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METEOROLOGICAL OFFICE.

THE SEAMAN'S HANDBOOK
OF
METEOROLOGY.

A Companion to the Barometer Manual for the Use of Seamen.

THIRD EDITION.

Published by the Authority of the Meteorological Committee.

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THE SEAMAN'S HANDBOOK OF METEOROLOGY.

A Companion to the Barometer Manual for the Use of Seamen.

PREFACE.

The writing of this book has been entrusted to Commander M. W. Campbell Hepworth, C.B., R.D., R.N.R., Marine Superintendent of the Meteorological Office, who has the advantage of long experience of the practical needs of seamen in connexion with the study of weather.

It is now nearly sixty years since the Meteorological Office was established as a Department of the Board of Trade under Admiral R. FitzRoy for organising the collection of Meteorological observations from ships traversing the various oceans of the globe.

The purpose was threefold:—First, that trustworthy information about the weather in every part of the navigable seas should be supplied to the seafaring community, and thereby the seaman should be enabled to know what to expect in the way of weather, *as a rule*, on any voyage which he might have to make. Secondly, by the use of the knowledge so collected, to enable him to make the most of conditions of weather generally favourable, by the choice of his route, or the time of his voyage, or the setting of his course; and thirdly, by the study of the laws of weather, to enable him to know what sort of weather to expect from day to day, and to make the best of bad weather, if he had to face it. These purposes have been steadily pursued at the Office, and the scope of its operations has meanwhile been greatly enlarged in consequence of the public interest in the development of the new method of anticipating coming weather.

The Old Method of Using the Barometer.

The early years of the Office were of great importance in the history of the study of weather. The barometer, that is an instrument for finding out the height of a column of mercury which would balance the pressure of the atmosphere, or briefly, for measuring the atmospheric pressure, had long been known as a weather-glass ; and the use of the barometer for anticipating changes in the weather was well established. But at that time each individual had only his own instruments for the purpose. Guidance in the use of the barometer was for the most part limited to the traditional inscription on a dial, which, unfortunately, may still be seen on many instruments.

A height of	31·0	inches of	mercury	was marked	Very dry.
,,	30·5	,,	,,	,,	Set fair.
,,	30·0	,,	,,	,,	Fair.
,,	29·5	,,	,,	,,	Change.
,,	29·0	,,	,,	,,	Rain.
,,	28·5	,,	,,	,,	Much rain.
,,	28·0	,,	,,	,,	Stormy.

It was already recognised that these stereotyped descriptions of the weather belonging to certain barometric heights, although in a way "founded on fact," were often disappointing and perplexing, and they were already regarded as misleading. Anyone who watches a barometer can confirm this view for himself. There was an example only a few weeks ago, when an evening paper described the climatic conditions in London on 10th December, 1912, as "utterly wretched," and illustrated them by a picture of a barometer pointing to "Fair," because the mercury read just over 30 inches. One of the early services of the Office to the public was to introduce a barometer for the use of fishing communities (*see* p. 181), which carried an inscription free from objection, and one of its most recent efforts (*see* p. 156) is to supply a new barometer dial showing pressure in absolute units ranging from about 95 per cent. to 105 per cent. of the middle position, and utilising information which has been gradually compiled about the distribution of pressure over the sea.

Cyclonic Depressions or Swirls of Air.

By the time the Office was established, it had been made out that the tropical hurricanes, the worst type of weather that a ship had then to fear, were swirls of air travelling, not very fast, through a comparatively quiet atmosphere with low pressure in the centre and gradually increasing pressure all round it. Many features of the behaviour of these hurricanes present an unmistakable likeness to those of a whirlpool or vortex such as may be formed when water runs out of a basin through a hole in the bottom. Before many years had elapsed it was found that the winds and gales of our own coasts, and indeed all over the world, had certain points of likeness to the tropical hurricane, and might indeed be regarded as parts of great swirls with less violent winds than those of the hurricane, but spread over vastly greater areas and generally making their way, sometimes faster, sometimes slower, over sea and land. It would hardly be correct to regard these swirls as making their way through a quiet atmosphere like a tropical storm; they are rather regarded as forming part of a great procession, so that the whole region is filled with swirls and counter-swirls. All the air takes part in the motion and there is nothing left that one can regard as the undisturbed atmosphere for the swirls to move in. As soon as these swirls, which we call "cyclonic depressions," were identified, every change in the atmospheric pressure shown on the barometer became an indication of the approach or departure of one of these swirls, and it was soon seen that the reading of an individual barometer depended upon its position with reference to the centre of the swirl that was passing. The legend on the dial lost its significance and its failure to foretell the weather was explained. Picturing to oneself a swirl passing over the country, one can easily understand that the weather may be exactly similar at two places where the pressure, according to the barometer, is different by as much as an inch, the difference between "fair" and "rain" or between "change" and "much rain," and, on the contrary, for two places on the same ring of equal pressure round the centre, the weather may be quite different and the winds will blow in opposite directions on opposite sides of the vortex.

Weather Maps.

As soon as we realise that what is going on in the way of weather at the one place, where we happen to be watching a barometer, is only part of a whole series of events taking place in a great swirl that may be a hundred or a thousand or even two thousand miles wide, we realise that what we can see at the one point is only a small part of the whole story. To know what is going on, we want to learn what the weather is and what the barometer reads at points all round us. We want, in fact, a weather chart, a map that enables us to put together all the information for our region at any time. It is for this reason that, since the Office was founded, the study of weather has come to depend so largely on the study of maps on which barometer readings and other particulars are set down. In these days a student of weather always thinks in maps.

Change in the Method of Using the Barometer.

But the barometer has not on that account lost its importance as a weather-glass ; on the contrary, its importance is largely increased, though the method of using its indication has quite changed. It now supplies the material out of which weather maps are constructed. For that purpose the instrument has to be carefully graduated and it has to be read with a care and precision which were altogether unnecessary for our grandfathers. When the readings are wanted for weather maps any errors, due either to the imperfection of the instrument or to mistakes in reading or reducing it, spoil the map so far as the locality of the reading is concerned, and a collection of readings set down upon a map results in hopeless confusion, even if only a few of them are incorrect.

The way the Barometer Readings are used at a Central Office.

In order that a weather map may be effective for anticipating coming weather, it must be made very quickly after the readings are taken. It would take too long to send them by post, so the barometer readings with other information for a large number of stations are reported by telegraph to a central office. The course of procedure in connexion with the Meteorological Office in London is as follows :—At seven o'clock in the morning every day in the year at about 150 stations in the British Isles, the other Islands of the Atlantic Ocean, and on the Continent of Europe, observers read the barometer and other instruments. Reports from about 60 of them are forthwith sent to London and reach South Kensington between 7h. 15m. and 9h. By 10 o'clock the weather map has been completed and the forecasts made. By 11 o'clock, except on Sundays and public holidays, a copy of the observations and of the map is ready for the printer. The printed copies begin to come up from the press at 12h. 15m., and before 1 o'clock they are in envelopes and messengers start to catch the 1h. 30m. post at the General Post Office. These maps are prepared and printed at the public expense, and anyone who is interested in weather maps can get a copy regularly by paying 5*s.* a quarter for the cost of postage and wrappers. In this way the weather map to a large extent now takes the place of the weather-glass for those who are within easy reach of the Office.

In this country weather maps are only published officially once a day. Observations are collected three times a day to enable the officials to draw the corresponding weather maps and so trace the course of the changes of weather. Transcripts of these maps are exhibited outside the Office as soon as they are made, and that representing the observations at 6 p.m. is published in the "Times."

The use of the Barometer by those who are out of reach of a Central Office.

But not everybody who is interested to know the coming weather can see the maps which are exhibited, nor even get a copy of the published maps in time for his purpose. What about the sailor at sea or the fisherman at an out-of-the-way port who has only his own barometer to go by; is his weather-glass, that according to his temperament he has learned to regard as good or bad for foretelling weather, henceforth to be of no use to him, because the old legend is misleading? By no means. It can be of far greater use to him than ever, only it must be used differently. We may say once for all, that all barometers which are accurate and properly read are equally good for this purpose. What he wants to know from the barometer is not only what the height of the mercury is now, but how it has changed and how it is changing. So he must keep a record if he cannot afford a barometer that writes its own record. And he must supplement the information that he gets from the barometer by noting the direction and force of the wind and their changes; he should also watch what clouds there are and how they are moving, and if he has a thermometer with which to tell the real temperature of the air (no easy matter), so much the better. To all this information, which he can get for himself on the spot, he must add a little knowledge of the use of weather maps, and then he will generally be able to judge for himself what part of the atmospheric swirl he is in and what sort of swirl it is. The direction of the wind will tell him on which side the pressure is low and on which side it is high ; the force of the wind will tell him what kind of intensity the swirl has ; the rate at which the barometer is changing will tell him what stage has been reached in the passage of the swirl ; the nature and motion of the clouds will often tell him what to look out for on his barometer, and the thermometer will often be a guide to the progress of the swirl.

Thus, with practice an observer at a single station may picture to himself with reasonable success the weather map which would represent for his neighbourhood the changes that are actually in progress and hence infer what is likely to follow.

While therefore the barometer has ceased to be regarded as an instrument which tells us by the height at which the mercury stands whether the weather is to be fair or rainy, dry or stormy, it still claims close attention. We watch for its changes with the knowledge that every change in its readings has to be accounted for by changes that can be represented on a weather map, and in accounting for the changes that have already shown themselves we can form an idea of the further changes to follow. It is the purpose of this book to set out with sufficient simplicity, and yet with sufficient detail, the knowledge that is necessary to enable an observer to use a barometer in the way here indicated.

The increasing importance of Meteorological Observations for Seamen.

Of the threefold purpose for which the Office was established, two sections have been more or less accomplished with the assistance of corresponding institutions in other countries. Reference to the list of publications of the Office will show that charts have been made and published from which the seaman can make out, in a general way, the sort of wind and weather which he may expect at any time of the year in any part of the navigable seas ; and sufficient information has been compiled to enable the seaman to choose, so far as average weather is concerned, the most advantageous route from one port to another. It is quite possible that the average seaman would not like to be held responsible for gathering the information and drawing conclusions from the charts as they are printed, but for the most part the information is there and for the North Atlantic Ocean and Mediterranean Sea as well as for the Indian Ocean the information is digested for him month by month and published by the Office as Monthly Meteorological Charts for those seas. There remains the third section of the threefold purpose, the variations from the usual conditions and the need for anticipating them and knowing how to avoid exposure to bad weather or how to make the best of it if it has to be faced. This has become an increasingly important study in all civilised countries.

The change from Sailing Vessels to Steam Vessels.

When Admiral Fitz Roy began his work at the Office ships were nearly all sailers, and dependent upon winds for their motive power. There are still a number of small sailing craft about the coast and a few large sailing vessels, but the high seas are mainly kept by steamers whose motive power is not dependent on the weather. The wind is, in fact, an incident agreeable or disagreeable according to the sea which it raises. Presumably either more coal or more time is necessary for a steamer to reach her destination against a strong head wind but we do not know how much more coal or how much more time, and indeed the effect of wind upon a steamer's voyage is for the most part unexplored.

It might be thought that with the transition from sail to steam and the general increase in the size and power of ocean-going vessels seamen would have lost their interest in the weather and that forecasting might have been left for landsmen, longshoremen, and small craft; but it is curious that since the loss of the *Royal Charter* in 1859 gave the necessary impulse for the beginning of the service, no year has made so persistent an appeal for the help of the Office in the interpretation of the laws of weather for the benefit of sailors as the year 1912.

As I write, December 28th, the newspapers are expressing general satisfaction at the safe return to London with 248 passengers of an outward-bound liner that has retired hurt from a tussle with a sou'-wester on Christmas Day off Ushant. The year began with a request for the extension of the service of meteorological messages distributed from wireless stations of the Admiralty for the benefit of H.M.

ships. There followed the terrible disaster of the *Titanic* on her maiden voyage, and the consequent demand for some means of anticipating the character of successive seasons as regards ice on the steamer routes, then the International Conference in London, and an agreement as to priority for radio-telegrams reporting weather messages from ships, and International Conferences in London and Paris about the organisation to be arranged for the collection of reports from the sea and the distribution of information to ships.

The Introduction of Radio-telegraphy.

So far as the larger ships are concerned, another change is now almost complete, for nearly all ocean-going passenger vessels are fitted with "wireless" apparatus, and presently they will regularly rate their chronometers by means of time signals from some distant wireless station. By that time they will be in a position to make their own weather maps, if they wish, by collecting readings of the barometer and other instruments from other ships and from shore stations within range.

Even if that event should occur, the use of the barometer will not diminish but increase, and, in fact, it would appear that the result of extended facilities for a knowledge of the weather is that the seaman is no longer willing to be without the most accurate anticipation of coming weather that he can get, either from outside or by his own observations, and the barometer and the weather map are becoming increasingly important to him. Whatever be the size or power of an ocean-going vessel, her success as a dividend-earner depends upon taking advantage of all circumstances, including the weather.

Instructions in Modern Methods of Using the Barometer.

It has been the tradition of the Office from its first days to issue two manuals on the barometer, one the "Barometer Manual for the Use of Seamen," which has recently passed into its 7th Edition, and the other the "Fishery Barometer Manual," intended to be used in connexion with the fishery barometers which were lent originally by the Board of Trade for use at small seaports and fishing ports. The former is practically a text-book of general marine meteorology, while the latter is an introduction to the use of the barometer in connexion with weather maps written in simple language.

It has been found necessary to issue a new edition of the "Fishery Barometer Manual," and at my request Commander Hepworth has written the new version. Since the "Barometer Manual for the Use of Seamen" is rather limited in its scope, it appeared to him that a manual which dealt with the various sections of meteorology necessary for an intelligent use of the fishery barometer would be appreciated also by seamen who keep a weather log and contribute observations to the Office. The new edition appears, therefore, with the title of "The Seaman's Handbook of Meteorology."

To a certain extent it covers the same ground as the "Observers' Handbook," which is issued annually for the use of observers at land stations, and that handbook has been utilised wherever it was necessary for the purpose of this work.

Seamen's Weather.

Of all the various facts of weather the most important from the seaman's point of view are wind, fog, and floating ice. Snow must be added, because a heavy snowstorm may be worse than a fog, but it occurs so seldom upon the most frequented ocean routes that it is apt to escape notice in a summary. The other meteorological elements, humidity, cloud, rain, sunshine, and temperature of the air or sea, are of importance only as being an essential part of the order of events with which wind, fog, snow, and ice are associated. Their relation to the most important elements is not always obvious; for example, it has recently been asserted, as the result of observations by Professor H. T. Barnes, in a letter to "Nature," that in the region of icebergs the water (18 ft. below the surface) is warmer in the immediate neighbourhood of a berg than it is further off, and, therefore, that warmer water, not colder water, is an indication of the near presence of a berg. It is obviously necessary in considering the meteorological relationships of the three elements with which the sailor is chiefly concerned to have an open mind as to the usefulness of careful observations of other elements. Before entering upon the specific consideration of the principles of meteorology which have been largely developed in the last sixty years, it may be as well to turn our attention to some facts and figures concerning the principal elements which have been gradually brought to light, and are indications of the problems with which the meteorologist has to deal in his endeavour to reach the laws which govern their occurrence.

Wind.

The strongest winds on the earth's surface are to be found in the hurricanes of tropical seas and the tornadoes of subtropical lands. The remarkable effects produced by these winds include the driving of blown straws into tree-trunks and other fantastic results, but they form a separate chapter in meteorology into which we need not enter further than to say that wind becomes extremely destructive if its velocity exceeds 45 metres per second or 100 miles an hour, and that the velocity of winds on the coasts or seas of the British Isles, or in corresponding latitudes elsewhere, seldom reaches such a high figure. That in itself is a matter of some wonder. The theorist who is acquainted with the elementary facts about the rotation of the earth and its dimensions may fairly point out that, if by some means or other a bag full of air could be picked up at the equator, suddenly transported to latitude 60° N. or S. and set free there, it ought to be found moving at the rate of 500 miles an hour to the East, and *vice versa* if the air was carried from latitude 60° to the equator. Now northerly or southerly winds over long stretches are by no means uncommon, so it would seem that 100 miles an hour is a very moderate velocity, and what we have to explain is not so much why the air sometimes moves so fast, but why it generally moves so slowly. Obviously, whatever means Nature uses for carrying air from the equator to the poles or in the reverse direction, she has some method of preventing its acquiring what might easily be thought to be its natural velocity.

Miles per Hour, Feet per Second, and Metres per Second.

We are accustomed in this country, when we wish to describe the wind, to give its velocity in miles per hour. The actual mischief which a blast or gust of wind can do, depends very greatly upon the velocity with which it travels ; the destructiveness increasing very rapidly with increase of velocity ; thus a wind of double velocity exerts four times the force, one of three-fold velocity nine times the force and so on ; thus a wind of 100 miles an hour would give a thrust of 30 lbs. on a circle one square foot in area, while a wind of 10 miles an hour would only give a thrust of less than one-third of a pound. Moreover in quoting these figures we must remember that the effect of wind may be likened to the effect of the jet from a fire hose. It is a continuous bombardment by successive particles of air and the result of the bombardment depends on the number and weight of the particles as well as on the speed with which they travel.

Now cold air is, other things being equal, heavier than warm air, dry air than moist air, and air near the surface is heavier than air at higher levels. Consequently the effect of a hundred-mile wind will depend to some extent upon whether it is warm or cold, moist or dry, and whether it is high up above the sea level or close thereto; but these effects are really for the most part overshadowed by the ordinary variations in velocity, and are only of importance in exceptional circumstances.

Hence the relation between the velocity of wind and the force which it exerts upon objects exposed to it is not by any means a simple one. It is further complicated by the fact that in the case of any particular object or structure the shape of the obstacle has to be taken into account, just as the resistance of a ship depends upon her lines. In the case of a flat board exposed directly to the wind, we have to take account not only of the "pressure" on the face, which is due to the impact of the air upon it, but also of the "suction," or reduced pressure at the back.

In order to carry definite ideas about the force which the wind exerts, we use the force on a circular disc one square foot in area directly exposed to the wind. In that case the "suction" amounts to a little more than one third of the whole effect, and the resultant force in pounds is obtained by taking three thousandths of the square of the wind velocity. This is expressed by a formula

$$P = \cdot 003\ V^2$$

where P is the resultant force in pounds and V the wind velocity in miles per hour.

A factor ·0029 for a disc area of one square foot was given in 1890 by Mr. W. H. Dines,* practically confirming the factor ·003 adopted by engineers in place of the widely erroneous factor ·005, which is still actually used in many books as the basis of tables of wind velocity and force. The factor ·003 has been confirmed within small limits for plane

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* "On Wind Pressure upon an Inclined Surface." W. H. Dines, Proc. R. Soc., Vol. 48, p. 253, 1890.

surfaces of about that size by subsequent experiments at the National Physical Laboratory. (See list of references, Report of the Advisory Committee for Aeronautics, 1909–10, p. 28.)

For metric units, when wind velocity is expressed in metres per second and force in kilodynes upon a disc one square metre in area, the formula is

$$p = 72 v^2.$$

Gunners generally express wind velocity in feet per second, so that there is a difference of practice which may necessitate our remembering that 100 miles an hour is the same as 147 feet per second, and 100 feet per second the same as 68 miles per hour. A measurement in feet per second is convenient for those who have to work out dynamical problems involving wind velocity, and the same purpose is still better served by the use of metres per second which conforms to the general practice of many services. It may therefore be useful here to remark that 100 miles per hour is the same as 45 metres per second, and 10 metres a second is the same as 22¼ miles per hour.

The confusion in wind measurements and the conclusions drawn from them, due partly to the inherent difficulty of wind measurement and partly to the repetition of an erroneous factor, often introduces difficulties into the discussion of practical questions concerning wind ; and the adoption of the metre per second may well be used as an occasion for opening a new chapter in which a nearer approach to accuracy will be secured.

The Measurement of Wind Force and Velocity.

It may seem to be an easy matter to give a figure for the highest velocity of the wind in any region and to say, for example, that 100 miles an hour is a reasonable figure for the limit of velocity reached in the British Isles. It is not without interest to consider how long a time it has taken and how difficult it has been to arrive at that conclusion. In order to measure the velocity of wind in miles per hour, it is necessary to use an anemometer. Various forms of anemometer are described in a subsequent chapter, but they are mostly designed for a fixed exposure on land, they are seldom used at sea. The sailor has his own method of determining the force of the wind, which is only another aspect of its velocity, and that is by means of the Beaufort Scale.

Admiral Beaufort's Scale of Wind Force.

The numbers used for estimating the force of the wind range from 0, calm, to 12, hurricane force. The scale was originally devised for the use of seamen by Captain, afterwards Admiral, Sir Francis Beaufort, in the year 1805 when in command of H.M.S. *Woolwich.*

In the definition of the scale descriptive names are given to the winds of different strengths, corresponding with each number of the scale, and in addition a method for estimating the several forces is given, which is based on references to the speed at which a ship may travel or the canvas she can carry under certain conditions.

This method, which was suitable for the class of ship of Admiral Beaufort's time, specified the full-rigged frigate of the period 1800–1850. Later on it had to be modified to meet the requirements of double-topsail yards which were introduced into the Mercantile Marine subsequent to the latter date. The modifications adopted were suggested by the Maritime Congress in 1872, and were confirmed by the Congress held at the Meteorological Office, London, in 1874. Since then many important changes have taken place in the rig, build, and tonnage of sailing vessels; and compared with the number of steamers, there are few of any kind on the seas; so that the revised specification had become no longer applicable, and among sailors the estimation of wind force on the scale of 0 to 12 had become simply a matter of undefined tradition.

Various attempts had been made in this country and abroad to interpret the surviving tradition by ascertaining the range of velocity in miles per hour which the wind would register when its force was estimated by a number on the Beaufort Scale. The inquiry was necessarily a long one, because the opportunities of obtaining trustworthy estimates of the wind on the traditional scale at a spot where there is also an anemometer with a good exposure to register the velocity, are rare, and moreover it was only ascertained towards the close of last century that the numbers given by our standard instruments for measuring the wind were about 25 per cent. too high.

The concluding stages of the investigation are described in a publication called "The Beaufort Scale of Wind Force" issued by the Meteorological Office in 1906. As a result of the investigation, the Meteorological Office has adopted a new specification of the Beaufort Scale, allotting to each number on the scale its equivalent in average velocity in statute miles per hour; the pressure in pounds upon a circular disc one square foot in area is also given. The original Beaufort Scale and the Alternative Specification of the Beaufort numbers are as follow:—

Admiral Beaufort's Scale of Wind Force, 1805.

			For Ships Rigged with Double Topsails.*
0 Calm			
1 Light air ...	Just sufficient to give steerage way.		
2 Light breeze ...	With which a well-conditioned ship of war of Admiral Beaufort's time (1800—1850), with all sail set. would go in smooth water, and "clean full," from	1 to 2 knots.	
3 Gentle breeze ...		3 to 4 knots.	
4 Moderate breeze		5 to 6 knots.	
5 Fresh breeze ...	To which she could just carry in chase, "full and by"	Royals, &c.	
6 Strong breeze ...		Single-reefed topsails and topgallant sails.	6 Topgallant sails.
7 Moderate gale ...		Double-reefed topsails, jib, &c.	7 Topsails, jib, &c.
8 Fresh gale ...		Triple-reefed topsails, &c.	8 Reefed upper topsails and courses.
9 Strong gale ...		Close-reefed toptails and courses.	9 Lower topsails and courses.
10 Whole gale ...	With which she could scarcely bear close-reefed maintopsail and reefed foresail.		10 Lower maintopsail and reefed foresail.
11 Storm	Which would reduce her to storm-stay-sails.		
12 Hurricane ...	Which no canvas could withstand.		

* These modifications were made in 1874 to meet the requirements of double topsails, introduced since Admiral Beaufort's time.

New Alternative Specification, 1906.

Admiral Beaufort's Numbers.	Average of Velocity	Limits of Velocity	Equivalent pressure in pounds upon a circular disc one square foot in area.	Description of Wind.	Mode of estimating on board Sailing Vessels.	Criteria for Steamships.
	in statute miles per hour.					
0	0	Less than 1	Less than ·01	Calm	—	

1	2	1 to 3	·01 to ·04	Light breeze	Sufficient wind for working ship.	Special consideration is required for the specification of the scale for use on board steamships. For this purpose it is recommended that as opportunity occurs use be made of the equivalents given in Col. 2. Thus, when the ship is running in a calm at 15 knots, the wind felt in an exposed position on board will be a moderate breeze, which, according to the table, is force 4 on the Beaufort scale, and, if a similar breeze is felt when the ship is running at 15 knots, *right before the wind*, the actual speed of the wind will be 30 knots, 7 on the Beaufort scale, according to the table of equivalents. Other opportunities occur from time to time for comparing the speed of the wind with the speed of the ship. A hand anemometer may be employed if used judiciously and if proper allowance be made for the motion of the ship.
2	5	4 ,, 7	·05 ,, ·16			
3	10	8 ,, 12	·17 ,, ·44			
4	15	13 ,, 18	·45 ,, ·96	Moderate breeze	Forces most advantageous for sailing with leading wind and all sail drawing.	
5	21	19 ,, 24	·97 ,, 1·75			
6	27	25 ,, 31	1·76 ,, 2·88	Strong wind	Reduction of sail becomes necessary even with a leading wind.	
7	35	32 ,, 38	2·89 ,, 4·43			
8	42	39 ,, 46	4·44 ,, 6·45	Gale force	Considerable reduction of sail necessary even with wind quartering.	
9	50	47 ,, 54	6·46 ,, 9·00			
10	59	55 ,, 63	9·01 ,, 12·16	Storm force	Close reefed sail when running; or hove-to under storm sail.	
11	68	64 ,, 75	12·17 ,, 15·97			
12	Above 75	——	15·98 and above	Hurricane	No sail can withstand even when running.	

Structure of Wind.

The relation between the Beaufort numbers and the corresponding wind velocities has been based upon the hourly velocity of the wind. The observer has estimated the force upon the Beaufort Scale at one of the fixed hours for observing, say 7h. and the estimate has been set alongside the mean velocity of the wind for the hour between 6h. 30m. and 7h. 30m. as taken from the record of the anemometer.

At the time that was the only available mode of procedure. But in reality winds are not steady currents of air, flowing hour by hour without variation. The average hourly wind current of the anemometer is made up of rapidly alternating gusts and lulls and occasionally varied by squalls lasting for some minutes. In light airs there are often "puffs" of wind and even calms are sometimes disturbed by "catspaws."

Efforts have been made to give observers more precise directions for estimating wind force and attention is now being paid to the study of wind structure. Some interesting results are given in the Technical Report of the Advisory Committee for Aeronautics, and for a ship at sea Mr. G. I. Taylor made a beginning in 1913 by comparing the wind velocity at 45 ft. above sea level with that at 70 ft. on board the "Scotia," in 1913, when she was on a cruise for the investigation of ice. He found a difference of 7 per cent. in favour of the higher level.

What is a Gale?

It will be seen that in the Beaufort specification the winds indicated by the numbers 7, 8, 9, 10, are called *Moderate Gale*, *Fresh Gale*, *Strong Gale*, and *Whole Gale* respectively, and the new specification suggests that, in the interests of meteorology, a distinction should be drawn between a breeze, a wind, and a gale. It would be easy to find evidence from English literature that making a hard-and-fast distinction between these three words is an innovation. Still, so far as distinguishing between a gale and other winds or breezes, the innovation is a necessary one, because we endeavour to warn the coasts for gales which are not expected to reach what Admiral Beaufort called a *storm* (Force 11), although the technical name of "storm-warning" or "storm signal" might convey the misleading inference that the issue of a warning implies the probability of a storm in the sense used by Beaufort.

It is well, therefore, to make it clear that in deciding whether to issue a "storm-warning" a meteorologist has in mind the probability of a "gale," the warning would be more appropriately termed a "gale-warning"; and in counting gales we do not include what Beaufort called "a moderate gale" (Force 7). A good deal of time might be spent in arguing whether or not a "moderate gale" is really a gale in a seaman's judgment without coming to any satisfactory conclusion. In fact, when it is necessary to draw a distinction for statistical purposes, the implied contradiction of a moderate gale is not satisfactory. In specifying a wind scale for land in the "Observer's Handbook" we have given the description "high wind" to Force 7. At sea winds of that force may perhaps be called "half a gale," but for our purposes a "gale" means a wind of Force 8 or more, that is, the average velocity during an hour should reach at least 38 miles an hour.

This definition of a gale is in conformity with that adopted by international agreement for regulating the use of the symbol  which is employed to denote the occurrence of a gale at meteorological stations on land.

Winds of Whole Gale and Storm Force.

Over the British Isles it is only during gales of exceptional severity that the wind reaches what is technically known as storm force, *i.e.*, exceeds 9 of the Beaufort Scale, or a run of 54 miles in an hour. Occasions during the past fourteen years on which a higher velocity than 54 miles in the hour has been recorded on anemometers at stations in various parts of the British Isles in connexion with the Meteorological Office are shown in the accompanying table, (Table A) with the dates, velocities, and places of occurrence. On the eight occasions when the figure for the velocity is marked ✻, Force 11, a "storm," according to Beaufort, has been reached. It must, however, be remembered that the absence of a record on an anemometer does not necessarily mean that the higher forces were not reached. The exposure of anemometers is sometimes not free enough to give the full force of the wind in the locality, because the vane or cups are not carried high enough above the surrounding buildings to give a measure of the current which may produce its full effect upon a ship at sea, not far away, or upon a projecting obstacle on an exposed shore.

TABLE A.

Wind Velocities of Force 10 or upwards of the Beaufort Scale, recorded on Anemometers at Stations in connexion with the Meteorological Office, 1899–1913.

Station.	Date.	Average Velocity during an hour or more.	Beaufort Numbers.	Maximum Velocity in gusts.
		Miles per hour.		Miles per hour
Holyhead	1899, January 2nd	—	?	94
Fleetwood	,, January 12th	*75	11	—
Southport	,, January 12th	—	?	90
Scilly	1900, December 28th	61	10	90
Shields	1903, February 26th–27th	55	10	—
Valencia	,, February 26th–27th	63	10	—
Kingstown	,, February 26th–27th	*66	11	—
Liverpool	,, February	*65	11	88, 86, 84. 82 and 81.
Blackpool	,, February	—	?	87
Fleetwood	,, July 5th–6th	59	10	—
Scilly	,, September 10th–11th	*64	11	—
Scilly	1904, January 13th–15th	62	10	75
Scilly	,, February 12th–13th	*65	11	77
Pendennis Castle, Falmouth.	1905, March 14th	—	?	†103, 93
Holyhead	,, March 15th	—	?	84
Scilly	1906, January 6th	59	10	81
Pendennis	,, January 6th	*65	11	85
Scilly	,, January 18th	55	10	76
Pendennis	,, January 18th	56	10	70
Scilly	,, December 5th–6th	62	10	85
Holyhead	,, December 5th–6th	55	10	79
Roche's Point	,, December 5th–6th	59	10	75
Deerness	,, December 26th–28th	62	10	—
Deerness	1907, January 28th	59	10	—
Fleetwood	,, February 19th–21st	59	10	—
Pendennis	,, March 16th–17th	55	10	69
Southport	,, March 16th–17th	60	10	81
Fleetwood	,, March 16th–17th	56	10	—
Pendennis	,, October 18th–19th	55	10	71
Fleetwood	,, November 12th–13th	59	10	—
Fleetwood	,, December 13th–14th	61	10	—
Pendennis	,, December 26th–28th	59	10	71
Scilly	1908, January 7th–8th	55	10	—
Fleetwood	,, February 22nd	55	10	—
Deerness	,, February 22nd–23rd	59	10	—
Pendennis	,, March 5th–6th	55	10	73
Pendennis	,, August 26th	55	10	69
Pendennis	,, August 31st	58	10	78
Scilly	,, September 1st	56	10	69
Pendennis	,, September 1st	56	10	75
Fleetwood	,, November 22nd–23rd	56	10	—
Deerness	,, December 28th–29th	56	10	—
Scilly	1909, January 16th	55	10	78
Edinburgh	,, January 18th	56	10	—
Pendennis	,, October 7th	56	10	67
Scilly	,, October 23rd	*70	11	90
Pendennis	,, October 23rd	55	10	73
Fleetwood	,, November 12th–13th	55	10	—
Pendennis	,, November 18th	56	10	75
Scilly	,, December 1st	56	10	66

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† On the wind record for this date there is an isolated mark which might be taken to indicate a velocity of 106·5 miles per hour, but careful examination at the time left the matter in doubt.

Wind Velocities of Force 10 or upwards of the Beaufort Scale, recorded on Anemometers at Stations in connexion with the Meteorological Office, 1899–1913—continued.

Station.	Date.	Average Velocity during an hour or more.	Beaufort Numbers.	Maximum Velocity in gusts.
		Miles per hour.		Miles per hour
Pendennis	1909, December 2nd	55	10	75
Southport	,, December 3rd	58	10	76
Fleetwood	,, December 3rd	*66	11	—
Scilly	1910, January 24th	57	10	80
Pendennis	,, February 14th	56	10	71
Kingstown	,, February 17th	55	10	—
Southport	,, February 17th	55	10	76
Pendennis	,, February 18th–19th	60	10	87
Plymouth	,, February 20th	56	10	73
Pendennis	,, February 20th–21st	62	10	82
Kingstown	,, February 21st	59	10	—
Southport	,, February 21st	63	10	85
Scilly	,, August 1st–2nd	56	10	60
Scilly	,, October 2nd	59	10	70
Pendennis	,, October 14th	57	10	72
Deerness	,, November 7th	56	10	—
Pendennis	,, December 7th	55	10	67
Pendennis	,, December 9th	56	10	70
Pendennis	,, December 16th	63	10	85
Pendennis Castle	1911, October 30th	57	10	71
Eskdalemuir	,, November 5th	62	10	90
Southport	,, November 5th	57	10	80
Fleetwood	,, November 5th	57	10	—
Quilty	,, December 4th–5th	55	10	78
Pendennis Castle	,, December 6th–7th	*64	11	79
Pendennis Castle	,, December 10th	57	10	71
Pendennis Castle	,, December 13th	61	10	77
Scilly	,, December 13th	58	10	73
Pendennis Castle	,, December 18th	59	10	75
Pendennis Castle	1912, March 4th	*64	11	98
Scilly	,, March 4th–5th	63	10	72
Pendennis Castle	,, March 5th	57	10	78
Pendennis Castle	,, March 21st	56	10	77
Fleetwood	,, November 10th	55	10	—
Pendennis Castle	,, November 13th	*66	11	83
Dwyran	,, November 26th	57	10	75
Deerness	,, November 27th	60	10	—
Quilty	,, December 24th	62	10	88
Pendennis Castle	,, December 26th	*70	11	98
Scilly	,, December 26th	*65	11	88
Roches Point	1913, January 9th	55	10	70
Roches Point	,, January 14th	58	10	75
Dwyran	,, February 7th	55	10	79
Pendennis Castle	,, February 7th	59	10	72
Kingstown	,, February 7th	62	10	—
Quilty	,, February 7th	56	10	80
Valencia	,, February 7th	55	10	—
Fleetwood	,, February 7th–8th	55	10	—
Southport	,, February 7th–8th	62	10	86
Pendennis Castle	,, March 16th–17th	57	10	72
Pendennis Castle	,, March 21st	58	10	67
Pendennis Castle	,, April 26th	59	10	72
Pendennis Castle	,, May 30th	56	10	70
Fleetwood	,, December 3rd	56	10	—
Southport	,, December 3rd	56	10	82
Pendennis Castle	,, December 3rd	59	10	74
Fleetwood	,, December 4th	56	10	—

Gusts.

In the preceding table it will be noticed that in the last column the extreme velocity reached in "gusts" is given. The figures are taken from the records of the pressure tube anemometer designed by Mr. W. H. Dines, F.R.S., and now used at many stations in connexion with the Meteorological Office. The records from these instruments show fluctuations of the force of the wind which may be of the duration of less than a minute, and we learn from them the range of the fluctuations which everybody knows to be constantly occurring even in what may be called a steady blow. It would appear from the records that the range between gusts and lulls is greater, the greater the average force of the wind; and that it is much greater at stations inland than at those well exposed on a flat, low shore. We may conclude that at sea the range from gusts to lulls is comparatively small; at present we do not know what it actually is. At a good exposure like that of Pendennis Castle or Spurn Head a 60-mile wind would probably show fluctuations between "lulls" of 52 miles an hour and gusts of 68 miles an hour.

Hence it must be understood that a wind which is not properly classed as a gale may still include gusts of gale force; and a wind which is classed as a wind of gale force may include gusts of storm force. The gusts of storm force recorded on the anemometers of the Meteorological Office are enumerated year by year in a special appendix to the Weekly Weather Report.

Prevalence of Winds from Different Directions.

Before concluding these general remarks about wind we may add some information in regard to the frequency of wind from different quarters on our coasts; winds from southward, south-westward and westward are most frequent, and the quarter from which the wind blows with the greatest frequency is south-west. Wind-frequency, however, varies with locality, and depends mainly upon the relative position of a locality with regard to the average path or paths of the centres of cyclonic disturbances which visit North-Western Europe and affect the weather conditions of our islands.

TABLE B.

AVERAGE* WIND FREQUENCY.

GREAT BRITAIN.	Average number of Days of Wind from various quarters in a year.								
	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
North Coast ...	51	29	23	48	59	48	56	38	13
East Coast	35	34	24	25	39	80	68	43	17
South Coast ...	45	39	42	24	34	60	61	45	15
West Coast	30	29	42	44	36	57	64	45	18
Greenwich	41	47	29	23	35	106	47	22	15
IRELAND.									
North and West Coasts.	36	26	38	40	53	65	52	45	10

Table B furnishes a statement of the average number of days of wind from each of eight cardinal and inter-cardinal points of the compass, and of calms experienced on the coasts of England, Scotland, the North and West of Ireland, and at Greenwich. The results are based on data which for the most part extend over a long series of years.

Fog and Snow.

While with the progress of invention and the consequent substitution of steam-power for sails the seaman has become less and less dependent upon the vagaries of the wind, the same course of events has made him much more inquisitive about fog. On land, and generally speaking also at sea, fog is an incident of calm weather. It is true that what is called "thick weather" may be experienced with a wind, and that thick weather may, on occasions, be called fog in meteorological registers and so give some foundation in statistics for fogs with strong winds; but in practice a sailor regards fog as a very special kind of thick weather, and in what he

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* The word *average*, which originally was employed to describe only the proportional distribution among shippers of damage or loss sustained by sea, is now used also to imply the mean or middle point or degree of any given quantity. For instance, suppose an observer who lived for 30 years at some place on the South Coast of England noted the direction of the wind each day during that period, and recorded a south-east wind on 720 days. The average day frequency of wind from that point of the compass in his locality would in that case be 24.

would call "real fog" there is little wind. So in the old sailing days, ships automatically slowed down when they got into fogs because the wind dropped. The seaman, therefore, had the comforting assurance, if he was himself held up by fog, that his neighbour was likewise going dead slow because he could not help it.

But now all this is changed; there is no automatic slowing down during fog; it requires an order to be given and two neighbours on the sea are not necessarily agreed as to procedure. There is consequently a sense of uncertainty at sea in a fog which makes everybody wish to avoid it if possible; and it is so capricious in its incidence, coming on and going off so suddenly, and with so little apparent reason, that more knowledge of the subject could hardly fail to be useful.

But as yet we have much to learn. We can set out conditions under which fog is likely, but it is not always there when the conditions are set up. It is possible that in the study of this subject especially we are hampered by our limitation to the surface. We can find out what happens to right and left, in front or behind, but what we most want to know is what is taking place overhead, and for that, at present, we have no provision. Yet means are now available, and perhaps within a few years liners may carry a small balloon and a few bottles of hydrogen so that they may find out what there is above and so account for the peculiar conditions at the surface that cause a persistent cloud there.

Snow comes under consideration here only as interfering with seeing. There is much interesting work to be done in studying the details of atmospheric obscurity. A cloud of water-drops, if there are enough of them and they are of the right size, may completely block out the daylight even without the assistance of smoke. One can see distant objects through heavy rain, but not the heaviest rain, nor through fog or mist, yet all are clouds of water globules. Snow is terribly obstructive, but the veils of ice crystals which form the uppermost clouds are transparent.

Floating Ice.

The last element of seamen's weather to which attention will be called here is floating ice. That is objectionable to the sailing ship and steamer alike—it is worse for the steamer on account of her greater speed. The tragic loss of the huge White Star liner *Titanic* on April 15, 1912, in the mid-Atlantic, in consequence of a collision with an iceberg on the normal steamer route, has drawn the attention of the whole world to these dangers to navigation, and has led to the demand for additional information about them. We already have a great deal of information upon the subject, and are gradually collecting more, which is not so well known to seamen as it ought to be. I have therefore asked Captain Hepworth to write an additional chapter for this book which will give an account of the information which we already possess.

As a matter of fact, floating ice may seem at first sight hardly to come within the province of meteorology as it is primarily related to the water rather than the air. It is doubtless carried along by the water, helped, hindered or crossed by the wind ; but a little reflexion will show that for meteorology floating ice is really one of the most important considerations. Whatever may ultimately become of it, it starts from the polar glaciers and ice fields ; its prevalence at any particular season or in any particular year depends, partly at least, on the state of the polar ice-cap some time previously and upon the meteorological changes that have been operative since it reached the sea. Thus the occurrence of floating ice is a part of the results of the general atmospheric circulation of which the polar ice caps are also incidents and may have a dominant influence in determining the meteorological conditions at any particular time.

A vessel is just now on the point of starting for Davis Strait to ascertain the conditions of the ice there, as a guide to shipowners in choosing a route which will be reasonably free from the risks of floating ice in the coming season. But while the vessel is looking for the secrets of the ice that reaches the steamship routes, she cannot help contributing to the study of the general problem of the weather. As soon as one begins to examine causes it is impossible to overlook the fact that the weather of the world forms a vastly complicated but still united whole, which does not allow itself to be divided up into independent sections that can be separately studied.

It is, perhaps, too much to say that the ice in the North Atlantic determines the character of the weather for our farmers at home, but it is not even an exaggeration to say that by looking for an explanation of the prevalence of ice in the North Atlantic we may find an explanation of the character of our seasons. People are apt sometimes to think that groups of meteorological events can be connected together without having relations with the rest of the world.

and to assume, for example, that the Atlantic is independent of the Pacific. It cannot be so. The causes of a wet English summer, of unusual ice in the North Atlantic, of a drought in India, or a plentiful rainy season in Australia, or of a succession of blizzards in the Antarctic, are all bound up together, and whoever would be successful in endeavouring to explain the one had better attempt the whole. When forecasts are made for seasons they will have to be likewise forecasts for the earth, not, of course, giving the same weather all over, but setting out regions of this type or of that, and the key to them all is not improbably to be found, not so much in the heat of the tropics as in the cold of the poles.

In like manner we cannot reasonably present simply the meteorology of winds, of fog, and snow and floating ice. It is all bound up with considerations of heat and cold, humidity and dryness, and all the rest of the complicated process which constitutes the life-history of weather.

Clouds.

I may take this opportunity of calling the attention of the reader to a guide to the classification of cloud forms which was introduced some years ago into the *Observer's Handbook*, with some illustrations which are reproduced here to help the seaman in the identification of the cloud forms defined in the International Cloud Atlas referred to in Chapter IV.

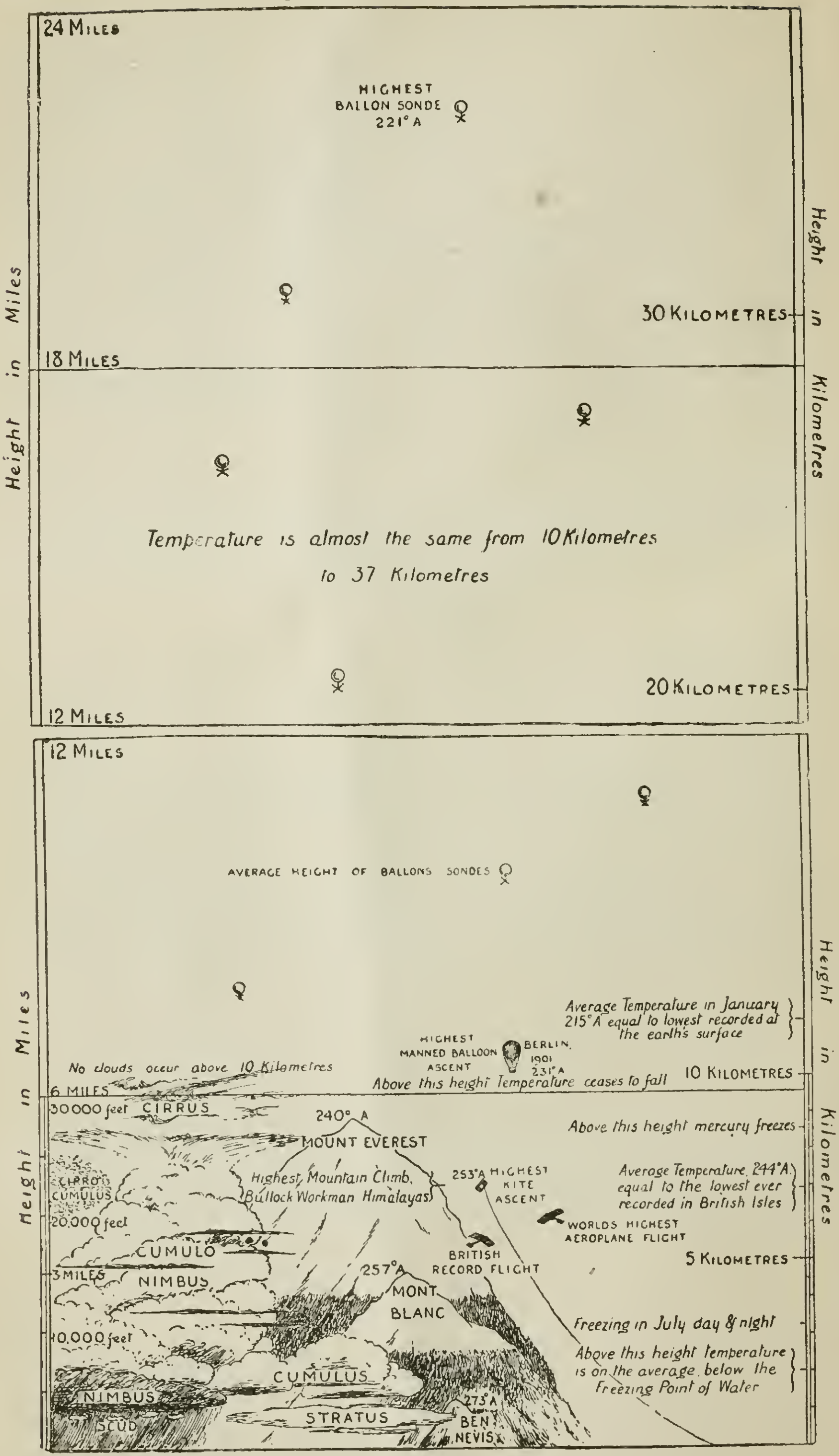
In these days when hand-cameras and dry plates or films are easily obtainable seamen who are interested in meteorology would do well to photograph clouds for themselves, and so make their own collection of typical forms. They will find that there are not many occasions on which the clouds visible in the sky can be assigned to a single type. Not infrequently the cloud-forms visible at one time are so numerous that an observer finds it difficult to fix upon one as appropriate for entry in the observation form ; the forms of *stratocumulus* are particularly numerous and diversified. A collection of photographs is a great aid to the observer in making his classification.

The approximate average height of the principal forms of cloud that are included in the following classification is shown in Fig. A on page xxxii. by reference to those of mountains of about the same height respectively. The average height, and the highest altitudes that are or have been attained by aeroplanes ; kites ; manned balloons ; and ballons sondes, severally, are also stated ; together with the temperatures thereat recorded. The former are given in miles, and in kilometres ; the latter in terms of the absolute scale of temperature.

The height of the troposphere, which is the lowest layer of the atmosphere ; and that of the stratosphere, which is the next layer above it, are also shown.

NOTE.—The GUIDE TO THE CLASSIFICATION OF CLOUD FORMS is printed as Appendix VI. of the *Marine Observer's Handbook*, and, for the convenience of reference, is included here in this volume, but it will be understood that the number of the Appendix and the references to pages belong to the "Marine Observer's Handbook" and not to this book.

The Exploration of the Atmosphere.



The Troposphere and lower region of the Stratosphere.

Fig. A.

ILLUSTRATIONS OF CLOUD-FORMS.

GUIDE TO THE CLASSIFICATION OF CLOUD-FORMS.

For the assistance of observers a scheme of classification of cloud-forms in accordance with the international classification is reproduced on pp. xxxiv, xxxv, from notes of a course of lectures in the University of London, 1908. It is based upon the consideration of the question whether the observer sees merely the extended under surface of a high distant layer, or of a layer, high or low, immediately overhead (clouds seen mostly in plan), or sees the general mass of the cloud at a distance in perspective (clouds seen mostly in elevation or profile). The height and vertical thickness of the clouds become important items from this point of view. Estimates of the heights of the various types are taken from the International Cloud Atlas. In practice it will be found that many forms of cloud of the British Isles which are not easily classified fall under the denomination *Strato-cumulus* as being seen partly in plan and partly in elevation or perspective but at no great height. Whether the scheme of classification is sufficiently exclusive to make the identification independent of the distance from which the cloud is seen is not yet ascertained.

EXAMPLES OF CLOUD-FORMS.

Photographs by G. A. Clarke, Aberdeen Observatory.

FIG. 1. Thread-like **Cirrus** in the Zenith. 1907—July.

FIG. 2. A tuft of "false" Cirrus. 1910—July 6. 16 h. 55 m.

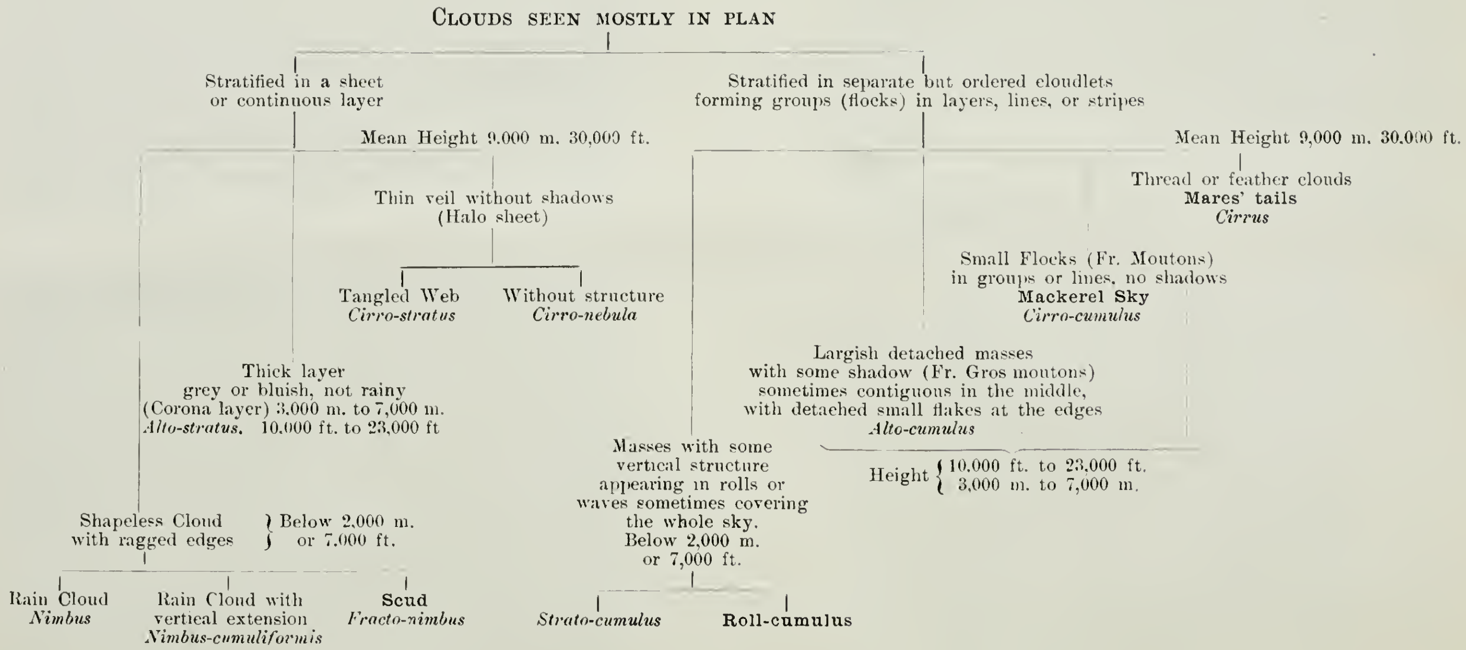
Fig. 5. Top of Cumulo-nimbus. 1907—June 28. 13 h. (G. A. C.)

Fig. 7. Veil of Cirro-stratus (Cirrus Haze), with Strato-cumulus in front. (W. J. S. L.)

Fig. 6. Lower part of Nimbus. 1907—May 18. 11 h. 33 m. (W. J. S. L.)

Fig. 8. Strato-cumulus with Alto-stratus above. 1908—Jan. 29, 11 h 45 m. (G.A.C.)

GUIDE TO THE IDENTIFICATION OF CLOUD-FORMS.



CLOUDS SEEN MOSTLY IN ELEVATION OR "PROFILE."

Cloud-Heaps of considerable vertical height.

Mean Height: Top 3,000 to 8,000 m. 10,000 to 26,000 ft.; Base 1,400 m., 4,600 ft.

- Rounded bulging top, mean height 1,800 m. 6,000 ft.
  Flat base, mean height 1,400 m. 4,600 ft.
  - Top smooth and Cauliflower shaped **Woolpack Cloud** *Cumulus*
  - Top ragged *Fracto-cumulus*
- Towering clouds with wisps of **false cirrus** and rain cloud base
  - **Anvil Cloud**
  - **Thunder Cloud**
  - **Shower Cloud**
  - **Arched Cloud** Line squall

  Cumulo-nimbus
  Seen in plan. *Mammato-cumulus*

LOW CLOUDS SEEN IN PLAN OR ELEVATION ACCORDING TO CIRCUMSTANCES.

Fog banks or wreaths, mountain clouds.

Below 1,000 m. 3,300 ft.

- **Fog**
- **Mountain Mist or Drifting Mist** *Fracto-stratus*
- Uniform layer without structure *Stratus*
- Fog layer with some vertical structure *Stratus-cumuliformis*

SEQUENCE OF CLOUD-FORMS. February 27, 1907.

Photographs by G. A. Clarke, Aberdeen Observatory.

Fig. 9. 14 h. 5 m. Cirrus and Cirro-cumulus.

Fig. 10. 14 h. 10 m. Alto-cumulus.

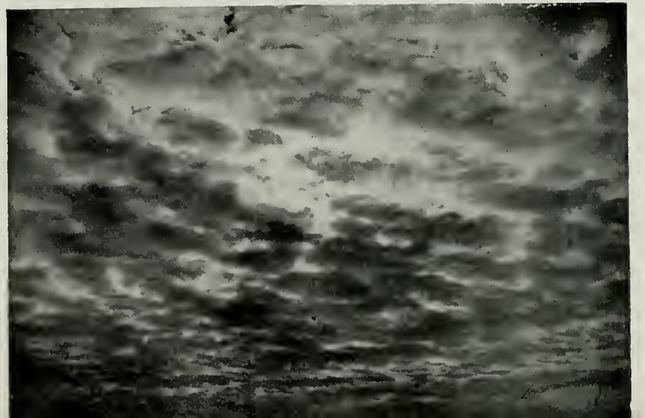


FIG. 13. Cirrus and rippled Cirro-cumulus. 10 h. 40 m.

FIG. 14. Rippled Cirro-cumulus. 11 h. 50 m.

FIG. 15. Cirro-cumulus becoming Alto-cumulus. 12 h. 5 m.

FIG. 16. Alto-cumulus becoming Strato-cumulus. 12 h. 50 m.

NOTE ON THE ILLUSTRATIONS OF CLOUD-FORMS.

The definitions of the typical Cloud-Forms are given in pp. 40 to 42. These definitions are taken from the International Atlas of Clouds which was approved at the International Conference of Directors of Meteorological Institutes and Observatories at Innsbruck in 1905 and published by Gauthier Villars in 1910. It includes a number of carefully selected illustrations of the typical forms reproduced by chromo-lithography, which are intended as a guide to observers as regards the nomenclature of clouds. Copies of the Atlas can be obtained from the Meteorological Office, price 10s.

It was originally intended to make a selection of the illustrations reproduced in the International Cloud Atlas and include copies of them in this volume, but when the Atlas was published it was felt that it would be unjust to the international selection to pick out some and leave others; the international selection must be taken in its entirety as illustrating what the Commission and the Conference meant to be included. Meanwhile it is a matter of common experience that the difficulty of the meteorological observer is not so much in recognising a cloud-form when a typical example occurs as in describing what may be called the every-day sky which is often very composite.

The Meteorological Office has become possessed of a rich collection of beautiful cloud photographs by Mr. G. A. Clarke, of Aberdeen Observatory, showing all kinds of skies, typical and other, for the naming of which the principles of the international classification ought to be an adequate guide. A selection has therefore been made from the photographs included in Mr. Clarke's album and to these names have been given in accordance with the principles of classification laid down in the International Atlas as understood in the Meteorological Office. It is not suggested that the selection includes all the types which an expert meteorologist will recognise.

THE MEASUREMENT OF PRESSURE.

The demand for a reprint of the *Seaman's Handbook of Meteorology* must not be allowed to pass without a note about the innovation of the past year, a change in the graduation of the barometers supplied by the Meteorological Office to the stations which report daily by telegraph and to the observers of the mercantile marine. Since the 1st May, 1914, the readings of the barometers published in the *Daily Weather Report* have been given in "millibars" instead of "inches," and it is intended to ask the marine observers to use the same scale in the meteorological log.

What a Millibar means.

A millibar is approximately the thousandth part of the ordinary atmospheric pressure at sea level. Face a wind of force 6 in an exposed situation and you will be withstanding a pressure of about a millibar. Multiply that by a thousand and you will get some idea of what you would have to withstand if somebody surreptitiously or otherwise removed the air from behind your back on a calm day. It amounts to about 14½ lbs. on the square inch, and taken over the front of the average human body would mean withstanding a force of seven tons, so that there would be little chance of holding it for long.

Fortunately there is not much chance of anyone unawares taking away the air from behind one's back, but, nevertheless when one has to think about the pressure of the atmosphere, it is forces of this kind that one ought to have in mind, forces which are estimated in pounds per square inch or, better still, their equivalent in millibars and not the inches of a mercury column which are only the conventional expression of atmospheric pressure.

Barometers might have been graduated in pounds per square inch instead of inches; and the range at sea level would then have been from 13½ to 15½ instead of from 27 to 31, and we should then have kept better in mind the forces which are operative in the problems of the atmosphere. It is still not too late to take such a step for there are many problems of the atmosphere that are not yet solved.

Corrections to Barometric Readings.

