wind upon an advancing and violent current is to crowd these enormous waves one against the other, so that their crests are much closer together than they would be under a free scope for their action. The result is, that heaving labouring sea, so straining and dangerous to heavy or deeply-laden ships.

Another effect of the entangled Meteorological features of hot and cold currents, and their action on a disturbed wind system, is to produce at times those curious atmospheric phenomena of singular clouds and illusions, which perhaps have given rise to the fable of the *Flying Dutchman*, which may also have taken its origin in the presence of those remarkable Icebergs which are at times drifted quite into the warm waters just spoken of.

There is one well-marked effect of the Agulhas Bank, in quieting the heavy seas which roll up to it. A vessel may be exposed to a most turbulent and irregular sea while in deep water outside the Bank, endangering her spars and threatening to break over the ship, and swamp her; but the moment soundings are gained in 60 or 70 fathoms, the sea becomes comparatively tranquil in a remarkable manner.

The Equatorial Currents.

The term Equatorial, although it has been generally applied, can scarcely be said to be applicable to that Current which rarely, and then at only one portion of the year, reaches to the Equator. In the Indian Ocean the S.E. Trade Wind, exerting its influence on the surface waters over the whole area of its occurrence, impels the waters towards the Coasts of Madagascar and Africa, between the Equator (in the Northern summer only), and the parallel of 30° S. in the Northern winter. Owing to the great irregularity in the area and persistence of the true Trade Wind, liable as it is to numerous interruptions in its course and power, the Currents of this Southern Tropical region are equally liable to irregularity of force in their character.

We have but few comparatively good observations on the velocity of the Surface Currents in this portion; their great variations in different seasons, both in limits and strength, make it difficult to lay down any law which may be taken as a guide in these particulars; but it may suffice the mariner to know that when sailing over the area in question, he may reckon on a Westerly Drift of 10 to 20 miles a day, modified by the direction of the wind, or rather more than that to the Westward when near the Western shores of the Ocean.

Of course this Westerly Drift will not be found to be regular over the whole region, except during the period when the Trade Wind blows. During the months between October and April, when the Cross Monsoon (p. 105) is blowing between the Equator and 10° S., the latter parallel is the Northern boundary of the Westerly Drift. This parallel is to the Northward of the North end of Madagascar, and therefore the surface-water is drifted directly on to the African Coast to the Westward of it, as it is to the Southward towards the Natal Coast.

It is usually stated that when the Tropical Drift reaches the meridian of Rodriguez, or about 75° E., it divides into two branches, the one directed to the S.W. towards Mauritius, and the other to W.N.W., past the North end of Madagascar. This generalization should also be received with some reservation, as it is more than probable that the Drift is continued past this meridian until it is neutralized by the opposition caused by the East Coast of Madagascar.

The Mozambique Currents.

The Mozambique Channel, being as it were under the lee of Madagascar, has peculiar Wind and Current Systems, each very much influenced by the season, and the latter by the direction of the land. The Equatorial or Great Tropical Current, just described, is diverted almost throughout its entire breadth by the island, and it is only round its North and South extremes that the general influence of the Drifts of the Trade Wind reach the channel inside it, and modify the direction of the waters through it.

On a former page (111), it is stated that Mozambique and Cape St. Andrew appear to form a limit to different Aerial Currents. Perhaps the same may be said of the Marine Currents. During the N.E. Monsoon the surface streams set to the Southward, especially on the African side, throughout its entire length, but they cannot be entirely depended on. There is also very frequently an opposite Current setting on the Eastern side. From the experience gained by an August passage Northwards, Captain Leighton considered that there was nothing to have prevented an equally good passage from being made to the Southward. The winds frequently came from the Northward, and with them a very cross, boiling sea. In the opposite season, in February, 1857, he found remarkably steady and strong S.W. winds, with a powerful lee Current, which it was almost impossible to make way against. Even in standing in close to the African Coast no advantage was gained, and when the other side was tried a fierce current of 2½ miles per hour to South-Eastward was found.

The Currents observed in the French frigate *Cordelière*, under the command of the Vicomte Fleuriot de Langle, on the East Coast of Africa, between 1859 and 1862, were very irregular, and varied with the season. It was thought that Cape Delgado was the point of division where these Currents bifurcated. They generally ran down the coast from this point to the South, and the Monsoon seemed to have but little influence in the direction they took between Cape Corrientes and the Bay of St. Elizabeth. Variable Currents were met with between Cape Corrientes and Cape Delgado. During the survey of this coast by H.M.S. *Nassau*, in 1875, the separation of the Equatorial Current appeared to take place between the parallels of 11° and 11° 10′ S., or off Mtundo Pass.

From Cape Delgado to Cape Guardafui the Currents vary with the Monsoon, and generally cease with the change in the wind. Thus it was usual to find a strong Drift to N.W. and N.E. along the coast between June and November or December, and when the N.E. Monsoon set in, the Currents set down with the same rapidity to S.E. and S.W. It was also observed, during the S.W. Monsoon, that the rain and bad weather followed the vein of Current which extended to 90 or 120 miles, and sometimes 200 miles from the coast. On the margin of this Current, too, a counter-Current was found, by means of which a vessel might work to windward.

The observations collected and recorded by Lieut. Fergusson seem to show that at the setting-in of the S.W. Monsoon, which in the Southern part may be considered to take place at the end of March or in April, and especially in May, that the Lee Current is felt throughout the whole extent of the Mozambique Channel ; and this Northerly set continues with greater or less velocity until August, when the channel becomes less frequented, and of course fewer observations are recorded. It might be supposed that these stronger drifts would be found most prevalent on the African side, being to leeward of the wind influence. The Madagascar side, generally, has the better weather.

But, as before said, there are so many interferences in the aerial and marine currents in this channel, that it is very uncertain what may be met with, and no very great dependence can be placed on a certain aid from either source.

The warmer water which thus flows to the Southward through the Mozambique Channel gradually becomes cooler in its progress. One of the highest temperatures of the Ocean's surface (87° Fahr.) is found in the Arabian Sea, but this great warmth becomes lost when the waters, by their motion, become mingled with the lower and cooler strata. Arrived at the Southern part of the channel, the Current runs strongly around the projecting points of the African Coast, and this circumstance has given the name to Cape Corrientes; here its velocity has been stated to reach 140 miles per day, a rate only equalled by the Atlantic Gulf Stream. Of course this enormous speed is quite exceptional.

The Mozambique Current thus pursues its course to the S.W., along the African Coast, and to the Southward, about Natal or Cape Padrao, the S.W. branch of the Equatorial Current meets the coast, and the two Streams combined form the well-known Agulhas Current.

Monsoon Currents.

In the Indian Ocean, during the S.W. Monsoon, it drives all the waters North of the Equator to leeward, and thus makes an Easterly Drift, which at that period, between May and September, is readily accounted for. But it does not extend far South of the Equator, which, as before stated, is then subject to Calms. It may then reach to about 3° to 5° S., and flows with considerable velocity. At the end of the S.W. Monsoon, Lieutenant Fergusson's charts show that the S.E. Trade then is about to usurp its sway in the Western part of the Ocean, and on the meridians of 65°—75° E. is drifting the waters to the N.W. in opposition to the Monsoon drift.

In the opposite season of the Middle or Cross N.W. Monsoon, between October and March, an Easterly Current is found when South of the Equator, or between 2° N. and 4° to 8° S., when it is encountered with a velocity of 10 to 30 miles per day. It is very irregular in its course and rate, but is usually to the Eastward. In January and February it is strong in the central parts of this area, and at times runs at 2½ knots. All the phenomena of this area have been before shown to be very irregular, forming calms, light airs, strong breezes, and variable winds; and the Currents partake of this irregular nature, but usually are in a contrary direction to the Tropical Drifts.

Arabian Sea.

To the North of the Equator the Currents in both the Arabian Sea to the Westward, and the Bay of Bengal to the Eastward, of the Indian Peninsula, are entirely influenced by the alternating Monsoons, and they form a kind of circulatory system in each of the areas in question. From their being closed in to the Northward, the waters in the Southerly Monsoon can only find an outlet by running down the coasts, sometimes in a direction opposite to the prevalent wind, and this occasions several anomalies, as will be seen in the subsequent brief notices. In general, the Currents of this part of the Ocean are comparatively unimportant, and it is only in special localities, as around the South extremity of Ceylon, where these waters find an outlet, that they become formidable on account of their velocity and extent.

South-West Monsoon.—The Currents in the Arabian Sea, at this season, are regular in direction, their velocity depending much on the force of wind and local circumstances. The general course of the Current in the middle of the sea is about East, inclining to S.E. as it nears the Western Coast of India. Its velocity varies from half a mile to 2 miles per hour.

On the Eastern Coast of Africa the Current sets along the coast to the N.N.E. at a velocity of from 2 to 4 miles per hour, passes through the channel between Sokotra and the N.E. point of Africa, at a rate of 1½ to 2 miles per hour, pursuing a course Northerly and Easterly, until it impinges on the Arabian Coast about Kosair, whence it takes a North-Easterly course along that coast to Ras-al-Hed, at a velocity of one-half to 1½ miles per hour.

To the South of Sokotra, at a distance of about 150 miles, is a great whirl of current, caused probably by the interposition of the island; or, it may be, that shoal water exists at that spot. It commences about the parallel of Ras Hafun, when the Current strikes off to the Eastward to the 55th meridian, then to the Southward, to the 5th parallel, whence it again curves up to the North-Eastward, forming a complete whirl. At the Northern limit the velocity is very great, being 4 to 5 miles per hour, while at its Southern extreme it is only three-quarters of a mile to 1 mile per hour. A very heavy confused sea is created by this whirl. Care should be taken to avoid the strongest portion of the Current in making the Coast of Africa from the Eastward, by keeping well to the Southward.—*Lieut Taylor, I.N.*

Little is known of the Currents at this season close to the Northward of Sokotra, but there is said to exist a whirl similar to, but of less magnitude than that South of the island. Horsburgh remarks that the Currents on the North side run with the prevailing breezes to the North-Eastward, but, when the wind moderates, an almost equally strong Current runs in the opposite direction. This most probably applies to localities within a few miles of the land.

Throughout the S.W. Monsoon, or from June to September inclusive, the water runs out of the Red Sea, while from November to May the contrary is the case. During the S.W. Monsoon the Current on the Arabian side of the Gulf of Aden runs to the Eastward, as far as Ras Rehmat, whence it strikes off to the South-Eastward to Cape Guardafui (Ras Asir), the N.E. point of Africa; it then turns to the Westward close along the African Coast, as far as the 47th meridian, whence it again curves to the N.W., forming a whirl.

From the Straits of Bab-el-Mandeb it sets along the African Coast to the 47th meridian, where it meets the Westerly Current, and turns with it to the North and N.W. The velocity of the Current throughout the Gulf varies from half a mile to 2 miles per hour.

North-East Monsoon.—The Current in the Arabian Sea, during this Monsoon, generally sets to the South-Westward, its velocity depending on the force of the wind. When the wind is light, there is little or no current.

The Currents in the *Gulf of Aden* are most irregular, depending entirely on the prevailing wind. Considerable time and attention have been paid to the subject by the several officers employed, from time to time, on the survey of the coasts, but to no purpose; all attempts to reduce them to principle, for the guidance of the navigator, have failed. The general conclusion arrived at is, that they are set in motion by the prevailing winds, increasing and decreasing in velocity in the same ratio as the force of the wind, and influenced in some degree by the moon's age and consequent change of the tides, which are very irregular. This latter remark only applies to the coast current.

In the centre of the Gulf the Current seems to set in all directions in large whirls or circles, except when the wind is blowing strong, when it will run in the same direction as the wind.

On the Coast of Arabia, from Ras Jezirat to the Straits of Bab-el-Mandeb, during the strength of the N.E. Monsoon, the Current runs with the wind, in the direction of the coast-line, to the Southward and Westward, but is always liable to checks by Southerly winds, when it changes its direction to the Eastward and North-Eastward.

On the East Coast of Arabia, between Ras Jezirat and Ras-al-Hed, the Current sets to the North-Eastward, with a velocity of three-quarters to 1 mile an hour; but this is also always liable to sudden checks by North-Easterly or Northerly winds. In January and February it is variable and very weak off shore; but late in February it sets to the Northward, at the rate of 1 to 1½ mile an hour, between Ras Madraka and Ras-al-Awani, subject, however, to sudden checks from no apparent cause. In March it sets to the N.E., but not strong. In April it begins to set strong to the N.E., all along the coast.

On the Somali or African Coast, within the Gulf of Aden, the Current in the N.E. Monsoon is very uncertain; but it generally sets to the Eastward, or totally opposite to that on the Arabian Coast. It sometimes, however, sets to the Westward without any apparent cause.

The Red Sea.

The Currents in the Red Sea, from Jiddah to Ras Mahommed, are variable all the year; no particular direction can be assigned to them. It may be generally remarked, that they set with the prevailing winds, which, when strong, cause a Current of sometimes 20 and 40 miles a day. If the wind continues long in the same quarter, they sometimes set against it, which can be seen by the short deep swell, in a N.W. wind, against which the best sailing vessels make nothing for the first and second days, when all at once they unexpectedly get to windward. Southerly winds, which sometimes prevail from October to May, generally bring a Current from 20 to 30 miles a day with them. After a North-Wester has been blowing, and light winds prevail, a Current generally sets to the Northward, more especially on the Arabian Coast; on which account the Arabian side, with the Northerly winds, is the best to work on, and not the Egyptian Coast, which the old navigators preferred on account of its being more clear of shoals. On the Arabian Coast a vessel will be able to take advantage of the winds, if she is near the reefs and coast, which winds almost always bear several points more from the land as the night advances, and particularly in the early part of the morning, and are well open to seaward during the day; this is not the case on the Egyptian Coast, when Northerly, N.N.E., N.E., and Easterly winds prevail. At times, from November to March, they cause a strong current to the Westward, and as the wind becomes light, it sets back again to the Eastward. —*Captain Moresby.*

The Persian Gulf.

From May to September the Current enters the Persian Gulf, and runs out during the rest of the year. In March and April, during the lesser Shemaal, they tend to the Northward, so that a vessel by their aid may gain 20 or 25 miles a day. At Cape Jask, from September to April, the Current runs to the South, and it does so between the Persian Coast and the opposite one of Arabia. This current extends to the parallel of 23° N. It is very rare, at this season, that the Currents run towards the Persian Gulf.

From March to September, while Northerly winds prevail in the Persian Gulf, the Currents in the strait leading to it run in opposition to the wind, so that a vessel may gain 20 miles a day by their means. From October to March, vessels entering or leaving the Persian Gulf should keep on the Persian Coast. From March to September, it is preferable to keep in mid-channel, or on the Arabian Coast.

On the *Persian Coast*, with the N.E. Monsoon, the Current runs to the South until March. In April it runs in the contrary direction with the S.W. Monsoon, and trends to the North for the ensuing half-year. Nevertheless, in the strength of the S.W. Monsoon, it runs with considerable strength to the Eastward along the Persian Coast.

The River Indus.

The River Indus discharges a large volume of water into the N.E. angle of the Arabian Sea. It is said that, like the Mississippi, the Amazon, and other large rivers of the New World, its effects are felt at a distance of 300 miles from its mouth, when it is much spread, and loses itself in the Ocean. It need scarcely be said that, except near to the delta, its effects are insignificant on navigation, and are at a maximum in July to September.

The West Coast of India.

In November the Currents are generally weak and variable on the Western side of the Indian Peninsula, except in the vicinity of Anjenga, and thence to Cape Comorin, at which part there are frequently S.E. Currents of considerable strength. In this part, also, Northerly Currents occur in January. During the N.E. Monsoon, or fine season, a Southerly Current, of 14 to 28 miles per day, is expected on the whole West Coast. In March and April, when the N.W. winds are violent at the change of the Monsoons, a slight Current to the S.E. is sometimes encountered; at others it does not exist. In May, according to D'Apres, a slight drain of Current, of 5 to 7 miles per day, runs along the coast towards Cape Comorin, increasing in its rate as it goes Southward. But it frequently happens that in May and June there is no Drift; and when the wind shifts to the South it runs to leeward. This is generally the case in the environs of Bombay. At the same period the Drift is usually to E.N.E. in the offing. In July, when the rains have swelled the rivers, the Current begins to run rapidly along shore to the Southward.

At *Bombay* there is rarely a Southern Current, and the waters from the rivers run to the West, till turned back by the flood tide. To the South of Bombay, the Drift to the South is at the rate of 10 to 15 miles, and at times 20 miles a day. This Drift, which is also felt in August and September, is more rapid at the Southern part of the coast; and in October attains a rate of 20 to 30 miles a day. At the end of September, or beginning of November, there are at times Drifts of from 1 to 1½ knot, running to S.E. and E.S.E.

Ceylon.

On the East Coast of Ceylon, during the N.E. Monsoon, or from the middle of September until February, a strong Current descends the coast to the Southward, and doubles its Southern extremity to Point de Galle, and even to Colombo. Its velocity is usually from 40 to 50 miles a day, and as much as 94 miles a day has been found; at other times it is weak.

On the Western Coast, at the same period, the Currents are very variable. Sometimes a fresh N.N.E. wind, continued two or three days, will cause a tolerably strong Current along shore to the Northward. This Current has been thought to be a prolongation of that which descends along the Eastern Coast to the South, and, passing along the South end of the island, turns up the opposite coast.

In the S.W. Monsoon the Currents here, as in all other parts North of the Equator, are more powerful, and it is only during the season of their continuance that their effects are of much importance to navigation.

The Bay of Bengal.

The Currents of the Bay of Bengal, during the S.W. Monsoon, have been investigated by Lieut. J. A. Heathcote, I.N., the materials being derived from the well-kept log-books of the East India Company. This disquisition is contained in the Journal of the Royal Geographical Society, vol. xxx., and we extract the following:—

From the S.W. corner of the Peninsula of India, the Current of the S.W. Monsoon runs in a direction varying from S.E. to S.S.E., according to the distance from the land, and at the rate of ½ to 1½ mile an hour, until, about the latitude of Point de Galle, it is diverted into a more Easterly course. On the line between Cape Comorin and Point de Galle there is a strong set into the Gulf of Manaar, which begins from 30 to 35 miles outside this line, and may prove a source of danger. Vessels from Bombay to the Eastward should, therefore, be careful to keep within the limits of the favourable South-Easterly Current. South of Ceylon, within 30 miles of the coast, the Current runs strongly to the Eastward from three-quarters to 2 miles an hour; but farther South, that is, between the parallels of 4° and 5°, its direction is more Southerly, or about E.S.E.

Mr. John Buchanan, Master of the Little Bassas Lightvessel, says, there are no regular Tides, but the Currents, from the middle of November, or during the N.E. Monsoon, set S.S.W. out of the Bay of Bengal for five months without variation. Thus a steamer, steering N.N.E., has not only to oppose a three-knot current, but also has the wind dead against her; some steamers make barely 2 miles an hour when bound to the Northward.

During the remaining seven months, April to November, the Currents are nearly equally divided. A remarkable circumstance occurs with regard to the Current during the S.W. Monsoon. After running 3 knots to the N.E. for ten days, suddenly it slackens, and runs from 2 to 3½ knots S.W., or from the Bay of Bengal, lasting sometimes only one day, at other times for a week; these changes happen at all times of the moon, and appear to obey no recognised law.

This South-Westerly Current is felt when farther than from 40 to 50 miles off shore, and from its Eastern limits a North-Easterly set begins. It is very possible that this Current is a return of that which flows with great velocity round the S.E. corner of Ceylon to the North-Eastward, a portion of which may be found to bend to the Northward; for, under circumstances somewhat analogous, a return current of this description *is* found off Cape Guardafui, in Africa. At the Bassas Rocks it is met by that already described as setting Eastward off the South Coast of the island; and they both together then take a North-Easterly and afterwards an East-North-Easterly direction across the Bay of Bengal; except that, in the vicinity of the parallel of 5° N., the set is less Northerly, while South of that parallel it becomes East-South-Easterly.

PASSAGES.

It will be seen, from the Meteorological descriptions, that making a Passage from one part of the Indian Ocean to another is a somewhat complicated problem, and that the tracks are entirely governed by the Monsoons, which thus require to be well understood before a certainty can be arrived at respecting the best track to follow.

Taking as a typical Passage, that between the Cape of Good Hope and Bombay, the following are recognised as the principal sailing track :—

The Cape to Bombay.

No. 1. The Inner or Mozambique Passage.

No. 2. The Passage East of Madagascar.

These two are adopted during the S.W. Monsoon, while there is a certainty of reaching the destination before its close. They take to the Red Sea, the Persian Gulf, the Coasts of India, and the Straits of Malacca.

No. 3. The Boscawen Passage.

Adopted for the route to the West Coast of India, when the season is so far advanced as to render it doubtful whether the port will be reached before the setting in of the N.E. Monsoon.

No. 4. The Middle Passage.

Adopted principally when the Cape of Good Hope is doubled between September 1st and October 1st. It takes to the West Coast of India.

No. 1.—The Inner or Mozambique Passage.

The route by the Mozambique Channel, or the Inner Passage, is the most direct for the Seychelles, the Red Sea, Bombay, or to Ceylon or Bengal, during the S.W. Monsoon, but it must not be taken unless there is a certainty of reaching the destination before the close of the Monsoon.

In proceeding to the ports of Western India, cross the Line in 54° E., and when North of it, steer for the destination.

No. 2.—Passage East of Madagascar.

The track to the East of Madagascar is often taken, for there are fewer dangers to be encountered than in the Mozambique Channel, and there is less chance of meeting with light or variable winds. On this account it is frequently the shortest route, especially in August and September, when the wind is unsteady in the Mozambique Channel.

The route to the East of Madagascar may be adopted from February to

October, but it must not be attempted at such a season that there is not a certainty of reaching the port before the close of the S.W. Monsoon. When it is followed, after having doubled the Cape of Good Hope, keep to the Eastward, and take care not to cross the Southern limit of the S.E. Trade before reaching the meridian of 52° or 53° E. Should you bear to the Northward too soon, the ship may be embarrassed by the strong E.N.E. winds, noticed on pp. 103-4, which not only will be difficult to beat up against, but occasion a strong leeward Current, sometimes of 40 or 50 miles a day, which passes to the South of Madagascar.

In crossing the zone of the S.E. Trades, keep between the meridians of 51° and 52° E. until the parallel of 15° S. is reached. When the East Cape of Madagascar, or the land to the North of it, or still better, Cape Ambre is made out, a fresh departure can be taken, and from the last the best direction to take is between North and N. by E. until past the islands to the N.E. and N.W. of that cape. Then with the S.W. Monsoon any port in India is readily attained.

No. 3.—The Boscawen Passage.

This track, which was known and used from early times, was thus named by the French in consequence of Admiral Boscawen, with a convoy of twenty-six sail, making a quick passage by this route in 1748. Subsequent to this it was much used, especially by the French.

The route lies first between the parallels of 37° and 38° S., in the Southern Connecting Current, until the longitude of 54° or 55° is attained. Then, turning to the Northward, it carries between Mauritius and Réunion. Leaving these islands, it runs directly North, leaving the Cargados-Garajos and the Saya de Malha Banks to the East, and to the West Galega and the Seychelles, crossing the Line in longitude 63° E.

The Boscawen Passage is especially adopted as the route to Bombay or the Malabar Coast, when the season is so far advanced as to make it doubtful whether the voyage will terminate before the N.E. Monsoon sets in.

For vessels which double the Cape before the 1st of September, this and the Middle Passage, next spoken of, are more advantageous than the two preceding. This is evident from the fact that, being much more to the Eastward, the vessel is in a better position for reaching her port should she be taken aback by the commencement of the N.E. Monsoon.[1]

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[1] The *first voyage* made on account of the East India Company pursued a part of this course. It was begun on February 12th, 1600. Captain John Davis was chief pilot, and Captain James Lancaster was general of the fleet. These names are celebrated in a very different quarter of the world. Davis made three voyages in search of the N.W. Passage to India, and discovered Davis Strait, July, 1585. Captain, afterwards Sir James Lancaster, advocated this N.W. Passage, and led to Hudson's famous voyage. His name is preserved in Lancaster Sound, Baffin's Bay.

No. 4.—The Middle Passage.

This is still farther to the East than the Boscawen Passage, leading outside or to the Eastward of the Madagascar Archipelago, and to the Westward of the Chagos. In taking this route, run East as far as 67½° or 68° E., so that in case the wind should keep much to the East in high latitudes, which, however, does not ordinarily occur except in March and April, there may be no difficulty in reaching to the Northward.

From this point keep at least a Northerly course, so as to cross the parallels 27° or 26° S., and on reaching the Trades keep likewise as much to the North as possible, between the meridians of 67° and 68°, as long as the wind will permit.

Near the Equator it is not unusual to find Westerly and N.W. winds between November and March; in fact, it is the Equatorial Westerly Monsoon, described on page 105, and to which the reader is specially referred.

Beyond the Equator, in the Western part of the Indian Ocean, this Cross Monsoon is not so prevalent, but the N.E. Trade is then encountered, though this comes at times very much from the North; it is, however, frequently light, and does not offer any very serious impediment to ships bound to the Malabar Coast.

Bombay to the Cape, in the N.E. Monsoon.

In leaving the Red Sea, the Persian Gulf, or the ports on the Western Coast of India, during the strength of the N.E. Monsoon, bound round the Cape of Good Hope, the Inner Passage, mentioned as No. 1 (page 125), may be adopted. From Aden or the Persian Gulf, it is the most direct route in this Monsoon; but, if from Western India, it should only be taken during its strength, in December and January, a season when the N.E. winds prevail throughout the whole extent of the Mozambique Channel, or, at least, until its Southern part is reached.

It is important in all cases, on quitting the West Coast of India, not to take this route too soon or too late in the season—that is neither before nor after the strength of the Monsoon sets in. Although it is the shortest track out of the Indian Ocean, there may be detention from contrary winds from the South, which are as frequent in the Mozambique Channel in October and November, as in February and March, that is, at the change of the seasons.

The strong Current to the South is doubtless favourable, but this passage should never be taken towards the end of the N.E. Monsoon. In January and February there are, moreover, strong gales met with in the Southern part of the channel. For these reasons many prefer the Middle Passage, No. 4, on all occasions on leaving the ports of Western India.

Leaving the West Coast of India, run down that coast until up with the

S.W. end of Ceylon, which may be followed as far as Dondra Head.[1] From this, keep on a S.E. track, and try to cross the Equator in 84° or 85° E.

Between May and November, it is very rare to meet with Hurricanes in the Southern Indian Ocean, and they are almost unknown at the Mauritius in this season. On this account there will be no danger in passing Rodriguez at 120 or 150 miles to the Eastward. At all other seasons it should not be approached nearer than within 210 to 240 miles.

Should it be necessary to touch at the Mauritius or Réunion, on leaving them, it will be requisite to steer so as to pass 90 miles to the Southward of the South end of Madagascar. Having attained the meridian of 45°, or thereabout, on the parallel of 26½° or 27°, run to the W.S.W., so as to make the Natal Coast. In this track, past Mauritius, &c., the vessel has the advantage of the steady Trade Wind as far as possible, although it may not lead over the shortest distance, which, if followed, would take into the space of Variable and Contrary Winds, so embarrassing to the mariner.

It is recommended to vessels, either coming from the Passages East of Madagascar, or from the Mozambique Channel, to fall in with the land at least as far North as Algoa Bay, if not previously sighted farther to the Northward. Then proceed near the edge of the Bank of Soundings, in the main strength of the Current, described on pp. 114—116. In the early months of the year, up to the commencement of April, while the S.E. Trade is felt, keep close along the outer edge of the soundings, until in about long. 24° or 23°, where the Current will generally be found to deflect to the S.W. by W., and at a few miles farther West to a more Southerly course still, as described on page 114. Proper allowance must be made for this by keeping the ship's head more to the Northward. Should the wind be strong from any quarter between N.E. and West, it is best to keep more on the Bank, to avoid being driven off to the Southward, and into the contrary Current, as in the space between these two opposing Drifts there is generally a turbulent sea. It seldom blows home on the coast, so that a vessel has more chance of clearing it, the more especially as the Current sets the vessel off it. The effect of the Bank in quieting the waves is noticed on page 116.

[1] The direction of the Monsoons on the West Coast of India is such, that sailing vessels at *all* seasons of the year can proceed from North to South, but cannot sail from South to North during the S.W. Monsoon.

FROM THE CAPE OF GOOD HOPE TO THE BAY OF BENGAL.

No. 1. The First Outer Passage.

Adopted for the route to the Bay of Bengal, with the certainty of arriving before the end of the S.W. Monsoon.

No. 2. The Second Outer Passage.

Adopted when doubtful whether the Bay of Bengal will be reached before the close of the S.W. Monsoon, or during the N.E. Monsoon.

No. 1—The First Outer Passage.

Between March and October, or during the S.W. Monsoon, this is the most direct track for the Bay of Bengal.

From the Cape of Good Hope keep away to the East on the parallel adopted (see page 130), until the meridian of 62° E. is attained. From this run about N.N.E., so as to enter the Southern edge of the S.E. Trade (lat. 28° or 29° S.) in 82° or 83° E., or thereabouts. From this bear away to the North across the Trades, taking care in this progress to increase your Easting as much as possible, so as to guard against any variation in the direction of the winds (in March, April, and May, they frequently come from the East), and also to overcome the effect of the Currents drifting to the Westward. On attaining the lat. of 1° or 2° S., it is tolerably certain that the S.W. Monsoon will be met with between May and October, which will carry the ship to any of the ports in the Bay of Bengal.

No. 2.—The Second Outer Passage.

If bound for the Bay of Bengal at such a time, that after passing the Cape of Good Hope there is no certainty of crossing the Equator but between the months of November and April, that is, while the N.E. Monsoon prevails, (pp. 110—111), this Second Outer Passage may be taken.

From the offings of the Cape of Good Hope keep on as far to the Eastward as is necessary to enter the S.E. Trades in 84° or 85° E., and passing through these winds, keep as much as possible to the Eastward, so as to approach the North part of Sumatra, but do not keep too far to the Eastward to get embarrassed among the islands which front the coast, or to sight Acheen Head, for it has been previously shown (page 113) that its neighbourhood is peculiarly liable to calms and light breezes, with squalls from N.W. and West, and that the Currents tend towards the Strait of Malacca. During the N.E. Monsoon, Lieutenant Heathcote shows that there is a strong adverse Current here, in the teeth of that Monsoon, so that the vicinity of the North point of Sumatra is peculiar in its Meteorology. Should the ship, however, have to pass into the Strait, of course this Eastward Current is then an advantage.

Having passed Acheen Head at the distance of 150 to 180 miles to the Westward, if the wind allows, run past the Western side of the Nicobars; but should the breeze tend to the East, sail as close as possible. On the parallels of 16° or 17° N., the wind frequently comes from the North, and advantage can then be taken to beat to the Eastward, so as not to be drifted on to the Western side of the Bay. The Arracan Coast should not, however, be neared, and in general it is best to work to windward in the Northern part of the Bay when it becomes necessary to do so, if bound to Bengal or the Sand Heads.

If destined for Madras or the Coromandel Coast, it is not necessary, as above stated, to close in with the Northern part of Sumatra, and therefore do not go East of the meridian of 87° E. For, as stated before, the Winds and Currents about Acheen Head, especially in October and the beginning of November, and at the change of the Monsoons, are particularly embarrassing, coming from the N.W. and West; while during the summer months, in the middle of the Bay, they are variable between South and West.

The *Strait of Sunda* is the great portal of the Indian Archipelago and China Sea, and is used in all seasons for the ports South of China, and frequently in all seasons as an entrance to the Eastern Passages.

Cape of Good Hope to the Strait of Sunda.

Notwithstanding all the long discussions which have ensued since the vast extension of Oriental commerce, and the consequent accumulation of experience, it is still a disputed point as to which is the best parallel for crossing the Indian Ocean in sailing Eastward round the Cape of Good Hope. On the one hand it is contended that by not going too far Southward, better weather, and as much advantage otherwise, is gained. On the other hand, it is said that by keeping nearer to the Great Circle course, that is in higher latitudes, the "Brave West Winds" are found to be more constant and of greater force, and that the distance to be sailed over is proportionately shortened. The following will illustrate this. The first remarks are taken from the Admiralty Sailing Directions, advocating a comparatively low parallel.

On leaving the Cape, steer boldly to the Southward, so as to run down the Easting in lat. 39° or 40° S., where the wind blows almost constantly from some Western point, and seldom with more strength than will admit of carrying sail; whereas, in a higher latitude, the weather is frequently boisterous and stormy, with sudden changes of wind.

Some navigators prefer making their Easting in a higher latitude than 39° or 40° S., whilst others steer a more direct course for Java Head than is here recommended; but the above directions are those usually followed in H.M. ships, and are generally believed to be the best.

Now, respecting this choice of the parallel of about 39°, on which to run Eastward, the distance to be traversed, or the approximate 75° of longitude from the offing of the Cape to the point where you must bear off to the Northward, is about 3,508 miles; a distance of nearly 600 miles would be saved if the latitude of 50° were taken.

On this point Captain Maury, who differs from the Admiralty, says as follows:—

The best course, under all circumstances, is, as a rule, to do thus:—Run from the Equator in the Atlantic to the South as fast as you can, caring little for Easting until you have cleared the Calms of Capricorn, and caught the "Brave West Winds" on the Polar side of that Belt; then shape your course so as to cross 20° E. between 47° and 52° S.; leave these parallels about the meridian of 60° E., and steer thence for the parallel of 40° S., near its intersection with 85° E.

With all deference to these great authorities, may it not be that all are right, if their views are followed in different seasons. It would seem to be quite natural that a lower latitude would carry all the advantages during the winter season that a high parallel does in the summer. The limit between the Trade Winds and the Westerly anti-Trades certainly vibrates in latitude with the progress of the sun in declination; and, therefore, during the inclement winter, the Admiralty parallel of 39°—40° may be quite as advantageous (except as regards the distance to be run) as the probably more boisterous but shorter course in a higher latitude. Again, in the summer months the parallels advocated by Maury and Towson may certainly be safely followed; but in this, also, some other considerations may enter. The sailing powers of the ship, the nature of her cargo, and the health of the crew and passengers (especially if the latter be an important item in the account), would lead the commander to hesitate before he would carry his vessel into climates very much colder than that he has recently left, and which he will soon enter again, and where he will probably meet with heavy winds and turbulent seas.

As said above, the point does not appear to be entirely decided, nor can it be so when each ship may, from motives of expediency, require different handling. The above facts and opinions are given, and the commander must make his own choice of them. For pursuing the voyage to the Northward, the following is given in the Admiralty Directions.

In the South-East Monsoon, i.e., from the middle of April to the middle of September, vessels, having passed the Island of St. Paul, should not edge away too quickly to the Northward, but should endeavour to reach first as far to the Eastward into the S.E. Trade Wind as the meridian of Java Head, crossing the Southern Tropic in about 102° E. In this season a Westerly Current runs along the South Coast of Java, and in the months of June, July, and August, when it is at its greatest strength, it will be indispensable to be well to the Eastward, or otherwise the ship will be liable to fall to leeward of Java Head. In the vicinity of Java the S.E. Monsoon also veers sometimes to East or E.N.E.