But the natural philosophers to whom we look for enlightenment on such points have taken another course. They have found out for us that the pressure-value of a mercury column is different at different temperatures and in different latitudes, and have explained that when we want to use the readings of a mercury barometer we must make corrections on these accounts as well as on account of the expansion or contraction of the brass scale which is used for the reading. We must also allow for the index error of the barometer which is determined by means of a comparison with a recognised standard instrument. Even then we are not at an end, for the reading must be reduced to sea level before it can be charted on a map. Now it has been explained that in these days a meteorologist thinks in maps, so before barometer readings can be used in meteorology they have to be corrected for index error, for the temperature of the mercury and the brass scale and for latitude, and also they must be reduced to sea level.

The Practice of the last Sixty Years.

This string of corrections and reduction has been hitherto regarded as an unnecessary refinement for the seaman who only wants to know roughly what the barometer is doing. All that an observer has been asked to do is to set down in the log the reading of the barometer and attached thermometer, and of course the latitude, and leave the rest to the Office. Somewhere in the log will have been entered the height of the barometer cistern above sea level and the number of the barometer of which we keep a record and know the index error. So we have had all the materials necessary for making these elaborate corrections, and they have all been duly made during the last sixty years with the exception of the correction for latitude, which has only been generally regarded by meteorologists as necessary within the last ten years.

Pressure in Pressure-units.

It is the introduction of this new correction which has made a difference to our outlook. We have been asking ourselves what is the real meaning of the philosopher's requirements, that we should reduce barometer readings to a true length of mercury at the freezing point of water in latitude 45°—the reduction to sea level is our own affair—and the answer is because you want to compare *pressures*. To that our rejoinder is then: Why do you lead us up to the brink and stop short of the final plunge which is the mere multiplication by a single factor? Why not give pressures? Why give "inches" of mercury? And we find that millibars are a very convenient expression of pressure. If there were no other reason, the fact that ordinary sea level pressures are about 1000 millibars is a very good one. There are others, about which there is something to be said later. For the present let us consider why we should aim at giving pressures in pressure units.

The Consequence of "Thinking in Maps."

We have said that a meteorologist thinks in maps, and the sailor at sea if he wishes to take part in the use and practice of modern meteorology must do so likewise. To do so he must use corrected and reduced barometer readings and not the crude uncorrected readings; they are worse than useless on a meteorological chart; if you are not sure about them they are distracting to the last degree. Ships within hail by "wireless." on the Atlantic exchange barometer readings by way of courtesy, and quite rightly, for they might be very useful; but the barometer is read in inches, corrected for temperature—still inches, reduced to sea level—still inches. None of them are actually inches in real life, but they are called so. and how can the recipient make any use of an observation unless he knows which is meant? If the sender has omitted to correct for temperature the reading is very likely out by the tenth of an inch, or for height it may be nearly as much out, and the index error may be almost anything. These differences may seem trivial to the onlooker, but they completely upset the weather on a map. It is fortunate that the observer is out of hearing when the map-maker is brought up by a barometer reading that will not fit.

The necessity for simplicity in dealing with Barometric Readings.

It is therefore very desirable that a barometric reading at sea should be reduced, there and then, to its meteorological form so that it may be immediately put side by side for comparison with any other reading that comes from another ship or from shore, or with a weather chart or a synoptic chart of mean pressures.

But the conventional process of correcting and reducing barometer readings is so tedious that only a central Meteorological Office could be expected to face the drudgery in the form in which the natural philosophers have presented it.

Now we have found that when we confine our attention to the accuracy required in practical work the drudgery is very largely artificial and unnecessary, rooted in the history of the barometer. With the new graduation of the barometer we propose to simplify the process and to arrange that in ordinary circumstances the corrections will be small and the trouble infinitesimal. An explanation of the whole process is set out at length on pp. 11 to 14, and a specimen in practical form is given on pp. 15, 16. With the old graduation the reading would have needed correction for temperature and latitude as well as for index error and reduction to sea level unless the ship was in latitude 45° and the barometer exposed to a temperature of 28° F., a combination of circumstances which must be very rare ; we propose, on the other hand, to have a barometer which will need no correction at all in the most usual conditions and, generally speaking, only a small correction that can be carried out in one's head from a reading of the attached thermometer, instead of requiring an elaborate series of tables of corrections that, so far as we are aware, no seaman ever uses.

So our advice to seamen who would help one another with their barometer readings is :—

First, use a mercury barometer because aneroid readings will not plot on a map. The index error is always uncertain.

Secondly, correct your readings for index error, temperature, latitude and height above sea level, and show that you have done so by quoting the result in millibars.

Absolute Temperature for the Attached Thermometer.

In graduating the attached thermometer we have used a scale of temperatures which is named after Lord Kelvin, because it starts from a certain zero which he called absolute, and which is of great theoretical importance. There are reasons for using this scale for all meteorological purposes, which appeal to those who have to deal with the physical problems of the atmosphere and which will ultimately make themselves felt in ordinary meteorology, but we are not concerned with them just now. What we have in mind for the moment is that the temperature of the barometer is one thing, it enables one to get the pressure of the atmosphere from the barometer reading ; and the temperature of the air for meteorological purposes is quite a different thing. The barometer can properly be kept indoors comfortably warmed, but the thermometer that is intended to give the meteorological temperature of the air must be out of doors in a screen which lets the air go through it, and at this stage of our work it is an advantage, rather than otherwise, that the thermometer, which is to give the temperature of the mercury column merely as an auxiliary for getting an accurate value of the pressure should be graduated differently from the thermometer which is intended to take the temperature of the open air.

We use the temperature given by the attached thermometer to enable us to get a correct measure of pressure from the barometer and for nothing else, so for the time being we use a special thermometer. And when we have employed its readings in the way described on p. 12 we get the pressure in pressure-units which we call millibars.

A Word of Caution.

It must be remarked here that since millibars are pressure-units a pressure in millibars represents the final result, and it would be wrong to use the word for anything but the final result. Consequently we ought to avoid using it until the final result with the correction for temperature has been obtained. The reduction to sea level is not necessarily included, but it is best to include it because the reduction to sea level is never a large matter at sea, but just large enough to spoil the use of the reading to your neighbour if it is omitted. So the first reading of the barometer is merely a meaningless number until the temperature correction is applied and the sea level reduction can be applied at the same operation.

Standard Temperature.

To show whether any correction is necessary we have the "standard temperature" clearly marked on the instrument. That is the temperature of the attached thermometer at which no correction would be required in latitude 45°. A different temperature would be appropriate in another latitude which we call the "fiducial temperature" for that latitude. So that all we require to know for correcting a reading is the fiducial temperature and the actual temperature of the attached thermometer and the appropriate correction for the difference of the two. If there is no difference there is no correction. When the correction has been applied the process is at an end and the result is the real pressure in millibars and the citation of a pressure in millibars is *prima facie* evidence that the correction has been applied. There is another way of dealing with the matter by which the correction is given by a sliding scale alongside the attached thermometer. It is quite easy to work in practice but lengthy to describe. An account of it is given in a paper by Mr. E. Gold in the quarterly *Journal of the Royal Meteorological Society.* The final result is, of course, the same.

If the original reading of the barometer is cited, please do not forget that the reading of the attached thermometer, the latitude, the index error, and the height above sea level, have all to be given as well before anybody can make use of the observation by plotting on a chart and that is the only way in which barometer readings can be of any real use in these days.

Some Facts and Figures about Pressure in Millibars.

The reader may be interested in the results obtained by observation of pressure expressed in millibars.

Here are some approximate figures for values between which the pressure usually lies at different latitudes along the meridian of 30° W. The values are based upon information given in terms of inches in the "Barometer Manual for the Use of Seamen," which has been modified by the application of the correction for latitude :—

North Latitude.	Winter.	Summer.
	mb. mb.	mb. mb.
60°	963 to 1024	990 to 1024
50°	975 ,, 1026	1000 ,, 1027
40°	992 ,, 1034	1012 ,, 1032
30°	1006 ,, 1028	1013 ,, 1027
Tropic of Cancer	1008 ,, 1022	1013 ,, 1023
Equator	1004 ,, 1011	1006 ,, 1013
Tropic of Capricorn ...	1007 ,, 1019	1014 ,, 1026
30°	1003 ,, 1022	1009 ,, 1029
40°	996 ,, 1023	994 ,, 1028
50°	971 ,, 1012	970 ,, 1024
55°	962 ,, 1006	959 ,, 1018
South Latitude.	Summer.	Winter.

It will be noticed that on the whole a deficiency of pressure is shown in the Southern Hemisphere which, unless it be an accident of figures due to the limitation of the area mapped, is a very remarkable fact.

The average frequency of occurrence of pressure in the British Isles is set out in the following table. The numbers of days given are those on which the lowest barometer reading of the day has been found to be within certain limits of "low" barometer, and on the other side when the highest reading is within certain limits of "high" barometer.

Limits in Millibars.	Aberdeen.	Valencia.	Kew.
940–950 ...	—	1 day in 5 years	—
950–960 ...	1 day in 2 years	1 day in 5 years	—
960–970 ...	3 days a year	2 days a year	1 day in 10 years.
970–980 ...	10 days a year	6 days a year	3 days a year.
980–990 ...	26 days a year	21 days a year	14 days a year.
990–1000...	57 days a year	42 days a year	39 days a year.
1020–1030...	109 days a year	123 days a year	133 days a year.
1030–1040...	29 days a year	37 days a year	34 days a year.
1040–1050...	1 day a year...	3 days a year	3 days a year.
Above 1050.	2 days in 5 years	1 day in 3 years	—

The highest recorded sea-level pressure in the British Isles is 1053·5 mb. at Aberdeen on 31st January, 1902, and the lowest 925 mb. at Ochtertyre on 26th January, 1884; the same figure was reached at sea in the Atlantic on 5th February, 1870.

The daily range of pressure in tropical seas, the most characteristic feature of continuous records of pressure in those regions, is about $2\frac{1}{2}$ mb. In British seas the average daily range is 0·7 mb. and is quite noticeable on a barogram whenever the pressure is steady.

The fall of pressure with height is 116 millibars for the the first kilometre or 1 millibar for 9 metres or 30 feet of height close to sea level. The change for greater heights is very closely represented by 3·4 multiplied by (pressure in millibars divided by temperature in degrees absolute).

Mercury versus Aneroid.

Why not use an aneroid ? It is very convenient on board ship, so easily read with its open scale, requiring no correction for temperature if it is properly compensated and no correction for latitude. That is all delightfully true, but it has an index error which nobody has yet managed to deal with. The reading depends not merely on the pressure, of which it records the variations with admirable facility, but also upon its past experience which it does not disclose. So that when you have got the reading so easily and minutely, there may still be, and frequently is, an error of which you are yourself quite unconscious but which is big enough to outweigh all the corrections of the mercury barometer and make the readings useless for plotting on a map. The index errors that are reported to us from time to time in connexion with the work of the Office run to tenths of an inch, sometimes to half an inch, and when the readings are plotted on a map the result, in the majority of cases, is simple confusion.

Education and Metric Units.

Allusion has been made to other advantages of the expression of pressure in millibars which have at present little to do with the daily use of the barometer at sea. They have to do with the relation of meteorology to dynamics and physics and to the place of the study of the weather in public education. It will easily be understood that in reality meteorology is the study of the physics of the atmosphere. Nowadays in many of our schools they teach the rudiments of physics and we hope that presently they will teach the rudiments of meteorology. But if any real good is to come of it they must teach meteorology in relation to physics. Now, the teachers of physics the world over use metric units and so do all those who are concerned with electricity and magnetism which are special departments of physics of world-wide application. The use of our customary units is therefore an obstacle in the way of a young student's learning meteorology effectively, and if we recognise the importance of the future as well as the present it is worth while to remove that obstacle so that meteorology may be taught and learned in combination with physics.

Scale of Equivalents of inches, millimetres and millibars.

Schools and colleges have not hitherto used millibars for the expression of pressure. The unit that they have employed is the millimetre of mercury at the freezing point of water in latitude 45°, which has little to recommend it and some disadvantages compared with the inch of mercury in the same locality and conditions. The Conference on the Saving of Life at Sea has recently adopted a code which, following the Continental model, is based on millimetres, so that millimetres have come within the seaman's practice; therefore it may be convenient to give here a short table of equivalents of the three scales, inches of mercury at 32° F. (0° C.) and latitude 45°, millimetres of mercury at 0° C. and latitude 45°, and millibars.

Inches.	Millimetres.	Millibars.	Inches.	Millimetres.	Millibars.
28·0	711·2	948·2	29·6	751·8	1002·4
28·1	713·7	951·6	29·7	754·4	1005·7
28·2	716·3	954·9	29·8	756·9	1009·1
28·3	718·8	958·3	29·9	759·5	1012·5
28·4	721·4	961·7	30·0	762·0	1015·9
28·5	723·9	965·1	30·1	764·5	1019·3
28·6	726·4	968·5	30·2	767·1	1022·7
28·7	729·0	971·9	30·3	769·6	1026·1
28·8	731·5	975·3	30·4	772·2	1029·4
28·9	734·1	978·6	30·5	774·7	1032·8
29 0	736·6	982·0	30·6	777·2	1036·2
29 1	739·1	985·4	30·7	779·8	1039·6
29 2	741·7	988·8	30·8	782·3	1043·0
29 3	744·2	992·2	30·9	784·9	1046·4
29·4	746·8	995·6	31·0	787·4	1049·8
29·5	749·3	999·0	31·1	789·9	1053 1

Rainfall.

With the change of pressure units is associated the change from inches, or in practice hundredths of an inch, to millimetres in the measurement of rainfall. It is as well to mention that here, because rainfall is such an important item in atmospheric changes over sea or land, though for seamen in practice it does not generally count for more than two or three letters of the Beaufort notation. We wish, however, to know more about rainfall at sea and are taking steps in that direction. Here let me say merely that the millimetre, besides being a metric unit, is a better unit for rainfall than the hundredth of an inch. It is almost exactly four hundredths of an inch, so that using millimetres instead of hundredths of an inch is exactly like counting one's money in pence instead of farthings; and just for the same reason that the penny is, in practice, better than a farthing for counting money, so in counting rainfall the millimetre is better than the hundredth of an inch. It economises figures without any sacrifice of practical utility.

Practical Utility.

It is therefore not from any lack of appreciation of the claims of practical utility that we have taken up the change of graduation of barometers and other meteorological instruments. On the contrary, immediate utility leads to closer attention and brings with it the greater accuracy which is now wanted for practical purposes. Here, for example, is an interesting point which might perhaps be solved by closer observation by anyone who has both a mercury barometer and a good aneroid. We find an instruction in the Marine Observer's Handbook that when the barometer is "pumping" the lowest point of the excursions of the mercury is to be taken as the reading. This is on the ground that the constriction of the tube prevents any appreciable flow of mercury along the tube during the up and down motion of the ship and that an oscillation which is visibly present must therefore take place from a break of the thread at the constriction. This basis of procedure is supported by the instinct and insight of practical observers, but to the theoretical mind it seems unsound; the mean position should give the true reading of pressure in a pumping barometer. Between these two views there is a difference of about a millibar, so that it is well within the scope of observation. Up to now, while we have been compiling mean values, we have comforted ourselves with the assurance that in the long run such differences will not affect the final result, but now that we think in maps that assurance fails. We are actually in want of a definite answer that will carry conviction both to the practical and theoretical mind.

The revised method of expressing the measurements of pressure has been adopted for the Meteorological service of the French Government from the beginning of this year.

W. N. SHAW.

Meteorological Office,
June 19, 1917

Note.—Further details for the manipulation of the instruments on board observing ships, and instructions for keeping the "Meteorological Log," are given in *The Marine Observer's Handbook* (M.O. 218), which is intended for use with the various forms of meteorological register supplied by the Office.

CORRECTION AND REDUCTION TO SEA-LEVEL OF MILLIBAR BAROMETERS.

Note.—Barometers graduated to read in millibars are provided with an attached thermometer graduated according to the absolute scale of centigrade degrees and the references to temperature in the following instructions are to the readings on that scale. In quoting the temperature the degree mark is omitted and instead of it a small "a" follows the number. Thus 273a on this scale corresponds with the freezing point of water, that is 0° C or 32° F, and 283a corresponds with 10° C or 50° F. A step of 10a in temperature is the same as a step of 18° F.

Standard temperature as shown on the Certificate.—The barometer will have been certified as *correct* in *latitude* 45° at a certain *temperature* which we call the *standard temperature.* The certificate means that when the temperature has the specified value, the barometer reading will give the true value of the pressure in *millibars* at the *level of the barometer cistern* in the specified latitude.

Example.—Barometer M.O. A.2074. The standard temperature is 286·5a, that is in latitude 45° the barometer reads correctly at 286·5a which is the same as 56·3° F.

With this information it is easy to make allowance for difference of latitude and difference of temperature; it is also easy to allow for height above sea-level in a similar manner and so put the observer in the position to compare his readings with a synoptic weather-chart or with the normal for the locality, provided that the height above sea-level is not greater than those at which ships' barometers are commonly fixed.

Fiducial temperature.—If the latitude is not 45° the reading will not be correct at the standard temperature, but there will be a temperature at which the reading would be correct if it were so chosen that the latitude correction would just balance the temperature correction. We call this temperature, at which the readings of the barometer need no correction, the *fiducial temperature* for the barometer in the particular latitude. For a station-barometer with fixed latitude the fiducial temperature remains the same, but at sea the fiducial temperature is different for the different positions of the ship in latitude.

To allow for the height of the barometer above sea-level the fiducial temperature can be adjusted because, in the ordinary circumstances in which the barometer is used at sea, the allowance to be made for 100 ft. of height lies between 3·3 mb. and 3·9 mb., and a correction of 3·6 mb. for 100 ft. would be sufficiently accurate in most cases.

Correction and Reduction.—The process of correction and reduction to sea-level is therefore as follows :—

(1) *To determine the fiducial temperature for the latitude at which the barometer is read, use the following table :—*

Latitude	0°	5°	10°	15°	20°	25°	30°	35°	4	45°
Subtract ... ... from the Standard Temperature.	15	15	14	13	11·5	9·5	7·5	5	2·5	0
Latitude	90°	85°	80°	75°	70°	65°	60°	55°	50°	45°
Add ... ... to the Standard Temperature.	15	15	14	13	11·5	9·5	7·5	5	2·5	0

Example.—Barometer M.O. A.2074. Standard temperature, the fiducial temperature in latitude 45°, is 286·5a. To find the fiducial temperature in latitude 52° add 3·5a (2·5a for latitude 50° ; and 1a for the additional 2°) : fiducial temperature required is 286·5a + 3·5a, that is, 290a.

(2) *To adjust the fiducial temperature in order to make allowance for the height above sea-level.*

Increase the fiducial temperature by 1a for every 5 ft. or 1·5 metres of height.

Example.—Barometer M.O. A.2074 is set at 52·5 ft. (16 metres) above sea-level.

Its fiducial temperature is therefore increased by 10·5a from 290a to 300·5a for 52° latitude.

(3) *Having obtained the adjusted fiducial temperature, to correct the barometer reading for the difference between the actual temperature as read on the attached thermometer (absolute scale) and the adjusted fiducial temperature.*

(*a*) When the attached thermometer reads *higher* than the adjusted fiducial temperature—

Subtract from the reading 1 millibar for every 6a in the difference "actual—adjusted fiducial."

The proportional parts are as follow :—

Difference : actual—adjusted fiducial...	1a	2a	3a	4a	5a	6a	7a	8a	9a	10a
Millibars	·2	·3	·5	·7	·9	1·0	1·2	1·4	1·5	1·7

(*b*) When the attached thermometer reads *lower* than the adjusted fiducial temperature—

Add to the reading 1 millibar for every 6a in the difference.

The proportional parts are the same as before.

Example.—Barometer M.O. A.2074, 16 metres above sea-level in latitude 52° N., reads 1017·6 ; attached thermometer 292·4a.

To find the true pressure in millibars—

The adjusted fiducial temperature (2) is 300·5a uncorrected reading	1017·6
Correction for defect of actual − adjusted fiducial (292·4 − 300·5), − 8·1a : add ...	1·4
Corrected reading	1019·0

The reading is now ready for plotting on a synoptic chart, but when a high degree of accuracy is required, the calculation should be carried out to the tenth of a degree to avoid the accumulation of error, and the following points must be attended to.

SUPPLEMENTARY CORRECTIONS FOR SPECIAL ACCURACY.

(4) **Proportional adjustment of correction.**—The correction as set out in (3) is in reality a *fractional part* of the pressure and ought therefore to be adjusted proportionally for different points in the range of atmospheric pressure. The adjustment is very simple: add 1 per cent. to the correction for each 10 millibars above 1000, and subtract 1 per cent. for each 10 millibars below.

One per cent. only begins to be appreciable when the whole correction is about 10 mb., and the additional correction for proportional adjustment is only necessary on quite exceptional occasions.

Example.—Barometer M.O. 2000 with fiducial temperature 306a in latitude 20° gave a reading of 920 mb. at 290a (the lowest observed reading of a cyclonic depression).

Temperature correction... ...	add 2·7 mb.
Proportional adjustment (for 80 mb.) − 8 %	subtract ·216
Adjusted correction	add 2·5 mb.
True pressure	922·5 mb.

(5) **Correction for scale error.**—This can be provided for by the table of Kew corrections which gives the standard temperature at different points of the scale. A properly graduated scale ought to have the same standard temperature throughout its range. If correction for standard temperature in different parts of the scale is necessary, it can be worked by the table of (3).

Example.—Barometer M.O. 2015 had standard temperature 286·5a at 1000 mb. but 280a at 900 mb.

Find the correction for scale to the reading in Example 4.

Take the standard temperature at 920 mb. to be 281·5a or 5a less than for standard conditions.

That is equivalent to reducing the fiducial temperature by 5a, which involves a correction of ·8 mb. to be subtracted from the reading.

(6) **Summary.**—The process may be recapitulated and summarised as follows :—

Barometer M.O. A.2074, 16 metres (52·5 ft.) above sea-level in latitude 52° N., reads 1017·6 with attached thermometer 292·4a.

Standard temperature (fiducial temperature in latitude 45°), by the certificate the same at all points of the scale ...	286·5a
Fiducial temperature in latitude 52° add	3·5a
For adjusted fiducial temperature at 16 metres add	10·5a
	300·5a

For adjusted fiducial − actual (300·5 − 292·4) = 8·1: add 1·4 mb. to 1017·6 mb.

Corrected reading ... ... 1019 mb.

Proportional adjustment 2 % of 1·4 mb. (negligible).

Scale error—nil.

(7) The marine observer is advised to have fixed up in the immediate neighbourhood of his barometer a card showing the adjusted fiducial temperature of his barometer for each degree of latitude. He can compile it for himself by the instruction given under (1) and (2). To correct a reading he has then only to consider the difference between the fiducial temperature and the actual temperature at the time of reading simply *adding* ·1 mb. to the reading for every ·6 of a degree by which the adjusted "fiducial" exceeds the "actual."

SPECIMEN OF CORRECTION OF READINGS OF MERCURY BAROMETERS WITH BRASS SCALES GRADUATED IN MILLIBARS, COMBINED WITH REDUCTION TO MEAN SEA LEVEL.

I. From the instructions given on pages 11 to 14, construct a table of Fiducial Temperatures in different latitudes for the barometer as mounted in the ship, as follows :—

For S.S. "Meteorology" Barometer M.O. 975.
(Standard Temperature at 1,000 mb. = 285a.)

Barometer is 55 ft. above Sea Level ; therefore the adjusted Fiducial Temperature at that height in Latitude 45° is 296a.

TABLE OF ADJUSTED FIDUCIAL TEMPERATURES OF BAROMETER M.O. 975 ON S.S. "METEOROLOGY" IN VARIOUS LATITUDES.

To be set out near the Barometer.

Lat. 60°–75°.		Lat. 45°–60°.		Lat. 30°–45°.		Lat. 15°–30°.		Lat. 0°–15°.	
Latitude.	Fiducial Temperature.	Latitude.	Fiducial Temperature.	Latitude.	Fiducial Temperature.	Latitude.	Fiducial Temperature.	Latitude.	Fiducial Temperature.
° N. or S.	a.	° N. or S.	a.	° N. or S.	a.	° N. or S.	a.	° N. or S.	a.
75	310	60	304	45	296	30	288	15	282
74	310	59	304	44	295	29	288	14	282
73	309	58	303	43	295	28	287	13	281
72	309	57	303	42	294	27	287	12	281
71	308	56	302	41	293	26	286	11	281
70	308	55	302	40	293	25	286	10	281
69	308	54	301	39	292	24	286	9	281
68	307	53	301	38	292	23	285	8	280
67	307	52	300	37	291	22	285	7	280
66	306	51	300	36	291	21	284	6	280
65	306	50	299	35	290	20	284	5	280
64	306	49	299	34	290	19	284	4	280
63	305	48	298	33	289	18	283	3	280
62	305	47	297	32	289	17	283	2	280
61	304	46	297	31	288	16	282	1	280
60	304	45	296	30	288	15	282	0	280

II. Correct for the difference between the reading of the attached Thermometer and the Fiducial Temperature by means of the following :—

TABLES OF CORRECTIONS FOR TEMPERATURE.

(A.) Actual Temperature *above* the Fiducial Temperature.

Actual Temperature − Fiducial Temperature.	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
Subtract	·2	·3	·5	·7	·8	1·0	1·2	1·3	1·5	1·7 mb.

(B.) Actual Temperature *below* the Fiducial Temperature.

Fiducial Temperature − Actual Temperature.	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
Add	·2	·3	·5	·7	·8	1·0	1·2	1·3	1·5	1·7 mb.

Relation of millibars to inches. (*See Figure B, opposite.*) —The units on the absolute scale are related to one another as follow :—

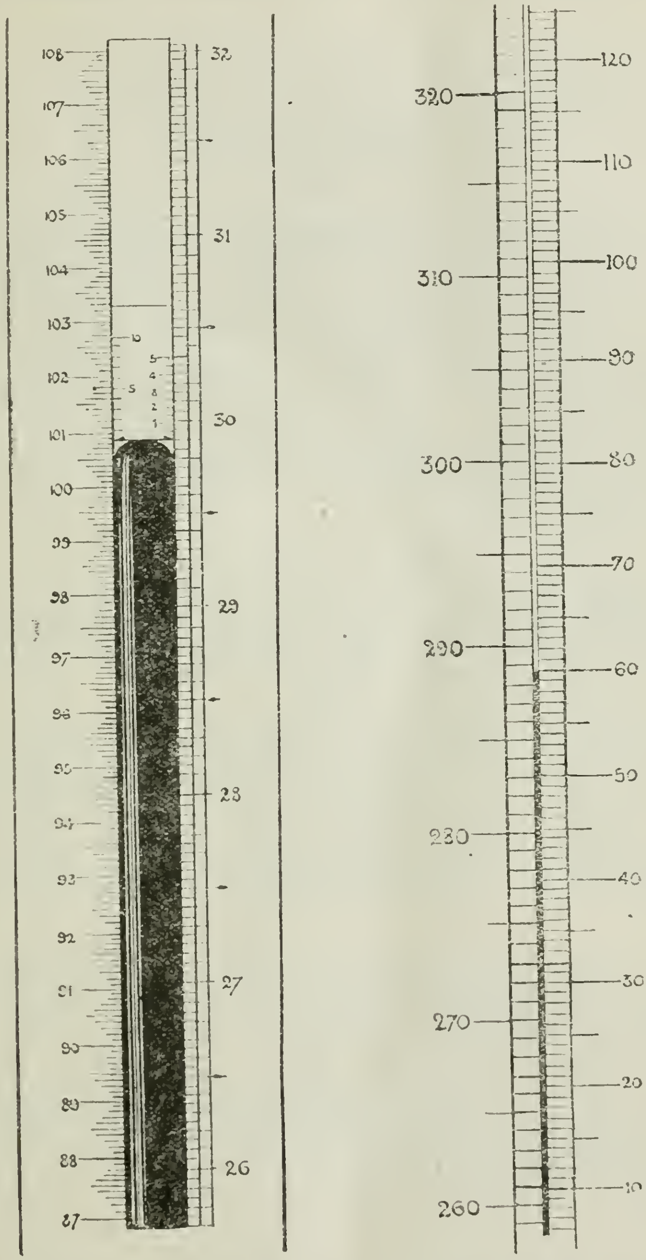
10 millibars = 1 centibar
10 centibars = 1 decibar
10 decibars = 1 bar.

The millibar is adopted as the working unit in the Daily Weather Service (*see* p. 1). The scale of millibars is related to the conventional scale of mercury inches as follow :—

Normal pressure for British Isles,
29·92 mercury inches = 1013·2 millibars.
Highest recorded pressure for the British Isles,
31·11 mercury inches = 1053·5 millibars.
Lowest recorded pressure for the British Isles,
27·33 mercury inches = 925·5 millibars.
1 millibar = ·029 mercury inch.

Thus one-tenth of a millibar corresponds with ·003 mercury inch, which may be taken as the limit of accuracy to which it is possible to read a barometer under favourable working conditions.

GRADUATION OF KEW PATTERN BAROMETER IN MILLIBARS AND INCHES, AND OF ITS ATTACHED THERMOMETER IN DEGREES ABSOLUTE AND DEGREES FAHRENHEIT.



Centibars, with millibar divisions.

Inches, with $\frac{1}{20}$-inch divisions.

Temperature in Centigrade Degrees from Absolute Zero

Temperature Fahrenheit.

FIG. B.

THE SEAMAN'S HANDBOOK OF METEOROLOGY.

INTRODUCTION.

The purpose of this Handbook is to supply some information with reference to the conditions of the atmosphere as regards Pressure, Temperature, Humidity, Wind, and Cloud, which collectively constitute what is called *weather*, and with reference to the change which is constantly taking place in one or more of these conditions implied in the expression *a change of weather*. Also to explain a method of foretelling weather, especially changes in weather conditions which may be attended by an increase of wind to gale force on the coasts of our islands.

In this second edition of the Handbook, pressure values in millibars have been added to the reproductions of the Synoptic Charts of the Daily Weather Report which are included among the illustrations.

A chapter on Icebergs and other forms of drifting ice is included, because of the close connexion which obviously exists between ice frequency in the North Atlantic and the Southern Ocean, and the meteorological conditions in those oceans and the respective polar regions which adjoin them.

In an appendix, mirage and its effects in causing displacements of the apparent sea horizon are referred to and these phenomena explained.

M. W. CAMPBELL HEPWORTH.

14th January, 1915.

INTRODUCTION TO THE THIRD EDITION.

To the ocean-going sailor, the Barometer Manual for the Use of Seamen affords information of immediate import, but before much that it contains is intelligible, it is necessary that he become acquainted with the rudiments of meteorology. This Handbook was written, therefore, as much for the guidance of the ocean-going sailor as with a view to assisting the custodian of the Fishery Barometer to interpret the readings of the instruments entrusted to his charge for the benefit of the fishing community in his district.

Although Chapters VII and VIII refer more directly to weather conditions on the Coasts of our Islands than to weather at sea, yet the references to anticipation of changes of wind and weather ; the sequence of weather during the passage of a depression over the observer's locality ; the motion of clouds of cirrus type in presaging weather changes ; weather signs ; and types of weather conditions apply to ocean meteorology as well as to that of our seaboards.

When making a passage across the North Atlantic, information included in these pages may assist the sailor to anticipate changes in weather conditions, if he takes into account those changes that occur in his geographical position in relation to that of the changing distribution of barometrical pressure.

In the Southern Ocean also, while running down the easting, the same obtains, if for the word "northerly," "polar" be substituted and for the word "southerly," "equatorial."

After the observer has become accustomed to regard the atmosphere as an ocean of air of varying density, the distribution of which is constantly undergoing changes through the intervention of rapid air-currents ; the oscillations of the mercury column ; the changes of wind, and the motion of upper clouds will become more and more intelligible to him and his anticipation of weather changes increasingly accurate.

M. W. CAMPBELL HEPWORTH.

April, 1917.

CHAPTER I.

The Atmosphere and its Circulation.

Completely surrounding our globe there exists a layer of air, the atmosphere, which partakes of its rotatory motion. The mutual rotation of this layer of air, or gaseous envelope, with that of the globe, would remain constant at all points were it not for the occurrence of local changes in the temperature, pressure, humidity, and, therefore, in the density of the air, which have the effect of disturbing its equilibrium and thus producing winds.

At any point, therefore, on the earth's surface where the atmosphere happens to be in a state of equilibrium and a complete calm prevails the air is in truth moving with great rapidity with the earth.

Composition of the Atmosphere.

The atmosphere may be likened to an aerial ocean of a certain depth, consisting of dry air and aqueous vapour intimately mixed; and, for the most part, existing as invisible gases. It is essentially a mixture of oxygen and nitrogen gases, its average composition by volume being :—

Nitrogen	77·11	per cent.
Oxygen	20·65	,,
Aqueous vapour	1·40	,,
Argon	0·79	,,
Carbonic acid	0·04	,,

Height of the Atmosphere.

The actual height of the atmosphere is not yet known, but the deduction drawn from careful observations, taken at different points, of meteors which become luminous when entering the atmosphere is that it must be at least one hundred miles high; and that in an extremely attenuated form it even reaches to an altitude of five hundred miles.

Density of the Atmosphere.

Following the same laws as ordinary gases, dry air is densest near the surface of the earth, and its density diminishes upwards. Seven miles above the surface of the earth it has one quarter the density it has at the surface, at fourteen miles one sixteenth of that density, and at twenty-one miles only one sixty-fourth of that density.

This is the case also with water-vapour in a gaseous form. At a temperature of 272a (30° Fahr.) dry air is able to hold in suspension, in an invisible state, a one hundred and sixtieth part of its own weight of water-vapour; at a temperature of 288a (59° Fahr.) it can hold in suspension an eightieth part; and at 303a (86° Fahr.), a fortieth part; so that for 16° (29° Fahr.) rise of temperature its capacity to sustain water-vapour is doubled. It is for this reason that there is, as a rule, more moisture in the air during summer than there is in winter, because, being warmer in the former season, it is then capable of holding more moisture. Air that is cooled locally contracts and descends; air that is warmed locally expands and rises; but, in proportion as it expands, its power of expansion decreases. If the disturbances to which the atmosphere is subject be disregarded, it may be considered as exercising the same pressure as would be the case were it a liquid of very small density. Over any given area the pressure of the atmosphere, at a given level, is equivalent to the weight of the column of the atmosphere above that level. The atmosphere presses, not only downwards towards the earth, but it presses also with equal force in all directions. As our bodies are surrounded by air, and partly filled with air, and in this way supported on all sides by its pressure, we are not conscious of the pressure; nevertheless, it presses on everything at the earth's surface with a force, or weight, of nearly fifteen pounds on the square inch of surface, one cubic foot of it weighing, at sea-level, more than 500 grains.

Cause of Wind.

Wind is air in motion and is a disturbance of the equilibrium in some part of the atmosphere, associated with differences of barometrical pressure between two adjacent areas; but for the effect of the earth's rotation, or the formation of whirls, the air would pass from the region of relatively high pressure towards the region of relatively low pressure, under the action of gravitation, as a river flows from a relatively high to a lower level.

The disturbances of the equilibrium in the atmosphere referred to, which result in inequalities of barometrical pressure, can frequently be traced to differences of temperature which take place between adjacent localities; for instance, it commonly happens that when the land in some locality becomes heated the temperature of the air in contact with it increases, the air expands, is displaced by cooler and therefore heavier air, and rises towards the higher regions of the atmosphere, while the upper layers flow from it towards cooler regions. The equilibrium at the surface is thus destroyed, for the barometrical pressure is greater in the relatively cold regions than it is in the warm, and in order to restore the equipoise the heavier cold air flows in below. Two distinct air currents are thus produced, an upper current setting outward from the heated region and a lower current setting inwards towards it. The currents of wind will have a velocity dependent on the difference between the high and low pressures.

At the earth's surface differences in temperature between adjacent localities are constantly occurring, diurnally as well as with the change of season. These differences in temperature arise from a number of causes, among the most potent of which may be mentioned geographical position, with regard principally to latitude; distribution of land and water; greater or less abundance of cloud, or rain, or quantity of water-vapour in the air. This explanation of the inequalities of atmospheric pressure at the earth's surface cannot, however, be regarded as by any means the complete solution of the problem, because instances of the association of warm air with high pressure and of cold air with low pressure are common. The question of pressure-distribution is too intricate to be disposed of thus.

The interchange of air which takes place between two adjacent areas of unequal barometrical pressure is not direct from one pressure to the other. Although there is an inclination of the air current outwards from the high pressure towards a lower pressure, and an inclination of the air current inwards towards the low pressure from the higher pressure, the flow of air is generally *round* areas of high or low pressure, for the reasons which are given below.

Effect of the Earth's rotation upon the Wind's direction.

The velocity of the earth's motion is greatest at the equator and gradually diminishes towards the poles; so that a current of air flowing from a lower to a higher latitude is deflected to the eastward, since the velocity of the earth's motion is greater in the lower than it is in the higher latitude; conversely, a current of air flowing from a higher to a lower latitude is deflected to the westward, since the velocity of the earth's motion is not so great in the higher as it is in the lower latitude. For instance, in the Northern Hemisphere a current of air setting northward—in other words, a southerly wind—instead of retaining its direction is deflected to the *right* and becomes a south-westerly wind; and a current of air setting southward—that is to say, a northerly wind—is deflected to the *right* and becomes a north-easterly wind. In the Southern Hemisphere the converse obtains; the northerly wind is deflected to the *left* and becomes a north-westerly wind, and the southerly wind is deflected to the *left* and becomes a south-easterly wind.

In this manner, when air currents set towards an area of low barometrical pressure from the relatively high pressure areas by which it is surrounded, they are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere by the earth's rotation, and, instead of flowing direct towards the centre of depression, will acquire a motion round it, but inclined inwards towards the centre. For this reason the wind circulating about an area of low pressure, or depression, in the Northern Hemisphere will have a movement against that of watch hands, while in the Southern Hemisphere the movement will be in the same direction as watch hands. Similarly, when the air from an area of high pressure sets outwards toward the relatively low pressure surrounding it, it is deflected either to the right or to the left according to the hemisphere in which the wind system is situated, and will acquire a motion round the area of high pressure, but inclined outwards from it. Thus the wind circulating about an area of high barometrical pressure will in the Northern Hemisphere have a movement in the same direction as watch hands, and in the Southern Hemisphere will have a movement in a contrary direction to watch hands.

Cyclonic and Anticyclonic Circulations.

Winds that have a circulation round an area of low pressure, or *depression*, are termed *cyclonic*, and such a distribution of barometrical pressure and wind is known as a *cyclonic system*, or *cyclone*; winds that circulate about an area of high barometrical pressure are called *anticyclonic*, and such a distribution of pressure and wind is known as an *anticyclonic system*, or *anticyclone*.

There is a general statement of the facts bearing on the relation of wind direction to pressure thus explained, which is known as *Buys Ballot's law*, because the principle it demonstrates was first publicly announced in Europe by

Professor Buys Ballot, of Utrecht. It may be enunciated thus :—

In the Northern Hemisphere, stand with your face to the wind and the barometer will be lower on your *right* hand than on your left.

In the Southern Hemisphere, stand with your face to the wind and the barometer will be lower on your *left* hand than on your right.

Origin of the term "Cyclone."

In recent years the term *cyclone* has largely become associated with atmospheric disturbances in which the wind blows with violence round a central area of low barometrical pressure, and is frequently used to express the *force* of the wind rather than a characteristic distribution of pressure and wind. The term *cyclone* was, however, originally adopted by Piddington, in a publication entitled "Sailor's Horn Book" (1848), in connexion with the classification of winds. In introducing it, he says :—

> I suggest that we might for this last class of circular, or highly curved, winds adopt the term "cyclone," from the Greek Κύκλος (which signifies, amongst other things, the coil of a snake), as neither affirming the circle to be a true one, though the circuit may be complete, yet expressing sufficiently the tendency to circular motion in these meteors.

Thus in a cyclonic depression the wind has a *tendency* to circulate round an area of relatively low pressure ; it may be of moderate force, and in some parts of the system even light, or it can be strong to a gale, and, especially in the tropics, may attain to the force of a hurricane.

Cyclonic depressions when formed travel, generally speaking, in temperate latitudes towards some easterly point in either hemisphere.

An account of the instruments used in determining the physical condition of the atmosphere and in detecting the occurrence of important changes is given in Chapter XI.

CHAPTER II.

Temperature and Humidity.

Temperature.

Temperature has been defined as the thermal condition of a body which determines the interchange of heat between it and other bodies. This interchange of heat occurs in one or more of three ways: by conduction, by convexion, or by radiation. Heat imparted by *conduction* involves contact with, or a near approach to, a warmer body; and is transferred from particle to particle. If one end of an iron rod be placed in a fire, the heat communicated to that part of the rod will be transmitted to other parts by conduction. A similar result may be obtained by substituting a wooden rod for the iron one; but in this case, although the degree of heat generated may be the same, the heat transmitted to other parts of the rod will be less, because wood is not so good a conductor of heat as iron. Solids are better conductors of heat than liquids, gases are the worst conductors, metals the best. By conduction changes in the temperature of the earth's surface, which becomes heated during the day and cooled during the night, are communicated to the layers of air in contact with, and immediately above, the earth.

Interchange of heat by *convexion* is effected when air, heated at the earth's surface, ascends and flows away, while the colder air by which it is surrounded flows in to take its place. Over the whole globe heat is constantly being transferred from one locality to another through the agency of winds and of ocean currents.

An interchange of heat is taking place, moreover, at all times between bodies that are freely exposed to each other; and the process by which heat is thus communicated is called *radiation*. The feeling of warmth derived from a fire, or other source of heat at some distance, is produced by radiation. The communication of heat by radiation proceeds, not from one particle to another, but through air or vacuum, and even through solids. Radiant heat is not heat in the ordinary sense of the word, but a form of energy which proceeds in straight lines and diverges in all directions.

The atmosphere derives its heat, directly or indirectly, entirely from the sun. Deprived of this source of heat the temperature of the atmosphere would fall far below the lowest temperature that has ever been recorded in any geographical position on the earth's surface.

The actual temperature of the atmosphere depends not so much upon the direct rays of the sun as upon the conduction and radiation from the surface of the earth heated by the sun's rays. The air is not heated to any perceptible degree by sunshine, the sun's heat is transmitted through air as sunlight is transferred through glass; the surface of the earth is heated by the sunshine and the air is warmed by contact with the earth: by radiation and by convexion.

Differences in the character of the soil in different localities have a considerable effect on the distribution of atmospheric temperature over large areas; heavy soils that have their particles closely packed together conduct heat better than soils that are loose and porous, because the air becomes entangled in the latter, and the conducting power of such soils is diminished. Land that has recently been ploughed absorbs and radiates heat more quickly than pasture land. A sandy soil heats the atmosphere above it more than a soil covered with vegetation. An expanse of sand heated by the sun's rays is soon cooled after sunset by terrestrial radiation: that is, by radiation from the earth; but this is not the case with an expanse of water, for when the sun's rays fall on water, the heat produced, instead of being arrested at the surface, as is the case when they fall upon land, penetrates far below the surface, and by vertical and horizontal currents is diffused to a considerable depth over a large expanse.

Water absorbs heat, stores it, and conveys heat whither it flows. The capacity of air to carry heat is inconsiderable as compared with that of water of the same volume.

Islands, peninsulas, and all localities situated in the neighbourhood of the sea, have for this reason more equable and frequently milder climates than is the case with localities far removed from the seaboard in the same latitude, and in other respects similarly situated.

The sun's rays have their greatest effect where they fall perpendicularly on the earth's surface; their effect diminishes as their obliquity increases, so that where the rays fall vertically, within the tropical belt, the effect is at its maximum, and it decreases poleward. Were it not for the modifying influences due to proximity to the sea, to winds, and to ocean currents, differences in the temperature of the air over land areas in different geographical positions on the earth's surface at the same time would depend almost entirely upon latitude.

It has been found that hillsides surrounding lakes or other large sheets of water derive heat from the reflection of the water surfaces; also that the temperature of the air in valleys is raised by reflection and radiation from mountain sides.

In contrast with the warming effects due to solar radiation and reflection is the cooling of the earth's surface, and consequent lowering of the air temperature above it, which takes place through terrestrial radiation. During the daytime, as well as during the night, the earth parts with heat received from the sun and pours it into space. The heat received from the sun during the day is, as a rule, greater than that which the earth parts with, but as the day declines and the rays of the sun fall more obliquely upon the earth's surface, these conditions are reversed, the temperature commences to fall and continues to do so until sunrise.

Terrestrial Radiation.

The loss of heat by terrestrial radiation is not so great when the sky is overcast or cloudy as when it is clear, because clouds intercept the heat thrown off from the earth and radiate it back; for this reason nocturnal cooling is greatest when the sky is cloudless. Wind churns the surface layers and mixes them with the upper layers, and therefore any disturbance of stagnant air cooled by radiation is necessarily accompanied by a rise in temperature, the cooling of the earth's surface and of the air resting upon it, by terrestrial radiation, is consequently not so great when the air is in motion as is the case when it is calm; as the force of the wind increases, other influences remaining the same, the effect of terrestrial radiation is less apparent.

Decrease of Temperature with Height.

The temperature of the air decreases with height to a great altitude,* for as the height increases there is necessarily a loss of warmth derivable from the heated surface of the earth. Moreover, as most of the sun's heat reaches the earth's surface, very little of it being absorbed in passing through the atmosphere, those layers, or strata, of air which lie nearest to the surface acquire by conduction more heat than those at a greater altitude, and the layer in contact with the earth receives most of all.

Decrease of temperature with height is caused by yet another process: air in the higher regions of the atmosphere is subjected to less pressure than obtains at lower altitudes,

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* Investigations of the upper air, conducted by means of *ballons-sondes* (sounding balloons) carrying self-recording instruments, have shown that the fall in temperature with height ceases suddenly at an elevation which varies from day to day, but is roughly estimated at about 6 miles. Above this height temperature changes but little in a vertical direction, but shows a slight tendency to increase. The thickness of this layer of equal temperature, or stratosphere as it is called, has not yet been ascertained; its lower surface, although irregular in height, may be considered as roughly horizontal. In equatorial regions, where observations have been made in this connexion, the fall in temperature with altitude has been found to continue to a height of about 9 miles.

and, while expanding under pressure, the heat required to cause the expansion becomes *latent*, or concealed (Latin: *latere*, to lie hid), thus a fall in temperature ensues.

At the same time it is not unusual in still, clear weather during summer for the temperature at a considerable elevation, even on the top of lofty mountains, to rise under the influence of solar radiation to the same height as it attains in the neighbouring valleys or adjacent places at sea level.

Seasonal Range of Temperature.

Within the United Kingdom the range of temperature, shown by a shaded thermometer in the open air, is ordinarily about 39a (70° Fahr.), that is to say, the readings of the instrument during the year may be expected to range from 261a (10° Fahr.) to 300a (80° Fahr.); but in the hardest winter-frosts the temperature occasionally falls below 261a, and on exceptionally hot days in summer not infrequently rises above 300a.

In our islands the range of temperature is less than in many other countries, owing to the influence of the ocean. In the interior of the great northern continents, where no relatively warm sea winds mitigate the cold of winter, and no relatively cool sea breezes allay the heat of summer, the extremes of cold and heat are often great. On the other hand, in islands of smaller extent than our own, situated in warm latitudes, the range of temperature is considerably less than obtains in the British Islands.

The seasons, as determined by the march of temperature, group themselves in the temperate zones into four periods, which in the Northern Hemisphere are as follow:—Spring—March, April, May; Summer—June, July, August; Autumn — September, October, November; Winter—December, January, February. On an average July is the warmest month, January the coldest; April has about the same average temperature as October. The date of the highest mean daily temperature at Greenwich during the 65 years 1841-1905 (291a, 64° Fahr.) occurs on the 15th July, while that of the lowest mean daily temperature (276a, 37·5° Fahr.) falls on the 12th January.

Diurnal Variation of Temperature.

There is also a diurnal variation of temperature which is well marked. Normally, temperature is lowest at about sunrise, highest at about 2 p.m., but during the three summer months later. At Greenwich, however, taking the average of 20 years' observations, 1849–1868, the minimum temperature occurred in summer at eight minutes *after* sunrise, in winter at 47 minutes *before* sunrise; and the maximum temperature was recorded at 2 p.m., both in summer and in winter. At Kew the average time of minimum temperature, based on 35 years' observations, 1871–1905, is in summer eight minutes *after* sunrise, in winter 1 hour 17 minutes *before* sunrise; and the time of average maximum temperature in summer is 3 p.m., in winter 2.20 p.m.

The distribution of temperature at any given hour over a given area may be shown graphically on a chart by lines uniting localities at which the temperature is equal at the same instant of time. Such lines are called *isotherms.*

Humidity.

It has already been shown that air consists principally of nitrogen, oxygen, and aqueous vapour. Now, between the molecules of the two gases, nitrogen and oxygen, which are the chief components of *dry* air, minute particles of water are floating which have risen into the atmosphere in the form of vapour; for by evaporation vapour is continually rising from water and other moist surfaces. Evaporation takes place from ice and snow also. The particles of water in the atmosphere are usually invisible because of their transparency.

Dry air does not change its gaseous state, and the quantity of dry air in the atmosphere remains constant, but such is not the case with aqueous vapour; the quantity of vapour in the atmosphere is, by the process of evaporation and by condensation, constantly changing, and although where invisible, water-vapour is in a state analogous to that of a gas, nevertheless it can be turned into water and back again from the liquid to the invisible gaseous state.

The general term *vaporisation* is used to indicate the process of transition of a liquid into a gaseous state, the term *evaporation* refers especially to the slow generation of vapour at the free surface of a liquid or any other moist surface.

The pressure of all gases in an enclosed space is increased by a rise and diminished by a fall of temperature. As temperature rises the capacity of space for holding moisture increases, and as it falls diminishes and therefore, the warmer the air the larger quantity of moisture can it sustain in an invisible state. As only a limited quantity of water-vapour can be held in suspension in an invisible state in a definite volume of air, when this limit is exceeded particles of water are formed which become visible as cloud, fog, or mist; and when the air having received its full load of moisture has its temperature reduced, it becomes charged with moisture beyond the point of saturation, and the excess is precipitated in the form of rain, hail, or snow.

Latent heat.

When a liquid is in process of conversion into a gaseous form a large measure of its heat becomes absorbed, and therefore latent; but, although the heat thus absorbed cannot be detected by the aid of a thermometer, and is imperceptible to the senses, it is not lost, but hidden, and will reappear when the vapour is restored to its liquid state.

As the conversion of water into vapour by the process of evaporation is attended with a decrease of temperature, due to the absorption of heat, so the conversion of vapour into the liquid state is attended with an increase of temperature, due to the release of latent heat.

Formation of Cloud.

When the air, charged with aqueous vapour, is brought below the temperature of saturation cloud is formed, or, should the conversion take place immediately above the earth's surface, fog or mist. The cooling of the air may result from various causes: from intermingling with air of a lower temperature, from radiation, from contact with cold surfaces, and from the absorption of heat resulting from an ascent to higher altitudes. The aqueous vapour in the atmosphere rising from seas, lakes, rivers, and other moist surfaces, is caused by evaporation. The rapidity of evaporation varies with temperature, for a rise of temperature, by increasing the elastic force of a vapour, will accelerate evaporation. Again, the rapidity of evaporation varies with the quantity of vapour already in the surrounding atmosphere, the drier the air the more vapour is it capable of receiving, no evaporation being possible from a liquid when the air surrounding it is saturated with the vapour of the same liquid. Evaporation is accelerated by renewal of the atmosphere, for, when the air over a moist surface is stagnant it speedily becomes saturated when vapour is rising. Rapidity of evaporation is influenced also by the extent of the surface of evaporation.

Wind, by dispersing vapour as it rises, promotes evaporation; and, because any vertical movement of the atmosphere is necessarily attended by a corresponding horizontal movement, the process of evaporation is to some extent favourable to the production of wind.

Relative Humidity.

The air at all times contains some water-vapour, held in suspension, and the quantity of vapour it is capable of sustaining depends upon the temperature. The higher the temperature the greater the capacity of the air for moisture When the air contains the largest possible quantity of vapour it is said to be saturated. Referred to a scale of 0 to 100, the latter being assumed to represent saturation, and the former perfectly dry air, the quantity of moisture in the air can be expressed in figures, as a percentage of the amount necessary to produce saturation, the temperature remaining the same. This proportion of moisture to saturation is known as *relative humidity.* The relative humidity is found by dividing the elastic force of aqueous vapour at the temperature of the dew-point by that corresponding to the temperature of the air as shown by the dry bulb thermometer ; the calculation may be greatly facilitated by the use of hygrometrical tables published originally by the late Mr. James Glaisher, F.R.S., in the year 1845. The temperature of the dew-point is the temperature below which the air must be cooled in order to cause condensation of vapour. When, by radiation, the air is cooled below that temperature dew is deposited and latent heat released. The release of this heat has the effect of delaying the fall of temperature of the air, but only for a time, because, as radiation proceeds the air is chilled below, the original point of vapour condensation or *dew-point*, with the result that heat is again released from its latent state ; and thus the process continues to be repeated. The lowest night temperature is, in consequence of this fluctuation of temperature, alternately a little above and below the point of vapour condensation. generally that of the dew-point.

Elastic force of Vapour.

The elastic force of aqueous vapour, or vapour pressure, is measured by that part of the barometric column which corresponds with the pressure of water-vapour in the atmosphere. For this purpose we may regard the atmosphere as composed of two separate gaseous parts : first the dry air, second the water-vapour. Each part contributes to the pressure as measured by the barometer. The part which the water-vapour can contribute is limited by its saturation pressure, which depends upon the temperature and nothing else. So long as that limit is not reached the water vapour, the weight of which, volume for volume, is five-eighths that of dry air, behaves like a gas. The course of procedure upon the gradual compression of a mixture of dry air and vapour is as follows:—At first the pressure increases inversely as the volume diminishes, both air and vapour behaving as if gases. Then, supposing the experiment began by vapour taking 17 millibars (half an inch) and dry air 999 millibars ($29\frac{1}{2}$ inches), they would balance the increased pressure in the same proportion until the saturation was reached, say at 25 millibars (three-quarters of an inch), which would be at 295a (71° Fahr.). No more pressure can be put upon the water vapour, it condenses while maintaining the fixed pressure. Thereafter when the air is compressed beyond saturation the dry air has to take any pressure beyond that fixed by the temperature of water vapour.

CHAPTER III.

Atmospheric Pressure and Wind.

In order to illustrate graphically the distribution of pressure over a given area at the earth's surface, at a given time, simultaneous readings of the barometer taken at a number of places are plotted in their respective positions on a chart, after having been corrected for index error and temperature, and reduced to sea level.

Isobars.

Through the places at which the corrected barometer readings are equal, lines are drawn connecting them ; these lines of equal barometrical pressure are called *isobars*. Isobars are usually drawn on a chart for each tenth of an inch or for each five millibars.

The relation between pressure distribution and wind distribution has been alluded to in Chapter II., where it was shown that over any area where atmospheric pressure is below that of the surrounding region a cyclonic circulation is developed. Air currents, under the action of gravity, set towards an area of relatively low pressure from the relatively high pressure by which it is surrounded ; but, by the earth's rotation, they are deflected to the right in the Northern Hemisphere, and to the left in the Southern; so that, instead of flowing direct towards the centre of depression, they acquire a motion round it, but inclined inwards towards the centre. Therefore the wind circulating about an area of low pressure in the Northern Hemisphere will have a movement against that of watch hands, while in the Southern Hemisphere the movement will be in the same direction as watch hands. Such a distribution of pressure, called by Piddington a *cyclone*, is now known as a *cyclonic depression*. Also over an area where pressure is high, and decreases in all directions from the maximum, an anticyclonic circulation of wind is developed; for air setting outward from the centre of a high-pressure area towards the relatively low pressure surrounding it is deflected to the right or to the left according to the hemisphere in which the system is situated, and thus acquires a motion round the high pressure, but inclined outward from it. The circulation of the wind in an anticyclonic system in the Northern Hemisphere will therefore be in the same direction as watch hands, but in the Southern Hemisphere it will be in a contrary direction to watch hands.

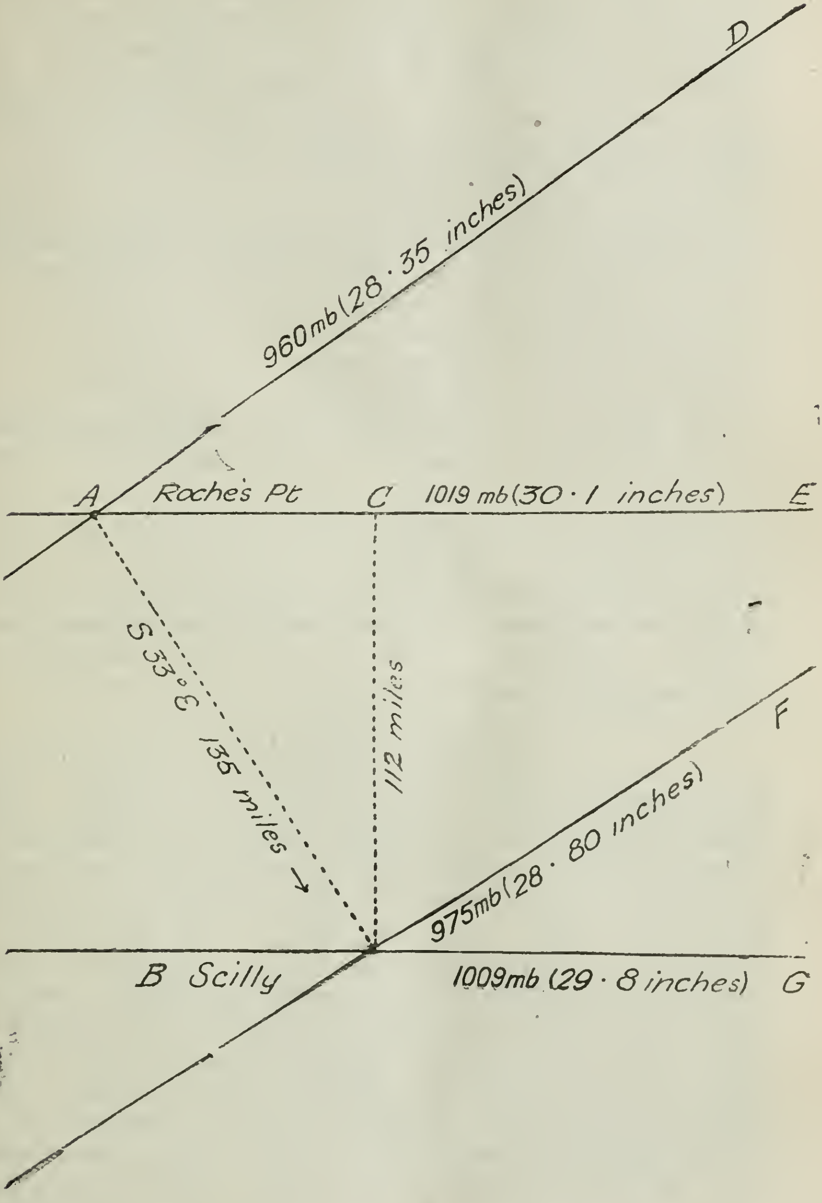
If to a chart on which isobaric lines have been drawn there be added symbols to represent correlative observations of wind direction and force, it will be found that the wind follows the course of the isobars to which they are related, but inclines somewhat towards an area of relatively low pressure and somewhat away from an area of relatively high pressure. The angle at which the wind inclines towards the isobar showing the lower pressure is considered to be roughly about 30 degrees, but no rule can be given.

In addition to the relation existing between the distribution of pressure and wind direction, there exists a relation between pressure distribution and wind force.

Pressure Gradients.

It has been found that the wind force associated with a difference of barometric pressure at two places at the same time is greater as that difference is greater; therefore, a relation will be observable between the distances separating isobars drawn on a chart and the force of the wind over the intervening area. Moreover, if one takes a chart on which the distribution of pressure over a given area is indicated by isobaric lines, based on synchronous observations, taken at a sufficient number of places, it is possible by means of a formula to calculate approximately the force of the wind between the several isobars from the *pressure gradient*, as it is called; and to add to such a chart symbols indicating the force of the wind by calculation, which will, as a rule, differ but slightly from the actual force as determined by observations.

Engineers measure the steepness of a slope by the proportion between its height vertically and its length horizontally, and describe the steepness of the slope or *gradient* (Latin: grădus, a step) as 1 in 60, 1 in 100, and so on. This suggested the application of the term *gradient* to differences of barometric pressure. Barometrical gradients, however, are not referred to the same units of scale in the vertical and horizontal directions as the gradients of the engineer; the vertical scale of the pressure gradient is expressed in units of barometrical readings, the horizontal scale in geographical measurements, and the standard of their comparison that has been adopted is the difference of pressure expressed in hundredths of an inch of the mercury column in 15 nautical miles of distance or in millibars per degree. For instance, the distance between Lundy Island and Cape Clear is 183 miles, and, supposing, at a given time, the corrected reading at the latter place to be 12·5 mb. (·37 inch) higher than it is at the former, then the gradient between the two places would be 4·1 mb. per degree, or (·03 inch) per unit of 15 miles; and if the isobars passing through each of these places ran north and south, the direction of the wind over the area separating them would be northerly. The gradient is calculated by dividing the difference between the simultaneous barometer readings at two places by the multiples of 60 in the case of millibars, and 15 where the readings are in inches, in the number of nautical miles between them in a straight line; but this line must be perpendicular to the isobars passing through them. Thus, Scilly bears S. 33° E. from Roche's Point, distant 135 miles; and this distance can be used for finding the gradient between the two places when the isobar passing through each of them trends N. 57° E.—S. 57° W. Let BF, AD (Fig. 1) be isobars of 975 mb. (28·80 inches) and 960 mb. (28·35 inches) passing through Scilly and Roche's Point, respectively, and trending N. 57° E.—S. 57° W., so that AB is perpendicular to both. To find the gradient we have the difference of barometric readings between the two places, which is 15 mb. (·45 inch), and, as there are $2\frac{1}{4}$ multiples of 60 in 135, the gradient is $\therefore$ 15 mb. $\div 2\frac{1}{4}$, or 6·7 mb. per unit of 60 nautical miles; expressed in inches, the gradient is ·45 inch $\div$ 9 or ·05 inch per unit of 15 nautical miles. Again, let BG, AE be isobars of 1009 mb. (29·8 inches) and 1019 mb. (30·1 inches) respectively, trending east and west, through Scilly and Roche's Point. Then



15 miles = ·3 inch.

Fig. 1.

the line BC, which represents the distance, 112 miles, between the two isobars, measured on a line perpendicular to them, must be used in this instance to find the gradient, not the line AB. We have then BC, 112 miles, approximately 1·9 multiples of 60, and the difference of barometer readings, 10 millibars ; therefore, the required gradient is 10 mb. ÷ 1·9 = 5·3 mb. per unit of 60 nautical miles. In the first of these two cases, as the higher pressure lies to the south-east, the gradient is for south-westerly winds ; in the second case, as the higher pressure lies to the north, the gradient is for easterly winds.

Assuming ordinary conditions of pressure and temperature, and making no allowance for the curvature of the path, the theoretical wind velocity for certain gradients is as follows :—

Barometric Pressure-difference		
per unit of 60 nautical miles.	per unit of 15 nautical miles.	Velocity.
1·2 mb.	0·01 inch	19 miles per hour.
2·8 ,,	0·02 ,,	39 ,, ,, ,,
4·0 ,,	0·03 ,,	58 ,, ,, ,,
5·6 ,,	0·04 ,,	77 ,, ,, ,,
6·8 ,,	0·05 ,,	97 ,, ,, ,,

Over the United Kingdom gradients do not, as a rule, exceed 6·8 mb., unless associated with gales of exceptional violence. The wind on deck at sea is about two-thirds of the theoretical or gradient wind.

Gradient Wind.

The observed wind velocity is seldom in agreement with the theoretical velocity, calculated from the gradient. The theoretical velocity is, as a rule, considerably in excess of the observed. The numerical relation between the steepness of the gradient and the velocity of the wind cannot, for several reasons, be stated with exactitude. The late Rev. W. Clement Ley, who published the results of his investigations in reference to the relation of barometric gradient to the force of the wind in the years 1875 and 1877,* has pointed out that " the mean velocity of the wind corresponding to each gradient is much higher in summer than in winter." His conclusion was based upon the result of observations for 8 a.m. taken at Stonyhurst and Kew during five years, from August, 1870, to July, 1875. The observations showed, moreover, that, with the same gradient, air currents from a polar quarter were stronger than those from an equatorial quarter.

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* " Suggestions on certain Variations, Annual and Diurnal, on the Relation of Barometric Gradient to the Force of the Wind." By W. Clement Ley, M.A., F.M.S.—*Quarterly Journal of the Meteorological Society.* Vol. III.

The late Captain Henry Toynbee, Marine Superintendent of the Meteorological Office, found, on comparing the gradients and accompanying winds of these islands with those of the tropical regions of the Atlantic, that with the same gradient there is much more wind in the tropics than in these latitudes.

In the preface to a report to the Director of the Meteorological Office on the Calculation of Wind Velocity from Pressure Distribution, by Ernest Gold, M.A., the Director explains clearly the process of adjustment of wind velocity to the gradient.

Sir Napier Shaw likens the movement of wind in a tropical revolving storm, when the air moves in a small circle, as it does approximately, the centripetal force of the pressure gradient being nearly balanced by the centrifugal action of the rotation in the small circle, to that of a body moving without change of speed in a circle in consequence of the action of a force which always pushes it towards the centre but never effects any approach thereto, because of the balance between the so-called centrifugal force of rotation and the centripetal dynamical force which pushes it inwards. He cites the motion of a heavenly body as an instance, and goes on to say :—

> We have thus three items which may arrange themselves to maintain motion of air without change of speed, viz., pressure gradient, the earth's rotation, and the curvature of the path.
>
> * * * * * *
>
> Buys Ballot's law, which takes motion along the isobar as a guide to the direction of the actual motion, is the fundamental law of practical weather study in temperate latitudes, and the calculation of the gradient wind is the subject of classical researches by Guldberg and Mohn.
>
> At the surface there is obviously a serious cause of disturbance in the surface friction, to which the authors mentioned have assigned a numerical value. To make a theoretical allowance for the disturbing cause in individual instances is a difficult matter, and for many years that difficulty has prevented the further prosecution of the subject. The working hypothesis of practical meteorology has been that the friction affects both the direction and the speed of the wind, so that the actual velocity can only be a rough and uncertain approximation to the gradient velocity, and the idea of thus treating the motion of air with gradient velocity as a basis of meteorological study has not been developed.
>
> * * * * * *
>
> In estimating the gradient wind from the isobaric distribution shown upon a weather map, we are met by the difficulty that one of the elements necessary for the calculation, viz., the curvature of the path, cannot be determined, as a general rule, from a single map.
>
> * * * * * *

In these circumstances it is difficult to know what allowance should be made for the curvature of the path. We may, however, regard the isobars as representing the paths of air in the limiting case when the motion is tangential and the barometric distribution remains stationary. Such a case is approximated to when a cyclonic depression moves slowly.

The use of isobars as lines of curvature thus gives an extreme value for the correction for curvature in most cases, but, in the absence of any means of determining the actual curvature, the estimation of the limiting value may give useful information about the atmospheric conditions.

There are, undoubtedly, cases in which the observed wind velocity is not in accordance with the gradient as thus calculated from the isobars plotted on a map. I shall refer to these exceptions later on ; at present I confine myself to saying that the existence of such exceptions is not surprising ; what is remarkable is that they are, comparatively, so few.

* * * * * *

In dealing, therefore, with the discrepancies between the computed and observed winds some allowance must be made for the insufficient means of estimation of the gradient for the exact locality in which the wind was observed. This part of the subject deserves more refined investigation than is possible with the arrangements, instrumental and other, at present in use. At the least, it supports the suggestion, put forward by M. Durand-Gréville, for the drawing of isobars with more scrupulous attention to the individual readings, and for small steps of pressure.

But no development in the construction of maps can do away with the effect of surface friction or surface eddies upon the velocity of the moving air current. We do not yet know what is the effect of surface friction over the sea ; it certainly takes a great deal of energy out of the moving air, and converts it into the energy of water waves or water currents. Still, it is probably much less than that of the obstruction offered by land. The first effect of a land area upon a current coming from seaward must be partly to arrest the motion, and cause some increase of pressure by mechanical means. Such an interference with the free motion of the air must thus produce what may be called a "refraction" of the isobaric lines on the transition between sea and land. This, again, is a branch of the subject to which not much attention has been devoted.

There remain the local peculiarities of contour which deflect the wind by mechanical process in a manner similar to that in which the shape of a valley guides the course of a river or a glacier. There is, of course, every stage of screening possible between the slight interference of a flat spit of sand and the absolute protection of a completely secluded valley ; but, so far, the effect of screening upon the direction and force of the wind at any particular station is a matter of speculation.

CHAPTER IV.

Clouds.

Cloud is aqueous vapour that has lost its gaseous state by being cooled below the point of saturation, either in ascending, through the process of expansion and consequent transformation of heat, or by mixing with an air current of lower temperature. A cloud is composed of minute spherical drops of water, except when formed at some point below freezing, when it consists of minute ice spicules.

The formation of cloud is facilitated by the presence in the air of *dust particles* on which the vapour condenses. This condensation of vapour into cloud round nuclei was first investigated by Dr. John Aitkin, F.R.S., by experiments in the laboratory.

Clouds are kept suspended in the air chiefly by ascending currents, but partly by the check the particles of water receive by their contact with air particles; they are sometimes so minute that their descent through the air is exceedingly slow, and can easily be checked by an ascending current however slight.

While a cloud is thus upheld by an ascending current of air, over which it is formed, it will, when the current ceases, diminish in size and density; and it is for this reason that when the weather has been cloudy during daytime, in the evening, when the temperature falls and the ascending current of air ceases, the clouds dissolve.

Luke Howard's Nomenclature.

The grouping and naming of the various forms of clouds was first undertaken by Luke Howard, who in the year 1803 suggested, in an essay entitled, "On the Modification of Clouds," the classification and nomenclature which will for all time be associated with his name.

In this essay the author states :—

> There are three simple and distinct modifications, in any one of which the aggregate of minute drops called a cloud may be formed, increase to its greatest extent, and finally decrease and disappear.

These *simple modifications* he thus named and defined :—

1. *Cirrus.*—Parallel flexuous or diverging fibres, extensible by increase in any or in all directions.
2. *Cumulus.*—Convex or conical heaps, increasing upward from a horizontal base.
3. *Stratus.*—A wide extended, continuous, horizontal sheet, increasing from below upward.

Luke Howard pointed out, however, that there were intermediate and compound modifications, and considered that those requiring notice were as follow :—

Intermediate Modifications.

4. *Cirro-Cumulus.*—Small, well-defined, roundish masses in close horizontal arrangement or contact.

5. *Cirro-Stratus.*—Horizontal, slightly inclined masses attenuated towards a part or the whole of their circumference, bent downward or undulated ; separate or in groups, consisting of small clouds having these characters.

Compound Modifications.

6. *Cumulo-Stratus.*—The cirro-stratus blended with the cumulus, and either appearing intermixed with heaps of the latter or superadding a widespread structure to its base.

7. *Cumulo-Cirro-Stratus or Nimbus.*—The rain-cloud. A cloud or system of clouds from which rain is falling. It is a horizontal sheet, above which the cirrus spreads, while the cumulus enters it laterally and from beneath.

Luke Howard's classification and nomenclature of clouds was at once almost universally adopted ; and it was not until towards the end of the last century that any additions to the types he distinguished were recognised.

Classification of International Committee.

Familiarity with cloud forms, and a more critical examination of cloud structure on the part of observers, revealed the necessity of modifications in the classification, and of additions to the number of types ; and in the year 1894 the International Meterological Committeee, held at Upsala, appointed a Sub-Committee to prepare and publish an International Cloud Atlas, which appeared in the following year and was soon out of print. The new edition, in which improvements suggested at the International Conference at Innsbruck, in 1905, were incorporated, was published in August, 1910. The following classification of clouds into ten main types has been adopted by the Conference :—

(1.) *Cirrus* (*Ci.*).—Detached clouds of delicate or fibrous appearance often showing a featherlike structure, generally of a white colour. Cirrus clouds take the most varied shapes, such as isolated tufts, thin filaments on a blue sky, threads spreading out in the form of feathers, curved filaments ending in tufts, sometimes called *cirrus uncinus*, etc. Occasionally cirrus clouds are arranged in parallel belts which cross a portion of the sky in great circles, and by an effect of perspective appear to converge towards a point on the horizon, or if sufficiently extended towards the opposite point also. (Cirro-stratus and Cirro-cumulus are also sometimes arranged in similar bands.)

(2.) *Cirro-Stratus* (*Ci.-St.*).—A thin whitish sheet of cloud, sometimes covering the sky completely and giving it only a milky appearance (it is then called cirro-nebula), at other times presenting, more or less distinctly, a formation like a tangled web. This sheet often produces halos around the sun or moon.

(3.) *Cirro-Cumulus* (*Ci.-Cu.*) (*Mackerel Sky*).—Small globular masses or white flakes without shadows, or showing very slight shadows, arranged in groups and often in lines. (French, *Moutons ;* German, *Schäfchenwolken.*)

(4.) *Alto-Stratus* (*A.-St.*).—A thick sheet of a grey or bluish colour, sometimes forming a compact mass of dark grey colour and fibrous structure. At other times the sheet is thin, resembling thick Ci.-St., and through it the sun and the moon may be seen dimly gleaming as through ground-glass. This form exhibits all changes peculiar to Ci.-St., but from measurement its altitude is found to be about one-half that of Ci.-St.

(5.) *Alto-Cumulus* (*A.-Cu.*).—Largish globular masses, white or greyish, partially shaded, arranged in groups or lines, and often so closely packed that their edges appear confused. The detached masses are generally larger and more compact (resembling strato-cumulus) at the centre of the group, but the thickness of the layer varies. At times the masses spread themselves out and assume the appearance of small narrow or curved plates. At the margin they form into finer flakes (resembling cirro-cumulus). They often spread themselves out in lines in one or two directions.

(6.) *Strato-Cumulus* (*St.-Cu.*).—Large globular masses or rolls of dark cloud, frequently covering the whole sky, especially in winter. Generally St.-Cu. presents the appearance of a grey layer irregularly broken up into masses of which the edge is often formed of smaller masses, often of wavy appearance resembling A.-Cu. Sometimes this cloud-form presents the characteristic appearance of great rolls arranged in parallel lines and pressed close up to one another. In their centres these rolls are of a dark colour. Blue sky may be seen through the intervening spaces, which are of a much lighter colour (Roll-cumulus in England, Wulst-cumulus in Germany). Strato-cumulus may be distinguished from Nimbus by its globular or rolled appearance, and by the fact that it is not generally associated with rain.

(7.) *Nimbus* (*Nb.*).—A thick layer of dark clouds, without shape and with ragged edges from which steady rain or snow usually falls. Through the openings in these clouds an upper layer of cirro-stratus or alto-stratus may be seen almost invariably. If a layer of nimbus separates up in a strong wind into shreds, or if small loose clouds are visible floating underneath a large nimbus, they may be described as *fracto-nimbus* ("Scud," of sailors).

(8.) *Cumulus* (*Cu.*) (*Wool-pack, or Cauliflower, Cloud*).—Thick cloud of which the upper surface is dome-shaped and exhibits protuberances while the base is horizontal. These clouds appear to be formed by a diurnal ascensional movement which is almost always noticeable. When the cloud is opposite the sun, the surfaces facing the observer have a greater brilliance than the margins of the protuberances. When the light falls aslant, as is usually the case, these clouds show deep shadows. When, on the contrary, they are on the same side of the observer as the sun, they appear dark with bright edges.

True cumulus has well-defined upper and lower limits. In strong winds a broken cloud resembling cumulus is often seen, in which detached portions undergo continual changes. This form may be distinguished by the name *fracto-cumulus.*

(9.) *Cumulo-Nimbus.* (*Cu.-Nb.*). *The Thunder Cloud; Shower Cloud.*—Heavy masses of cloud rising in the form of mountains or turrets or anvils, generally surmounted by a sheet or screen of fibrous appearance (false cirrus), and having at its base a mass similar to "nimbus." From the base local showers of rain or of snow (occasionally of hail or soft hail) usually fall. Sometimes the upper edges assume the compact form of cumulus, and form massive peaks, round which the delicate "false cirrus" floats. At other times the edges themselves separate into a fringe of filaments similar to cirrus clouds. This last form is particularly common in spring showers. The front of thunderclouds of wide extent frequently presents the form of a large arc spread over a portion of a uniformly brighter sky.

(10.) *Stratus* (*St.*).—A uniform layer of cloud which resembles a fog, but does not rest on the ground. If the cloud-layer is broken up into irregular shreds in a wind or by mountains, it may be distinguished by the name *fracto-stratus.*

For those who are unacquainted with the classification and nomenclature both of Luke Howard and of the International Committee, the following remarks may be of assistance in identifying some of the cloud forms, with the aid of illustrations included in the Preface, p. xxxi.

Cirrus clouds are spoken of colloquially as *mares' tails*, and as such may be easily recognised.

Cirro-stratus has jointly the characteristics of cirrus and stratus; and, as a rule, makes its appearance first in horizontal bands or patches somewhat thicker in the middle than at the edges. When this form of cloud overspreads the sky, the sun or moon may be seen through it having a blurred or hazy outline. Mock suns, called *parhelia*, and mock moons, called *paraselenæ*, are occasionally seen in association with it; also rings of light round and near the moon, called *coronæ*, as well as the larger rings round the sun or moon called solar or lunar halos. Cirro-stratus claims special notice as a herald of atmospheric disturbance.

Cirro-cumulus clouds, when they occupy a large area, give the dappled appearance popularly described as a *mackerel sky.*

Alto-cumulus is far-off cumulus that, unlike cirro-cumulus, does not seem to be fixed against the blue vault, but appears to have a place perspectively in the sky.

Fracto-nimbus is well described as small loose clouds floating at a low level underneath a large nimbus, and is synonymous with the *scud* of sailors; but fracto-stratus, which is a fragment of the stratus cloud, and may be seen flying rapidly with the wind at a lower level, is also called "scud" by sailors; and both are easily distinguished from the fleecy-looking, wind-scattered cumulus called fracto-cumulus, which traverses the sky at a higher altitude than fracto-stratus.

Cumulus is not often seen during the winter months of the year; in the spring and autumn, and less frequently in summer, it may turn into cumulo-nimbus, the lower portion of the cloud becoming denser and darker and terminating in a hard edge, which marks the level at which condensation takes place. When this transformation is observed in spring, summer, and autumn the weather is usually showery; it may be caused by an increase of water vapour in the atmosphere, resulting from rapid evaporation of moisture from the earth's surface under a burning sun.

Roll-cumulus would more properly be called roll-stratus; it never develops into cumulo-nimbus, and is rarely, if ever, followed by rain.

The Height and Speed of Clouds.

In recent years the heights of various cloud formations have been carefully measured at the following places:—

Cape Thordsen, in Spitzbergen; Bossekop, in Norway; Storlien and Upsala, in Sweden; Pawlowsk, in Russia; Irkutsk, in Siberia; Danzig and Potsdam, in Prussia; Toronto, in Canada; Washington and Blue Hill, in the United States of America; Allahabad, in India; and Manila, in the Philippines.

The speed at which clouds travel at different heights, in winter and in summer, has been estimated also, at Upsala, Toronto, and Blue Hill.

The results of these investigations are clearly and concisely set forth by Dr. Julius von Hann, Professor in the University of Vienna, in his book entitled, "Lehrbuch der Meteorologie" (Compendium of Meteorology), published at Leipzig in 1906.

Measurements of the height of clouds (says Dr. Hann) have led to the following general results:—

Cirrus clouds in all climates are found at a height of 7–11 kilometres (22,966–36,090 feet; about 4½ to 6¾ miles).

Cirro-Stratus clouds are, on the whole, somewhat lower, between 6·5 and about 9 kilometres (21,326–29,528 feet; about 4 to 5½ miles); occasionally, however, they have been observed at a greater height than the Cirrus.

Cirro-Cumulus have a fairly constant height of 7–8 kilometres (22,966–26.247 feet; about 4½ to 5 miles).

Alto-Cumulus vary very much in height; measurements, therefore, generally distinguish between high and low alto-cumulus. For the high alto-cumulus Upsala gives a mean of 5,600 metres (18,373 feet; about 3½ miles); for the low, 2,800 metres (9,187 feet, 1¾ miles); and in the recent measurements, 5,200 metres and 2,700 metres (17,061 and 8,858 feet; under 3½ and 1¾ miles respectively). Blue Hill; high alto-cumulus, 6,400 metres; low, 3,200 metres (20,998 feet and 10,499 feet; about 4 and 2 miles respectively).

Strato-Cumulus, on the other hand, show in all their measurements consistency in height, the average is between 2 and 3 kilometres (6,562 feet and 9,843 feet; nearly 1½ and rather more than 1¾ miles respectively).

Cumulus, or "Wool-pack Cloud." The base of this is observed very consistently at an average height of 1·4 to 1·8 kilometres (4,593 to 5,906 feet; rather more than ¾ of a mile to about 1⅛); this corresponds to the average level of condensation at places near the coast. The mean height of the rain cloud (nimbus) is very variable, and is therefore of little importance; likewise the mean height of stratus, which we have entirely omitted.

In support of this generalisation the author furnishes summaries of results of the measurements of the height of clouds in two tables; and in a third the speed of clouds, in metres per second, in winter and in summer, as estimated at Upsala, Blue Hill, and Toronto.

By referring to the latter table and striking averages of the values given for each of the three places respectively, at the various heights, we obtain the following results :—

SPEED ACCORDING TO THE TIME OF YEAR.

Height in feet.	1,640—6,562	6,563—13,124	13,125—19,685	19,686—26,247	26,248—32,809	32,810—45,933
	Miles per hour.					
Winter	23	37	53	70	80	113
Summer	19	25	31	45	58	73

It will be seen, then, that the rate at which clouds in the upper atmosphere travel is greater than that of the wind at the earth's surface; even when these clouds appear to be moving slowly they may in reality be travelling at a rate of 50 miles an hour or more.

Direction of Clouds.

Excepting near the surface of the earth, the clouds rarely move in the same direction as the surface wind, and a great deal of information with regard to coming changes in weather conditions may be gained by the forecaster, dependent solely upon the observations he is able to make in his own locality by watching the movements of the clouds, especially of the upper clouds; that is to say, the cirrus, cirro-cumulus, and cirro-stratus.

It has already been pointed out that the wind at the earth's surface does not circulate exactly parallel to the isobars, or lines of equal barometrical pressure, but that in a cyclonic system it inclines inwards towards the lowest pressure; and in an anticyclonic system, although it follows roughly the course of the isobars, it inclines outward somewhat from the higher pressure. The air in a cyclonic system, as pointed out by Dr. Hildebrandsson, must, therefore, eventually rise; and as it rises the direction of its deflection is gradually reversed, so that when it has risen into the higher regions of the atmosphere its flow is outward over the indraught of the lower current, and ultimately it descends and replenishes the neighbouring depleted system of higher pressure. The air near the earth's surface flowing outward from an anticyclonic system takes the place vacated by the rising air in the cyclone; but in the upper regions of the atmosphere the direction of its deflection is reversed and it flows inwards towards the centre.

Observations of upper clouds have shown that air currents in the upper regions of the atmosphere may flow in a direction that will make an angle with that of the air currents at the earth's surface of as much, and even more than 90°.

The motion of the upper clouds, then, is, as a rule, from a region of relatively low barometrical pressure towards that of a relatively high pressure; and it will now be shown how the knowledge of this fact may be utilised in foretelling the weather.

Dr. H. H. Hildebrandsson, in a paper on the Distribution of Meteorological Elements round the Barometric Minima and Maxima, published in the Transactions of the Royal Society of Sciences, Upsala, in 1883, says:—

> The upper currents of the air leave the minima to enter those regions where there is a high barometric pressure. This centrifugal movement from the centre is feeble in the interior zone, but it becomes stronger in the outer parts of the depression, and still more so in the maxima. This movement is also considerably greater for the gradient directed towards west-south-west or south than for gradients directed in the opposite directions; that is to say, that the flow of air from the centre in the upper strata is much stronger in the front part than at the back, where the movement of the cirrus approaches the tangent to the isobars. In the maxima the influx high up is also much greater over the western slope than over the opposite slope.

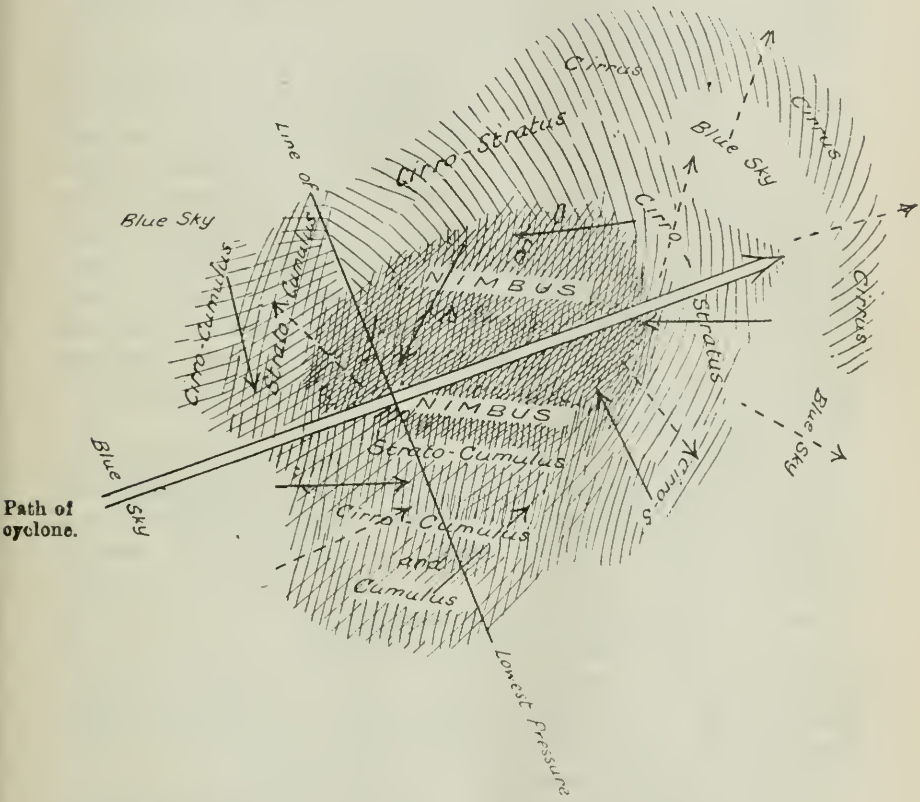
Dr. Hildebrandsson goes on to say that in lower latitudes the vertical axis of an eddy is lower, and does not always reach the region of the cirrus. In the investigation on the movements of the upper atmosphere upon which he had been engaged, it was proved that often in Germany, and usually in countries farther south, such as China and the United States, the cirrus passes above the barometric maxima and minima; and therefore it must be admitted that either the height of the cirrus is much greater in lower latitudes than in Sweden, where the investigations were carried out, or the height of cyclones and anti-cyclones is not so great. It was proved, moreover, by an examination of the international observations of clouds obtained during a year of International Cloud Investigation, which Dr. Hildebrandsson alludes to as "the year of clouds," that the height of cyclones and of anticyclones varies in different cases in the same country; and that the upper clouds are not always affected by disturbances at the earth's surface. Sometimes the motion of the cirrus is not influenced at all by changes in the distribution of atmospheric pressure at the earth's surface, and sometimes, on the contrary, the minima and maxima extend upwards to so high an altitude that the circulation of the air, shown by the movement of the cirrus, is the same as the circulation exhibited by the lower clouds; that is to say, it is nearly parallel to the isobars at the earth's surface. Dr. Hildebrandsson mentions that he and Mr. Clement Ley found that satellites, otherwise known as secondary disturbances thrown off from a primary, are generally not high, especially when they form to the south of a great depression and that they have no influence on the direction of upper currents; that, in fact, the cirrus moves in a direction round the primary depression practically uninfluenced by the secondary.

Synchronous observations of cirrus clouds made at selected stations covering a considerable area, when examined, demonstrate the difference in the distribution and nature of clouds in the upper atmosphere, when associated with cyclonic depressions, in different parts of, what for convenience may be termed the *storm field*. They show, moreover, that while a depression retains its progressive motion its characteristic air circulation is maintained; not only in the surface, and middle layers of the atmosphere, but also in the regions of the cirrus cloud.

The sequence of events that an observer of the clouds may witness who watches the sky during the passage over his locality of a cyclonic depression will therefore depend upon the position in which he is situated with regard to its centre and the direction in which the centre is moving.

Cloud Distribution in a Depression.

Well in advance of an approaching depression, and to the right and left of its front, the sky is usually clear, for the most part, except for streaks of cirrus (Fig. 2). Nearer the central area of lowest barometrical pressure the cirrus gradually changes into cirro-stratus, which subsequently overspreads the sky. Seen through this haze of frozen



———→ Wind direction at the earth's surface.
- - - -→ Wind direction in the region of the cirrus cloud.

FIG. 2.

Adapted from a diagram in "Clouds and Weather Signs,"* by the late Rev. W. Clement Ley, M.A.; modified by the light of Dr. H. Hildebrand Hildebrandsson's investigations in reference to upper cloud movement.†

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* A lecture delivered by the late Rev. W. Clement Ley, M.A., F.M.S., under the auspices of the Meteorological Society, in 1878.

† Rapport sur les Observations Internationales des Nuages. Par. H. Hildebrand Hildebrandsson, Upsala, 1905.

moisture the sun or moon appears blurred. Still nearer the centre the cirro-stratus deepens, descends and changes to nimbus. In that segment of the storm field situated to the right of the line of progression, which in the diagram, Fig. 2, is indicated and described as the *Path of the Cyclone*, the nimbus gives place to dense strato-cumulus, when the line of lowest barometer readings is passing or soon after it has passed. To the left of the line of progression the nimbus generally is continuous until well in rear of the lowest barometrical pressure.

Thus: supposing a cyclonic depression to be crossing the British Islands in an east-north-easterly direction, then an observer stationed in some locality lying directly in the path of its centre, were he to watch the sky, might observe cirrus clouds appearing above the south-western horizon bearing about west-southwest. As these clouds rose nearer the zenith the watchful observer would probably find they were moving from some south-westerly or westerly point. Soon the wind at his station would come from eastward and the cirrus from some point southward of south-west, showing that the air current in the upper regions of the atmosphere above him had backed somewhat.

This backing of the upper air current would continue while the sky became overcast, the cirrus changing into cirro-stratus, and later into nimbus, when the sky would become overcast and rain would set in. The sky would probably remain obscured and the rain continue until the barometer had ceased to fall or commenced to rise—in other words, until the line of lowest barometrical pressure had passed over the observer's locality—at about which time the rainfall would have become intermittent. When the upper clouds could again be seen they would probably be found to stretch in a south-east to north-west direction.

To an observer located in a position to the south-eastward of the cyclone's centre, which has been assumed to be from west-south-west, towards east-north-eastward, the cirrus generally, when first seen above the horizon, bears about west-north-west or north-west; and, when its motion can be detected, will probably be found to move mainly from north-westward.

Before the cirrus merges into cirro-stratus its direction becomes rather more southerly; subsequently, as it descends, it deepens into nimbus. At about this time, or soon afterwards, rain commences to fall, probably a drizzling rain at first, increasing to a steady fall later, while barometrical pressure diminishes. Before the *trough* or line of lowest pressure has passed over the observer's locality nimbus gives place to strato-cumulus, and the rainfall becomes intermittent. When the sky is sufficiently clear for the reappearance of upper clouds, cirrus or cirro-cumulus is, as a rule, seen moving from some westerly or south-westerly point, while the wind at the surface has veered to about west-south-west.

Again: suppose the observer to be stationed to the north-westward of the cyclone's centre, the upper clouds may then be first seen bearing about south-south-west or south-west, probably at a comparatively low altitude. They will, as a rule, have a movement from south-west or south-south-west, while the surface wind is from east-north-eastward. A pall of cirro-stratus or alto-stratus, deepening into nimbus, subsequently overspreading the sky, will then obscure the upper clouds; rain will set in and continue to fall, probably for some time after the trough of the depression has passed over the observer's station, and the barometer has commenced to rise.

The wind at the surface will have backed to north-eastward, and will continue to back. When, the rain having ceased, the sky has cleared sufficiently to observe upper clouds, cirrus or cirro-cumulus may frequently be seen, usually moving from southward or south-eastward. The surface wind will then have backed to some northerly point.

Motion of Upper Clouds.

The motion of upper clouds is generally very slow and their direction detected with difficulty at times even by those who are accustomed to upper-cloud observation; with practice, however, an observer can learn how to follow their movements.

The information given in the foregoing relating to the motion of the upper clouds is derived from a lecture given by the late Rev. W. Clement Ley, M.A., on "Clouds and Weather Signs,"* and this is supplemented and modified by information contained in a Report upon the Circulation of the Air about Barometric Minima and Maxima and the Formation of Satellites, by Dr. H. H. Hildebrandsson.†

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* "Clouds and Weather Signs," by the late Rev. W. Clement Ley, M.A., F.M.S. Published in "Modern Meteorology," a series of lectures delivered under the auspices of the Meteorological Society, 1878.

† "Rapport sur des Observations Internationales des Nuages." Par H. Hildebrand Hildebrandsson, Upsala, 1905.

The latter has pointed out, in reference to the motion of upper clouds, when associated with cyclonic depressions, that the height of cyclones varies in different cases ; and, that the upper clouds are not always affected by disturbances at the earth's surface.

CHAPTER V.

Mist, Fog, Precipitation.

Mist and Fog.

Mist is water vapour in the air rendered visible by being cooled below the point of saturation. Fog is mist of greater intensity, and both may be regarded as cloud at the earth's surface. The distinction that the Meteorological Office endeavours to draw between them is that mist offers no practical hindrance to navigation beyond what arises from an obscured horizon, whereas when in fog sound as well as sight is used to mark a vessel's whereabouts.

The mists and fogs which are often experienced on our coasts in spring and summer usually have their origin over the neighbouring seas and channels ; the land fogs of late autumn and winter frequently extend to these coastal waters.

The distribution of atmospheric pressure favourable to the formation of mist and fog over land areas is generally, but not necessarily, of an anticyclonic nature. Fog, as a rule, occurs when uniformity of atmospheric pressure, the almost complete absence of a pressure gradient, causes stagnation of the atmosphere, and this may occur whatever be the height of the mercury ; although, it may be remarked, the cases in which fog has prevailed when the barometer was low have been rarely recorded in recent years.

The dense and protracted fogs which during the winter months so seriously interfere at times with navigation round our coasts, are frequently associated with well-developed anticyclones, attended by light airs and calms and low temperature.

Sea Fog.

The formation of sea fog is due principally to the effect of a warm, moist wind passing over relatively cold water ; and, less frequently, to that of a cold wind passing over warm water.

A warm humid wind passing over water of a lower temperature is cooled, and the excess of vapour, after the point of saturation has been reached, may be condensed and form mist or fog. In like manner, a cold wind passing over water of a considerably higher temperature than its own chills below the point of saturation the vapour as it rises, when it becomes visible. For the lower the temperature of the air the less aqueous vapour can it hold in an invisible state.

In the first case, the fog, as a rule, does not extend more than a few hundred feet above the sea ; in the second case, it may rise to a comparatively high altitude, but does not always extend quite to the surface.*

Land Fog.

In a lecture on "Forecasting Weather," delivered by Dr. W. N. Shaw, Sc.D., F.R S., the Director of the Meteorological Office, at the School of Economics in London, since published, the following valuable information was given upon this subject :—

> Fog on land (said the lecturer) is specially characteristic of anticyclonic conditions which allow a slow drift of air over projections from the warm moist surface of land areas ; these are cooled by radiation and therefore chill the lower layers of air. We may summarise the conditions as chilled air, moist ground, and a slow drift either downwards along the slopes or across the surface. Land fogs often reach from the coasts over the sea, and, when conditions are favourable for the general development of land fog over our islands and the adjacent parts of the Continent, we may find the fog extended over the narrower straits or enclosed seas by a sort of drainage from the land.
>
> These are, in the main, the autumn and winter fogs over the seas near our coasts, but the process is not properly characteristic of true sea fog. Fogs at sea are more generally to be associated with the gradual passage of a warm and moist air over cold sea-water, and are most frequent in those parts of the ocean where cold water passes under a warm air current and gradually reduces the temperature and increases the relative humidity of the surface layer, while the motion of the surface of air and sea produces the gradual mixing of air of different temperatures which causes condensation in a surface layer.
>
> In the localities where sea fog is prevalent it is most prevalent in the spring and early summer when the temperature of the water lags behind the air in the march of its seasonal variation. It is absent or least conspicuous in the winter when the temperatue of the air is apt to be lower than that of the sea.
>
> Although we may regard the gradual passage of moist air over relatively cold sea as the more normal condition for the formation of

---

* "The Relation between Pressure, Temperature, and Air Circulation over the South Atlantic Ocean." By M. W. Campbell Hepworth, Second Edition, 1917.

fog at sea, it is not possible to leave out of account the occasions when fog is formed by the passage of cold air over warm sea-water.

The physical conditions in this case cannot be so easily formulated as in the case of warm air over cold sea-water. There is no difficulty in the formation of the surface cloud by mixing, but we should naturally suppose that, whereas the cooling of the surface layer in the case of warm air over cold sea-water keeps the air which has been affected close to the surface, and in time makes a saturated or cloudy layer of limited height, the warming of the lower layer of a cold current of air would result in the air affected rising out of reach of further warming. We should expect the cloud to be formed, if at all, at some distance above the surface when dynamical cooling due to elevation has reduced the air below the point of saturation.

In the absence of any quantitative observations, which would enable us to examine the separate cases numerically, we can only conclude that the explanation of surface fog by cold air over warmer water lies in the existence of a small temperature gradient in the surface air current. If there is a little drop in the temperature in the air current as we go upward so that we have nearly isothermal conditions, then the warm air would not rise far before it became dynamically cooled to the temperature level of its surroundings, and the effect of the warming would be limited to a comparatively thin layer. The whole of the layer in question would gradually become saturated, and might pass beyond that point to condensation.

Whether this be the full explanation or not, it is a matter of common experience in forecasting that any notable change in the air current is apt to produce fog over coastal regions. If, after a spell of warm weather, the air supply becomes cold, fog is generally experienced at some point or other of the coast, and still more frequently the replacement of a cold current of air by a warm one after a spell of cold weather shows itself as coastal fog. Hence the note "fog locally on the coast" is a frequent addendum to the statement of prospects of weather when the general change of conditions, either from warm to cold or from cold to warm, is expected.*

Fog associated with High Pressure.

With regard to what has been stated in the foregoing in reference to coast fog and mist, Fig. 1, Plate I, adapted from the Weather Charts in the Daily Weather Report, issued by the Meteorological Office on the 5th November, 1901, is introduced. This shows the distribution of barometrical pressure and wind; also the state of the weather, in letters of the Beaufort notation, obtaining over North Western Europe at 8 a.m. on that day, and furnishes an illustration of the association of anticyclonic conditions with thick weather over the British Islands, which spread over the channels and seas in their neighbourhood.

A large anticyclone, which on the 1st of the month was central over Denmark, moved south-eastward so slowly that

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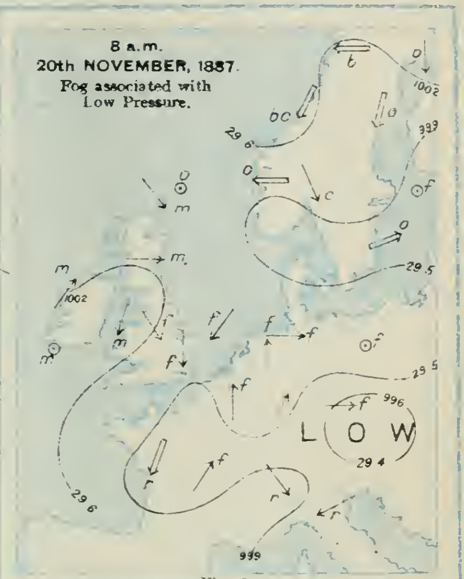
* "Forecasting Weather." By W. N. Shaw, LL.D., F.R.S., Sc.D. (pp. 289–291). Published by Constable & Co., Ltd.

8 a.m.
5th NOVEMBER, 1901.
Fog associated with
High Pressure.

Fig. 1.



8 a.m.
20th NOVEMBER, 1887.
Fog associated with
Low Pressure.

Fig 2.

BAROMETER.—Isobars, or lines of equal barometrical pressure, are drawn for each tenth of an inch; with equivalents in millibars.

Direction and Force of Wind ⊙ → → ⇒ ⇒ ➡ ●
Calm, 1-3, 4-6, 7 & 8, 9 & 10, 11 & 12, Squalls.

WEATHER.—Shown by the following letters: *b*, clear sky; *c*, cloudy; *f*, fog; *m*, mist; *o*, over-cast; *g*, gloomy.

BAROMETER, WIND AND WEATHER
At 7 a.m. 27th MARCH, 1910.

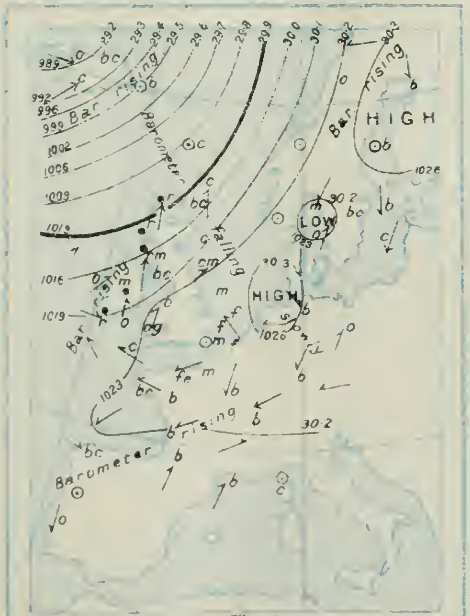


Fig. 3.

EXPLANATION.

BAROMETER.—Isobars are drawn for each tenth of an inch; with equivalents in millibars

WIND.—Arrows flying with the wind show Direction and Force, thus:—

Force above 10 ⋙ ➔ Force 8 to 10 ➔—➔ Force 4 to 7 ——→ Force 1 to 3 ——→ Calm ⊙

PRECIPITATION.—Rain falling ● WEATHER shown by letters of the Beaufort Scale.

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until the 6th it may be said to have covered the whole of Europe. During this time the prevailing light air had an easterly or south-easterly direction. Mist and fog were experienced generally.

The weather conditions shown in Fig. 1, Plate I., relating to the 5th, are characteristic of those prevailing during the first six days of the month. The barometer was highest, 1033 mb. (30·5 inches), and upwards, in the central area of an anticyclone covering the greater portion of Western and Central Europe. It was lowest, 1009 mb. (29·8 inches), and less, over Northern Russia. The weather was foggy over nearly the whole of England; over parts of Ireland, France, and Germany; also off the east, west, and south coasts of England; off the east coast of Ireland, in the Strait of Dover; and, probably, over the North Sea, English Channel, St. George's Channel and Irish Sea. It was misty off the coasts of Scotland and the south and west coasts of Ireland.

With a change of wind to the westward on the 6th and an increase in its force, caused by the surge southward of a low pressure system, the fringe of which had on the previous day been noticed over Lapland, the weather became clearer on the 7th, except over the Southern Districts and the Channel, where it remained thick for some days longer.

Fog associated with Low Pressure.

As affording an instance of the association of land fog with uniform low pressure, the Weather Chart for 8 a.m. on the 20th November, 1887, has been selected (Fig. 2, Plate I.).

A comparison of the conditions there shown with those of the 5th November, 1901, reveals a striking similarity in the trend of the isobars, although the distribution of pressure is inverted, and the barometrical values differ by about 37 mb.: being as low as 996 mb. (29·4 inches) in the "low," as against 1033 mb. (30·5 inches) in the "high"; yet, on both, extensive areas of fog and mist are indicated.

Sea Fog on Coast.

An instance of the spread to the coast from seaward of fog occasioned by the passage of a cold air current over relatively warm water is shown in Fig. 3, Plate I., a reproduction of the Weather Charts for 7 a.m., 27th March, 1910, which appeared in the Daily Weather Report issued by the Meteorological Office on that day.

It will be observed that pressure at that time was high: 1023 mb. (30·02 inches) and above over a great part of North Western Europe, highest, 1026 mb. (30·3 inches) and over the southern portion of the North Sea. Light easterly breezes prevailed over the English Channel and France, but in all the more northern, and western parts of our islands the wind had shifted to the southward or south-westward, and soon afterwards the British Islands generally came under the influence of the equatorial wind. The sea off the East Coast of Britain was at least 1·7a (3° Fahr.) cooler than the air, and had been so for some days past. There is reason, therefore, for believing that the thick weather experienced on the morning of the 27th over the southern portion of the North Sea, and at Fanö, Cuxhaven, the Helder, Cape Gris Nez, Dungeness, Dover, Clacton-on-Sea, Yarmouth, Spurn Head, and North Shields, was caused by a change in the direction of the air current: the flow of warm, humid air over a cold sea surface.

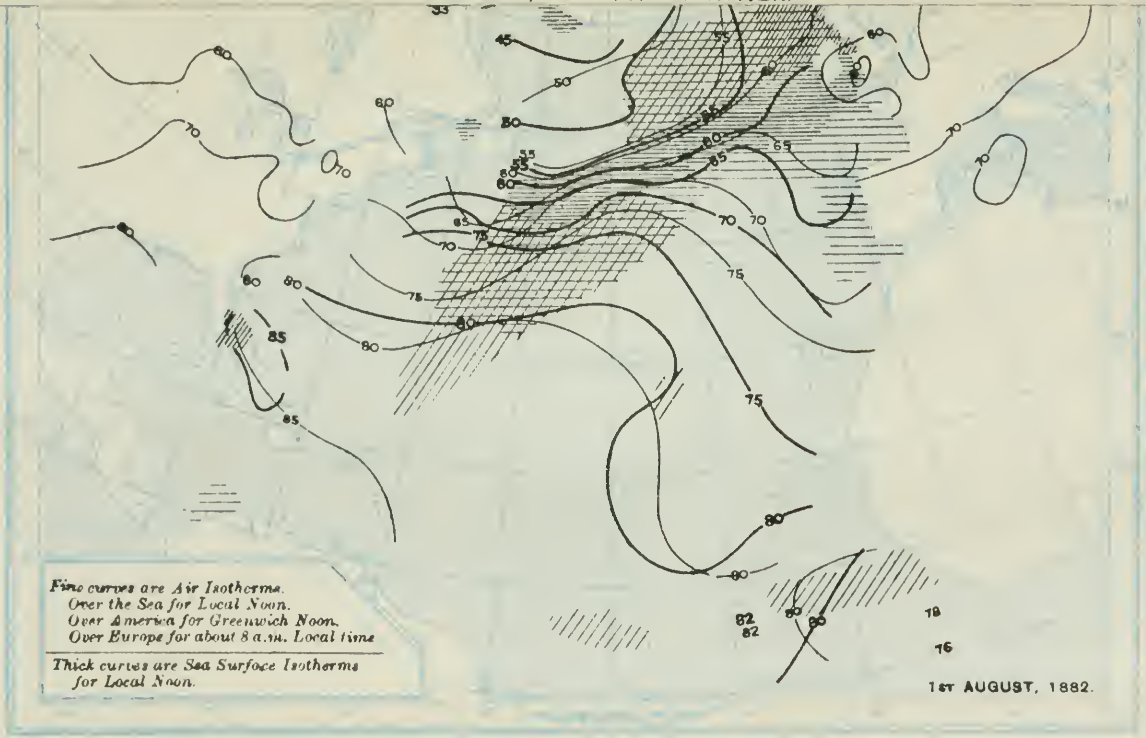
Sea Fog.

As affording a more definite illustration of the association of fog with the passage of a warm air current over relatively cold water the weather charts of the North Atlantic for noon of the 1st August, 1882, are shown in Plate II*a* and *b*. They are copies of charts which are included in a set of Synchronous Weather Charts of the North Atlantic covering a period of 13 months, and were prepared in the Meteorological Office and published by the authority of the Meteorological Council in 1886.

By referring to the chart of Barometer, Wind, and Weather, (Fig. 1) it will be seen that an extensive anticyclone covers the North Eastern Atlantic, the highest barometric pressure within the system being situated immediately to the west of the Bay of Biscay. The air over the North Eastern Atlantic will be seen to circulate about the baric maximum; and to the west and north of this area of highest pressure the wind comes from an equatorial quarter, and is therefore warm and humid. The Chart of Air and Sea Temperature (Fig. 2) shows, by the trend of the respective isotherms of air and sea, that the surface temperature of the latter is considerably below the temperature of the former, the difference being as much as 5° over a large portion of the air referred to. For instance: the air isotherm of 65° Fahr., between the 45th and 20th meridians, runs, for the most part, side by side with the sea isotherm

BAROMETER, WIND AND WEATHER.

PLATE II.



Fine curves are Air Isotherms.
Over the Sea for Local Noon.
Over America for Greenwich Noon.
Over Europe for about 8 a.m. Local time

Thick curves are Sea Surface Isotherms for Local Noon.

1st AUGUST, 1882.

FIG. 2.

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BAROMETER, WIND AND WEATHER.

PLATE II.

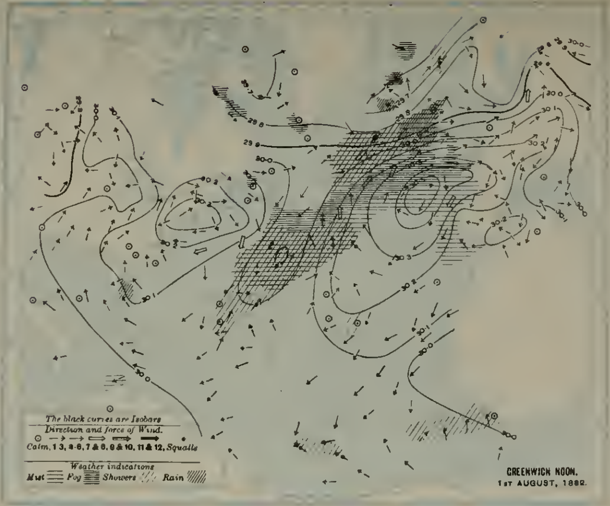

FIG. 1.

AIR AND SEA TEMPERATURE AND WEATHER.

FIG. 2.

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of 60° Fahr. and the air isotherm of 60° Fahr., is found by the side of the sea isotherm of 55° Fahr. In fact, wherever the warm equatorial wind is shown to be passing over water of a lower temperature than that of this wind, there fog or mist for the most part is indicated on these charts.

The latest information relating to the formation of fog and mist, however, was contributed by Major G. I. Taylor, formerly Schuster Reader in Meteorology, now Professor of Meteorology in the Royal Flying Corps, in a lecture delivered at a meeting of the Royal Meteorological Society; a concise summary of which has been published in Symons' Meteorological Magazine, for April, 1917, and is as follows:

"Fogs are due either to precipitation of water in the air or to a condition of the atmosphere which prevents smoke from being dispersed from the air close over the roofs of a town. The two necessary conditions for the formation of a smoke fog are that the wind velocity must be very small, and the air near the ground must be relatively cold compared with the air higher up for a period sufficiently long to collect enough smoke to form a fog.

"The formation of fog at sea can usually be traced to the cooling of the surface air when it flows from a place where the sea is warm to a place where it is cold, but sometimes a fog is caused by air flowing from a cold to a warm part of the sea. In the former case the fogs are usually low-lying and thick, while in the latter they are more frequently light fogs which stretch up to a considerable height.

"Fogs consisting of small drops of water are formed on land, too, by the cooling of surface air, but in this case the air usually stays still while the lowering of the temperature of the ground by radiation to the sky at night cools the air near the surface.

"Fogs of this type are not formed till the temperature has fallen considerably below the dew-point of the air during the day. This is because the formation of dew dries the air near the ground. Theoretical considerations show that the amount by which the temperature must fall below the dew-point before fog is produced depends on a complicated series of causes, but an empirical method has been devised for estimating whether, on any given night, there is enough water vapour in the air to form a fog if other conditions are suitable. This method can be used for local forecasting."

Fog and Mist round British Isles.

The average distribution and frequency of mist and fog over the seas and channels surrounding the British Islands is shown graphically on Plates III. to VI.

Mist is represented by open shading; fog by closer cross shading. In places the shading which defines mist is masked by that defining fog, but as the areas of mist are enclosed by a dotted line and the areas of fog by a plain line this does not signify.

The results thus illustrated are based on four-hourly observations of weather recorded on board ships of the Royal Navy and the Mercantile Marine during the 30 years ended in December, 1908. The total number of observations utilised for obtaining these results is no less than 55,126 for all months; and the number of observations per month ranges from 3,560 for February to 5,577 for July. Nevertheless, there are in some months localities for which the data available for the purpose are insufficient, and a few other localities for which there are no data. Where such occur the words *insufficient data* or *no data*, as the case may be, are noted in the unshaded areas.

The shading which denotes fog refers to a frequency of 10 or under 10 per cent. of all observations. In no localities to which these charts relate does the frequency of fog exceed 10 per cent. throughout the 12 months.

Relation of Thick Weather to Wind Direction.

With respect to the correlation of mist and fog frequency, which may be briefly referred to as thick weather frequency, with wind direction, from a careful examination of a large number of simultaneous observations of wind direction and weather it has been found that, broadly stated, thick weather occurs most frequently in the North Sea with light winds and airs, which may be referred to as air movement, from between south-east and south-west. In the southern half of the North Sea thick weather occurs almost exclusively with air movement from south-westward, but off the north-east coast of Scotland it is generally experienced with air movement from southward and south-eastward. In summer, however, thick weather is often associated with calm; and in the Strait of Dover and its neighbourhood, in the months of October and November, it may be expected to occur with equal frequency with light breezes from almost any direction when the relation between air and sea surface temperatures is favourable to its formation.

To face p. 56.

PLATE II

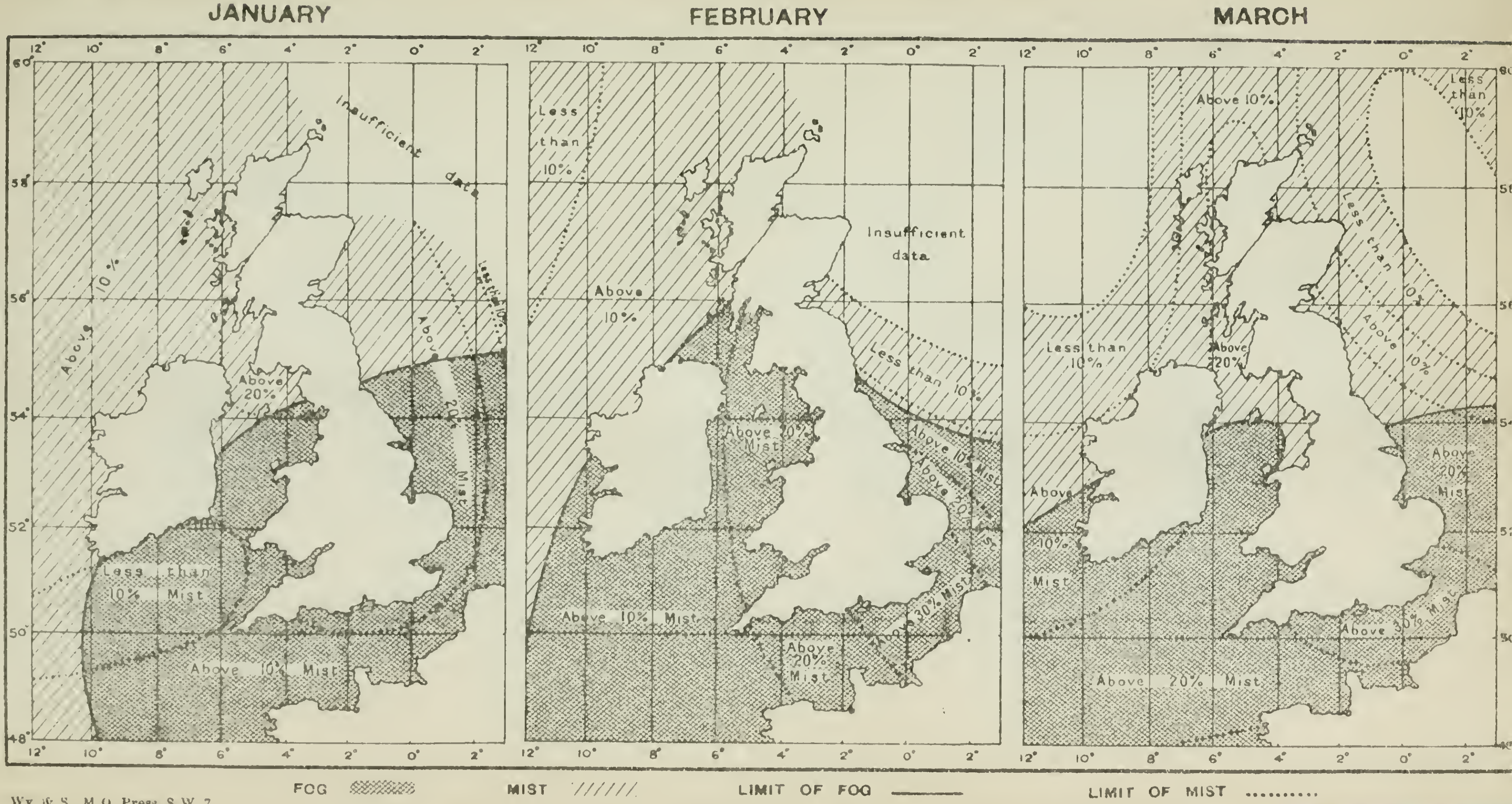
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PLATE IV.