In the North-West Monsoon, i.e., from the middle of October to the middle of March, but especially in December and January, the Southern Tropic should be crossed several degrees to the Westward of the meridian of Java Head, when a direct course can be steered for Sunda Strait, or to make Engano Island, or the land about Flat Point, the Southern extreme of Sumatra. Great care must be taken during this Monsoon not to fall to leeward of Java Head, for the Westerly winds blow with great violence along the South Coast of Java, and their strength, united with the strong Current setting to the Eastward, makes it impracticable to beat up along this coast; a vessel may thus have to steer to the Southward, and re-enter the S.E. Trade, in order to make sufficient Westing to fetch Flat Point. When nearly on the parallel of Java Head, and one or two degrees to the Westward of it, a direct course may be steered for the Strait, with an allowance for a probable current setting to the Southward.

If contrary winds are met with shortly after leaving St. Paul Island, in November, December, or January, a vessel may steer at once to the Northward, and cross the Tropic in 80° or 90° E., when she will meet with Westerly winds to carry her to the Strait.

Shifting of the Monsoons.—During the period when these changes occur, i.e., from about the middle of September to the end of October, and from about the middle of March to the end of April, the winds are variable and uncertain. It is advisable at those times to make sufficient Easting in the S.E. Trade to bring Java Head nearly North, and then to steer direct for it, borrowing a little to the Eastward or Westward, when it is approached, as may be required by the prevailing wind or other circumstances.

From the Cape to Australia.

The remarks previously made on the latitude in which it is desirable to cross the Indian Ocean, are equally applicable to these Passages.

The Great Circle Track from the Cape to Hobart passes over 5,384 miles, as compared with the Rhumb Track of 6,149 miles, but it takes a vessel into the very high latitude of 62° S. In making this Passage in the winter season, vessels following the Admiralty Route (not South of 39° S.) avoid much danger, and at other seasons of the year a Composite Route is selected attaining any desired maximum latitude.

Australia to the Cape of Good Hope.

Ships bound from Sydney to Europe or India may, from the 1st of September to the 1st of April, proceed by the Southern Route through Bass Strait, or round Tasmania, Easterly winds being found to prevail along the South Coast of Australia at that season, particularly in January, February, and March, when ships have made good passages to the Westward, by keeping to the Northward of 40° S., and have passed round Cape Leeuwin into the S.E. Trade Wind, which is then found to extend farther South than during the winter months. In adopting this Route, advantage must be taken of every favourable change of the wind, in order to make Westing; and it is advisable not to approach too near the land, on account of the S.W. gales which are often experienced, even in the summer, and the contrary currents, which run strongest near the land. The prevalence of strong Westerly gales renders the Southern Route *very difficult*, indeed, generally impracticable, for sailing vessels, in the winter, although the passage has been performed at that season by ships in good condition which sailed well; but the Northern Route, through Torres Strait, is preferred in the winter months.

Bombay to Aden in the S.W. Monsoon.

It is not advisable to attempt the Direct Passage from Bombay to the Gulf of Aden during the S.W. Monsoon months, or from early in June to the end of August, either for steamers or sailing vessels. There is no record of any sailing vessel having succeeded during the strength of the Monsoon, though some have tried it. The East India Company's steamer *Akbar* attempted the Direct Passage in June, 1846, but was obliged to bear up for Bombay with her cutwater damaged. The steamer *Feroze* tried it in July, 1849, but finding the wind and sea increase as she advanced to the Westward, so as to require four men at the helm, and the decks being constantly flooded, after four days she bore up to the Southward and made the Southern Passage. Lieut. Taylor adds:—This leaves no doubt on my mind that it is useless to attempt the Direct Passage; and that if powerful steam vessels were brought to do it, they would certainly take two days longer than by the usual Southern track.

It is usual, after the setting in of the S.W. Monsoon, for sailing vessels, bound from Bombay to Aden and the Red Sea, to make what is called the *Southern Passage*, or to run down South of the Equator into the S.E. Trade to make their Westing. After working out of Bombay Harbour into 15 or 20 fathoms water, a vessel may steer down the coast, keeping in soundings of from 40 to 50 fathoms; this is advisable to prevent running on to the Easternmost of the Laccadive group of islands, as, owing to the thick, overcast, rainy weather that may be expected, observations may not be obtainable for days together. After passing these islands as little Easting as possible should be made, as the S.E. Trade is fallen in with sooner to the Westward than to the Eastward. The wind will be from S.W. to W.S.W., with hard Westerly and West-North-Westerly squalls, accompanied by heavy rain. A current to the South-South-Eastward of from 20 to 30 miles a day will be experienced.

As the Equator is approached the weather will be finer, and the wind more moderate; and on the Equator light airs and calms, with cloudy weather, and possibly rain will be experienced. This weather will continue until the S.E. Trade is fallen in with, which is generally in from 5° to 6° S. latitude, but it varies; it is sometimes met in 1° S., at others not North of 8° or even 9° S. latitude. A vessel may run down her Westing as soon as she is fairly in the Trade Wind, but is generally obliged to pass to the Southward of the Chagos Archipelago.

On getting the S.E. Trade, a course should be shaped for the Seychelle Islands, one of which may be sighted, for a fresh departure. The Equator should be re-crossed on the meridian of 53° or 54° E. The Trade Wind will be steady and strong, with fine weather, and carried as far as the Equator, gradually veering to South and S.W., continuing moderate till in about 4° N., when the S.W. Monsoon will increase and reach its greatest force in about 10° N.

After crossing the Equator, a course should be shaped to make the African Coast between Ras Hafun and Ras Asir, due allowance being made for the strong North-Easterly Current which will be experienced on nearing the coast, and Ras Asir must be rounded close, to prevent being set to the Northward The course should then be shaped close to the African Coast until Burnt Island is reached, when steer for Aden. Vessels should have good sails bent, for the wind frequently blows in severe gusts along the African Coast.

CHAPTER V.

THE INDIAN ARCHIPELAGO AND CHINA SEA.

WINDS.

The Great Archipelago, which lies between Asia and Australia, by far the largest of the insular regions of the world, covering, as it does, an area of about six millions of square British miles, has been vaguely termed, by various authorities, the East India Islands—the Asiatic, or Eastern, or Oriental Archipelago, or the Malay Archipelago; but, following its great historian, Mr. John Crawfurd, we prefer to designate it as the *Indian Archipelago*, a name, also, by which it is generally recognised.

The Equator passes nearly through its centre, and thus much of it lies on the division between the Meteorological systems of the North and South Hemispheres, the general particulars of which have been recounted and described in the previous Chapters. This peculiar physical condition renders the attempt to define the characteristics of its Climatology somewhat complicated and difficult.

It might be supposed that along this neutral line of separation, under the great cloud-ring, as it has been termed by Captain Maury, there would be some uniformity of wind and weather. Not so, however, for the relative influences of the vast land of Australia, on the one hand; those of the Continent of Asia on the other; the direction of the evaporating winds blowing over the Indian Ocean to the West, or over the Pacific Ocean on the Eastern side, cause the climate and characteristic weather of the Eastern or Western portions of the Archipelago to be very different from each other.

For these reasons the changes in the Monsoons, the alternation of the Wet and Dry Seasons, in some parts, are very puzzling and difficult of explanation;

a fact, also, due in some degree to the want of long series of accurate observations which would be required to elucidate them.

A large portion of the islands thus lies in what has been termed the "Doldrums" of mid-ocean, and on the line of the maximum rainfall. This latter arises from the Trade Winds in passing over the Ocean, evaporating so much from the surface, that on their reaching this central line, or before that occurs, the air becomes surcharged, and great deposition follows. It will be manifest that the case is altered when the wind has to pass over great breadths of arid land, and thus arises the complication caused by the reversed Monsoons.

The disturbing effect of land influences on the great aerial currents, is more apparent in the Indian Seas than in any other part of the world. The result is a complete reversal of the N.E. Trade, and in a minor degree of the S.E. Trade Wind, producing the well-known phenomena of the Monsoons—winds which blow for one-half the year in one direction, and for the other half in the opposite.

While this deflected S.E. Trade Wind, in the form of the S.W. Monsoon, North of the Equator, is blowing between May and October, the S.E. Trade proper prevails over all that part of the Indian Ocean which is not skirted to the South by large tracts of land. Where this is the case, as in the Java Seas as far as New Guinea, which lie North of the great Australian Continent, there is again a double maximum temperature in the sea and the land, and the phenomenon of a N.W. Monsoon taking the place of the S.E. Trade.

The Monsoons, therefore, of the Indian Archipelago are not *two* in number, but are *four*—the N.E. and S.W. to the North of the Equator, and the S.E. and N.W. to the South of it. To the two first the Northern parts of Sumatra, Borneo, and Celebes, the Philippine Islands, and the Malay Peninsula, as well as the whole of the China Sea, are subject. To the two latter the Southern parts of the above-named islands, with the range between Java and New Guinea, and the Northern part of Australia, are subjected.

In general, it may be remarked, that to the South of the Equator, as far as the parallels of 10° or 12° S., the direction of the wind differs ten or twelve points from that prevailing to the North of the Equator at the same period; that is, to the North of the Equator, if the wind or Monsoon is from North, that to the South of it will be W.N.W.; and if the Southerly Monsoon is blowing North of the Equator, in the Eastern Passages it will be from E.S.E. or East.

These brief, general remarks, will suffice to give a notion of the Meteorology of the Central or Equatorial portion of the Indian Archipelago; the remarks given in the introductory part of the chapter on the Indian Ocean, will be equally applicable to this portion of the world.

Storms are of rare occurrence, and Typhoons are unknown. They only occur beyond the limits of the Equatorial Calms, and are seldom felt so far South as the Northern part of the Philippine Islands. On the Coast of China they are experienced in both Monsoons, as further alluded to hereafter.

Malacca Strait.

Although Malacca Strait is within the region of the N.E. and S.W. Monsoons, yet the winds are very variable within its limits. There are various reasons for this; one is, that it lies almost within the limits of the Equatorial Calms, and therefore the Monsoons reach it with diminished force; another is the high land of Sumatra, which impedes the course of the S.W. Monsoon, and the N.E. Monsoon being the fine season here, the wind is never very strong.

The land and sea breezes are regular on the West Coast of the Malay Peninsula, and also on the N.E. Coast of Sumatra, which limit the Strait. The Monsoons are not always regular, except when they are at their height in the surrounding seas, and even then the winds are only moderate in the channel, and only last a part of the day.

The *North-East Monsoon*, which, as before stated, is the fine season, lasts from November to May; the S.W. Monsoon, bringing rain and thunder, generally commences at the end of April or the beginning of May, and ceases in October.

During the S.W. Monsoon sudden and heavy squalls come off the Sumatra Coast, generally during the early part of the night. From their direction they are called *Sumatras*, and are accompanied by loud thunder and heavy rain. They are probably occasioned by the mountains on the Pedir Coast, and blow sometimes for six or eight hours at a time, being strongest at their commencement. In Malacca Road they generally set in at 7 or 8 p.m., and are at their height at midnight; they have caused many ships to part their cables.

The wind in these squalls does not often come from the N.W., but at times it blows from this direction right through the Strait to Singapore. Sumatras come on very suddenly and violently, but do not last long. They are generally preceded by a black cloudy arch, rising rapidly from the horizon toward the zenith, which only allows sufficient warning to reduce sail as quickly as possible, and should a ship be at anchor, she should immediately weigh, or the burst of the storm will not allow her to do so.

The approach of a "Sumatra" has much to attract the attention of the student of nature. The most imposing characteristic is in the immense arch that it forms, stretching from the zenith to opposite points of the horizon; and below the arch, which is of the darkest hue, there are suspended dark grey vapours, about to descend on the surface of the earth. Above the dark arch will be seen light grey fog banks, over which a slighter arch will be spanning, and which is again crowned by white fleecy clouds, contrasting, if the squall approach at daylight, strongly with the blue sky above and the dark masses below.

The Java Sea.

In the *Java Sea*, as in the neighbourhood of the Moluccas, the N.W. Monsoon commences in the first part of November, but does not attain its greatest force till near the end of December. It lasts till the end of March, when the intervals of calm commence, with variable winds, squalls, and rain. The S.E. Monsoon commences in April, and gets gradually stronger till May; it ends in October, during which month the winds are variable. This is the law generally observed in this sea, except that it must be remembered that there are variations in the direction; it draws sometimes to the North and West, and sometimes to the South and East. Besides this, the changes of the Monsoons do not take place at settled times; that of the S.E. is subject to calms, and the wind is less stormy, while it lasts, than during that of the N.W. Monsoon.

Around the islands East of the Strait of Sunda, as far as Timor, the Monsoons are the same as have been described before; that from the East commences in May, and the winds vary from East to S.S.E. These winds are strongest in June and July. This Monsoon is finer than that from the West, which brings bad weather during November and December. The rains commence in this month, accompanied by squalls and winds. The Western Monsoon commences in November, and attains its greatest force in January. The rains fall from December to the middle of February, accompanied by storms and tempests. Then the Monsoon gradually weakens till March; in April the winds are variable, and the weather is fine.

Among the Archipelago and the intervening seas to the South and East of Borneo there are usually two Monsoons, generally called the North or West Monsoon, and the South or Easterly Monsoon, some considering that the wind hangs more to North than West in the former and more to South than East in the latter. The first corresponds with the N.E. Monsoon North of the Equator, and the second with the S.W. Monsoon. From the configuration of the islands, the direction of their mountain chains, and the effect these have in causing the rain clouds to deposit their moisture, these alternating Monsoons are much less regular than they are in the open Ocean, far from these disturbing causes.

Borneo.

The *Island of Borneo* forms the S.E. boundary of the China Sea, and is intersected by the Equator; the result is as in the Island of Sumatra, that the Monsoons of the N.W. Coast do not take place at the same time as those on the West Coast. The S.W. Monsoon prevails on the N.W. Coast from May to October, at the same time as the S.E. Monsoon on the West Coast; and the N.E. Monsoon blows on the N.W. Coast, while the N.W. Monsoon prevails on the West Coast. On the Northern part of Borneo the S.W. Monsoon is not established till between the

15th and 30th of May, when there is continual rain. The weather is not so bad in September, and the dry season sets in with the N.E. winds, varying to the East. However, this can hardly be called the dry season; for, in consequence of its position under the Equator, the island is incessantly inundated with rain. On the West Coast the S.E. Monsoon prevails towards the end of May, and fine weather then sets in. From September to April the West or N.W. Monsoon occurs, with continual rain and heavy gales.

The Philippine Islands.

Among the *Philippine Islands* the two regular Monsoons prevail, which are met with in the China Sea. These Monsoons sometimes extend as far East as the Mariana Islands in the Pacific Ocean, and as far North as the Coast of Japan. The Philippine Islands, lying North and South, their high lands naturally intercept the course of the wind; and the result is that at 120 or 150 miles from them much bad weather is encountered, which becomes worse as the islands are approached. The N.E. Monsoon commences about October, with fine weather, lasting till April, with winds varying from North to N.E. If it should occasionally veer to N.W. it blows hard. The S.W. Monsoon is not observed here till between the commencement and end of May, and does not become regular till June. During this Monsoon the weather is gloomy, cloudy, and very wet. About this period severe storms sometimes occur, called "Collas Tempestados," which are generally accompanied by thunder and rain, the wind changing about and blowing from all points of the compass with the same force. These Collas and bad weather take place at the end of July, or middle of August, and sometimes in October. They are not unlike the Typhoons. In September the wind loses strength, the rain is less, and the sky is fine; but in the morning there is a thick fog, which lasts till noon. At the change of the Monsoons bad weather is sometimes felt, as in the China Sea.

Cochin China.

On the *Coast of Cochin China* wintry weather is found with cold Northerly winds and rain, from December to February. Heavy rains occur in the months of September, October, and November. During the N.E. Monsoon Easterly winds are frequent. Between the Paracels and the coast the same wind is found as far as Cape Varela; and in this channel calms are frequent, while on the offing from this bank the Monsoon blows fresh and regularly. During the S.W. Monsoon, on this coast, the land and sea breezes are tolerably regular, the sea breeze being replaced by a land breeze every evening. This wind generally lasts till noon, when the sea breeze from S.E. again sets in. On the Coast of Cochin China the winds are variable during the whole year, and the Monsoons generally light. The leeward coast is not dangerous with the N.E. Monsoon.

The China Sea.

The S.W. Monsoon commences about the middle or end of April in the China Sea, a little after it is felt in the Gulfs of Siam and Tonkin, and before it reaches the Northern part of its area. It also lasts longer in the Southern part of its course than it does in the Northern. It is at its height in June, July, and August. The N.E. Monsoon, or the bad weather season, commences in the Northern part of the China Sea, about the end of September or early in October, and lasts till February or March. It sets in with a burst of stormy weather, lasting about a week or ten days, and is in its strength in November, bringing much rain and a turbulent sea.

CURRENTS.

It will be manifest that if it be difficult to define exactly the direction and seasons of the Monsoons which blow over the Indian Archipelago, it will be still more difficult to describe the Currents; and therefore only those experienced in Malacca Strait and the China Sea will be here mentioned.

One general remark may be made. A large portion of the Archipelago lies between the two great Tropical Drifts to Westward; in other parts of the world, as on the Guinea Coast, and in the Gulf of Panama, a *counter*-Current is found near the Equator running to *Eastward*, between these Westward Drifts. It cannot be said that such a counter-Current is found in the Indian Archipelago; but the same causes, difficult to define, which produce this Equatorial counter-Current, will help to make the movements of the waters here more complicated and difficult of comprehension. North and South of this central belt, on the Eastern Coasts of Asia and Australia, the Equatorial Streams recurve and form streams analogous to the Gulf Stream in the Atlantic; and this is especially the case in the stream flowing through the Formosa Channel past the Japan Islands.

The Temperature of the Ocean in the Archipelago is high, as might be expected; and, from its peculiar condition, it may be looked on as the head waters of that great circulatory system, which reaches every portion of the Ocean in its course, and gives one universal character to its waters.

Malacca Strait.

The great Island of Sumatra, from its lying directly across the line of direction of the two Monsoons, causes the Currents which enter, or run out of the China Sea by Malacca Strait, to be much modified by tidal influences. As a broad rule, it may be stated that the waters flow to West and N.W. during the N.E. Monsoon, between November and March, and set in the opposite direction with a lesser velocity during the S.W. Monsoon, which blows the water into the Bay of Bengal. In September, while the S.W. Monsoon still lasts, a strong Current sets Eastward around the South part of Ceylon, and thence directly for Acheen Head in Sumatra, where it is divided, a portion running down the West Coast of Sumatra to S.E., and the other as a weak current down the Strait of Malacca. In October this drift is weak and uncertain, but in November, when the N.E. Monsoon is in full force, the Current to N.W. and along the North Coast of Sumatra runs at the mean rate of a mile an hour. From December to February this Current still moves to leeward, and in March and April is sometimes very strong. When the S.W. Monsoon sets in, in May or June, the reverse Current commences, and in July and August attains considerable strength, and thus continues, with some fluctuations, until September or October.

The China Sea.

In the South-West Monsoon, the Currents in the China Sea are very changeable, their direction and velocity depending much upon local circumstances. Late in April, or early in May, they generally begin to set to the Northward, in the Southern and middle parts of the sea, and continue to run in a North-Easterly direction until September, while the S.W. Monsoon is strong; they are not, however, constant in this Monsoon, for at times, when the wind is moderate or light, they are liable to change and set in various directions. After the strength of the Monsoon has abated, there is often little or no current in the open sea, running to the North-Eastward; but sometimes its direction is to the Southward.

Along the Coast of Cochin China, from Pulo Obi to Cape Padaran, the Current sets mostly to the E.N.E., parallel to the shore, from April to the middle of October; and during the same period its direction is generally to the Northward along the East Coast of the Malay Peninsula, from the entrance of Singapore Strait to the Gulf of Siam. To the Northward of Cape Padaran there is but little current in the S.W. Monsoon, near the Cochin China Coast; for, from thence to the Gulf of Tonkin, a small drain is sometimes found setting Northward, at other times Southward. When a gale happens to blow out of the latter Gulf from the N.W. and Westward, the Current at the same time sets generally to the S.W. or Southward, in the vicinity of the Paracel Islands and Reefs, or where these gales are experienced; and this Current running obliquely, or contrary to the wind, a turbulent and high sea is thereby produced.

On the Southern Coast of China the Current is much governed by the wind; when heavy S.W. winds prevail, it runs along shore to the Eastward, but seldom strongly. Near and amongst the islands, Westward of Macao, there is generally a Westerly Current, occasioned by the freshes from Canton River, which set in that direction; frequently sweeping along the islands from Macao to St. John between W.S.W. and W.N.W., about 1 or 2 knots per hour. This Westerly Current is, however, not always constant in the S.W. Monsoon, for it slacks at times; then a weak current may sometimes be experienced running Eastward.

On the Coasts of Luzon and Palawan, the Current generally sets Northward in the S.W. Monsoon, but frequently there is no current, and near these coasts it seldom runs strongly. Near the Bashi Islands it sometimes sets Eastward when strong Westerly winds prevail; but generally strongly to the Northward, or between N.N.W. and N.E.

In the North-East Monsoon.—The Current in the China Sea during the N.E. Monsoon generally runs South-Westward, with a velocity depending on the strength of the wind. When the force of the Monsoon is abated, or during moderate and light breezes, there is often little or no current.

In the Western parts of the sea, along the Coasts of Cochin China and the

Malay Peninsula, the Current generally begins to run to the Southward about the middle of October (sometimes sooner on the former coast), and continues until April. During the month of March its direction is constantly to the Southward about Pulo Aor, with light Easterly winds and calms at times. On the Coast of Cochin China, and adjacent to Haïnan Island, a current varying from South to S.W., commences sometimes about the middle of September; near the land, from lat. 15° N. to 11° or 11½° N., it increases in strength; but its rate decreases in proportion as it flows Southward. During the prevalence of the N.E. Monsoon, from about lat. 14° N. to Cape Padaran, the Current near the coast frequently runs 40 or 50, and sometimes 60 miles to the Southward in 24 hours; the rate, however, is variable, and it is only in the limits above mentioned that it is occasionally so strong, for its strength abates at Cape Padaran; it runs with less velocity to the S.W., towards the entrance of the Gulf of Siam.

On the Southern Coast of China the Current, during the N.E. Monsoon, runs almost constantly to the W.S.W., nearly parallel to the land; and sometimes with inconceivable rapidity, when a Typhoon or a storm occurs. At the distance of 70 or 80 miles from the coast, it seldom runs so strongly as near it; and in 30 or 40 fathoms soundings there is much less current than in shoal water, near the shore and amongst the islands. The Westerly Current sometimes slacks, and, near the land, is succeeded by a kind of tidal current.

Between Formosa and the China Coast the Current runs to the Southward during the N.E. Monsoon. When strong N.E. winds prevail, its direction is generally to the S.W. or Southward, between the South end of Formosa and the North end of Luzon; but here, in light and variable winds, it often sets to the Northward. On the West Coast of Luzon the Current is changeable, sometimes setting Southward along the coast, at other times Northward. On the Coast of Palawan it is also variable, being governed by the prevailing winds, but seldom runs strongly in any direction, unless impelled by severe gales. To the Eastward of Formosa, about Boteltobago Island, it frequently runs strongly to the Northward and North-Eastward, so early as the 1st of March; and although changeable at times, it sets mostly in that direction during the S.W. Monsoon, and in the opposite direction during the N.E. Monsoon.—*China Sea Directory.*

PASSAGES.

One general principle may be laid down for ships traversing the Indian Archipelago, and that is, that during the S.W. Monsoon (April to September) ships approaching China must go by the channels *Westward* of Borneo, and in the opposite season they will take one of the Passages to the *Eastward* of Sunda Strait and of Borneo: the return voyage being also reversed in these particulars.

Therefore, the Passages through the Archipelago, which lie Westward of the great Island of Borneo, are termed generally the *Western Passages*, being the Straits of Sunda and Malacca; and those which lie Eastward of Java and Borneo are called the *Eastern Passages.* To these may be added what was termed the *Great Eastern Passage*, or that to the Southward and Eastward of Australia and Tasmania, and which was first followed by Capt. Butler, in the *Walpole*, in the Northern Monsoon of 1794. Of this route Captain Maury says:—This is now never or very seldom used, and should not be attempted except for very special reasons.

An exception may be made to this absolute conclusion in favour of clipper or well handled ships, which sometimes have successfully attempted to beat up the China Sea against the N.E. Monsoon. Of this more will be said hereafter.

Singapore to Hong Kong.

In the South-West Monsoon.—When June approaches, and the S.W. Monsoon has regularly set in, the track from Singapore to China by the Main Route, Eastward of Pulo Sapatu and over Macclesfield Bank, is preferable, the winds being more steady in the open sea than near the coast. About full and change of the moon, and as early as April, a Westerly breeze will sometimes be found blowing out of the Gulf of Siam to carry a vessel to Macclesfield Bank, and afterwards Easterly winds to run her to Hong Kong.

This route becomes precarious if a sailing vessel is not up with Pulo Sapatu early in October; for near this island, about the middle of that month, strong Southerly currents begin to prevail with light Northerly winds, variable airs, and calms, by which many vessels have been delayed for several days, and have made no progress to the Northward. Fresh winds from the Southward have been met with, even so late as the 1st of November, but these instances are rare.

Some vessels proceeding by the Main Route have carried strong S.W. and Southerly winds, when others taking the Inner Route have at the same time experienced N.W. and Westerly gales blowing out of the Gulf of Tonkin, with dark weather and rain, and have been in danger of being driven among the Paracel Reefs; the Inner Route ought, however, to be chosen in the strength of the S.W. Monsoon, if the vessel is weak and making much water, for the sea will be smooth, and being near the land she may reach an anchorage if required. The gales out of the Gulf are not frequent, and the land may be kept in sight nearly all the time.

Taking the Inner Route, steer for Pulo Aor along the coast to the Redang Islands, thence across the Gulf of Siam, and along the Coasts of Cambodia and Cochin China, keeping the latter aboard to Cape Touron. From thence steer for the S.W. part of Haïnan, coasting along this island, and passing between it and Taya Islands; then cross over to make the Coast of China about Tien-pak, or Hailing Island. The islands from thence to Hong Kong may be coasted along at discretion, or shelter may be found amongst them on an emergency. If this route be taken before the middle of March or the 1st of April, the passage will be tedious unless the vessel is a good sailer.

In the North-East Monsoon.—Sailing vessels leaving Singapore for China in February, March, and part of April, may expect a tedious beating passage, if they adopt the Main Route. In March, April, or May, they can proceed by the Inner Route along the Coast of Cochin China, which is generally the most expeditious in these months.

The Passage to China by the Coasts of Palawan and Luzon may be followed late in the S.W. Monsoon; without much difficulty in October and November; and it is now often made in December, January, and at every period of the N.E. Monsoon.[1]

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[1] It was formerly the general custom for the clipper vessels employed in the opium trade between India and China, to beat up the middle of the China Sea in the strength of the N.E. Monsoon, keeping as close to the Western edges of the reefs as possible, where the current was found to be generally in their favour. Many commanders who have been accustomed to make their passages in that way are strongly of opinion that it is the best route for vessels later in the season than the month of November, whilst others who have been accustomed to proceed by the Palawan have just as strong opinions in favour of that route. The following remarks of Mr. T. B. White, who was for many years in command of clipper vessels engaged in the opium trade, appear to be exceedingly valuable, inasmuch as they furnish a balanced opinion on the respective advantages of these routes. He says:—"I am sorry I cannot say much from experience in beating up the Palawan in a sailing vessel, for during the entire period of my command of the *Lanrick* I never once went that way, but always along the Western edges of the shoals. I am, however, now quite certain that I should have often made much quicker passages, and saved much wear and tear, by going up the Palawan. In the *Fiery Cross*, although a powerful steamer, I found it preferable to take the Palawan, and always did so during the strength of the N.E. Monsoon (November to February), saving fuel and wear and tear; and, though a longer route, made better passages by getting smooth water and often favourable currents. I believe nearly all heavily-laden ships now take the Palawan from October until the end of February in preference to the outer passage, and a current to the North-Eastward is generally felt the nearer the Borneo Coast is kept aboard, and usually the weather is moderate, with a rolling *beam* swell on; at least, that has been my experience when going up in the steamer. Mr.

Hong Kong to Singapore, &c.

In the North-East Monsoon.—Ships bound from China to Singapore, or to the Straits of Gaspar and Banka, should in March and April adopt the Main Route by the Macclesfield Bank, which is then the most expeditious, keeping away to the Eastward on leaving the China Coast; and also in passing Pulo Sapatu they ought to borrow to the Eastward towards the shoals, where the winds are more favourable in these months than farther to the Westward. In April, the *Vansittart*, by keeping about 3 degrees more to the Eastward than the *Herefordshire*, made as much progress in one day as the latter did in ten days.[1] At all other times, the Inner Route by the Coast of Cochin China seems preferable; for it is the shorter, and the ease afforded to ships by steering from the Grand Ladrone immediately before the wind, when blowing strong at N.E., is a great advantage; whereas, by the Main Route, a S.S.E. course is shaped for the Macclesfield Bank, often bringing the wind and sea before the beam, which strains a deeply-laden ship.

In the South-West Monsoon.—Captain Blake, of H.M.S. *Larne*, remarks:—Although formerly considered impracticable, it is now a common practice for ships to work down the China Sea at all periods of the S.W. Monsoon. After leaving Hong Kong, the usual course is to stand towards Haïnan, which will be often fetched without tacking, as the wind frequently blows for days together from the S.E. or Eastward in that part of the China Sea; from thence across the Gulf of Tonkin to the Cochin China Coast. Land and sea breezes and smooth water generally prevail close to that coast, for which reason it is usual to work down as close to the shore as possible, taking advantage of every slant of wind, but being careful not to get too far off the land. It is sometimes possible to get as far to the Southward as Cape Padaran

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Reynell, in the clipper *Waterwitch*, usually took the Palawan in the N.E. Monsoon, and made some very good passages. Now that it is so thoroughly well surveyed, I consider it quite as safe as the outer passage."

[1] Captain Stephens says:—"Vessels leaving the Coast of China or Manilla, and bound towards Sunda Strait, in March, April, or in the early part of May, may expect a tedious passage down the China Sea if proceeding by the old route which passes Pulo Sapatu, particularly if they do not sail before the 5th or 10th of April. Whereas, if the track be taken along the Coast of Luzon, down the Palawan Passage, along the Coast of Borneo, past Direction Island, round Soruetou, and through the Carimata Strait, passing close round the North Watcher, and on for St. Nicholas Point on Java, they are likely to carry Easterly winds, with fine weather and a smooth sea, the whole distance, thus making a direct course, and will avoid calms. The current will also be more favourable than otherwise until May is well advanced. To prove the advantages of the Eastern Route, it may be stated, that in April, 1861, two American ships sailed from Fu-chau-fu: one proceeded by Pulo Sapatu on the West side of the China Sea, the other by the Palawan Passage and Carimata Strait; the latter ship passed Anjer twenty days before the other. The *Harkaway*, on her passage in April and May, 1862, carried an Easterly wind the whole way down, and had no occasion to anchor."

in this way, but generally after passing Cape Varela the Monsoon is found blowing very fresh, with frequent hard squalls out of the Gulf of Siam, rendering it impossible for a ship to do much to windward. From Cape Varela, or from Cape Padaran, if a vessel has been able to fetch it, stretch away to the Southward—making a tack, if necessary, to weather the West London and other Shoals—till the Coast of Borneo is reached, along which work, and pass out through any of the South Natuna Channels. Stand across to Singapore, keeping well to the Southward before closing Bintang, to be sure of your landfall, as the currents run very strongly, sometimes 2 miles an hour to the Northward.

Eastern Routes to China, &c.

The Passages hitherto described are those which are entered by the Straits of Malacca or Sunda, the two principal highways into the China Sea. But during the adverse N.E. Monsoon it may be thought preferable to take one of the channels situated *Eastward* of Borneo, and thus avoid the wear and tear of beating up the China Sea in the teeth of the Monsoon. In this case, the general practice is to follow one of the Eastern Straits, passing to the East of Borneo, and taking the Strait of Macassar, which leads into the Celebes Sea, from this sea proceeding North, and passing East or West of the Philippines, according to circumstances. A vessel can also, in this season, take Pitts Passage to the East of Celebes, crossing the Moluccas, and entering the Pacific Ocean by Pitts Strait, Dampier Passage, or that of Gilolo; then keep to the Eastward of the Philippines, entering the China Sea by the Strait of Formosa.

Thus, in a general way, it may be taken as a rule, that when the Monsoon is favourable in the China Sea, ships must pass to the West of Borneo, but with a contrary Monsoon must pass to the East of that island.

October and November are considered the two most favourable months in which to pass the Strait of Macassar quickly. This is the first of the Eastern Routes. In the other months it is more advantageous to take Pitts Passage, especially from the middle of December to February.

CHAPTER VI.

THE NORTH PACIFIC OCEAN.

WINDS.

General Remarks.

THE North Pacific more resembles the North Atlantic than the other Oceans in its Meteorology, but differs from that Ocean in not having any connection with the Arctic area, for the passage of Behring Strait is too shallow and too narrow to affect the Ocean generally. Further than this, the great area of the Pacific seems to exercise a deadening effect on the motive forces of the Atmospheric and Ocean Currents which pass over it, both being of a more moderate character than in the Atlantic.

The general arrangement of the Wind System of the North Pacific is this:—To the Northward of about lat. 30° (a parallel varying with the season) are found the S.W. anti-Trade Winds; between that parallel and lat. 7° or 10° N. (also varying with the sun's declination) is found the N.E. Trade Wind; and between the last-named parallel and the Northern limit of the S.E. Trade Wind is a narrow Belt of Calms or Variable Winds, to which the name of "*Doldrums*" has been applied; it is a well-known belt of difficulty to the sailor.

Trade Winds.

The extent of the Trade Winds in latitude is usually considered to be from 30° S. to 30° N., but these limits are subject to so many variations, that such a statement must be received with great limitations. We have not the means of drawing such a close approximation to a true mean as can be done in the Atlantic Ocean, from the fewer recorded observations. The following Table is given by the late Chevalier Ph. de Kerhallet, of the French Marine, as the result of the observations of ninety-two vessels which crossed the Line between the longitudes of 106° and 147° W.

Table of the Limits of the N.E. and S.E. Trades, between long. 106° *and* 147° *W., and the breadth of the interval between them in each month.*

Months.	Trade Winds.				Breadth of the intervening zone of calms, &c.
	Polar Limit.		Equatorial Limit.		
	Of the N.E. Lat. N.	Of the S.E. Lat. S.	Of the N.E. Lat. N.	Of the S.E. Lat. N.	
	° ′	° ′	° ′	° ′	° ′
January	21 0	33 25	6 30	3 0	3 30
February	26 28	28 51	4 1	2 0	2 1
March	29 0	31 10	8 15	5 50	2 25
April	30 0	27 25	4 45	2 0	2 45
May	29 5	28 24	7 52	3 36	4 16
June	27 41	25 0	9 58	2 30	7 28
July	31 43	25 28	12 5	5 4	7 1
August	29 30	24 18	15 0	2 30	12 30
September	24 20	24 51	13 56	8 11	5 45
October	26 6	23 27	12 20	3 32	8 48
November	25 0	28 39	..	..	..
December	24 0	22 30	5 12	1 56	3 16

It will be seen, according to this table and the Wind diagram, that the Polar and Equatorial limits of the Trade Winds vary with the season, and remove farther from or nearer to the Equator, according as the sun has North or South declination; also that the breadth of the intervening zone in its Eastern part is less in the winter than in the summer of the Northern Hemisphere. In other respects this zone has much resemblance to the corresponding Belt in the Atlantic, but is not so sharply defined. It is in reality broader between the meridians of 90° to 120° than farther to the Westward, or on those between 120° and 150° West longitude: that is to say, the breadth of the Calm Zone diminishes according as you advance Westward, precisely analogous to the Wind System in the Atlantic.