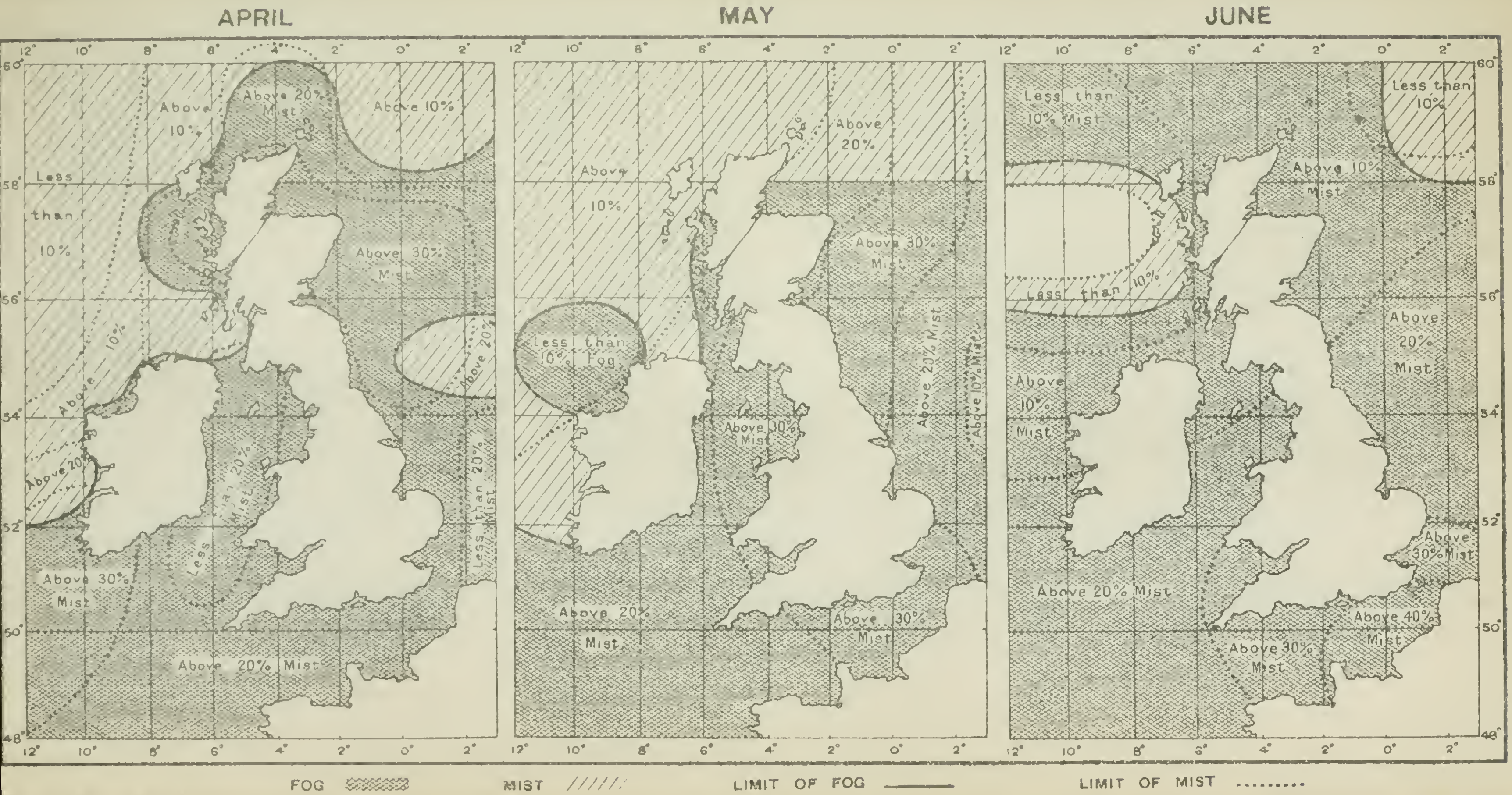

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PLATE V.

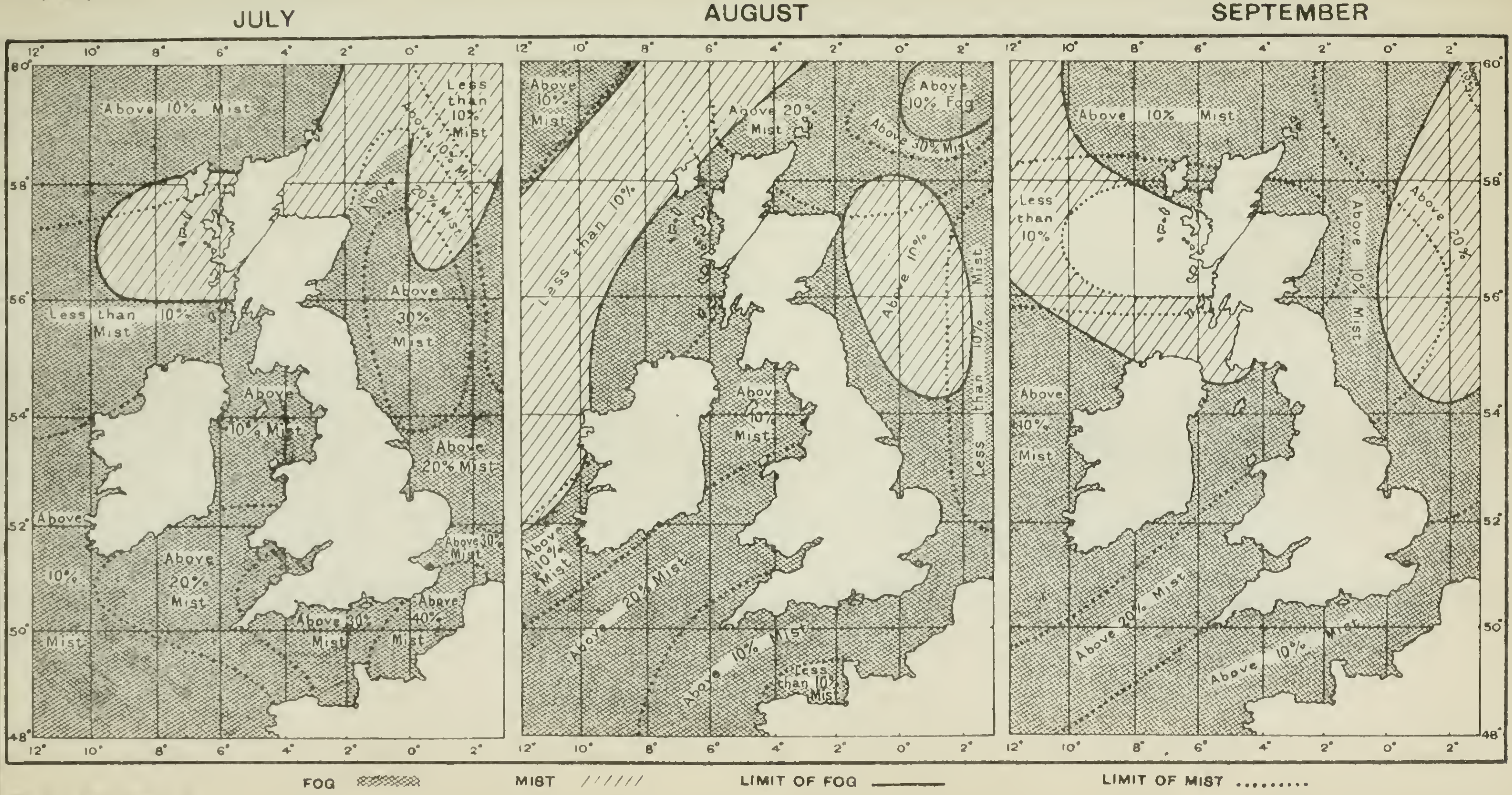

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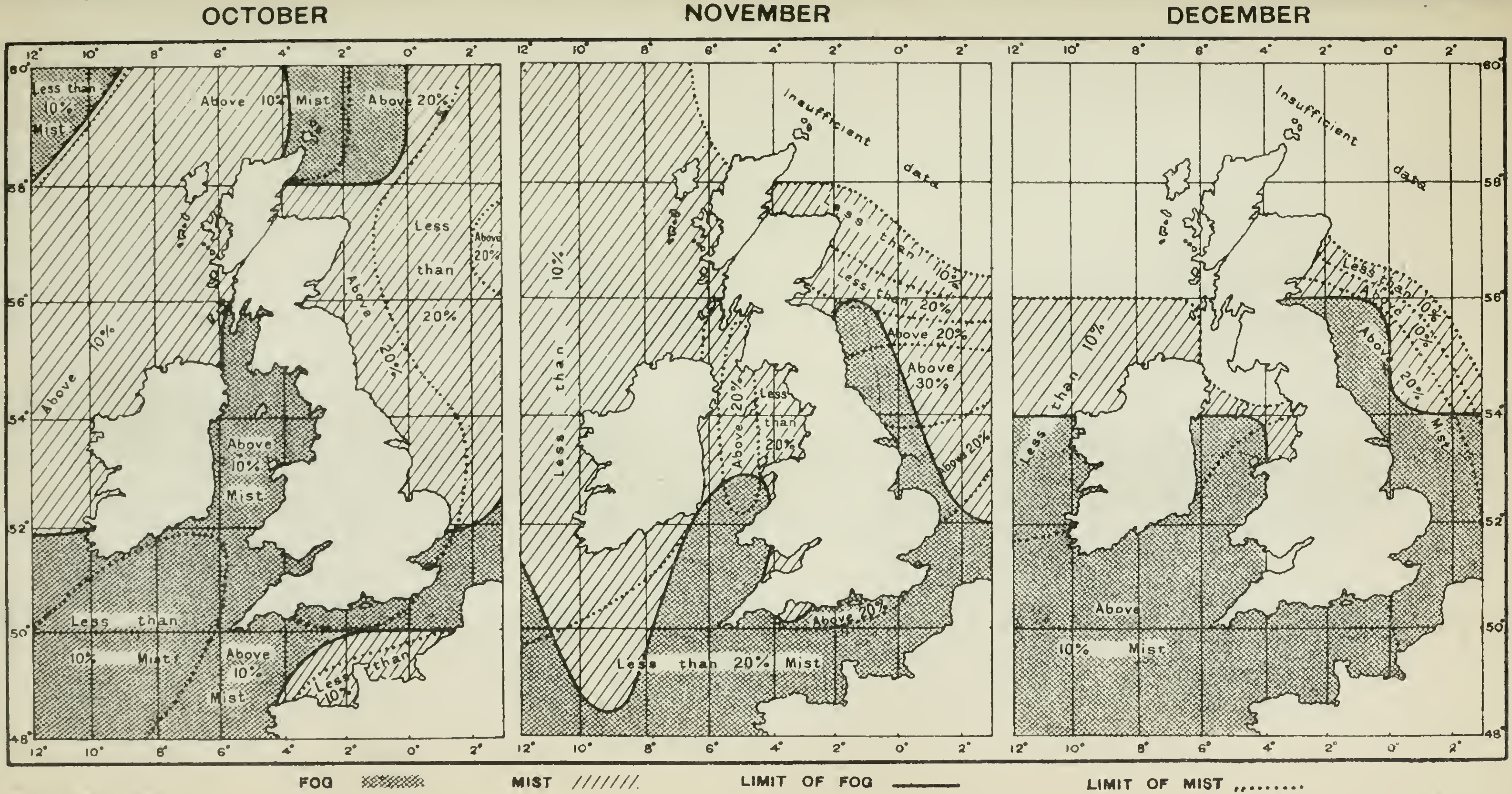
PLATE VI.



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Off the south and west coasts of Great Britain and off the coasts of Ireland experience has proved that the air movement most frequently associated with thick weather is from an equatorial quarter. Over the English and Bristol Channels, and the coastal waters of the United Kingdom bordering the North Atlantic, where there is any air movement in thick weather, it is generally from a southerly or south-westerly point ; but in St. George's Channel and in the Irish Sea its direction is more frequently south-easterly.

In order to assist an observer in estimating and recording grades of atmospheric obscurity due to mist or fog the accompanying scale and specification of fog intensity has been adopted by the Meteorological Office, the Admiralty, and the Trinity House.

Scale of Fog Intensity.

Scale.	Name.	On Sea.	On River.
0	No fog or mist	Horizon clear.	
f 1	Light fog or mist	Horizon invisible, but lights and landmarks generally visible at working distances.	Objects indistinct but navigation unimpeded.
f 2 f 3	Moderate fog	Lights, passing vessels, and landmarks generally indistinct under a mile. Fog signals are sounded.	Navigation impeded, additional caution required.
f 4 f 5	Thick fog ...	Ships' lights and vessels invisible at ¼ mile or less.	Navigation suspended.

Rain, Hail, Snow.

Rain is caused by a diminution in the temperature of the air below the point of saturation. When the minute spherical drops of water, of which cloud is composed, become larger and heavier by the condensation of aqueous vapour and unite they fall as *rain*.

The temperature of the air may be lowered in various ways, but the cooling is brought about chiefly, either by its expansion in ascending or by movements of the atmosphere which bring relatively warm air into mixture with air of a lower temperature. For instance, cold, dry, and therefore heavy air currents, by forcing warm, moist air into higher regions of the atmosphere lower the temperature of the rising air dynamically and occasion precipitation. The rate at which dry air loses its temperature in ascending is 1° Fahr. for every 180 feet, but if the air be not dry this rate is diminished, because the latent heat of condensed vapour tends to keep up the temperature of the ascending column. The rate of decrease, therefore, is usually about 1° for every 300 feet. Again, the obstruction to the passage of an air current, caused by a range of mountains across its course, by raising the air to a higher altitude will, in reducing its temperature, increase the rainfall of the locality situated on the windward side of the range at the expense of that to leeward of it.

The mixing of air of different temperatures might be productive of rain. Winds coming from relatively warm to colder regions increase the rainfall of the latter, because the vapour in these air currents is in this way quickly cooled below the point of saturation.

The rainfall associated with atmospheric disturbances is attributable to the condensation of moisture in the warm ascending air, caused by air currents from colder regions, which set in and replace the rising air, or, more correctly, force upwards the warm air, as well as by the lowering of the temperature of the rising air by expansion. For this reason the rainfall associated with the polar semicircle of a cyclonic depression, which in the Northern Hemisphere lies to the left of its centre, is, as a rule, more copious than that which is associated with the equatorial semicircle, because winds that enter the system on its polar side have their origin, for the most part, in high latitudes, and are therefore relatively cold.

The mean rainfall of a locality depends in a measure upon the mean relative humidity of the air over the locality ; and the copiousness of the rainfall at any particular period upon the quantity of aqueous vapour carried by the winds with which it is associated.

Rainfall is measured to millimetres or to hundredths of an inch by means of the rain gauge and measuring glass described in Chapter XI. One inch of rain caught in a rain gauge implies 64,640 tons of rain per square mile, or 101 tons per acre ; the latter measures 22,624 gallons, or 3,630 cubic feet. These estimates are based on the fact that ·01 inch of water over a 5-inch circle weighs 49·77 grains, and that a cubic inch of water weighs 252·458 grains.*

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* "British Rainfall" by Hugh Robert Mill, Sc.D., LL.D. 1910.

Hail.

The size of the globules of ice which fall in the atmosphere called *hail* varies : some are as small as small shot, others have a diameter of several inches.

True hail is hard and compact, thus differing from the *soft* hail, which consists of fine light grains of a snowlike substance, called *graupel* by the Germans and *grésil* by the French. Soft hail rarely falls in summer, but commonly in winter, and not infrequently precedes snow.

Its Formation.

True hail stones usually have a core of compressed snow, which is encased in layers of ice.

Many theories have been advanced to account for the formation of hail, but no one of them can be considered as wholly satisfactory. The explanation of the formation of true or hard hail which has gained the most general acceptance is that suggested by the American Meteorologist. the late William Ferrel.* An abridged account of Ferrel's theory is tersely given in a book entitled *On Hail*, by the late Hon. Rollo Russell, which is as follows :

> All hail is probably connected with whirlwinds more or less developed. Raindrops formed below are carried up into the snow region by powerful ascending currents, suspended a little while, and frozen into hail. If, now, these be thrown quite outside the limits of the tornado, they fall as clear ice. If, however, they are carried in towards the vortex, they are again carried up to the freezing region. A number of such revolutions may be made. When up in the snow region they receive a coating of snow, but lower down, when rain is being carried up, they are coated with clear ice. When the nucleus is composed of snow, as it generally is, the hailstone had its origin high up in the snow region.

In a summary of the characteristics of hailstorms and hailstones in the book on hail referred to, Mr. Russell states that in the temperate zones a moderate proximity to high mountains, an inland situation, and exposure to great heat and varying winds, are favourable to the incidence of severe hailstorms and that they are generally confined to small areas.

Severe hailstorms are caused by the confluence of conflicting air currents, preceded by heat and sultriness. There is excessive display of lightning, and a sudden strong wind.

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* "Meteorological Researches for the use of the Coast Pilot." Published for the United States Survey, 1877.

The clouds are distinguished by their great height, towering form, massiveness, and darkness. The indications given by the barometer are, he considers, slight, and Ferrel has expressed the same opinion ; but there occurs a considerable reduction in temperature immediately after the hailstorms, and the electrometer shows strong and varying electric action during the storm.

Mr. Russell has found that in Europe hailstorms occur most frequently during late spring and in summer months ; commonly between the hours of 11 a.m. and 5 p.m., but that some of the most severe have been experienced in the middle of the night.

Hailstones take different forms, and he mentions the following as being the most common : Pyramidal ; top-shaped or conical with a rounded convex base ; spherical ; ellipsoid or lenticular ; irregular and angular masses of ice of various shapes.

In this connexion it should be mentioned that the large masses of ice which are occasionally seen to fall in hailstorms are formed by the process called *regelation* : that is to say by the congelation of several hailstones brought into contact during their passage through the air above the freezing point.

The famous meteorologist Dove was of opinion* that the characteristic noise which precedes hailstorms is owing to the rotatory motion of the hailstones before they fall. He attributes the formation of hail to a deposit of ice, which forms at a great height, on a grain of sleet which makes several revolutions in an inclined whirlwind, and during its passage through cold and warm strata alternately obtains the shell of ice which covers the grain of sleet, and becomes at last so heavy that it falls to the earth.

Snow.

Below some temperature, at present unknown, the excess of aqueous vapour in the atmosphere condenses on dust particles in the air in the form of ice crystals, and falls as snow.

Viewed under the microscope or through some powerful lens, snow crystals exhibit stellate structures of great delicacy and beauty, especially when formed in a calm atmosphere. The form they assume is that of a six-pointed star.

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* "The Law of Storms," by H. W. Dove, F.R.S., p. 309.

In the Monthly Weather Review of the United States Department of Agriculture, W. A. Bentley, of Nashville, U.S.A., in a contribution entitled *Twenty Years' Study of Snow Crystals*, says, that since he commenced to examine specimens of these crystals, he had added from four to twenty new forms to his collection in almost every snow storm that had occurred; and that one storm alone had furnished as many as thirty-four new forms.

He divided snow crystals into two fundamental classes, as regards form: the *columnar* and the *tabular*; and, as a result of this differentiation, concluded that temperature and humidity at the earth's surface were of less importance in determining the form and size of crystals than had hitherto been supposed.

As regards the origin of snow crystals, however, or the cause of the difference in the forms of their nuclei, his researches supply no positive knowledge, nor has he ascertained why the columnar form predominated at one time, and the tabular form at another.

Nevertheless he was able to frame plausible hyotheses respecting the conditions and factors that govern the occurrence of the nuclear forms in such conditions. He says: —*

> In general, our data tend to further confirm the conclusions of all observers, that a more or less intimate connexion exists between form and size of nuclei, and the altitude and temperature of the air in which the crystals form. There can be no longer any doubt that there is a general law of distribution of the various types of crystals throughout the different portions of a great storm. On this point the data secured, both by direct observation, and by a study of the weather maps, are much more complete and satisfactory than have ever yet been published.
>
> This aspect of our study received special consideration, because it was thought to be most important.

Bentley then goes on to say that snow storms cover a vast area, in which pressure, temperature, humidity, electrical conditions, &c., differ materially from place to place, and that the number, dimensions, height, and density of the clouds over the several localities differ so considerably one from the other that the snow crystals emanating from these clouds often raise opportunities for studying the effects of local conditions upon these forms.

He shows, by means of tables, the number of occurrences of perfect forms of crystals, and of other types, within the

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* Studies among the Snow Crystals during the Winter of 1901-2, with additional data collected during the previous Winters. By Mr. Wilson A. Bentley, dated Jericho, Vt., June 10, 1902. Monthly Weather Review, 1902. Vol. XXX.

respective segments of storms that were experienced during four winters, and that out of 64 cf these five-sixths were related to the west and north quadrants of storms ; the occurrence of perfect forms in other quadrants being infrequent ; also that the association of such forms with the south and south-east quadrants were rare.

Various modifications of these crystals have, however, been observed, more than a thousand in all ; but, as a rule, those that fall in a locality at the same time are alike.

Roughly stated, a foot of snow is equivalent to an inch of rain.

The ice crystals of which sleet is composed are in the form of small needles pressed together in a confused manner.

Our knowledge in regard to the conditions favourable to the formation of snow and sleet will not permit of any more definite statement than the above. In one of the lectures on "Forecasting Weather," delivered by the Director of the Meterological Office and already referred to, Dr. Shaw said in this connexion :—

> There is no occurrence which is more important to forecast with accuracy than a heavy snowfall. Yet we cannot at present distinguish adequately between the conditions for rain and the conditions for snow. Nor do we know the conditions for the condensation of the atmospheric vapour in the form of snow. In polar regions the atmospheric precipitation is in the form of fine ice crystals ; what is the secret of the formation of large snowflakes we do not know.*

He went on to say that so far as he was aware no one had succeeded as yet in demonstrating in the laboratory the formation of snow. That, while hoar-frost on refrigerating pipes is common enough, condensation to ice in the air itself was beyond his experience. Water drops are easily cooled below the freezing point but he had never seen an ice cloud formed artificially. Dr. Shaw said :—

> However cold it may be, the cloud shows the iridescence of the corona, not the detached circle of the halo. Yet the occurrence of the halo is clear proof of the existence of refracting crystals of ice, for the spherical globules of water produce no halo. Whether the large snowflake is formed by the aggregation of smaller crystals or the extension of a crystalline nucleus by condensation we do not know. We do not know whether snow is often formed and melts before reaching the ground, whether the mixture of rain and snow, which we call sleet, was originally all snow and is partly melted, or was all

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* "Forecasting Weather." By W. N. Shaw, F.R.S., Sc.D., pp. 169–170. Published by Constable & Co., Ltd. The Weather Map (Third Edition). By Sir Napier Shaw, F.R.S.

rain and is partly frozen. All that we do at present is to anticipate snow if the conditions are favourable for precipitation and the surface temperature is near the freezing point.[*]

Snow is measured by thawing what is collected in the rain gauge and measuring the resulting water ; or by melting the snow by adding a known quantity of hot water, which quantity is deducted.

In connexion with Dr. Shaw's reference to the *corona* and the *halo*, it may here be explained that the corona (so named from the Latin *Corona*, which means a *crown*) appears as a ring or a number of concentric rings around the moon when partially screened by high fleecy clouds, an effect produced by what is called *diffraction*.[†] The inner ring of the corona is of a faint brownish-red colour ; between this and the moon the colour is faint blue. Coronæ doubtless are formed frequently around the sun, but in consequence of the intensity of the sun's light, they are seen only under favourable conditions, unless looked for through smoked glass or in a reflector.

Halos are circles showing, when well developed, prismatic colours around the sun or moon ; but when they are of slight intensity they appear white. Coronæ may be seen frequently, in fact, whenever fleecy clouds pass before an otherwise unclouded moon near the full, but halos are of rare occurrence. In halos the red prismatic colour is next the sun or moon, outside this comes orange, yellow, and occasionally green. Halos are formed by refraction[‡] and reflection from ice crystals in cirrus clouds ; they take various forms and their structures are often complicated.

Careful observations of coronæ are not without use in foretelling the weather ; a contraction of the diameter of a corona round the moon may be regarded as a sign of coming rain, because it indicates that the watery particles of clouds producing the effect are becoming heavier and will be precipitated. Conversely, an extension of the diameter of the corona

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[*] "Forecasting Weather." By W. N. Shaw, F.R.S., Sc.D., pp. 169–170. Published by Constable & Co., Ltd. The Weather Map (Third Edition). By Sir Napier Shaw, F.R.S.

[†] When light passes the edge of an opaque body it undergoes a modification ; it becomes bent and forms parallel bands. This effect is known as *diffraction*.

[‡] The change effected in the direction of a ray of light or heat while passing through an even surface into a medium of different density is termed *refraction*. The conditions which occasion mirage and displacement of the horizon through refraction are explained in Appendix I.

may be considered to presage fair weather, because it denotes increasing dryness of the atmosphere.

Rainfall is so dependent upon geographical position that the different parts of the country require separate consideration.

For the purposes of forecasting weather at the Meteorological Office the United Kingdom is divided into eleven districts, which are indicated roughly on the accompanying map, Fig. 3, and with greater detail in Appendix II.

Of these districts the respective coast lines and islands are as follow :—

FORECAST DISTRICTS.

FIG. 3.

0. Scotland, North	...	Fort George on the east coast to Moray Firth, Orkneys, Shetlands and Hebrides.
1. Scotland, East	...	Fort George to Berwick-on-Tweed.
2. England, North - east		Berwick-on-Tweed to The Wash.
3. England, East	...	The Wash to the Thames.
5. England, South - east		The Thames to Lyme Regis.
6. Scotland, West	...	South - western border of Invernesshire to Solway Firth.
7. England, North-west ; and North Wales.		Solway Firth to Aberdovey.

PLATE VIA.

SOLAR HALOS OBSERVED AT ABERDEEN.

Reproduced from sketches by G. A. Clarke, Aberdeen Observatory.

Solar Halo of 22° radius, May 27, 1912. Complete circular halo, with arc of contact. Semi-major axis of the ellipse of which the arc of contact forms a part was about 29°.

Solar Halo of 22° radius, March 5, 1908, with arc of contact, mock sun ring, and mock suns (parhelia).

8. England, South-west; and South Wales.	Aberdovey to Lyme Regis.
9. Ireland, North ...	Southern border of Co. Meath to Southern border of Co. Galway.
10. Ireland, South ...	Remaining coast-line of Ireland.
11. English Channel, including Scilly and Channel Islands.	

Table 1 affords statistics relating to the average rainfall in these districts, based on daily measurements during a period of thirty years. The values given include falls of hail, snow, sleet, and dew. Table 2 relates to snowfall only at the representative stations specified.

TABLE 1.

Rainfall Frequency, 1881-1910.

From Appendix I. of Weekly Weather Report, 1910.

Districts.	1ST QUARTER (91 days).			2ND QUARTER.			3RD QUARTER.			4TH QUARTER.		
	Mean No. of Days of Rain.	Per-centage Fre-quency.	Average Amount of Rain.	Mean No. of Days of Rain.	Per-centage Fre-quency.	Average Amount of Rain.	Mean No. of Days of Rain.	Per-centage Fre-quency.	Average Amount of Rain.	Mean No. of Days of Rain.	Per-centage Fre-quency.	Average Amount of Rain.
			ins.			ins.			ins.			ins.
Scotland, N. ... 0	67	74	14·8	53	58	8·5	59	65	11·9	69	75	16·8
Scotland, E. ... 1	51	56	7·2	46	51	6·3	51	56	8·4	56	61	9·2
England, N.E. ... 2	47	52	5·0	42	46	5·4	44	48	6·8	53	58	7·5
England, E. ... 3	48	53	4·8	40	44	5·5	41	45	6·4	52	57	6·9
England, S.E. ... 5	45	49	6·1	38	42	5·4	40	44	6·6	51	55	9·1
Scotland, W. ... 6	57	63	12·1	47	52	8·6	52	57	12·0	59	64	15·1
England, N.W., and North Wales ... 7	52	57	8·0	44	48	6·8	49	54	9·4	57	62	11·1
England, S.W., and South Wales ... 8	52	57	9·3	42	46	6·9	46	51	9·1	60	65	13·5
Ireland, N.... ... 9	61	67	9·2	52	57	7·6	58	64	10·1	64	70	11·4
Ireland, S. 10	55	60	10·1	47	52	7·7	51	56	9·7	60	65	12·4
English Channel ... 11	57	63	7·9	42	46	5·6	46	51	7·1	65	71	12·0

TABLE 2.

Snow Frequency.

Average Results for the Period 1881—1910.

Percentage Frequency.

District.	Stations representing Districts.	1st Quarter, Jan. to March.	2nd Quarter, April to June.	3rd Quarter, July to Sept.	4th Quarter, Oct. to Dec.	Remarks.
		%	%	%	%	
Scotland, N ... 0	(*a*) Sumburgh Head; Stornoway.	16	4	0·0	7	——
	(*b*) Wick; Glencarron	13	3	0·1	6	Glencarron for 21–23 years only.
Scotland, E. ... 1	Nairn; Aberdeen ...	20	3	0·0	8	——
England, N.E. ... 2	North Shields; Spurn Head.	16	2	0·0	5	——
England, E. ... 3	Great Yarmouth ...	14	2	0·0	3	——
England, S.E. ... 5	Dungeness	10	1	0·0	3	1881–1884, Dover observations used.
Scotland, W. ... 6	Laudale; Rothesay.	20	5	0·2	9	Laudale 29 years, 1881–1909.
	Douglas, Isle of Man.	13	1	0·0	4	——
England, N.W., and North Wales. 7	Aspatria; Holyhead.	8	1	0·0	2	Aspatria—14 years' observations used, 8 years, 1903–10, at Aspatria; 6 years, 1881–1886, at Scaleby.
South Wales and England, S.W. 8	Pembroke; Portland Bill; Scilly.	5	0·4	0·0	1	Portland Bill:—1881–1899 observations at Prawle Point; 1899–1910 observations at Portland Bill.
Ireland, N. ... 9	Malin Head; Blacksod Point; Donaghadee.	7	1	0·0	2	Malin Head and Blacksod Point, 26 years only, 1885–1910.
Ireland, S. ...10	Valencia; Roche's Point; Dublin.	8	1	0·0	2	——

CHAPTER VI.

Atmospheric Pressure Distribution and Weather Conditions.

The relation between the distribution of atmospheric pressure and wind has been referred to in Chapter III. There exists also a relation between the general distribution of pressure over a given area, as exemplified by the configuration of isobars representing it on a synoptic weather chart and the general conditions which characterise the weather prevailing simultaneously over that area.

Preparation of Weather Charts.

The methods adopted at the Meteorological Office in the preparation of the Daily Weather Charts are as follow:—A blank outline map of Europe is taken, on which the positions of the stations from which meteorological reports are received are represented by dots. The telegrams from these reporting stations arrive at the office in varying order, but as soon as each message is received the observations are plotted in correct position upon the chart; the details charted comprising:—(*a*) the direction and force of the wind, shown by small arrows; (*b*) the reading of the barometer, corrected; (*c*) the reading of the dry-bulb thermometer; and (*d*) the state of the weather, given in letters of the Beaufort notation as follow:—

Letters to indicate the State of the Weather.

b	Blue sky.
c	Clouds (detached).
d	Drizzling rain.
e	Wet without rain.
f	Foggy.
g	Gloomy.
h	Hail.
l	Lightning.
m	Misty.
o	Overcast.
p	Passing showers.
q	Squally.
r	Rain.
s	Snow.
t	Thunder.
u	Ugly (threatening appearance of weather).
v	Visibility. Objects at a distance unusually visible.
w	Dew.
z	Haze.

It is well to bear in mind that **w** = dew, but **d** = drizzle, and **e** = wet without rain; **p** = passing showers of rain, and **q** = squalls, but **s** = snow.

In the case of a morning chart, the changes which have occurred at each station in the readings of the barometer and thermometer in the past three hours are then indicated in red and blue figures; red representing a rise, and blue a fall. When most of the telegraphic reports have been charted, isobaric lines are drawn connecting places or positions in which the barometer stands at the same height. These lines are drawn for each 5 millibars (·15 inch); thus, 1005 mb., 1010 mb., 1015 mb., and so on; but as the barometer readings at the various stations are given to tenths of a millibar, it is usually necessary to run the lines along positions lying between two stations. Thus, if the reading at one station be given as 1004 mb., and the reading at the nearest adjacent station as 1006 mb. the isobaric line representing a barometric pressure of 1005 mb. will be drawn midway between the two stations. But if the reading at one station be given as 1002·7 mb. and the reading at the next adjacent station as 1006·4 mb. the line representing 1005 mb. will, of course, be drawn much nearer the latter than the former station. When completed the isobars show at a glance the regions in which the barometer is high and those in which it is low; and by the distance separating the lines it can be gathered whether the differences in pressure over any portion of the regions represented on the chart are great, moderate, or slight. Great differences in pressure, which are technically known as *steep gradients*, are recognised by the isobars lying closely together, and these are almost always associated with gales or strong winds. Slight differences in pressure, or *slight gradients* as they are termed, are, on the other hand, recognisable by the isobars lying widely apart, and these are always associated with winds of little strength.

By comparing the weather chart for any particular hour, say, 7 a.m. to-day, with those for previous times, say 7 a.m. and 6 p.m. of yesterday, it is possible to follow the changes that have taken place in the interim, more particularly as regards the relative positions of the areas of high and low pressure; and thus to form an estimate in regard to probable changes in the near future. A series of synoptic charts affords, in fact, the bases upon which the official forecasts of the weather are drawn up.

To revert to the relation of pressure to weather; the distribution of the former is undergoing changes continually, but the general character of its disposition may be maintained for a considerable time, although the whole layer of air near the earth's surface and for some distance above may be in motion.

There are certain well-defined shapes which isobars assume on a synoptic weather chart that are found to be closely allied to certain definite conditions of weather. The shapes representing dispositions of atmospheric pressure which appear to exercise the most dominating effect on weather conditions are those which are circular or approximately so; pressure either increasing or decreasing towards the central area of highest or lowest pressure about which the air circulates.

The characteristic distributions of pressure in which the circulation of the air is round a central area of low barometric pressure termed *cyclonic*, and that in which the circulation is round a central area of high barometric pressure termed *anticyclonic*, have been discussed in a former chapter. Other definite shapes which occur on synoptic weather charts, and are allied to specific conditions of weather, are for the most part modifications of these types, and will be referred to after typical instances of the cyclone and anticyclone have been introduced.

The Cyclone.

Fig. 3, Plate VII, is mainly a reproduction of the synoptic chart given in the Daily Weather Report issued by the Meteorological Office for 7 a.m. of the 25th March, 1909, but the data shown on the original chart have been supplemented by observations received, for the most part, subsequent to its publication, by wireless telegraphy from Transatlantic liners, so that the area under observation has been extended westward by these means.

In this chart the centre of a cyclonic depression, which passed directly over the British Islands, is indicated near the coast of Yorkshire by the closed isobar of 979 mb. (28·9 inches). The isobars of 982, 985, 989, 992 and 996 mb. successively (29·0, ·1, ·2, ·3 and ·4 inches) are shown encompassing this central area of lowest barometer reading or *baric minimum* as it is called. The wind, represented by arrows, is seen to follow the course of the isobars, but inclines inwards towards the centre of the system showing complete circulation about the system. It is easterly to north-easterly, fresh or strong, over the south of Norway, and over Scotland; north-westerly and westerly. fresh to light, over Ireland, England, and the North of France; south-westerly and southerly over Germany, Holland, and the North Sea.

This cyclonic depression was traced from mid Atlantic by means of reports transmitted by wireless telegraphy. On the 23rd March, at 7 a.m., the centre of the system was situated in about 50° N. latitude; 35° W. longitude (Fig. 1, Plate VII). Its path from 7 a.m. of the day following (Fig. 2, Plate VII), when it began to influence the weather over our islands, to 7 a.m. on the 26th, when it was centred

To face p. 70.

PLATE VII

BAROMETER AND WIND. 7 AM

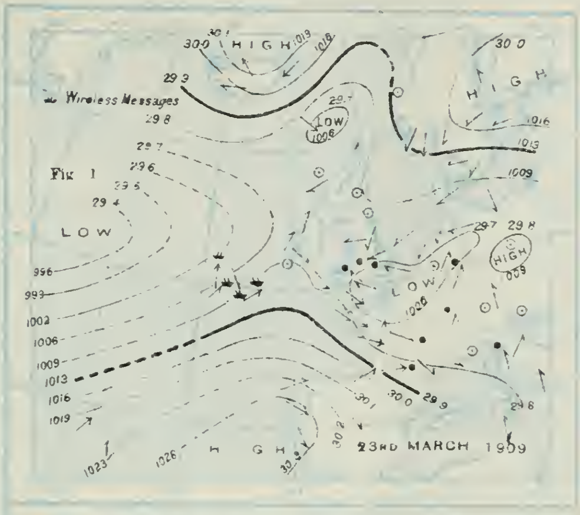


Fig 1.

23RD MARCH 1909

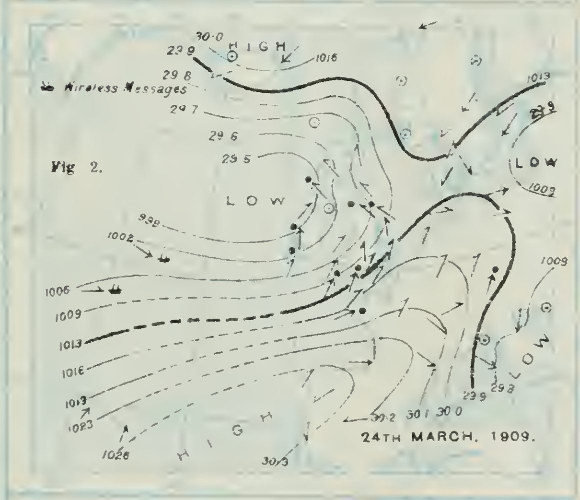


Fig 2.

24TH MARCH, 1909.

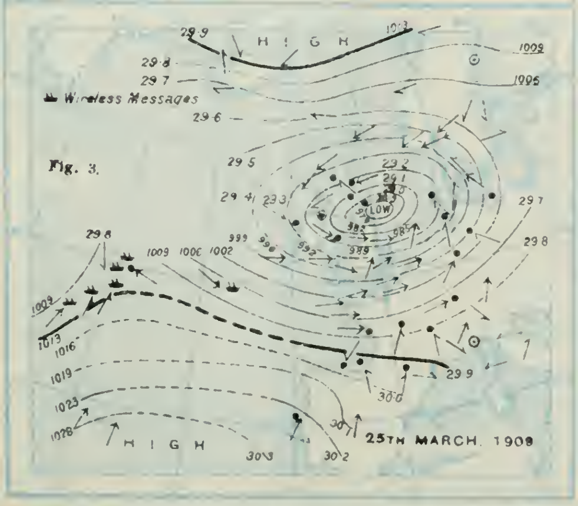


Fig. 3.

25TH MARCH, 1909

Isobars drawn to every tenth of an inch; with equivalents in millibars.
Wind force 1-3 —→, 4-7 —→→, 8-10 →→→, Calms ⊙ Rain ●

722 10,000 1/10

Wyman & Sons, Ltd., Litho. M.O. Press, London, S.W.

BAROMETER AND WIND 7 A.M.

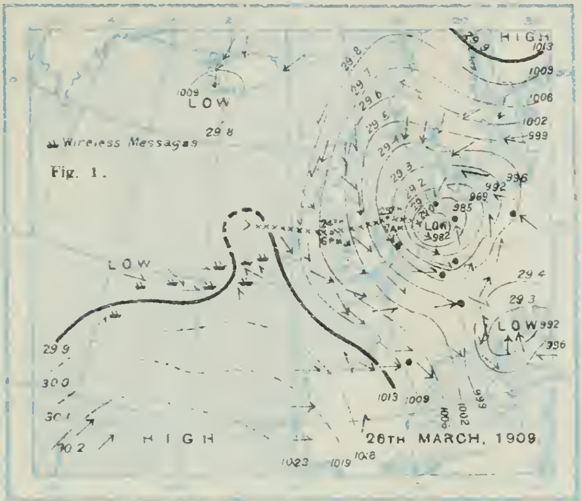


Fig. 1.

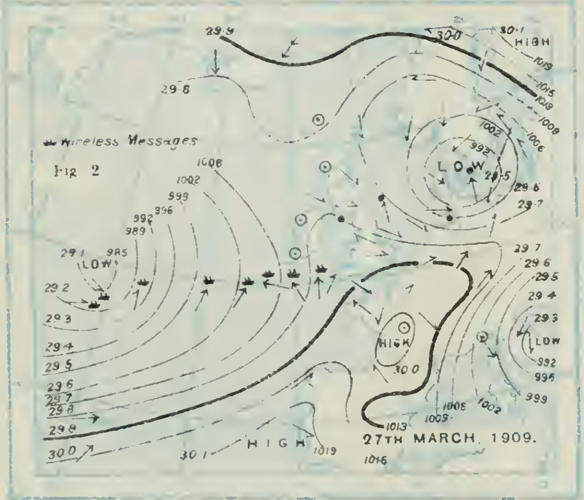


Fig. 2

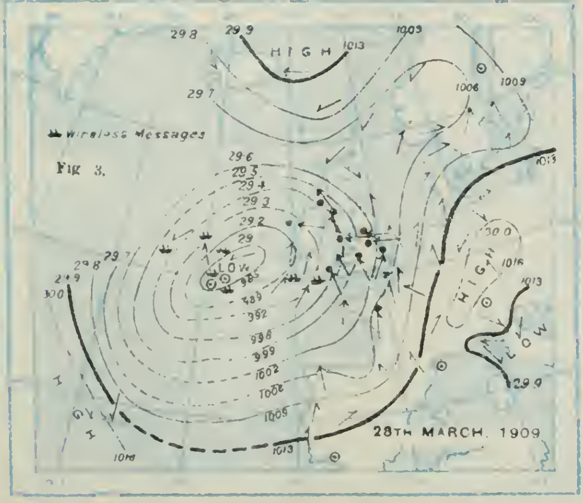
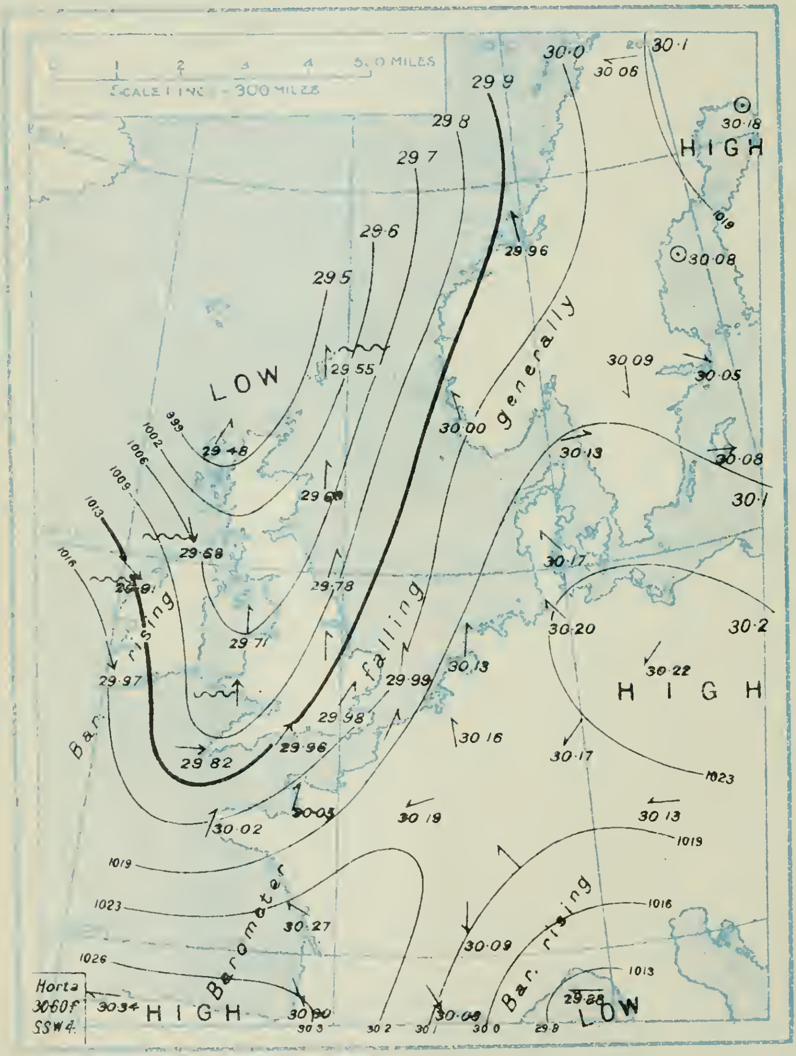


Fig. 3.

Isobars drawn to every tenth of an inch; with equivalents in millibars.
Wind force 1–3 →, 4–7 →, 8–10 →→, Calms ⊙ Rain ●.

Wyman & Sons, Ltd., Litho. M. O. Press, London, S.W.7

BAROMETER, WIND AND SEA 8 a.m., 5th MARCH, 1905.



BAROMETER.—Isobars are drawn for each tenth of an inch; with equivalents in millibars.
WIND.—Arrows flying with the wind show Directions and Force.

Force above 10 ⤜→ : Force 5 to 7 —→ : Calm ⊙.
Force 8 to 10 ⟶ : Force 1 to 4 - - -> :

SEA.—Rough 〜. High ≈.

28, 3222. 15940/44 10000 11/18. Wyman & Sons Ltd., Litho. M.O. Press. London, S.W.

near the coast of Holland, is indicated by a succession of crosses (Fig. 1, Plate VIII). From 6 p.m. on the 24th, when the depression showed a well-defined cyclonic circulation, to 7 a.m. on the 27th, when its centre lay over the Kattegat, the general characteristics of wind and pressure distribution exhibited, although becoming modified from time to time, did not materially change (Figs. 2, 3, Plate VII, to 1, 2, Plate VIII). During the passage of this depression over the British Islands and North Sea the force of the wind did not exceed 6 of the Beaufort scale, except at Spurn Head, where force 7 was registered ; nevertheless the distribution of barometrical pressure and wind it exhibited from time to time was typically cyclonic ; and had the pressure gradient on the 25th been steeper, in which case the isobars illustrating the distribution of pressure on the chart of that date (Fig. 3, Plate VII), would have been closer together in the neighbourhood of the baric minimum, gales would doubtless have been experienced in many parts of the United Kingdom. It will be seen by referring to this chart that at places in front of a line which may be supposed drawn in about a north and south direction through the depression, bisecting the baric minimum, the barometer must have been falling as the system travelled eastward.

In this portion of the depression the temperature, as is almost invariably the case, had risen under the influence of the relatively warm and humid southerly and south-westerly winds from lower latitudes, and rain was falling in several localities. At places in the rear of the depression, when as it travelled eastward, the barometer was rising, temperature, affected by air currents from higher latitudes, north-easterly, northerly, and north-westerly, was falling : the wind had become squally and the rain intermittent. These conditions are characteristic of this part of a cyclonic depression. The hypothetical line dividing that part of a depression in which the barometer is falling from the part in which it is rising is called the *trough* of the depression.

At 7 a.m. on the following day the centre of the cyclonic depression was situated over Holland (Fig. 1, Plate VIII), and during Saturday the 27th March (Fig. 2, Plate VIII) our islands came under the influence of a *wedge* of relatively high pressure, the depression passing away to the north-eastward.

The Wedge.

The *wedge* formation of isobars or *ridge* occurs frequently in certain types of weather conditions. When cyclonic systems moving across or skirting our islands follow one another in quick or comparatively quick succession, there is formed between the retreating and advancing systems an area of relatively high pressure, similar to that indicated on the chart for 7 a.m. of the 27th March, which covers the greater part of England and Ireland, and is bounded, on its north-eastern, northern, and western sides, by the isobar of 1009 mb. (29·8 ins.).

The weather on the eastern side of a *wedge* is usually bright, and the atmosphere extremely clear, objects being visible at a greater distance than usual. The wind from north-westward on this side of the wedge or *ridge* is moderate, and the sky often cloudless or almost cloudless. In the warmer months of the year these conditions are frequently associated in the daytime with burning heat in the sun's rays; and in the winter months with frost at night; both effects are caused by extreme radiation, solar radiation in the one case, terrestrial radiation in the other. On the western slope of a wedge atmospheric pressure rather rapidly diminishes towards the centre of the oncoming depression.

On the 28th March at 7 a.m. (Fig. 3, Plate VIII) Ireland and the West of England and Scotland had already come under the influence of the new cyclonic system, and the wind had backed to the southward; the barometer was falling, temperature had risen, and rain had set in over many localities.

The expression, *backed to southward*, that has been used requires some explanation. Meteorologists employ the term *backing*, whether at an observing station on land, or on board ship, in the Southern Hemisphere as well as in the Northern Hemisphere, to denote a change in the direction of the wind against the hands of a watch; for instance, from northward towards south round by west, or from southward towards north round by east; for a change in the opposite direction the term *veering* is used.

The Anticyclone.

In order to illustrate the disposition of atmospheric pressure, the wind circulation, and the weather, characteristic of an *anticyclone*, the synoptic charts given for 7 a.m. in the Daily Weather Report for the 10th April, 1909, are reproduced. Fig. 1, Plate IX, shows a well developed anticyclonic system situated over the British Islands.

A central area of maximum pressure, with the barometer at 1023 mb. (30·2 ins.), lies over the mouth of the Severn and its neighbourhood, and round the baric maximum and within the

BAROMETER AND WIND.
10TH APRIL, 1909, 7 A.M.

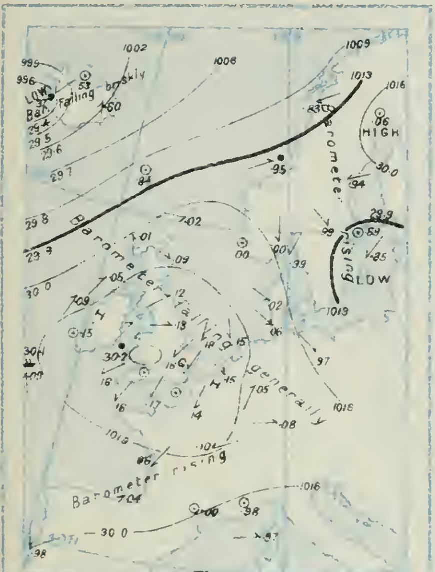


Fig. 1.

EXPLANATION.—BAROMETER.—Isobars are drawn for each tenth of an inch. WIND.—Arrows flying with the wind show Direction and Force, thus:—Force 4 to 7.⟶ Force 1 to 3.—→ Calm. ⊙ Rain falling.●

TEMPERATURE AND WEATHER.
10TH APRIL, 1909, 7 A.M.

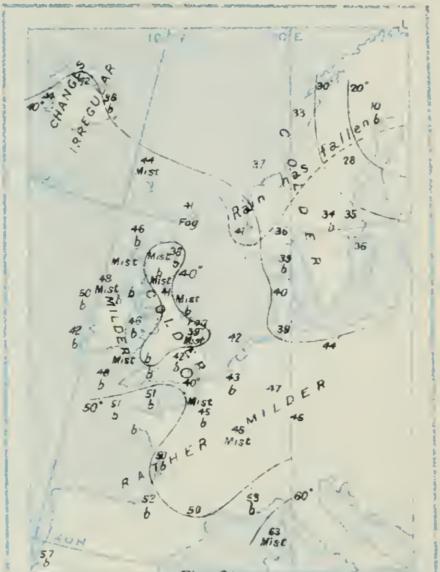


Fig. 2.

EXPLANATION.—TEMPERATURE.—Isotherms are drawn for each 10°. WEATHER.—Shown in places by letters of the Beaufort scale. RAINFALL.—A dotted line separates areas in which rain has fallen from those without rain.

7 A.M., 29TH DECEMBER, 1908.

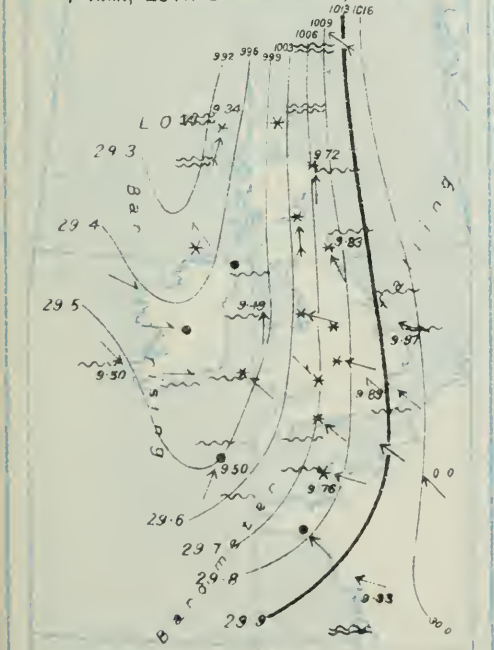


Fig. 3.

6 P.M., 29TH DECEMBER, 1908.

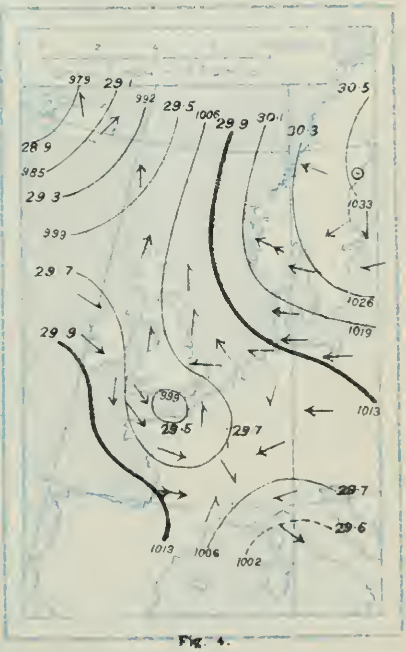


Fig. 4.

EXPLANATION.—BAROMETER.—Isobars are drawn for tenths of an inch; with equivalents in millibars. WIND.—Arrows flying with the wind show Direction and Force, thus:—Force above 10 ⇉→, Force 8 to 10 →—→, Force 4 to 7 —→, Force 1 to 3 — →, Calm ⊙. Rain falling ●, Snow falling. ✶
SEA DISTURBANCE.—Rough 〰. High ≋.

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closed isobar of 1019 mb. (30·1 ins.) there is complete circulation of light breezes which are from southward and south-westward to the west and north-west of our islands, from the westward and north-westward over the north of Scotland and northern portion of the North Sea, from north-westward and northward over the southern portion of the North Sea, and from north-eastward over the English Channel and over France. Thus the wind circulation was in the same direction as that of clock hands.

Over England the temperature (Fig. 2, Plate IX) had fallen since the previous day, and was below the normal ; the weather was fine over North-western Europe generally, excepting at Christiansund and in the south-west of Iceland, where rain was falling, and on the East Coast of England where fog was reported, but the atmosphere was rather misty in some localities. Under the influence of a depression spreading from the south-west over Iceland, the barometer was falling in our islands but was rising over France and the Spanish Peninsula.

Next day the anticyclone had moved south-westward over the ocean towards the Azores.

Secondary Wind Systems.

Accompanying the cyclonic depressions there frequently occurs an interruption to the regular sequence of changes in pressure and wind by the formation within the area of disturbance of a subsidiary depression called a *secondary*, and sometimes termed a *satellite* depression, because it appears to be thrown off the larger cyclone or *primary*. Over these islands and their neighbourhood, when a secondary accompanies a cyclonic depression, it is almost always located to the south of the latter, and is commonly found in the rear of the lowest barometer reading ; but not infrequently it develops in a position, which, shown on a synoptic chart, lies in line with the trough of the primary. Occasionally, however, the secondary forms in front of this trough and moves, usually in an easterly or north-easterly direction, faster than the primary depression.

The winds associated with a secondary during its passage over a locality are generally, but not always, moderate to light, and are accompanied by rain or snow. Precipitation commences on the near approach of the secondary, when the barometer is falling quickly ; and ceases or becomes intermittent after the lowest barometer reading has passed, and the system is retreating, while pressure rapidly recovers ; but the amount of precipitation is not large as a rule.

In illustration of a secondary depression Fig. 4, Plate IX, is here reproduced from the Supplementary Chart of Barometer and Wind, relating to 6 p.m. on the 29th December, 1908, which appeared in the Daily Weather Report of the following day. The Daily Weather Chart for 7 a.m. on the 29th showed a distribution of pressure, immediately to the west of Great Britain, that is known as a "*V"-shaped depression*, and is so called from the contour of the isobars illustrating it, which run to a point, in the form of a "V" (Fig. 3, Plate IX). The trough of this depression, lying nearly north and south, was situated over, and to the north and south of Ireland. Strong winds from between south and south-east were reported from nearly all parts of England, and gales from some parts of Scotland. At Valencia, Ireland, the wind had veered to north-west and blew freshly. The wind was squally over the United Kingdom, and snow was falling over a considerable portion of England and Scotland, and rain in Ireland.

At 6 p.m. of that day (Fig. 4, Plate IX) the centre of a secondary, thrown off the primary cyclonic depression, central to the north-west of Iceland, is indicated over a part of the English Channel and the north of France by the closed isobar of 999 mb. (29·5 inches).

The wind, which, as shown, follows the course of the isobars, was gentle to strong round the baric minimum; from northward and north-westward, over the mouth of the English Channel, and west and south of France; from southward over the east of France; and from eastward over the south-east of England.

Snow was falling at Liverpool, Portland Bill, La Hève, Paris, Bath, London, Dungeness, Dover, Cape Gris Nez, Clacton-on-Sea, Yarmouth, Spurn Head, and Aberdeen; rain at Perpignan and Biarritz.

Next day this secondary appeared to have parted from the primary depression, and travelled to the south-eastward, while the latter had moved to a position north-west of Scotland, and the barometer at localities between the two systems was rising.

This secondary depression was exceptionally well developed; but frequently a secondary disturbance of the atmosphere, when depicted on a synoptic chart, appears as a loop or kink in an isobar; nevertheless the conflicting air currents, represented by this irregularity in the course of the isobar, usually give rise to precipitation. Sometimes, on the other hand, the secondary depression assumes large proportions, and occasionally, though less frequently, it is difficult on this account to determine which of the two wind systems is the primary.

"*V*"-*shaped Depressions.*

The "V"-shaped depression belongs to the type of secondary depression; and is formed by a prolongation of the southern segment of a cyclonic system, and develops, not infrequently, in the lane of low barometrical pressure, separating two adjacent areas of high pressure, termed by meteorologists a *col*. The extension of the cyclonic system southward, in the manner described, appears to be attributable to abnormal activity of the polar air current in rear of the *trough* of the system.

"V"-shaped depressions, as a rule, move eastward with their primary, and occasionally develop into separate disturbances.