The anti-Trade.

The *S.W. anti-Trade*, or *Passage Wind*, which occupies all the Northern part of the Ocean, requires still less description. It has all the general characteristics of the similar wind in the Atlantic, and perhaps is most persistent on the Western side of the Ocean. Here, however, it is very much affected by the vast area of land it passes over, and reaching the Ocean as a very dry and cold wind, it has a correspondingly severe effect on the Climates of the Northern parts of Japan, Saghalin, the Sea of Okhotsk, &c., which are proverbially inclement, and for a long period of the year completely ice-bound. On reaching the open Ocean, where the great return Stream, called the Japanese Current, runs to the North-Eastward, carrying with it the warmer water of the Tropical latitudes, this cold and dry wind so chills the warmer vapours which hang over the Current, that they are condensed into almost perpetual Fogs. A similar and well-known region is found in the vicinity of the Banks of Newfoundland, but here these Fogs extend far to the Eastward, and envelope more or less continually the extensive groups of the Kurile and Aleutian Islands.

Dissolving these vapours and acquiring further humidity, and also increased temperature, in its further progress to the Eastward and North-Eastward, it is found on the Alaska Coast as a warm, rain-bearing wind, which deposits its abundant moisture on the shores and islands of that comparatively unfrequented region.

Farther to the Southward, on the coast regions of the Territories of British Columbia, the Climate, as is well known, is not subject to extremes of heat and cold; but within the range of mountains, which intercept much of this anti-Trade Wind, and consequently of its warmer moisture, the climate is much more severe.

From a consideration of the two *principal* Wind Systems of the North Pacific, we proceed to mention a few important *local* Wind Systems.

Bay of Panama.

Between the Southern point of the Gulf of San Miguel and the Gulf of Dulce, including Panama Bay and the Coast of Veragua, the Winds are regulated by the seasons. During the fine season, commencing in October, the *Northers* prevail. These are fine, dry breezes, which generally come on in the afternoon, and blow very fresh from N.N.E. to N.N.W. till near midnight, with a perfectly clear and cloudless sky, and the air so dry and rarefied that objects on a level with the horizon are distorted and flattened, and the same effects are caused as are seen during an Easterly breeze off our own coast. Though generally a double-reefed topsail breeze, they occasionally blow much harder, especially off the Coast of Veragua, where, in the months of January and February, even a close-reefed topsail breeze is not uncommon. During even the strongest of these, a dead calm often prevails 10 or 15 miles off the land, the only evidence of the gale that is blowing within a few hundred yards of a ship being the agitation of the water, which is raised into short hollow waves.

Towards the end of March and up to the middle of April, the Northers are not so regular, having more Westing in them, and are succeeded by calms and light sea and land breezes, with occasional squalls from the South-Westward. As April advances the squalls get stronger and more frequent, and by the latter part of May the Rainy Season generally sets in, during the greater part of which South and South-Westerly winds prevail. These are not very violent within the Bay of Panama; but from Punta Mala, Westward, gales from the above quarters are frequent, and sometimes severe, bringing a very heavy sea with them. Still the old N.W. wind is mostly found after noon, and vessels sailing from Panama at all seasons will generally have a fair wind until South of Punta Mala.

Between the Galapagos Islands and the coast, Westward of the meridian of 80°, and Southward of the parallel of 5° N., the winds are between South and West all the year round, and, except between the months of February and June, they are of sufficient strength and duration to make the navigation easy; but Northward of lat. 5°, between 80° and 110° W., is a region of Calm and Doldrums, accompanied by rains and squalls of a most vexatious description. The weather met with can hardly be better illustrated than by the fact that in May, 1848, H.M.S. *Herald*, in her passage towards the Sandwich Islands, although towed for six days as far West as 89° 20′, still took forty days from Panama to 110° W., owing to keeping between the parallels of 8° and 10° N.; and in March of the following year, on the meridian of 87°, and in latitude 8° N., she only made 30 miles in nine days.

Mexico.

On the S.W. Coast of Mexico, though in North latitude, the Fair Season, or what is called the Summer, is from December to May, inclusive. During this interval alone is it advisable to navigate near the coast; for, in the winter, from June to November, inclusive, every part of it is liable to hard gales, tornados, heavy squalls, and calms; also, to constant deluges of rain, and the most dangerous lightning; added to which, almost all parts of the coast are at this time so unhealthy as to be abandoned by the inhabitants. At the Eastern end of this range of coast, about Panama, the winter sets in earlier than at San Blas, which lies at the Western end. Rains and sickness are looked for early in the month of March at Panama; but at San Blas rain seldom falls before the 15th of June; sometimes, however, it begins on the 1st of June. Of the intermediate coast there is no exact information, except that December, January, and February, are fine months everywhere; and that, with respect to the coast between Acapulco and Panama, the months of March, April, and half of May, are also fine; at other times the coast navigation may be generally described as dangerous, and on every account to be avoided.

From December to May, inclusive, the Prevalent Winds between Panama and Cape Blanco (Gulf of Nicoya) are N.W. and Northerly. Thence to Realejo and Sonsonate, N.E. and Easterly. At this season, off the Gulfs of Papagayo and Tehuantepec, hard gales blow, the former being generally N.E., and the latter North. These, if not too strong, as they sometimes are, greatly accelerate the passage to the Westward; they last for several days together, with a clear sky overhead, and a dense red haze near the horizon. We experienced both in the *Conway*, in February, 1822. The first, which was off the Gulf of Papagayo on the 12th, carried us 230 miles to the W.N.W.; but the gale we met in crossing the Gulf of Tehuantepec on the 24th, 25th, and 26th, was so hard that we could show no sail, and were drifted off to the

S.S.W. more than 100 miles. A ship ought to be well prepared on these occasions, for the gale is not only severe, but the sea, which rises quickly, is uncommonly high and short, so as to strain a ship exceedingly.

From Acapulco to San Blas, what are called Land and Sea Breezes blow; but, as far as my experience goes, during the whole of March, they scarcely deserve that name. They are described as blowing from N.W. and West during the day, and from N.E. at night; whence it might be inferred, that a shift of wind, amounting to eight points, takes place between the day and night breezes. But, during the whole distance between Acapulco and San Blas, together with about 100 miles East of Acapulco, which we worked along, we never found, or very rarely, that a greater shift could be reckoned on than four points. With this, however, and the greatest diligence, a daily progress of from 30 to 50 miles may be made.—*Capt. Basil Hall.*

The change of wind from a general N.W. direction to a general S.W. direction, at the opposite season of the year, causes them sometimes to be described as the Mexican Monsoons.

Juan de Fuca Strait.

From *San Francisco* to the *Strait of Juan de Fuca* the North-Westerly are the Prevailing Winds; in the months of June, September, and October, we found them almost constantly so. Hard gales from all points of the compass, however, may be looked for here at all seasons, especially during the winter and the Equinoctial months. These begin generally from S.E. to S.W., bringing thick rainy weather with them. After blowing from these directions for some hours, they fly round to the Northward (by the West), with little if any warning, except the increased heaviness of the rain, and blow even harder than before. During the spring, Easterly and North-Westerly breezes are more prevalent than at other seasons. In the summer months, Westerly winds and fine weather prevail; but, from the end of July to the end of August, the Fogs are so frequent that many weeks will sometimes pass without a clear day.—*Lieut.-Com. J. Wood.*

Japan Archipelago.

Though there are considerable local variations in the direction of the winds along the extensive sea-board of the Japanese Archipelago, the following appear to be the normal changes which occur throughout the year. The Prevailing Wind throughout the year is from the Northward, varying between N.E. and N.W.

From January to March, inclusive, winds from the Northward and Westward prevail, shifting occasionally to the North or North-Eastward. From April to June the winds are light and variable, principally from the Northward round to West, and sometimes S.W. with frequent calms. The latter end of May and the whole of June is said to be the Rainy Season on the South and East Coasts; the winds are then variable, but haul to the Southward towards the middle of June.

From July to September warm Southerly winds, varying between S.E. and

S.W., prevail, winds from S.E. being more prevalent during August and September than in any other months. The weather is unsettled about the period of the autumnal Equinox, and the wind becomes variable, continuing so until the middle of October, but gradually settling to the North-Westward, and becomes tolerably steady from that quarter about the latter part of that month. In July, thunder-storms are of frequent occurrence.

From October to December, inclusive, moderate Northerly winds, from N.W. to N.E., prevail, with fine weather; a bright day with a clear sky being generally a sign of a strong N.W. wind. Occasionally a N.E. wind freshens into a gale.

Gales.—Ordinary gales occur frequently throughout the year, their prevailing direction being from seaward, between S.E. and S.W. In the winter months, gales from N.E., S.W., and West, are often experienced near the coast. The Barometer generally rises previous to a gale from the Northward, and if it fall after a strong N.E. wind has set in, bad weather will follow. Before a Southerly gale the Barometer falls, and frequently a long heavy swell rolls in from the Southward.

From November until May, local gales blow down the numerous channels and gulfs, especially in the Boungo and Kii Channels, and the Gulfs of Owari, Suruga, and Yedo, frequently lulling at the sun's or moon's setting.

Barometer.—From December to February, inclusive, the mean pressure over the Japanese Archipelago varies from 30·10 to 30·30, the lowest Isobar in these months being farthest inland, whilst the highest follows the line of coast. In March, April, and May, the pressure is more evenly distributed than at any other period of the year, excepting November. The weather during these months is very fine, though moderate rain falls, increasing in the latter month. In June, July, and August, there is great variation of pressure over the Southern portion of Japan, more especially on the S.E. Coast. In October, the pressure increases, and much rain falls on the S.E. Coast. In November, the pressure is nearly equalised, and the weather is fine.—*Staff-Commander T. H. Tizard*, H.M.S. *Challenger*, 1875.

CURRENTS.

The general System of Currents in the Pacific is thus concisely described by M. Biot, who examined with great care the modern and early observations on this subject :—

Two Currents, remarkable for their force, traverse, like two immense rivers, the whole of the regions of either Ocean, the Atlantic and Pacific. That appertaining to the latter seems to flow from the extensive line of Antarctic Coast discovered by Sir James Ross in 1841, and from the great Icy Barrier which extends from thence towards the Pole, perhaps as far as the Pole itself. At its entrance into the Pacific this Current advances to the North; but before reaching New Zealand it trends East, and proceeds until it strikes the Western Coast of Patagonia. This obstacle separates it into two branches. The minor one re-descends towards the South and doubles Cape Horn; the principal one turns to the North, following the Coasts of Chile and Peru, lowering the temperature of these countries. When it reaches the Equator its further advance to the Northward is prevented by the tongue of land, lying obliquely to the meridian, which connects the two Americas. Meeting with this, the Current turns to the West, thence continuing to advance with scarcely any obstacle in this direction until it is again arrested by Oceania, the Indian Archipelago, and the Asiatic Continent. Arrived here, it subdivides, following the inflections of the coasts it strikes against: one branch flowing to the East of Oceania trends to the South; another enters and is lost in the Indian Archipelago; a third, reflected by the Eastern Coast of China, turns to the Northward. This, however, soon meets directly in its course with the Japanese Archipelago, the Peninsula of Kamchatka, and the Eastern prolongation of Siberia. Under the combined influence of these causes, its course bends to the Eastward, and following the direction now quite open to its progress, it proceeds to the Western shores of North America, above the Oregon Territory. Again deflected from its Eastern course, it bears to the South along the Californian Coasts, and again entering the great Equatorial Current it bears away once more to the Westward.

By this movement in continual circulation the cool waters coming from the South Pole become heated under the Equator, and at length moderate the region of the Northern climate they next reach. Thus the branch of the Equatorial Current which ascends to Kamchatka is the cause that the sea never freezes round the Northern extremity of that peninsula.

The North Pacific is the most simple in the arrangement of its Currents. It is a system of circulation, around a central area lying along the Tropic, analogous to the Sargasso Sea in the North Atlantic, and having the same feature of a broad Equatorial Stream setting Westward, with more or less constancy, between 8° or 10° N. and the Tropic; a reverse and strongly marked Current (the Japanese Current), similar to the Gulf Stream; and a broad extra-Tropical Belt setting generally Eastward, but subject to much fluctuation.

But the North Pacific differs from the North Atlantic in not encountering any Arctic influences. Behring Strait is too narrow and shallow to allow either the waters of the Pacific to flow into the Arctic Basin, as is the case with the warmer waters along the Western Coast of Europe, or to permit the Ice-bearing streams from the Polar Basin to flow down to the Pacific, as does the Labrador Current. These varied changes are almost inappreciable here.

The area of the Pacific is so great that the forces which act upon the waters of the smaller Oceans, the Atlantic and Indian Oceans, exert a much more marked effect on them than they do on the Currents of the Pacific. It is the same with the Winds, and thus its Meteorology exhibits but few of those grander features which may be found elsewhere, and pre-eminently characterise it as the "Pacific" Ocean.

On this account the Ocean Currents are of less importance to the navigator except in a few regions, such as near the Equator, the Gulf of Panama, the Coast of Mexico, or Southward and Eastward of Japan. Elsewhere they seem to exert no very definite influence on a ship's course.

The North Equatorial Current.

The North Equatorial Current, extending to the mean latitude of 24° N., is subject to variations in the Southern portion of its extensive Drift.

In its Eastern portion there is no well-marked origin, as is the case in the Peruvian Current flowing to the N.W. and Westward at the Galapagos Islands. On the contrary, as elsewhere remarked, the Mexican Coast Currents are comparatively weak and undecided, so that there is *some* source from whence the Westward tendency of the Ocean is derived, beyond the apparent effects of the Trade Winds and the action of the sun's heat.

Whether it be the effect of temperature, or from the continued action of the Trade Winds, one fact seems to be tolerably well determined, and that is, in the circulation of the oceanic waters around their respective basins, the greatest Velocity or force of the Currents is at their *outer* limits; this force gradually diminishes within the area, and leaves a space not acted on by the circulatory movement, and which area, by analogy, we should expect to find of a higher temperature than might be calculated on if the Polar Streams should not add their lowering influence. Following this theory we must expect to find the currents in greater force nearer the Equator, a fact apparently established. In the central portion of the North Pacific there does not appear to be any regularity in the set of the waters, and the limit before assigned may even be too high, as the Sandwich Islands, in lat. 20°, do not appear to be surrounded by any permanent current.

On the passage of H.M.S. *Challenger* from Honolulu to Tahiti, in September, 1875, very strong currents were experienced. The North Equatorial Current extended to 11° N. (the Southern limit), its general direction being S. 60° W., 18 miles per day, and its temperature varying from 77° to 79°.—*Staff-Comm. T. H. Tizard.*

The Equatorial counter-Current.

In the general remarks on the Winds (on page 148), it is said that in the Wind systems of the Pacific, as elsewhere, there is a space between the two great belts called the N.E. and S.E. Trade Winds, in which the wind is variable and light, and in which calms and rains prevail. This zone of Variable Winds, as they are known, is affected, in its breadth and latitude, by the annual progress of the sun in declination.

In the Current Systems we have a precisely analogous phenomenon—that of a body of water moving with more or less regularity to the Eastward, bounded to the North and South by Currents moving in the opposite direction. This counter-Current has been traced, with considerable certainty, nearly across the entire breadth of the Pacific.

On her passage from Honolulu to Tahiti, in September, 1875, from 11° N. to 6° N., the Equatorial counter-Current was found, by H.M.S. *Challenger*, running to the Eastward at an average rate of 30 miles per day, but its force in 7° N. was 50 miles per day, and its temperature varied from 80° to 82°.

The following remarks on the counter-Current are by Admiral Krusenstern:—"This Current, running from West to East, forms to the North of the Equator a zone which extends to the 6th degree of latitude, and the velocity of which is frequently 20 leagues in the 24 hours. Ships returning from China during the season of the S.W. Monsoon, and proceeding by the Pacific Ocean towards the Strait of Ganem (Dampier Strait), do not generally go farther towards the East than the Pelew Isles; but if they do not pay great attention to this Current, they will usually be carried several degrees towards the East. The best means of avoiding this stream of Current is to attempt to cross it as quickly as possible from North to South, because South of the Equator the S.E. Trade is met with, accompanied by a Current running to the West, the rate of which, near the Coast of New Guinea, is from 15 to 40 miles in the 24 hours, in a West and W.N.W. direction."

The Kuro Siwo, or Japanese Current.

The movements of the waters, as well as those of the Atmosphere, seem to be on a more limited scale, and less decidedly marked in the Northern Pacific than they are in the Southern Hemisphere. This is probably owing to its comparatively enclosed character. From this cause it deserves, in some degree, the title of Pacific, and its navigation is not attended with any difficulty, as any ordinary ship may with perseverance, work to windward in its central portion.

But towards its Western side the movement of the surface water of the

Ocean becomes more manifest, and we find a great analogy in this respect to that of the North Atlantic, and, accordingly, a very distinctly characterized Current in the Pacific follows a similar course to that of the Gulf Stream, well known in the Atlantic.

From the different configuration of the land, however, the absence of any Western barrier, such as the Mexican Coast presents to the Western progress of the Atlantic waters, and the contraction of its channel by the Bahama Islands, this Pacific Gulf Stream has not such a distinct character as is seen in the Gulf of Florida. Still this warm ocean river may be traced in its course by observation and analogy around the Northern side of the North Pacific.

It would be easy to multiply evidence of its character, but we take the description given of it in Commodore Perry's account of his mission to Japan, by Captain Silas Bent, as derived from the investigations by the U.S. officers in 1854.

The results of these observations show quite conclusively that the Kuro Siwo, or Japanese Current, has its origin in the great Equatorial Current of the Pacific Ocean, near the South end of Formosa, in about the latitude of 22° N., longitude 122° E. How it is deflected to the Northward along the East Coast of Formosa, and it then bears off to the Northward and Eastward, washing the whole S.E. Coast of Japan as far as the Straits of Sangar (Tsugar).

Near its origin the Stream is contracted, and is usually confined between the Islands of Formosa and Majico-sima, with a width of 100 miles, but to the Northward of the latter it rapidly expands its Southern limit, and reaches the Loo-Choo and Bonin Groups, attaining a width of 500 miles to the Northward of the latter.

The North-Western edge of the Stream is strongly marked by a sudden change in the temperature of the water, of from 10° to 20°, but the Southern and Eastern limit is less distinctly defined, there being a gradual thermal approximation of the air and water.

Along the borders of the Stream where it chafes against the counter-Currents and torpid waters of the Ocean, as also in its midst, where whirls and eddies are produced by islands and the inequalities in its bed, strong tide-rips are encountered, often resembling heavy breakers on reefs or shoals. Its average velocity, between the South end of Formosa and the Straits of Sangar, was found to be from 35 to 40 miles per 24 hours. Yet, upon one occasion, off the Gulf of Yedo, its maximum strength was recorded as high as 80 miles per day.

To the Northward of the parallel of 40° N., in long. 143° E., there is a cold counter-Current intervening between it and the South Coast of Yezo, as shown by a sudden thermal change in the water, of from 16° to 20°, which, it is believed, sets to the Westward, through the Straits of Sangar; but the limited stay of the squadron in that vicinity, and the harassing prevalence of fogs, prevented such observations being made as to satisfactorily determine whether or not there was a predominant current flowing in either direction, or whether it was merely the ebb and flow of the tides through the Straits. To the Westward, however, of a line connecting the North end of Formosa and the South-Western extremity of Japan, a cold counter-Current was again found, which sets to the Southward through the Formosa Channel into the China Sea; and it does not, therefore, seem unreasonable to believe that a Current will be found in the Japan Sea, setting to the Southward between the Japanese Islands and the main Coast of Asia, fed by that on the South Coast of Yezo, and supplying that setting through the Formosa Channel.

The average maximum temperature of the Kuro Siwo is 86°, and the difference between its temperature and that of the Ocean due to the latitude is about 12°. There was no counter-Current intervening between the Kuro Siwo and the Coast of Japan, to the Southward of the Straits of Sangar, and nothing was found to manifest the existence of such a Current as *under-running* that stream. There is a floating sea-weed found in the Kuro Siwo, similar in appearance to the *Fucus natans* of the Gulf Stream.

Staff-Commander T. H. Tizard, H.M.S. *Challenger*, makes the following remarks on the Kuro Siwo:—Our observations show that when we approached Japan from the Southward, in April, 1875, we passed through a belt of water running to the North-Eastward at the rate of 3 miles an hour, between lat. 32° 30′ and 33° 30′ N., in long. 138° 15′ E. On the Southern edge of this belt the Stream had a more Northerly, and on its Northern edge a more Easterly tendency than N.E. When to the Northward of this rapidly-moving belt of water, a set of 1 mile an hour to the Eastward was experienced. When in the Stream the temperature varied from 63° to 68°, changing suddenly, giving alternate bands of cold and warm water without our being able to detect any alteration in its rapidity.

In May we had a moderate set to the Eastward close to the South Coast of Nipon Island. In June we had no current at 30 to 40 miles from that coast, but South-Eastward of Nipon found a Stream, of 72·5° mean temperature, running 2 miles an hour to the Northward.

The Kuro Siwo sets through Van Diemen Strait at from 1 to 5 knots an hour, the maximum velocity occurring while the ebb stream is running (by the shore) at spring tides; the Current decreasing in strength as the Coast of Kiusiu is approached.

The Oya Siwo.

The *Oya Siwo*, a counter-Current of cold water, sets to the Southward along the S.E. Coast of Kamchatka and the Kurile Islands, and, flowing along the East Coast of Yezo and the N.E. Coast of Nipon, is felt as far South as Inu-bo-ye saki. It has an average breadth of 200 miles, but varies in velocity and extent in the different seasons, being much stronger in the winter than in the summer. Except between the Kurile Islands, through the Straits, and past Cape Noyshaf, its velocity is about 18 miles a day; through these narrows, however, it sweeps occasionally with great speed, particularly during or after a strong North-Easterly wind. Its temperature varies, according to the season, from 10° to 15° lower than that of the Kuro Siwo. The average temperature of this Current in May was 37° (10° below that of the surrounding atmosphere). In July the temperature was observed to be 66° at between 10 and 30 miles from the shore; farther off shore where the temperature rose to 70°, or where it bordered on the Kamchatka Current flowing to the Northward, the Current is not perceptible. The Oya Siwo is not felt close to the shore of Nipon, along which the tidal streams are well defined.

This counter-Stream to the Kuro Siwo flows from the North; part reaches the Sea of Japan, and meets the Kuro Siwo somewhere about the Korean Straits. In this neighbourhood I have seen the meeting of these two streams, which is most remarkable, the one so dark and deeply blue, the other of a pale green colour. They do not mix, but rub against each other. So decided is this, that on taking the temperature, almost on either side of the ship, the difference was 14°.—*Capt. H. C. St. John.*

The Kamchatka Current.

The *Kamchatka Current* is a branch of the Kuro Siwo, from which it separates in the parallel of 40° N. on the meridian of 150° E. It flows at an average rate of 18 miles a day, with a breadth of about 200 miles, to the North-Eastward as far as 51° N., where it deflects to the Eastward towards the Aleutian Islands.

The N.W. Coast of America.

The great extra-Tropical Drift has been traced in its Eastern progress, from the imperfect data at our command, in the previous pages. Like the Currents on the Coast of Europe, the warmer waters are driven on to this coast, and so cause great peculiarities of water and land climates. The sea abounds with animal life to an enormous extent. It is the greatest fishery in the world, while the S.W. winds, blowing on to the coast over water which is warmer than is due to the latitude, deposit on the land the accumulated evaporation, and cause the Climate of Alaska to be among the wettest in the world.

The *Alaska Current*, a branch of this Drift, sets when Northward of lat. 50° along the coast; Southward of this parallel the main body appears to turn to the S.E. and South.

The Coast of California.

The Drift we have been tracing assumes a more decided character along the Coast of California, and is here much colder than the corresponding latitude, so that the harbours, such as San Francisco, &c., are frequently enveloped in Fogs. It follows the general trend of the coast, and may be 300 miles broad in the more marked portions of its course, but this is very indefinite. Under the shelter of the projecting headlands, and frequently close in-shore, there are counter-Currents, by which small vessels can advantageously work their way against its general influence. Its velocity is 14 or 15 miles a day, reaching a maximum of 22 miles off the entrance to the Gulf of California.

On approaching the Southern parts of California, and in the latitudes of the Peninsula, it assumes a higher temperature and a more Westerly course, and is gradually merged in the great Equatorial Drift first described.

The West Coast of Mexico.

The Currents on this debateable ground are difficult of definition. The navigation of sailing vessels is frequently very tedious, owing to the embarrassment of calms and varying drifts, but there is no doubt the Currents in general fluctuate with the Shifting Monsoons which prevail here. Cape Corrientes, in lat. 20° 25′, that is fairly within the Tropic, and which is subject to the varying streams which gave it the name, is probably the Northern limit of these shifting streams, and between that and Cocos Island, around which the streams are very devious, it may be considered that the general set will be to the Southward, between S.E. and E.S.E., in the winter months, and Northward, between N.W. and W.N.W., during the rest of the year, but, as before stated, nothing very definite can be laid down. These Currents appear to have a breadth of nearly 360 miles, and there are counter-Currents close in-shore.

The *central* portion of the North Pacific appears to be devoid of Currents dependent on any primary cause; around this space they circulate in the order which has been described.

Ice.

Floating Ice has little or no influence upon the navigation of the North Pacific Ocean, its Northern border being practically always free from this danger, except possibly a rare fragment formed in some narrow passage or drifted South by some severe winter gale. In the Okhotsk and Behring Seas, however, Ice is prevalent in winter.

THE SOUTH PACIFIC OCEAN.

WINDS.

South-East Trade.

It was formerly considered that the Trade Winds blew regularly over the entire breadth of the Pacific, but the accumulation of facts has demonstrated that this is incorrect, and that in the South Pacific especially there is a great variation from this normal condition. The S.E. Trade, in fact, is only felt with certainty over that portion where there is no land, or between the meridians of the Galapagos Islands and the Low Archipelago—not one-half its extent. To what cause this is due is not as yet capable of any very clear explanation, as the small area of the islands which appear to arrest its uniformity would seem to be wholly disproportionate to such an effect. However, such is the case, and in the details to which the brief remarks which follow are limited, it will be seen that it is so. In the North Pacific, on the contrary, the N.E. Trade blows as far as the Marianas, where the regular Monsoons supersede it. In the Western parts of the South Pacific there are also regular Monsoons, though of a less decided character.

The Eastern limit of the S.E. Trade is where the effect of the interception caused by the lofty Andes Chain ceases to be felt, which is at 200 or 300 miles off the shore, for along the Coast of Peru the wind blows almost constantly from the Southward. The ridge of the Andes extends above the limits of the Trades, which it is supposed do not reach above 3 miles in height.

Off the American Coast, from 450 to 600 miles distant, and between the parallels of 30° S. and 4° N., the wind is very steady, and gales or squalls are seldom experienced. The Trade, varying between East and S.E., blows constantly in the middle of this zone. In the summer the direction varies from E.S.E. to S.S.E., but never to the North of East. When the sun is in the Northern Hemisphere, the Southern Trades blow across directly from S.S.E., and on the contrary more from the Eastward when it is South.

By examining the table on page 149, it will be seen that the Polar limits rarely reach the parallel of 30° S., and that the Equatorial boundary frequently rises into North latitude. From this it may be inferred that the S.E. Trades are more certain and less variable than the N.E. In the region of the former, calms and storms are much less frequent than in the Northern Hemisphere, besides which the temperature is lower in the Southern zone.

The S.E. Trade is only felt among the Archipelagoes lying between the Paumotu Group and the Coast of Australia between March and October; during the rest of the year it is replaced by Westerly winds, calms, storms, and rains.

There are many singular anomalies, as before said, observed in its course over the islands, which cannot, perhaps, be well accounted for. At the Marquesas, lat. 10° S., it is tolerably regular. Among the islands of the Low Archipelago, especially from October or November to March, the Easterly wind fails, and heavy squalls come from the opposite direction, and this more frequently by night than by day. The natives also say that the severe storms which they encounter come from the N.W. That the South-Westerly gales of the higher latitudes approach the Archipelago, is shown by the heavy sea which frequently sets in on their lee sides against the regular wind, making it more dangerous to land on that side than on the other.

Captain Cook, when at Tahiti, found fresh gales from S.W. for two or three days at a time, and sometimes, though very seldom, from the N.W. When they were variable they were always accompanied by a swell from the S.W. or W.S.W., which also came in when it was calm. The conclusion he arrived at (most probably the just one as regards the Society Islands) was, that as the Trade Wind as found by him did not extend farther to the South than lat. 20°, and beyond that limit he generally found a Westerly gale blowing, this Westerly wind, when it became stronger, drove back the weaker margin of the Easterly wind, and thus encroached on its usual limits. At the Samoan Group these variations assume the character of the Cyclone or revolving storm, and commit great devastation. We shall speak of these in the next Chapter.

That the parallel of 20° is *about* the Southern limit of the S.E. Trade, is apparent at the Tonga Group. Here the Trade Wind is by no means the constant wind, but Westerly winds (called "foolish winds," by the natives) occasionally blow in every season. They are peculiarly prevalent during February, March, and April, often blowing for several days together. The heavy swell from S.W. is also almost continual. This season of variable winds is characterised by the phenomena of Hurricanes, as is the case with the Samoan Group and Cook's Islands.

At the Fiji Group the Trade Wind prevails from April till November. From November till April Northerly winds are often experienced, and in the months of February and March heavy gales are frequent, assuming the usual character of the revolving storm.

When the sun is in South declination, the Northern edge of the Trades advances to the Southward; thus they are interrupted at the Sandwich Islands during the months of January and February, and the S.W. winds usurp their place.

Within the Tropics, wherever large groups of islands are found, the Trades are subject to great variation, both in direction and force. Also to the Northward of the Tropic of Cancer, when bound from the Sandwich Islands for the American Coast, there are many instances, during the spring and summer, of 45°, or even 50°, of North latitude, being reached before a Westerly wind could be obtained.

The Strait of Magalhaens.

Westerly winds are the most prevalent throughout the year, and at the Eastern end of the Strait there is generally a strong breeze with heavy squalls between N.W. and S.W. Rain occurs while the wind is Northward of West; and usually clear bright weather, with sunshine, when the wind draws Southward of West. With the wind at N.W., a decided rise in the Barometer is a sure sign of a shift to S.W., which shift invariably takes place before the wind lulls for any time, or fine weather can be expected. The backing of the wind from S.W. to N.W. is always accompanied by a falling Barometer.

Easterly winds are certainly more common, and the Strait is on the whole less windy in winter (June, July, and August) than in summer, but when against this possible advantage is placed the cold, with the long nights and short days, this season is not likely to be preferred by the mariner in a vessel bound Westward. It may be well to mention that ships getting as far as Cape Froward with a S.W. wind, will generally find it N.W. on rounding the cape, as the wind follows the direction of the channel.

Here, as elsewhere, the Equinoctial months are the most windy, though the heaviest gales do not always occur at the Equinoxes. March is very boisterous, and its gales are usually followed by some fine calm weather in April and May. Towards the middle of May the weather becomes sensibly colder, and the snow, which has been covering the summits of the hills, perhaps for some time, will be observed to advance down the slopes; it, however, varies greatly.

December, January, and February, are the warmest months, the mean temperature for several years for these months being 54°; the days are then long, there is some fine weather, and the sun when out has some power. Westerly winds, however, which often increase to violent gales and furious squalls in the Western part, accompanied by much rain, are frequent even throughout this season, which, as far as the mariner is concerned, carries with it less of summer than almost any other part of the world. East of Sandy Point the weather on shore is very fine, though rather windy, during summer; the temperature is pleasant, the air bracing and healthy. The change between this and the Western part of the Strait and the Northern channels is very marked in this respect.

Fogs are of rare occurrence and short duration in the Eastern part of the Strait, though occasionally they set in thick for a few hours, and with no warning during calm weather. Dense fogs have, however, been known to last two or three days at Sandy Point in the winter months. Thick rainy weather is the ordinary condition of the Western part. *Squalls* blow with great force and suddenness all over the Strait, making boat work dangerous. *Thunder* and *Lightning* are very rare, indeed scarcely known, except in very bad weather, when violent squalls come from the South and S.W., usually giving warning of their approach by masses of clouds. These storms are rendered more formidable by snow and hail of a large size.

Cape Horn.

Westerly winds prevail during the greater portion of the year, the East wind sometimes occurring in the winter months, and but seldom in the summer. They invariably rise light with fine weather, increase gradually, and sometimes end in a heavy gale, but more frequently do not rise to this strength.

North winds are generally accompanied by thick weather and rain; they always commence moderately, but increasing in strength, they draw to the Westward, blowing hardest between North and N.W., the strength of which lasts from 12 to 50 hours; they sometimes shift suddenly into the S.W. quarter, blowing harder than before.

Winds from the S.W. generally last several days, blowing strongly, but moderating towards the end. Northerly winds then again commence, and thus constant shifts from North to South, round by the West, are felt during the summer.

Bad weather never comes on *suddenly* from the East, nor does a S.W. or Southerly gale shift quickly to the Northward. Gales from the South and S.W. rise suddenly and violently, and should be well considered in choosing an anchorage.

The constant prevalence of winds between S.W. and N.W. renders the passage round Cape Horn from the Atlantic frequently one of difficulty and hard work. April, May, and June, are perhaps the best months for making the Westerly passage. The summer months are preferable for the other direction, but this is so easy as scarcely to require much consideration.

The following observations are by Captain FitzRoy :—

The Coast of Chile.

Very few words will suffice to give strangers to the Coast of Chile a clear idea of the Winds and Weather that they may expect to find there, for it is one of the least uncertain Climates on the face of the globe.

From the parallel of 35° S., or thereabouts, to near 25° S., the wind is Southerly or South-Easterly during nine months out of the twelve; in the other three there is really bad weather, with some calms and light variable breezes. Northerly gales and heavy rains prevail at that time not only on the coast, but far across the Ocean in parallel latitudes.

From September to May is the Fine Season, during which the skies of Chile are generally clear, and, comparatively speaking, but little rain falls. It is not, however, meant that there are not occasional exceptions to the general rule; strong Northers have been known (though rarely) in summer; and two or three days of heavy rain, even with little intermission, now and then disturb the equanimity of those who have made arrangements with implicit confidence in the serenity of a summer sky. These unwelcome interruptions are more rare, and of less consequence, to the Northward of 31° than South of that parallel; and, indeed, so nearly uniform is the climate of Coquimbo, that the city is called La Serena.

In settled weather a fresh Southerly wind springs up a little before noon (an hour sooner or later) and blows till about sunset, occasionally till midnight. The wind is sometimes quite furious in the height of summer, so very strong that ships are often prevented from working into anchorages, such as Valparaiso Bay, although they may have taken the precautions of sending down topgallant-yards, striking topgallant-masts, and close-reefing their sails. But the usual strength of this sea breeze (as it is called, though it blows along the land) is such as a good ship would carry double-reefed topsails to when working to windward.