Plate X, which is reproduced from the Chart of Barometer, Wind, and Sea, in the Daily Weather Report, issued by the Meteorological Office, for 8 a.m. on the 5th March, 1905, affords another illustration of a "V"-shaped depression, which had advanced from the Atlantic over our islands since the previous day. It extended from beyond the north of Scotland to the extreme south-west of England, but in the west of Ireland the barometer had begun to rise briskly. The barometer readings ranged from 1026 mb. (30·3 inches) and upwards over the Spanish Peninsula, and above 1023 mb. (30·2 inches) over Germany to 1010 mb. (29·82 inches) at Scilly, and to about 996 mb. (29·4 inches) to the northward of the Hebrides. In front of the trough of the depression or eastward of a line drawn between the Minch and Scilly, the barometer was falling generally; temperature, under the influence of the wind from warmer regions, southerly to south-westerly, had risen; and at Oxford, Bath, Portland Bill, Scilly, Pembroke, and Holyhead, rain was falling; while at other stations the sky was overcast or cloudy. In rear of the *trough* the wind had veered to north-westward; the barometer was rising; temperature, under the influence of winds from colder regions, mainly north-westerly, had fallen; and the weather had become squally and showery.

Gusts and Squalls.

A gust is a marked increase in the force of the wind, sudden and transient; a squall is a gust of greater intensity and of longer duration. Either may occur whatever be the prevailing force of the air current. A squall may spring up during light airs and calms, as is frequently the case in the *doldrums* or belt of variable winds and calms separating the north-east and south-east trade winds of the Atlantic and Pacific Oceans, or it may even reinforce a hurricane.

The force of the wind, however steady its apparent motion, is constantly fluctuating, and may be said to consist of gusts and lulls. This is clearly shown in traces of a pressure-tube anemometer.

Squalls are associated with disturbed conditions of the atmosphere and are most frequently the attendants of strong winds and gales. They are caused by the meeting and mixing of air currents of different temperatures, either near the earth's surface or in the upper regions of the atmosphere. In the latter case the confluent air currents may have their origin at different levels, and their meeting may be effected by convection. The effect of vertical air motion, originating in the upper air, and transferred to the surface is exemplified by the waterspout.

Within any area of atmospheric depression at the junction of diminishing and increasing barometrical pressure, where the warm wind from an equatorial quarter comes into contact with the relatively cold wind from higher latitudes circulating in rear of the *trough*, the pressure gradient commonly becomes steeper, causing a sudden increase in the velocity of the wind which, as a rule, is accompanied or followed by copious precipitation—the "clearing shower."

Such a crisis is not, however, confined to the trough of a depression. Occasionally a current of cold air, in advance of the main air current of relatively low temperature, invades the warm current from lower latitudes, causing a brief increase of wind, and fall of rain, hail, or snow. Cause and effect are demonstrated by the temporary character of the wind shift, which in the northern hemisphere is with watch hands, and the simultaneous rise of the barometer, which soon after, again falls, while the wind backs to its former direction.

On the other hand, the relatively cold air circulating in rear of the trough of a depression may be invaded by a lagging stream of the equatorial wind, and sharp squalls accompanied by precipitation ensue; or a current of air from a still more polar direction be intruded with similar results. In many cases the nimbus cloud heralding the approach of the squall is arched and heavy.

Line Squall.

When the trough of a "V"-shaped depression is passing over any area; and, the rapid diminution of barometric pressure ceasing in the localities over which it passes successively the barometer commences to rise, there occurs in those localities, almost always, a simultaneous brief increase of wind, accompanied by a heavy shower of rain, hail, or snow. Occasionally the change from diminishing to increasing pressure is exceptionally rapid as the trough passes, and the increase of wind correspondingly sudden and violent. This sudden increase in pressure occurs simultaneously along a continuous line over the area affected, and it is usually represented on a synoptic chart as a *fault* or discontinuity in the isobars. In a barogram the crisis is shown by a sharp upward turn in the trace, almost, if not quite, at right angles to that part of the trace which precedes and follows it.

The violent squall resulting from the incursion of this sudden wave of relatively high pressure has been called a *Line Squall.*

On the afternoon of the 8th February, 1906, our islands were visited by a line squall which may be considered as typical of such disturbances. It was attended by severe thunderstorms and heavy falls of hail in many parts of the kingdom.

An exhaustive report on the development and progress of this squall was contributed to the Royal Meteorological Society, in 1906, by R. G. K. Lempfert, M.A., the Superintendent of the Forecast Division of the Meteorological Office, then Superintendent of Statistics; it was published in the Quarterly Journal of the Society referred to.* To illustrate the progress of this squall across the British Islands, Mr. Lempfert introduced a selection of synchronous charts which are here reproduced in Figs. 4, 5, and 6. These charts with the whole of the information in reference to the squall which follows are summarised with the author's permission from his published report.

The squall, first noticed at Stornoway at 12.30 a.m. on the 8th, travelled to the south-eastward at an average speed of 38 miles per hour; and at, at least, two stations the velocity of the wind recorded by anemometer was 80 miles per hour. The last station to feel its effects was Hastings, over which place it passed at about 4 p.m.

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* "Quarterly Journal of the Royal Meteorological Society," Vol. XXXII. No. 140. October, 1906.

At 6 p.m. on the 7th the barometer commenced to fall rapidly, the pressure gradient soon afterwards becoming steep. The positions of the line of squall are marked on all of the charts by a dotted line, on those for 2 p.m. and 3 p.m.

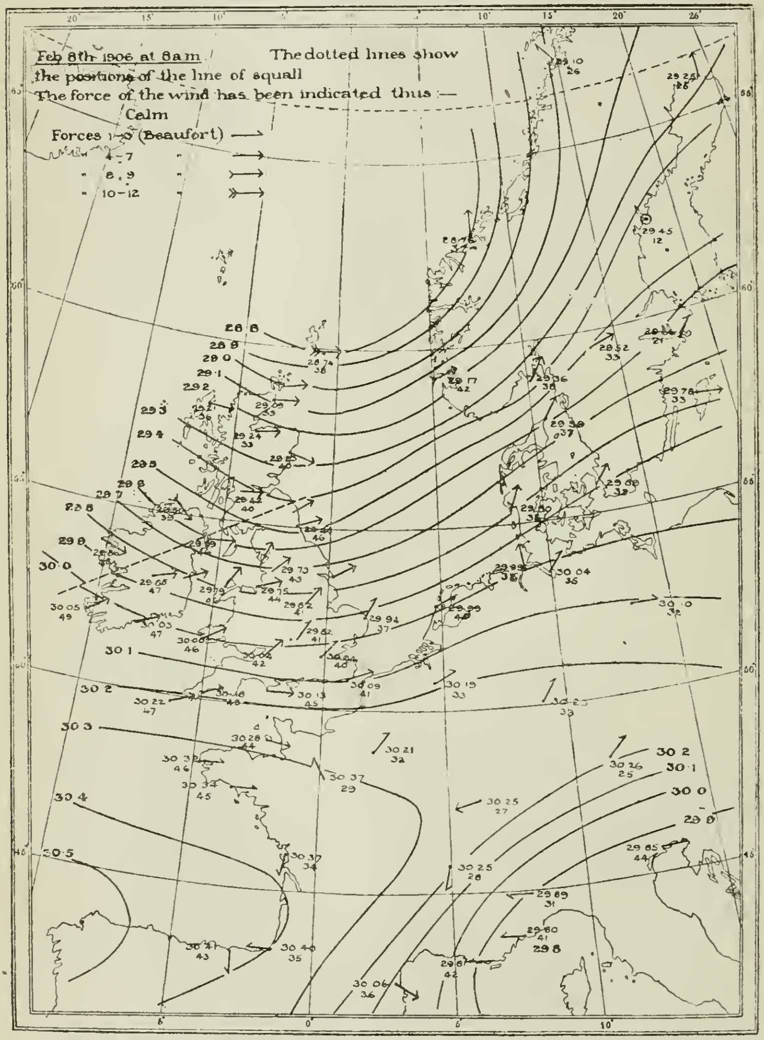
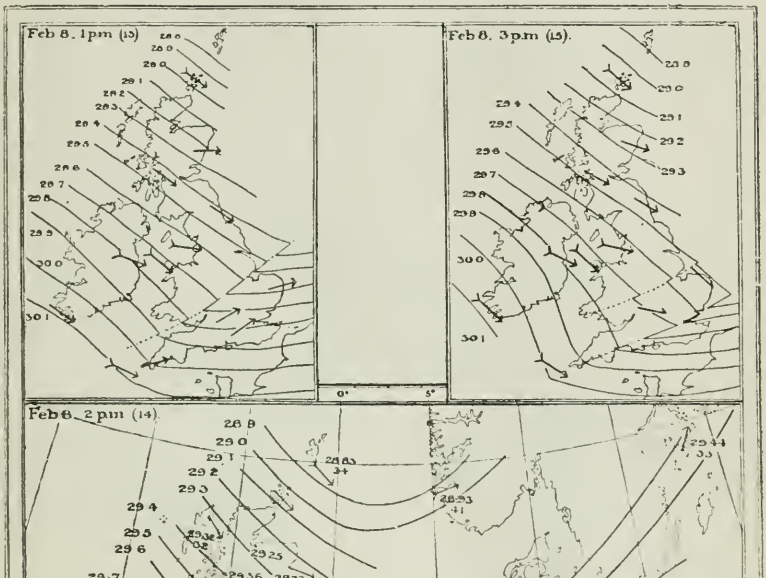


FIG. 4.

by the lower of the two dotted lines, the upper marking the passage of a secondary squall which followed. In front of the line of squall the pressure distribution is for west-south-westerly winds, in rear, it is for north-westerly winds; the line thus separating the two air currents.

The velocity of the wind in the squalls varied considerably: at Bidston and Shoeburyness it reached 80 miles per hour, about double the velocity at which the line of squall travelled. In the east of England and Scotland the velocity of the north-west wind, in rear of the line, was not so great as that of the wind in front of it; in the south-eastern districts the wind dropped to a light breeze after the squall was over, but in the west it was strong both in front and in rear of the line, and at Holyhead the wind blew strongest after the passage of the line. At Oxshott, in Surrey, no increase of wind was


Feb 8. 1pm (13)

Feb 8. 3pm (15)

Feb 8. 2pm (14)

FIG. 5.

shown by the pressure-tube anemometer : the current which was brisk from south-westward in front of the line fell light after veering suddenly to north-west ; and at Kew the velocity of the wind in the squall appears to have been

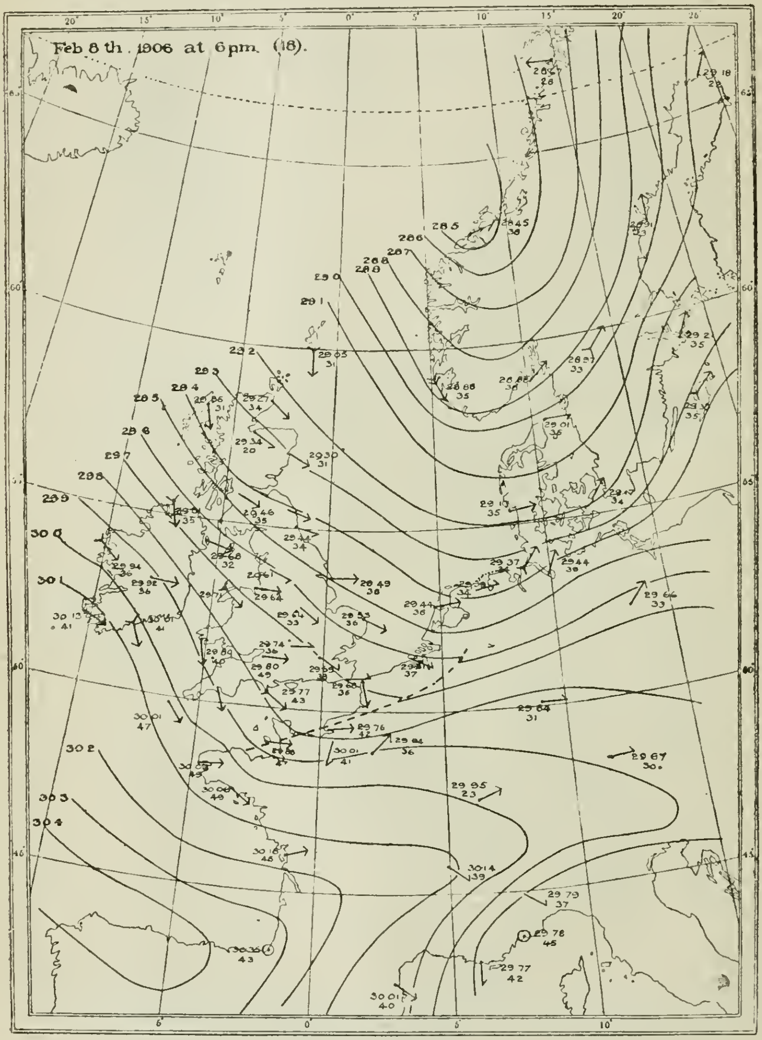


Fig. 6.

about the same as the rate of translation of the line of squall.

The barograms lent by observers for the Meteorological Office and others, for use in connexion with the enquiry. all showed a sudden cessation in the diminution of pressure, and, at the English stations, east of the 3rd meridian of west longitude a sudden increase. At the Scottish stations the sudden increase of pressure was absent, but the crisis was none the less well marked by the steep angle shown on the barogram caused by the sudden cessation in the rapid diminution of pressure.

The time of passage of the line of squall over the respective stations from which thermograms were received was well marked on the traces by the contrast shown between the steady conditions of temperature, associated with the warm south-westerly current of air, and the unsteady conditions obtaining in the cold north-westerly current. .

The rainfall in connexion with the squall varied between 0·1 inch and 0·2 inch, except at stations in the south of England where it exceeded 0·2 inch. The secondary squalls experienced were, in some localities, of considerable intensity. It is a feature worthy of note in connexion with similar disturbances that the primary squall is frequently followed by secondary squalls, more or less intense.

The air became considerably drier after the squall than it was before it ; despite the heavy rain and hail, and the diminution of temperature which accompanied and followed the passage of the line of squall.

The Col.

The weather is quiet but unsettled within a *col*, or neck, of relatively low pressure, which occasionally forms between two areas of high pressure ; and the winds generally are light and variable.

In the warmer months of the year the temperature within a *col* is usually above the normal, the weather dull and, on the coast, mist or fog is common in the autumn.

The distribution of pressure is favourable to the occurrence of thunderstorms. In the colder months the temperature within a *col* is below the normal, the atmosphere often misty to foggy inland, but, as a rule, clearer near the sea, and frequently the thick weather does not extend to the coast.

To instance the formation of a *col* in early autumn, the Chart of Barometer and Wind at 7 a.m., 12th September, 1909, is reproduced from the Daily Weather Report issued on that day (Fig. 1, Plate XI.). At this time the barometer was high over the north-west of Ireland, and over the adjacent portions of the North Atlantic ; also in a band extending from the south of Sweden to the White Sea. It was below 1009 mb. (29·8 ins.) in a depression over Iceland, and in another depression over France and Spain ; a neck of relatively low pressure or *col* connecting these two low-pressure systems. Calms and light airs or light breezes, from between north-east and north-west, were reported at the majority of stations in the United Kingdom, gentle to moderate breezes at a few of them. The sky, for the most part, was cloudy or overcast, there was a good deal of mist on the coasts and fog at Spurn Head. The weather was showery in the Hebrides, rain was falling at Malin Head, in Ireland, and was experienced later in most parts of our islands, with thunder at some southern stations; while severe thunderstorms occurred in different parts of France. During the day air temperature rose to 294·7a (71° Fahr.) at Brighton, and 294·1a (70° Fahr.) at Eastbourne, Weymouth, and Jersey; but, while above the normal generally, it remained below 288·6a (60° Fahr.) in many parts of the United Kingdom.

In illustration of a winter *col*, the general conditions prevailing over our islands and North Western Europe at 8 a.m. on 18th February, 1902, are shown in Fig. 2, Plate XI, which is from the Daily Weather Report of that date.

The barometer was then highest, 1029 mb. (30·4 ins.) and upwards, in an anticyclone which had formed over Scandinavia; another area of relatively high pressure, in which the barometer readings were 1019 mb. (30·1 ins.) and upwards, had appeared over the Bay of Biscay and south-west of France. Two areas of low pressure, one in which 1016 mb. (30·0 ins.) was the highest barometer reading, situated over south Germany, and another in which the readings were 1013 mb. (29·9 ins.) and less, were connected by a neck of relatively low pressure. Thus Great Britain was under the influence of a *col*, in which temperature was below the normal. The sky was clear in some parts of Scotland, but cloudy or dull generally, with fog, over England and over some parts of the Continent; but clearer or clear weather prevailed on the coasts.

CHAPTER VII.

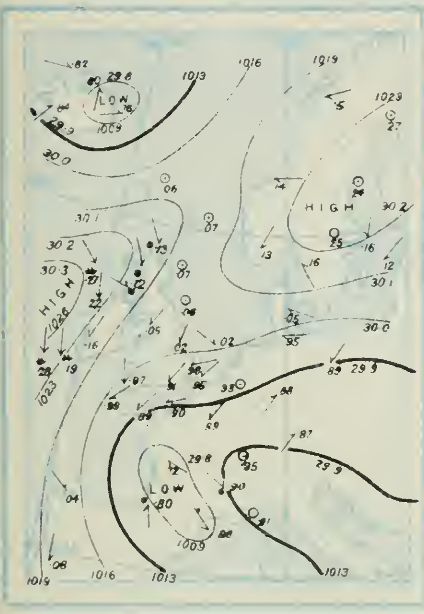
Anticipation of Weather by Observations at a Single Station.

In the previous chapter the method of preparing the Daily Weather Charts at the Meteorological Office was described; and it was explained how by comparing a chart for any hour with others for previous hours, noting at the same time the

PLATE XI.

BAROMETER, WIND AND WEATHER
12th SEPTEMBER, 1909, 7 a.m.

Fig. 1.



BAROMETER, WIND AND WEATHER
18th FEBRUARY, 1902, 8 a.m.

Fig. 2.

EXPLANATION.

BAROMETER.—Isobars are drawn for each tenth of an inch; with equivalents in millibars.

WIND.—Arrows flying with the wind show Direction and Force, thus:—

Force 4 to 7 ——➝ Force 1 to 3 ——➝ Calm ⊙

WEATHER is indicated by letters of the Beaufort scale; Fog and Mist excepted.

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changes that had taken place in the interval, an estimate could be formed regarding probable changes that would occur in the weather conditions of the near future.

The method described calls for, and depends upon, accurate synoptic observations, instrumental and otherwise, transmitted by telegraph from a large number of selected stations, located in suitable positions.

In this chapter it will be shown how by noting from time to time at regular intervals observations of barometer, wind, and clouds, supplemented, if possible, by readings of the wet and dry-bulb thermometers, the trained observer may anticipate, with some degree of accuracy, the more important changes in wind and weather that are likely to follow.

Approaching Depressions.

The most marked changes that occur are usually due to the approach of cyclonic depressions or their opposites, anticyclones, and the passage of these or of secondary disturbances in connexion with the former across the country.

First Indications.

As a rule the approach of a depression is first indicated by the appearance of cirrus clouds; and, as explained in the chapter on clouds, the observer's position in relation to the path on which the depression is travelling can be roughly determined by watching the motion of the upper clouds, and noting the changes in the direction of the wind at the surface. As the depression draws nearer the observer's locality the wind veers or backs, as the case may be, and soon afterwards the barometer commences to fall.

Bearing of Centre.

For the purpose of forecasting weather it is necessary, as soon as the barometer shows a decided fall, to ascertain the direction in which the central area of low barometric pressure of the depression is situated, and the path on which it is travelling. Subsequently it can be determined whether the centre is nearing or receding from the locality.

Standing facing the wind the bearing of the central area of a cyclonic depression in our hemisphere will be about two points in rear of the observer's right arm outstretched at right angles to the wind's direction. For instance, supposing an observer, who has reason to believe that a cyclonic depression is approaching his locality, stands facing the wind from south-south-east at A, Fig. 7, his right arm, outstretched at right angles to the wind's direction, will point west-south-west, and the bearing of the central area of low pressure will be about west.

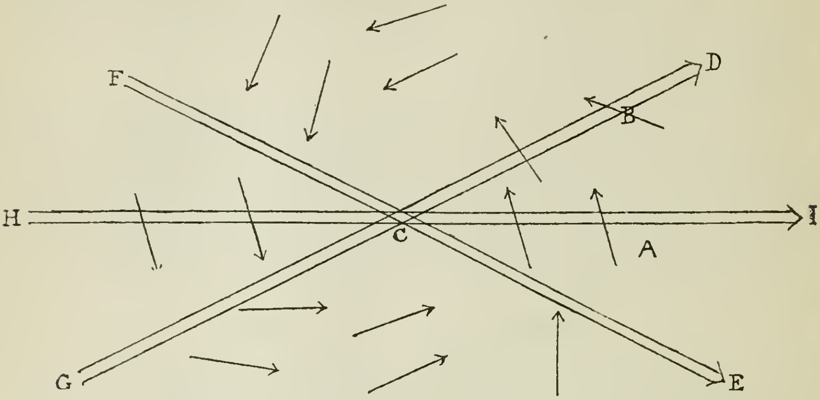


Fig. 7.

Again: suppose the wind he faces to be from east-south-east at B, his outstretched right arm will point south-south-west, and the bearing of the central area of low pressure will be about south-west.

Path of Centre.

Having determined the bearing of the central area of lowest pressure, changes in the wind's direction must be carefully observed and recorded. If at A the wind veers—that is to say, shifts with watch hands to southward and south-westward—the centre must be taking a path to the north of the observer, the path, for instance, G C D; and, as the depression moves onward and passes away in a north-easterly direction, the wind will veer to south-west and west. The barometer will then commence to rise and the weather to improve.

If, on the other hand, the wind backs—that is to say, shifts against watch hands to south-eastward and eastward—the centre must be taking a path to the south of the observer, the path, for instance, F C E; and as the depression moves onward, and passes away in a south-south-easterly direction, the wind will continue to back to east, east-north-east, and north-east.

Soon after the wind has backed to north-eastward the barometer may commence to rise, but the improvement in the weather will be gradual. Should the wind remain steady at south-south-east, and increase in strength, the centre will pass over the observer's locality, and the wind shift suddenly to north-north-west. The path of the depression's centre in that case will be that indicated by the letters H C I.

It may be, however, that the diminution of pressure that has taken place is caused by the incursion of a "V"-shaped depression or prolongation of the southern segment of a cyclone, moving eastward in higher latitudes. It will be shown in the next chapter that some knowledge as to the type of weather conditions prevailing at the time will assist an observer in arriving at a correct conclusion on this point.

Weather Sequence.

The sequence of weather an observer may expect to experience in connexion with a cyclonic depression that influences the weather conditions of his locality depends upon his position in relation to the path of the centre of the depression. As a rule, temperature rises, and the air becomes humid before the wind shifts or pressure diminishes; soon after the barometer has fallen decidedly precipitation may be expected to commence; light at first, becoming heavier as the central area of the disturbance approaches, the wind at the same time increasing in force. When the path of the centre lies to the north of the observer the rain often becomes intermittent somewhat before or soon after the line of lowest barometer readings passes over his locality; and the passage of the trough over it is commonly marked by a brief increase of wind and a sharp shower of rain.

When the barometer, having ceased to fall, commences to rise, and the wind is still veering to westward, temperature falls, the air nevertheless becoming less humid. Occasionally a drier condition of the atmosphere, evinced by increasing difference between wet and dry-bulb thermometer readings, presages the near approach of the line of lowest pressure or trough, the clearing squall, and accompanying shift of wind to westward before the barometer has given any indication of the coming change.

When a deep depression is followed by an area of considerably higher barometric pressure than that which preceded it, either as a ridge between it and an advancing depression or in the more extensive form of an anticyclonic system, the wind blows harder in rear of the trough of the depression than it did in front of it, because of the steeper pressure gradient thus produced in rear. When this is not the case the wind gradually moderates in the observer's locality as the distance separating the locality from the central area of depression increases.

When the path of the centre lies to the south of the observer rain or, in winter, sleet or snow usually continues to fall in his locality for some time after the trough of the depression has passed over it ; but the atmosphere becomes less humid, notwithstanding the fall in temperature, soon after the wind has backed to north-eastward.

The wind increases as the central line of low pressure approaches the observer's station ; but, unless the pressure gradient be steeper in rear of the centre than it is in front of it, the wind gradually moderates, after the transit of the trough, as the distance between it and the station increases.

The sequence of events is very similar when the path of the centre passes directly over the observer's locality, but in that case precipitation may be expected to become intermittent so soon as the trough of the depression has passed.

The foregoing statement regarding the normal sequence of wind shifts and weather changes pertaining to different localities in any area over which a cyclonic depression passes, will be made clearer by referring to Plate XII, which are introduced to illustrate the distribution of barometric pressure and wind at 7 a.m. and 6 p.m. on the 16th and 17th December, 1910, during the passage of a cyclonic depression over the British Islands. These illustrations are reproduced from the Weekly Weather Report of the Meteorological Office for the week ended on the 17th of that month ; and the information in reference to the conditions they represent is derived from the same source.

The barometer on the morning of the 16th at 7 o'clock was below 972 mb. (28·7 ins.) in a depression centred over the west of Ireland (Fig. 1, Plate XII), while over a considerable part of Russia it was above 1029 mb. (30·4 ins.), and was relatively high over Algeria and Morocco. An extensive cyclonic wind circulation was shown over our islands and their neighbourhood.

The wind from between south-west and south blew strongly to a gale in the south and south-east of Ireland, St. George's Channel, the south of England, the English Channel, and the north of France, where temperature was rising rapidly. It was from between south and south-east, strong, over the remaining parts of England, the Netherlands, and the North Sea ; from between east and north-east, moderate to strong, in the north and north-west of Scotland and Ireland ; and from north-west, a strong to whole gale, to the west of Ireland, where the rise of temperature was slower or very slight.

BAROMETER AND WIND.

7 a.m. 16th DECEMBER, 1910.

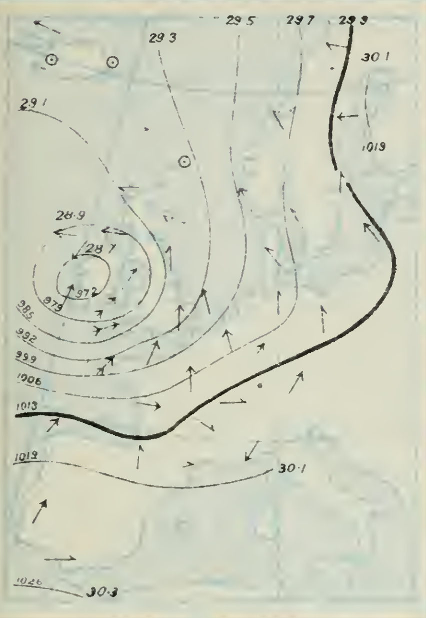


Fig. 1.

6 p.m. 16th DECEMBER, 1910.

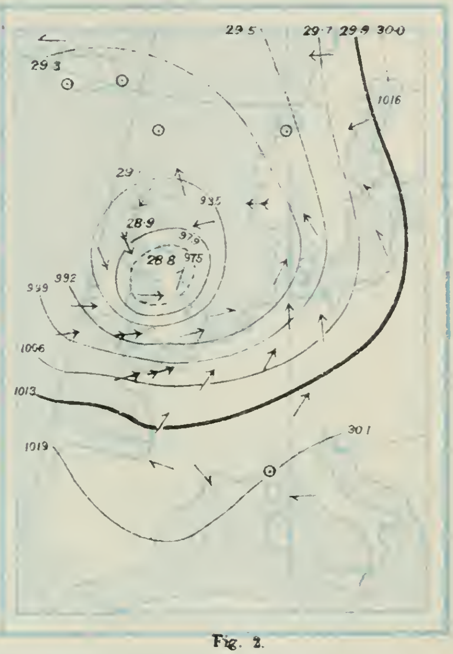


Fig. 2.

7 a.m. 17th DECEMBER, 1910.

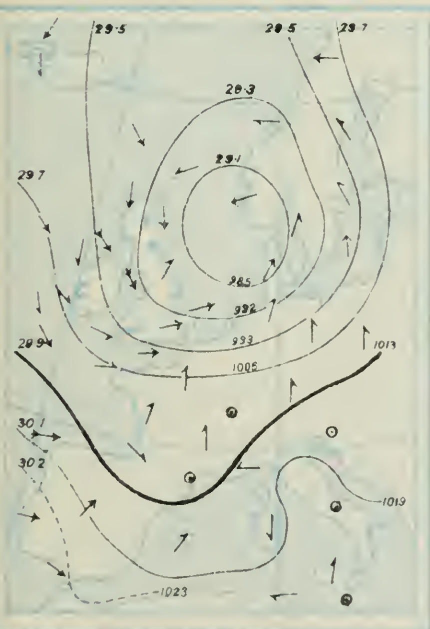


Fig. 3.

6 p.m. 17th DECEMBER, 1910.

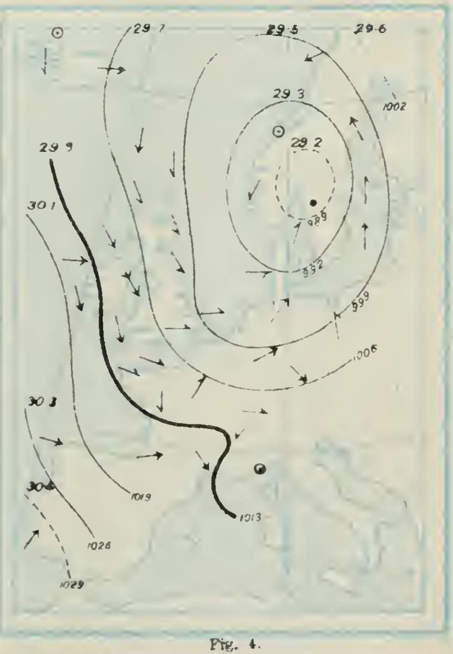


Fig. 4.

EXPLANATION

BAROMETER.—Isobars are drawn for each two-tenths of an inch, with equivalents in millibars.

WIND.—Arrows flying with the wind show Direction and Force, thus:—

Force above 10 ⟶, Force 8 to 10 ⟶, Force 4 to 7 →, Force 1 to 3 →, Calm ⊙

[illegible] 5000 1/14 Wyman & Sons Ltd. Litho. M.O. Press, London, S.W.

Rain was falling over the greater portion of the United Kingdom and the nearer regions of the Continent ; over our area generally the sky was overcast, and in the north of Sweden snow fell, but the temperature was above the normal.

The depression moved eastward during the day, the pressure gradient becoming steeper, and the wind increasing over Ireland, England, and the English Channel. At 6 p.m. (Fig. 2, Plate XII) the central area of the depression was located over the North of England and the Irish Sea ; the wind had backed to the north-eastward in the north-west of Scotland, and to north-westward in the north-west of Ireland. It had veered to westward in the south of Ireland, in the English Channel, and over the North Atlantic immediately to the south-westward of our islands.

A north-westerly gale was blowing in the north of Ireland ; a westerly gale in the south-west of England, the north of France, and, presumably, in the English Channel ; an easterly gale in the south of Norway, and, doubtless, in the northern part of the North Sea. At 7 a.m. on the 17th the central area of the depression had reached the North Sea, its minimum pressure being situated probably at no great distance from the south coast of Norway (Fig. 3, Plate XII). The air circulation about the minimum pressure was still completely cyclonic ; a northerly, north-westerly to westerly current prevailing over the United Kingdom ; a southerly current over north Germany and Denmark, and an easterly to north-easterly flow of air over Norway and the northern portion of the North Sea.

The wind blew with gale force in the North of Ireland and north-west of England, and strongly in the English Channel. The temperature had fallen in most parts of our islands and showers of rain were prevalent in many localities. The depression travelled slowly to the eastward during the day and became less deep, while pressure increased briskly over the United Kingdom, the wind becoming more northerly in the west of our islands and north-westerly in the east and south-east (Fig. 4, Plate XII).

As frequently happens, this depression was followed by a ridge of relatively high pressure, which moved to the eastward over the British islands during the 18th and 19th, and was associated, while the wind remained northerly, with colder and drier weather.

The copies of barograms and thermograms on Plate XIII show the fluctuations in atmospheric pressure and air temperature at Aberdeen and Crathes respectively, on the north side of the cyclone's path ; and at the Meteorological Office and Warlingham respectively, on its south side, from midnight on the 15th to noon on the 19th December, 1910, during the approach of the depression, the passage of its centre between those stations, and its retreat eastward which has been described in the foregoing. Symbols denoting the corresponding changes in wind direction and force, and in weather have been added to the barograms.

Pinewood Crathes is situated 12 miles to the south-westward of Aberdeen ; Warlingham 13 miles south-south-east of the Meteorological Office.

The strongest winds at Aberdeen, also at the Meteorological Office, did not exceed seven of the Beaufort scale, the pressure gradient having become less steep before the centre of the depression arrived over the meridians of those places. Gale force was recorded at most of the reporting stations on the coasts of Ireland and on the west coast of England.

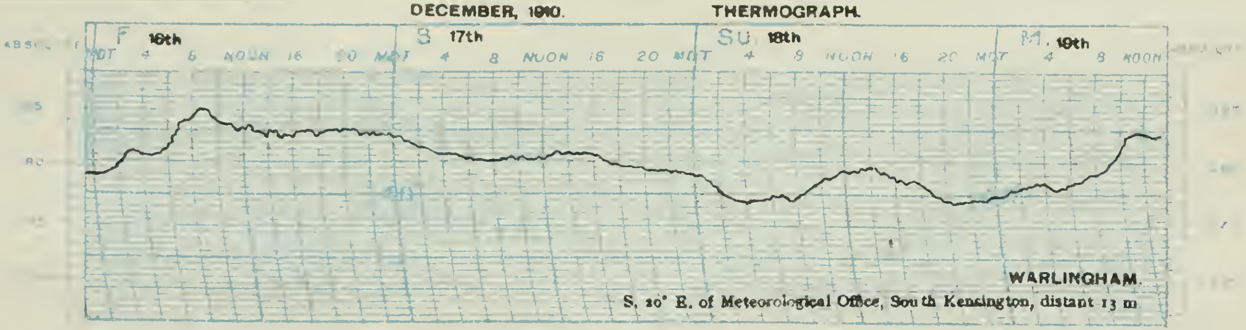
The rainfall appears to have been general over our islands. but confined mostly to times when the front of the depression was passing ; in many localities the fall was heavy—more than half an inch. After the passage of the line of lowest pressure over a locality the rain either ceased or became intermittent, even on the left side of the central area usually prolific of rain, and continuing after the passage of the trough.

The ridge that moved over the British Islands as the depression passed away was formed by the protrusion northward, between the retreating and oncoming depressions, of an area of high barometrical pressure or anticyclone, situated on the 18th over the Bay of Biscay, and it passed eastward over the North Sea and Scandinavia on the 20th of the month. As it moved from our islands to the North Sea the wind backed to the southward on the northern side of the path of the oncoming depression, and to south-westward on the southern side, freshening at the same time ; the temperature quickly rising, and the air becoming humid.

When our islands came directly under the influence of the new depression the barometer commenced to fall, and by 7 a.m. on the 20th a south-west gale was blowing on the west coast of Ireland.

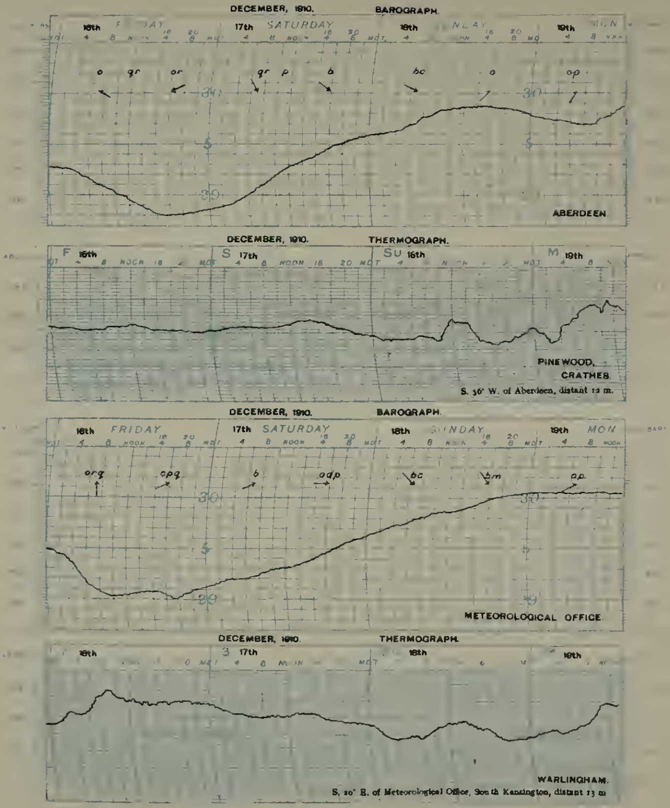
Such a sequence of pressure wind, and weather changes is characteristic of certain types of weather conditions over the British Islands and their neighbourhood, and may be repeated during many days, even weeks ; one depresson, with its accompanying ridge of relatively high pressure, following another in regular succession.

To face p. 88. PLATE XIII.



Synchronous Barograms and Thermograms showing changes in Barometric pressure and Air temperature at places situated on the north and on the south sides respectively of a cyclonic depression during the passage over those stations of the central area of low pressure. To the former have been added symbols denoting changes in wind force and direction, and in weather

Wy. & S., M.O. Press, S.W. 7. Ps. 1181. 15940. 44. 6000. 2/18.



Synchronous Barograms and Thermograms showing changes in Barometric pressure and Air temperature at places situated on the north and on the south sides respectively of a cyclonic depression during the passage over those stations of the central area of low pressure. To the former have been added symbols denoting changes in wind force and direction, and in weather

Wy. & S., M.O. Press, S.W. 7. Ps. 1181. 15940. 44. 6000. 2/18.

The depressions usually follow about the same path; in this instance, however, the anticyclone over the Bay, which has been referred to, spread slowly northward, with the result that the path of the advancing depression was deflected more towards the east. Thus a westerly type of weather conditions replaced the south-westerly type which had previously obtained.

As a rule, while our islands are still under the influence of the ridge of relatively high pressure, the weather being fine, cirrus clouds make their appearance in what may be an otherwise cloudless or almost cloudless sky; and the relative humidity of the air becomes abnormally high soon afterwards. The excess of moisture in the air may at once be detected by readings of the wet and dry-bulb thermometers, and should be recorded in the "weather" column of a climatological register by the letter "e," which indicates wet without rain. This wetness of the air frequently gives warning of the approach of a low pressure area before the wind has backed or the barometer has commenced to fall. The fact is of considerable importance in foretelling weather by means of observations obtainable at an observer's station only.

Had the cyclonic depression been slowly followed by a more extensive area of high pressure, or anticyclone, instead of a ridge of high pressure, the centre of which had taken the same path as that taken by the centre of the cyclone, the direction of the wind would have changed more slowly, and these changes would have been contrary to the movement of watch hands on the northern side of this path, *i.e.*, from north-east towards north, north-west, west, and south-west as the anticyclone slowly moved across the United Kindom; but with watch hands on the southern side of the path, *i.e.*, from north-west towards north, north-east, east, and south-east. During the passage of the central area of highest barometer readings, however, there may have been no wind, and only gentle to light winds or light airs would be experienced in the neighbourhood of the central area. The air in an anticyclone is characterised by its dryness. In summer the weather is generally quiet and warm in the daytime, the sky clear, inland, but is sometimes misty in the early morning. On the coast mist or fog commonly occurs and may continue during a considerable part of the day.

Temperature in Anticyclones.

In the colder months of the year thick weather is frequently associated on land with anticyclonic conditions, and the atmosphere is thickest where pressure is highest and most uniform, and where there is consequently little or no breeze to dispel the fog or mist. It diminishes in intensity as the distance from the area of highest pressure increases, where the pressure gradient becomes steeper, and the air current stronger.

The occurrence, on some occasions, of spells of cold weather in these islands, when barometrical pressure is high, has led to the assumption that winter anticyclones are generally attended by abnormally low temperatures. This supposition has been shown by an eminent meteorologist, Mr. W. H. Dines, F.R.S., to be erroneous, so far as it may be considered to apply to the anticyclonic conditions that are germane to the British Islands.

Mr. Dines found, by examining the Greenwich records, that during the 50 years 1841–1890, 74 periods of frost were shown*. During 20 of these periods, which between them represented 216 days of frost, the mean barometric pressure was below 1009 mb. (29·80 inches); and during 13 of the periods, representing 93 days of frost, barometric pressure was above 1023 mb. (30·20 inches).

Mr. Dines also found that nearly every frost in the fifty years' period, of marked severity or length, occurred during the low-pressure series, and that the mean temperature on all those days on which the barometer was above 1023 mb. (30·20 inches) is close to the mean temperature of winter (276·5a, 38·3° Fahr.). He noticed, moreover, that the percentage of frosty days, that is to say, days on which the mean temperature for the day was below 273a (32° Fahr.), which was 15, is also the percentage of frosty days for the whole 150 winter months included in the period.

Mr. Dines sums up by saying :—

> The figures at Greenwich show that severe cold in the south-east of England is most likely to occur with the barometer below its average value, and that on days when the barometer is very high the temperature is close to its mean value.

He considers the direction of the wind to be the dominant factor, because in Europe during winter an east wind brings cold and a west wind warmth; so that the northern segment of an anticyclone and the southern segment of a cyclone are warmed by west winds, while the southern segment of an anticyclone and the northern segment of a cyclone are chilled by east winds.

Nevertheless, the clear skies and light breezes or calms, which frequently accompany summer anticyclones, and

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* Symon's Meteorological Magazine, March and May, 1911.

conduce to excessive solar radiation, occasioning high day temperatures, are not confined to that season. When such conditions obtain during the colder months they favour the causation of excessive terrestrial radiation at night, and occasion corresponding low temperatures, the effect of which remains, to some extent, throughout the day.

The foregoing information relating to the sequence of wind and weather changes pertaining to different parts of an area over which a cyclonic depression passes, although it refers to one type of weather conditions only, may enable the reader to realise the changes that would take place during the passage of disturbances associated with other characteristic types of weather conditions in the various localities that come under their influence. An acquaintance, therefore, with the more marked types, which will be described in the next chapter, should aid an observer, dependent upon observations taken solely in his own locality, in anticipating from time to time changes of wind and weather for many hours in advance, not only in his own locality, but also in other parts of the area over which he anticipates a disturbance will travel.

Cirriform Cloud Motion and Weather Changes.

In order to assist him in foreseeing these changes an observer should be on the watch for the appearance of cirrus clouds, noting their bearing and the direction of their movement. He may thus gain early information in regard to the approach of a depression and its movements, in the manner described in Chapter IV. which subsequent observations of wind should, as a rule, confirm.

It must, however, be borne in mind that depressions do not always follow the path they appear to be taking; that instead of passing, for instance, north of the observer a depression may pass south of his locality, and the sequence of wind and weather will thus differ from that which he anticipated.

His anticipations may prove incorrect from other causes also: the progress of a depression may be arrested; the depression may travel faster or slower than it was expected to move; it may become shallower, that is to say, barometrical pressure within the area of disturbance may become more evenly distributed; and it may become so evenly distributed as to lose its energy, in other words, it may "fill up."

After the central "Low" of a depression has passed over the locality of an observer, situated to the south of its path, while the barometer is rising, the wind veering and moderating, the weather at the same time improving, it frequently happens that the wind rather suddenly backs, the rise of the barometer is checked, and the mercury commences to fall. The sky then becomes overcast and soon afterwards there is a temporary increase of wind and fall of rain or snow.

Such changes occur when the primary depression is followed by a secondary disturbance, the characteristics of which have already been described.

In certain types of weather conditions depressions follow one another in somewhat quick succession, and when the normal sequence of events is not interrupted by the interference of secondaries between the retreating and advancing primary low-pressure systems, the continued rise of the barometer, while the wind veers and moderates, is before long accompanied, as a rule, by a brief spell of quiet weather.

Then, as the new depression advances, cirrus clouds appear, and when our western shores come under its influence the incursion is heralded by backing wind and diminishing pressure; while the cirrus deepens into cirro-stratus, heavy clouds gather, and soon afterwards precipitation sets in and the breeze freshens.

At all seasons of the year, when a cyclonic depression passes over these islands it brings cloudiness, followed by either rain or snow in places where the wind comes from directions between south-east and north-east round by west; and when precipitation sets in with an easterly or north-easterly wind the fall is generally prolonged.

In winter the passage of a depression over our islands is accompanied by a rise in temperature, caused by the introduction of warmth by the equatorial wind blowing in front of its centre; but in summer, by reason of the cloudiness and consequent obstruction of sunshine with which it is attended, it frequently produces a fall in temperature.

Cyclonic depressions usually travel at a comparatively rapid rate over our islands, and come, as a rule, from south-westward or westward, rarely from eastward.

The force of the wind associated with any area of relatively low pressure depends, not upon the degree to which atmospheric pressure is reduced therein, but upon the pressure gradient or difference in pressure between various points within an area of disturbance and its neighbourhood; in other words, it depends, not upon the height of the barometer in any place, but upon the difference between that height and the height subsisting over a neighbouring place, the force of the wind being greater as that difference is greater.

Cyclonic depressions usually move over our islands comparatively rapidly ; anticyclones *move* much more slowly, and not infrequently are stationary, or nearly so, for days.

When changes in barometrical pressure are slow quiet weather may be expected. Even when the mercury stands low in any locality winds may be moderate or light and the weather dry in the locality. A low barometer, however, is an indication of atmospheric instability, and violent winds may at any time arise caused by increase in barometrical pressure beyond the area of low barometer. A slow fall in barometrical pressure is usually followed or accompanied by increased humidity and with rain, not necessarily with much increase of wind. Sudden changes in pressure, whether shown by a sudden rise of the barometer when it stands low, or by a sudden fall when it stands high, indicate a disturbed state of the atmosphere, and are invariably followed by increase of wind.

It has been stated in the earlier part of this chapter that when a deep depression is followed by an area of considerably higher pressure than that which preceded it, the velocity of the wind is greater in the rear of the trough of the depression than it was in front of it, because of the steeper pressure gradients thus produced in the rear.

The sequence of weather conditions accompanying the passage eastward of a cyclonic depression that visited our islands on the 29th and 30th September, 1911, may be cited as an appropriate case in point.

At 6 p.m. on the 29th a high-pressure system occupied the eastern portion of the North Atlantic ; pressure being highest, 1033 mb. (30·5 ins.), immediately to the west of the Bay of Biscay ; lowest, 982 mb. (29 ins.), over Scandinavia. A shallow depression which during the day had advanced from the Atlantic was situated to north-westward of our north-western shores. In the course of the night this depression deepened, and moved rapidly eastward across Ireland and England, and at 7 a.m. on the 30th was centred near Spurn Head, with the barometer at about 999 mb. (29½ ins.), and pressure increasing rapidly in its rear. The winds, showing a complete cyclonic circulation about this centre, blew strongly to a gale in places, and at 6 p m. (Plate XIV), while the centre lay over the Netherlands, a steep gradient prevailed over the North Sea, the east of England, and all neighbouring parts of the Continent. Winds from northward, on the eastern and south-eastern coasts of England and the adjoining sea, as well as in Holland and in the north of Germany, blew strongly to a gale, causing a rough to high sea in the Strait of Dover and North Sea. During the evening the velocity of the wind attained to that of a whole gale at Dover, Yarmouth, and Spurn Head, and to that of a fresh to strong gale at Dungeness and Flushing, while temperature fell in most parts of our islands.

Subsequently the cyclone passed across Germany and away to the eastward, and the United Kingdom came under the influence of a large anticyclone, which extended westward over the North Atlantic to the 30th meridian.

In connexion with the occurrence of this severe autumn gale on the East Coast, it should be mentioned that the fall of temperature and increase of pressure taking place over Continental Europe and Asia during this season, while the sea to the westward still retains its warmth, are intimately connected with the unsettled weather conditions which characterise the season. During the month of October, or in the latter part of September, a severe gale is almost invariably experienced over the British Islands. Depressions at this time, which, while moving to the eastward over the ocean, are shallow and possess little energy, often deepen during their passage across the land, and frequently develop steep gradients, which may occasion gales, before they pass away to the Continent across the North Sea.

Weather Signs.

In the Fishery Barometer Manual, compiled under the direction of the Meteorological Council by the late Dr. R. H. Scott, M.A., F.R.S., formerly Secretary of the Meteorological Council, the author includes a number of general weather signs which are from Admiral Fitz Roy's Barometer Manual, greatly abridged. These are as follow :—

Light, delicate, quiet tints or colours, with soft, indefinite forms of clouds, indicate and accompany fine weather; but gaudy or unusual hues, with hard, definitely outlined clouds, foretell rain, and probably strong wind.

Small inky-looking clouds foretell rain; light scud (*fracto nimbus*) driving across heavy masses indicate wind and rain; but if alone, may indicate wind only, proportionate to their motion.

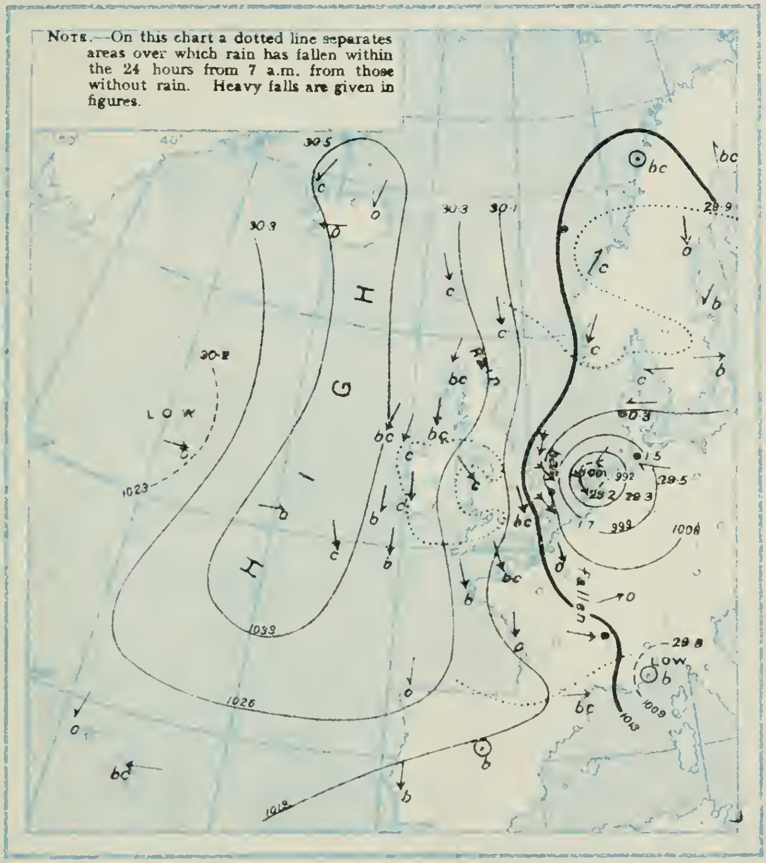
After fine clear weather, the first signs in the sky of a coming change are usually light streaks, curls, wisps (*cirrus*), or mottled patches of white distant cloud (*cirro-stratus*), which increase, and are followed by an overcasting of murky vapour that grows into cloudiness. This appearance, more or less oily or watery, as wind or rain will prevail, is an infallible sign.

Usually the higher and more distant such clouds seem to be, the more gradual, but general, the coming change of weather will prove.

Misty clouds forming, or hanging on heights, show that wind and rain are coming if they remain, increase or descend. If they rise or disperse, the weather will improve or become fine.

PLATE XIV.

BAROMETER, WIND AND WEATHER for 6 p.m., 30th SEPTEMBER, 1911.



NOTE.—On this chart a dotted line separates areas over which rain has fallen within the 24 hours from 7 a.m. from those without rain. Heavy falls are given in figures.

Direction and force of Wind

Calm ⊙, 1-3 —→, 4-7 ——→, 8-10 → → Above 10 → →.

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Dew is an indication of coming fine weather. Its formation never begins under an overcast sky, or when there is much wind.

Remarkable clearness of the atmosphere, especially near the horizon ; distant objects, such as hills, unusually visible or well defined or raised by refraction, and what is called a good hearing day, may be mentioned among signs of wet, if not wind, to be expected in a short time. When smoke from chimneys does not ascend readily, straight upwards, during calm, unfavourable change is probable.

Near land, in sheltered harbours, in valleys or over low ground, there is usually a marked diminution of wind and a dispersion of clouds during the early part of the night.

During bright weather and westerly (north-west to south-west) airs or light winds, the appearance of very high clouds of the Mare's Tail type (*cirrus*) moving from north-westward is usually an indication of the backing of the wind to the southward, and its increase in force, probably to a fresh or strong gale.* This movement of the very high clouds under such conditions is a very decided indication of bad weather, if at the same time a batch of such clouds be rising in the west, and the barometer, after rising, is inclined to fall. Again, when the wind is westerly or north-westerly of moderate strength, if high, hair-like or thready (*cirrus*) clouds appear moving from north or north-north-east they very commonly portend a great increase of wind from north-westward, with snow, sleet, or soft hail in winter.*

If the wind be easterly, and high clouds appear, similar to those just mentioned, but moving steadily from south-south-west, they point to an increase in the force of the easterly wind,† and during sultry summer weather, to the early approach of thunderstorms, followed probably by a shift of wind to the south-westward.

In all these cases, however, the direction of the wind at the surface must be noted, and it may be added that the value of the sign is increased when it occurs after a spell of exceptionally bright weather, and a sudden rise of the barometer.

Recurrence of Warm and Cold Periods.

In the year 1867 the late Dr. Alexander Buchan, M.A., F.R.S., then Meteorological Secretary to the Scottish Meteorological Society, contributed three papers to that Society upon "Interruptions in the regular Rise and Fall of Temperature in the Course of the Year."‡

In these papers Dr. Buchan drew attention to the recurrence yearly, at the same seasons, of certain periods, more or less well defined, in which temperature, instead of rising in accordance with the regular march of the season, remains steady or retrogrades ; and instead of falling in agreement

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* Also that the path of the disturbance causing the gale lies to the north of the observer's station.

† In the northern segment of the disturbance or in front of its centre.

‡ Journal of the Scottish Meteorological Society, New Series, pp. 4, 41, 107.

with the seasonal diminution of temperature ceases to fall or rises.

From observations taken at a few well-selected stations in Scotland during the years 1857–66 inclusive, he found that the regular rise and fall in air temperature during each of them had been interrupted six times from an excess of cold and three times from an excess of heat. The cold periods were :—

6th to 11th February ;
11th to 14th April ;
9th to 14th May ;
29th June to 4th July ;
6th to 11th August ;
6th to 10th November.

The warm periods :—

12th to 15th July ;
12th to 15th August ;
3rd to 14th December (St Martin's Summer).

Experience has shown that these abnormally cold and warm periods are not confined to Scotland, but are common to the British Islands generally ; also, to some extent, to North Western Europe.

To these periodical departures from normal weather conditions may be added : a cold spell associated with easterly winds in March ; a warm period at the close of September, synchronising with the *Indian Summer* of Eastern Canada ; disturbed weather at the commencement or in the middle of October, during which a severe gale is usually experienced ; followed by another warm period, known as *St. Luke's Summer*.

The above-mentioned interruptions in the seasonal rise and fall in temperature do not invariably take place ; and, when they do, may not occur exactly between the dates specified, which are based on average results ; but they may be looked for with considerable confidence, for they generally arrive.

From an examination of the records collated in connexion with the investigation Dr. Buchan came to the conclusion that the interruptions in the regular rise and fall in temperature which occur in the months of July and August are determined, and regulated by the direction of the wind ; that the warm periods in those months are associated with winds from south-south-east and east, which are our warmest winds in summer ; and that the prevailing winds during the cold period in August are from between north-north-west and south-west, the coldest winds in that season. He attributed the cold periods in May and November to deficiency in solar heat, and remarked upon the dry, cold, foggy weather, and easterly winds that usually follow the spell of cold in the latter month.

From comparatively recent information in regard to ocean circulation and surface temperature, it now appears probable that the cold periods of April and May are connected, as they are associated with the annual failure of the Gulf Stream Extension to reach our shores in the spring, and the temporary increase in the activity and volume of the Greenland current in the months referred to. Above a zone of cold water extending from the far north southward to the west of Scotland and Ireland a ridge of relatively high barometrical pressure is thus formed, and the air supply to our island is in consequence drawn from polar regions.

The author is of opinion that the relatively high pressure over the Icelandic region which gives rise to the easterly winds that are prevalent in March and November is due in the former month to the seasonal rise in temperature over Europe taking place in the spring, while the accumulation of ice in the Denmark Strait keeps the temperature low, and pressure consequently relatively high in that neighbourhood. Similarly in the latter month to the comparative mildness of the weather in Europe, no decided decline in temperature having occurred, while a rapid decrease in temperature, associated with a relatively high pressure, has been caused by the formation of ice in Denmark Strait ; around Iceland ; and along the south-east coast of Greenland.

The mild weather in the earlier half of December was shown by Dr. Buchan to coincide with a predominance of winds from an equatorial quarter, by far the largest percentage of which are from south, and there being an almost total absence of winds from northward. He arrived at the opinion that the great annual fall in temperature does not take place until near Christmas.

As regards the cold period in February, it may perhaps be attributable as much to deficiency in solar heat as to the easterly winds that are frequent in that month ; and, although the direction of the wind during the cold and warm periods of July, August, and December doubtless accentuates the interruption in the regular rise or fall in temperature in those months, it cannot be considered wholly to account for these recurrences ; for it is noticeable that when the cold periods recur the air current is not always from a polar quarter ; nor is it invariably from an equatorial quarter when the warm periods recur.

It has been suggested that all periodic interruptions in the seasonal march of temperature are partially due to periodic variations in solar heat, the cause of which research in solar physics has yet to discover.

As an aid to weather forecasting generally, and more especially to the presaging of changes by means of observations restricted to a single station, the knowledge that annually, on more or less definable dates, departures from the normal sequence of weather conditions that are germane to the several seasons may be expected to recur will be found of no small assistance to the forecaster on the watch for any signs of coming changes.

CHAPTER VIII.

Types of Weather Conditions.

The weather conditions of these islands, and largely of North-Western Europe, frequently maintain, during periods of varying duration, a similarity as regards their general characteristics. Sometimes for weeks together certain well-defined types of weather prevail, the general distribution of atmospheric pressure remaining, for the most part the same; the wind backing and veering some points, under the influence of depressions which come chiefly from the Atlantic Ocean.

These depressions, which usually approach our shores from the westward or south-westward, cause an increase of wind force, and not infrequenily a gale in some part or parts of our coasts.

The sequence of wind and weather changes in these islands, associated with the passage of depressions, depends upon the paths they follow in concordance with the distributions of pressure over North Western Europe and the adjacent seas.

An acquaintance with the salient features of the most characteristic of these types, added to the knowledge of their more than occasional persistence when established, will materially aid an observer in anticipating weather changes.

Of the several types of weather conditions to which reference will be made, the south-westerly type is the commonest.

South-Westerly Type.

When this type obtains barometrical pressure is relatively high over the Spanish Peninsula, and the Bay of Biscay, as well as to the south-east of England ; and relatively low over the north-eastern arm of the North Atlantic, including the Icelandic region.

The centre of cyclonic depressions advancing from the westward or south-westward usually skirt the high-pressure area and pass away in a north-easterly direction.

On the approach of a depression the wind from a south-westerly direction on our western shores backs somewhat and increases in force ; pressure diminishes, temperature rises, and a drizzling rain sets in, which is followed by a heavier fall.