This is also near the average strength of the Southerly wind in the open sea, between the parallels above mentioned; but there it is neither so strong by day, nor does it die away at night. Within sight of the land a ship finds the wind freshen and decrease nearly as much as in the ports, where the nights are generally calm till a land breeze from the Eastward springs up; this light message from the Cordillera is, however, never troublesome, neither does it last many hours. With these winds the sky is almost always clear; indeed, when the sky becomes cloudy, in summer, it is a sure sign of little or no sea breeze, and probably a fall of rain; in the winter it foretells an approaching Northerly wind, with rain.

In summer, ships anchor close to the land, to avoid being driven out to sea by those strong Southerly winds; but as the winter approaches a more roomy berth is advisable, though not too far out, because near the shore there is always an undertow, and the wind is less powerful. Seamen should bear in mind that the course of the winds on this coast, as in all the Southern Hemisphere, is from the North round by the West; that the winds which blow the hardest, and bring the most sea, come from the Westward of North; and that therefore they should get as much as possible under the shelter of rocks or land lying to the Westward, rather than of those which only defend them from North winds. Northers, as they are called, give good warning; an overcast sky, little or no wind unless Easterly, a swell from the Northward, water higher than usual, distant land remarkably visible, being raised by refraction, and a falling Barometer, are their sure indications. All Northers, however, are not gales; some years pass without one that can be so termed, though few years pass in succession without ships being driven ashore on Valparaiso beach. Thunder and lightning are rare. Wind of any disagreeable strength from the East is unknown. West winds are only felt while a Norther is shifting round, previous to the sky clearing and the wind moderating. The violence of Southerly winds lasts but a few hours; and even a Northerly gale seldom continues beyond a day and a night, generally not so long.

The Coast of Peru.

The Prevailing Winds on the shores of Peru blow from S.S.E. to S.W., being seldom stronger than a fresh breeze, and often, in certain parts of the coast, scarcely sufficient to enable shipping to make a passage from one port to another. This is especially the case in the district between Cobija and Callao.

Sometimes during the summer, for three or four successive days, there is not a breath of wind; the sky beautifully clear, and with a nearly vertical sun.

On the days that the sea breeze sets in, it generally commences about ten in the morning, and is then light and variable, but gradually increasing till one or two in the afternoon. From that time a steady breeze prevails till near sunset, when it begins to die away; and soon after the sun is down there is a calm. About eight or nine in the evening light winds come off the land, and continue till sunrise; when it again becomes calm until the sea breeze sets in as before.

During winter (from April to August), light Northerly winds may be frequently expected, accompanied by thick fogs, or dark, lowering weather; but this seldom occurs in the summer months, although even then the tops of the hills are frequently enveloped in mist.

To the Northward of Callao the winds are more to be depended on; the sea breeze sets in with greater regularity, and is fresher than on the Southern parts; near the limit of the Peruvian Territory (about Payta and off Cape Blanco), a double-reefed topsail breeze is not uncommon.

It is to be remarked, that, although such moderate winds are the general rule on the Coast of Peru, yet that sudden and heavy gusts often come over high land after the sea breeze sets in, and, from the smallness of the ports, are attended with some inconvenience, if precautions are not taken in duly shortening sail previous to entering them.

The only difference between winter and summer, as far as regards the winds, is the frequency of light Northerly airs during the former months; in winter the difference of temperature is far greater than one would imagine in so low a latitude. In summer the weather is delightfully fine, with the Thermometer seldom below 70° F., and often as high as 80°, in a vessel's cabin; but during winter the air is raw and damp, with thick fogs, and a cloudy, overcast sky.

It *never* rains on the Coast of Peru; but there are sometimes, during part of the night and morning, fogs or dews, which are perhaps more effective than light rains.

New Zealand.

The great extent of New Zealand in latitude will lead to the inference that a considerable variation will exist in the Winds prevalent in different portions of it. Since it lies outside the verge of those regular winds which characterise the Tropical regions, such uncertainty must be expected as is found in similar latitudes, the predominant direction being from the Northward of East or West. Such, in fact, is found to be the case, from a register kept at Wellington, from October, 1840, to September, 1842; by which it appears that the Northerly winds predominate over the Southerly, in the ratio of 432 to 226, but this ratio is unequally distributed over the different seasons. Thus, from October to December, the number of days on which the North winds prevailed was 170; South, 72; Westerly winds, 8; and Variable, 13. From January to March, Northerly, 89; Southerly, 86, being nearly equal; West, 2; Variable, 6. From April to June, North, 96; South, 50; West, 8; Variable, 22. From July to September, North, 95; South, 75; West, 4; Variable, 7.

It is observed that the North and N.E. Coasts of North Island are most exempt from heavy gales; that the Eastern and Southern Coasts are subject to S.E. gales, to which, from the scarcity of harbours, ships are much exposed; and that Cook and Foveaux Straits are visited by frequent and sometimes furious gales from N.W. and S.E., while the prevailing winds on the entire Western Coasts are from N.W. to S.W.

When going from East Cape to Cook Strait a very marked phenomenon frequently takes place on rounding East Cape. The strong Westerly wind that drives across the bay carries its line a few miles Eastward of the cape, but Southward of this the breeze is N.E. Sometimes a vessel may be becalmed for hours between two strong breezes from West and N.E.

In Cook Strait the prevailing, indeed the almost constant winds are N.W. or S.E.; and when approaching either entrance with N.E. and S.W. winds, the former will almost certainly change to S.E., and the latter to N.W. The changes are frequently very sudden. Lightning, or a dark bank of clouds rising, are pretty certain indications that the wind will come from the quarter in which they appear, but it is not an uncommon circumstance for a vessel running through the Strait with a fair wind, on opening out either entrance, to be taken aback with one from the opposite quarter, with little or no warning. Gales from N.W. and S.E. are also frequent, and blow with great violence; those from S.E. are most frequent during the winter months of May, June, and July; a falling Barometer is a certain indication. They come on very suddenly, last often three days, and are generally accompanied by rain and thick weather. N.W. gales are most common in spring and summer; they are exceedingly violent, though generally of short duration, and when at their strongest are accompanied by a high Barometer. A remarkable transparency of the Atmosphere is a sign of a N.W. gale, which comes on at once to blow furiously.

The finest months are April, August, November, and December. Thunder and lightning are unusual.

Australia.

The East Coast of Australia, with respect to Winds and Currents, requires a division, the part to the Southward of the Tropic of Capricorn being placed under different, and almost opposite circumstances, to that within, or close to it.

The S.E. Trade cannot be said to blow home upon the East Coast of Australia between Sydney and Sandy Cape, except during the summer months, when winds from that quarter prevail, and often blow very hard; they are then accompanied by heavy rains and very thick weather. Generally, however, from October till April, they assume the character of a sea breeze, and except their suspension by South-Easterly or Westerly gales, are very regular.

In the month of December hot winds from N.W. will sometimes last for two or three days, and are almost always suddenly terminated by a gust of wind from the Southward. South-Easterly gales also are not uncommon during this month; and in February and March they are very frequent.

In winter, from May to September, there are frequent Westerly winds, with fine weather. The gales at this season blow from seaward, between N.E. and South, and bring rain; nor is there any settled weather in winter with sea winds, and even when between North and N.W. there is often rain, though the wind is usually light in those quarters.

The most prevailing winds at all seasons of the year are from the Southward, and probably oftener from the Eastward of that point than from the Westward.

Whilst the wind blows from various quarters on the Southern parts of the East Coast, the S.E. Trade prevails with more regularity within, and close to the Tropic, and generally blows home to the coast, from April to September, producing in some places land and sea breezes near the shore, with fine weather, which lasts longer as Cape York is approached. Although the S.E. Trade may generally be considered steady, from April to September, between the Tropic and Torres Strait, yet H.M.S. *Bramble* experienced violent gales in the months of March and May, in the vicinity of the Tropic.

During the N.W. Monsoon, from November to March, the winds on the East Coast to the Northward of Sandy Cape are variable, but generally from the Northward and Westward, with occasional calms, rain, and clear weather; during this season violent gales frequently blow, accompanied by rain, thunder and lightning.

From the early part of October to April, the coast in the vicinity of Port Jackson is subject to tolerably regular sea and land breezes, the former blowing from N.E., and the latter from the Westward. The sea breeze generally begins at 10 a.m., and subsides after sunset; the land wind commences at about midnight, and continues until 8 a.m. The exceptions to this rule are

North and South winds, which occasionally prevail, as do also the N.W. hot winds; these latter, after blowing for a period varying in duration from 12 to 72 hours, are usually succeeded by sudden violent gusts from S.S.E. to S.S.W., which generally settle into a gale from those quarters, accompanied with rain. The greatest vigilance exercised by masters of vessels possessing local experience, is frequently insufficient to prepare for the suddenness with which these gusts overtake then; strangers, especially, should therefore be particularly careful to be ready for the change during the time when the hot wind is blowing, or during the brief calm which sometimes intervenes.

From April to October, after the gales which usually succeed the autumnal Equinox are over, and before those which generally precede the spring Equinox commence, winds prevail from the Westward, between N.W. and S.W., with fine clear weather, and occasional gales from the North or South, with rain.

Except during the Equinoctial gales, the wind very rarely blows on shore with sufficient violence to endanger a well appointed vessel; but in the spring Equinox, when these gales set in from S.E. to East, accompanied with dense rain and a high Barometer, they blow with great fury from 24 to 48 hours, and finish with a long continued slowly declining gale from South to S.W.

Easterly gales, which appear to be regular in the number as well as the periods of their visits during the year, are the winds of all others most dreaded both on shore and afloat.

June, July, and sometimes August, are the months in which the province of New South Wales is visited by them in their full violence. During these months, when the weather is unsettled, with the wind unsteady, cloudy weather and occasional rain, with an Easterly gale, lasting two or three days, may be looked for. They generally come with light winds from the Northward, accompanied with rain sometimes lasting twenty-four hours, and an overcast, murky sky; veering round to the N.E., they freshen gradually into a gale. The Barometer is not in any way affected by their approach or continuance, standing steadily at from 30·12 to 30·18 throughout their duration. A large number of coasting vessels are missed after one of these gales. In July, 1866, fourteen coasting vessels were driven on shore at various parts of the coast or foundered at sea; and in June, 1867, during a similar gale from the Eastward, eight or nine more followed.

On the South Coast of Australia similar weather may be looked for between Cape Howe and Wilson Promontory as prevails on the Eastern Coast, and the same dangerous Easterly gales may be looked for. The prevailing wind, however, on this coast is from the Northward, both in summer and winter. This wind generally commences early in the day, and after lasting two or three days suddenly terminates with a thunderstorm from West or S.W., indicated by the fall of the Barometer, which remains low until the storm is quite over, although there may be intervals of fine weather for two or three days. In the spring and autumn S.W. or sea breezes are felt. Of the Easterly gales, Wilson Promontory appears to be the boundary, as they very seldom occur on the coast to the Westward.

Westward of Cape Howe South-Westerly breezes generally prevail during October, November, and December; and in January, February, and March, from the opposite direction. In the vicinity of Bass Strait N.E. winds blow during the hot summer months, lasting four or five days, and changing suddenly to the S.W. They are generally accompanied by a thick mist, but in the winter a clearer sky accompanies them. Westerly winds prevail for nine months of the year.

On the Coast of South Australia, from June until the end of November, the prevailing winds are from the Westward; they usually commence at N.E. or North with a falling Barometer, veer to the N.W. and blow hard, sometimes veering about between N.W. and S.W. for two days, with much rain. With a rising Barometer the wind changes to S.W. and South, and blows strongly.

From December until the beginning of June is what may be called the fine weather season on this coast. The prevailing wind is from S.E., and is of moderate force; it veers to the Eastward during the night, and to the Southward in the day, being strongest in the afternoon. A high Barometer indicates a long continuance of South-Easterly winds. Westerly gales sometimes occur during the fine weather season.

CURRENTS.

It has been stated that the Drift Current from the Antarctic regions, after proceeding to the Eastward, strikes the Patagonian Coast, and separates into two branches, the southernmost of which is that now to be considered.

Cape Horn Current.

Its existence has been questioned, and even denied; but more complete examinations have determined its character, and we here give some of the facts upon which it rests, apart from any speculative ideas.

The first experiments which afford undoubted evidence were those made by Captain Henry Foster, R.N., in H.M.S. *Chanticleer*. From the appendix to the account of his voyage we extract the following:—

At the distance of 10 or 12 miles to the Southward of Cape Horn there is a Current running to the E.N.E., at the rate of about 1 mile per hour; but in what manner this Current may influence the tides near the shore, or what changes may be produced in the direction and the strength of the Current itself by the flood and ebb tides, will require a very extensive series of observations to ascertain.

The circumstance of there being no well-authenticated account of the existence of a Current to the Southward of Cape Horn, induced me to collect the following observations upon that subject, made during the passages of H.M.S. *Chanticleer* from Staten Island to Cape Horn, from Cape Horn to South Shetland, from South Shetland to Cape Horn, and from Cape Horn to Staten Island, during the summer and autumnal months of those regions.

The ship's way through the water was measured by Massey's self-registering log, and the variation of the compass was ascertained by actual observation on the course steered, whenever the state of the weather would permit. The local attraction of the *Chanticleer* did not exceed 2° in extreme cases.

The observed places of the ship were computed with every possible care and attention. The effect which these observations appear to point out, is that of an Easterly motion of the sea, in the vicinity of Cape Horn, produced no doubt by the prevalence of N.W., West, and South-Westerly winds; and although its direction is sometimes much to the North, as well as to the South of East, this deviation, in all probability, arises from the prevalence or greater strength of the N.W. or S.W. winds during the intervals between the observations, as it was generally remarked that the Current's deviation from the East, towards the North or South point of the compass, was in accordance with the prevalence of one of these winds over the other during the interval.

The strength of this set appears also to be much influenced by that of the winds, for, during the voyage from Cape Horn to South Shetland, it was found, at the time of meeting with N.E. winds, on the parallel of 60° S., that the set to the Eastward was diminished in its velocity to about half the amount we had previously experienced. From these several irregularities, the individual observations do not admit of any very satisfactory conclusions being drawn; but taken collectively, they indicate an Easterly or North-Easterly set. The result of the tables shows that in the voyage from Staten Island to Cape Horn, a Current setting N. 80° E., at the rate of 12 miles in twenty-four hours, may be expected in the summer months, and that between Cape Horn and South Shetland a Current setting S. 65° E., of equal strength, was experienced during the same season of the year; while in the autumnal months this Current was found to set N. 49° E., with nearly twice the velocity; and on one occasion, in May, 1829, the set was N. 51° E., 54 miles in twenty-three hours.

The Peruvian or Humboldt's Current.

The waters of the South Pacific Ocean, apparently from their Northward and Eastward tendency in high latitudes, form a Current on the West Coast of South America, which extends as a mighty river of cooler water from the latitude of Chiloe to the Galapagos Islands on the Equator. From its becoming more evident in the warmer and lower latitude of Peru, it has been denominated the Peruvian Coast Current; from its having been first distinctly explained by the great Naturalist, it has been termed Humboldt's Current.

Its effects, however, have been long known. At a very early date after the conquest of America, the Spaniards learned to cool their drinking vessels in its frigid waters in the Bay of Callao, a practice still continued. Another evidence, now traced to the correct source, is the cooler climate which many parts of Peru enjoy, to what their geographical position and natural character would otherwise cause. This is also the cause of the *Garau* or haze, which for months together obscures and cools the air in the Peruvian plains. These fogs commence in the morning, and are not dissipated till noon, and reappear in the form of heavy dews at night.

The first elucidation of this Current is due, as above stated, to Humboldt, in the autumn of 1802. The account was published by Professor Berghaus, in his Physikalischer Atlas, from the Baron's manuscript, from which the following extracts are taken:—"The first concern of a traveller, on arriving at the sea-coast, after a long absence in a mountainous country, is to observe the height of the Barometer and the temperature of the water. I was occupied with the latter in a district between Truxillo and Guaman, near Callao de Lima, and also on the voyage from Callao to Guayaquil and Acapulco, on a tract of the Pacific Ocean of more than 400 miles in extent, when to my great surprise, I found that the temperature of the surface of the sea under latitudes where, outside of the Current, the temperature ranges from 78·8° to 83·3°, was at Truxillo, at the end of September, 60·8°, and at Callao, in the beginning of November, 59·9°. The temperature of the air was at the first period 64·04°, in the second 72·86°, and then (which is of importance to remark) 12·6° warmer than the oceanic Current."

This surface temperature was found uniform at Callao, at night being only 0·7° colder than by day; so that the air could have but little to do with it, as will be more clearly shown presently. Once only did a variation occur; an immensely high and hollow wave dashed suddenly in on the shore. Whether this arose from the effect of a submarine earthquake, as is usually considered by the inhabitants, or was the effect of a distant storm, the result was that the water was cooled down to 59·9° and 58·35° in a few hours. This is easily conceivable; the lower and cooler strata of water had been disturbed by the increased surface action, and thus becoming incorporated with the upper portion, lowered the temperature. Or it might have arisen from the lower strata of water being driven up-hill toward the shore by the action of the waves, as may be supposed to be the case when a current meets a shoal, and causes the surface temperature to be sensibly lowered, from the same mode of action.

From the beginning of November to the end of December, Humboldt observed that the temperature gradually and regularly increased, until it reached 69·8°,—a fact which was more fully established afterwards by Duperrey in 1828. This would accord perfectly with the climate of high Southern latitudes.

That it is not a mere surface action is manifest; a current of cold surface water in temperate climates would soon be precipitated to a lower position by virtue of its greater specific gravity. Nor is there anything in the climate to cause such an anomaly. Besides, we have the direct evidence of the experiments of M. du Petit Thouars to establish the fact of its depth.

On April 16, 1837, the frigate *La Venus* was to the S.W. of Chiloe (lat. 43° 47′ S., long. 83° 46′); the weather being perfectly calm, and the frigate carrying no sail, a line of 1,000 fathoms was let down, carrying a self-registering Thermometer. The sounding-line appeared to be perfectly perpendicular, nevertheless the frigate was drifted from South to North, with the velocity of the surface Current she was in. If the lead and the case of the Thermometer had not found in the descent a stratum of water moving in the same direction, and with equal velocity with that of the surface, it would have swerved from the perpendicular, and the variation from this perpendicularity would have demonstrated the difference in direction and strength of the deep-seated currents, but none such was observed.

The Chilian or Peruvian Current cannot, then, be considered as a simple and superficial river of cool water. It is produced by large portions of the waters of the Polar Sea advancing majestically from South to North. The body of the Current reaches to and beyond the Equator, where it is not less than 973 fathoms in depth.

The limits and extent of this Current, or rather, perhaps, we might say, of the superficial portion of it, must vary. As stated in the outset, the cold Current running to the N.E. from the Antarctic regions, strikes the Coast of America about the parallel of Chiloe or Concepcion. Its breadth, therefore, as far as the latitude of Valparaiso, is open to conjecture ; at all events, it is not very rapid in this portion of its course, and therefore more liable to be neutralized by the effects of the winds acting on its surface.

It is perhaps at the Galapagos Islands that the evidence of the Peruvian Current becomes most manifest. The Currents, from the concurring testimony of all voyagers, are most remarkable in the vicinity of this archipelago. The Thermometer would indicate to a certainty the origin of these strong Currents, which chiefly run to the North and West, but in the earlier voyages no notice was taken of this feature. Colnett notices the drift-wood, bamboos, wild sugar-canes, and small cocoa-nuts, lying on the S.E. side of Chatham Island. Captain FitzRoy mentions one fact which bears very strongly on the subject. The *Beagle* was here in October, 1837. On one occasion the temperature of the sea a foot below the surface, on one side of Albemarle Island, was found to be 80° Fahr., but at the other side of the island *it was less than* 60°. This is a surprising variation, and well worthy of attention by future navigators, who may easily and readily do great service to Hydrography by making and recording such observations.

This low temperature of the water, constant or fluctuating, has one remarkable effect, according to Mr. Dana—the absence of all coral reefs around the Galapagos, though they lie much within the geographical limits in which the coral-building insects can live.

Humboldt says :—" From Valparaiso and Coquimbo, but especially from Arica, North to Lima, the Current at the strongest runs from 12 to 14, and sometimes even 18 miles in twenty-four hours.

" In this, as in other streams, when it meets with an impediment by striking the coast, its velocity is increased, and thus the greatest rate is found close inshore. The force of this Current is the cause why ships sailing from Quilca to Callao, at the time of the *garau*, and being unable to obtain sights for latitude during long intervals owing to the fog, are drifted unexpectedly to the North of Callao to Huaura and Guarmey, while still considering themselves to be, according to the dead reckoning, to the South of their port. This haze is most dense between Pisco and Lima."

South Equatorial Current.

Captain Duperrey, who has devoted much labour to the elucidation of the Currents, places the Southern limit of the Equatorial Current, beyond the influence of the Continent, at lat. 26° S., and its Northern border at lat. 24° N., or (partially) occupying a zone of 50° in breadth. It is more than probable that these latitudes may vary at the different seasons.

Commencing with the S.E. portion, it must be remarked, that the cold

Peruvian Current forms a portion of its initiatory course. This Current, previously described, first assumes a direction to the West of North in about lat. 20° S., near the South American Coast; and in long. 108° W., its Southern limit, as evidenced by its low and equable temperature (77·5°), was found by M. Tessan to be in lat. 9° 40′ S.

It is probable that in this Eastern portion the Current may be less strongly marked than farther to the West. For Captain Lütke states that he did not find any current in his passage between lat. 20° S., and long. 81° W., and 28° S. and 116° W., a distance of 2,400 miles.

In September, 1875, from 5° N. to 5° S., the South Equatorial Current was found by H.M.S. *Challenger*, running Westward at the rate of 43 miles per day, but in 1° N. its speed was no less than 70 miles. Its temperature varied from 77° to 79°, being 77° at its axis of greatest rapidity. This extraordinary rate was also experienced in the French corvette *L'Eurydice*, in August, 1857, in 3° 50′ N. We also found this Current setting to the Westward, just North of the Admiralty Islands, in March, 1875, with an average rate of 30 miles per day, but its temperature then was from 83° to 84°. From 5° S. to Tahiti the Currents were to the Southward, about 12 miles per day.—*Staff-Commander T. H. Tizard.*

The Australian Current.

In the Northern part of the Equatorial Current in the North Pacific, it has been shown that when it reaches the neighbourhood of the Continent West of the Marianas it turns to the Northward and Eastward, forming the well-defined Japanese Current—the Gulf Stream of the North Pacific.

We have a somewhat similar arrangement of Current on the Northern edge of the South Equatorial Stream, which, as previously stated, striking the Coasts of New Caledonia, the New Hebrides, &c., trends away to the N.W.; so, in like manner, the portion South of this reaching the Australian Coast, is deflected and runs to the Southward, forming a warm stream, off the Coast of Australia. This course it pursues until it encounters the cold Antarctic Drift to the N.E., which thus again deflects it and becomes incorporated with it. The following remarks on this Current are from Admiral Krusenstern's treatise:—

Although the winds blow throughout the year either from S.E. or S.W., the Current constantly runs to the South, with a velocity of 1 or 2 miles an hour, at the distance of from 4 to 20 leagues from land. Beyond these limits there is no current found, and very close to the land, particularly in the bays, we have a current to the North, but which does not exceed a quarter, or at most a mile, an hour. At the S.E. and Southern part of Australia the Current is very violent, and runs to the South; near Cape Howe its direction draws more towards the East. In ranging along this part of the coast to go to the Southward, it would be well to keep at the distance of 40 or 50 miles from land, because you will then be sufficiently far off shore not to fear the gales of wind from seaward which will be met with in the course of the Current which runs to the South. On the contrary, if a vessel is making way for the North, she ought not to leave the coast more than 10 miles; but this navigation demands much caution, to guard against gales from seaward. The Barometer will then be the best guide; the mercury rises on this part of the coast with S.E. winds, and falls with those from N.W.; N.E. or S.W. winds do not equally influence the Barometer.

We shall conclude with a few remarks on the Connecting Currents which are found between Australia and New Zealand.

In other portions of the world recent experiments have shown that a system of revolution is going on in the separate basins into which the Ocean is divided; where the land bounds any expanse of water in several directions, the Currents circulate around its borders, leaving the central space comparatively or perfectly free from their action. This notion was, perhaps, first distinctly enunciated by Professor Whewell, as to the North Sea tides, and confirmed by Captain Hewett.

In the space between Australia and New Zealand, the same operation is going on. To the Westward is the Southerly warm Current just described. To the South this warm Current is pressed upward by the Northerly cold Antarctic Current. On the New Zealand Coast this Current is felt as far to the Northward as Cook Strait, while to the Northward of the islands the warm Equatorial and the cool Polar Currents by turns gain ascendancy. This system developes one feature, that of a central space in which no Current (except those dependent on the wind) is to be found. It is called by the whalemen the *Middle Ground*, and has been exceedingly productive to the New Zealand and Australian whale fishery. Its physical character we must suppose to be favourable to the production of the food of the whale, which perhaps flourishes here undisturbed by the influence of currents causing fluctuations of temperature, and occasioning different water climates, so to speak, in the same locality. It is probable that the whales frequenting this Middle Ground come, or rather have come, to the shores of New Zealand, N.W. of Cook Strait, to calve in the bight called by the whalers *Motherly Bay*. However, it is most probable that the navigator, by availing himself of the various set of the Currents, which will be elucidated by this theory, may greatly assist his passage across this part of the Ocean.

PASSAGES.

Cape Horn to California and British Columbia.

In the Pacific, as in the Atlantic Ocean, the route from South to North, or vice versâ, by traversing the different Belts of Winds and Calms, requires much consideration as to the best points for crossing the various parallels of latitude and the Equator. The entering or leaving one zone at the most advantageous point has a very great influence on the speed and safety of the ship through the rest of the voyage. What has been previously said on the Winds and Currents will be necessary to understand the requirements of this section.

To Captain Maury, and also to the Dutch Meteorological Institute, under Captains Jansen and Van Gough, we owe very much for their lucid discussions and long series of examples from which a correct decision may be arrived at. We therefore quote the words of the former, but omit the tables upon which the conclusions are based. They are very interesting, but to insert them would unduly enlarge this work.

"The California-bound vessels should aim to enter the S.E. Trade Wind region of the Pacific as far to the West as they well can, provided they keep on the Eastern side say of 118° W.; they should not fight with head winds to make Westing, nor should they turn much from the direct course when the winds are fair. But when the winds are dead ahead, stand off to the Westward, especially if you are South of the Trade Wind region. Having crossed the parallel of 35° S., and taken the Trades, the navigator, with the wind quartering and all sails drawing, should now make the best of his way to the Equator, aiming to cross it between 105° and 120°, according to the season of the year.

I wish here to call the attention of navigators to the winds they are to expect in the Pacific, between the parallel of 50° S. and the Equator, especially as regards their reliability.

The distance from the fairway of Cape St. Roque (lat. 7° S.) to the parallel of 50° S., in the Atlantic, is about 2,900 miles, the average time 30 days, and the mean daily run about 100 miles.

The distance from 50° S., in the Pacific, to the usual crossing-place on the Line—California track—is about 3,300 miles, the average time 27·7 days, and the mean daily run 132 miles.

The winds between 50° S. and the Equator are much more strong, steady, and reliable, as the Barometer would lead us to expect, on the Pacific, than they are on the Atlantic side of the Continent; the ratio between them in these respects is greater than 2,900 to 3,300 miles, for it is easier to make 3,300 miles with them in the one Ocean than 2,900 miles in the other.

An examination of the mean monthly passages from crossing to crossing will also show a greater regularity, implying thereby more stable winds. The greatest monthly average on the East side is 31·1 days in August; on the West 27·9 in May; the extreme difference being 3·2 days. The greatest monthly average on the West side being 27·9 days, and the least 22·2 days, the extreme difference is 5·7 days.

Between the Equator and 10° or 12° N., according to the season of the year, the California-bound navigator may expect to lose the S.E., and to get the N.E. Trade Winds.

He will find these last nearer the Equator in January, February, and March; but in July, August, and September, he will sometimes find himself to the North of the parallel of 15° N. before he gets fairly into the N.E. Trades. And sometimes, especially in summer and autumn, he will not get them at all, unless he keeps well out to the West. Having them, he should steer a good rap-full at least, aiming, of course, to cross the parallel of 20° N., in about 125° W., or rather not to the East of that, particularly from June to November. His course, after crossing 20° N., is necessarily to the Northward and Westward, until he loses the N.E. Trades. He should aim to reach the latitude of his port without going to the West of 130° W., if he can help it, or without approaching nearer than 250 or 300 miles to the land, until he passes out of the belt of the N.E. Trades, and gets into the anti-Trades, the prevailing direction of which is Westerly.

" Where shall we lose the N.E. Trades on the passage to California ?" is an important question for a navigator who is striving for a short passage.

From the parallel of Cape Horn up to the Belt of light Winds and Calms, through which you generally pass before getting into the S.E. Trades, the prevailing winds are Westerly winds, having Northing more frequently than Southing in them. Between the N.W. Coast of America and the meridian of 130° W., from 30° to 40° N., the prevailing direction of the wind in summer and autumn is from the Northward and Westward, whereas, to the West of 130°, and between the same parallels, the N.E. Trades are the prevailing winds of these two seasons. There is a marked difference in the direction of the winds on the opposite sides of the meridian of 130° W. in the North Pacific. The cause of this difference has been completely unmasked by the researches connected with the Wind Charts. The agent which produces it has its seat in the arid plains of New Mexico, Northern Texas, and the regions round about. At this season of the year the prevailing winds in the Western part of the Gulf of Mexico are from the Southward and Eastward; that is, towards the great centre of rarefaction. At this season of the year, too, the prevailing winds in the Pacific, off the Coasts of Central America, are from the Southward, and also towards the same centre of heated plains and ascending columns of air;

and we have seen that off the Coasts of California, between the parallels of 35° and 40° N., the prevailing winds of this season are from the Northward and Westward, also towards this great inland "blow hole." In it is seated a Monsoon agent, whose influence is felt for more than a thousand miles out to sea, drawing back the N.E. Trades of the Pacific, and converting them into a Southwardly Monsoon for half a year; deflecting the N.E. Trades of the Gulf of Mexico, and converting them into a South-Easterly Monsoon during the same season, and so influencing the prevailing S.W. winds off the N.W. Pacific Coast that they, too, are almost made to blow as a North-Westerly Monsoon.

Therefore, vessels bound to San Francisco should not, unless forced by adverse winds, go any farther Westward of the meridian of 130° W. than they can help. Supposing that vessels generally will be able to reach 30° N. without crossing the meridian of 130° W., the distance by Great Circle from Cape Horn to its point of intersection with that parallel is about 6,000 miles.

Supposing, moreover, that California-bound vessels will generally, after doubling Cape Horn, be able to cross the parallel of 50° S., between the meridians of 80° and 100° W., their shortest distance thence to 30° N., at its intersection with the meridian of 130° W., would be to cross 40° S. in about 100° W.; 30° S. in about 104°; 20° S. in about 109°; the Equator in about 117° W.; and 30° N. in about 130° W. (126° if you can). By crossing the Line 10° farther to the East, or 10° farther to the West of 117°, the Great Circle distance from Cape Horn to the intersection of 30° N. with 130° W., will be increased only about 150 miles.

It appears, from the summing up, that the average passage to California for all classes of ships that cross the Equator between 105° and 120° is, the year round, 130 days. When these investigations commenced, the average passage the year round of all classes of ships, from the Atlantic ports of the United States to California, was 180 days.

Indeed, it may now be considered as reduced to 128 days, for that is the average of the 87 vessels that crossed between the meridians of 115° and 120° W., which these investigations have shown to be the best crossing place. Indeed, the average of the 220 vessels that have crossed between 110° and 115° W., taken with the 87 vessels that have crossed between 115° and 120°, makes the average rather less than 129 days.

The average passage of upwards of 300 vessels that have crossed between 110° and 120° is 128·9 days. There is no reason why all vessels should not cross the Equator between these two meridians, and hence we may consider it as an established fact, that the average length of the sailing voyage from Europe or the Atlantic ports of the United States is less than 130 days.

The average crossing place of 50° S., in the Pacific, is about 82° W. Winds are sometimes, though not often, fair for making Westing on the Polar side of

50° S. When they are so, the skilful navigator will not fail to take advantage of them to gain a still more Westerly crossing of this parallel.

In urging upon California-bound vessels the importance of making Westing about the parallel of 50° S., I do not mean that they should expose themselves to heavy weather, or contend against adverse circumstances. I simply mean that if a vessel, after doubling Cape Horn, can steer a W.N.W. course as well as a N.W., or a N.W. as well as a N.N.W., or a N.N.W. as well as a North course, that she should, on all such occasions, give preference to the course that has most Westing in it, provided that she does not cross 50° S. to the West of 100°, or thereabouts, nor 30° S. to the Westward of 115°, nor enter the S.E. Trade Wind region to the West of the last-named meridian. This is the Western Route. It is so called because it requires you to keep as far West, within certain limits, as you well may, without running broad off to make Westing, or without fighting with head winds, or baffling winds, or calms, to get West.

The Western Route from Cape Horn to California is, as a rule, to be preferred by all vessels at all seasons.

The farther from the land, the more regular and steady the wind, may be safely taken as a general rule."

In July, 1876, the ship *Wasdale* left Liverpool, and made the voyage to San Francisco, *viâ the Cape of Good Hope*, in 136 days, although the distance is from 5,000 to 8,000 miles longer than by Cape Horn. In May, 1881, the ship *MacMillan*, Captain Gray, left Antwerp, and reached San Diego in 128 days by the Cape of Good Hope, or in 3 days less than the *Jupiter*, which left Cuxhaven 4 days after the *MacMillan* left Antwerp, and went round Cape Horn, crossing the Equator in the Pacific in 117° W.

The *MacMillan* went through Bass Strait, past North Cape (New Zealand), Sunday and Penrhyn Islands, crossing the Equator in 155° W., 10° N. in 150° W., 20° N. in 152° 12′ W., and 30° N. in 148° 6′ W.

San Francisco to Cape Horn.

First proceed as on the voyage to Callao (pp. 182-3), and after standing well full on the port tack, through the S.E. Trade, steer South until the region of Westerly Winds is reached, between 35° and 40° S. Then bear away round Cape Horn on a Great Circle Route.

These remarks, and the illustrative chart of the Passages, will serve to elucidate these routes. Vessels have also reached California from Europe quickly by way of the Cape of Good Hope and Australia, as shown before.

Mr. Davidson, U.S.N., in his excellent directions for the Western Coast of the United States, gives the following statistics of the voyages made to San Francisco, which will be interesting; but from the improvement in the sailing powers of ships of late years, the average duration of the voyage has become correspondingly shortened.

The number of clippers arriving at San Francisco from New York during the 10 years, 1850 to 1859, was 663, and the average length of the passage was 135·7 days. In the same years 373 arrived from Boston, and the average passage was 136 days.

In 1850 six clippers arrived from New York averaging only 115 days; the *Sea Witch* being reported at 97 days, but her actual passage was 101. The average passage of *all* American vessels that arrived from Atlantic ports was 187 days.

The shortest monthly means are 104 and 116 days, and these are for the vessels that crossed the Equator in the Pacific during the months of January and December. To this crossing they had an average run of 96 and 98 days. Vessels that sail from the United States to California in September and October are the vessels which, upon an average, should have the fairest winds and make the best passages.

Between California and Panama.