When the line of lowest barometer readings, or *trough* of the depression, has passed the locality of the observer, pressure increases ; the wind veers to south-westward, and perhaps more westerly later ; the temperature falls, the rain becomes intermittent, and soon afterwards ceases, the sky clears, and the wind moderates.

If the recovery of pressure, or, in other words, the rise of the barometer, in rear of the trough be rapid and considerable, the wind will increase, probably to gale force on some parts of the coast, after the shift of wind to a more westerly point ; and this crisis may be attended by a heavy shower ; the wind will not moderate in that case until the rise of pressure is checked.

After a short interval of fair weather, the wind may be expected again to back in consequence of the approach of a new disturbance, and a similar sequence of weather to follow.

Fig. 1, Plate XV, copied from the Daily Weather Report of 25th January, 1903, affords a good instance of the severe weather that may attend the passage of a cyclonic depression while the south-westerly type prevails.

Between 12th and 24th January, 1903, an area of high barometrical pressure situated over Europe barred the passage eastward, in the immediate vicinity of our islands, of disturbances coming from the Atlantic. A depression had on the 16th encroached sufficiently on our western shores to occasion a shift of wind from east to south-east, and the break up of a week's frost ; but this "low," repelled by the anticyclone, returned to the Atlantic or filled up. It was not until the approach of successive depressions had caused a considerable diminution in atmospheric pressure over our islands, and the area of high pressure had spread southward and westward, that a complete change took place in the type of weather, which lasted well on into February.

On the morning of the 24th January, a cyclonic system was centred off the Shetlands, causing strong winds to a gale on the northern and western coasts. At 8 a.m. next day, (*see* Fig.) this system had passed north-eastward, and a deeper disturbance had advanced from south-westward, to a position off the Hebrides. Over the north and west of Scandinavia, the northern part of the North Sea, and the major portion of the British Isles, gradients were very steep, and southerly or south-westerly gales or strong winds prevailed, attaining to storm force on the west coast of Ireland. Along the North Atlantic seaboard a rough to very high sea was experienced.

Southerly Type.

This type closely resembles the south-westerly, from which it often changes, and into which, it frequently merges.

When the southerly type is established, barometrical pressure is relatively high over that portion of Europe which lies to the east and south-east of the United Kingdom, and relatively low over the North-Eastern Atlantic.

Cyclonic depressions advancing from the Atlantic are usually held up by the high pressure, and pass away in a northerly or north-north-easterly direction.

On the approach of a depression, the wind, from a south-westerly or southerly quarter, backs and freshens; pressure diminishes, temperature rises, and rain commences to fall. After the passage of the trough over the observer's locality, pressure increases, temperature falls, the wind moderates, and the weather clears.

The Weather Chart for 8 a.m., 16th January, 1903 (Fig. 2, Plate XV), copied from the Daily Weather Report, for that day, serves as a good illustration of disturbed weather occasioned by the incursion of a cyclonic depression during conditions characteristic of the Southerly type.

At 8 a.m. on the 15th a large anticyclone was shown over North Western Europe, its centre situated over the southern parts of Norway and Sweden, where the barometer stood at 1043 mb. (30·8 inches). Pressure had commenced to give way over the United Kingdom, and over France where the wind was from southward and south-eastward, in harmony with anticyclonic circulation.

During the night the centre of the anticyclone moved slightly northward, and at the same time a deep cyclonic depression, from the Atlantic, spread over our more northern and western districts, greatly increasing the pressure

To face p. 100.

PLATE XV.

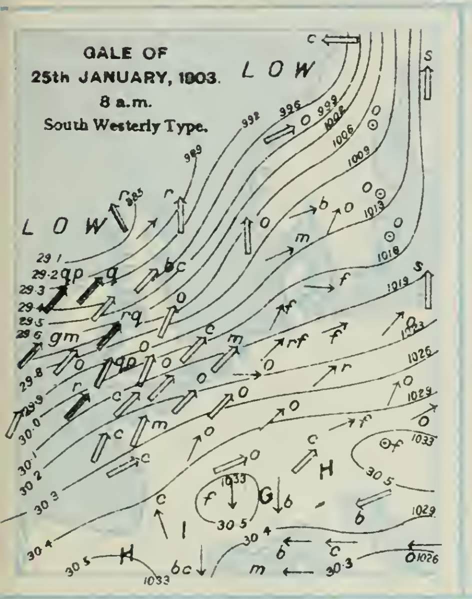

FIG. 1

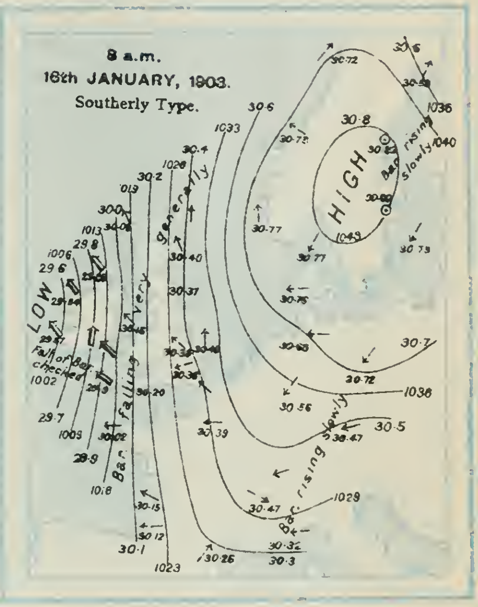

FIG. 2

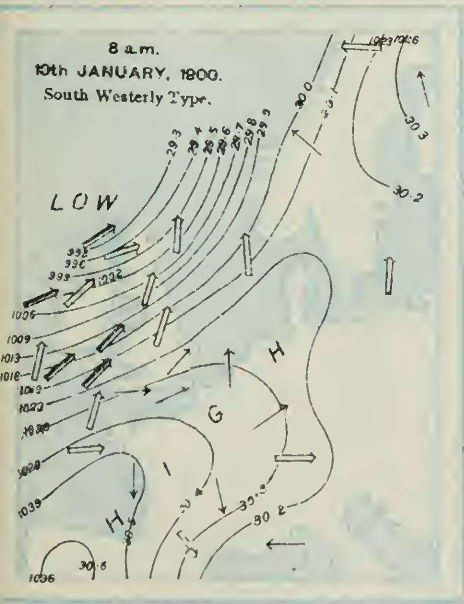

FIG. 3

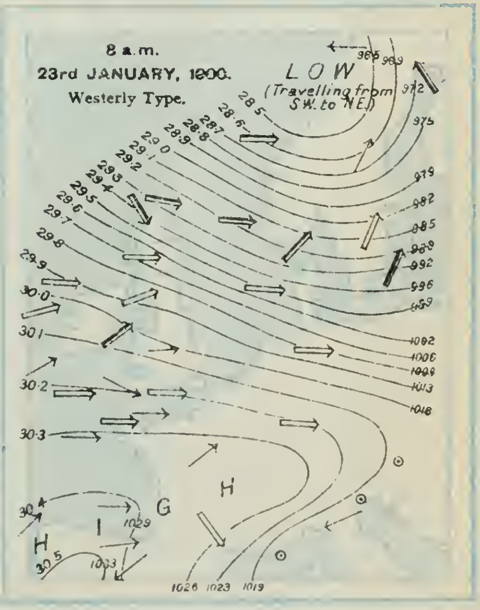

FIG. 4

Direction and force of Wind

⊙ ⟶ ⟶ ⇒ ⇒ ➡ •

Calm, 1–3, 4–6, 7 & 8, 9 & 10, 11 & 12, Squalls.

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gradient over, and in the neighbourhood of our Islands, where the wind, in consequence, steadily increased in force.

At 8 a.m. on the 16th (*see* Fig.) the wind, from between south and south-east over Ireland, Scotland, and the West of England, had increased greatly in force, and blew a fresh to whole gale in many places. Over our eastern and south-eastern districts it did not rise above a fresh breeze, and was even light in places, its direction mainly south-easterly, but in France the wind came from eastward. The sky had become overcast in the north-east of Scotland, and in most parts of Ireland; rain was falling at Valencia, but in most other parts of our area the sky was clear. The sea, rough or rather rough off the greater portion of our coasts, ran high to very high to the west of Scotland, and to the north and north-west of Ireland.

Barred by the extensive area of high pressure referred to, the depression appeared, on the day following, to have broken into two parts, and to have moved subsequently, one in a south-easterly direction, the other north-eastward; both, at the same time, becoming less deep.

No material change appears to have taken place in the general distribution of atmospheric pressure over North Western Europe during the next five days, and the weather conditions of our western and northern districts continued to be affected by the incursions of depressions moving northward or north-eastward. On the 23rd January pressure had increased over the Bay of Biscay and the Spanish Peninsula, and diminished over Scandinavia and the northern portion of the North Sea. Thus the southerly type of weather conditions merged into the south-westerly type.

Westerly Type.

During the prevalence of the Westerly type an area of high pressure, an extension northward of that which is situated at all times between the 20th and 42nd parallels of north latitude and is known as the North Atlantic anticyclone, is constantly to the southward of our islands, while pressure to the east, the west, and most markedly to the north, remains comparatively low. Depressions traversing the North Atlantic from west to east pass north of this high pressure, and thus, by producing a steeper pressure gradient, cause an increase of wind from a westerly direction attended by precipitation.

This type sometimes alternates with the south-westerly, into which it develops when pressure diminishes over France and the Bay of Biscay, and increases to the east and south-east of the United Kingdom. If, on the contrary, pressure diminishes to the east and south-east, and the "high" over the Bay of Biscay expands northward, this type merges into the North-westerly and Northerly types. On the approach of a disturbance while the Westerly type obtains, the wind backs, and soon afterwards the barometer commences to fall; temperature rises, and subsequently rain sets in; but after the trough of the depression has passed the observer's locality the rain becomes intermittent, and the weather squally, with bright intervals. The wind will by that time have veered to the north of west; temperature will have fallen, rather decidedly; and the barometer will be rising.

Occasionally the low pressure area to the north of our islands spreads southward towards the North Atlantic anticyclone, thus producing steep pressure gradients, with the result that strong westerly winds and gales are experienced, with very little change in the direction of the wind.

The distributions of barometrical pressure, and wind characteristic of this type of weather conditions, are well illustrated in Fig. 4, Plate XV, which is copied from the Daily Weather Report for 8 a.m. on the 23rd January, 1900. Fig. 3 exhibits for the same area the distributions of barometrical pressure and wind obtaining during the South-westerly type which preceded the Westerly.

North-Westerly Type.

The North-westerly type, alternating with the Westerly, is frequently experienced during the month of December, but may prevail in any other month. During its continuance, barometrical pressure is high over the Bay of Biscay and South Western Europe, while disturbances coming from the North Atlantic appear to the northward of our islands, and, crossing Scandinavia, take a south-easterly course across the Continent.

The Chart for 8 a.m., 7th December, 1895 (Fig. 1, Plate XVI.), reproduced from the Daily Weather Report for that date, is selected to illustrate this type.

It will be seen that the barometer was highest over the western and central parts of the Spanish Peninsula, while a cyclone covered Scandinavia, its centre of lowest barometer readings lying over the south of Sweden. Pressure gradients were steep over the North Sea, Denmark, Germany, and the Baltic, and gales from north-westward were experienced over Western Europe generally.

PLATE XVI.

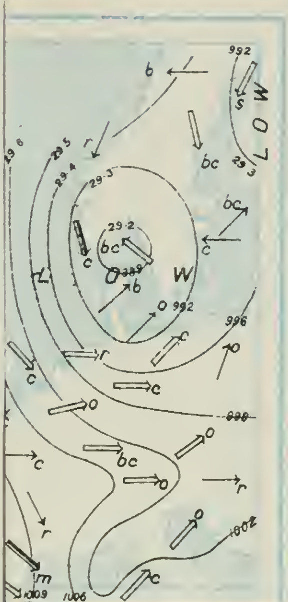
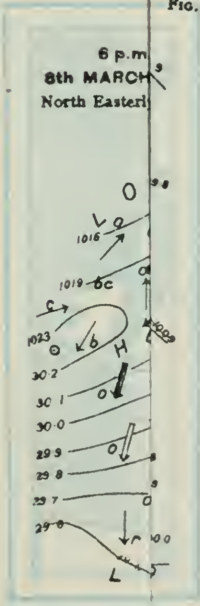


FIG. 2


6 p.m
8th MARCH
North Easterl

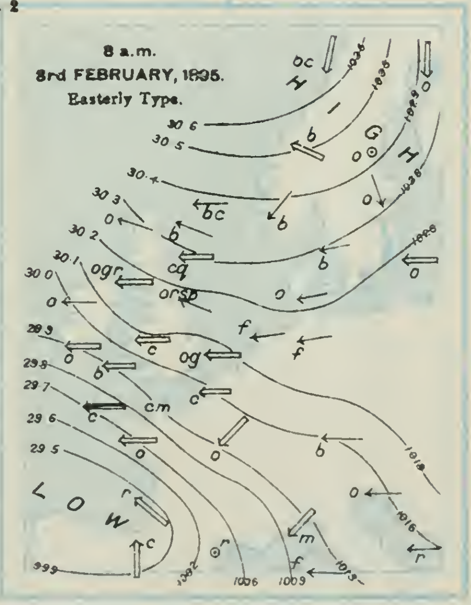

8 a.m.
3rd FEBRUARY, 1895.
Easterly Type.

FIG. 5

Is.

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To face p. 102.

PLATE XVI.

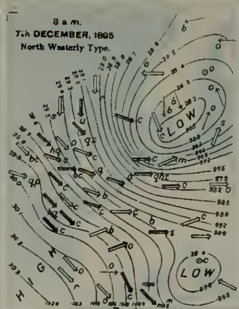
8 a.m.
7th DECEMBER, 1895
North Westerly Type.

Fig. 1

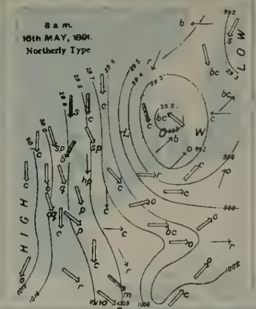
8 a.m.
18th MAY, 1891.
Northerly Type

Fig. 2

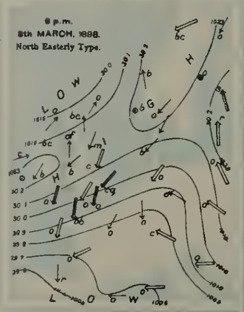
6 p.m.
8th MARCH, 1898.
North Easterly Type.

Fig. 3

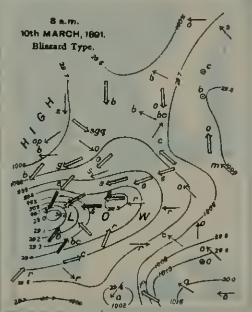
8 a.m.
10th MARCH, 1891.
Blizzard Type.

Fig. 4

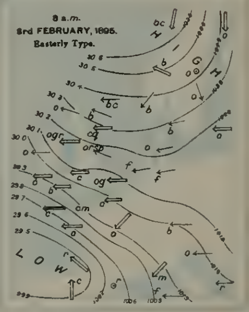
8 a.m.
3rd FEBRUARY, 1895.
Easterly Type.

Fig. 5

Direction and force of Wind

⊙ ⟶ ⟶ ⟹ ⟹ ➡ ↓
Calm, 1–3, 4–6, 7 & 8, 9 & 10, 11 & 12, Squalls.

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Subsequently the anticyclone having moved eastward, the paths of depressions crossing Europe became more northerly, and the type merged into the Westerly. These types ruled from the 30th November to the 16th December, 1895.

Northerly Type.

When barometrical pressure becomes relatively high to the westward of the British Islands and relatively low to the eastward, the wind over our area and its neighbourhood is drawn from northward, and a Northerly type of weather conditions results.

Fig. 2, Plate XVI, from the Daily Weather Report for 8 a.m., 16th May, 1891, affords an excellent illustration of this type, which during the first or second week in May, or even later, is generally experienced, and is the cause of decidedly low temperature while it lasts.

On the day to which the chart refers an extensive anticyclone over the North Eastern Atlantic, united with another area of high barometrical pressure covering Greenland. To the westward of the British Islands, and stretching across the face of the Bay of Biscay, the isobar of 1019 mb. (30·1 ins.) is shown to lie almost north and south, and the supply of air to Europe consequently was drawn from Greenland and the Greenland Sea, northerly winds prevailing. An area of low barometrical pressure, having two centres of minima barometer readings, lying north-east and south-west of each other, situated respectively over Lapland and over the southern part of Scandinavia, occasioned gales and very inclement weather over, and in the vicinity of, our islands and the North Sea.

The conditions commenced on the morning of the 13th May and lasted until the morning of the 19th.

The maximum temperature in London on Whit Monday, 18th May, was as low as 278·6a (42° Fahr.), whereas on the 12th and 13th it stood at 298·6a (78° Fahr.).

North-Easterly Type.

The characteristics of the North-easterly type, which frequently is the prevailing type in the month of March, are demonstrated in the Weather Chart for 6 p.m., 8th March, 1898, from which Fig. 3, Plate XVI, is drafted.

Areas of high barometer readings are shown over the United Kingdom and Scandinavia, while the barometer is relatively low over Portugal, Spain, and the western half of the Mediterranean.

The distribution of pressure associated with this type may continue for many days; in the instance here cited it lasted from the morning of the 7th March to the evening of the 12th, during which time depressions entering the Mediterranean from the Atlantic by crossing over the Spanish Peninsula, produced steep gradients in the vicinity of our shores, with the result that strong winds and disturbed weather were experienced.

In rare cases, when the high pressure over Great Britain is less pronounced, these depressions take a more northerly course, and pass up the English Channel, causing in winter heavy falls of snow in our islands. Similar conditions caused a fierce blizzard from the 9th to the 11th March, 1891. (Fig. 4, Plate XVI.)

Reverting to the foregoing remarks relative to the conditions which dominated the weather from the 7th to the 12th March, 1898, inclusive, it may be mentioned in supplement that for some time prior to the 7th the area of high barometer was situated over, and to the westward of, the United Kingdom, and extended southward across the Bay of Biscay, but pressure over Scandinavia and Central Europe was relatively low, and the Northerly type, therefore, prevailed during that period.

After the 12th March, barometrical pressure over Scandinavia was again relatively low, but to the south of the British Islands it had increased, the area of high pressure extending over the Peninsula, and to the Mediterranean; thus the type merged into the Westerly, which predominated for many days.

Easterly Type.

The commonest form of the Easterly type, and one that often prevails in the month of February, is illustrated in Fig. 5, Plate XVI, from the Daily Weather Report for 8 a.m., 3rd February, 1895.

The salient features in the distribution of atmospheric pressure associated with this type are as follow:—The North Atlantic anticyclone is situated farther south, and is less extensive than usual. Its influence is therefore lessened as regards our weather, which is dominated by an area of high barometer prevailing over Scandinavia, and a relatively low barometer over Central and Southern Europe, the latter having at times a westerly movement. As disturbances advance from the North Atlantic, approach and partially displace the Scandinavian anticyclone, they either fill up or pass away to the south-eastward; thus producing easterly winds, which fluctuate between south-east, with a rise of temperature and foul, rainy weather, and north-east with fairer but colder weather.

This alternation goes on while disturbances continue to arrive near our shores; provided the general relative distribution of barometrical pressure remains the same; and it may retain its characteristics for weeks consecutively. This type is usually preceded by the northerly, or north-easterly, and, with these, especially with the latter, it not infrequently alternates. The accompaniment of rain with east wind, and rising barometer, is a feature of this type.

The easterly type of conditions described in the foregoing is only one out of several modifications of this type. Any decided decline in barometrical pressure that may take place south of the English Channel, while an anticyclone lies over or to the north of the British Islands, will occasion easterly to north-easterly winds of more or less intensity and persistency. For instance, a low pressure system or depression situated over Spain, France, the Bay of Biscay, or the Gulf of Lyons may surge northward and produce steep gradients over the southern portion of England, causing strong winds and gales on our south and south-east coasts, while the centre of the low pressure shows for some time little or no progressive motion; or such a depression, centred over Europe, to the south-east of England, may expand to the westward, giving rise to similar results.

The distribution of pressure and wind shown on the chart of barometer, wind, and weather, at 6 p.m. on the 23rd November, 1911 (Fig. 1, Plate XVII), which is copied from the chart for that time given in the Daily Weather Report of the following day, is typical of the first of these two cases.

On the morning of the 23rd a rather large anticyclone lay immediately to the north, north-east, and north-west of England and Ireland, while a somewhat deep depression was situated over the Bay of Biscay, the north of Spain, and the south-west of France. This low-pressure system deepened, and spread laterally northward, the barometrical gradient between the two systems thus becoming steep. At 6 p.m. a gale from north-eastward prevailed in the English Channel, and by midnight a fresh to strong gale was blowing on our southern and south-eastern coasts. The low-pressure system which had moved over the Bay from the North Atlantic on the 21st remained almost stationary, and on the 24th commenced to fill up. Between the 21st and 24th, strong easterly and north-easterly winds and gales were experienced in the Channel and in various parts of the United Kingdom.

A good instance of the north-easterly to easterly type of conditions resulting from the expansion north-westward of a depression situated over central Europe, when pressure is high to the north-west and north of our islands, is shown in Fig. 2, Plate XVII, which is reproduced from the synoptic chart for 7 a.m., on the 26th March, 1911, in the Daily Weather Report issued for that day.

It will be seen that the central area of a large anticyclone, lying over the north-western arm of the North Atlantic, was situated immediately to the north-west of the British Islands; and that a depression, which covered central Europe, was centred over Venetia. On the previous morning the centre of the high-pressure system had been located between Iceland and the Hebrides. Moving south-eastward, and intensifying during the next twenty-four hours, while the depression referred to spread north-westward, the pressure gradient between the two systems became steep, with the result that the wind, from north-eastward on the south-east coast of England, the adjacent coasts of the Continent, as well as over the extreme southern portion of the North Sea, and in the Strait of Dover, blew strongly, gale and with force at times.

Subsequently the anticyclone spread eastward, and the depression moved in a south-westerly direction; the air current, therefore, veered to the eastward, the pressure gradient became less steep, and the wind moderated.

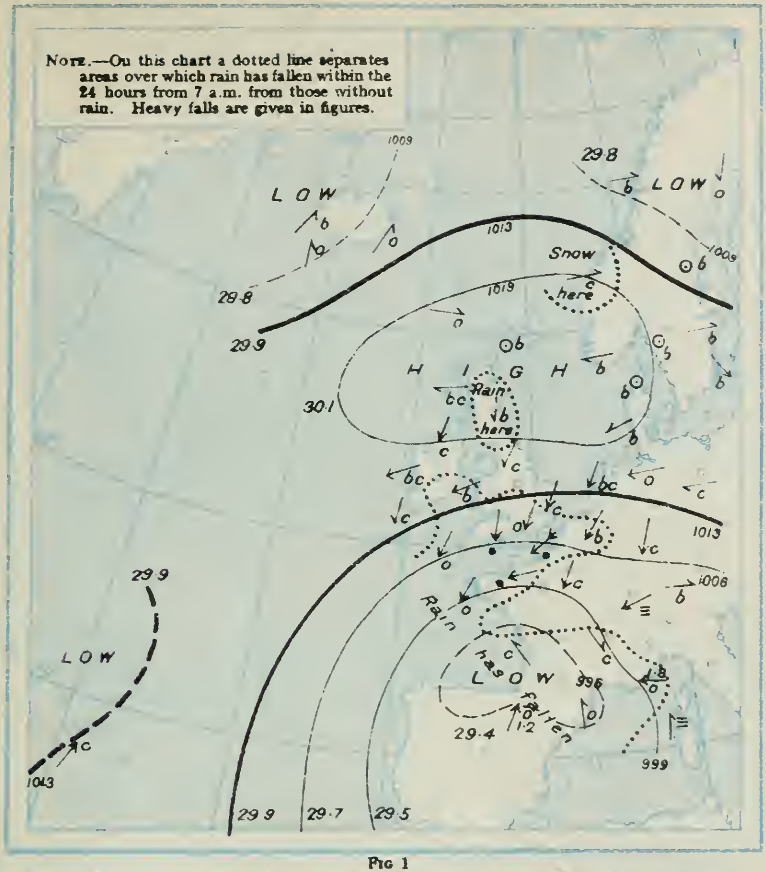
This alternating easterly to north-easterly type of weather commenced on the 16th of March, and continued to the end of the month, when the conditions became northerly.

South-Easterly Type.

In illustration of the distribution of pressure pertaining to the south-easterly type, the chart of pressure and wind published in the Daily Weather Report, for 8 a.m. 6th January, 1897, is reproduced in Fig. 1, Plate XVIII; the state of the weather, in letters of the Beaufort notation, taken from the accompanying chart of temperature and weather, being added.

Pressure was then highest, 1036 mb. (30·6 ins.) and upwards over the Gulf of Bothnia and the northern part of the Baltic; lowest, 982 mb. (29·0 ins.), and less, in a deep depression having its centre off the south-west of Ireland. Gradients were rather steep over all the western parts of our islands; the wind was from south-eastward over western Europe generally, and on our extreme western and northern coasts blew strongly to a gale. This type of weather conditions, which had set in on the 4th January, lasted until the 10th of the month.

BAROMETER, WIND AND WEATHER 6 p.m. 23rd NOVEMBER, 1911.



NOTE.—On this chart a dotted line separates areas over which rain has fallen within the 24 hours from 7 a.m. from those without rain. Heavy falls are given in figures.

Fig 1

BAROMETER, WIND AND WEATHER 7 a.m. 26th MARCH 1911.

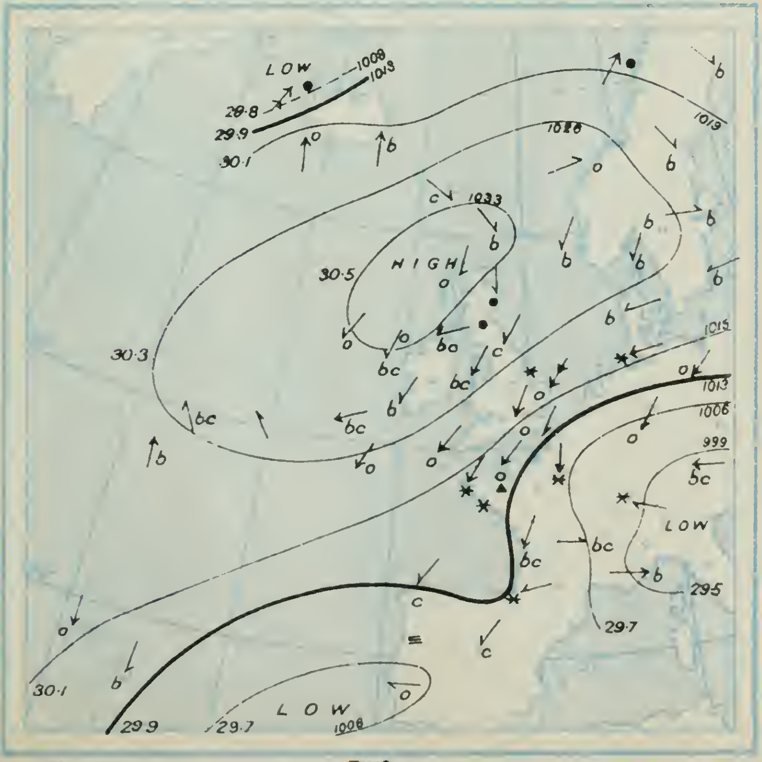


Fig 2

PLATE XVIII.

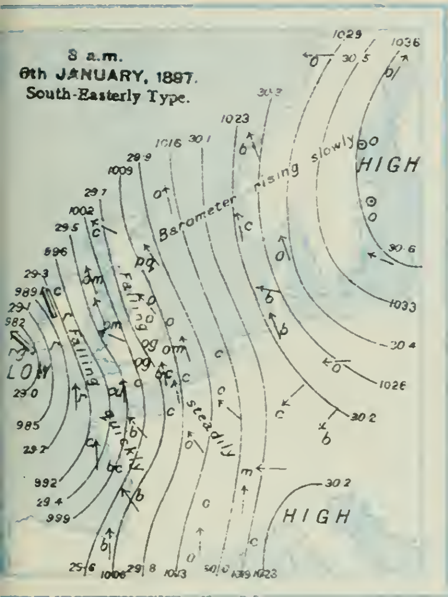


FIG. 1

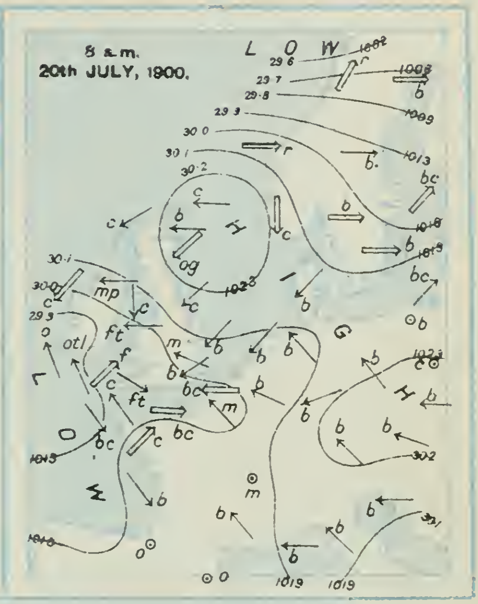


FIG. 2

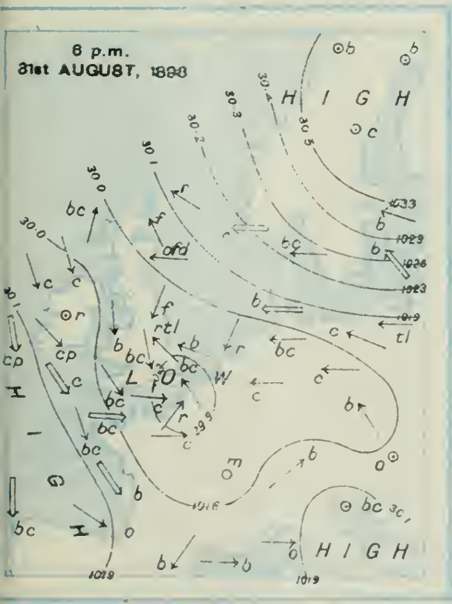


FIG. 3

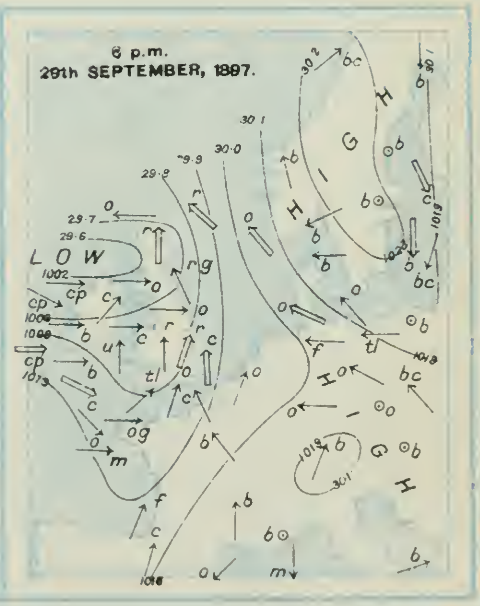


FIG. 4

Direction and force of Wind

⊙ → ⇢ ⇒ ⟹ ➡ •

Calm, 1-3, 4-6, 7 & 8, 9 & 10, 11 & 12, Squalls.

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Typical Thunderstorm.

Thunderstorms that occur over our islands are frequently, but not necessarily, incidental to the transition between two types of weather conditions.

For the purpose of examining the characteristics of their development they can be grouped into three distinct classes: (1) Those coming to us from southward; (2) those forming locally; (3) those appearing as secondaries to depressions in the north. Most thunderstorms are associated with secondary formations, or with the bend or "kink" in an isobar that may be regarded as a modification of such a formation.

Thunderstorm coming from South.

The class of thunderstorm first mentioned is the commonest. To cite an instance: on the 18th July, 1900, the weather over the British Islands and Western Europe may be said to have been under the influence of an extensive area of high barometrical pressure. On the morning of the 19th a shallow depression appeared over the Bay of Biscay. and at 6 p.m. of that day had travelled north, its centre, with the barometer at 1009 mb. (29·8 inches), being situated off the mouth of the English Channel. A "kink" in the isobar of 1013 mb. (29·9 inches) which had spread eastward appeared in the vicinity of Lorient, indicating the probable formation of a secondary. Between this time, 6 p.m. of the 19th and 8 a.m. on the following day, thunderstorms occurred at Roche's Point, Pembroke, Scilly, and in London. Fig. 2, Plate XVIII, adapted from the weather charts in the Daily Weather Report for 8 a.m. on the 20th July, shows the distribution of pressure and wind, with the state of the weather at that time; and the development over the north of France and eastern half of the English Channel of a secondary will be seen to have taken place as anticipated. The primary was then centred south-west of the British Islands.

The isobar of 1013 mb. (29·9 inches) exhibits a bend across the southern entrance of St. George's Channel, and this locality was the scene of heavy thunderstorms on the 20th.

It has been found that when lightning strokes occur most frequently numerous oscillations are shown in the barograph trace, and that heavy rain falls when the barometer rises suddenly ·3, ·7 or even 1·0 mb. (2, 3 and 4 hundredths of an inch respectively). The conflicting currents in the atmosphere during thunderstorms, so noteworthy a feature, is exhibited by the motion of the clouds at varying heights.

Thunderstorms forming Locally.

In illustration of the less common class of thunderstorms which form locally the distribution of barometrical pressure and wind and the state of the weather at 6 p.m., 31st August, 1896, are shown in Fig. 3, Plate XVIII.

On the morning of that day a shallow depression appeared over the south of England and the eastern part of the Channel. The 6 p.m. reports, when charted, showed that the disturbance had moved south-southeast, and was then centred near Cape Gris Nez. To the westward of this "low," round which there was shown to be complete wind circulation, as well as over Europe generally, pressure was relatively high, but unevenly distributed. Between 6 p.m. and midnight, thunderstorms, accompanied in most cases with heavy rain, were experienced over the east of England and the centre of Ireland.

Thunderstorms connected with Northern Depressions.

The synoptic chart of barometer and wind relating to 6 p.m., 29th September, 1897, is reproduced in Fig. 4, with weather added, in letters of the Beaufort notation. It illustrates a disposition of isobaric lines that has been found to be essentially characteristic of the third class of thunderstorms; those which appear as secondaries to depressions in the north.

At 6 p.m. on the 28th September a large anticyclone covered Central and Northern Europe, and an apparently shallow depression was found to be approaching our north-west coasts, which, at 8 a.m., on the following day, had advanced and deepened. At 6 p.m. (Fig. 4, Plate XVIII) this disturbance developed over England and France a "V"-shaped secondary, shown by the isobar of 1013 mb. (29·9 ins.), and during the night severe thunderstorms occurred over the south-eastern and south-midland parts of England, where the rainfall measured in most places exceeded an inch. The system passed away to the eastward, and it is probable that thunderstorms were experienced over the southern portion of the North Sea.

CHAPTER IX.

Gales on the Coasts of the British Islands.

The statistics and illustrations given in this chapter relating to the prevalence of gales on the coasts of the

British Islands are derived with few exceptions, from Mr. F. J. Brodie's contributions to the Royal Meteorological Society upon that subject.*

The results obtained by Mr. Brodie are based upon information collected in the Meteorological Office for the purpose of testing the accuracy of the Storm Warnings issued to stations on our coasts.

Prevalence of Gales.

During the 30 years to which these results refer about 48 gales occurred annually on the coasts of the British Islands, and of these more than 10 were severe or partially severe : that is to say, they attained to a force of at least 10 of the Beaufort Scale ; in other words, to a velocity of at least 59 miles an hour. A larger number of gales were, of course, experienced in some years than in others ; but it is noteworthy that those years in which gale frequency was either greater or less than the average, as the case may be, not infrequently followed one another for several years in succession.

Definition of the term Gale.

At the Meteorological Office, in accordance with international agreement, the term *gale* is applied to winds that attain to a force of 8 and upwards of the Beaufort Scale.

Classification of Gales in Quadrants.

To return to Mr. Brodie's statistics : For the purpose of classification, gales recorded on the coasts of the United Kingdom were grouped into four districts—the Northern, Western, Southern, and Eastern.

The *Northern District* comprised the coasts of Scotland, the extreme northern coasts of England and Ireland, and occasionally a portion of the northern half of the Irish Sea. The *Western District* included Ireland and the west coasts of England to the mouth of the English Channel. The *Southern District* comprehended the English Channel from its mouth to the North Foreland. The *Eastern District* commenced at the mouth of the Thames and followed the eastern coast-line to the Tweed.

Distribution of Gales.

It is found that on an average 48 gales occur annually, and out of this 11 are general ; that is to say, they are

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* "The Prevalence of Gales on the Coasts of the British Islands during the 30 years 1871-1900."—Quarterly Journal, Meteorological Society, July, 1902, Vol. XXVIII. ; July, 1903, Vol. XXIX.

experienced in three out of the four districts; eight are confined to the Northern and Western Districts; four to the Western and Southern; one to the Northern and Eastern Districts; five are felt in the Western District only; seven in the Northern only; three in the Southern only; and one in the Eastern only. Three gales experienced annually are classed by Mr. Brodie as *sporadic*, by which it is meant that they are felt at a considerable number of isolated places, scattered over a wide area, and five are classed as *local*, the term *local* meaning in this connexion that they are felt at several stations, but in a portion only of one district.

Average Frequency of Gales.

With regard to the average prevalence of gales in different seasons, 10 occur in spring, three in summer, 15 in autumn, and 20 in winter. The fewest gales, as might be expected, are experienced in the months of June and July; the largest number in January. In February a falling off in the number of gales is shown, but there is a slight increase in March; after about the middle of March, gale frequency steadily declines, rapidly until about the middle of April, less rapidly, but none the less steadily, until the middle of June. The mean monthly prevalence of gales is shown in the accompanying diagram (Fig. 8).

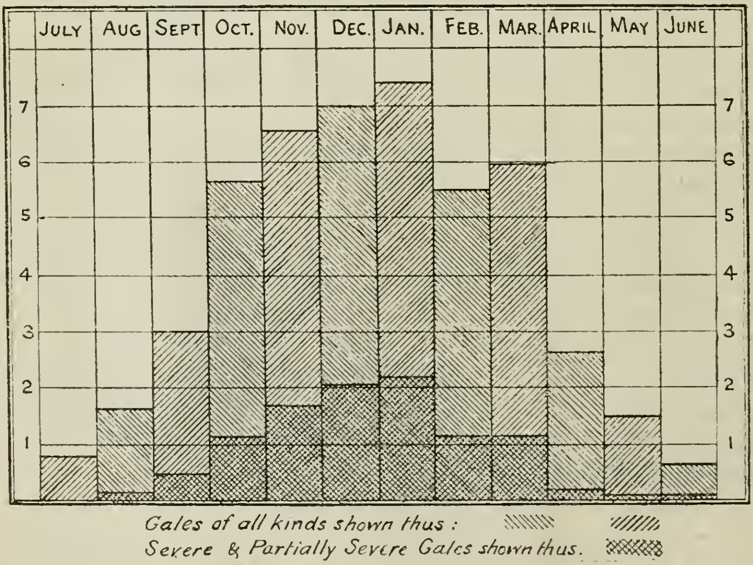


FIG. 8.—Mean Monthly Frequency of Gales.
Adapted from the figure given by Mr. Brodie.

The average number of gales in each of the 12 months is shown by the height of the columns; the scale of numbers is shown on each side of the diagram.

Wind Direction in Gales.

Respecting the direction of the wind in the gales, out of the 48 referred to as about the average number that visited the coasts of the British Islands, about 10 per cent. blew from northward and north-eastward, 14 per cent. from eastward and south-eastward, 38 per cent. from southward and south-westward, and 30 per cent. from westward and north-westward. Eight per cent. of the gales were associated with cyclonic depressions, the centres of which passed over the more central parts of the United Kingdom, so that, the wind having complete circulation about a central area of minimum pressure, moving eastward, there was no quarter from which it did not blow in some part or parts of our islands, and attain to the force of a gale, during the progress of the depressions from the North Atlantic to the North Sea To such gales the term *vortical* was applied by the author.

The highest proportion of equatorial gales, *i.e.*, gales from between south-east and west round by south, occurred in the months of December, 68·6 per cent., and January, 68·9 per cent.; the proportion was, however, nearly as high in February, 67·7 per cent. : in each of these three winter months more than two-thirds of the gales blew from some equatorial direction. The proportion was lowest in March, 55 per cent. ; but was low also in October, 56·9 per cent, and somewhat low in November, 58 per cent. The proportion of gales from polar quarters was greatest in July, 40·9 per cent., which appears singular, but, as Mr. Brodie points out, the total number in that month was so small that the result was not considered satisfactory, and a more extended series of observations would, it was thought, be necessary before such a conclusion could be accepted as representing a general rule. Next to July, the greatest proportion of polar gales in any month, 40·7 per cent., occurred in March, and April had the third highest percentage, 37·9 per cent. The smallest proportion by far of polar gales, 19·6 per cent., occurred in December, and this leads to the somewhat paradoxical conclusion that cold-wind gales were most common in the warmest months of the year, and least common in the coldest months. The proportion of vortical gales was greatest in June, 14·3 per cent. ; but here again the total number of gales recorded was too small to yield a conclusive result. Next to June the greatest proportion of such gales was found to have occurred in December, when 11·8 per cent. of our gales are due to cyclonic systems, the centres of which advance directly over the United Kingdom. In May, and in each of the autumn months, September, October, and November, about 10 per cent. of the gales are of this character, but in April the percentage is only 2·4, and in July such gales did not occur.

A more minute subdivision of the various directions from which gales blow in different months shows that the proportion of gales from north and north-east is greatest in November and least in June; the proportion of those from east and south-east is greatest in April, and they do not appear to occur in June; the proportion of gales from south and south-west is greatest in January and least in April; and from west and north-west is greatest in July and least in November. With regard to the direction of the wind in gales which visited our islands, rather more than 10 per cent. blew from northward, 14 per cent. from eastward and south-eastward, 38 per cent. from southward and south-westward, and 30 per cent. from westward and north-westward. Nearly 8 per cent. are vortical.

It is apparent from the foregoing that on the coasts of the British Islands generally gales from between south and south-west are the most frequent, and that the largest number blow from south-westward; after that gales from between north and east are the least frequent.

Relative Frequency of Gales from various Points of the Compass.

With reference to the relative frequency of gales from various points of the compass (*see* Fig. 9) during spring, gales from between south-west and north-west were most frequent, those between north and east least frequent, but more frequent than at any other season of the year. In summer gales blew almost entirely from between south-west and north-west, the largest number being from west.

In autumn south-west gales largely predominated, but a number of gales were experienced from south, from west, and from north-west. In winter gales from south and south-west were most frequent, those from south-west predominating. Gales from north-west and south-east were not infrequent during winter, but from between north and east they were of comparatively rare occurrence.

The wind-roses in diagram, Fig. 9, show the prevalence of gales from various directions in each of the four seasons of the year. The figures enclosed within each of the inner circles give the percentage of "vortical" gales, while the thick lines pointing towards these circles show the proportion of gales from each of the eight principal points of the compass. The length of these thick lines is determined by the outer circles, each of which, counting from the inner one, represents a portion of 5 per cent. For purposes of comparison with the general results, the central gale-rose gives the proportion for the entire year.

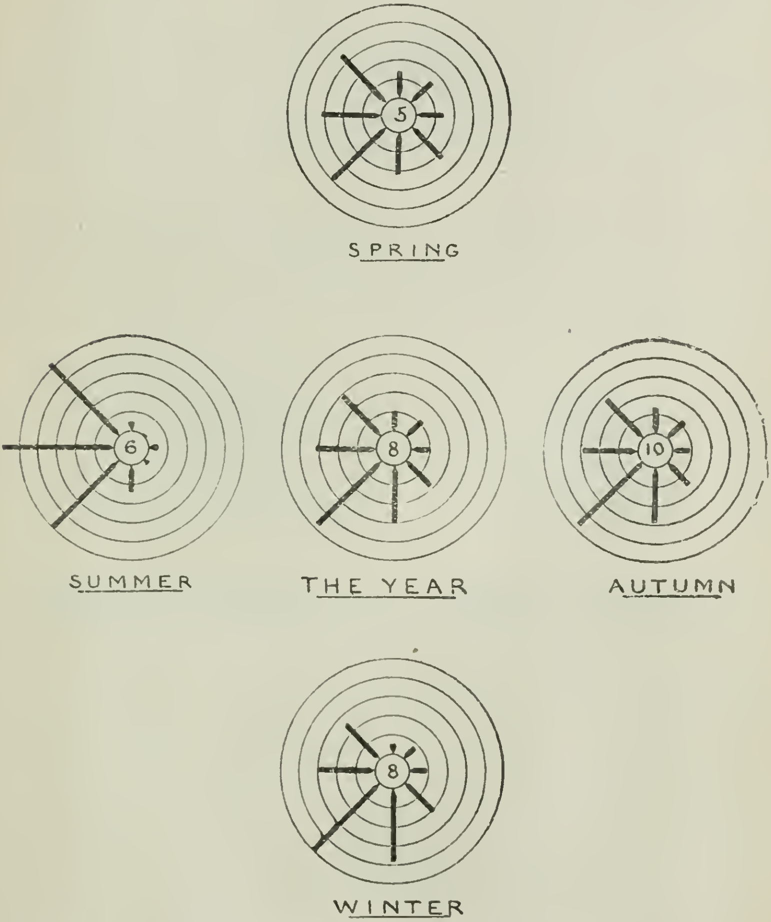
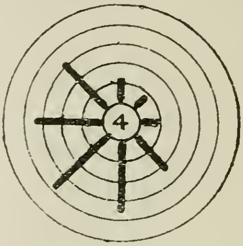


Fig. 9.—Relative Frequency of Gales from various Points of the Compass.

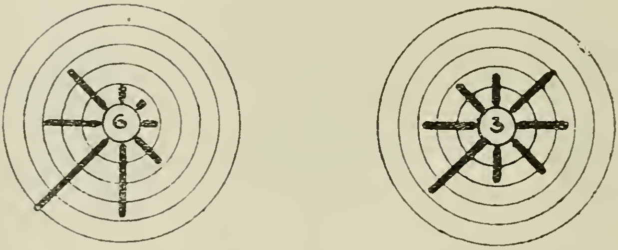
Relative Frequency of Gales on the respective Coasts of the British Isles, from different Points of the Compass.

So far the direction of the wind in gales has been considered only with regard to our coasts generally; the prevailing directions, however, vary considerably according to the district. (*See* Fig. 10.)

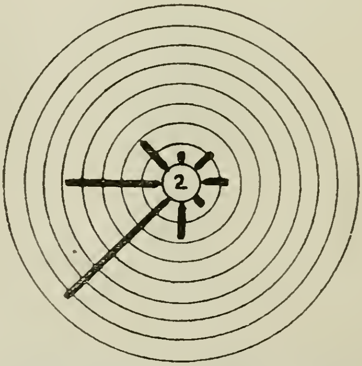
On the north coasts about 10½ per cent. of gales were from northward and north-eastward, about 15½ per cent. from eastward and south-eastward, about 37 per cent. from southward and south-westward, $32\frac{1}{2}$ per cent. from westward and north-westward, and about 4 were vortical.



GALES IN NORTH



GALES IN WEST GALES IN EAST



GALES IN SOUTH

FIG. 10.—Relative Frequency of Gales on the respective coasts of the British Isles, from different points of the compass.

In Fig. 10 the direction from which gales blow in the various divisions is shown graphically by wind roses. The figures enclosed within each of the inner circles give the percentage of "vortical" gales, while the thick lines pointing towards these circles show the proportion of gales from each of the eight principal points of the compass. The length of these thick lines is determined by the outer circles, each of which, counting from the inner one, represents a proportion of 5 per cent.

On the south coasts the percentages were respectively about $8\frac{1}{4}$ from northward and north-eastward, nearly 10 from eastward and south-eastward, 46 from southward and south-westward, $33\frac{1}{2}$ from westward and north-westward, and about 2 were vortical.

On the east coasts the percentages of gales were about $21\frac{1}{2}$ from northward and north-eastward, nearly 25 from eastward and south-eastward, nearly 28 from southward and south-westward, $22\frac{1}{2}$ from westward and north-westward, and nearly $3\frac{1}{4}$ vortical.

On the west coasts nearly $7\frac{1}{2}$ per cent. of gales were from northward and north-eastward, nearly 13 per cent. from eastward and south-eastward, nearly 45 per cent. from southward and south-westward, and rather more than 29 per cent. from westward and north-westward; nearly 6 per cent. were vortical.

With reference to the gales associated with cyclonic depressions, the centres of which pass over the more central parts of the United Kingdom, and to which the term *vortical* has been applied, it may be well at this point to state that almost all gales which are experienced in these islands are associated with wind systems of a cyclonic character, the characteristics of which will be explained in the next chapter, but that the central areas of low pressure in these systems, round which the wind circulates, follow most frequently a path that lies to the northward and westward of our northern and western seaboard. When this is the case our islands come under the influence of winds, related to the seaward semicircle of the cyclonic system: from between south-east and north-west.

The large number of southerly and south-westerly gales which visit our northern and western shores are caused by these cyclonic depressions, which travel in a north-easterly direction across the north-eastern arm of the North Atlantic, and pass between the north of Scotland and Iceland, or over Iceland. They rarely cause an increase of wind to gale force on our south-east and east coasts, because the centres of the depressions pass far to the north-westward of Ireland and Scotland.

Tracks of Storm Centres.

The tracks ordinarily pursued by storm centres are shown in Fig. 11.

With reference to this illustration the author makes the following statement : —

> The undue preponderance of gales from south-west and west on our southern coasts is at once accounted for by the fact (doubtless a very familiar one) that the vast bulk of the storm systems move along either in an easterly or a north-easterly direction over the more northern parts of our area, and that we in the south get the winds blowing round their southern and south-eastern sides.
>
> In the west many of the gales from south and south-west are due to cyclonic areas moving along in the directions shown by the storm tracks A and B*, these disturbances being in very many cases too remote to cause any serious increase of wind in the south and east. In the north a gale is also caused very frequently by these two sets of storm systems, while in the rear of Class A it is not unusual for a gale to spring up from west, or even north-west. The relative frequency of gales from these latter directions in the north is also partially accounted for in disturbances moving in the tracks marked C and D ; the latter must, however, be very large and deep to affect our own coasts at all seriously. In the north, and to a limited extent in the east also, storm systems moving along in the tracks E and J will, if of sufficient depth, cause gales from south-east, and, as these two types are not uncommon, we see at once that the percentage of gales from that quarter on the coasts mentioned is somewhat large. The high percentage of gales on our east coasts from some easterly direction (south-east to north-east) is accounted for, but only partially, by cyclonic systems travelling in the somewhat low tracks marked G, H, and J. Many of the easterly gales both on this and on our southern coasts are, however, caused by storm systems, the centres of which fail to come anywhere near our islands. It is not unusual for a cyclonic area which appears over Spain, or even over the Mediterranean, to remain almost stationary for some time but to spread out laterally in a northerly direction, the surging process resulting in a gradual increase in the easterly gradient over our own southern and eastern districts. Another but rarer type of gale which blows from eastward to north-eastward is due to cyclonic systems surging westward and north-westward from Central Europe ; in some cases the centres actually move out in this direction to the neighbourhood of our eastern and southern coasts, but these instances are so infrequent that I have omitted them altogether from the map of storm tracks. The high proportion of *vortical* gales on the west coasts is due very largely to the fact that the district in question covers a wide range of latitude, some 350 miles from north to south, and the possibilities of a storm centre moving eastward or north-eastward over the more central parts of the district and causing a complete cyclonic circulation are therefore great.

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* Since the year 1906, when telegraphic communication with Iceland and Faeroe was established, observations have been received at the Meteorological Office daily, and have been utilized in the preparation of the Daily Weather Report. Had such observations been available when Mr. Brodie drafted Fig. 11, he would, doubtless, have placed tracks A and B much nearer Iceland than he placed them on this map.

Next to the west coasts, *vortical* gales are most common in the north and east, these being due respectively to storms moving in the tracks E and F. In the southern district the range of latitude embraced is very small, and as very few storm centres move across it in a due easterly, and scarcely any in a due northerly or southerly direction, the gales experienced there are seldom of a vortical character.

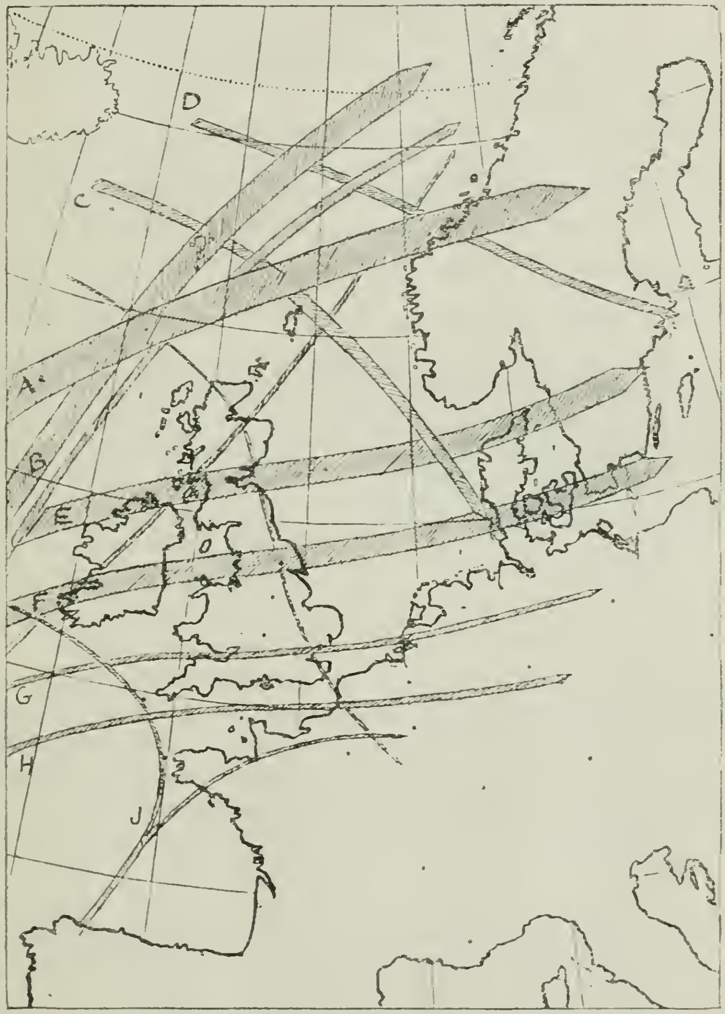

FIG. 11.—Tracks ordinarily pursued by cyclone Centres appearing over various parts of North Western Europe. (The relative frequency of each track is shown by the width of the shaded line.) Since 1907 the area under daily observation has included Faeroe and Iceland, and the track B has been found to have been drawn too near the European side.

Speed of Storm Centres.

As regards the speed at which storm centres travel, Mr. Brodie found that many of the centres of the larger cyclonic disturbances follow paths lying outside our area of observation; so that although the direction of movement can usually be determined with a reasonable degree of accuracy, it is often impossible to locate the centres of the systems from time to time, and thus measure their rate of travel. Out of 311 important storm systems the speed of travel of not more than 267 could be determined. The average rate at which these moved was found to be 24·1 geographical miles per hour.

The variations in the speed of travel were so great, however, that the average appears to be of little value; it included, for instance, numerous storms that showed a speed of not more than 8 or 10 miles per hour; while in the case of several others it amounted to 40, 50 and even 60 miles per hour.

The rapidity of motion was found to vary in the different seasons of the year, and according to the data relating to summer was greatest in that season; but as in the 30 years' records only seven summer gales could be classed as severe; the evidence in this connexion, as regards that period of the year, is obviously insufficient.

The average speed of travel in the autumn was found to be 21·7 miles per hour, in the winter 25·4 miles, and in the spring 23·4 miles. Thus, disregarding the results relating to summer, the storms of winter appear to have the fastest rate of travel, the autumn storms the slowest.

Average results referred to all months of the year indicate that the storms which attain the maximum rate of travel, which is 25·1 miles per hour, move in an easterly direction, *i.e.*, east-north-eastward, eastward, and east-south-eastward. Storms moving northward and north-eastward, southward and south-eastward, have about an average rate of travel 24 miles per hour.

Storm systems that moved in irregular paths were found to have irregular rates of travel, and the average speed of the comparatively few that were examined for this purpose was found to be as low as 19·1 miles per hour.

Systems moving in north-westerly and south-westerly directions, instances of which are rare, showed a comparatively slow rate of travel: the average speed being 13·4 and 10·7 miles per hour respectively.

There were 60 cases, during the 30 years' period under examination, in which storm systems travelled at a higher speed than 30 geographical miles per hour. Of these 25 travelled at speeds of 31 to 35 miles, 14 at speeds of 36 to 40 miles, 11 at speeds of 41 to 45 miles, and 4 at speeds of

46 to 50 miles. The remaining 6 cases included 3 that travelled at 51 to 55 miles, 2 at 56 to 60, and 1 at 62 miles per hour. The exceptional speed of 62 miles was attained by a small secondary cyclone which travelled over Ireland, England and the North Sea in a north-easterly direction on the 24th March, 1895.

CHAPTER X.

Icebergs and other forms of Drifting Ice.

Ice Formation.

Ice is a mass of stellate crystals, which form in a freezing fluid while in process of passing from a liquid to a solid state.

The crystals usually take the form of six-pointed stars similar to those of which particles of snow are composed.

Ice is formed also from snow by pressure, which, by expelling the air intermingled with its particles, renders it hard and transparent; for it is the close contact of the crystals, blending as it does the individual particles into a compact, continuous mass, that makes ice more or less transparent.

Tyndall's Experiment.

The beautiful structure of ice may be seen by repeating an experiment that was made originally by the late Professor Tyndall, which may be described as follows:—A thin slab of ice is cut parallel to its plane of freezing. This plane can be ascertained by examining the direction in which the bubbles in the ice are distributed either thickly, parallel to the surface of the water when freezing or sparsely in striæ at right angles to it.

If the disintegration of the ice be watched through a lens while a ray of light is allowed to pass through it, numerous small crystals will be seen gradually assuming star-like forms of rare beauty.

In polar regions, and on mountain heights above the *snow line* or limit above which snow perpetually lies, some melting takes place at the surface of the snow under the rays of the summer sun.

The water thus melted at the surface percolates to the lower layers of snow, raising their temperature to that of 273a (32° Fahr.); and while this is taking place the weight of the snow above presses the lower layers into a coherent mass, from which the air is expelled by further compression, and ice is formed by *regelation.*

Regelation is a property of ice which was discovered by Faraday, who found that when two pieces of melting ice are placed together they adhere one to the other by freezing at their places of contact.

Faraday's Discovery and Explanation of "Regelation."