Captain Maury, referring to the data he had collected, says:—"After carefully studying the description of the Winds, derived, it is true, from no great abundance of materials, I have to suggest the following routes for the consideration of navigators bound N.W. from Panama.

From the Bay of Panama make the best of your way South until you get between 5° N. and the Equator.

Being between these two parallels, it will be for the navigator to decide whether he will shape his course West, and keep between them until he crosses the meridian of 85° W., or whether he will cross the Equator, and make his Westing in South latitude, with the S.E. Trades on his quarter. The winds that he finds between 5° N. and the Line should decide this question for him. If he can get West here with a good breeze he should crack on, and, when his good wind leaves him, steer South again.

If the passage from Panama be attempted in January, February, March, April, May, or June, time will probably be saved by going South of the Equator; for, at this half of the year, the N.E. Trades and the Equatorial Doldrums are often found between the Equator and 5° N. Between the meridians of 80° and 85° W., in this part of the Ocean, these winds and calms are found even in the months of July and August. Therefore, in coming out of Panama, and after crossing 5° N., in any season, make a S.W. course if the winds will allow. If the wind be S.W., brace up on the starboard tack; but if it be S.S.W., and a good working breeze, stand West. If, however, it be light and baffling, with rain, know that you are in the Doldrums, and the quickest way to clear them is by making all you can on a due South course.

Suppose that after crossing 5° N. you have got to the West of 85° without having crossed the Equator. Now, if the time of the year be in that half which embraces July and December, the prevailing winds will be between S.E. and South, inclusive, and the course is West as long as there is a breeze. As soon as the breeze dies away, and you begin to fight the baffling airs, conclude that you are in the vicinity of the Doldrums that are often found here either between the N.E. and S.E. Trades, or between one of these Trades and the system of Southwardly Monsoons that blow North of the Line, between the coast and the meridian of 95° W.

These Belts of Doldrums lie East and West, and the shortest way to cross them is by a due North and South line; therefore, let it be a rule, whenever the navigator finds himself in one of these Calm Belts, to make all the latitude possible, for by that means he will soonest clear it.

Having crossed the meridian of 95°, stand away to the Northward and Westward with a free wind.

West of longitude 100°, and between the parallels of 5° and 10° N., the winds, in the months of November and December, are variable between N.E. and South, by way of East. In January, February, and March, they are quite steady as N.E. Trades. In April they are variable. The Doldrums are generally found between those parallels in this month. During the rest of the year the winds are all the time between S.E. and S.W.

It will be well to cross the parallel of 10° N. at least as far West as the meridians of 105° or 110° W. Here, between the parallels of 5° and 10° N., the winds in November are steady from S.S.E. and South; December, April, and May, are the worst months for the Doldrums in this part of the Ocean.

Having crossed the parallel of 10° N., between 105° and 110°, the navigator is then in the fair way to California.

San Francisco to Panama.—From May to October stand well out to sea with fair N.W. winds, and steer to cross 20° N. near 118° or 120° W., and then head South or S.S.E. Southward of 10° N. settled S.E. Trades will be found; here haul up on the port tack, and stand on until sure of reaching Panama on the starboard tack, when go about. The Galapagos Islands can be passed to the Northward, and 90° W. crossed near 4° N.

From November to April the winds to 20° N. are generally favourable, from N.E. to N.W.; 10° N. can be crossed at 110° W. When the N.E. Trades begin to grow light, steer South for the S.E. Trades, with which stand on, on the port tack, until certain of fetching Southward of the Galapagos on the starboard tack.—*M. Labrosse.*

Between California, &c., and Peru.

San Francisco to Callao.—Capt. Maury says:—Most vessels on this voyage make a mistake, especially in summer and autumn, in the passage across the belt of N.E. Trades. Being anxious to get to the East, they edge along, aiming to lose those winds in long. 90° or 100°, as the case may be. There they encounter the Southwardly Monsoons in the Pacific off the American Coast, similar to those along the African Coast in the Atlantic. The vessels taking that course, and being so baffled, have now to make a sharp elbow and run off 8° or 10°, or even more to the Westward before they clear this Belt of Calms and Monsoons and get the S.E. Trades. Of course the voyage is greatly prolonged by this.

The route which, as at present advised, I would recommend, is, that navigators steer the same course from California that they would if bound to the United States, until they pass through the S.E. Trades, and clear the Calms of Capricorn. Therefore I say to the vessel bound to Peru, when you get your offing from San Francisco, steer South, aiming to cross the Line *not to the East* of 115°, for the rule is, the farther East the harder it is to cross the Equatorial Doldrums in the Pacific as well as it is in the Atlantic.

When you get the S.E. Trades, crack on with topmast studding-sail set, until you get the Brave West Winds on the Polar side of the Calms of Capricorn. Now turn sharp off from the route around Cape Horn, and run East until you bring your port to bear to the Northward of N.E., when you may steer for it. Now, by this rule the Peruvian-bound navigator may sometimes, before he gets these Westerly winds, find himself as far South as 40° or 45°, and as far West as 120° or 125°. Let him not fear, but stand on until he gets the winds that will enable him to steer East, or until he intercepts the route from Australia to Callao, when he may, without fear of not fetching, take that route.

In the summer and autumn of the Northern Hemisphere (June to November), the Calm Belt of Capricorn will be cleared generally on the Equatorial side of the parallel of 30° S.; at the other seasons you will have frequently to go 6° or 8° farther.

M. Labrosse advises sailing vessels leaving San Francisco to endeavour to cross the Equator near 118° W. between May and October, and near 113° W. between October and May. Auxiliary steam-vessels taking the Easterly route, will be enabled to cross 10° N. between 89° and 91° W., and will then experience variable winds till they reach Cape San Francisco. Steam will have to be used about half the time in this locality. From Cape San Francisco to Callao the passage will be tedious, as both wind and current are from the southward.

Peru to Chili.

The passage from Peru to Chili requires some attention, and may generally be made by a man-of-war in less than three weeks; it has been made in less than a fortnight by a frigate, which, however, on the next occasion, took 28 days. The point which contributes most to the success of this passage is keeping well off the land after leaving Callao, and not having any scruples about making Westing, providing Southing can also be gained. The S.E. Trade Wind, through which the greater part of this course is to be made, invariably draws to the Eastward at its Southern limit, and therefore a ship eventually can always make her Southing. The object, however, being to get past the Trade into the Westerly Winds, which lie to the Southward, a ship ought to keep the wind at least abeam, while crossing the Trade. In winter, that is, when the sun is to the Northward of the Equator, the Trade Wind blows steadier, and its Southern extreme lies 4° or 5° to the Northward of its summer limit, which may be taken at about 30° or 31° S.

Sandwich Islands to Tahiti.—There is great difficulty in making this passage across the Trades. The whalers and all others speak with great doubt of fetching Tahiti from the Sandwich Islands. Captain Bruce says that a vessel should keep to the Northward until she gets a start of wind before steering for her destination. In his passage between the islands in November, 1837, he had no Variables near the Line in coming South, and never could make Easting on either tack, though he endeavoured by every means in his power to do so.

Between the Islands, &c.

The most favourable time to make this passage is from the end of March to the middle of June, but even then it will be difficult to fetch Tahiti without going about.

The *Imogene* left Karakakooa Bay, October 17, 1837, and reaching the South point of the island after twenty-five hours' sail, bore away on a S.S.E. course with a fiery Trade at E.N.E.; this failed on the 22nd; the ship was tacked to a Southerly breeze, which lasted till the 25th, when a fresh S. by E. Trade sprang up. Between the 21st and 25th an Easterly Current set for 30 to 35 miles a day; after that a Westerly Current of 16 to 40 miles per day was found. Every opportunity was seized to gain Easting, and to get to windward of the meridian of Tahiti, but without success. The Equator was crossed on October 28th, in long. 154° 40′, wind E. by S., the ship having been close hauled ever since leaving Hawaii. Passed Bellingshausen Island on November 5th; and, as the ship drew to the Southward, the wind gradually changed to East, E.N.E., and N.E., always bringing the port directly in the wind's eye. November 8th, passed Rimitara; on the 9th, squalls, with most terrific rain; on the 10th, the wind veered to N.W., and finally S.S.W.; on the 11th, saw Rurutu. The wind now favoured the ship, and for the first time since leaving Hawaii she laid her course, and continued to do so. Bearing W.N.W., 7 or 8 leagues, made Tahiti on the 13th, and anchored the same day at Papiete. Thus, had not a favourable change in the wind occurred in the latter portion of the passage, the vessel would have been to leeward.

Tahiti to the Sandwich Islands.—From June to November a vessel could easily fetch to windward of the Sandwich Islands if she crossed 10° N. near 148° W. During the rest of the year it will be difficult to cross 10° N. so far to the East, and almost impossible to make Hawaii.

In the passage from Tahiti to Hawaii, Capt. Beechey says:—From the time we passed Maiatea we endeavoured to get to the Eastward, and to cross the Equator in about 150° West longitude, so that, when we met the N.E. Trade wind, we might be well to windward. There is, otherwise, some difficulty in rounding Owhyhee, which should be done about 40 miles to the Eastward to ensure the breeze. The passage between the Society and Sandwich Islands differs from a navigation between the same parallels in the Atlantic, in the former being exempt from the long calms which sometimes prevail about the Equator, and in the S.E. Trade being more Easterly. The Westerly Current is much the same in both; and if not attended to in the Pacific, will carry a ship so far to leeward, that, by the time she reaches the parallel of the Sandwich Islands, she will be a long way to the Westward, and have much difficulty in beating up to them.—*Beechey's Voyage*, vol. i., page 230.

Between Australia and China.

The following is derived chiefly from an analysis by Captain Allen, Harbour Master at Newcastle, New South Wales, of the logs of various sailing vessels that made passages during the years 1869—1873, and collected by Staff-Commander T. H. Tizard, H.M.S. *Challenger*, 1874.

During the above years four different routes have been taken by ships bound from the province of New South Wales to China; three of these routes are to the Eastward of New Guinea, and one (the well-known Torres Strait Route) passes to the Westward of that great island.

These routes are herein styled respectively, the Eastern, the Middle, the Western, and Torres Strait Routes.

The description of the new route through the Louisiade Archipelago will be found on pages 940—945 of the South Pacific Directory. It will, when better known, probably become much used, forming as it does a much shorter Western Route.

The Eastern Route follows a line from Newcastle (or from Sydney) to Norfolk Island, thence to Matthew Island, and North along the 171st meridian to 11° S., then N.N.W. to Pleasant Island, crossing the Equator in 166° E., and through the Eastern part of the Caroline Islands to the ship's destination.

The Middle Route is from Newcastle (or Sydney) midway between Lord Howe Island and the Elizabeth Reef, to the D'Entrecasteaux Reefs off the N.W. extreme of New Caledonia, and thence between the Solomon and Santa Cruz Islands to the Equator, which is crossed in 159° E.; thence through the middle of the Caroline Islands, when a course may be shaped for the destined port.

The Western Route from Newcastle followed by these vessels is N.E. to the 157th meridian, and due North on that meridian to the latitude of the Pocklington Reef in 11° S., thence either to the North-Westward between New Ireland and the Solomon Group, or to the Northward through the Bougainville Strait, between Bougainville and Choiseul Islands, crossing the Equator in about 153° E.; from this position a straight course may be shaped for either

Shanghai or Yokohama; but for Hong Kong the course is through the Western part of the Caroline Islands, thence to the Balintang Channel.

The Torres Strait Route is also from Newcastle, N.E. to the 157th meridian, then North on that meridian to the latitude of the Mellish Reef, and N.W. for Bligh Entrance to Torres Strait. It has been taken by only one ship, the *England,* which made the passage to Hong Kong in 41 days, in the month of July.

Much depends on the sailing qualities of the vessel, but, as a general rule, ships leaving Australia in the months of January, February, or March for China or Japan should adopt the Middle Route, and may expect to make the passage in about 40 days; leaving in April, May, or June they should adopt the Western Route, and may expect to make the passage in about 36 days; leaving in July, August, or September they should, if they can reach Torres Strait before the end of August, take that route; and if not, either the Western or Middle Route, and may expect to make the passage *viâ* Torres Strait in 40 days, and by the other routes in 55 days; and, finally, ships leaving in October, November, and December, should adopt the Middle Route, and may expect to make the passage in about 44 days.

CHAPTER VII.

HURRICANES.

Among the most extraordinary phenomena of nature may be classed those tremendous Meteors, the Hurricanes and Tornados of the Tropical regions. Until within a recent period they were very imperfectly understood, and were only regarded as terrible convulsions of the aerial system, when all order seemed to be broken up. But these, like many other apparent anomalies in nature, have been found reducible to system; and their various seemingly capricious motions to be all subject to general rules, which, in this case, have been aptly denominated "*The Law of Storms.*"

The discussions on the *progressive* nature of Hurricanes appear to have originated in a paper, entitled, "Remarks on the Prevailing Storms of the Atlantic Coast of the North American States, by William C. Redfield, of the City of New York," 1831, which has proved to be a very important and valuable addition to nautical literature. The subject, adopting the "Redfield Theory," has since been amplified and illustrated by the late Lieutenant-Colonel (afterwards Sir) William Reid, R.E.,[1] formerly Governor of the Bermudas, in a volume, bearing for the title, "An Attempt to Develop the Law of Storms by means of Facts, arranged according to Place and Time, and hence to point out a Cause for the Variable Winds, with a view to practical

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[1] The origin of the revolving theory has been attributed to others earlier in the field than Redfield and Reid. Among others, to Colonel Capper, who published his well known work on Winds and Monsoons, in 1801; to Romme, a French author, in 1806; and to several others. But these all fell short of establishing the law, inasmuch as they only noticed the shifting character of the winds in one spot, and did not reach the conclusion that these shifts had an invariable character, and that the whole Meteor was progressive.

use in Navigation," &c., 1838. As connected with this subject, the names of Redfield and Reid will be imperishable.[1]

We say that the discussion appears to have originated in the before-mentioned works; but without deciding on the claims of priority, it must be mentioned that, besides the names of Reid and Redfield, those of Mr. Piddington, at Calcutta; of Dr. Thom, and more recently Professor Meldrum, in the Indian Ocean; of Mr. Espy, in America; and of Professor Dové, at Berlin, must be enrolled with them, as the primary instigators of the enquiry into the origin and nature of storms. Mr. Piddington's "Hornbook" contains most valuable information on this important topic.

There are various names aplied to these storms: Cyclones, Revolving Storms, Hurricanes, Tornados (Spanish and expressive, meaning "turned"), Typhoons, &c.; but all are meant to describe the same thing.[2]

Although the "Law of Storms" is now fully recognized, yet opinion is still divided as to the real character and condition of these remarkable Meteors. Reid, Redfield, and others, contend that they are real vortices—currents of air *revolving* round a progressive centre; others, as Thom, and Meldrum, contend that the wind blows in *spirals* around this centre; Espy, that the wind blows *toward* the centre; others, again, consider that the *vertical* motion of the air will explain many of the phenomena. It is also argued that, instead of a circle, the form of the storm is elongated, ellipsoidal, or even straight, moving broadside onwards. Jinman considers that, as the air is blowing away from one area, another current necessarily blows towards and into that area, causing the peculiar features of these Hurricanes. It would be out of place, and far too discursive for this work, to discuss these various propositions. They may readily be found in the numerous works extant.

From all the investigations on the subject, the following general conclusions, which appear sufficiently accurate for practical application, have been arrived at. The Hurricane, or rotary storm, commences within the Tropics, on either side of the Equator, but rarely in a lower latitude than 5°; *that in North latitude, the motion of the revolving circle is from right to left, past the North, or against the sun*, i.e., in the opposite direction to the hands of a watch, and that the storm bodily progresses to the W.N.W., N.W., and North, recurving in about 30° North lat., and running off to the N.E.

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[1] "My attention was first directed to the subject from having been employed at Barbadoes in re-establishing the Government buildings blown down in the Hurricane of 1831; when, from the violence of the wind, 1,477 persons lost their lives in the short space of seven hours. I was induced to search everywhere for accounts of previous storms, in the hope of learning something of their causes and mode of action."—*Reid*, "*Law of Storms.*"

[2] In the West Indies they are known as Hurricanes; in the Indian Ocean as Cyclones; and in the China Sea as Typhoons.

South of the Equator, or in the Southern Hemisphere, *this rule is reversed, the storm revolving from left to right, or* with watch hands, and passing onwards in a W.S.W., S.W., and finally in a South and S.E. course.

The diameter of these circular vortices varies from 40 to 50, or even 1,000 miles, probably increasing in size in their onward progress. Their rate of travelling varies from 3 to 50 miles per hour.[1]

Prognostics.

With that threatening aspect of the sky which generally precedes all storms —such as the greasy halo round the sun or moon, the rolled and tufted forms of the clouds, with the lurid streaks of light and extraordinary colours, and the heavy bank clinging to the horizon with its darting forks and threads of pale lightning—every seaman is acquainted. The best and surest of all warnings will, however, be found in that invaluable, and seldom-failing monitor, the *Barometer ;* the language of which, in the Torrid zone, is unmistakeable, because there it is usually steady and undisturbed. When such warning symptoms are observed, in *any* quarter of the world, it may be supposed that no time should be lost in making all due preparation, and especially if to such menacing appearances be added the confused and troubled agitation of the sea which often precedes these revolving storms, and always shows that they are at no great distance. But if these combined prognostics should occur within the limits of those regions in which these Cyclones occur, let the seaman immediately consider the possibility, at least, of his being about to encounter a storm of that revolving type of which we are treating.[2]

As a general rule, the following will be the usual oscillations of the Barometer :—Just previous to the commencement of the Hurricane, the mercury will suddenly rise above its ordinary level ; soon after it will begin

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[1] In the West Indies their average rate of bodily progression may be taken as 200 miles in one day, and in the Indian Ocean from 200 miles to 50 miles a day, sometimes even remaining stationary for some days. In the Bay of Bengal and China Sea they travel on an average 200 miles a day.

[2] Although it is true that the prognostics of a common coming storm are, in general, sufficiently plain to be understood by a spectator, from the angry appearance of the firmament, yet it is also true that there is no particular indication in any one quarter of the horizon sufficiently marked, like the space occupied by the *Black Squall* panoply of the Caribbean Sea ; so that an acute seaman shall say "thence will the blast come." On the contrary, the clouds gather together (we speak from experience) in dense masses, of a dusky hue, in every direction, until the whole canopy of heaven is overspread, and the gloom at last becomes so intense that, even at mid-day, to speak within bounds, beyond a quarter of a mile no object can be even indistinctly seen. There are, however, some degrees of variation in the intensity of the obscurity, and we all know that the measure of distance by the eye upon such an exciting occasion is not likely to be very exact ; at one period in a Hurricane, just as the ship was dismasted, at the *crisis*, near noon, we could not clearly distinguish the end of the bowsprit from the quarter-deck.—*Lieut. Evans.*

to fall, and the wind will probably rise, showing that the storm has begun. The mercurial column then begins to descend, rapidly at first, and then more slowly, till the centre of the Hurricane has passed over, when it begins gradually to rise, and the reverse of the movement at the commencement ensues; it attains a higher level, and then as suddenly falls to the mean height. This is supposing the whole of the Meteor to pass over, and the centre to be crossed; the mercury showing the pressure of atmosphere above.

Upon a little consideration, it will be evident that the form of the upper surface of the revolving storm, or the section of the vortex, is indicated by the variations in the Barometric column. It by no means follows that, practically, this will always be found; a ship may only skirt the exterior of the storm, and, consequently, the mercury will only rise, or oscillate, according to the relative position of the Hurricane and the ship; but it may be taken as an indication, when the Barometer begins slowly to rise, after being depressed, that the greatest danger has passed over, or that the ship is steering away from it. Therefore, should there be any sudden change in the Barometer, either rising or falling, its indications should never be neglected, especially during the period, and in the regions, subject to these storms. It sometimes sinks *two inches* during the progress of a Hurricane.[1]

One great advantage in the *Aneroid* Barometer is, that its variations occur simultaneously with their causes. In the mercurial Barometer the friction of the mercury on the tube, and other reasons, concur to make the column rise or fall at some time after the change has occurred. In this the Aneroid Barometer possesses great advantage, and it has another very great claim to notice—that it clearly shows very minute changes, which the oscillation or pumping motion of the mercury in very bad weather will not allow to be estimated.

Estimation of Direction.

Acting under this anticipation, the first care should be to discover the position of the storm with respect to the vessel, or, in other words, to ascertain its bearing. Fortunately this is a problem of extreme facility, for, as we have already stated, it is one of the remarkable laws of these storms that in opposite Hemispheres they revolve in opposite directions—in *North* latitudes *against* the course of the sun, that is to say from *right to left*, or in a direction contrary to the movement of the hands of a watch; and in *South* latitudes from *left to right;* and, secondly, it is known that, no matter how great or how little may be the size of the

[1] The lowest recorded Barometer in a Cyclone is 26·30, stated in the "Sailors' Hornbook," as registered in the Indian Ocean in 1833; one of the greatest recorded falls during the progress of such a storm is 2·80 inches, which occurred in the China Sea in 1849.

At Calcutta, on May 21st, 1833, the Barometer fell 2·59 inches in 3 hours. At Nassau, on 1st October, 1866, the Barometer fell $\frac{7}{10}$ inch in one hour, falling to 27·70 at that place, when at 286 miles distant the reading was 29·70.

storm-field, the wind continually blows in an approximately circular course round and round a centre or vortex. It therefore necessarily and demonstratively follows that this centre must always be nearly at right angles to that circular course; or, in other words, that the bearing of the centre lies eight points of the compass from the direction of the wind.[1] Now, these two considerations are quite enough for our purpose, for they enable us to answer the question instantly and certainly by the following general rule:—

Rule.—Look to the wind's eye—set its bearing by the compass—take the eighth point to the **RIGHT** thereof—and that will be the bearing of the centre of the storm if in North latitude; or, if in South latitude, the eighth point to the **LEFT** of the direction of the wind. For example: suppose the vessel to be in 14° N. latitude, the wind from E.S.E., and the Barometer and sky indicate a coming gale—then look at the compass, take the eighth point to the right of E.S.E., and S.S.W. will infallibly be the bearing of the brewing storm, *if it be* of a revolving type; or, under similar appearances of the weather in 14° S. latitude, with the wind S.W., take eight points to the left of S.W., and S.E. will consequently be the direction of the centre of the impending gale. In the former case, the vessel will be on the Northern edge of the storm-field; and, in the latter, she will be somewhere in its North-Western segment.

A transparent diagram, in which the compass is shown with the wind marked by concentric circles—for North latitude, the East wind blowing at the North point; for South latitude, the West wind on the North side—is recommended by Sir William Reid and Mr. Piddington. By laying these on the chart, the ship's place corresponding with the proper wind on the circle, shows the direction of the focus.

Estimation of Distance.

A rough attempt may be made to compute the distance of the focus by its change of bearing from the vessel. For instance, suppose a vessel in lat. 14° N., long. 40° W., meets with strong indications of a gathering storm, the wind being at East, and therefore if the storm is a revolving one, its centre must bear South.

In an hour's time, the vessel being hove-to, the wind has come round gradually to E.S.E., and hence the centre now bears S.S.W.

Assuming the probable path of the storm to be W.N.W., and its rate of bodily progress in that direction 10 miles an hour for a first estimate, if the Traverse Table is entered with the change of wind (two points) as a course,

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[1] Mr. Meldrum remarks that in the Cyclones of the South Indian Ocean N.E. and Easterly winds often blow *towards* the centre of the storm, and not at *right angles* to it.

He also observes that on approaching the *Southern* side of a Cyclone in the South Indian Ocean, it is advisable to lie to until the Barometer has fallen about six-tenths of an inch, and *then* consider the centre of the Cyclone to be at right angles to the direction of the wind, but not before.

and 10 miles as departure, the corresponding distance, 26 miles, will be that of the centre of the storm at the time of the first bearing, and 24 miles at that of the second bearing.

If the storm has not yet reached abreast of the ship, so that one of its bearings may form a right angle with its path, the observer must be at the trouble of working out the result in an oblique angled triangle.—*Remarks on Revolving Storms, published by the Hydrographic Office.*

Rules for avoiding Hurricanes.

It will be very readily understood that the whole care of the shipmaster, when he first encounters a storm, is to know how it may be avoided, or otherwise its destructive effects may pass over his vessel in its utmost fury, and the application of the law then becomes his safeguard. When the expected Hurricane reaches the ship, the first point that requires to be known is what part of the circumference it is on which the vessel may be; that being ascertained, it is usually comparatively easy to get out of its way, or at least to avoid its worst effects.

Colonel Reid's Rule for Laying Ships to in Hurricanes.—"That tack on which a ship should be laid-to in a Hurricane has hitherto been a problem to be solved, and is one which seamen have long considered important to have explained.

In these tempests, when a vessel is lying-to, and the wind veers by the ship's head, she is in danger of getting sternway, even when no sail is set; for in a Hurricane the wind's force upon the ship's masts and yards alone will produce this effect should the wind veer ahead, and it is supposed that vessels have often foundered from this cause.

When the wind veers aft, as it is called, or by the stern, this danger is avoided, and a ship then comes up to the wind, instead of having to break off from it.

If great storms obey fixed laws, and this explanation of them be the true one, then the rule for laying a ship to follows like the corollary of a problem already solved. In order to define the two sides of a storm, that side will be called the right-hand semicircle, which is on the right of a storm's course as we look in the direction in which it is moving, just as we speak of the right bank of a river. The rule for laying a ship to will be *when in the right-hand semicircle* to heave-to *on the starboard tack, and when in the left-hand semicircle on the port tack, in both Hemispheres.*[1]

In a progressive storm there wlll be one quadrant in which it will be more

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[1] In the right-hand semicircle in *both* Hemispheres the wind shifts with the hands of a watch, and in the left-hand semicircle in both Hemispheres the shift is in the opposite direction. A striking example of the danger of vessels lying-to on the wrong tack is afforded by the fleet under Admiral Graves in 1782, which, with a convoy of 90 vessels, encountered a circular storm in the middle of the Atlantic, and through being on the wrong tack a loss ensued of 8 line of battle ships, 70 of the convoy, and 3,000 lives.

dangerous for a ship to scud than in the other, that being the one in which a vessel steered so as to sail before the wind, would be led in advance of the centre of the storm's track. The rule thus applies to three-quarters of the storm's circle. But care should be taken lest in its application a ship be carried into what has been called the quadrant of greatest danger, and before the centre of an advancing storm. The practical seaman knows that a ship is difficult to steer during a storm, and in a high sea, with the wind on the quarter.

It is evident that if a ship is overtaken by a storm in its progress, it must be the advancing edge or semicircle which envelopes her, but this may not always be the effect of its progressive motion. As the storm gradually increases, great irregularities of dimensions and form must doubtless occur on its outer edges; so that by this extension of area it may reach a ship when she is to the North or South of the centre, or even to the Eastward of the North and South diameter, that is, in the advancing semicircle.

Besides the more usual evidence of change of position, the focus itself will sometimes have a tortuous or spiral motion. This will cause great perplexity and apparent want of regularity, yet the storm itself may be strictly a revolving one.

One cause of complexity in revolving storms is, that they have been known to separate into two, and in other cases two or more storms encountering each other have coalesced.

There is one position in which a ship may enter a revolving storm which is attended with the utmost danger, that is directly in its path. In this case the wind will not shift, as it would on either side of the line of progress, but continue in its first direction until the focus be passed, when it would *suddenly* shift to exactly the opposite point, a change which the seaman would dread.

The focus, as has been before mentioned, is the most dangerous part of the Hurricane. Near it the wind blows more furiously, added to which is the danger of a sudden shift.[1] Here, too, the sea becomes confused; the waves raised by the opposing winds surrounding it here interfere with each other, and the appearance, as described by some, is that of the water rising and falling in pyramidal heaps, the usual succession of waves being obliterated. Sometimes the sea rises or subsides in a very sudden manner.

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[1] The force with which the wind blows under those circumstances may be illustrated by the following well authenticated cases:—During a severe Hurricane at Barbadoes in 1780, a 12-pounder gun was moved 140 yards from its original position by the violence of the wind.

In the landlocked basin of English Harbour, Antigua, West Indies, in 1792, a line of battle ship, which had stepped her lower masts alongside the dockyard in the morning, had them broken short off on the following night during a furious Hurricane. This curious fact is recorded on a brass plate in the dockyard.

The form of the Hurricane may not be quite symmetrical. The advancing semicircle sometimes becomes flattened, especially when approaching land, and the following portion lengthened, so that the whole figure becomes ellipsoidal, and the shifts of the wind around the focus will not be perfectly regular in consequence.

The first of the two diagrams on the next page is intended to represent one of the (Bengal) Hurricanes moving from S.E. by S. to N.W. by N. in the direction of the great arrow drawn across it. The commander of a ship can ascertain what part of a circular storm he is falling into by observing how the wind begins to veer. Thus, in the figure, the ship which falls into the right-hand semicircle would receive the wind at first from about E. by N., but it would soon veer to East as the storm passed onward, supposing her lying-to. The ship which falls into the left-hand half of the storm would receive the wind at first from N.E., but with this latter ship, instead of veering towards the East, it would veer towards the North.

The explanation of the rule for heaving-to will be best made out by attentively inspecting the two figures. In both the *black ships are on their proper tack;* the white ships being on the wrong tack.

The second figure represents one of those Hurricanes in South latitude (such as those which pass near the Mauritius) proceeding to the South-Westward. The whirlwind is supposed to be passing over the vessels, in the direction of the arrow-head. It will be seen that the black ships are always coming up, and the white ships always breaking off; and that they are on opposite tacks, on opposite sides of the circles.

If Hurricanes were to move in the opposite course to that which they have hitherto been found to follow, then the rule would be reversed, for the white ships would come up, and the black ships break off.

From this it follows, that if two ships be hove-to within the compass of the same revolving gale, and on the same tack, and the one ship comes up while the other ship falls off, the centre of such revolving gale will be passing between them. This will assist in judging approximately of the track gales may be following, even in the case of single ships.

Some Cyclones are interrupted in their development by the near approach of another storm. Care must be taken, therefore, not to mistake the N.E. wind of a storm whose North-Western limb is thus intercepted by a bordering storm, for the changes that pertain to the gale itself."

FIGURE FOR
THE NORTHERN
HEMISPHERE.

*Proper North,
and Wind East.*

*Ship on
Starboard
Tack.*

*Proper West,
and Wind North.*

*Proper East,
and Wind South.*

*Ship on
Port Tack.*

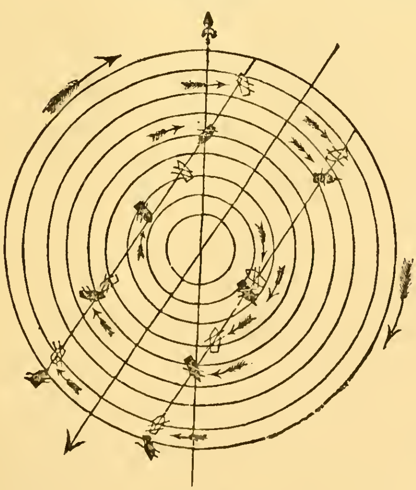
*Proper South,
and Wind West.*

FIGURE FOR
THE SOUTHERN
HEMISPHERE.

*Proper North,
and Wind West.*

*Ship on
Starboard
Tack.*

*Proper West,
and Wind South.*



*Proper East,
and Wind North.*

*Ship on
port Tack.*

*Proper South,
and Wind East.*

The following remarks illustrate the Seasons and frequency with which Hurricanes occur in some of those localities where most prevalent:—

The West Indies.

The Season which is most liable to these visitations in the West Indies is between July and October; they are comparatively rare during other months, though not entirely unknown. The following is a list, arranged in the months they occurred in the West Indies during 300 years, taken from the Proceedings of the Royal Geographical Society:—

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
5	7	11	6	5	10	42	96	80	69	17	7	355

Loomis, from his investigation of West India Hurricanes, concludes that they do not exist South of 10° N.

The South Indian Ocean.

The Southern Indian Ocean is pre-eminently the field for Cyclone phenomena, and a large number of them have been investigated by the various indefatigable observers who have been before alluded to. From their teaching we can now speak with confidence of the usual tracks over this great extent of Ocean, as being generally from E.N.E. to W.S.W.; but from long. 80° E., Westward, and particularly when approaching the Mauritius group, they have a tendency to curve to the Southward, and frequently, according to Colonel Sir W. Reid's results, *back* to the E.S.E., when they reach the Southern Tropic.

Between lat. 50° and 25° S., and long. 75° and 105° E., is a space where, as yet from some unknown cause, frequent Cyclones appear to rise, and progress from thence, slowly at first, then more rapidly; their slow progressive, or uncertain tracks, entitling them almost to be called *stationary* Cyclones.

The frequency of their occurrence may be gathered from the following list, derived from Mr. Piddington, whose book is invaluable.

The first line shows the number of Hurricanes (fifty-eight) registered for 39 years, from 1809 to 1848, encountered in the Southern Indian Ocean.

The second line gives the number in each month experienced at the Mauritius for 35 years, 1809 to 1844, by which it will be seen that they have all occurred in the 5 months between December and April:—

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Southern Indian Ocean ..	9	13	10	8	4	0	0	0	1	1	4	8
Mauritius	9	15	15	8	0	0	0	0	0	0	0	6

Besides those which travel on a curvilinear path, there are others which seem to be nearly or quite stationary, and others exhibit many puzzling anomalies, so that there is still some difference of opinion as to their always obeying the same law of origin and progress. However, this question must be left to the works more specially devoted to the subject, and to the remarks which have been given as to the rules for avoiding their fury.

A Hurricane of very unusual phenomena visited the Mauritius and Réunion in February, 1861. Owing to its slow rate of progress, it remained over the islands for *five* days. Although not of so violent a character as others, such as that on February 26th, 1860, its effects were much more manifest at the Mauritius than at the latter island. The amount of rain which fell there was enormous, amounting to 39·8 inches. Its axis passed to S.W. between the islands, and in its progress each quadrant of the Cyclone devastated opposite islands alternately.

In the Mozambique Channel, and to the North and South of it, there are only two Cyclones investigated, and these seem to have followed the usual track from E.N.E. to W.S.W. There are no records of any to the North of the Comoro Islands, except the one experienced at Zanzibar, in April, 1872, which travelled from E.N.E. to W.S.W., striking the town of Bagamoyo on the mainland. It is said that Cyclones are unknown at the Seychelles and the Chagos Islands, but one was encountered in September, 1851, and another in October, 1862.

The Bay of Bengal.

The Hurricanes which are encountered in the regions of the S.W. and N.E. Monsoons, occur chiefly at the periods of their changing. In the Arabian Sea Cyclones are almost unknown, and those recorded have been experienced on the Indian Coast, and are very few in number. They are more frequent in the Bay of Bengal, and are stronger on the Western than on the Eastern side of the Bay. They are also more formidable at the setting in of the N.E. Monsoon, in October and November, than in the opposite season of the change to the S.W. Monsoon, in April, May, and June.

The North Pacific Ocean.

Typhoons.—The whole of the Western portion of the North Pacific Ocean, between the parallels of 10° and 45° N., together with the China Sea, is subject to violent Cyclonic storms, termed Typhoons, which, between 20° and 45° N., are experienced from June to November, more particularly about the Equinox. They are seldom felt within 5° or 6° of the Equator, and have not been traced into very high latitudes.

Typhoons originate in Tropical latitudes, and, according to Professor Dové, are caused by the upper winds forcing their way into the lower; but Professor Reye, in his work "Die Wirbelstürme, Tornados, und Wettersäulen," contends that the cause is the equilibrium of the Atmosphere being upset by the caloric set free by the condensation of Atmospheric vapour.

At the outset they usually take a W.N.W. course, but when the centre passes out of Tropical limits they almost invariably re-curve, passing away to the Northward, and then to N.E., expending their force in the open Pacific. Their average rate of progression off the shores of Japan is about 18 miles an hour. They blow in violent squalls, accompanied by heavy rain; in their centre the Barometer sometimes sinks as low as 28 inches.

Captain H. C. St. John, H.M.S. *Sylvia*, makes the following remarks:—The Typhoons which occur in Japanese waters are, I believe, always distinct from the China storms. Originating in Tropical latitudes, their first course is to the N.W., the same as that of the Kuro Siwo. It appears they then pass over the same ground, gradually turning to the North with the warm Current, striking the South Coast of Japan, just as they incline away to the North-Eastward. Their Northern disc now becomes flattened in against the high mountain ranges. The general N.E. direction of the coast is then followed, until the S.E. point of Nipon is reached, when they pass out to the open Pacific. The result of these circular storms becoming flattened on their Northern sides is, that Easterly winds prevail during their passage along the coast, these winds being exactly against the course of the Current. The result of two such forces meeting is a very confused sea, alike trying to man and ship.

In the Tropics, where the Barometer varies so slightly under ordinary circumstances that any fall greater than ·35 in. is a sure sign of an Atmospheric disturbance, the prognostics of a Typhoon are evident; but in more temperate latitudes, where the Barometer varies considerably with no apparent Atmospheric change, the prognostics are less certain. In Japan, the Barometer during September and October varies between 29·9 and 30·0; but when it remains very steady, with an increase of oppressive heat above the mean temperature, and when this is accompanied by a threatening aspect of the sky, a misty halo round the sun or moon, lurid clouds tufted in shape, a heavy bank of leaden-coloured clouds in the horizon, lightning, and frequently a long, heavy, ocean swell, then a Typhoon may be confidently expected.

We may here make mention of a valuable and interesting Paper, illustrated with charts, by Mr. H. Harries, of the Meteorological Office, read before a meeting of the Royal Meteorological Society, November 18th, 1885. Mr. Harries there traced the course of a Typhoon (which originated in about lat. 13° 30′ N., long. 134° E., September 27th, 1882) across the North Pacific Ocean and the Continent of North America, whence it proceeded over the North Atlantic Ocean, arriving on the Western Coast of Europe on October 27th, and thence passed away to the West Coast of Norway and the Baltic Sea, completing its course of about 14,000 nautical miles in 36 days, or at an average rate of 16 miles an hour. The observations made on this Typhoon show that the size of these Meteors is sometimes considerably greater than various writers on the subject have supposed it to be, as in the early stage of its existence this disturbance extended on the N.W. side to a distance of 1,300 miles from its centre.

An Analysis of severe Typhoons experienced in the China Sea, from 1780 to 1845, gave the following distribution in the various months:—

May	June	July	August	Sept.	October	Nov.
1	2	5	5	18	10	6

None were recorded in the other months of the year.

The South Pacific Ocean.

In the Southern Pacific Ocean we have a groundwork for asserting the character and occurrence of the true Cyclones; and, as Mr. Piddington states almost all that need be said on the subject, we quote his words :—

In the Tropical regions of the South Pacific, from the Barrier Reefs of Australia through the numerous groups of islands to the Low Archipelago, and perhaps even to near the Coast of South America, and from the Equator to lat. 25° S., there is no doubt that true Hurricane storms (Cyclones) occur, ot as great violence at least as those in the North Pacific; but from the scattered accounts of single ships, as also of missionary residents on the various islands, we cannot say anything positive as to their tracks, though they appear to come from the Eastward amongst the islands, and sometimes to curve to the Southward. The seasons at which they prevail seem, also, to be the same as those when they occur at Mauritius and Bourbon. The following are a few notes.

From lat. 10° S. to the Southern Tropic, Hurricanes are likely to be experienced from November until April, agreeing also, in this respect, with the Indian Ocean; and I make no doubt that one of these occasioned the loss of La Pérouse and his fellow-voyagers. These scourges of the sea are more prevalent near the New Hebrides and New Caledonia than the Fiji Group and Friendly Islands. From all I can gather of these Hurricanes of the South Pacific, having conversed with several masters who have encountered them, some of whom have had their ships dismasted, I scarcely think they are of that terrific description occasionally experienced elsewhere; and am almost inclined to believe them more often and more severely felt near the islands, than well clear of the land, although aware of this disagreeing with the new theory; but more facts will be necessary to elucidate this subject.

They are apparently of unfrequent occurrence in the Pacific, several years intervening without any ship encountering one. I possess no facts which would be serviceable in pointing out their track or direction of rotation. They will, without doubt, be considered to agree with other places in the same latitude, yet a few more well authenticated descriptions of these Southern Hurricanes would not appear to encumber the evidence of their uniformity in these particulars.

EXAMPLES.—To illustrate the preceding remarks and directions, accounts of a series of Revolving Storms in the North Atlantic Ocean is given. They are illustrated by the Chart.

Routes on the Chart.—No. I.—Trinidad to Yucatan, over the middle of the Caribbean Sea, June 23 to 28, 1831.

No. II.—Barbadoes to the Mississippi, August 10 to 17, 1831.

No. III.—Guadaloupe to the Bank of Newfoundland, August 17 to 29, 1827.

No. IV.—Guadaloupe and Antigua to Charleston, and thence to the Bay of Fundy, September 3 to 10, 1804.

No. V.—Antigua, over Cuba, to the Coast of Texas, August 12 to 18, 1835.

No. VI.—Barbuda to Charleston, and thence to the Bank of Newfoundland, August 12 to 19, 1830.

No. VI .—From the intersection of 20° N. and 60° W. (N.E. of Barbuda), passing to the West of Bermuda, and thence N.E. to the parallel of 42½°, September 29 to October 2, 1830.

No. VIII.—From the parallel of 22° (North of Porto Rico) to Cape Hatteras and the Coast of Maine, September 1 to 5, 1821.

No. IX.—From near the same spot as No. VIII., on a similar route, but more to the Eastward, August 22 to 27, 1830.

No. X.—From the parallel of 30° N., on the East side of the Florida Stream, to Cape Sable of Nova Scotia, January 13 to 16, 1831.

No. XI.—Inland storm, over the Lakes, and thence to the Gulf of St. Lawrence, November 10 to 12, 1835.

The route designated as No. I. is that of the hurricane which visited the Islands of Trinidad, Tobago, and Grenada, on the 23rd of June, 1831. Pursuing its course through the Caribbean Sea, it was subsequently encountered by H.M. schooner *Minx*, and other vessels, and its swell was thrown with great force upon the south-eastern shores of Jamaica on the 25th, while passing that island, where the wind at this time was light from the northward. After sweeping through the Caribbean Sea, the hurricane entered upon the coast of Yucatan, on the night of the 27th, having moved over the entire route from Trinidad to the western shore of the Bay of Honduras, in a little more than 100 hours, a distance of nearly 1,700 miles, equal to 17 miles an hour.

Track No. II. is that of the hurricane which desolated Barbadoes in the night of the 10th of August, 1831; and which passed Porto Rico on the 12th; Aux Cayes, in Hayti, and S. Iago de Cuba, on the 13th; Matanzas on the 14th; was encountered off the Tortugas on the 15th; in the Mexican Sea on the 16th; and was at Mobile Pensacola, and New Orleans on the 17th; a distance of 2,000 miles in about 150 hours, exceeding 13½ miles an hour. Its course, until it crossed the tropic of Cancer, was nearly W.N.W. Mr. Redfield adds—"In pursuing its northern course, after leaving the ocean level, it must have encountered the mountain region of the Alleganies, and was perhaps disorganised by the resistance opposed by these elevations It appears, however, to have caused heavy rains in a large extent of country north-eastward of the Mexican Sea."

Track No. III. is that of the destructive hurricane which swept over the Windward Islands, 17th August, 1827; visited St. Martin and St. Thomas on the 18th; passed the N.E. coast of Hayti on the 19th; Turk's Islands on the 20th; the Bahamas on the 21st and 22nd; was encountered on the coast of Florida and South Carolina on the 23rd and 24th; off Cape Hatteras on the 25th; off the Delaware on the 26th; off Nantucket on the 27th, and off Sable Isle and Bank on the 28th. Its ascertained course and progress were nearly 3,000 miles in about eleven days; or at the average rate of about 11 miles an hour. The direction of its route, before crossing the tropic, nearly N. 61° W., and in lat. 40°, while moving eastward, N. 58° E.

Track No. IV. An extensive hurricane of September, 1804, which swept over the Windward Islands on the 3rd of that month; the Virgin Islands and Porto-Rico on the 4th; Turks' Islands on the 5th; the Bahamas and the Strait of Florida on the 6th; the coast of Georgia and the Carolinas on the 7th; Chesapeake and Delaware, with the continuous portions of Virginia, Maryland, and New Jersey, on the 8th; and the States of Massachusets, New Hampshire, and Maine, on the 9th; being on the high lands of New Hampshire, a violent snow-storm. The destructive action of this storm was widely extended on both sides of the track indicated upon the chart, and the same fact pertains in a greater or less degree to the other storms herein mentioned. It appears to have passed from Martinique and the other Windward Islands to Boston, by the usual curvilinear route, in about six days a distance of more than 2,200 miles, at an average progress of about 15⅓ miles an hour.

Track No. V. The route of the hurricane which ravaged Antigua, Nevis, and St. Kitt's, in the afternoon and night of August 12th, 1835; St. Thomas, St. Croix, and Porto-Rico, on the 13th; Hayti and Turks' Islands on the 14th; the vicinity of Matanzas and Havana on the 15th; was encountered off the Tortugas, on the Bank of Florida, on the 16th; in lat. 27° 21′, long. 94°, and other points on the 17th and 18th; and at Matomoras, near the Mexican shore, lat. 26° 4′, on the 18th, where it was most violent during the succeeding night. It also passed over Galveston Bay, in Texas, and there blew with violence from the S.E.; while at the mouths of the Mississippi and along the northern shores of the gulf, the gale was not felt. This storm is remarkable, as moving more directly and further to the West than is usual for storms which pass near the West Indian Islands, it having reached the Mexican shores before commencing its sweep to the northward. Course about N. 73° W.; progress more than 2,200 miles in six days; nearly equal to 15⅓ miles an hour.

Track No. VI. The memorable gale of August, 1830, described hereafter, which, passing close by the Windward Islands, visited St. Thomas on the 12th, was near Turks' Islands on the 13th; at the Bahamas on the 14th; eastern coast of Florida on the 15th; coasts of Georgia and the Carolinas on the 16th; off Virginia, Maryland, New Jersey, and New York on the 17th; off George's Bank and Cape Sable on the 18th; and over the Newfoundland Bank on the 19th; having occupied about seven days in its ascertained course from near the Windward Islands, a distance of more than 3,000 miles; the rate of its progress being equal to 18 miles an hour. If, adds Mr. Redfield, we suppose the actual velocity of the wind, in its rotatory movement, to be five times greater than this rate of progress, which is not beyond the known velocity of such winds, it will be found equal, in this period, to a rectilinear course of 15,000 miles. The same remark applies, in substance, to all the storms which are now passing under review.

Track No. VII. was encountered to the northward of the Caribbee Islands on the 22nd of September, 1830; its route was to the eastward of all those previously described, and was found on the Grand Bank of Newfoundland, October 2, having caused great damage and destruction on its widely-extended track, to the many vessels which fell in its way. The ascertained route may be estimated at 1,800 miles, and the average progress 25 miles an hour.

Track No. VIII. experienced in September, 1821, as more fully shown hereafter. This hurricane was extremely violent; it was encountered to the north-eastward of Turks' Islands, on the 1st of the month; to the northward of the Bahamas and near the latitude of 30° on the 2nd; on the coast of the Carolinas early in the morning of the 3rd; and from thence, in the course of that day, along the coast of New York and Long Island; and it is represented to have continued its course across the States of Connecticut, Massachusets, New Hampshire, and Maine. The diameter of the storm appears to have exceeded 100 miles; its ascertained route and progress about 1,800 miles in sixty hours, equal to 30 miles an hour.

A similar but less violent storm swept along the same portion of the coast of the United States on the 28th of April, 1835.

Track No. IX. The route of a violent and extensive hurricane, which was encountered to the northward of Turks' Islands, August the 22nd, 1830; northward of the Bahamas on the 23rd; and off the coast of the United States on the 24th, 25th, and 26th of the same month. It produced much damage, but scarcely reached the

American shores. Its duration was about forty hours, and progress more tardy than some others.

Track No. X. A violent hurricane and snow-storm, which swept alongthe American coast from the parallel of 30° North, on the 5th and 6th of December, 1830. This track corresponds to another storm of similar character, which swept along the coast on the 13th, 14th, and 15th of January, 1831. These violent winter storms exhibited nearly the same phases of wind and general characteristics as those which appear in the summer and autumn.

Track No. XI. The violent inland storm which passed over the Lakes Erie and Ontario on the 11th of November, 1835. This storm was very extensive, spreading from the sea-coast of Virginia into the Canadas, to a limit unknown. The anterior portion of this gale was but moderately felt, and its access was noted chiefly by the direction of the wind and the great fall of the barometer; the violence of the storm being exhibited chiefly by the posterior and colder portion of the gale, as is common with extensive overland storms. The regular progression of the storm, in an easterly direction, was established by facts collected by Mr. Redfield, from the borders of Lake Michigan to the Gulf of St. Lawrence and the coasts of New England and Nova Scotia.

In pursuing the descriptions above, it is to be noted that the lines on the chart representing the routes, are given by Mr. Redfield as but approximations to the centre of the track or course of the several storms; and the gales are to be considered as extending their rotative circuit from 50 to 300 miles or more, on each side of the delineations; the superficial extent of the storm being estimated both by actual information and by its duration at any point near the central portion of its route, as compared with its average rate of progress.

The circular figure which appears upon the Chart, on Tracks Nos. I., V., and VII. will serve, in some degree, to illustrate the course of the wind in the various portions of the superficies covered by the storm, and also to explain the changes in the direction of the wind, which occur successively at various points, during the regular progress of the gale.

The Great Hurricane, which commenced at Barbadoes on the *10th of October*, 1780,* was preceded in the evening of the 9th by weather remarkably calm, but the sky surprisingly red and fiery, and during the night much rain fell. The storm approached from the S.E., and the ships of the squadron stationed here experienced the hurricane, each in turn, according to the place she was in. A letter from Dr. Blane, dated from the *Sandwich*, Sir George Rodney's flag-ship, stated that it was not previously apprehended that there would be anything more than such a gale as they experience from time to time at that season; but, on the evening of the 10th, the wind rose to such a degree of violence as clearly to amount to what is called a *hurricane*. At eight p.m. it began to make an impression on all the houses, by tearing off the roofs, and overthrowing some of the walls. As the inhabitants had never been accustomed to such a convulsion of nature, they remained for some time in security, but they now began to be in the utmost consternation. * * * * It was thought to be at its greatest height at midnight, and did not abate considerably until eight next morning. During all this time, most of the inhabitants had deserted their houses, to avoid being buried in the ruins; and every age, sex, and condition, were exposed in the fields to the impetuous wind, incessant torrents of rain, and the terrors of thunder and lightning. Many were overwhelmed in the ruins, either by clinging for shelter too long in the buildings, or attempting to save what was valuable, or by unavoidable accidents in the fall of walls, roofs, and furniture, the mate-

* The track of this hurricane is shown on the Chart, commencing between No. i. and ii.

rials of which were projected to great distances. Even the bodies of men and cattle were lifted off and carried above the ground. From an estimate of the number of deaths reported to the governor, they amounted to more than 3,000. All the fruits of the earth were destroyed; most of the trees torn up by the roots, and many of them stripped of their bark. The sea rose so high as to destroy the fort, carrying the great guns many yards from the platform, and demolishing the houses near the beach. A ship was driven on shore against one of the buildings of the naval hospital, which, by this shock, and by the impetuosity of the wind and sea, was entirely destroyed and swept away. * * * * The mole-head was swept away; and ridges of coral rock were thrown up to above the surface of the water; but the harbour and roadstead were, upon the whole, improved, having deepened in some places 6 feet, in others many fathoms. The crust of coral, which had been the work of ages, leaving a soft oasy bottom, and many shells and fish were found ashore which had been previously unknown.

The hurricane passed, in succession, over the Islands of St. Vincent, St. Lucia, Martinique, and Dominica, and included within its area those of Guadaloupe, St. Christopher, St. Eustatius, &c. At St. Vincent, every building was blown down, and the town destroyed. At St. Lucia, which was near the centre of the hurricane, all the barracks and other buildings were blown down and the ships driven to sea. At Martinique, likewise, all the ships that had brought troops and provisions were blown off the island. On the 12th, four ships with their crews foundered in Fort Royal Bay. The other ships were blown out of the roads. In the town of St. Pierre, on the N.W. coast, every house was blown down, and more than 1,000 people perished. At Fort Royal, the cathedral, seven churches, other religious edifices, many public buildings, and 1,000 houses, were blown down, as was the hospital of Notre Dame, in which were 1,600 sick and wounded, the greater part of which were buried in the ruins. The number of persons who perished in Martinique is said to have been 9,000. Dominica likewise suffered greatly, and Guadaloupe was within the northern verge of the hurricane.

At *St. Eustatius*, although not far within the N.E. verge, the loss was very great. On the 10th of October, at eleven a.m., the sky on a sudden blackened all round; it looked as dismal as night, attended with the most violent rains, thunder, lightning, and wind. In the afternoon the gale increased; seven ships were driven on shore near the North point, dashed to pieces on the rocks, and their crews perished. Nineteen vessels cut their cables and went to sea. In the night every house to the northward and southward was blown down, or washed away with the inhabitants into the sea, a few only escaping. The houses to the East and West were not so much hurt till the afternoon of the 11th, when the wind, on a sudden, shifted to the eastward; and at night it blew with redoubled fury, and swept away every house; but the forts, barracks, hospital, cathedral, and four churches remained. Here between 4,000 and 5,000 persons are supposed to have lost their lives.

Advancing north-westward, the centre of the hurricane on the 14th had reached to the Mona Passage, on the West of Porto Rico. Here the *Ulysses* and *Pomona*, with a fleet under their convoy, suffered greatly, and here the *Deal Castle* frigate was wrecked. Another frigate, the *Diamond*, fell within the western verge of the storm on the 15th, but happily escaped by passing Alto-Vela, on the South side of Hayti. Above the parallel of 20°, the *Stirling Castle* was lost on the Silver Kay Bank, and most of her crew perished. On the 18th we find, in about $22\frac{1}{2}$° N., and 69° W., the *Trident*, *Ruby*, *Bristol*, *Hector*, and *Grafton*, men-of-war, on the S.W. verge of the storm. The ship last mentioned, on the 16th, at noon, was in lat. $26\frac{1}{2}$°, long. (by estimation) 71° 30′; heavy gales and cloudy weather; lying-to under trysails; the gales split the sails to ribands. On the 18th, lying-to: strong gales and heavy squalls.—17th to 18th, carried rapidly to the south-eastward, when the *Trident*, *Ruby*, and *Hector*, came in sight as above. At eleven a.m., spoke the latter, in great distress.

The *Ruby*, *Trident*, and *Bristol*, on the 15th, were as high as $27\frac{1}{2}°$ N., and they, too, from the western border of the hurricane, were driven to the southward, until they joined company.

Here the detail becomes imperfect, until we reach the Bermudas; but to the N.E. of these isles we find the *Berwick*, on the 19th, which had fallen, on the 17th, within the border of the hurricane from a position to the W.N.W., near the latitude of 35°. This ship had previously been one of Rear-Admiral Rowley's squadron; she was proceeding to England under jury-masts, and had reached to the North of the latitude of the Bermudas when the hurricane overtook her. On the 16th, at eleven a.m., during calm, there was a great swell from the eastward. On the 17th, at one p.m., she was taken aback; wore ship and handed topsails; at three, squally, with rain; loosed the topsails; six to eight, wind E. by N. fresh gales. On the 18th, winds variable from the eastward, E. by N. to E.S.E.; after midnight, strong gales and heavy squalls. At noon, by estimation, Bermudas S. 53° E., 31 leagues. 19th, at one a.m., weather moderate, and the ship proceeded on her course.

On the 18th about fifty vessels were driven on shore at Bermuda.

We have been the more particular in giving these details, from having formerly been misled by imperfect data. In the delineation of the "Great Hurricane," given by Colonel Reid, he first assumes a circle having a radius of about 170 miles, which gradually expands, on its N.W., North, and N.E. course, to 270, with, we may presume, a diminished and proportionate momentum, on the parallel of Bermuda. The colonel observes that, on reading the logs and the various accounts of this hurricane, and comparing the different reports of the wind, it will be found that no storm yet described, proves more strongly than this, the rotatory nature of hurricanes.

Trinidad, June, 1831.—(*No. I. on the Chart.*)—It will not readily be forgotten that, on the 23rd of June, 1831, Trinidad, in the parallel of $10\frac{1}{2}°$ N., experienced one of the most awful storms of wind and rain ever remembered by the oldest inhabitant. The gale commenced at five o'clock on Thursday morning, and continued till eleven. The wind, after shifting from East, North, West, and South, finally settled at S.W., and blew without intermission until three in the afternoon. Eleven or twelve vessels were driven on shore, and several of them severely damanaged.

It was subsequently stated that the hurricane was felt at all the southern islands, where the loss it occasioned was very great. Such a storm had not happened at Granada since the year 1780; the devastation was extensive and dreadful; and the loss in that colony was estimated at £80,000. Its course to Yucatan is described hereafter.

(129.) *Barbadoes, August*, 1831.—(*No. II. on the Chart.*)—In the night following the 10th of August, one of the most devastating hurricanes that had ever been experienced visited Barbadoes. Not a single house was left uninjured, and the greater part were levelled with the ground. On the 11h it passed over the Islands of St. Vincent and St. Lucia, extending a portion of its influence to Martinique and islands to the N.W.. and to Granada on the South, but exhibiting its principal violence between $12\frac{1}{4}°$ and 14° N., or the parallels of Barbadoes and Martinique. On the 12th it arrived on the southern coast of Porto Rico; from the 12th to the 13th it swept over the South side of Hayti, and extended its influence as far southward as Jamaica. On the 13th it raged on the eastern portion of Cuba, sweeping in its course over large districts. The town of Aux Cayes, in Hayti, was almost destroyed by its force, and that of St. Iago de Cuba was very much damaged. On the 14th it was at Havanna and toward the West end of Cuba. On the 15th it proceeded north-westward, and on the 16th and 17th it arrived on the northern shoses of the Mexican Sea, in about the 30th degree of latitude, raging simultaneously at Pensacola, Mobile, and New

Orleans, where its effects were continued till the 18th. At New Orleans, on the 17th, it came on in dreadful gales, from N.E. to S.E., accompanied with torrents of rain. Almost all the shipping in the river were driven on shore, and very few of the smaller craft escaped total wreck. The back part of the city was completely inundated. The sugar-canes, above and below the city, were laid flat, and the loss was enormous. The gale was felt at Natchez, 300 miles up the river; and hereabout it spent itself in heavy rains, after having occupied a period of six days in the cycloidal course from Barbadoes.

At most of the islands, during the hurricane, the winds in the earlier part of the storm were from a northern quarter, and in its later periods from a southern quarter, of the horizon; from which it results, that the gyratory action was from *right* to *left*, as in the storms which pass to the northward of the great islands, and along the western coast of the ocean.

The distance passed over by the storm, in its passage from Barbadoes to New Orleans, is equal to 2,100 nautic miles. The average rate about 14 miles an hour.

Hurricane of 1830.—The storm which passed the city of New York, on the 17*th of August*, 1830, was there, and along all the coast northward of Cape Hatteras, considered as a *north-east storm*.—(*See Chart, Route VII.*)

It appears that this commenced at the Island of St. Thomas, in the West Indies, on the night between the 12th and 13th of August. On its progress, in the afternoon of the 14th, it commenced at the Bahama Islands, and continued during the succeeding night, the wind almost round the compass during the existence of the storm. On the 15th, in the Florida Channel, its effects were very disastrous. Without the strait, in lat. 26° 51′, long. 79° 40′, the gale was severe from N.N.E. to S.W. Late on the same day, off St. Augustin, it was equally so. At 20 miles North of St. Mary's, from 8 p.m. on the 15th, to 2 a.m. on the 16th, it was from an eastern quarter, then changed to S.W.

Off Tybee and at Savanna, on the night of the 15th, it changed to N.W. at nine a.m., on the 16th, and blew till twelve, On the 18th, at Charleston, the gale was from S.E. and East, till four p.m.; then N.E. and round to N.W. At Wilmington (N. Carol.) the storm was from the East, and veered subsequently to the West. In the vicinity of Cape Hatteras, at sea, the storm was very heavy from S.E., and shifted to N.W.

Early in the morning of the 17th, the gale was felt severely in the Chesapeake, from the N.E. Off the Capes of Virginia, on the 17th, lat. 36° 20′, long. 74° 2′, "a perfect hurricane," from South to S.S.E., from five a.m. to two p.m., then shifted to N.W.

Off Cape May, lat. 32°, long. 74° 15′, in the afternoon of the 17th, a heavy gale from E.N.E. Coast of New Jersey, same afternoon, heavy at N.E. Again, in lat. 39°, long. 73°, at E.N.E. In the same latitude, long. 70° 30′, a "tremendous gale," commencing at S.S.E., and veering to North.

Afternoon and evening of the 17th, at New York and in Long Island Sound, gale at N.N.E. and N.E. Off Nantucket Shoals, at eight p.m., severe at N.E. by E. In the night of the 17th, off Nantucket, and in the Gulf Stream, lat. 38° 15′, long. 67° 30′, "tremendous," commencing at South, and veering, with increasing severity, to S.W., West, and N.W. Peninsula of Cape Cod, in the night between the 17th and 18th, severe at N.E.; 18th, at Salem and Newbury, heavy gale from N.E. In lat. 39° 51′, long. 69°, severe from S.E., suddenly shifting to North. In lat. 41° 20′, long. 60° 25′, "tremendous hurricane" from N.N.E.

Off Sable Island, in the night of the 18th, lat. 43°, long. 59½°, "tremendous heavy gale," from South and S.W. to West and N.W. In lat. 43°, long. 48°, a severe gale from the South; the manner of change not reported.

This remarkable storm appears to have passed over the whole route above described in about six days, at an average of about 16 miles an hour; the duration of its most violent portion, at the several points over which it passed, may be stated at from seven to 12 hours; and the width of its track is supposed to have been from 150 to 200 miles.

"On the western part of the Atlantic Ocean, between the parallel of New York and the northern limit of the trade wind, the prevailing winds, for a considerable period, both previously and subsequently to the occurrence of this storm, were south-westerly, or from the southern quarter; and over the whole breadth of the Atlantic, on the route frequented by ships in the European trade, fresh south-western or westerly winds also prevailed at the same period, for many weeks. These facts are well established by numerous marine journals, which have been consulted in relation to this subject.

Of the vorticular or rotative character of the storm, striking evidence has been afforded by the journals of two ships, the *Britannia* and the *Illinois*, both bound from America to Europe; the particulars of which are fully given in the Exposition by Mr. Redfield.

In about a week after the storm last described, another occurred, which passed New York on the 26th and 27th of August, and which was, also, on this coast, a N.E. storm, of about three days duration. From the eastward of the Bahamas it appears to have passed northwardly between the Florida Stream and the Bermudas; and touching the American shore near Cape Hatteras, raged with great fury for about forty hours at each locality, as it swept the great central curve of the coast; and passing from thence, continued its course over George's Bank, in a north-easterly direction. It was evidently of greater compass, and slower progress, than the preceding storm, as is proved by a collation of the various reports of mariners; and its long duration, and its effects were almost equally violent.

The next remarkable series of hurricanes appear to have originated in the vicinity of the Windward Islands, near the close of September, 1830, and which, passing westward of the Bermudas, on a course nearly North, assumed thence a more easterly course, toward the southern edge of the Grand Bank of Newfoundland.—(*See the Chart, Route VII.*)

This storm was very disastrous. In lat. 20½°, long. 63°, it commenced, on September 22nd, at one p.m., and continued till half-p st six p.m., from N.E. and S.W. alternately. On the same day it passed through lat 22° 46′, long. 65°. At night, on the 30th, in lat. 26° 7′, long. 66½°, "very heavy," for five hours and a half. On the 1st of October it arrived at lat. 30° 38′, long. 63°; severe at S.E., shifted to N.W.; thence it was found in lat. 33°, long, 66½°; lat. 34° 9′, long. 66° 12′; lat. 35°, long. 68°; lat. 38°, long. 63°; lat. 38½°, long. 57°; lat. 40°, long. 61°; lat. 40° 25′, long. 58° 24′; lat. 41°, long. 55°, and very severe. By an average estimate of rates and distances, it appears to have proceeded at the rate of about 27 miles an hour.

The extensive hurricane of 1804, which swept over most of the Windward Islands in the West Indies, commenced at Martinique, on the 3rd of September, reached Savanna on the 7th, Boston on the 9th, and became a *snow-storm* on its arrival in the interior of New Hampshire.

The great gale of 1815 commenced at St. Bartholomew's on the 11th of September, and reached Rhode Island on the morning of the 23rd, where it was awfully destructive from the S.E., while in the south-eastern parts of Massachusets, it was then blowing at South; at New London from E. to S.E.; and at New York from North to N.N.W.

A S.E. storm in September, 1821—*see Chart, Tract VIII.*)—was expeperienced in the central parts of Connecticut, commenced blowing violently from E.S.E. and S.E., at about six p.m. on the 3rd of September, having been preceded by a fresh wind from the southern quarter, and flying clouds. It continued blowing in heavy gusts, and with increasing fury, till about 10 p.m., when the wind suddenly subsided. A calm or *lull*, of perhaps fifteen minutes' duration, ensued, but was terminated by a violent gust from the N.W., which continued till about eleven p.m., and then gradually abated. Much damage was sustained, and fruit-trees, corn, &c., were uniformly prostrated toward the N.W.

At New York the same storm was experienced, with at least equal violence, about three hours earlier than in Connecticut, but blowing from a more eastern quarter. In the north-eastern parts of Massachusets it was experienced some hours later; and at Providence, in Rhode Island, the storm was felt in the south-eastern quarter, but not severely; as was also the case in the south-eastern parts of Connecticut. In the N.W. portions of the latter state, and the adjacent towns of Massachusetts, the gale blew with its chief violence from the N.W. quarter, and the trees and corn were uniformly prostrated toward the S.E.

At New York the gale was from N.E. to East, and commenced blowing with violence at five p.m., continued with great fury for three hours, and then changed to W. More damage was sustained in two hours than was ever before witnessed in the city, the wind increasing during the afternoon, and *at sunset was a hurricane.* At the time of *low water* the wharfs were overflowed, the water having risen 13 feet in an hour. Previous to setting in of the gale, the wind was from S. to S.E., but changed to the N.E. at the commencement of the storm, and blew with great fury till evening, and then shifted to the westward.

The Cyclone of August 1870* took the following course. The calm centre passed Antigua on August 21 at 6^h 40^m a.m.; St. Kitts, at 9^h a.m.; St. Eustatius, at noon; St. Thomas, at 5^h 15^m p.m.; Turk's Island, August 22, at midnight; Long Island, August 23, at 5^h 30^m p.m.; Great Exuma, at 8^h 30^m p.m.; Nassau, August 24, at 4^h 30^m p.m.; Key West, about 8 p.m.; Panta Rassa, 5^h p.m.; Lake City, 6^h p.m.

The rate of progress of this cyclone in passing Antigua was 18 miles per hour. At St. Thomas it slackened to $13\frac{1}{2}$ miles per hour. In Florida it was only $8\frac{1}{4}$ miles per hour, and farther North only 5 miles per hour. This diminution in the progressive movement may probably be accounted for by the obstruction to the cyclone created by the hills in several of the islands over or round which it had to pass.

With regard to the diameter of the cyclone, Mr. Jahncke, of St. Thomas, who seems to have studied the whole phenomena most scientifically, estimated what he calls the "inner or furious part," at about 180 or 200 miles; the entire diameter was about 300 miles. Others, however, judging from the track marked on some of the islands by the damage done, estimated the diameter at only 50 or 60 miles. As to the central part, where a comparative calm existed that of course was formed by the meeting of opposite winds, just as near the equator a calm region prevails from the same cause. The diameter of this central cyclonic calm may be estimated; for if it lasted half an hour at any place passed by the cyclone, and the cyclone itself was moving forward at the rate of 18 miles an hour, the calm centre must have been about 9 miles in diameter.

The following shows the barometric depression and direction of wind at St. Thomas:—August 21, noon, 29.83, wind N.E.; 1 p.m., 29.57, N.N.E.; 2 p.m., 29.19, N.N.E.; 3 p.m., 29.17, North; 4 p.m., 28.85, N.N.W.; 5 p.m., 26.68, West; 5^h 35^m p.m., calm; 6 p.m., wind S.W.; 7 p.m., wind S.S.W. The barometer rose gradually after the calm.

This cyclone is stated to have been *divided into two portions* in passing the high ground (6,000 feet) of Puerto Rico. One part of the cyclone diverged to the N.N.W., and the other and larger portion proceeded onward W.N.W. The first part of the cyclone, Mr. Jahncke states, went towards Bermuda, and was encountered by the brig *Ada*, in lat. 26°, long. 69°.

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* Notes on West India Cyclones, by D. Milne Holme, L.L.D. "Journal of the Scottish Meteorological Society," January and April, 1873. See also page 261.

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It has been proposed by Mr. Piddington to make use of these storms, by taking advantage of the favourable wind which some portions of their circumference offer for expediting the voyage. This has also been proposed by Sir W. Reid, in his "Law of Storms." Mr. Piddington has given rules for this, in the regions he has made more particularly his study—the Indian and China Seas; but here the Hurricanes do not appear to travel at so great a speed as those of the Atlantic.

On Making Use of Hurricanes.

In order to benefit by the Hurricane, several conditions are necessary; and it need not be again insisted on, that any error or ignorance of the position of the centre of rotation may be fatal. The first consideration is, in what part of the circumference is the ship, and what is the bearing of its centre?—then, at what rate, and in what direction, is it travelling?—and is it so violent that the ship cannot weather it? All these things must be weighed well by the mariner, before he endeavours to lay his ship on that tack which will appear the best to forward his voyage. Should the storm be advancing in the same direction as his course, and the position of the ship be upon the advancing track, should it travel at a rate above that which he can keep up with, it is evident that it will pass over him, and the consequence need not be remarked upon. Should the vessel be upon the retreating edge of the Hurricane, it will, if travelling at 20 or 30 miles an hour, soon leave her, and then no advantage can follow.

Thus, to "Make Use of a Hurricane," several conditions are absolutely necessary: these are—"1. The ship must get into the storm precisely where the wind blows fair for prosecution of the voyage—which is quite a matter of chance. 2. If she happen to do so, she must, to derive benefit, regulate her speed exactly to that of the Meteor.—Can she do that at pleasure? There would be no difficulty in ascertaining the fact of her preserving her station, or not, by the wind remaining steady, or veering; but there is a necessity that would bind her, and which cannot be evaded with impunity when a high sea follows; she must carry a certain proportion of sail to prevent her from being pooped. Now this sail may give her a greater velocity than the Meteor at the time; hence she would run ahead of it. Again, the rate of the Hurricane may be greater than her utmost speed; hence she would be left behind."