Faraday's explanation of this phenomenon is, in effect, as follows :—The particles on the surface of a block of ice are held together by cohesion on one side only, the side that is not exposed to the air ; whereas those particles that are in the interior of the block are pressed together on all sides. With the temperature at 273a (32° Fahr.), the particles exposed melt first, and form a film of water over the surface of the ice. Now, if the block of ice be cleft in twain, melting takes place of the fractured surfaces also. By placing the two halves together in their original position the melting surfaces, where fractured, are again pressed on all sides by frozen particles, and become one by *regelation.*

The accepted Explanation.

The accepted explanation, however, is that given by Prof. J. Clerk Maxwell, in his "Theory of Heat." It is as follows :—When two pieces of ice at the melting point are pressed together, the pressure causes melting to take place at the portions of the surface in contact. The water so formed escapes out of the way and the temperature is lowered. Hence, as soon as the pressure diminishes the two parts are frozen together with ice at a temperature below 273a (32° Fahr).

Illustration by Dewar.

In one of the Christmas lectures to children at the Royal Institution, in December and January, 1912–1913; Sir James Dewar, in order to illustrate by a well-known experiment the fact that ice cannot be cut, furnished also an example of adhesion by the above process.

A fine wire, with weights attached to each end, was suspended on a block of ice. The wire gradually cut its way through the ice, but when it emerged at the other side the block was found to be intact. The ice, or *water in a solid state*, as the lecturer preferred to describe it, had liquefied in front of the wire by pressure, and the cleft parts behind the wire had reunited by regelation.

The regelating property of ice was applied by the late Professor Tyndall to explain the formation of glaciers.

The Formation of Glaciers.

Glaciers are rivers of snow, which have their origin in elevated regions, and are compacted into ice in the manner described. This compacted mass of ice is urged downward by gravity, and by the increasing pressure of the masses in the rear, caused by the continuous accumulation of ice and snow. A glacier behaves in all respects like a river: its rate of motion accelerating in its steep descent through narrow passes and becoming slower where its channel widens.

Analogy between River Flow and Glacial Motion.

Moreover, as a river flows with a greater velocity in the middle of the stream than is the case at its sides, because of the greater friction it has to overcome near its banks, so the motion of a glacier is faster at its centre than at its margins: and the analogy may be carried still farther, for both river and glacier move faster at their surface than near their beds.

The Colouring of Icebergs and the Causes.

The whiteness of icebergs is due to the fine lineal pores, equidistant, parallel, and of about the same size, which are uniformly distributed throughout the greater portion of the mass. In the broad stripes, clear and of a dark-blue colour, which intersect a berg in places; air bubbles are either absent or else they differ in size, and are distributed sparsely and irregularly.

Glacial Regions.—Formation of Icebergs of Glacial Origin.

In arctic and antarctic regions glaciers are found at all levels, and they frequently occupy extensive tracts of country; but in temperate and tropical zones they exist only on mountains at great altitudes; and near the equator they do not form below a height of 16,000 feet above sea level. In these zones a glacier melts when it has descended to a level below the snow line, where it becomes the source of a river; but in polar regions a glacier continues its descent to the lowest levels and carves its way to the coast. Being still under the influence of pressure from behind, the glacier gradually protrudes seaward, but its base rests on the ground, until it reaches a sufficient depth to become water-borne. This protrusion continues until, as a result of resistance from continuous pressure in rear, but also through the agency of sea disturbance, the so-called *calving* of an iceberg (German : *Eis:* ice ; *Berg:* mountain) takes place ; a portion of the floating mass of ice is severed from the parent glacier, and, when the wind is favourable to its release, the berg drifts out to sea.

Bergs of Ice-Barrier Origin.

All icebergs, however, are not of glacial formation ; a large percentage of these masses of floating ice originally formed part of ice barriers.

Ice Barriers and their Formation.

The origin of ice-barriers is yet a matter of uncertainty, but it seems probable that they are formed by a gradual and steady extension seaward of the ice frozen to the shore, which is called the *ice-foot*, and to the growth vertically of the extended ice-foot by the formation of new ice on its surface from snow through the process of regelation.

Icebergs that have formed part of an ice-barrier, or of an *ice-cliff* that extends from and is attached to the face of a precipitous foreshore, are generally tabular : a natural result of their formation. Most of the bergs of the southern hemisphere, as will be shown later, are in this form.

Field Ice : Its Formation and Colour.

Field ice, which is flat ice, often occupying a large area and rendering it unnavigable, is formed near the shore, and, when in motion, being more under the influence of wind than of current, it frequently *piles*, thus becoming uneven. Fragments of bergs, or *growlers*, as they are termed, which at times become trapped and embedded in field ice, are an additional menace to shipping, although they can, as a rule, be detected at some distance in consequence of their dark-blue colour.

Floating Ice in Other Forms.

Floating ice in other forms is described in the "Newfoundland and Labrador Pilot,"* as follows :—

Floe ice consists of several pieces of field ice frozen or pressed together.

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* "Newfoundland and Labrador Pilot," Fourth Edition, 1907, pp. 27 and 28. Published by order of the Lords Commissioners of the Admiralty.

Land ice is field or floe ice attached to the shore since the winter.

Hummocky ice is formed by the edges of ice floes meeting in strong breezes, when they are pushed up and formed into pyramids, which are then named *hummocks*; and it is of these that the high mounds of ice met with in the Gulf of St. Lawrence are generally composed.

Pack ice is a large collection of pieces of ice from broken-up floes or icebergs, which have, to a certain extent, closed together again. The pack is said to be *open* when it presents leads or lanes of water between the pieces of ice, forming more or less navigable channels; and *close* when it is not possible to navigate through the pack.

Drift ice it unattached pieces of floating ice, easily navigable.

Brash or sludge ice is a collection of very small pieces of broken-up ice through which a ship can easily force her way.

Pancake ice is newly-frozen ice of sufficient thickness to prevent navigation, and is sometimes separated into pieces of a form suggestive of the name.

Bay ice is newly - frozen ice sufficiently thick to prevent navigation.

A *Floeberg* is a thick piece of salt-water ice presenting the appearance of a small iceberg.

Slob ice, which is the first ice to form, should also be mentioned It is crushed by wind and sea, and piled to a height of from 3 to 10 feet. Sometimes the harbours and bays of Newfoundland are filled by it.

The Detection of Drifting Ice.

When navigating in regions where ice may be encountered, no possible means for detecting its presence should be neglected. For many years past the use of the thermometer in this connexion has been discredited; yet instances are not wanting to prove that timely warning of ice, in the immediate neighbourhood of a vessel, which cannot be seen owing to thick weather, may be given by means of observations of sea-surface temperature, particularly on occasions when the current is setting from the direction of the ice towards the vessel.

The Recording Micro-Thermometer.

For registering minute changes in sea temperature a *recording micro-thermometer* has been devised by Professor H. T. Barnes, F.R.S., Director of the Physics Department in the McGill University, Montreal. This instrument, which is designed on the principle of the electrical-resistance thermometer, was tested on board one of the hydrographic survey vessels employed by the Canadian Government during a voyage from the St. Lawrence to Hudson Bay, passing through the Strait of Belle Isle, in the year 1910.

It was found that a *rise* in the temperature of the water at five feet below the surface was registered as the vessel drew near an iceberg; but that this rise was followed by a fall which continued until the berg was in a position nearest to the vessel. The sea then gradually became warmer as the distance from the berg increased, until the latter ceased to have any effect upon the temperature of the former.

The explanation offered by Professor Barnes in regard to the rise in sea temperature when nearing the iceberg is in effect as follows:—The fresh water melting from an iceberg is carried downward by the convective action of the inflowing salt water; and the surface water, which, he says, has no tendency to sink, because of its horizontal motion, and is not dispersed by sea movement, absorbs and accumulates all the heat radiated from the sun and sky; and in this way the water around the berg becomes warmer than that of the surrounding sea. This explanation is given by Professor Barnes in his Report to the Deputy Minister of Marine and Fisheries, Ottawa.*

It is possible, however, that by dilution with fresh water from an iceberg that has been carried below the surface by convective action, a warm undercurrent of relatively high salinity may be brought to the surface and cause the rise of temperature referred to.

The inventor subsequently tried the apparatus during a passage from Halifax to Bristol; and, in addition to testing its utility in the detection of drifting ice, he claims to have obtained interesting results in connexion with the disturbing influence of land on the temperature of the sea.

The Ice Blink.

The *ice blink*: an effulgence, reflected from ice, which is seen in the sky near the horizon in its direction, generally indicates the presence of this danger, and renders a berg that is snow-covered distinguishable at some distance. At short distances this brightness may assume the appearance of a white cloud.

First appearance of Iceberg in Thick Weather.

When approaching an iceberg in thick weather the first appearance it presents is that of a relatively dark object.

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* "Report on the Influence of Icebergs and Land on the Temperature of the Sea, as shown by the use of the micro-thermometer on a trip of the C.G.S. 'Montcalm,' in the Gulf of St. Lawrence and the coast of Labrador, &c." By H. T. Barnes, D.Sc., F.R.S., Director of the Physical Laboratories and Professor of Physics, McGill University, Montreal. Sessional Paper No. 21c. Supplement to the forty-fifth Annual Report of the Department of Marine and Fisheries for the fiscal year 1911-12. Ottawa, 1913.

The Whistle or Siren.

The whistle or siren of a steamship, sounded at frequent intervals, has been tried by some navigators for the detection of icebergs in thick weather, with the object of obtaining an echo from the mass which would reveal its presence in the immediate neighbourhood of the vessel in sufficient time to avert a collision with it. If this method has on any occasion been found to succeed, the fact, it is believed, has not been published.

Ice in the Northern Hemisphere.

The glaciers of Greenland to which the majority of the large icebergs that drift southward into the North Atlantic doubtless owe their origin, occupy immense tracts of country extending far inland.

The area of Greenland, including its outlying islands, is estimated at about 827,275 square miles. Its extreme length, assuming its northernmost point to be situated on the north coast of one of the two large islands to the north, in latitude 83° 40′ N., longitude 31° 15′ W., and Cape Farewell, which is also on an island, its southernmost point, is about 1,660 statute miles.

Its extreme breadth, which may be accepted as the measurement between Cape Alexander in 78° 11′ N., 73° 13′ W., and Cape Bismarck in 78° 47′ N., 18° 30′ W., is about 820 statute miles.

The rugged, precipitous coasts of Continental Greenland are, for the most part, characterized by deep glaciated indentations or fiords; that have been, and continue to be, the birth-places of icebergs, which break away from protruding glaciers; also by numerous islands, many of which lie at the entrance of these fiords.

This is specially the case between the 64th and 74th parallels; and from the 70th parallel northward on the east side.

The inland ice mantle, which may be regarded as an immense glacier, with arms stretching to the coast, covers the interior of the Continent; a plateau rising from about 2,000 feet to an elevation of 9,000 feet or more.

This inland ice sheet is estimated, by General Greely, the famous American Arctic explorer, to have a thickness of 1,000 to 5,000 feet.*

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* Handbook of Polar Discoveries. By A. W. Greely, Major General, United States Army. London, T. Fisher Unwin, 1910.

Owing to the barrier, of land and sea ice, the exploration of the East Coast of Greenland is not yet complete ; and the greater part of the coast from Cape Farewell, northward, has been surveyed from time to time under great difficulties arising from the prevalence of fog.

The land ice may extend, it is stated,* to ten miles from the shore ; and includes icebergs that are calved from inland glaciers ; while outside of this inland ice, a stream of drift ice, from the Polar basin, consisting, presumably, of both sea and land ice, is carried north-westward by a constant current

The breadth of this ice-drift varies during the year ; in spring it stretches from about Cape Dan to Cape North, in Iceland ; thence north-eastward to the island of Jan Mayen, and north-westward to Spitzbergen. South of Cape Dan the ice-drift, which there is a comparatively narrow belt, skirts the coast to Cape Farewell.

Diverse opinions are held with regard to the origin of the inland ice : there are those that support the theory, formed by Dr. H. Rink, of Copenhagen, of an ice deluge, that originated in the valleys by the freezing up of the river systems and spread upwards over the water-sheds until the whole land was covered.

Others believe that the formation of the ice mantle commenced on the heights ; and streaming down from immense masses of perpetual snow, welded together in its descent, the various ramifications into an uniform mass, ultimately spreading over the land, covering valleys and heights alike.

The first theory presupposes excess of cold, and of precipitation : because the temperature now prevailing in Greenland is not sufficiently low to maintain throughout the summer the ice formed during the winter, even in the smaller rivers ; and to allow moreover an increase of ice in the winter following.

The second theory refers the formation of the ice mantle to excessive precipitation ; contending that that alone is sufficient explanation.

As regards the extent and the outward form and elevation of the Inland Ice ; the most reliable information is that which is imparted by the intrepid Norwegian explorer, Fridtjof Nansen, in the narrative of his famous journey

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* Arctic Pilot, Vol. II, Second Edition, 1911. Published by order of the Lords Commissioners of the Admiralty.

across the Continent, entitled *The First Crossing of Greenland.*[*]

Nansen states that the inland ice stretches in an unbroken sheet over that part of the Continent along which he and his party travelled ; and that he feels justified in concluding that from the 75th parallel southward the whole country is similarly covered ; there being no reason to suppose that the atmospheric conditions are not approximately the same over the whole interior. He holds in fact that his investigations actually supplied him with evidence in that direction. Nansen concluded therefore, with a high degree of confidence, that in the southern part of Greenland, across which he made his journey, there were no oases ; although, as exceptions to the general rule, there may be peaks in the interior which project above the ice sheet. He added, that as yet nothing had been observed in Greenland which would lend support to a supposition of their existence. The last 'nunataks'[†] that they passed, he says, on the eastern side of the Continent, were little more than thirty miles from the sea board, and were plainly visible from the mountains on the coast.

Dr. Rink on Glaciers and Icebergs.

Rink resided for several years in Greenland. He imparted much interesting information upon this point in a paper he contributed to the Royal Geographical Society in the year 1853,[‡] in which he makes the following statement :—

> For the formation of icebergs a tract of land of a certain extent is necessary, in which the sea forms so few and small creeks or inlets, that rivers or water courses 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 plain ; the river beds are concealed, as well as every vestige of the original form of the country.*

He goes on to say that the outer edge of this mass of ice is thrust forward towards the sea by a movement which commences far inland ; and that when the ice reaches a frith

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[*] The First Crossing of Greenland. By Fridtjof Nansen. Translated from the Norwegian by Hubert Majendie Gepp, B.A. Lecturer at the University of Upsala. Vol. ii. London, Longmans, Green & Co., 1890.

[†] A *nunatak* is a peak, hill, or mountain top, which rises above the surface of the inland ice.

[‡] "On the large Continental Ice of Greenland, and the Origin of Icebergs in the Arctic Seas." By Dr. H. Rink, of Copenhagen. Journal of the Royal Geographical Society, Vol. xxiii. 1853.

it may be seen to sink and to diverge, and even to extend subsequently for several miles.

Then, through the agency of the *obliterated rivers*, the glacier is carried forward to the ocean; and reaching the shore, while still preserving its continuity, protrudes seaward, borne up by the sea; until, by sea disturbance, by its own weight, or some other agency, equilibrium is destroyed, and a portion of the floating mass parts from the parent glacier and an iceberg is born.

Commenting on the fact, regarded as remarkable by Scoresby, that icebergs are rarely met with in the neighbourhood of Spitzbergen, Dr. Rink pointed out that, neither that island nor the narrower parts of Greenland, nor lands adjacent to that continent, are adequate as regards extent to produce the yearly excess of ice which is necessary for their formation.

Such conditions, he considered, were found only in Greenland, and were characteristic more especially of that portion of Greenland which lies to the north of the Arctic Circle, where sufficient space is afforded to serve as the cradle of large icebergs.

The opportunities Dr. Rink enjoyed, during a somewhat prolonged residence in Greenland, of becoming acquainted with that part of the west coast which is situated between 68° N. and 74° N. latitude, were unique, and lend to his evidence regarding the formation of icebergs in the Arctic a special weight.

Ice-friths.

He expressed the opinion that the largest icebergs which drift southward in Davis Strait issue from *ice-friths*, as the friths or fiords which transmit the bergs are called, situated in the above-mentioned region. His knowledge in this connexion was based, partly on his own observations, and partly on information derived from intercourse with the inhabitants.

There exist, Rink concluded, five principal ice-friths along the coast, from 67½° N. to 73° N. latitude, every one of which receives annually many thousand cubic feet of ice. He named and located them as follows:—Jakobshavn, in 69° 10′ N. lat.; Torsukatak, behind the island of Arvemina, in 69° 50′ N. lat.; Karaiak, in 70° 25′ N. lat., a large ice-frith; Kangerdlugsuak, in 71° 25′ N. lat., a still larger ice-frith, which with Karaiak is a ramification of the Bay of Umanak, Upernivik, in 73° N. lat., behind a large group of islands.

According to another authority upon the subject, the region that is richest in glaciers, and presumably therefore the most prolific of icebergs, on the West Coast of Greenland, is in the neighbourhood of the Umanak Fiord ; especially on the Nugsuak Peninsula, which is situated on the Southern side of the Fiord. A large expanse of this peninsula rises above the snow line. The Northern side of the Fiord is formed of a series of small peninsulas and islands that yield, in relation to their sizes, abundant formations of high ice.

The greatest number of glaciers on Nugsuak are located on the Eastern end of the peninsula, a low rocky mass between a line of lakes and the Fiord ; on a strip of the Coast, about 62 miles in length. On the North side of the rocky mass there are no less than 23 glaciers debouching to the sea ; the easternmost of these have no connection with the ice-cap of the plateau and belong to the type of *pendant* glaciers; so-called because they do not reach the surface of the sea or land, as the case may be.

There are three other glaciers of the same type farther West ; and to the West of these are situated five of the greatest glaciers of the peninsula, namely, the Sarkak ; the Little and the Great Umiartorfik ; the Asakak, and the Semiarsut. To the left of the Great Umiartorfik on the rise from the valley there is, moreover, a pendant glacier, which ends in two sharp tongues.

West of Semiarsut, another succession of mighty glaciers begins : Kome, Sarfarfik and nine others, these however are all pendant glaciers, and end at a height above the sea, that increases in each case, westward.

The few glaciers on the South side of the peninsula all end inland, descending towards the lakes ; but on the West side of the mainland, in the neighbourhood of the peninsula, there are at least seven important glaciers, most if not all of which descend to the sea.

Other glaciers on the west coast of Greenland from which icebergs doubtless are derived are Humboldt glacier, in Peabody Bay, between Smith Sound and Kennedy Channel ; a glacier unnamed and Petowik glacier, on the northern coast of Baffin Bay, between 76° and 76½° N.

There are, moreover, on the western shores of Baffin Bay, and Davis Strait several iceberg-bearing glaciers such as Rice's, in 77° N , on the east coast of Ellesmere Land ; two glaciers unnamed on the north side of Glacier Strait, at the entrance to Jones Sound. Others on the southern shore of Bylot Island, Eclipse Sound ; the Grinnell glacier on the northern shores of Hudson Strait; and an unnamed glacier near Cape Horsburgh, north east of Lancaster Sound.

Some idea of the distribution of ice in the north polar regions may be gained by reference to the maps on Plates XIX and XX, and which relate to the months of May and August, 1911. These maps are reproduced from representations given in a special print of the Nautical-Meteorological Annual of the Danish Meteorological Institute,* with the permission of the Director, Captain Carl Ryder. In these the names of the ice-friths and glaciers referred to have been added in their respective positions.

When an iceberg has drifted from the parent glacier it may at once become subject to the influences of wind and current, or it may remain under the shelter of land on either side of the ice-frith for a considerable period before it is driven from its birthplace and commences its wanderings towards, and in the open sea.

The Proportion of Icebergs above Water.

The approximate weight of a cubic foot of sea water is 64 lbs., and that of a corresponding mass of ice not more than 57 lbs.: an iceberg, therefore, if homogeneous throughout will float with about one-ninth of its height from base to summit above water.

Howbeit the proportion of a berg above water depends, not upon its form, but only upon the relative solidity of the submerged and visible portions, including, presumably, the quantity of earthy matter at its base, which has been carried away from the glacier bed.

It may be assumed, for these reasons, that a tabular iceberg floats with from one-seventh to one-ninth of its bulk above water; so that when such a mass is drifting under the influence of wind and current, it is, as a rule, acted upon more by the latter than by the former; at the same time, wind doubtless plays a more or less important part in steering a drifting berg.

The Distribution of Atmospheric Pressure and the Disruption and Movements of Ice.

The centres of many cyclonic depressions that influence the weather conditions in Davis Strait and Baffin Bay during

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* Isforholdene i de arktiske Have, 1911. (The state of the ice in the Arctic Seas, 1911.)

THE STATE OF THE ICE IN THE ARCTIC SEAS 1911.

published by the Danish Meteorological Institute.

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THE STATE OF THE ICE IN THE ARCTIC SEAS 1911.

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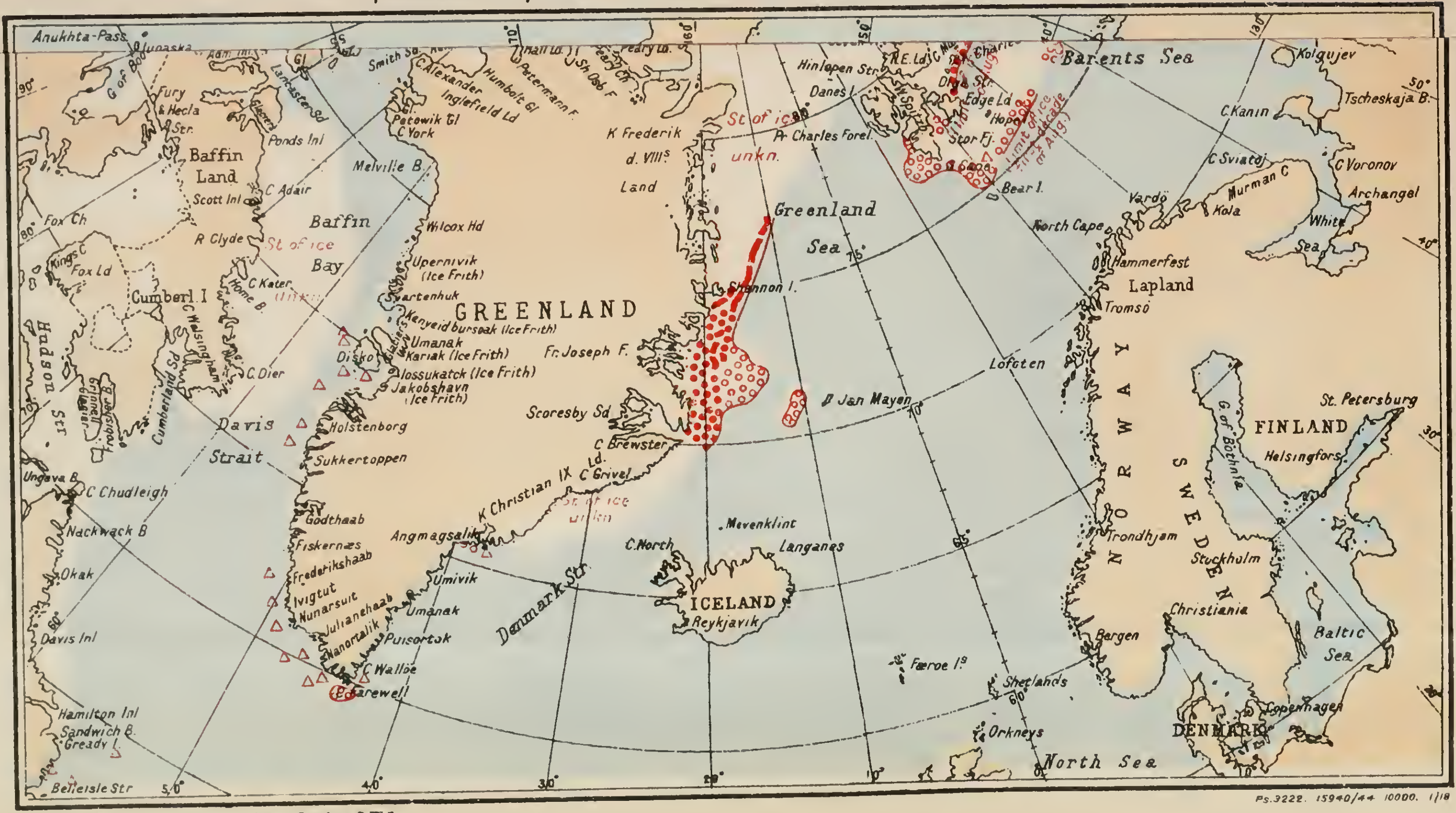

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Note

▬	unbroken polar ice
▨	landfloe
‒ ‒ ‒	great ice-fields
●	light pack-ice.
○	open ice.
⁘	bay-ice and brash
St of ice unkn	state of ice unknown
△	iceberg

The red curves indicate the observed limits between open sea and ice. No colour indicates ice supposed, but no information at hand.

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their progress eastward pass to the south of those regions, and the strong winds and gales associated with these disturbances, blowing as they do from eastward in their northern segment, drive the icebergs that have not left the shelter of the friths on the west coast of Greenland into open water.

During the spring the average distribution of atmospheric pressure to the eastward and westward of Davis Strait and Baffin Bay is conducive to the prevalence of northerly or north-easterly winds ; pressure is relatively low over southern Greenland, and a large area of low pressure is situated over the ocean immediately to the south-east or south of Greenland. It is relatively high over the Dominion of Canada between the 80th and 120th meridians of west longitude.

These winds act with the prevailing current in carrying bergs, with other ice, to the southward, steering them at the same time towards the western shores of the strait, where, it may be assumed, some of them winter, while others are again driven into the open by westerly gales that are experienced when the centres of cyclonic depressions pass to the north of the strait. Ice that has broken away from the western side would also be carried to the eastward by these westerly gales, and to the southward by the current ; after which, it seems evident, that the assemblage would either clear the land and move into the Atlantic or drift towards the south-west coast of Greenland, and there become hampered by land and other fast ice and imprisoned for the winter.

Probably a few icebergs, with some field and pack ice that has collected near the southern coasts of Greenland and Labrador, are released by the early winter gales and the accompanying sea disturbance, so that they resume their drift southward into the Atlantic, and, with other free ice from the north, reach the Transatlantic trade routes as early as January or February, and soon after come under the influence of the warm current from the south.

The Dissolution of Icebergs.

The time which elapses between the entry of an iceberg into the warm water south of about the 42nd parallel of latitude, and its dissolution doubtless varies considerably, depending on its mass, structure, condition, and the temperature of its environment ; possibly upon other circumstances also ; and it may here be suggested that the rock and other earthy matter which adheres to the parent glacier while carving its way to the sea may so materially affect the buoyancy of its offspring that the iceberg founders after the greater portion of its mass has dissolved. The number of bergs that survive their encounter with the Gulf Stream and drift to the southward and eastward are few ; but, as will be shown later, small icebergs and large masses of ice that must at one time have been huge bergs have been seen as far south as 31° N. latitude, and as far east as 5° 50′ W. longitude.

Drift of Ice from Greenland Sea.

Following its disruption in summer most of the ice in Denmark Strait drifts to the south-westward along the east coast of Greenland in the polar current that follows the coastline round Cape Farewell. This ice has its origin in, and in the neighbourhood either of Spitzbergen or Greenland. That which comes from the former region is chiefly of the nature of great level floes or of field ice ; the drift from the latter region consists for the most part of icebergs, which ground in 60 to 70 fathoms of water, and field ice.

Arctic explorers, it is stated*, have found the ice to the north of Spitzbergen, and between that island and Greenland, to be moving in a body to the south-west. Great quantities of field and hummocky ice pass each year between Spitzbergen and Greenland and between Greenland and Iceland, these waters being almost covered with ice, which greatly impedes navigation or renders it impossible.

Drift ice appears around Iceland sometimes as early as January, and lasts until the autumn ; usually there is little in the last four months of the year.

Ice off South Coast of Greenland.

Polar ice arrives off the south coast of Greenland in May, June, and July ; during the four months November to February none is seen in that locality. According to Dr. Rink, who mentioned that he had good authority for the statement, sealing vessels, which in June visit the ice southward and eastward of Cape Farewell, from which headland it extends 50 to 80 miles, find it to be moving westward at the rate of eight to ten miles a day.

After rounding Cape Farewell this assemblage of ice continues, with the current, to follow the coast to the northwestward until it reaches about the 59th parallel, when, its

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* Arctic Pilot, Vol. II., Second Edition. Published by order of the Lords Commissioners of the Admiralty, 1911.

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RIOD 1901-1912.

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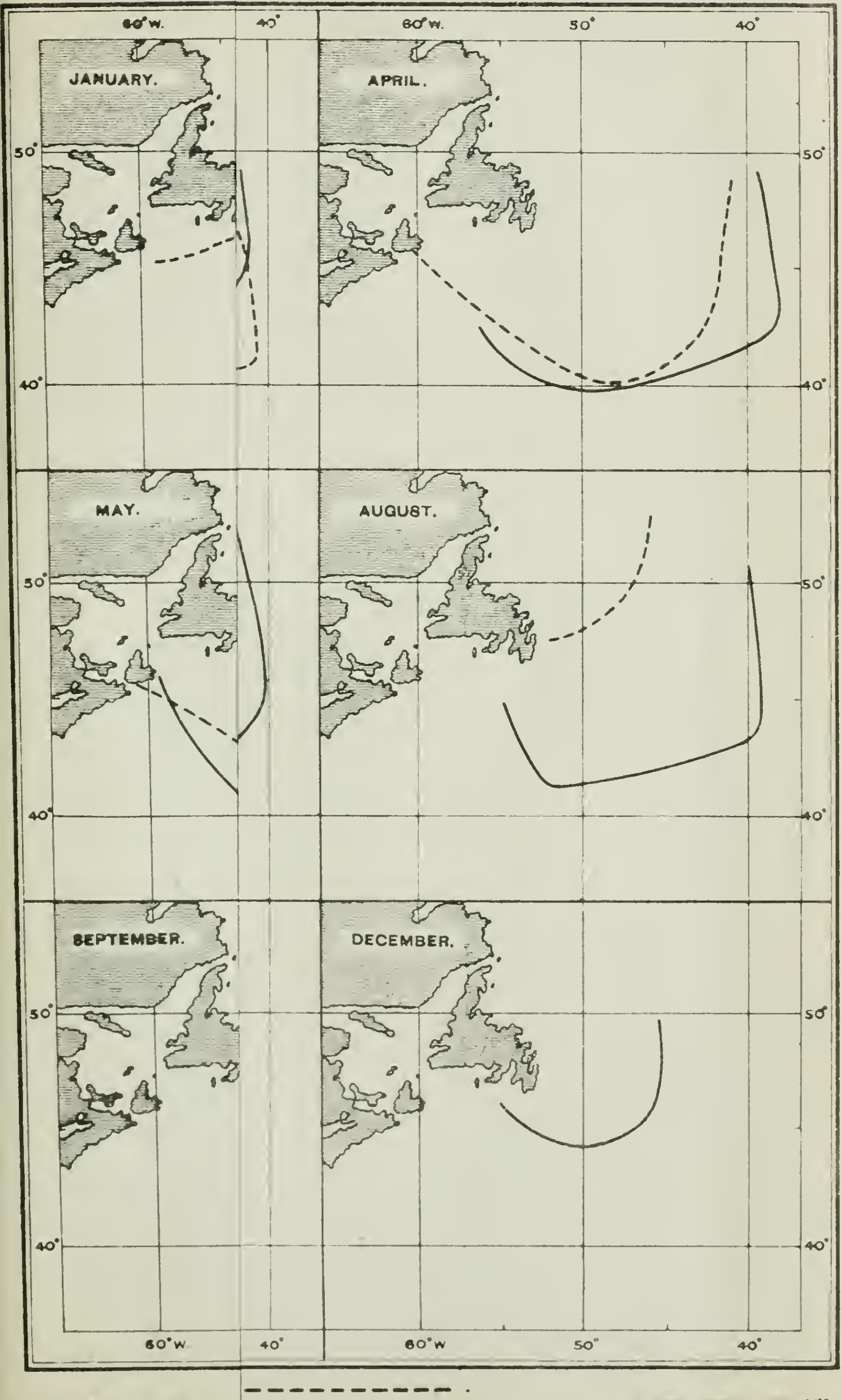

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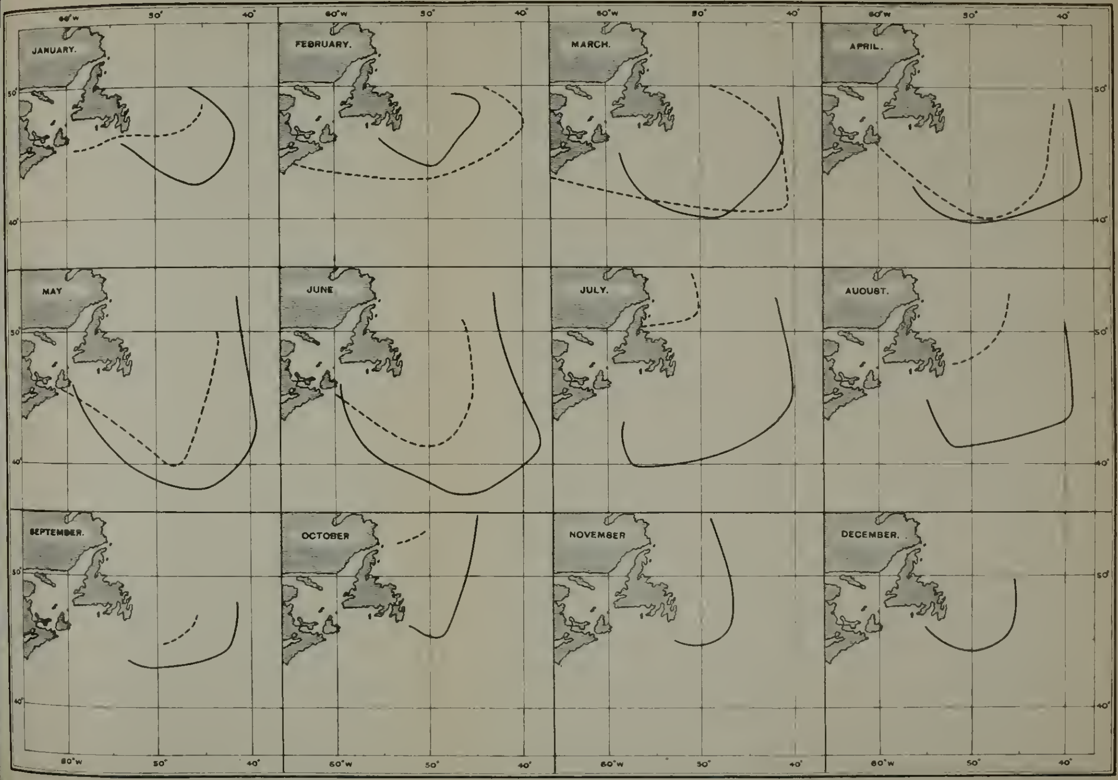
EXTREME LIMITS OF ICEBERGS AND FIELD ICE
on and in the neighbourhood of
THE GRAND BANKS OF NEWFOUNDLAND DURING THE PERIOD 1901-1912.

Prepared from the data given on the Monthly Meteorological Charts of the North Atlantic and Mediterranean.



LIMITS OF ICEBERGS. ————————, LIMITS OF FIELD ICE. – – – – – – – – – – – –

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course being deflected to the westward, it joins the ice which is being carried southward by the current from Baffin Bay.

Ice Frequency in North Western Atlantic.

Icebergs and field ice reach the trade routes earlier in some years than in others. Reports of ice increase, as a rule, from January or February to May or June, but in some years the maximum quantity reaches the area frequented by shipping as early as April or as late as August. During the ten years period 1903–1912 the maximum number of ice reports received per month at the Meteorological Office through various sources, from steamers engaged in North Atlantic trades, related in seven of these years to the month of May, in two of the years to the month of April, and in the remaining year to the month of July.

Field and slob ice usually melt away rapidly after April; it may beset a vessel, for instance, in the evening, yet have disappeared on the following morning.

Ice Limits.

The southern and eastern limits of ice in the North-Western Atlantic vary from month to month, and from year to year. The extreme limits of icebergs and of field ice on and in the neighbourhood of the Grand Banks of Newfoundland during the twelve years ended December, 1912, is shown for each month in the maps on Plate XXI, which are supplemented by a statement in Table 3.*

The earliest date on which ice of any kind was observed in the North Atlantic each year, from 1903 to 1912 inclusive, and was subsequently reported from a reliable source to the Meteorological Office, was 6th March, 9th February, 18th January, 2nd January, 2nd February, 1st January, 24th January, 2nd March, 28th January, and 7th January respectively.

Drifting ice may, however, be observed in almost any part of the North Atlantic north of 30° N. latitude, about as far east as the 10th meridian of west longitude on the eastern side of the ocean; and about as far west as the 75th meridian on the western side, north of 35° N.

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* "Monthly Meteorological Charts of the North Atlantic and Mediterranean for March, 1913." Issued by the Authority of the Meteorological Committee.

TABLE 3.

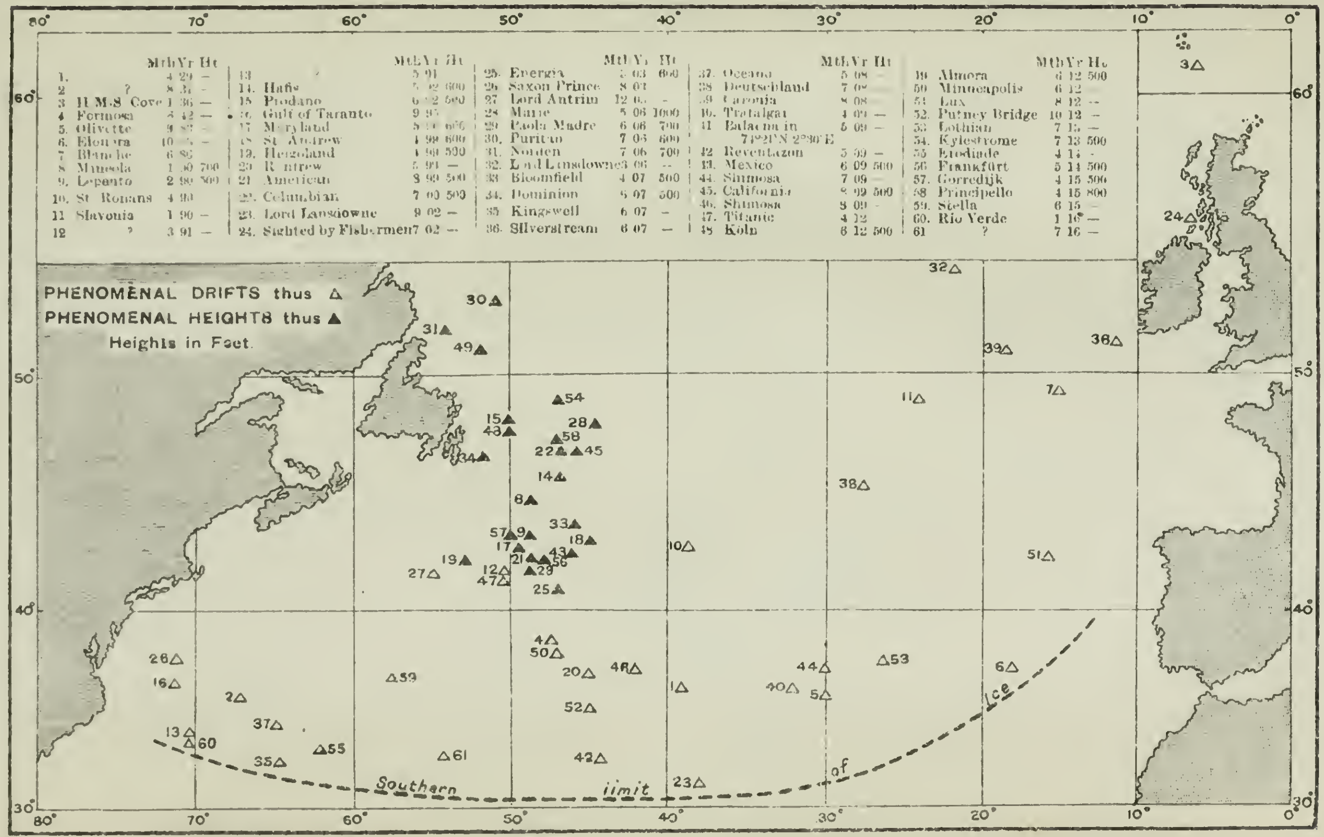
EXTREME LIMITS, 1901–1912.

Year.	FARTHEST SOUTH.									
	Icebergs.					Field Ice.				
	Lat. N.		Long. W.		Month.	Lat. N.		Long. W.		Month.
	°	'	°	'		°	'	°	'	
1901	41	0	47	25	July	—		—		—
1902	42	30	43	32	July	41	30	48	38	April
1903	40	50	45 55	0 to 0	March June	41	50	50 51	0 to 0	April
1904	40 40	10 10	49 47	45 10	April June	42	10	48 49	0 to 0	May
1905	39	40	48 49	30 to 30	May	41	45	50 51	0 to 0	April
1906	39	40	46 48	30 to 0	May June	42	0	50 51	0 to 0	May
1907	40	0	48	0	March	43	40	58	0	April
1908	41	0	46 49	0 to 0	June	41	50	49	0	July
1909	41	0	48	0	June	41	40	51	0	May
1910	42	50	49	30	April	42	0	49	0	March
1911	40	10	57	0	July	42	10	52	0	April
1912	35	15	44	50	October	40	0	47	10	May
1901 to 1912	35	15	44	50	October	40	0	47	10	May

EXTREME LIMITS, 1901–1912.

Year	FARTHEST EAST.									
	Icebergs.					Field Ice.				
	Lat. N.		Long. W.		Month.	Lat. N.		Long. W.		Month.
	°	'	°	'		°	'	°	'	
1901	47	11	42	58	July	—		—		—
1902	46	0	42	47	July	41	30	48	38	April
1903	43	30	38	0	May	46	20	43	30	April
1904	46	0	41	0	April	46	50	47	0	April
1905	43	30	41	0	May	43	30	44	0	April
1906	41	0	38	0	June	46	0	45	30	March
1907	41	50	39	50	May	47	50	45	0	April
1908	46	15	42	0	May	43	50	46	30	July
1909	44	0	40	20	May	46	30	40	0	March
1910	44	20	39	20	August	46	0	45	50	April
1911	43	50	41	0	July	47	30	45	0	March
1912	42	3	15	26	May	45	36	42	32	April
1901 to 1912	42	3	15	26	May	46	30	40	0	March

NORTH ATLANTIC ICE—PHENOMENAL DRIFTS AND HEIGHTS.



		Mth	Yr	Ht
1.		4	29	—
2	?	8	[illegible]	—
3	H.M.S Cove	1	36	—
4	Formosa	3	42	—
5.	Olivette	9	87	—
6.	Eleonora	10	[illegible]	—
7	Blanche	6	86	
8	Mineola	1	90	700
9.	Lepanto	2	90	500
10.	St Romans	4	90	
11	Slavonia	1	90	—
12	?	3	91	—
13		5	91	
14.	Hafis	5	92	600
15	Prodano	6	92	500
16.	Gulf of Taranto	9	95	
17	Maryland	5	[illegible]	[illegible]
18	St Andrew	4	99	600
19.	Helgoland	4	99	500
20	Renfrew	5	99	—
21	American	8	99	500
22.	Columbian	7	00	500
23.	Lord Lansdowne	9	02	—
24.	Sighted by Fishermen	7	02	—
25.	Energia	5	03	600
26	Saxon Prince	8	03	
27	Lord Antrim	12	[illegible]	–
28	Marie	5	06	1000
29	Paola Madre	6	06	700
30.	Puritan	7	06	600
31.	Norden	7	06	700
32.	Lord Lansdowne	3	06	—
33	Bloomfield	4	07	500
34.	Dominion	5	07	500
35	Kingswell	6	07	—
36.	Silverstream	6	07	—
37.	Oceana	5	08	—
38	Deutschland	7	08	—
39	Caronia	8	08	—
40.	Trafalgar	4	09	—
41	Balaena in 74°21'N 2°30'E	6	09	—
42	Reventazon	5	09	—
43.	Mexico	6	09	500
44.	Simoosa	7	09	—
45.	California	8	09	500
46.	Shimosa	8	09	-
47.	Titanic	4	12	
48	Koln	6	12	500
49	Almora	6	12	500
50	Minneapolis	6	12	—
51	Lux	8	12	—
52.	Putney Bridge	10	12	—
53	Lothian	7	13	—
54.	Kylestrome	7	13	500
55	Etodiade	4	14	-
56	Frankfurt	5	14	500
57.	Gorredijk	4	15	500
58	Principello	4	15	800
59.	Stella	6	15	—
60.	Rio Verde	1	16	—
61	?	7	16	—

From "Monthly Meteorological Charts of the North Atlantic and Mediterranean,"

Ps 3222 15940, 44 10000. 1/18.

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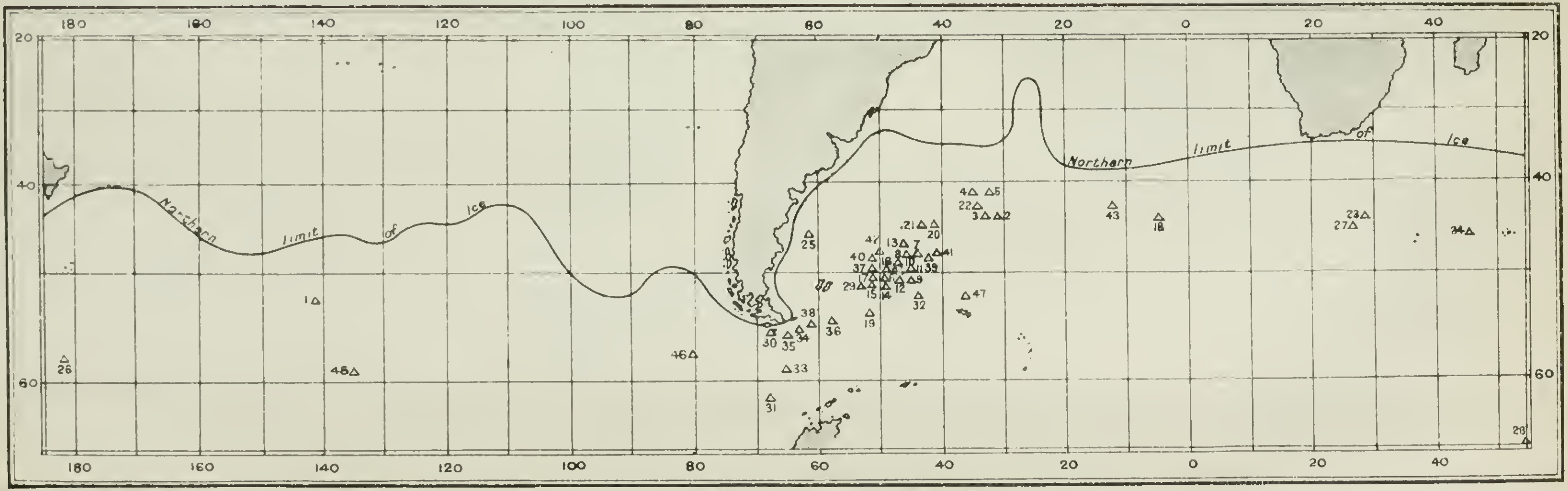
SOUTHERN OCEAN ICE.—PHENOMENAL LENGTHS.

No.	Ship reporting	Year.	Mnth.	Length in miles.	No.	Ship reporting.	Year.	Mnth	Length in miles.	No.	Ship reporting.	Year.	Mnth.	Length in miles.	No.	Ship reporting.	Year	Mnth.	Length in miles.
1	Marianna	1891	Feb.	10	13	Coldinghame	1893	Feb.	10	25	Garnet, H.M.S	1894	June	10	37	Dumfriesshire	1908	Mar.	11
2	Strathdon	1892	May	40	14	Francis	,,	,,	6	26	Antarctic	,,	Nov.	70	38	Sabroan	,,	,,	10
3	Alice	,,	June	40	15	Æthelberht	,,	Mar	82	27	Erin's Isle	1895	April	6	39	Cognati	,,	Aug.	10
4	Parsee	,,	,,	40	16	Persian Empire	,,	,,	16	28	Valdivia	1898	Dec.	10	40	Dee	,,	Sept.	50
5	Kinfauns	,,	July	12	17	Chili	,,	,,	15	29	Bengairn	1899	Sept.	8	41	Francois d'Amboise	,,	,,	7
6	Marianna	,,	Aug.	9	18	Loch Eck	,,	Sept.	10	30	Anglesey	1902	,,	10	42	Lakemba	,,	,,	60
7	Drumcraig	,,	Dec.	25	19	British Empire	,,	,,	9	31	Eugenie Fautrel	,,	,,	7	43	Maletta	1909	Mar.	6
8	Florence	,,	,,	10	20	Salamis	,,	Nov.	6	32	Zinita	1904	Nov	7	44	Foohng Suey	1910	June	50
9	Loch Torridon	1893	Jan.	50	21	Beechwood	,,	Dec.	18	33	Pythomene	1905	June	20	45	Marere	1911	Feb.	10
10	Ariadne	,,	,,	30	22	Scottish Dales	1894	Jan.	7	34	Bangalore	,,	,,	10	46	La Rochejacquelin	,,	Oct.	6
11	Hurunui	,,	Feb.	25	23	Anna	,,	Feb.	8	35	S. Celeste	,,	,,	8	47	Ramleh	1916	Aug.	30
12	Cutty Sark	,,	,,	19	24	Blairhoyle	,,	,,	8	36	Rhuddlan Castle	,,	Aug	12					



From observations collated in the Meteorological Office.

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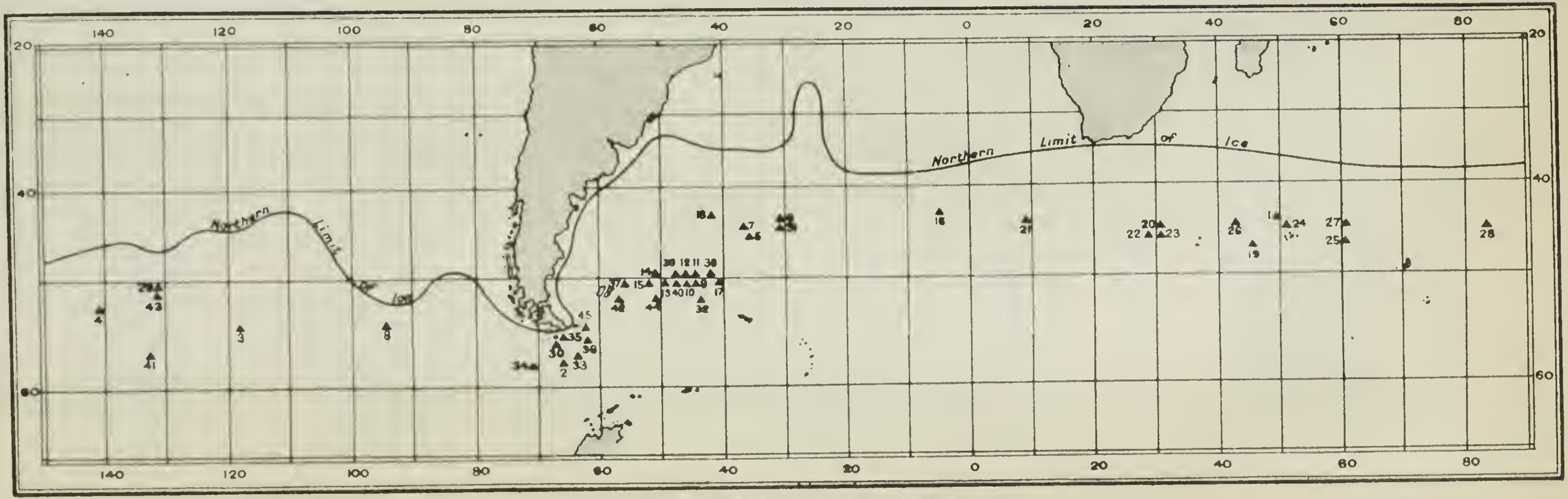
To face p. 134.

PLATE XXIV

SOUTHERN OCEAN ICE.—PHENOMENAL HEIGHTS.

No.	Ship reporting.	Year	Mnth.	Height in feet.	No.	Ship reporting.	Year	Mnth.	Height in feet.	No.	Ship reporting.	Year.	Mnth.	Height in feet.	No.	Ship reporting.	Year.	Mnth.	Height in feet.
1	Emil Julius	1884	June	1,700	12	Atalanta	1893	Mar.	980	23	Loch Bredan	1895	Dec.	900	34	Poltalloch	1906	June	800
2	Richard Wagner	1887	Sept.	900	13	Marion Inglis	,,	,,	800	24	Charles Racine	1896	,,	1,500	35	Bossuet	,,	July	1,000
3	Noel	1890	Oct.	1,000	14	Brier Holme	,,	April	1,000	25	Port Melbourne	,,	,,	820	36	Palgrave	,,	,,	800
4	Marianna	1891	Feb.	1,000	15	Charles Racine	,,	May	1,000	26	Ellora	1897	Jan.	800	37	Smeroe	,,	Oct.	800
5	Croundale	1892	April	1,000	16	Loch Eck	,,	Sept.	1,000	27	Nineveh	,,	,,	800	38	Cognati	1908	Aug.	1,300
6	Strathdon	,,	May	1,000	17	Woosung	,,	,,	980	28	Gulf of Bothnia	,,	Feb.	800	39	Walden Abbey	1909	Dec.	1,000
7	County of Edinburgh	,,	June	900	18	Pisagua	,,	Nov.	900	29	Loch Katrine	1901	Sept.	1,000	40	Eugene Pergeline	1910	Jan.	980
8	Liverpool	,,	Oct.	800	19	Barmen	1894	Jan.	890	30	Sokoto	1902	,,	1,000	41	Invertay	,,	Feb.	1,000
9	Loch Torridon	1893	Jan.	1,500	20	Lodore	,,	,,	800	31	Curzon	,,	Oct.	1,000	42	Halewood	,,	Aug.	1,000
10	Cutty Sark	,,	Feb.	1,000	21	Rigel	,,	Nov.	830	32	Zinita	1904	Nov.	1,500	43	Wynford	1911	May	1,000
11	Turakina	,,	Mar	1,200	22	Culgoa	1895	Dec.	900	33	Belen	1906	May	1,000	44	Havrsfjord	1912	,,	800
															45	Metropolis	,,	Aug.	1,000



From observations collated in the Meteorological Office.

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Phenomenal Drifts of Icebergs and Bergs of Exceptional Height.

Phenomenal drifts of ice in the North Atlantic are charted on Plate XXII, which shows also the positions in which a number of icebergs of exceptional height have been seen. The names of the ships from which the respective bergs or fragments of bergs were sighted are given with a reference number at the head of the chart.

Effect of Weather Conditions upon Ice Drift into the North Atlantic.

The quantity of ice which drifts into the North Atlantic each year depends for the most part probably upon the meteorological conditions that have obtained in that ocean and in the adjoining arctic region during the previous summer ; also upon the velocity of the Labrador current during the intervening period. When the prevailing distribution of atmospheric pressure during the summer is such as to direct the majority of east-moving areas of low pressure into paths that invade high latitudes—that is to say, when pressure is relatively high over the temperate zone of the North Atlantic and relatively low over the adjoining Arctic region—the paths of depressions coming from westward are deflected to the north-eastward, with the result that the weather conditions in the latter region are of a stormy character, and therefore favourable to the disruption of ice. Such a distribution of pressure prevailed during the summer of 1910, when the captains of whaling ships experienced strong winds and gales in Davis Strait and Baffin Bay during the greater part of the whaling season.

Moreover, in the four months January to April of the following year the Labrador current appears to have been unusually active, and the quantity of ice in the North Atlantic increased from January to May, rapidly to April, when it was exceptionally large, and icebergs had drifted unusually far south and east.

The Loss of s.s. "Titanic."

On the 14th of April, 1912, the new White Star liner *Titanic* struck an iceberg in lat. 41° 16′ N., long. 50° 14′ W., and foundered. Several other steamers sustained damage through collision with ice.

Velocity of Labrador Current.

The rate at which the cold ice-bearing current from Arctic Seas moves southward has been found to vary near the coast of Labrador from 10 to 36 miles a day, and occasionally, when southerly gales prevail, to cease.*

The influence of the wind upon its rate of motion is considerable, especially near the coast, and its volume is greatly increased during the spring and summer by the melting of ice in the Arctic Seas. The current attains its maximum velocity after northerly winds; its average rate near the land is 11 miles a day. Although the general trend of the current is to southward, its course is not infrequently deflected to the eastward or westward by the wind, and it has been stated that icebergs, within the average limits of the stream, have been known to move northward, "without any apparent cause."*

ICE IN THE SOUTHERN HEMISPHERE.

Phenomenal Lengths of some Southern Ocean Icebergs.

The majority of icebergs in the Southern Hemisphere, as previously mentioned, are tabular in form, and originally formed part of an ice barrier. Many of them are remarkable for their great length: south of the 40th parallel bergs from 5 to 20 miles long are frequently sighted, and the length of a few has been estimated at 50 miles and upwards.

Phenomenal Heights of some Southern Ocean Icebergs.

Numbers of southern ocean bergs are equally remarkable in consequence of their great height, for an altitude of 800 feet is by no means uncommon. Some that have been reported since the year 1884 are stated to have reached a height of from 800 to 1,700 feet from water line to summit.

The Positions in which phenomenally Long and phenomenally High Bergs were Observed.

The positions in which many of these icebergs of phenomenal length and of phenomenal height were observed are shown in the maps given on Plates XXIII and XXIV respectively. The name of the ship from which each berg was observed, the year and month on which it was sighted, the length or the height of the berg regarded as phenomenal,

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* "Newfoundland and Labrador," No. 73, 1899. Published by the United States Hydrographic Office.

as the case may be, and the number by which it can be identified, is indicated in the table at the head of each map. In addition, the extreme northern limit of ice is defined by a fine line.

The barrier of ice capable of producing icebergs of such remarkable dimensions as those referred to must extend for a long distance seaward from the land, and border uninterruptedly a far reaching coastline.

The Discoveries of Ross.

Such an ice barrier was first discovered by the eminent explorer, Captain (afterwards Admiral) Sir James Clark Ross, R.N., F.R.S., who, with H.M. ships *Erebus* and *Terror* under his command, visited the Antarctic in the years 1841 and 1842.

Victoria Land.

Ross discovered a continent south of 70° 30′ S. latitude, west of 71° E. longitude, to which he gave the name *Victoria Land* ; and subsequently sailed more than 400 miles along an ice barrier, the height of which he estimated at about 150 feet to 200 feet, to the eastward of an island which bears his name, the eastern extremity of which is situated in 77° 29′ S. ; 169° 32′ E.

The Great Ice Barrier.