Lieut. Macfarlane remarks that he has never seen a warning given to vessels, making use of the favourable wind on the Eastern side of a Cyclone in Northern latitudes, to avoid the storm at its point of recurving from N.W. to N.E. A vessel steering to the Northward, having the wind aft, may possibly keep up with the progress of the Hurricane; but, on its reaching its point of recurving, would be in danger of having the vortex pass over her.[1]

[1] From remarks on the Hurricane of August, 1873, by Captain H. Toynbee, F.R.G.S., &c. See "Quarterly Journal of the Meteorological Society," No. 9, January, 1874.

CHAPTER VIII.

DEPTH, TEMPERATURE, ETC., OF THE OCEAN.

Sounding.

It was formerly considered that the lower bed of Ocean-water was, from the pressure and weight of the incumbent masses, so dense as to be rather of the character of solid matter than fluid. However, a few facts will serve to dispel such a notion. The descent of the deep-sea lead is quite as rapid at a depth when the weight of water above it must be enormous, as at a less distance from the surface, and no tendency to obstruct its downward passage can be observed at the greatest depth yet attained, except that which is due to the friction of the sounding-line. Again, the whale fishers frequently find their prey descend perpendicularly to such an enormous depth, that the idea of an impenetrable density, or even of any considerable increase of it, cannot for a moment be entertained.

It is true that the pressure increases with the depth, to the amount of 15 lbs. upon the square inch for every 34 ft. in depth; but the density is not thereby sensibly increased, owing to the incompressibility of water; so that neither the buoyant force, nor the resistance to the motion of any body, are materially increased from the surface to the bottom. At the depth of 3,000 fathoms, for instance, the pressure upon a square inch is nearly 8,000 lbs., but the column of water of 18,000 ft. is only shortened about 160 feet.

At $2\frac{1}{2}$ miles depth the increase of *Density* is not equal to the difference in the density between fresh and salt water. The late Dr. W. A. Miller calculated it would be at that depth equal to one-forty-seventh of its volume, while sea-water, at the mean specific gravity of 1·027, is one-thirty-seventh heavier than fresh water. There is, therefore, not the slightest difficulty in understanding that the Sounding-lead or Telegraph-cable should sink uniformly from the surface to the greatest depths, and not only such heavy weights, but even that the delicate organisms and remains of microscopic animals which have lived on the surface, may quietly sink to the bottom, and there add to the immense deposits which are now shown to exist everywhere over the sea-bed.

Among the earliest experiments, perhaps the first, of these deep-sea soundings, is that recorded by Captain (afterwards General) Edward Sabine, who, on November 13th, 1822, when about midway between the Caymans and Cape Antonio, in the Caribbean Sea, sank a cylinder and obtained the temperature at a depth exceeding 1,000 fathoms. This was followed by Capt. Wauchope, in H.M.S. *Eurydice*, who gained water from a depth of about 1,300 fathoms. Following that, Captain (afterwards Admiral Sir Francis) Beaufort thought that he attained a depth nearly the same in the Strait of Gibraltar; but his sounding has since been shown to be fallacious.

After this, many experiments were tried, with more or less success, but there can be little doubt but that many of the early results are not trustworthy, and are greatly in excess of the truth. At first it was not always tried to recover the lead, and the line employed was of very inferior character; moreover, it was thought that at very great depths the friction of the water was sufficient entirely to arrest the descent of the weight.

On August 8th, 1848, Captain Barnett, R.N., when between the Azores and Newfoundland, tried a line of *iron wire*, varying in size from Nos. 1 to 5, 4,000 fathoms in length, wound on a small reel, the smallest part first, with a weight attached of 61 lbs., a hand-lead would probably have been better. It broke at 2,000 fathoms, which ran out in 20 min. 53 sec. This experiment was suggested by Lieutenant Mooney.

The greatest length of wire line sent down in the Atlantic was that effected by Lieut. J. C. Walsh, in the U.S. schooner *Taney*, on November 15th, 1849, to a depth of more than 5,700 fathoms (34,200 ft., or more than 6 statute miles), without finding bottom, as was supposed, in lat. 31° 59′ N., long. 58° 43′ W. The wire broke at this length, 5,700 fathoms, at the reel, and was lost. It preserved the exact plumb-line throughout the sounding; there was a steady, uniform increase of weight and tension; no check whatever being found at any instant of its descent. This experiment, however, is of a negative character; for it is evident that the wire would be carried down and run out by its own weight.

One of the earliest specimens of *bottom* obtained at great depths was by Comm. C. H. Davis, U.S.N., in October, 1845, when greenish mud was brought up in the Stellwagen cup from a depth of 1,350 fathoms in the Gulf Stream.

The possibility of obtaining a knowledge of the great depth of the Ocean being established, the Government of the United States first commenced utilising this knowledge, on a more extended scale, by the despatch of the brig *Dolphin*, on her well-known cruise, under the command of Lieutenant-Commanding Lee, U.S.N. The result of this voyage was the disproof of many of those shoals and dangers which had long held a place on our Charts, to the continual annoyance and embarrassment of navigation. This cruise of the *Dolphin* was confined to the North Atlantic, except a portion in South latitude about Fernando Noronha, and the Rocas. The *Dolphin* was again sent out under the command of Lieut. O. H. Berryman, with the same object.

The soundings taken in the *Dolphin* were made with the thin sounding line, seven-hundredths of an inch in diameter, and with one or two 32 lb. shot. It has been questioned, and it certainly seems with reason, whether the evidence upon which the deeper soundings rest is quite valid, as before alluded to.

There are two methods of estimating the true depth obtained: the one by the rate of descent of the line, which has been carefully estimated from the numerous experiments made, but which estimate, of course, is liable to the vitiating influence of under-currents; and the other by Sounding Machines. In sounding with a line of seven-hundredths of an inch in diameter, the velocities of the descent diminish, with one 32 lb. shot, from 8·83 ft. per second at 50 fathoms, to 2·84 ft. at 1,000 fathoms, and 2·09 ft. at 2,000 fathoms; and with two 32 lb. shot, from 12·5 ft. per second at 50 fathoms, to 3·48 ft. at 1,000 fathoms, or 2·99 ft. at 2,000 fathoms; these figures have, however, been much modified by later experience.

A very important consideration is—what effect would an under-current have on the line passing through it?

It is certain that a current must act upon the *bight* of the sounding-line after the weight has passed through it, and it may operate in swerving the weight itself from its perpendicular descent at great depths. Again, the force exerted by a current against the *bight* of the sounding-line will have the effect of taking the twine off the reel at considerably more than *double* its own velocity.

From these considerations it was supposed that the depths stated, even when it is certain that the bottom has been reached, are in excess, and this, too, in an uncertain degree. But this source of error was much over estimated. At that time there was no experience by which a knowledge would be acquired as to the movements of the water at any considerable depth. It is now well ascertained that any movement which would greatly affect the registered depth ceases at a comparatively short distance below the surface, and that, although the lower strata of ocean waters must have some circulatory movement, this motion is so slow as to be inappreciable by any means hitherto applied to estimate it on the open Ocean. In laying the various Telegraph cables across the Atlantic, the strain it exerts is most carefully and continuously watched by its action on a dynamometer, and the angle it makes with the surface of the sea also well looked at, and these evidences accord so nearly with the calculations that would be made for water in a quiescent state that it is now beyond controversy, that rapid motion is confined to the upper strata.

To obviate these sources of error or doubt, a line of fine sewing silk has been proposed, but we have not heard of any trial with this.

Previous to the deep-sea soundings obtained during the cruise of H.M.S. *Challenger*, the most important, and probably the most accurate, soundings that had yet been taken, were those which originated in the question of connecting Europe with America by the Submarine Electric Telegraph. The first of these series was obtained by Lieutenant-Commanding O. H. Berryman, in the U.S. steamer *Arctic*, in August, 1856. The line of deep-sea soundings, twenty-four in number, being on the Great Circle joining Valentia in Ireland with St. John's, Newfoundland. The depths were estimated by a Massey's Sounding Machine, and a similar one by M. Lecointre, and the line was wound in by a small engine on the deck.

The same round was gone over with the same object, by Lieutenant-Commanding James Dayman, R.N., in H.M.S. *Cyclops*, in June and July, 1857, and thirty-four soundings were obtained, the depths being estimated by the length of line and by the machine as heretofore. The sinker employed was self-detaching upon touching the bottom, and in a quill attached to the support, bottom was brought up in almost every instance in small quantities. The nature of this bottom is alluded to hereafter, and the very interesting features it first brought to light are there related.

The first failure of the Atlantic Cable having suggested the necessity of shorter sea sections of the cable, Commander Dayman was despatched in H.M.S. *Gorgon*, in September and October, 1858, and obtained soundings between Newfoundland, the Azores, and England, gaining much experience as to the best methods of sounding, and also of estimating the depths.

Another project for the Telegraph cable, to pursue a more Northern route, having arisen, in July, 1860, H.M.S. *Bulldog* started under the command of Captain Sir Leopold M'Clintock, of Arctic celebrity, and obtained the depths between the Færoe Islands and Iceland, and thence to Greenland and Labrador, with most satisfactory results.

The apparatus used in ascertaining the depth and obtaining specimens of the bottom has been gradually modified to obviate the difficulties that have been encountered. These chiefly refer to the means of detaching the sounding weights, and in the form of the apparatus which secures a portion of the bottom when it is attained. At first a peculiar pair of claws or hooks, the invention of Mr. Bonnici, were used. The weight or spherical shot was suspended to these hooks, and when it touched the bottom they detached and set the weight free. This, in various forms, was used in the earlier experiments. But when the *Bulldog* was equipped, another description of sinker and scoop were used.

The soundings were obtained generally by cod-line, with an iron sinker of 118 lbs., the line and sinker being lost at each sounding. The depth being thus obtained, a machine for bringing up the bottom was next sent down by a stronger line, and a self-detaching tubular weight or sinker of 100 lbs. The apparatus which brought up specimens of the bottom was a double scoop, 5 inches in diameter, kept open so long as the weight is dependent on it, but forcibly closed by means of a vulcanised india-rubber band the moment it is detached by touching the bottom. This brought up specimens in large quantities. It was contrived by Dr. Wallich and Mr. Steil, the assistant engineer, and has been called the Bulldog Machine.[1]

The subject of the Atlantic Telegraph being still of great importance, and it being desirable that the apparent sudden dip from 550 to 1,750 fathoms on the parallel of 52° 15′ N., at about 170 miles West of Valentia, found by Capt. Dayman in 1857, should be avoided, H.M.S. *Porcupine* was despatched, in June, 1862, to make a further examination. Mr. Hoskyn, R.N., made a very careful examination of the edge of the Bank of Soundings, between the parallels of 51° and 54°, as well as of that between Iceland and Rockall. It will be needless to recapitulate this work—the Charts are by far the best guide; but it may be said that no such sudden dip or abrupt precipice was found, the steepest incline being a difference of level of 3,060 ft. in $2\frac{3}{4}$ miles, or about 19 ft. in 100 ft.

One important result of this expedition was the discovery of the unsuspected bank, which lies 120 miles West of Galway Bay, and has been named *Porcupine Bank;* the least depth found was 82 fathoms. This bank is about 40 miles in extent, with 150 to 180 fathoms to the Eastward of it, while to the Westward it deepens rapidly to 300, 500, and 1,500 fathoms.

Several other expeditions were afterwards organised with a view to obtaining an exact knowledge of the nature of the sea-bed and of the depth of the Ocean. The voyage of H.M.S. *Hydra*, Capt. P. R. Shortland, R.N., and that of the *Lightning*,[2] in 1868, under Dr. Carpenter and Dr. Wyville Thomson, may be cited as the most prominent.

In 1869, H.M.S. *Porcupine* was sent out to continue these interesting researches, and under her commander, Captain Calver, R.N., the apparatus used was brought much more nearly to perfection.

As it was considered advisable by Captain Calver that provision should be made for carrying on sounding and dredging at either end of the ship, a "derrick" with an "accumulator"[3] was rigged out both at the bow and the stern.

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[1] The full particulars of this machine, and of the whole subject of deep-sea sounding, are to be found in Dr. Wallich's excellent work on the Atlantic Sea Bed.

[2] Dr. Carpenter says, H.M.S. *Lightning* has a further historical interest, as one of the *first two* steam-vessels built in 1825 for the Royal Navy.

[3] The Accumulator is composed of a number of strong india-rubber springs combined at their extremities; and its use is two-fold:—*first*, to indicate by its elongation any excessive strain upon the sounding or dredging line, which passes through the block; and *second,* to ease off the suddenness of such strain, and give time for the action by which it may be relieved. This is specially valuable in deep-sea sounding and dredging when the vessel is pitching; for the friction of 2 or 3 miles of immersed line is so great as to prevent its yielding to any sudden jerk, such as that given to its attached extremity by a vertical motion of a few feet when the vessel rises to a sea. And it is absolutely needful when dredging is carried on from a vessel as large as the *Porcupine*; since, whenever the dredge fouls, the

An ample supply of sounding-line was provided, specially manufactured for the purpose: this line, made of the best Italian hemp, although no more than 0·8 inch in circumference, bears a strain of 12 cwt.

For the deeper soundings, the *Hydra* Apparatus was employed. The essential principle of this is the same with that of all the other forms of deep-sea sounding apparatus now in use; the weights or sinkers being so attached as to be let go by a mechanical contrivance when it touches the bottom, so that the line is relieved from the duty of raising them to the surface,—the rod or tube alone, with the water-bottle and thermometers, being brought up by it. For soundings at depths of from 1,000 to 1,500 fathoms, *two* sinkers, each of 112 lbs., were employed; and for yet deeper soundings *three* were used. The peculiarity of the *Hydra* Apparatus consists partly in the mechanical contrivance for the detachment of the sinkers; and partly in the construction of the rod which carries them, this being a strong tube furnished with valves that open upwards, so as to allow the water to stream through it freely in its descent, whilst they enclose the mud or sand into which the tube is forced on striking the bottom before the sinker is detached.

The important results of this expedition in the seas N.W. of the British Isles will be briefly alluded to presently, but the topic is too wide for full notice here.[1]

The most extensive deep-sea exploring expedition was conducted on board H.M.S. *Challenger*, between December, 1872, and May, 1876, a period of three years and five months, three years of which time were spent between 40° N. and 40° S. of the Equator. Elaborate investigations were made in each of the great Oceans of the globe, and it may be interesting to record that during this lengthened voyage the ship sailed and steamed over upwards of 68,000 miles, that nearly 400 deep soundings were taken, of which two were over 4,000 fathoms, nine between 3,000 and 4,000 fathoms, 168 between 2,000 and 3,000, 124 between 1,000 and 2,000, the remainder being under 1,000 fathoms. There were 360 observing stations established, at each of which, as far as circumstances would permit, the exact depth was determined; samples of the bottom from 1 oz. to 1 lb. were obtained; samples of water from the bottom and from various depths were procured for physical and chemical examination; the bottom and intermediate temperatures were determined; at most stations a fair sample of the bottom *fauna*, and of that of intermediate depths was obtained by the dredge or trawl variously adjusted; Atmospheric and Meteorological observations were made; the direction and rate of the surface (and in one or two cases of sub-surface) currents were

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momentum of such a vessel, however slowly it might be moving through the water, would cause the dredge-line to part, if the strain were sudden instead of gradual.

[1] See Proceedings of the Royal Society, vol. xviii., No. 181, for a full report of the voyage.

determined. For deep-sea sounding a modification of the *Hydra* machine was used, the invention of Lieut. C. W. Baillie, R.N.; many improvements in the means of obtaining water for analysis from great depths were also brought into use, including the "slip water bottle" and Buchanan's "Stopcock water bottle" (named after J. Y. Buchanan, M.A., chemist of the Scientific Staff). In the North Atlantic 130 soundings were taken and other observations made (December 30th, 1872, to August 30th, 1873), between Portsmouth and Tenerife, Tenerife and St. Thomas in the Caribbees, St. Thomas and Bermuda, Bermuda and Halifax, having crossed the Gulf Stream in a North-Westerly direction, Halifax and Bermuda, Bermuda and Madeira, Madeira and Bahia, crossing the Eastern portion of the Guinea Current in a Southerly direction. On the return voyage in 1876, crossing the Equator in about 14° 25′ W., on April 7th, Spithead was reached on 24th of May. The work of Sir Wyville Thomson[1] will supply further particulars.

Depth.

For a comprehensive view of *Ocean Depths* we must refer the reader to the illustrative diagrams in the various Directories, as a verbal account of the depths obtained in these and other voyages would convey but little intelligible information. Of course the question does not affect navigation, however interesting it may be to the physical geographer.

The form of the sea-bed of the Atlantic Ocean (North and South) is thus described by Sir Wyville Thomson :—

" Combining our own observations with reliable data which have been previously or subsequently acquired, we find that the mean depth of the Atlantic is a little over 2,000 fathoms. An elevated ridge, rising to an average height of about 1,900 fathoms below the surface, traverses the basins of the North and South Atlantic in a meridional direction from Cape Farewell, probably as far South at least as Gough Island, following roughly the outlines of the coasts of the Old and New Worlds.

" A branch of this elevation strikes off to the South-Westward about the parallel of 10° N., and connects it with the Coast of South America at Cape Orange, and another branch crosses the Eastern trough, joining the continent of Africa probably about the parallel of 25° S. The Atlantic Ocean is thus divided by the axial ridge and its branches into three basins : an Eastern, which extends from the West of Ireland nearly to the Cape of Good Hope, with an average depth along the middle line of 2,500 fathoms; a North-Western basin, occupying the great Eastern bight of the American Continent, with an average depth of 3,000 fathoms; and a gulf running up the Coast of South America as far as Cape Orange, and open to the Southward, with a mean depth of 3,000 fathoms."[2]

[1] Voyage of the *Challenger*.—The Atlantic.—2 vols. Macmillan, 1877.

[2] Voyage of the *Challenger*, vol. ii., pp. 290—291.

South Atlantic Ocean.

The experiments that have been made for ascertaining the depth of the South Atlantic have been much less numerous than those to the North of the Equator, and those recorded are much less conclusive. In the North Atlantic Memoir, 1879, pages 812—821, the particulars and list of the soundings which have been made North of the Equator, have served another purpose in Atlantic Hydrography—they have disproved the existence of by far the greater number of reported shoals and dangers, to test which many of them were made. In the South Atlantic, on the other hand, these vigias and vaguely-determined rocks are very few in number, and the deep sea lead has not been completely applied to their verification or disproof.

Notwithstanding the former careful experiments which have been made on the South Atlantic, our conviction is, that they are all, or almost all, of a negative character: that is, that the enormous length of line run out in some cases does *not* show the true depth of the ocean.

This doubt we have expressed and assigned reasons for in other places, and it may here be briefly stated that the lead, in most cases, has apparently drawn out the line at very irregular intervals, which a spherical shot would not do, and it is more than probable that the bottom has been reached very much within the depth apparently shown by the sounding line. For if it should pass through one or more opposing submarine streams, which it is tolerably certain that it would do in some greater or less degree, this movement of the water would carry the line off the reel with greatly increased velocity, or, in many cases, with a speed quite equal to that with which it would be drawn by the sounding weight. Also, that the impact of a moving mass of water upon a line whose sectional area is equal to 50 square feet per 1,000 fathoms would be vastly greater than the force exerted upon it by a sounding weight, which would consequently be drifted away by the line. The friction of a tortuous line, its buoyant power, and other reasons also, may be brought forward to invalidate the conclusions drawn from these experiments.

It may therefore be stated, that when the line at these great soundings does not run out with a regularly decreasing rate, some other cause must be in operation to cause this irregularity, and that it does not show the true depth. Besides this, the *exact* drift of the ship or boat should be taken into account, as any motion from the true perpendicular will cause the resulting depth to be not the hypothenuse of a right-angled triangle, whose base is equal to the drift, but the perpendicular to the base and a *curve* formed by the sounding line.

In the North Atlantic Memoir, above quoted, this subject is given more at length, and details of numerous experiments will there be found, including the results obtained in the most important voyage that has yet been undertaken in connection with this branch of science, that of H.M.S. *Challenger*.

Pacific Ocean.

It is only within the last few years that any serious attempts have been made to explore the depths of the Pacific Ocean. Of the principal expeditions for this purpose may be mentioned those of the U.S. ships *Tuscarora* and *Alaska;* H.M. ships *Challenger* and *Alert*, and the steamer *Dacia*, and the German war-vessel *Gazelle.* But notwithstanding the numerous soundings taken from these vessels, before we can form an accurate idea of the conformation of the bed of the Pacific Ocean, many more observations are necessary.

Dr. Petermann has endeavoured, by uniting all the available observations, to form a chart of the bed of the Pacific, by which it would appear that it is divided into two regions by an arc of a Great Circle joining San Francisco and the East Coast of New Zealand. The region East of this line seems to be moderately even, with depths of between 2,000 and 3,000 fathoms. The Western region, on the contrary, has a number of deep depressions, and here a greater depth has been found than in any other part of the world.

In the North Pacific the *Tuscarora* attained the greatest depth yet found, 4,655 fathoms, or over 5¼ *statute miles*, in lat. 44° 55′ N., long. 152° 30′ E., to the S.E. of Urup Island, one of the Kurile Islands. The greatest depth found by the *Challenger* was 4,575 fathoms, in lat. 11° 24′ N., long. 143° 16′ E., to the S.W. of the Mariana or Ladrone Islands; the bottom was composed of red clay, with a thick top layer of pumice and manganese; the temperature being 33·9°. The greatest depth found in the South Pacific was 2,750 fathoms, in lat. 7° 25′ S., long. 152° 15′ W., to the S.E. of Starbuck and Malden Islands. With a heavy sounding weight it takes about 1¼ hour for the line to reach the bottom in a depth of 4,500 fathoms, and 35 minutes in 2,500 fathoms.

Temperature.

Up to the latter part of 1869, all enquiries into deep-sea Temperatures appear to have been alike deceptive and unsatisfactory, as the indications obtained, even by the most careful observers, and best of instruments, were utterly at variance with any theory that could associate Temperature as a leading cause of the circulation of the waters of the Ocean. Thus Temperatures that theory would expect to find—say 30° Fahrenheit—at great depths, were made to appear to be 42° or 43°, the disparity being less as the depth diminished.[1]

This was caused by the elasticity of the glass bulbs yielding to the pressure of the water, though they recovered their normal condition on reaching the surface, so that the effect of this pressure still remained unknown.

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[1] Mr. Prestwich has collected these series of observations with a view to the geological bearing of the subject, and they will form a valuable supplement to those collected since 1868. See "Tables of Temperature of the Sea at Various Depths below the Surface, taken between 1749 and 1868." Collated and reduced with notes and sections, by Joseph Prestwich, F.R.S., F.G.S. (from the Proceedings of the Royal Society, No. 154, 1874.)

It may be said that about this time most of the leading Governments had determined, if possible, to ascertain the real Temperatures of the sea. The efforts of the American, Russian, and German Governments in this direction are well known, whilst the authorities of our Hydrographic Office applied to the Royal Society on the subject, and at their desire, towards the end of 1869, an hydraulic machine was constructed in which to test the effect of pressure on the Thermometers employed. A standard registering Thermometer, shielded in a stout glass cylinder, was therefore placed in the water, together with one of the deep sea Thermometers, and the water was compressed to an extent equal in pressure to about 3 miles of depth in the sea. All previous suspicions of error were now fully confirmed, as the pressure on the bulb was found to cause an error of 12° to 13° Fahrenheit at this depth.

To remedy this defect, a glass shield was suggested by Dr. W. A. Miller, then Vice-President of the Royal Society, as a protection to the bulb, and from which the well-known Miller-Casella Thermometer has been named.[1]

More full details regarding this interesting question will be found in the writings of Dr. Carpenter.[2]

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[1] The following, from the Proceedings of the Royal Society, No. 113, 1869, will further explain the interesting result:—

Self-Registering Thermometers adapted to Deep Sea Soundings.—" Several of these thermometers have been prepared for the purpose with unusual care by Mr. Casella, who has determined the conditions of strength in the spring and diameter of tube most favourable to accuracy. He has also himself had an hydraulic press constructed expressly with the view of testing these instruments.

" The expedient adopted (as suggested by Dr. Miller) for protecting the thermometers from the effects of pressure, consisted simply in enclosing the bulb of such a Six's thermometer in a second or outer glass tube, which was nearly filled with alcohol, leaving a little space to allow of variation in bulk due to expansion. The spirit was heated to displace part of the air by means of its vapour, and the outer tube and its contents were sealed hermetically.

" In this way, variations in external pressure are prevented from affecting the bulb of the thermometer within, whilst changes of temperature in the surrounding medium are speedily transmitted through the thin stratum of interposed alcohol.

" Notwithstanding the great pressure to which these instruments had been subjected, all of them, without exception, recovered their original scale-readings as soon as the pressure was removed."

In sea-water of specific gravity 1·027, the pressure in descending increases at the rate of 280 lbs. upon the square inch for every 100 fathoms, or exactly one ton for every 800 fathoms.

[2] " Further Enquiries on Oceanic Circulation." By William B. Carpenter, M.D., LL.D., F.R.S., &c., &c.—(Proceedings of the Royal Geographical Society, vol. xviii., No. iv., 1874).

" On the Temperature of the Deep-Sea Bottom, and the Conditions by which it is Determined." By Dr. Carpenter, M.D., LL.D., F.R.S., &c.—(Proceedings of the Royal Geographical Society, vol. xxi., No. iv., 1877).

Surface Temperature.

Speaking roughly, the mean annual surface Temperature of the Atlantic, is about 75° Fahrenheit at the Equator (between 10° N. and 10° S.). Between 10° N. and 38° N. it is 70°. Northward of 38° N. the *Summer* Isotherms (lines passing through places of equal mean temperatures) of 54½°, 50°, and 45½°, turn sharply Northwards to the East of the Banks of Newfoundland: diverging one from another and from the summer Isotherms of 60° at intervals which are pretty nearly equal almost as far to the East as the meridian of 30° W.; but then again trending strongly to the North, so that the summer Isotherm of 54½° crosses the parallel of 60° N. before (by a slight trend to the South) it passes through the Pentland Firth. Thence, crossing the North Sea, this Isotherm passes along the Coast of Norway as far as Tromsö (very near the parallel of 70°), and then turns Southwards along the land, keeping within the coast-line of Russian Lapland, and passing across the narrow entrance of the White Sea. Still further North we find the summer Isotherms of 41° and 36½° showing a nearly West to East direction until they have passed the meridian of 10° W., and then suddenly turning Northwards; the line of 36½° passing up to the West of Spitzbergen as far as 82° N., and also extending itself irregularly Eastwards along the parallel of 75° as far as Nova Zembla.

The course of the *Winter* Isotherms of 45½°, 41°, 36½°, and 32°, as shown in Dr. Petermann's chart, is no less significant; for they all turn sharply to the North on the Eastern side of the Banks of Newfoundland, cross the entrance of Baffin's Bay, and then keep a course of general parallelism to the Coast of Greenland, crossing the meridian of 30° W. at almost equal intervals. The Winter Isotherm of 45½° follows almost exactly the course of the Summer Isotherm of 54½° as far as the Shetland Islands; but it then turns back on itself so as to form a loop, passing Southwards along the Western Hebrides towards Belfast. Finally, the Winter Isotherm of 32° proceeds along a similar course from the Bank of Newfoundland to the Northernmost point of Iceland, and then onwards towards Jan Mayen, beyond which it has not been traced.

In the above, it will be remarked that the surface Temperature North of 40° N. is much higher on the Eastern than on the Western side of the Atlantic, both in summer and winter; this is due in a great measure to the prevalent South-Westerly winds, blowing the warmer water in a North-Easterly direction, and also, as will be hereafter explained, to the general oceanic circulation.

It is beyond the scope of this work to enter more into detail as to the power of the various surface currents in distributing heat over the Ocean; but that this heated water does not extend to any great depth will be understood from the following remarks on sub-surface Temperatures. We must also refer the reader to the earlier portions of this book, where in the description of the

Currents, some further particulars of the depth to which their warm water extends will be found.

Sub-surface Temperature.

Taking a general view or mean for the year of the water in Mid-Atlantic, in a section taken nearly North and South we find the Temperatures as follows:—

Temperature Section (North and South) of Mid-Atlantic in deg. Fahrenheit.

	60° N.	55° N.	47° N.	38° N.	22° N.	Equator.	20° S.	38° S.
At the Surface	50	57	63	70	70	75	70	54
50 fathoms	50	56	62	65	70	75	69	53
100 ,,	49	53	55	64	69	70	65	52
200 ,,	48	50	51	52	55	48	45	45
500 ,,	45	46	47	45	44	39	38	37
1000 ,,	40	38	38	37	38	38	36	36
2000 ,,	..	37	36	36	35	34	33	34
Bottom	..	..	..	35	35	32	33	33
Depth of bottom	800 fms.	1500 fms.	2000 fms.	2700 fms.	2700 fms.	2500 fms.	2200 fms.	2200 fms.

It may now be confidently stated as a general fact (1) that over not only the Temperate but also the Intertropical portions of the oceanic area, a bottom-temperature prevails of between 32° and 35·5° Fahr.; whilst within the Polar areas this temperature falls to 28°. Further, it may be asserted (2) that this vast oceanic basin, whose average depth may be estimated at about *two miles and a half*, is occupied to within 400 fathoms of its surface (save in the exceptional case in the Gulf Stream region), by water whose temperature is below 40° Fahr.,—this cold water actually coming up nearer to the surface in the Equatorial Atlantic (as several of the older observers had noticed) than it does beneath the Tropics.

Were the bottom of the Atlantic a perfect basin, the bottom temperatures might remain the same across its whole breadth, but, as described in page 216, and shown in the diagram, the Atlantic sea-bed is divided by ridges into several basins. Now, it has been found that, however deep a basin or depression of the sea-bed may be, yet that the temperature of its water at the bottom will not be less than that which can pass across its ridge, from outside sources. This was observed by Captain Chimmo in the Sulu Sea, a striking example, where at and below a depth of about 300 fathoms (the depth of the enclosing barrier) to the bottom, at 1,778 fathoms, the temperature remained uniform at about 50° Fahr., whereas in the China Sea the flow from the Polar to the Equatorial regions of cold water reduced the temperature, at a depth of 416 fathoms, to 41°, and at the bottom (1,546 fathoms) to 37° Fahr., 13° Fahr. less temperature than at the *deeper* station of the Sulu Sea. The same system holds good in such large areas of depressed sea-bed as those in the North Atlantic, and it has been found that the bottom temperature is never below 35·3° Fahr. in the Eastern basin, however deep the water may be; nor below 34·6° Fahr. in the North-Western. The only place on the Atlantic sea-bed where the water has been found below 32° (freezing point of fresh water) in the Temperate or Tropical regions, is in the depression between the Coast of South America and the central ridge to the South of the Equator. In conclusion, it may be remarked, that these deep-sea Temperature soundings have been of great practical utility to telegraph engineers in regulating the size of the wire, &c., in deep-sea cables, and they will be alluded to presently as affecting the question of Circulation.

Though but little *heavier*, the South Atlantic is decidedly *colder* than the North by nearly 5°, their mean Temperatures being 71·6° and 66·7° respectively, and that this difference is tolerably uniform parallel for parallel is evident by the thermal curves that have been projected.

During the voyage of H.M.S. *Challenger*, a great deal of attention was devoted to the study of the Temperature and specific gravity of the water of the Atlantic Ocean, as obtained on the surface and from various depths, a full account of which will be found in the interesting work by the late Sir C. Wyville Thomson (The Voyage of the Challenger, 2 vols., 1877), and from which the following few extracts are taken :—

Bearing in mind that at a certain depth below the surface, varying only slightly in different regions, there is a thick belt of water at a nearly uniform temperature of 4° to 5° C. (39° to 41° F.), it is evident that the much higher temperature of the surface-layers must be due, for each position, directly or indirectly to the heat of the sun. Normally the surface-temperature would attain its maximum near the Equator, and would decrease uniformly towards the Poles; and the very abnormal distribution of temperature which actually exists must depend upon some disturbing cause or causes. That several such causes come into play, and many complicated combinations of these causes, there appears to be little doubt; but one disturbing cause seems to be so paramount, so sufficient in itself to account for the observed phenomena, that I do not think it necessary in this preliminary sketch to pursue the inquiry beyond it.

The comparative thinness of the belt of warm surface-water in the Equatorial region is at first sight remarkable, and has given rise to a good deal of speculation. The phenomenon is essentially a continuation to the North of the Equator of Southern conditions, and the small effect of the vertical sun in raising the temperature to any depth below the surface is doubtless due to the removal of the heated layer as soon as it is formed by the Trade Winds and their counter-Currents, and to the rapid abstraction of heat in the formation of watery vapour.

One of the best-marked and most important phenomena of the distribution of Temperature in the upper layers of the Atlantic is the steady increase in the volume of warm water from the South, Northwards. For example, between Monte Video and Tristan d'Acunha we find the Isotherm of 7° C. (44·3° Fahr.) at an average depth of about 250 fathoms, along the Equator at under 300 fathoms, between Teneriffe and Sombrero it occurs at a depth of 500 fathoms, and between Bermuda and Madeira at about 600 fathoms; the principal accumulation of warm water, at depths below 400 fathoms in the North Atlantic, is to the Eastward.

Shallow as the stratum of water forming the Ocean is—a mere film in proportion to the radius of the earth—it is very definitely split up into two layers, which, so far as all questions concerning Ocean movements and the distribution of Temperature are concerned, are under very different conditions. At a depth varying in different parts of the world, but averaging perhaps 500 fathoms, we arrive at a layer of water at a temperature of 40° F., and this may be regarded as a kind of neutral band separating the two layers. Above this band the temperature varies greatly over different areas, the Isothermobathic lines sometimes tolerably equally distributed, and at other times crowding together towards the surface, while beneath it the temperature almost universally sinks very slowly and with increasing slowness to a minimum at the bottom.

One of the most singular results of these investigations is the establishment of the fact that all the vast mass of water, often upwards of 2,000 fathoms in thickness, below the neutral band, is moving slowly to the Northward; that, in fact, the depths of the Atlantic, the Pacific, and the Indian Oceans, are occupied by tongues of the Antarctic Sea, preserving in the main its characteristic temperatures. The maintenance of a low temperature while the temperature of the floor of the Ocean must be higher, and that of the upper layers of the sea greatly higher, is in itself a conclusive proof of the steady movement of the water from a cold source; and the fact that the temperature of the lower layers of water, both in the Atlantic and the Pacific, is slightly but perceptibly raised to the Northward, while the continuity of every layer with a corresponding layer in the Southern sea can be clearly traced, indicates the Southern position of that source.

Dr. Carpenter says:—There is a marked difference between the Bottom-Temperatures of the *Western* and of the *Eastern* portions of the South Atlantic sea-bed; that of the latter, between Tristan d'Acunha and Ascension Island, nowhere falling below 35·3°, though between Ascension Island and the Equator there is a narrow but deep stratum of water ranging downwards between 35° and 32·7°, which must obviously be an extension from the Antarctic basin. This extension is clearly traceable on the line between Tristan d'Acunha and the Cape of Good Hope; the Bottom-Temperature ranging downwards to 32·9°, and a considerable thickness of abyssal water having a temperature below 35°. Now this distribution of abyssal temperatures is precisely conformable to the contour of the sea-bed; for the "Dolphin Ridge," which divides the North Atlantic into an Eastern and a Western basin, seems to have its parallel in the "Challenger Ridge" of the South Atlantic; the two being connected by an oblique ridge that lies about half-way between the Guiana Coast and the opposite Guinea Coast. And while the *Western* basin is in free communication with the Antarctic, so that its glacial water flows Northwards until checked by the "Connecting Ridge," the deep communication of the Antarctic with the *Eastern* basin is so far interfered with, that very little of the glacial water of the former can find its way along the bottom of the latter, which consequently receives only the coldest that can flow over the ridges.

The question of the dynamical effect of Temperature on the Ocean, and of its relation to the density of the water, has been carefully discussed in the United States Meteorological Bureau, and Capt. Maury endeavoured to ascertain by direct experiment what the amount of this effect was. He had delicate Thermometers made, by which to estimate the relative increase in volume of sea-water with the well-ascertained increase in mercury at varying temperatures, and thus to arrive at some hitherto occult law which might govern the motion of the great mass of ocean water, or of some portion of the changes which are at present hidden in the greatest obscurity. But it may be fairly but deferentially questioned, whether the minute means employed were in any way commensurate with the vast problem they had to solve; whether the existence of a minute amount of air in the water might not invalidate their results, and give rise to conclusions more in error than the quantities they are intended to eliminate. The idea obtained was that there is a thermal tide which ebbs and flows but once a year.

One of the most important works which have appeared on the surface temperature of the South Atlantic, is the "Investigations with the Sea-Thermometer," published by the Netherlands Royal Meteorological Institute[1], in 1861, and with this has been combined the observations collected by the Board of Trade under Admiral FitzRoy and his successors. From the English work, published in 1869, we give the following:—

In the extraction of the observations from the English registers kept on board ship, no notice had been taken of the exact positions of the respective ships, beyond the fact of their being within the area of a certain 5° square.

The Dutch discussions have been effected with reference to bands of 5° of longitude, but for single degrees of latitude, so that five distinct means are given for the space which is only represented by a single mean in our own results. This is, of course, a very great improvement; but even this subdivision is far from being minute enough to enable us to trace satisfactorily the direc-

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[1] Onderzoekingen met den Zee-thermometer. Utrecht, 1861.

tion of the ocean currents. It is evident that, in order to investigate currents running in a meridional direction, each observation must be examined to the full as closely with reference to the longitude as to the latitude of the spot where it was taken.

Isothermal Charts.

In addition to their monthly charts, the Dutch have published Charts, showing the course of the Isothermal lines for Surface Temperature in the hottest and coldest months of the year. As is well known, these do not coincide with mid-summer and mid-winter, but fall much later, being, in fact, March and September in the Southern Hemisphere. In the publication of the "Pilot Charts for the Atlantic Ocean," by the Hydrographic Office of the Admiralty, the chart of Stream and Drift Currents with the surface Temperature, which forms part of that series, exhibits the course of several of the Isotherms in summer and winter, all available sources of information being used in its preparation.

The remarks on the course of the lines in question, which accompany the Dutch charts, are so clear and concise that we can scarcely do better than reproduce them.

Extract from "Onderzoekingen met den Zee-thermometer," page 49 :—

When we compare the position of the Isothermal lines corresponding to the several parallels of latitude, North and South of the Equator, we notice immediately that there is a great difference between the Temperatures of the North and South Atlantic Oceans.

In the Northern Hemisphere it is shown that in the warmest month of the year the Isotherm of 77° F. (25° C.), between the meridians of 80° and 30° W. (i.e. over the greater portion of the Ocean), lies between the parallels of 30° and 34° North latitude, and that it is only in the Eastern portion, between the meridians of 30° and 15° W., that it reaches the latitude of 17° N.

In the Southern Hemisphere, on the other hand, we meet the Isotherm of 77° F. (to the Eastward of the meridian of 20° W.) as soon as we reach the parallel of 13° South latitude, while it is only to the Westward of the same meridian (i.e. over a very small portion of the Ocean) that it is found at the mean latitude of 30° S.

The difference between the two Hemispheres as to the position of the Isotherm of 68° F. (20° C.) is quite as remarkable.

In the Northern Hemisphere we have seen that during the warmest months it runs in an Easterly direction from Cape Hatteras to Cape Finisterre, and accordingly lies between the parallels of 42° and 44° N.

In the Southern Hemisphere the mean course of the same Isotherm during the warmest months is along the parallel of 37° S., and between the meridians of 5° and 10° E. it even sends a bend Northwards, so as to reach the parallel of 30° S.

If we examine closely the sea temperatures observed North and South of the Equator, and compare the mean values obtained from each month, we find that the temperatures observed North of the Equator are always much higher that those observed to the South of it. We consider this investigation the more important, because the colder character of the water in the Southern Hemisphere can only be proved by the position of the Isothermal lines with reference to the Equator.

Let us now proceed to inquire into the extent of the annual range compared with that for the Northern Hemisphere.

The Isothermal line of 77° F. which we found in summer at the mean latitude of 39° N., in the Western portion of the North Atlantic Ocean, sinks in winter to the parallel of 16° N., and thus comes 23° nearer to the Equator.

In the summer of the Southern Hemisphere the Isotherm of 77° F. never descends to the South of the parallel of 30° S., Westward of the meridian of 20° W., except between the meridians of 50° and 45° W., where it reaches a maximum latitude of 35° S. In the Eastern part of the Ocean it scarcely reaches the parallel of 13° S. In winter, the same Isotherm approaches the Equator to the parallel of 13° S., West of the meridian of 25°, while in the Eastern portion of the Ocean it even crosses the Equator, and is found some degrees to the North of it.

Thus, on the average, in winter, this Isothermal line lies in the latitude of 6° S., and the total amplitude of its variation in position is 17°.

The slight amount of annual variations in position of the isotherms of 59°, 50°, and 41°, is especially deserving of notice, and also their decrease as we reach higher latitudes, so that the Isotherms of 50° and 41° only oscillate through a distance of 4° or 5° of latitude. Accordingly, to the Southward of the parallel of 42° S., summer and winter climates differ but little from each other, whilst in the neighbourhood of the South point of South America the climate is distinguished by its increased mildness in winter.

Thus we see that the corresponding Isotherms in the Northern Hemisphere oscillate in position to a greater extent, and, on the whole, lie at a greater distance from the Equator. In the Southern Hemisphere, on the contrary, they oscillate to a less extent, and lie nearer to the Equator. The sea to the South of the Line is thus decidedly colder, and accordingly the central line of the belt of warmest water does not coincide in position with the Equator, but lies for the most part to the Northward of it. We see, then, that the Climatological Equator must of necessity, at all seasons, lie a few degrees North of the Geographical Equator. It is self-evident that the line which divides the two Hemispheres climatologically shifts its position according to the seasons; but all these changes of situation take place to the North of the Equator, except in February and March, when this line has its most Southerly position, and the Equator is crossed in a few places.

If we keep in mind what has been already published in general terms with reference to the distribution of temperature on the earth's surface in the short sketch of the theory of the Winds,[1] we do not require to go into any particulars to show that the smaller lateral extension of the continental masses in the Southern Hemisphere is the principal cause why the waters in the South Atlantic are on the whole colder, and that the sea cannot exhibit the remarkable differences of temperature at the various seasons which meet us in the North Atlantic.

It deserves special notice that the South Atlantic Ocean is much colder to the East of the meridian of 20° W. than to the West of it.

All the Isothermal lines take a sudden bend Southwards in the neighbourhood of this meridian. This change in direction takes place even in summer, but at that season its place lies more to the Westward, near the meridian of 25° W.

We see here, as in the North Atlantic, that there is a cold current flowing Northwards along the Coast of Africa, and a warm current flowing Southwards along the Coast of Brasil. We find, from the Monthly Charts, that the Brasilian Current, which we may consider as a Southern branch of the Equatorial Current, splits into two parts in the neighbourhood of the parallel of 30° S. One portion flows in a South-Easterly direction, and loses itself, after throwing off several branches, in the Polar Current; the other portion flows by Patagonia and the Falkland Islands, and exerts such a warming influence on the climates of these countries, in spite of their high Southern latitudes, that the numerous herds of black cattle, horses, and sheep, which roam over the plains, can find abundant nourishment even in the winter time.

The South Polar water which we see flowing past the Gulf of Guinea is warmed on its way; the coast-line forces it to assume a Westerly course, and it is to this source that we are indebted for the warm water which we find flowing in a Northerly and Southerly direction along the Western shores of both Oceans, and not to the Agulhas Current, which can only send its waters, during a few months of the year, to the West of the South point of Africa. The very low temperatures found in the Eastern portion of the Ocean prove this statement completely. Between the meridians of 20° and 15° E. we see that the warm current shows itself very distinctly at lat. 35° S., while its influence is no longer noticeable as soon as we come to the Northward of 33° S.

The Temperature Charts show us also the cold Polar Current, which is often covered by streaks of warm water which come forth from the Brasilian Current, and on the African side from the Agulhas Current; of this there is abundant proof in the charts.

The first locality in which considerable alterations of temperature are met with is almost exactly on the Equator, about the 23rd meridian of West longitude. At this spot, in the month of July, Capt. Code, in the *Orient*, reports

[1] *Vide* Maandelijksche Zeilaanwijzingen, 1860, pp. v. and vi.

that the temperature fell 5°, and rose again in the space of 24 hours, the water appearing of a light green colour.

Admiral Sir F. Grey noticed very remarkable changes of temperature on the Coast of Africa, between the parallels of 10° and 20° S., in the month of May. He observed the surface temperature below 60° on two occasions when he was about 25 miles off shore, and he remarks :—" It would appear that the temperature of the water decreases as we approach the shore." The charts show a striking discrepancy between the mean temperature of the square in question, which is 60·8°, and that of the squares to the North and South of it, which are 76·3° and 62·2° respectively.

We now come to the district bounded by the meridians of 10° E. and 40° E., and lying between the Coast of Africa and lat. 50° S. In this region most sudden and remarkable alterations of temperature are met with at all seasons of the year.

Changes of temperature have been observed by some homeward-bound vessels between the parallels of 35° and the coast, when crossing the Agulhas Bank, and Capt. Toynbee remarks, that the temperature of the water is a good guide to show whether you are on the bank or not.

However, by far the greater number of the extracts refer to a region lying one or two degrees on either side of the 40th parallel of latitude. In the Northern part of this belt the observations all fall to the Eastward of the meridian of 10° E., but in the Southern part it will be seen that, in a few instances, considerable alterations of temperature have been noticed as far West as the 8th or 9th meridian of East longitude.

Throughout the whole of this area the alternations of cold and warm water are most striking, and the changes of temperature are nearly as sudden and as great as those well known to be experienced on the Northern edge of the Gulf Stream, where it is bounded by the Arctic Current. The greatest actually observed has been a fall of 19·5° in one hour, recorded by Capt. Major in the month of February. His position was in 41° 38′ S., and 21° 30° E., and the surface temperature was observed to be 69·5° at 9 a.m., 50° at 10 a.m., and again 69·5° at noon.

Another region where sudden changes are noticed is off the Coast of South America, from the 20th parallel of South latitude Southwards, and there are several well-marked areas, notices of which will be found in the extracts from the registers.

It appears, from the additional notes, that colder water is to be met with off Rio Janeiro, inside the line of soundings than outside. This would appear to show that the branch of the Equatorial Current of warm water which flows Southwards along the Coast of Brasil is usually unable to force its way into the shallow water on the bank of soundings, along which a narrow stream of colder water flowing Northwards is met with. The difference is greatest in February, when it exceeds 4°. However, in July and August the conditions are quite changed, for then the temperature outside soundings is lower than inside.

When we come South of the parallel of 30° S., the changes of temperature which are noticed, though not so striking as those observed off the African Coast, are yet very remarkable. The entire area in which the observations are made lies West of the meridian of 50°. Between the parallels of 35° and 40° S. changes of temperature of 20° within 12 or 14 hours have been repeatedly observed, with great variations in the colour of the water. As regards the relation of the currents to the depth of the water, Capt. James Gales states, "The warm water is on the bank of soundings, the cold along the edge of it." This is a marked difference to the state of things noticed off Rio Janeiro. However, this cold water forms only a narrow strip, for to the Eastward again the water is decidedly warmer. When we pass the parallel of 40° S., the charts show that the mean temperature in lat. 40° to 45° S. is higher between 50° and 55° W. than in either of the squares situated East or West of it. The mean annual difference of temperature is 1·8° to the Eastward, and as much as 5·4° to the Westward. One observer, Capt. James Brack, cuts across this warm water in September, going Westward. In lat. 41° to 44° S., long. 54° W., he finds an increase of 13° in 14 hours, succeeded by a decrease of 14° in 10 hours. The same observer had previously passed through a cold current in lat. 40° S., long. 53° W.

Another area, frequently referred to in the extracts, is that bounded by the parallels of 45° and 50° S., and the meridians of 47° to 53° W. Here the differences of temperature are not very great, but there appears to be evidence of the existence of two currents, a cold and a warm one, close to each other. The edge of a warm current is frequently noticed at about the 51st meridian, between the above-named latitudes, while the cold current appears to extend, at least in lat. 49°, from that meridian Eastwards to that of 46° W., as many observers report a sudden fall in temperature about long. 47° W. Off Cape Horn a warm current close inshore has been commonly noticed. Capt. James Gales, in March, remarks, when the sea temperature rose 2·4°, "Standing Northward, and temperature of the sea increasing. In dark or thick weather, that increase in the temperature of the sea would be a hint to tack a ship." The observation was taken about 40 miles South of Cape Horn.

The whole of this Coast of South America seems, even from the small amount of information which has been attainable relating to it, to present features of interest as regards the sea surface temperature observed along it, which are, perhaps, equal in importance to those of the Agulhas Current.

Much additional information on the Temperature, &c., of the water of the Ocean at various depths, will be found in the reports of the investigations made during the voyage of H.M.S. *Challenger*, by Captains Nares and Thomson, Staff-Commander Tizard, and the late Professor Wyville Thomson.

From 40° N. to 40° S. (in the Pacific Ocean) the temperature of the 1,500-

fathoms line remains the same (34° to 35° F.). Below that line the water is slightly colder in the South than in the North Pacific; while above that line, to the 200-fathoms line, the water is colder in the North than in the South Pacific. But though the bottom-water is colder in the South than in the North Pacific, yet, from the much greater depth of the latter, the body of water there whose temperature is below 35°, is vastly greater than in the former, an excess averaging 750 fathoms. As in the Atlantic, so in the Pacific, we find that the water at the bottom in the Western portion is colder than that of the Eastern, which is caused by the revolution of the earth trending the Northerly-flowing current to the Westward.

The highest surface Temperature found in the Pacific Ocean, during the cruise of H.M.S. *Challenger*, was 84° in lat. 2° 33′ S., long. 144° 4′ E., off the North Coast of New Guinea. This was on March 1st, 1875. The lowest surface temperature was 52·5°, on October 25th, 1875, in lat. 39° 16′ S., long. 124° 7′ W., nearly midway between New Zealand and the Coast of Chile.

From Temperature observations on board H.M.S. *Challenger*, the space between the N.E. Coast of Australia and New Caledonia, New Hebrides, Solomon Islands, and New Guinea, appears to be surrounded by a bank, not exceeding 1,300 fathoms in depth, the temperature within this area at a depth of 2,650 fathoms being 35°, or the same as at a depth of 1,300 fathoms.

Another similar area, between New Guinea and the South part of Japan, appears to be surrounded by a bank of 1,500 fathoms. Mr. J. J. Wyld says this deep basin might appropriately be called the "Sea of Magellanes," after the discoverer of the Ladrone and Philippine Islands, and in honour of the first European who crossed the Pacific Ocean. One of the most prominent features of this sea is the extensive surface-stratum of warm water, 84° to 77° F., from 70 to 100 fathoms thick.

Between the Sandwich Islands and Tahiti, and in a Southerly direction from Tahiti to 40° S., Professor W. Thomson describes the bottom as consisting mainly of red clay, except around volcanic islands, where it is chiefly composed of volcanic débris and shore-mud. In nearly all the soundings manganese was found. In depths exceeding 2,000 fathoms, in other parts of the Ocean, the bottom appeared to be principally red clay, and occasionally gray ooze.

Saltness and Density.

A very interesting essay on the Salinity of the Ocean was laid before the Royal Society, in 1865, by Professor George Forchhammer, of the University, and Director of the Polytechnic Institute, at Copenhagen.[1] We can only make a few extracts from it.

"The elements which occur in the greatest quantity in sea-water have been long known, and chlorine, sulphuric acid, soda, magnesia, and lime, have, for

[1] On the Composition of Sea-water in different parts of the Ocean.—"Philosophical Transactions of the Royal Society of London," 1865, Part I., pp. 203 *et seq.*

more than a century past, been considered as its essential parts. In our century, iodine, bromine, potash, silica, phosphoric acid, and iron, have been discovered in sea-water, and the latest enquiries, my own included, have brought the number of elements occurring in sea-water up to twenty-seven.

"They are:—1, oxygen; 2, hydrogen; 3, chlorine; 4, bromine; 5, iodine; 6, fluorine; 7, sulphur; 8, phosphorus; 9, nitrogen; 10, carbon; 11, silicium; 12, boron; 13, silver; 14, copper; 15, lead; 16, zinc; 17, cobalt; 18, nickel; 19, iron; 20, manganese; 21, aluminium; 22, magnesium; 23, calcium; 24, strontium; 25, baryta: 26, sodium; 27, potassium.

"The next question to be considered refers to the proportion between all the salts together and the water; or, to express it in one word, I may allow myself to call it the *salinity* of the sea-water; and in connection with this salinity or strength, the proportion of the different solid constituent parts among themselves. On comparing the older chemical analyses of sea-water, we should be led to suppose that the water in the different seas had, besides its salinity, its own peculiar character expressed by the different proportions of its most prevalent acids and bases, but the following researches will show that this difference is very trifling in the Ocean, and has a more decided character only near the shores, in the bays of the sea, and at the mouths of great rivers, wherever the influence of the land is prevailing.

"If we take the mean numbers for the five regions of the Atlantic between the Southernmost point of Greenland and that of South America, we find the mean quantity of salt per thousand parts for the whole Atlantic 35·833, while the sea between Africa and the East Indies has only 33·850; the sea between the East Indies and the Aleutian Islands, 33·569; and the South Sea, between the Aleutian Islands and the Society Islands, 35·219. The Atlantic is thus that part of the Ocean which contains the greatest proportion of salt, which result is rather surprising if we consider the vast quantity of fresh water which the rivers of Africa, America, and Europe pour in: of Africa, four-fifths are drained into the Atlantic either directly or through the Mediterranean; it is most probably nine-tenths of America which is drained into the Atlantic, since the Cordilleras run close to the Western shore of the Continent; and of Europe, also, about nine-tenths of its surface sends its superfluous water to the Atlantic. This greater quantity of fresh water from the land, and the greater quantities of salts in the corresponding sea, seem to contradict each other, but can be explained by a higher temperature, and, as the result of this higher temperature, a greater evaporation.

"Some of the large bays of the Ocean have in the Tropical or sub-Tropical zone a greater mean than the Atlantic. Such are the Mediterranean, with 37·936 per 1,000 salt (mean of eleven observations); the Caribbean Sea, with 36·104 per 1,000 (one observation); the Red Sea, 43·067 per 1,000 (mean of two but little differing observations), which is the greatest salinity of the sea I know of.

"In approaching the shores the sea-water becomes less rich in salts, a fact which finds its explanation in the more or less great quantity of fresh water which runs into the sea. On such shores, where only small rivers flow out, the effect produced is but very trifling, as, for instance, on the Western shores of South America. The effect of large rivers in diluting the sea-water is much greater than is generally supposed; thus, the effect of the La Plata River, whose mouth lies in about 30° of South latitude, was still observable in a sample of sea-water taken at 50° 31′ South latitude, at a distance of 15° of latitude, or 900 English miles from the mouth of the river; at about the same distance the water of the North Atlantic Ocean suffered a considerable depression in salinity, probably owing to the water of the St. Lawrence. This influence is of a double kind, partly in diluting the sea-water, partly in mixing it up with organic substances that will occasion its decomposition by putrefaction."

In illustration of the effect of heavy rains, in at least temporarily diminishing the specific gravity of the surface, a most remarkable instance was observed by Dr. C. K. Ord, of H.M.S. *Hermes*, when that ship was lying in Simon's Bay, in August, 1859. On the 4th of that month, at 9 a.m., the specific gravity was 1·0266, and in one hour it was reduced by the heavy rain that fell to 1·0193, the water becoming "brown in colour, merely brackish in taste, and its current setting distinctly outwards." By noon the density had increased to 1·0253, and at 3 p.m. the surface had recovered its former density of 1·0266. The next day the specific gravity was again reduced by heavy rain, and again rose. The *temperature* of the surface was also temporarily lowered from 58° to 55°, the temperature of the rain being 50°.[1]

There is one singular fact, which appears to be gradually determined as observations on the specific gravity of the Ocean water are multiplied: this is, that at a certain depth below the surface, beneath the effects of rain, evaporation, congelation, or the mingling of river waters, the density is very nearly uniform all over the world. This identity of constitution points to another conclusion—that the water of the Ocean does circulate over and intermingle with every portion of the water surface of the globe, in the same way that the Atmosphere is continually changing and passing over every part of the globe in turn, thus becoming of one universal character, capable of sustaining life in any and every part of the earth.

As the result of the *Challenger Expedition*, we quote the following, by J. Y. Buchanan, M.A. (the Chemist of the Expedition), from a Paper read before the Royal Geographical Society, in 1877:—

The source of saltness in sea-water is rock-substance, which has been disintegrated and decomposed by atmospheric influences.

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[1] According to Erman's elaborate investigations, the weight of salt in 1,000 parts of sea-water of different specific gravities is—

Specific gravity	1·025	1·026	1·027	1·028
Salts per 1,000	33·765	35·049	36·343	37·637

The specific gravity of the water from the surface was determined (at a temperature of 39° F.) every day during the cruise when at sea, and from the bottom and intermediate depths as often as opportunity offered.

As far as the surface is concerned, the general results were as follows. The concentration of the waters of the Atlantic is greater than that of either the Pacific or the Southern Oceans, and it is greater in the North Atlantic than in the South Atlantic, although the actual maximum may be slightly higher in the South Atlantic. In the North Atlantic the maximum (1·0275) was observed in 22° N. latitude, and 40° W. longitude, from which point it diminishes in all directions. (On the South Coast of Iceland it was 1·0260).

The mean specific gravity of the whole of the North Atlantic from the Equator to latitude 50° is 1·02664, while that of the South Atlantic between the corresponding parallels is 1·02676, showing an excess on the side of the waters South of the Equator, but only of ·00012.

The accession of the River Plate has considerable influence in diminishing the density of the sea in its vicinity, and by omitting all observations above 30° N. and 30° S., the mean densities become respectively 1·0267 and 1·0271: that is to say, between the Equator and 30°, the Southern waters are heavier than the Northern by ·0004.

This difference is less than has hitherto been generally supposed, and even *this* exists only between the Equator and 20°, and is chiefly occasioned by the greatly diminished density of the water between the Equator and 10° N. in the Belt of Equatorial Calms and Rains.

If we consider the water below the surface, as shown in the vertical sections, we find, in the Atlantic, that in the concentration-areas the specific gravity diminishes until a minimum (1·0260) is reached at a depth of about 800 or 1,000 fathoms, after which it increases slightly down to the bottom. In investigating the causes of the variations in specific gravity in the Ocean, we find that they depend on the means available for removing or supplying *water*. Thus, the areas of greatest concentration coincide with those where the dry Trade Winds are constantly blowing, taking their rise in the lower Temperate latitudes, and proceeding in their course always from colder to warmer regions, so that, for the first part of their journey, at least, although they are continually taking up moisture, their capacity for doing so is continually increasing. Hence the great concentration of the water in the steady Trades of the Atlantic.

The observations make it probable that in the Atlantic the water from the surface, down to a depth of 1,000 fathoms, has on the whole a flow *inwards*, or from South to North, and below that depth and down to the bottom it appears to have an opposite flow, thus providing for the removal of the salt which otherwise would accumulate in the North Atlantic. The Atlantic thus presents on a larger scale what is observed in the Mediterranean, where the mean drying power of the Atmosphere is higher than even in the North Atlantic. In the Pacific, owing to its form and general climate, these conditions are not so evident.

The Gulf Stream, or rather the edge of it, was very clearly indicated simply by the specific gravity, where the warm and dense water of the Gulf Stream met what was called the "Cold Wall" of the Labrador Current. The Equatorial Currents, also, were very marked, being fresh. The Agulhas Current of South Africa showed similar variations in density.

In the Pacific Ocean the distribution of the surface salinity differs considerably from that in the Atlantic. In the Pacific only the Southern concentration area is well marked; in the Northern part of the Ocean the variations in salinity are slight, and the mean saltness low. In no part of the North Pacific was the specific gravity observed above 1·0265, while in the Southern part, in the region of the Trade Wind, it exceeds 1·0270, and the mean specific gravity is comparatively high. The maximum in the North Pacific is 1·02644 in lat. 30° 22′ N., and in the South it is 1·02719 in 19° S. near the Society Islands. The whole of the Southern Ocean, between 40° S. and the edge of the Ice, appears to have a very uniform surface specific gravity of about 1·0250, that of the bottom water of the Pacific being from 1·0257 to 1·0259.[1]

Circulation.

That there is an interchange between all the water in the Oceans is shown at pp. 25-26. Of the means by which this interchange is produced, numerous theories have been advanced, and it is only in recent years that any really reliable *data* have existed to elucidate the subject. At the present time, Physicists are pretty well agreed that the great cause of the circulation of the water is its varying specific gravity. This specific gravity or density, is regulated chiefly by temperature, but also by the amount of salt contained in the water. Without going into further details, the simple theory which recent investigations have strengthened is, that a cold under-flow of water is continually kept up from the Polar to the Equatorial regions.[2] This

[1] See a Paper "On the Distribution of Salt in the Ocean," by J. Y. Buchanan, Chemist in the *Challenger* Expedition, printed in the "Proceedings of the Royal Geographical Society," vol. xxi., pp. 255—257, and in the Journal of the same Society, vol. xlvii., 1877, pp. 72—86.

[2] That *under-Currents* do actually exist is well known. (See page 67.) H.M.S. *Challenger* several times tested the rate and direction of the under-Current by means of a wooden framework, covered with canvas, lowered by a rope to the depth at which the current was to be tested; the upper end of the rope being attached to a buoy which floated on the surface; and, after allowing for the effect of the surface-Current, the latter showed by its progress the direction of the current at the depth where the framework was floating. This same process was used by Dr. Carpenter in testing the flow of cold water from the Atlantic into the Mediterranean through the Straits of Gibraltar. It is, of course, possible that these under-Currents may in places be so near the surface as to affect the course of a ship deep in the water.

theory Professor Lenz, of St. Petersburg, advanced as *an inevitable deduction* from the facts ascertained by the remarkable series of observations on the Temperature and Specific Gravity of Oceanic Water at various depths, which he had made in the second voyage of Kotzebue, during the years 1823-6. He drew from these results the very conclusions which now derive remarkable confirmation from the temperature soundings and specific gravity observations of the *Challenger*, viz. :—1. The doctrine of a deep under-flow of glacial water from each Pole to the Equator. 2. The ascent of Polar water towards the surface under the Equator, as evidenced by the rise of the bathymetrical Isotherms, by the keeping down of the surface temperature, and by the low (Polar) salinity of Equatorial surface water. 3. The movement of the upper stratum of oceanic water from the Equatorial region towards each Pole, as the necessary complement of the deep Polar under-flow. 4. The dependence of this double movement upon the disturbance of hydrostatic equilibrium constantly maintained by Polar cold and Equatorial heat. The opposition which has been raised to this doctrine of a Thermal circulation has mainly rested on one or both of two pre-conceptions :—1. The origination of all oceanic movements in the surface-action of Wind. 2. The sufficiency of the Gulf Stream to produce the amelioration of the climate of North-Western Europe.

We conclude with some remarks by Sir Wyville Thomson :[1]—

"All the facts of temperature distribution in the Atlantic appear to favour the view that the entire mass of Atlantic water is supplied by an indraught from the Southern Sea, moving slowly Northward, and interrupted at different heights by the continuous barriers which limit its different basins; but this involves the remarkable phenomenon of a vast body of water constantly flowing into a *cul de sac* from which there is no exit. When I suggested this view some years ago, I was asked, very naturally, how it was possible that more water could flow into the Atlantic than flowed out of it, and at that time I could see no answer to the question, although I felt sure that a solution must come some day. Now it seems simple enough ; but, in order to understand the conditions fully, I would ask my readers to recall the appearance of the Atlantic, and of the Pacific also, which is under exactly the same conditions. On a globe one sees much more clearly than on a map that the Atlantic is a mere tongue, as it were, of the great ocean of the water Hemisphere stretching up into the land. The Arctic Ocean, with which it is in connection, is again a very limited sea, and nearly land-locked. The North Pacific is another gulf from this 'water-Hemisphere,' but one vastly wider and of greater extent: while the South Pacific is included within the 'water-Hemisphere.'

"Although from the meridional extension of the Continents to the Southward, the water of the Atlantic is, as I have shown, directly continuous, layer

[1] Voyage of the *Challenger*, vol. ii., pp. 324—326.

for layer, with the water of the Antarctic basin, it must be looked upon not as being in connection with that basin only, but as being a portion of the great Ocean of the water-Hemisphere; and over the central part of the water-Hemisphere precipitation is certainly greatly in excess of evaporation, while the reverse is the case in its extensions to the Northward. The water is, therefore, carried off by evaporation from the Northern portions of the Atlantic and of the Pacific, and this vapour is hurried down towards the great zone of low Barometric pressure in the Southern Hemisphere; the heavy, cold water welling up from the Southward into the deepest parts of the Northward extending troughs, to which it has free access, to replace it. It is unfortunate that we have, as yet, scarcely sufficient data to estimate the relative amount of rain and snow in the Northern and Southern Hemispheres, but the broad fact that there is very much more in the Southern is so patent as scarcely to require proof. This excess becomes still more apparent when we include, as we must do, in this source of supply of water to the North, the Tropical region of the South Pacific, which forms part of the great Ocean."

Animal Life.

"Animal Life in the deep sea is so intimately related to the temperature of the bottom, as obviously to be determined by that condition in a much greater degree than by its depth. This was very strongly impressed on Sir Wyville Thomson and myself in our early investigations. For in the deep trough lying N.E. and S.W. between Shetland and the Færoe Islands, which, as having been our cruising ground in 1868, I have ventured to call the "*Lightning* Channel," we found at corresponding depths of between 500 and 600 fathoms, and sometimes within a few miles of each other, two areas whose temperatures differed by more than 13° F.; the bottom temperature of the "warm area" being about 43°, whilst that of the "cold area" was somewhat below 30°. The Faunæ of these two areas showed the most marked diversities. And I was thus led in my report for 1869 to express my entire concurrence in the speculation thrown out some years previously by Professor Lovén, that "there exists in the great Atlantic depression, perhaps in all the abysses of our globe, and continued from Pole to Pole, a Fauna of the same general character, thriving under severe conditions, and approaching the surface where none but such exists—in the coldest seas."[1] This expectation has been most remarkably confirmed by the *Challenger* researches; one of the most important of the general results of that expedition being the recognition of an abyssal Fauna essentially the same over the whole

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[1] "Proceedings of the Royal Society," November 18, 1869, page 475. The similarity of Antarctic to Arctic forms of Marine life had, indeed, been previously noticed by Sir James Ross, and had been attributed by him to the prevalence of a "similar temperature" over the whole intervening Sea-bed. This temperature, however, he erroneously supposed to be 39·5° Fahr.

oceanic area that is reached by the glacial under-flow, without any relation whatever to the Terrestrial climate of the locality, and scarcely showing any difference according to its Arctic or Antarctic derivation. Thus we see that, even at the present time, the essential conditions of a "glacial epoch" prevail upon the Deep Sea bed from each Pole to the Equator; so that the presence of Arctic types of animal life in any *marine* deposit of Temperate or even Tropical zones, affords not the least evidence, *per se*, of the former extension of glacial action over the *land* of these localities."—*Dr. Carpenter.*

"The most prominent and remarkable biological result of the more recent investigations is the final establishment of the fact that the distribution of living beings has no depth limit; but that animals of all the marine invertebrate classes, and probably fishes also, exist over the whole of the floor of the Ocean. My present impression is, that, although life is thus universally extended, the number of species and of individuals diminishes after a certain depth is reached, and that at the same time their size usually decreases.

"Using all precautions, and with ample power and the most complete appliances,[1] it is extremely difficult to work either with the Dredge or with the Trawl at depths approaching or exceeding 3,000 fathoms. A single dredging operation in such depths takes a long time; the Dredge is put over at daybreak (the ship being kept as nearly as possible stationary), and it is usually dark before it is recovered, so that the number of such operations must be comparatively small. We must, therefore, bear in mind that only an infinitesimally small portion of the floor of the Ocean, at depths over 2,500 fathoms, has yet been explored.

"As we had previously anticipated, the Fauna at great depths was found to be remarkably uniform. Species nearly allied to those found in shallow water, of many familiar genera, were taken in the deepest hauls, so that it would seem that the enormous pressure, the utter darkness, and the differences in the

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[1] In the examination of the Animal Life, three forms of apparatus were used by H.M.S. *Challenger*. 1. A *dredge*, consisting of a dredge-bag attached to an iron frame $4\frac{1}{2}$ ft. long by $1\frac{1}{2}$ ft. broad. To the bottom of the frame was attached a bar, bearing *tangles* of rope yarn (the invention of Captain Calver), in order to entrap various animals while passing over the bottom. The dredge-bag usually came up from the bottom at great depths, full of mud (*globigerinæ oaze, &c.*), but on one occasion a huge block of syenite was brought up in the mouth of the dredge from a depth of 1,340 fathoms, about 150 miles Southward of Cape Sable in the North Atlantic. 2. The *Deep-sea Trawl*, a conical bag 30 ft. in length, weighted at its bottom end, and suspended by one side of its mouth to a beam of wood; the other side of the mouth, which drags along the sea-bottom, hangs loose, and in order that the bag may keep open is weighted with some pieces of lead. The mouth of the Trawl-bag is fitted with a netted funnel arrangement which prevents the escape of animals after their capture. 3. An *ordinary Trawl-net*, kept open at its mouth by an iron ring, was dragged behind the vessel at small depths. The accumulators (page 816), to which the dredge ropes were attached, were slung from the main-yard-arm of the *Challenger*, and the hauling in of the dredges was effected by a donkey-engine.

chemical and physical conditions of the water, and in the proportions of its contained gases depending upon such extreme conditions, do not influence animal life to any great extent.

"The geographical extension of any animal species, whether on land or in the sea, appears to depend mainly upon the maintenance of a tolerably uniform temperature, and the presence of an adequate supply of suitable food.

"There is every reason to believe that the Fauna of deep water is confined principally to two belts, one at and near the surface, and the other on and near the bottom; leaving an intermediate zone in which the larger animal forms, vertebrate and invertebrate, are nearly or entirely absent."—*Sir Wyville Thomson.* (Voyage of the *Challenger*, vol. ii.).

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