In his narrative of this Expedition of Scientific Research to the Antarctic Regions,* Sir James Ross thus records his first impressions of the *Great Icy Barrier*, as he termed it :—

> As we approached the land (Ross Island) under all studding sails, we perceived a low white line extending from its eastern extreme point as far as the eye could discern to the eastward It presented an extraordinary appearance, gradually increasing in height, as we got nearer to it, and proving at length to be a perpendicular cliff of ice, between one hundred and fifty and two hundred feet above the level of the sea, perfectly flat and level at the top, and without any fissures or promontories on its even seaward face. What was beyond it we could not imagine ; for being much higher than our mast-head we could not see anything except the summit of a lofty range of mountains extending to the southward as far as the seventy-ninth degree of latitude.
>
> * * * * * *
>
> If there be land to the southward, it must be very remote or of much less elevation than any other part of the coast we have seen, or it would have appeared above the barrier.

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* "A Voyage of Discovery and Research in the Southern and Antarctic Regions, during the years 1839–43." By Captain Sir James Clark Ross, R.N., Knt., D.C.L., Oxon., F.R.S., &c.

Ross on the Disruption of Ice Barriers.

Ross, referring to the disruption of ice-barriers, expresses the opinion that in the winter, when the temperature of the air is probably forty or fifty degrees below zero, and the sea from twenty-eight to thirty degrees above, the unequal expansion of the mass exposed to so great a difference of temperature cannot fail to produce the separation of large portions of the barrier, which are driven to the north by the prevailing wind. In arctic regions, he adds, he had often witnessed the astonishing effects of a sudden change of temperature during the winter season, causing great rents and fissures of many miles extent.

United States Expedition under Wilkes.

While engaged in an exploring and surveying expedition during the years 1838 to 1842 inclusive, Captain Charles Wilkes, U.S.N., with the United States ships *Vincennes*, *Porpoise*, and *Peacock* under his command, visited the Antarctic in 1840 prior to the arrival of Ross in south polar regions.

Wilkes discovered land and encountered ice barriers in several localities between the 67th and 64th parallels of south latitude, and the 160th and 76th meridians of east longitude.

In some localities the barrier extended as far as the eye could reach, and along one stretch of it where the land appeared behind his ship sailed for more than 50 miles, the obstruction presenting the appearance of a straight and perpendicular wall of ice, the altitude of which he estimated at from 150 to 250 feet from sea level to summit.

The icebergs afloat near the barrier were from a quarter of a mile to five miles in length.

Wilkes on the Formation of Ice Islands.

Captain Wilkes mentions in his account of the voyage* that the formation of *ice islands*, a name given to the larger icebergs by early navigators of far Southern Seas, claimed much of his attention ; and he arrived at the conclusion that these masses of ice increase in bulk after they have separated from the parent barrier by means of the accumulation of rain, snow, and moisture deposited in fogs. It might, he

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* "Narrative of the United States Exploring Expedition during the years 1838, 1839, 1840, 1841, and 1842." Vol. II. By Charles Wilkes, U.S.N., Commander of the Expedition, 1845.

thought, be safely asserted that icebergs are at all times increasing in size while in antarctic seas, because the days are few, according to his experience, in which precipitation in some form, does not take place in those high latitudes. Observations on the temperature of the sea, taken by the expedition, led him to believe that these ice islands undergo little change by the process of melting before they reach the latitude of 60°.

Borchgrevink's Expedition in "Southern Cross."

Mr. C. E. Borchgrevink, Kt. St. Olaf, the leader of a British Antarctic Expedition undertaken in the ship *Southern Cross* during the years 1898–1900, was the next explorer to visit South Victoria Land and examine the great ice barrier in the Ross Sea.

In the book he published* soon after the return of the expedition, Borchgrevink alludes to the formation of antarctic icebergs, and expresses the opinion that they are either of glacial or barrier origin.

The Birth of an Iceberg.

While collecting specimens of rocks and vegetation at the foot of Mount Terror, Ross Island, he witnessed the calving of an iceberg from a glacier, situated immediately to the west of the little beach on which he and the captain of the *Southern Cross* had been landed, and thus he describes the incident:—

> With a deafening roar a huge body of ice plunged into the sea, and a white cloud of water and snow hid everything before our eyes.

The plunge of this mass of ice, weighing, as he affirms, millions of tons, raised a wave which he judged to have been from 15 to 20 feet in height; and had it not been for a projecting ice slope, which broke the force of the wave as it advanced up the beach, he and his companion would, he believed, have been smashed by it against the rock to which they were both clinging.

Swedish Expedition under Nordenskiöld.

Dr. Otto Nordenskiöld, the leader of the Swedish Antarctic Expedition, in the ship *Antarctic*, during the years

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* "First on the Antarctic Continent: being an Account of the British Antarctic Expedition, 1898–1900." By C. E. Borchgrevink, F.R.G.S., Commander of the Expedition.

1902–1903, discovered, while cruising in the neighbourhood of Terre Louis Philippe in about 65° S. latitude, 57° W. longitude, a perpendicular barrier of ice, which appeared to rise 130 feet above the water, stretching as far as the eye could reach.

Scott on the Origin of Icebergs.

In the year 1902, the ship *Discovery*, of the National Antarctic Expedition, under the command of the heroic seaman the late Captain Robert Falcon Scott, C.V.O., R.N., cruised along the full extent of the great ice barrier in the Ross Sea, which was closely inspected, prior to and after the discovery of land to the eastward of the 160th meridian of west longitude, to which he gave the name King Edward VII. Land.

In his graphic narrative of this expedition,* Scott says that although the barrier was not more than 70 feet high when they started to cruise along it on the morning of the 23rd January, 1902, by the evening of the 23rd it had risen to a height of 240 feet, and subsequently the *Discovery* passed close to a *sheer wall of ice* 280 feet high.

With reference to the origin of the icebergs that were observed in the Ross Sea, Captain Scott states that the main supply is derived from this barrier and from King Edward VII. Land, the latter presumably from a glacier ; for, he says, the glaciers in Victoria Land are in a condition of stagnation, and nearly all the bergs that were met with along the coast came from the east. He mentions that from Cape Adair (the northernmost point of South Victoria Land) to Cape Crozier (Ross Island), only two *icefloes* were observed that were capable of giving off a clean tabular berg of any dimensions.

The positions of the localities referred to in the foregoing are shown in the map of the Antarctic on Plate XXV, which is also intended to indicate, in a general manner, the area over which, according to our present imperfect knowledge, the polar ice-cap extends.

In his remarks upon the size and form of icebergs in southern seas, he alludes to the early southern voyagers, who doubtless had a knowledge of the bergs of the Northern Hemisphere, but in the Southern Ocean met with masses of ice incomparably larger than anything they had seen in the north ; and that to these they gave the name *Ice Islands* ; a

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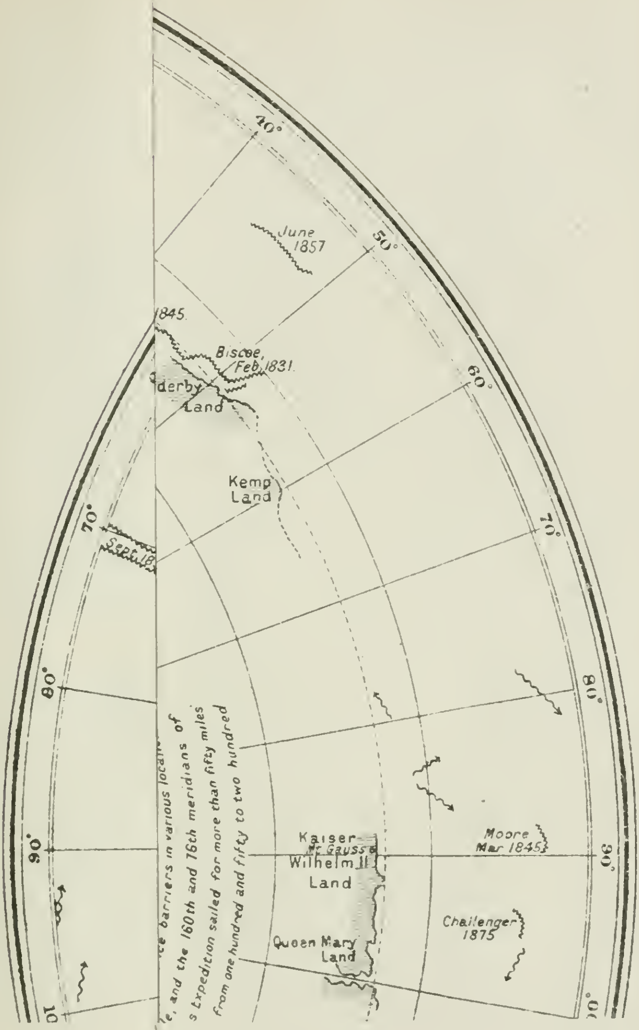
* "The Voyage of the *Discovery*." By Captain Robert F. Scott, C.V.O., R.N. London : Smith, Elder & Co., 1905.

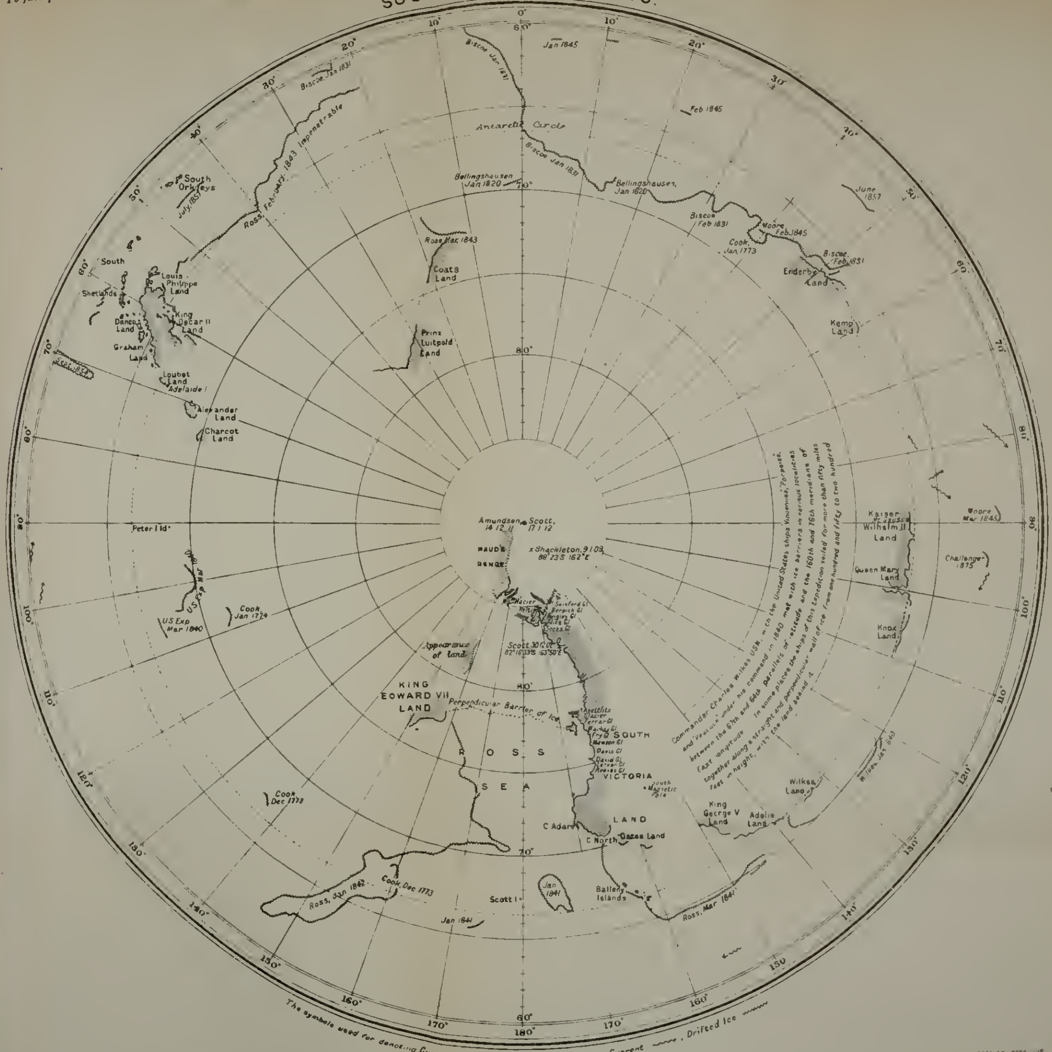
PLATE XXV.


40°
50°
60°
70°
80°
90°
June 1857
1845.
Biscoe, Feb. 1831.
derby Land
Kemp Land
Sept. 18
ce barriers in various locali
e, and the 160th and 76th meridians of
s Expedition sailed for more than fifty miles
from one hundred and fifty to two hundred
Kaiser Wilhelm II Land
Gauss
Moore Mar 1845
Challenger 1875
Queen Mary Land
70°
80°
90°
100°
10

To face p. 140.

PLATE XXV.

SOUTH POLAR REGIONS.



Commander Charles Wilkes USN, with the United States ships Vincennes, Porpoise, and Peacock under his command in 1840 met with ice barriers in various localities between the 67th and 64th parallels of latitude and the 160th and 76th meridians of East longitude. In some places the ships of this Expedition sailed for more than fifty miles together along a straight and perpendicular wall of ice from one hundred and fifty to two hundred feet in height, with the land behind it.

The symbols used for denoting Current and Drifted Ice are as follow – Current ~~~, Drifted Ice ~~~

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name which even Cook preserves in describing the long tabular iceberg which is typical of the southern regions.

Except, Scott remarks, in cases where they have suffered denudation or have lost stability and capsized, the shape of Antarctic icebergs is uniform : they are flat-topped and wall-sided, and appear to have broken away from some huge sheet of ice.

Calving of Icebergs from High Cliffs.

The *Discovery* passed innumerable bergs aground on the shoals off King Edward VII. Land, some very large ; one or two small bergs were seen in the act of calving from the high cliffs in the neighbourhood, but none were observed separating from the ice barrier.

Icebergs are rarely seen in the southern seas between the meridians of 130° E. and 170° W. within the parallels of latitude frequented by shipping, and during the seven months April to October that zone is practically ice-free.

Drifting ice in temperate latitudes of the Southern Hemisphere is exclusively in the form of bergs.

Ice Frequency in Southern Ocean.

The number of icebergs observed yearly in those latitudes varies considerably ; the number reported each month during each of the twenty-eight years 1885 to 1912 is set forth in Table 4 ; the total number of bergs reported in each of these years is also stated, as well as the total number during the whole period.

It will be noticed that in each of the seven years 1885 to 1891, and again in the years 1898, 1899, and 1900 th number of icebergs reported was small ; whereas in the years 1892, 1908 the number was large, and in the years 1893, 1906 excessively large.

Yearly Variation in Ice Frequency.

This marked variation in ice frequency in southern seas may perhaps be due to causes similar to those suggested to explain the yearly variation in the quantity of ice which drifts into the North Western Atlantic ; it may depend chiefly upon the meteorological conditions over the Southern Ocean and the adjoining polar regions which have obtained during the previous summer, conjointly with the strength subsequently of the polar currents.

The map of the South Polar Regions on Plate XXV is supplemented by a map on Plate XXVI, on which the distribution of ice is shown in detail.

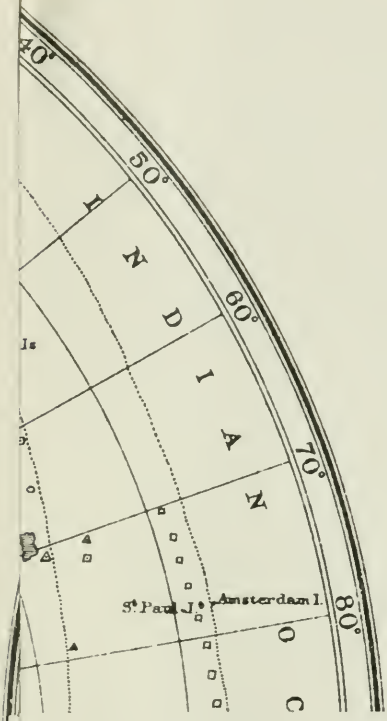
TABLE 4.

Number of Reports of Icebergs.

From Monthly Meteorological Charts of the Indian Ocean.

YEARS ...	85.	86.	87.	88.	89.	90.	91.	92.	93.	94.	95.	96.	97.	98.	99	00.	01.	02.	03.	04.	05.	06.	07.	08.	09.	10.	11.	12.	1885 to 1912.
MONTHS:—																													
January ...	0	1	0	1	0	4	0	2	19	12	5	1	30	3	11	0	2	5	4	9	1	14	9	3	9	14	1	1	161
February ...	0	0	1	0	0	0	1	3	26	11	12	0	7	1	1	2	5	4	5	2	0	25	6	5	5	5	2	1	130
March ...	0	1	1	1	0	0	2	1	51	5	6	0	9	2	2	0	3	1	3	4	1	7	0	33	4	7	0	1	145
April ...	1	0	0	0	0	0	1	5	29	8	9	0	0	1	4	2	0	3	2	1	0	3	0	34	1	3	4	2	113
May ...	0	0	0	0	0	1	0	6	20	6	1	3	0	1	0	1	0	1	1	3	0	20	2	11	5	6	7	2	97
June ...	0	0	0	0	0	1	0	19	16	2	11	2	1	1	0	0	1	1	2	1	1	31	0	4	2	11	3	0	110
July ...	0	0	0	0	2	1	0	8	5	0	15	3	0	0	0	1	1	1	9	4	0	40	1	4	1	17	6	0	119
August ...	0	0	0	1	2	0	1	17	2	2	7	6	0	2	1	1	5	2	4	1	1	35	1	17	2	20	3	3	136
September	0	0	1	0	0	1	0	16	14	1	1	1	0	1	3	1	12	14	3	8	1	19	4	30	2	8	3	6	150
October ...	0	0	1	1	0	2	0	24	19	4	3	11	0	0	0	1	8	9	4	10	0	17	1	6	3	2	7	3	136
November	0	0	4	0	0	3	3	3	29	7	3	14	4	0	2	1	2	5	8	6	0	49	9	11	8	4	17	2	194
December	0	0	0	1	2	1	13	4	26	5	8	13	6	2	0	5	2	5	6	3	7	44	3	13	18	1	4	3	195
Total for each Year.	1	2	8	5	6	14	21	108	256	63	81	54	57	14	24	15	41	51	51	52	12	304	36	171	60	98	57	24	1,686

PLATE XXVI



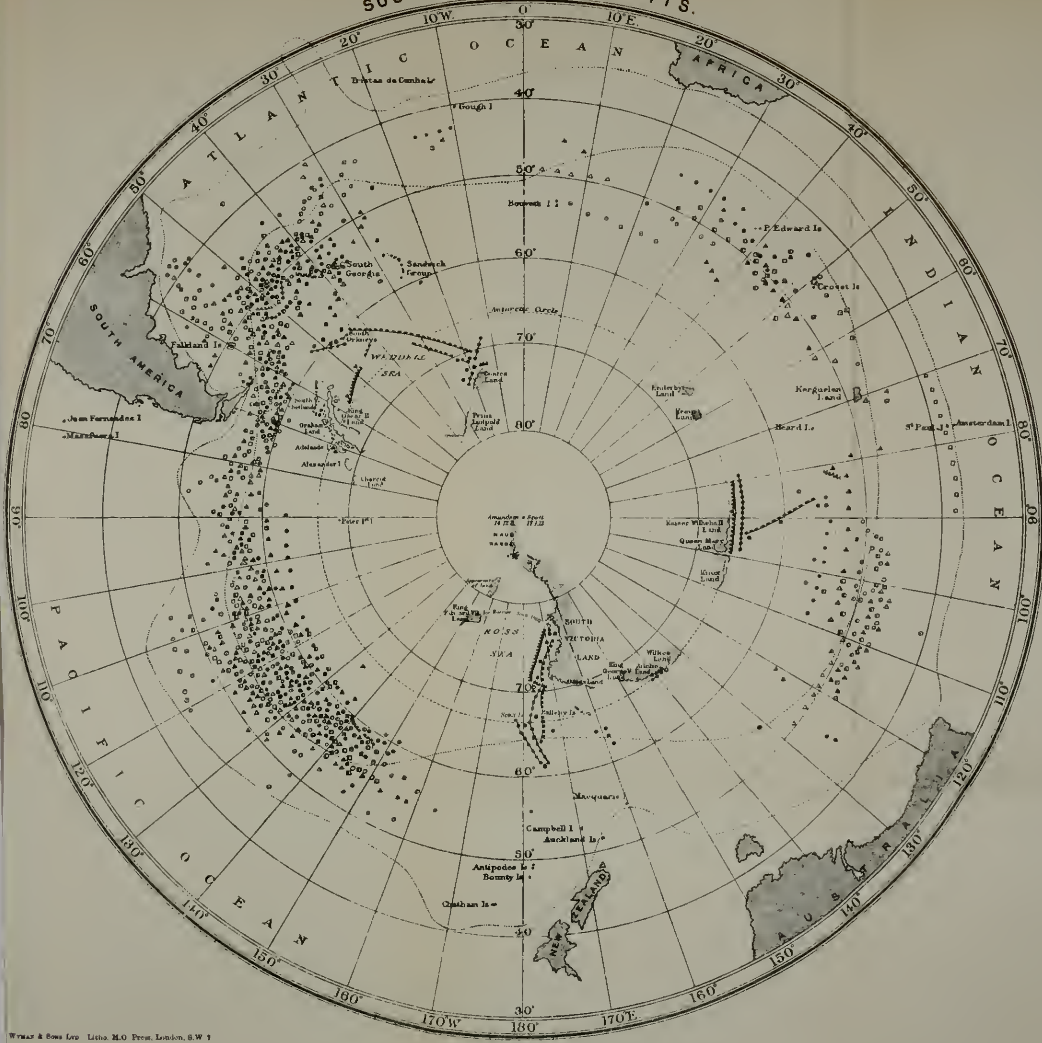
The northern limits of ice throughout the year lie between the two dotted lines that are drawn through all meridians. These limits are referred to observations that date back to the year 1772. The symbols employed to distinguish between the ice reports of the respective months are as follow :—

WINTER.

	Bergs.	Pack
July	△	⋀⋀⋀⋀
August	□	⎍⎍⎍
September	○	o-o-o-o

atmosphere. At the Meteorological Office the practice of

SOUTH POLAR ICE LIMITS.



The northern limits of ice throughout the year lie between the two dotted lines that are drawn through all meridians. These limits are referred to observations that date back to the year 1772. The symbols employed to distinguish between the ice reports of the respective months are as follow :—

WINTER

	Bergs	Pack
July	△	∧∧∧∧
August	□	⊓⊓⊓
September	○	○-○-○-○

SPRING.

	Bergs.	Pack
October	▲	▲▲▲▲
November	⊡	⊓⊓⊓
December	⊙	●-●-●-●

SUMMER.

	Bergs.	Pack
January	▲	▲▲▲▲
February	■	■■■
March	■	●-●-●-●

AUTUMN.

	Bergs.	Pack.
April	▲	▲▲▲▲
May	◘	⊓⊓⊓
June	●	○-○-○-○

The general distribution of ice, which can be seen at a glance, relates to the fifteen years 1902—1916.

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CHAPTER XI.

Meteorological Instruments.

The Barometer.

This is the technical name for the weather-glass, and is often called simply the *glass.* It is an instrument used for ascertaining the pressure of the atmosphere, or, to state the facts more correctly, for determining the pressure of the atmosphere by measuring the height of a column of mercury supported by it ; and it is so named from two Greek words—*baros*, weight, and *metron*, a measure.

Torricelli's Experiment.

If one end of a glass tube, about 33 inches long, be dipped into a bowl of mercury and an air pump applied to the other end a column of mercury will gradually rise in the tube as the pump is worked. It is pushed up by the air pressing on the surface of the mercury, and when the operation is complete, that is to say, when the mercury ceases to rise in the tube, it will stand at about 30 inches. We thus have a column of mercury supported by the pressure of the air.

The space left between the top of the column of mercury and the top of the tube will be a vacuum. In the barometer this is as nearly a perfect vacuum as can be produced. It is known as the *Torricellian* vacuum, because the original form of the apparatus was made in the year 1643 by an Italian named Torricelli.

As the mercury in the tube is held up by the pressure of the atmosphere on the mercury in the bowl—in other words, as the weight of the column of mercury exactly balances the pressure of the atmosphere—any variations in the pressure of the latter will be shown by corresponding variations in the height of the mercury column.

The apparatus used in making the experiment referred to is in truth a simple form of the Cistern Barometer, and would require only the addition of a fixed scale by which the height of the mercury column could be measured to make it serviceable for ascertaining the pressure of the atmosphere.

In this book the scale of the barometer is generally assumed to be a scale of inches of mercury which, when duly corrected for the difference of temperature from the freezing point of water and the difference of latitude from latitude 45°, gives a measure of the pressure of the atmosphere. At the Meteorological Office the practice of expressing the pressure of the atmosphere in so-called absolute units (centibars or millibars) instead of inches of mercury is now being introduced. The dial of the sea barometer shown in Fig. 21, p. 156, gives the relation of centibars to inches.

Action of Mercury Barometer analogous to that of Pump.

Mercury being thirteen and a half times as heavy as water, the latter could be raised from a well by means of an ordinary pump to a height of from 32 to 34 feet, provided a perfect vacuum could be obtained,* because a column of water 34 feet long has the same weight as a column of the atmosphere of similar transverse area. The atmosphere, pressing on the surface of the water in the well, forces the latter up the pipe when the piston is raised and the pressure from above thus removed ; but this action ceases as soon as the weight of the column of water in the pipe is equal to the pressure of the atmosphere.

Water can be raised by a pump to a somewhat higher level when the pressure of the atmosphere is abnormally great than when it is about normal and *vice versa* ; in like manner the column of mercury in a barometer tube will rise as the pressure of the atmosphere increases and fall when it diminishes ; and while pressure remains unchanged the mercury column will remain at rest. Thus, any variations in atmospheric pressure will be shown by corresponding variations in the height of the mercury.

The instrument known as the *Fishery Barometer*, a *weather-glass* lent by the Meteorological Office for the use of fishing communities, consists of a tube of large bore connected with a cistern, both containing pure mercury, the whole being mounted in a solid oak frame to which is attached a fixed scale, marked in inches and tenths of an inch from 26 to 31 inches ; and a sliding scale, or vernier, so called after its inventor, Pierre Vernier (A.D. 1630). In some instruments two verniers are fitted, one on each side of the scale. To the frame of the instrument there is also attached a thermometer, graduated from 0° to 120° Fahr. The vernier is moved by a rack and pinion, the latter fitted with a milled head for convenience of adjustment.

The thermometer connected with the instrument, called the *attached thermometer*, is required for the purpose of ascertaining what allowance should be made for temperature when correcting the barometer readings. The column of mercury in

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* In practice the height is not more than 27 feet.

the tube expands when heated, and a longer column of the lighter liquid is required ; it contracts, and a shorter column is required when cooled ; therefore, in order to render comparable readings of the barometer with those of instruments in other localities taken at the same time, it is necessary to know the temperature of the mercury in order that the readings may be reduced to a standard temperature. A temperature of 32° Fahr. has been adopted universally as the standard to which all barometer readings should be reduced.

A correction is also required to compensate for the variations of temperature of the brass scale when the scale is made of that metal.

Where great accuracy is required it is necessary to apply other corrections to barometer readings than those already mentioned ; one of these is a correction for index error, an error in the scale introduced in the process of graduation.

Cistern barometers are subject also to two other sources of error, one of these arising from what is called *capillarity* and the other from what is known as the *error of capacity*. The error arising from capillarity is due to the fact that mercury has no such attraction for glass as water has ; it does not wet it, and has therefore to overcome the resistance of the glass, and is in consequence somewhat depressed in the tube. The error of capacity results from changes of level in the cistern ; for when the mercury rises in the tube it leaves less in the cistern, thus lowering the level of the mercury in the cistern ; similarly, when it falls in the tube it raises the level of the mercury in this cistern. The capillarity correction, for a barometer, which is always additive, is the same for all readings of the instrument to which it applies.

Not infrequently the correction for index error, combined with that for capillarity, is expressed in one number, which is engraved on the scale of the barometer.

In a type of instrument known as *Fortin's Barometer*, in order to get rid of the error of capacity, the surface of the mercury in the cistern is temporarily adjusted to a level which corresponds with the zero of the scale. This is effected by raising, or lowering the base of the cistern, which is flexible, by means of a screw.

In the Kew pattern of barometer the error due to capillarity, and the error of capacity are both annulled in graduating the scale ; allowance being made, when the scale is laid off, by comparison with a standard instrument, for the depression of the mercury column in the tube through friction, and for the differences of level in the cistern created by the rise and fall of the mercury in the tube ; the allowance made for the latter depending upon the relative diameter of the tube and the cistern.

When barometer readings from different parts of the world have to be compared by plotting on a chart, and an accuracy of 100th of an inch is required, a correction for gravity also is now applied, because the earth being a spheroid, the force of gravity varies with latitude, and places at the equator are at a greater distance from the earth's centre than places at the poles. Barometer readings, therefore, are reduced to standard latitude, for which the parallels of 45° N. and 45° S. have been adopted. The corrections required in this connexion are as follow :—

CORRECTIONS for reducing BAROMETRIC READINGS to STANDARD GRAVITY in LATITUDE 45°.

Lat. N. or S.	Correction.		Lat. N. or S.	Correction.	
	At 27 inches.	At 30 inches.		At 27 inches.	At 30 inches.
	In.	In.		In.	In.
0	— ·070	— ·078	28	— ·039	— ·043
1	·070	·078	29	·037	·041
2	·070	·078	30	·035	·039
3	·070	·077	31	·033	·036
4	·069	·077	32	·031	·034
5	·069	·077	33	·028	·032
6	·068	·076	34	·026	·029
7	·068	·075	35	·024	·027
8	·067	·075	36	·022	·024
9	·067	·074	37	·019	·021
10	·066	·073	38	·017	·019
11	·065	·072	39	·015	·016
12	·064	·071	40	·012	·013
13	·063	·070	41	·010	·011
14	·062	·069	42	·007	·008
15	·061	·067	43	·005	·005
16	·059	·066	44	— ·002	— ·003
17	·058	·064	45	± 0	± 0
18	·057	·063	46	+ ·002	+ ·003
19	·055	·061	47	·005	·005
20	·054	·060	48	·007	·008
21	·052	·058	49	·010	·011
22	·050	·056	50	·012	·013
23	·049	·054	51	·015	·016
24	·047	·052	52	·017	·019
25	·045	·050	53	·019	·021
26	·043	·048	54	·022	·024
27	·041	·046	55	·024	·027

CORRECTIONS for reducing BAROMETRIC READINGS to STANDARD GRAVITY in LATITUDE 45°—*cont.*

Lat. N. or S.	Correction.		Lat. N. or S.	Correction.	
	At 27 inches.	At 30 inches.		At 27 inches.	At 30 inches.
	In.	In.		In.	In.
56	+ ·026	+ ·029	74	+ ·059	+ ·066
57	·028	·032	75	·061	·067
58	·031	·034	76	·062	·069
59	·033	·036	77	·063	·070
60	·035	·039	78	·064	·071
61	·037	·041	79	·065	·072
62	·039	·043	80	·066	·073
63	·041	·046	81	·067	·074
64	·043	·048	82	·067	·075
65	·045	·050	83	·068	·075
66	·047	·052	84	·068	·076
67	·049	·054	85	·069	·077
68	·050	·056	86	·069	·077
69	·052	·058	87	·070	·077
70	·054	·060	88	·070	·078
71	·055	·061	89	·070	·078
72	·057	·063	90	+ ·070	+ ·078
73	·058	·064			

For the correction of barometer readings in C.G.S. units, *see* pages 11–14.

The divisions of the fixed scale on a *Fishery Barometer* are each 0·1 of an inch. Eleven of these are taken as the length of the vernier, which is, therefore, 1·1 inch long. The vernier is divided into 10 equal parts, as seen in Fig. 12 from 1 to 10 ; thus each division is 0·11 inch in length, so that the difference in length between a division of the vernier and a division of the scale is 0·11 inch − ·10 inch = ·01 inch, and this arrangement enables the observer to ascertain the height of the barometer to the nearest 100th of an inch. This is the form of vernier originally proposed by its inventor, and it is one that is commonly attached to the scale of a Fishery Barometer (*see* Fig. 12). It has an advantage over other forms with respect to the clearness of its divisions, but it has to be numbered backwards, or in a contrary direction to the numbering of the fixed scale of the instrument.

To obtain a reading of this class of mercury barometer, the upper edge of the vernier should be brought into coincidence with the top of the mercury. Should the upper edge of the vernier happen to be in the same straight line as a division of the scale, then that division points out directly the reading to be recorded. If, however, the upper end of the vernier fall between two adjacent divisions of the scale, then the reading has to be obtained by use of the vernier. The observer should, therefore, look down the vernier for a division which coincides with one on the scale, and when found this division will indicate the reading to be recorded. For instance, by referring to the right-hand vernier in the accompanying illustration (Fig. 12) the upper end is seen to lie between 29·7 inches and 29·8 inches hence the barometer reading so indicated is above 29·7 inches, but below 29·8 inches. As it is necessary to determine the reading to the nearest 100th of an inch, the observer must look down the vernier, when it will be seen that the line marked 6 on the vernier coincides with a division of the scale and gives the reading in detail as follows :—

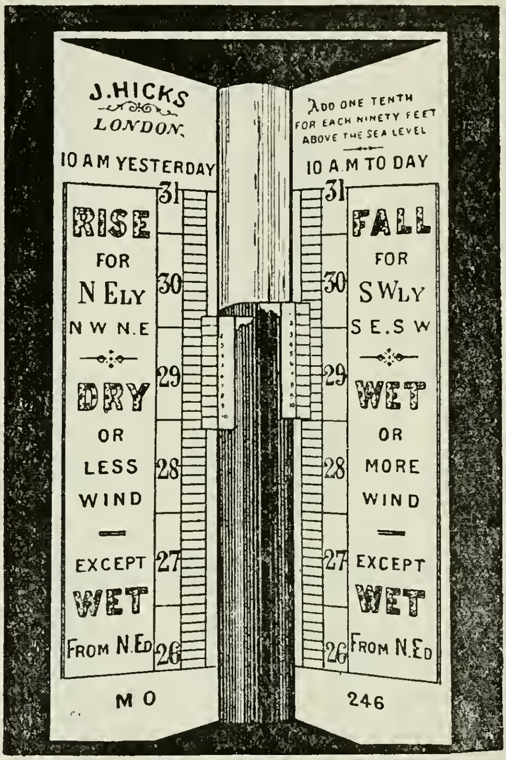

Fig. 12.

Reading on scale	29·70
Reading on vernier	·06
Actual barometer reading ...	29·76 inches.

Using the left-hand vernier a similar method is adopted. By referring to the illustration it will be seen that the upper end of the vernier lies between 29·6 and 29·7 on the scale, so that the barometer reading for that position of the vernier is slightly above 29·6 inches. Looking down the vernier it is found that the line marked 3 on the vernier coincides with a division on the scale, and this signifies that the upper end of the vernier is four hundredths of an inch above the 29·6 inch division of the scale. The reading set out in detail is :—

Reading on scale	29·60
Reading on vernier	·04
Actual barometer reading ...	29·64 inches.

In a Fishery Barometer of another pattern (M.O. 187) the divisions of the fixed scale are each 0·5 inch. Twenty-six of these divisions are taken as the length of the vernier, which is therefore 26 × ·05 = 1·3 inches long. This length is divided into 25 equal parts, as seen in Fig. 13, and thus each division of the vernier is 1·3 ÷ 25 = ·052 inch long ; so that the difference in length between a division of the vernier and one of the scale is ·052 inch − ·050 inch = ·002 inch. Looking down the vernier it is seen that the second line below the figure 4 lies evenly with a line on the scale. The figure 4 indicates ·04, and the second subdivision below it ·004, thus we have :—

Reading on scale	30·200
Reading on vernier	·040 ·004
Actual barometer reading ...	30·244 inches.

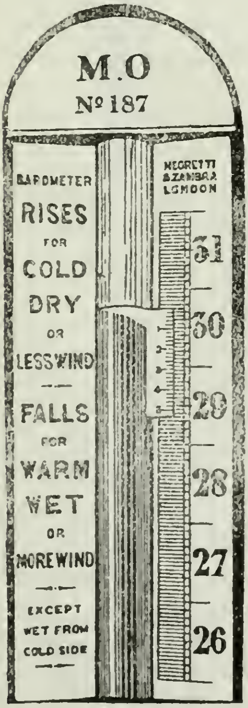

Fig. 13.

Fig. 14.
Kew Pattern Barometer.

Kew Pattern Barometer.

At Climatological and Telegraph Reporting Stations in the British Isles, the Kew Pattern Station Barometer is in general use. This mercury barometer (Fig. 14) consists of a glass tube closed at one end, which is filled with pure mercury before being connected with the cistern, all air being carefully excluded; the tube is then inverted and its open end immersed in the small cistern, also containing mercury, in such a manner as to preclude the possibility of air entering the tube. As air, even a minute quantity, is detrimental to the satisfactory working of the instrument, the utmost care is taken to exclude it. A small hole in the upper part of the cistern H admits access to the air, a washer of leather preventing the escape of mercury from the cistern, while permitting the atmosphere to exercise pressure upon it. About eight or nine inches from the top of the tube the bore is small downwards, and at the termination of this contracted portion of the tube, or in some other part of it, there is an air trap. In Fig. 15 a section of the greater part of a tube is shown, in which C is the contracted portion of the tube, A the air trap.

Fig. 15.

Barometer Tube, not drawn to scale.

The barometer is suspended in gimbals, and this method secures that the scale is vertical when the instrument is hanging quite freely. When in position, the top of the barometer should be at such a height that the observer can read the scale comfortably while standing upright, and, if possible, it should be so placed that the light comes slantwise from somewhere behind the observer.

In handling a barometer, it should be borne in mind that it is a delicate instrument. Should it be necessary to move the barometer, it should first be inclined slowly, so as to allow the mercury to flow gently to the top of the tube. Then, the tube being full, the instrument may be transported with safety in a horizontal or inverted position (cistern uppermost), but care must be taken not to subject it to concussion.

To mount the instrument, lift it carefully out of its case and slip the hinged part of the suspension arm into the socket. Take care that the screws which secure the instrument in its gimbals are screwed home, otherwise it may slip through its supports.

No observation should be taken until at least two hours have elapsed after mounting the barometer, in order that the mercury may have time to acquire the temperature of the air. The tube of some station barometers is so much contracted to avoid "pumping" that a considerable time is required for the mercury to reach its level after being first set up.

In standard barometers of the Kew pattern which are graduated in inches, the fixed scale is divided into inches, tenths and half-tenths, each of the last named therefore represent ·050 of an inch. Twenty-five divisions of the vernier are made to coincide with twenty-four of the smallest divisions of the fixed scale; a space on the scale, therefore, is larger than a space on the vernier by the twenty-fifth part of ·050, that is to say, by ·002 of an inch. In standard barometers which are graduated in millibars, the fixed scale is divided into centibars and millibars. The vernier for this scale covers thirty-nine divisions of the fixed scale, and therefore is less by one millibar-division than the length of forty millibars on the fixed scale.

The vernier of this instrument, like that of the Fishery Barometer, is moved by a rack and pinion, the latter carrying a milled head. The vernier is set for reading by turning the milled head until the front edge of the vernier is brought into alignment with the uppermost part of the convex surface of the mercury column, and the edge of the sliding piece at the back of the instrument. Great care should be taken to acquire the habit of setting the vernier when the eye is exactly on a level with the top of the mercury, that is, with the line of sight at right angles to the tube, which, while the observation is being made, should hang freely in a vertical position, because any inclination will cause the column to rise in the tube.

The sliding piece at the back of the instrument is provided in order to aid the observer by showing him when his eye is at the same level as the top of the mercury column, for should the observer's eye be too high or too low when setting the vernier, an error in the reading will result; such errors are known as *errors of parallax*, graphic representations of which are given in the accompanying diagram (Fig. 16).

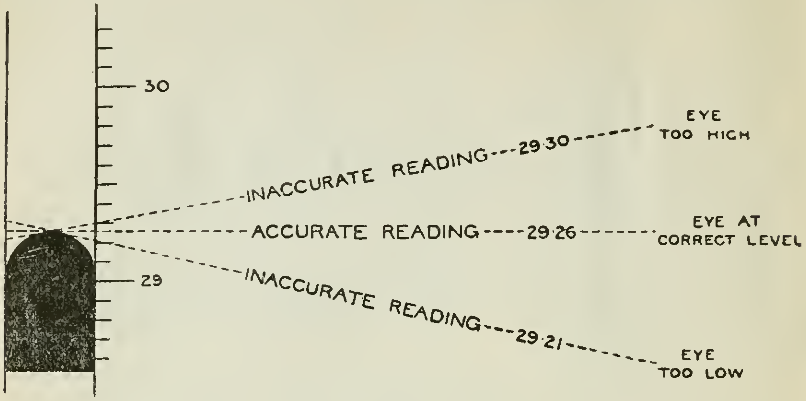

FIG. 16.

The mode of reading off the height can be understood best by the aid of the diagrams, Figs. 16 and 17, in which A B represents part of the scale, and C D the vernier, the lower edge of which, D, has been brought to coincide with the top of the mercury column.

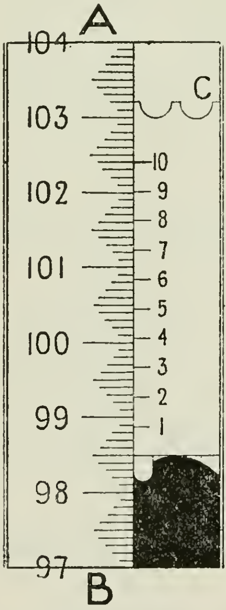

FIG. 17.

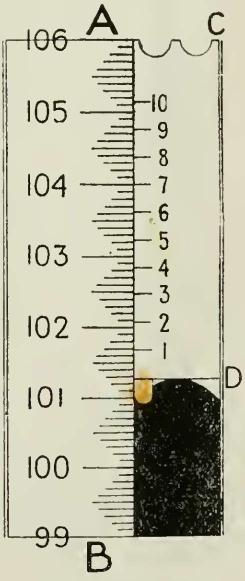

FIG. 18.

First.—Note the value of the scale division *next below* the zero division on the vernier marked D in Figs. 17 and 18. The scale is graduated in *millibars*, and numerical values in *centibars* are figured along it (10 millibars = 1 centibar).

In order to assist the eye when determining the value of a division, the millibar graduations are of unequal length. In Fig. 17, D is supposed to be in the same straight line with the fifth (the long) division above the scale division numbered 98, in other words with the graduation 985 millibars. In Fig. 18 the graduation next below D is the second above the graduation numbered 101 ; its value is therefore 1012 millibars.

Second.—Look along the vernier for a division which is in one and the same straight line with a scale division. The value of this division on the vernier gives the decimal place. In Fig. 17 the vernier division 0 is exactly coincident with a scale division ; the reading of the barometer is therefore 985·0. In Fig. 18 the vernier division 7 is exactly opposite a scale division ; the barometer reading is therefore 1012·7.

If the vernier has not been shifted between two observations, it is advisable to check the previous reading before proceeding to a fresh setting.

The mode of reading off the height, when the vernier has been set and the instrument is graduated in inches, may be learned from a study of the diagrams, Figs. 19 and 20 (p. 154), in which A B represents part of the scale, and C D the vernier, the lower edge of which, D, has been brought to coincide with the top of the mercury column.

The scale is readily understood : the bottom line at B represents 29·000 inches ; the first line or division above is 29·050 ; the second line or division 29·100, and so on. The scale division just below D must first be noted ; it is then necessary to ascertain which division on the vernier is on a line exactly with a division on the scale. In Fig. 19 the lower edge of the vernier, D, is represented in exact coincidence with the scale division 29·5 ; the barometer therefore reads, 29·500. It will be seen that the top of the vernier C again coincides with a line on the scale, and that all of the other divisions of the vernier are more or less separated from the divisions of the scale. As one division of the vernier is ·002 inch smaller than one division of the scale, consequently with the vernier in the position shown the division *a* is ·002 inch below the nearest line, *z*, of the scale. If, therefore, the vernier be moved upward, so as to place *a* in line with *z*, the edge D would be raised ·002 inch, and the reading would be 29·502, for this would be the height of D on the scale. In like manner it can be seen that *b* on the vernier is ·004 inch below the line next above it on the scale ; *c*, ·006 inch below that next above it ; *d*, ·008 inch from that next above it ; and 1, on the vernier, is ·010 inch below *y* on the scale. For this reason, if the lines *b*, *c*, *d*, and 1 be moved in succession into line with the divisions next above them, D would be raised ·004, ·006, ·008, and ·010 in succession, and would read 29·504, 29·506, 29·508, and 29·510 successively. Thus, coincidences of lines on the vernier and the scale at the numbers 1, 2, 3, 4, 5 on the vernier, indicate that D is raised above the scale line next below it by 1, 2, 3, 4, or 5 hundredths, and coincidences at the intermediate lines mark the intermediate even thousandths of an inch.

The application of this will be seen by referring to Fig. 20 in which the bottom of the vernier D having been brought into coincidence with the top of the mercury, the scale line just below D is 29·650. Looking up the vernier, the third line above the figure 3 is seen to lie evenly with a line on the scale. The number 3 indicates ·030, and the third subdivision ·006 ; so that D is ·036 above the scale next below it, and thus we have—

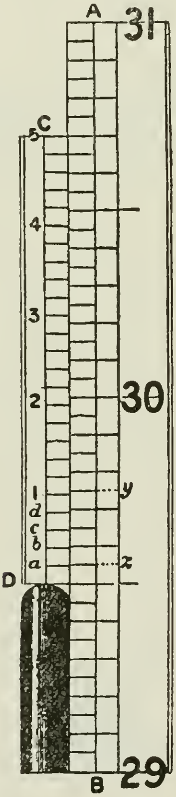

Fig. 19.

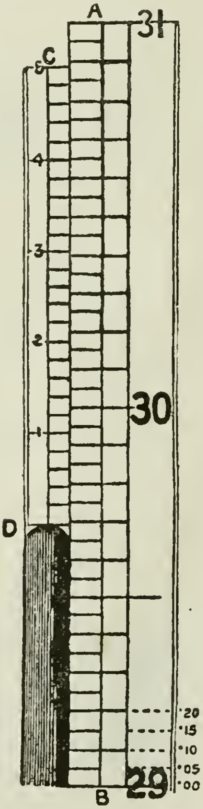

Fig. 20.

	Inches.
Reading on scale	29·650
Reading on vernier	·030 ·006
Actual reading, or height of mercury	29·686

Sometimes two pairs of lines will appear to coincide, in which case the intermediate thousandth of an inch would be set down as the reading. Thus, suppose coincidences appear corresponding to 29·684 and 29·686, then 29·685, half-way between them, should be adopted as the reading.

The foregoing description of the Kew pattern barometer, and mode of reading off the height of the column of mercury by the scale, is derived from the "Barometer Manual for the use of Seamen."

Aneroids.

The Aneroid barometer is another instrument for measuring changes of pressure. It consists of a circular metallic chamber partially exhausted of air and hermetically sealed. By an arrangement of levers and springs a hand is worked which indicates the pressure of the air. The aneroid barometer is not to be regarded simply as alternative to the mercury barometer for the purpose of weather maps, because its indications are liable to variable errors. It is, however, very convenient for reading, and is useful for watching the variations of the pressure of the air provided its readings are properly controlled by those of a mercury barometer. For this purpose the aneroid should be compared from time to time with a standard mercury barometer, and when necessary, it can be adjusted by means of a screw at the back of the instrument. Whenever such an alteration of the index error is made, the fact should be stated on the records of observations as a guide to persons consulting the data for use at a future time.

Readings of aneroids require correction for height above sea level and index error only, not for temperature, if properly compensated, nor for latitude.

At the Meteorological Office a new dial has been introduced for aneroid barometers intended for use at sea, of which a representation is given in Fig. 21. The graduations are shown in "centibars," 100 centibars being the "standard atmosphere" in the C.G.S. (centimetre—gramme—second) system of units. On the barometer dial graduation in inches and in millimetres is also shown, and it will be seen that the pressure of 100 centibars corresponds very nearly with that of 29½ ins. or 750 millimetres. The dial shows a range from below 93 centibars (27½ ins.) to 105 centibars (31 ins.), and so covers the whole range of pressure that is likely to be experienced at sea level in any part of the world. For the convenience of sailors the special form of instrument which is called a *sea barometer*, and which is figured here, a curve is given which indicates the *mean annual pressure* in certain degrees of latitude along the meridian of 30° west.

This meridian goes over sea from the Arctic to the Antarctic, and crosses the "Icelandic low," the "highs" of the tropics of Cancer and Capricorn, and the deep low of the higher southern latitudes. Similar variations are to be found in other oceans, so that the variations which are indicated by this curve on the dial are a guide to the average values which the mariner may expect. These values should enable him to judge first whether the instrument is in reasonable adjustment, or, secondly, whether the season of his voyage is a normal one so far as pressure is concerned.

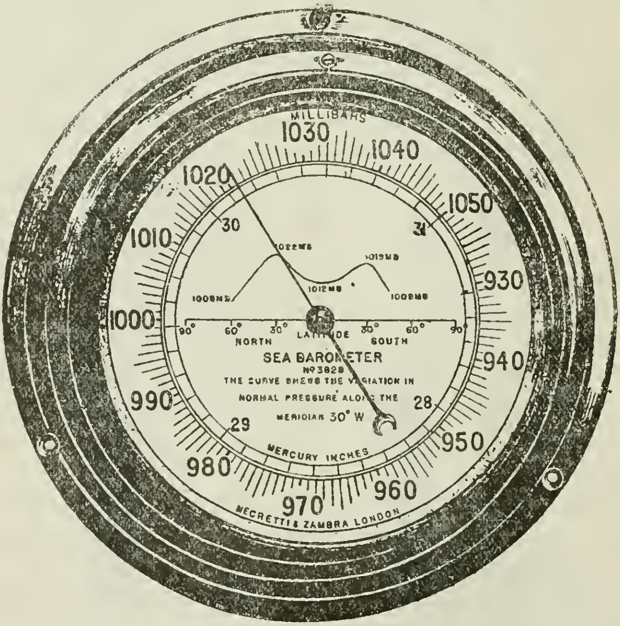

FIG. 21.

A portable "Barograph" (Fig. 22), which is an aneroid barometer provided with a lever recording variations of pressure on a revolving drum, is a more valuable supplement to the mercury barometer than the aneroid of ordinary form. It is useful not only in enabling an observer to detect casual errors in the readings of a mercury barometer, but also in giving a continuous record of barometric pressure for reference. The barograph should be placed in some position where it will be protected from concussions and from sudden changes of temperature, but otherwise needs no special exposure.

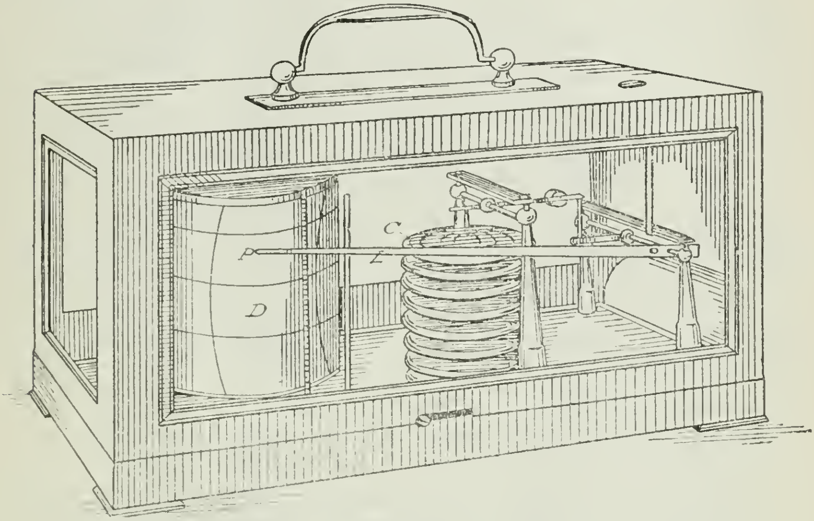

FIG. 22.

The action of the barograph, briefly, is as follows :—The circular metallic chamber (C) consisting of a series of vacuum metal boxes with elastic lids is connected with the revolving drum (D) by means of a lever (L) carrying a pen (P) filled with specially prepared ink.

The rotation of the drum is effected by means of clockwork contained in the drum which is designed to complete a revolution in seven days.

The variation in the volume of these vacuum boxes, caused by the changes in atmospheric pressure, is transmitted through the lever to the pen, which registers the changes in a continuous line on a printed chart fitted round the drum (Fig. 23).

The timepiece may be regulated by moving the pointer on the balance of the clockwork. Should the timepiece be fast the pointer should be moved in the direction R.S. (retard, slow) ; if slow, in the direction A.F. (avance, fast) ; but frequent movement of the pointer should be avoided.

The pen should be set correctly to Greenwich Mean Time, and a mark showing 12 o'clock, noon should be made on the chart each day.

The records of the instrument, or *traces*, as they are termed, should be examined carefully by the observer from

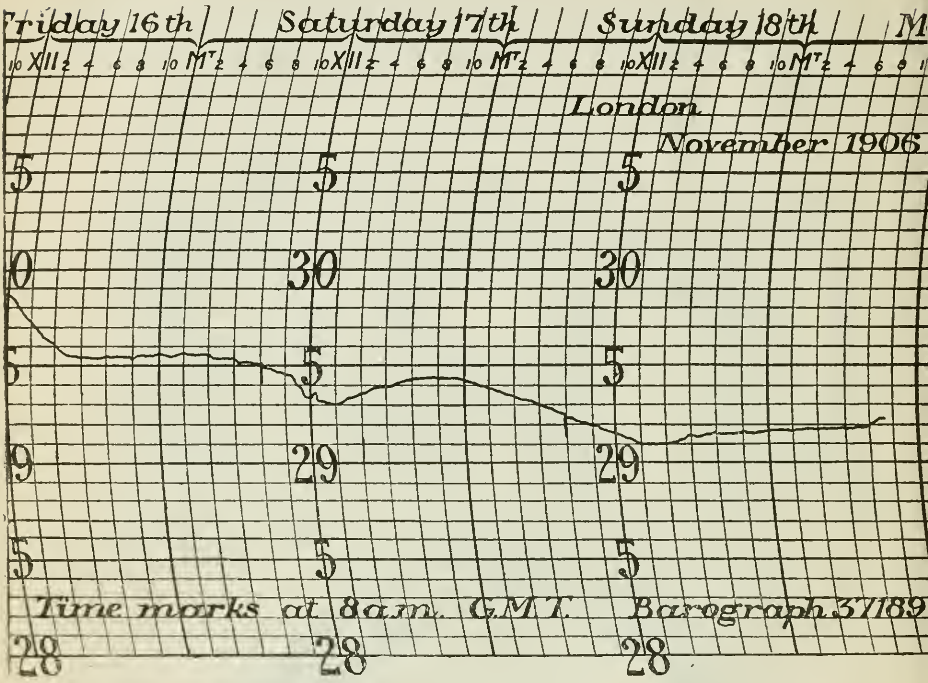

Fig. 23.

time to time in order that inaccuracies caused by the pen pressing too closely on the chart may be discovered. The pen should press sufficiently on the chart to leave a clear uninterrupted trace. The records should be compared frequently, or when an opportunity occurs, with readings of a reliable mercury barometer corrected for temperature and instrumental error, and the result noted on the back of the chart. Should it be found, however, that the difference between the barograph and the barometer readings is large the pen of the former should be reset.

A fine clear line should be traced by the pen of the barograph ; if a thick line is produced it may be due to rough or badly sized paper, to bad ink, or to a foul pen. If the pen requires cleaning it should be detached from the lever, carefully cleansed with a brush, and as carefully dried. An implement such as a knife should on no account be used for this purpose.

Thermometers (Greek: thermē—heat, metron—a measure).

The temperature of the air is found by a reading of the thermometer, an instrument which consists of a closed glass tube of very small bore, bulbed at one end, and partially filled with mercury, or, when required for use in climates where the cold is extreme, with spirit of wine, because mercury solidifies at about 234a, 70° Fahr., below the freezing point of water.

While responding quickly to variations of temperature, the thermometer is not sensibly affected by changes of the pressure of the air. Almost all substances expand when heated, and contract when cooled; mercury expands more than glass so that when the bulb of a thermometer is warmed the mercury expands, and is forced up the tube, and when cooled it contracts, and recedes towards the bulb. By observing the length of the thread of mercury in the tube, or *stem* of the thermometer, as it is called, as measured by the graduations marked on the stem, or on the scale at its side, the temperature of the air by which the bulb is surrounded, and, in like manner, the temperature of any liquid in which the bulb is immersed, can be determined.

For graduating the scale of a thermometer there are two fixed points of temperature available that can be depended upon for accuracy. One of these is the temperature at which distilled water freezes, the other the temperature at which distilled water boils when the barometric pressure is 1012·7 mb. (29·905 inches of mercury at 32° F.).

These two points being marked on the tube, the interval between them is divided into a number of equal divisions, and these divisions are called degrees. The earliest scale to be adopted, a scale which is still in common use in all English-speaking countries, was originated by a native of Danzig named Fahrenheit, at the beginning of the eighteenth century, and was called after him.

On this scale the interval between the freezing and boiling points is divided into 180 equal parts, and 32 similar equal divisions are set off below the freezing point, the last division being taken as the zero point of the scale. This zero point represented at that period the greatest cold known to have been experienced in Iceland, and was then thought to be the lowest possible temperature. It is moreover the lowest temperature of a mixture of ice and salt.

The examination of the expansion of gases shows that if air or any other of the permanent gases were to go on contracting at the same rate with cooling as they do at ordinary temperatures they would have no volume and cease to exert any pressure at a temperature of about 459° below zero, Fahrenheit. This temperature is found to be nearly identical with the temperature computed by Lord Kelvin as that to which the temperature of a working substance must be reduced in order to get the full equivalent in work of heat supplied to it. This latter temperature, which we may take as — 459·4° Fahr., is known as the absolute zero.

On Fahrenheit's scale it will be understood then that the freezing point is 32°, and the boiling point, being 180° above the freezing point, is 212°.

The sub-division of the scale between the two fixed points is, of course, entirely conventional ; and there are two other methods of graduation employed.

Early in the eighteenth century an eminent French physicist, called Réaumur, invented the thermometer scale which bears his name. The space on the scale of Réaumur's thermometer between the freezing and boiling points is divided into 80 equal parts ; the freezing point is zero, the boiling point 80°. This system of graduation has in recent times fallen largely into disuse. The thermometer in general use throughout Continental Europe was originated in 1742 by Anders Celsius, a professor of astronomy in Upsala. This is the *Centigrade* thermometer, so called because of the division of its scale into 100 equal parts ; the freezing point being zero, and the boiling point 100°.

For some years after a thermometer has been made the glass of the bulb contracts, and in course of time the contraction may give rise to an error of as much as a degree, or even more. It is therefore necessary to compare the readings of a thermometer with those of a standard instrument from time to time, in order to ascertain the correction, if any, to be applied to readings of the former.

The Thermograph.

A self-recording thermometer, or thermograph, is now largely employed for obtaining a continuous record of temperature, and if studied in connexion with the record of a barograph for the same period, will demonstrate the close relation existing between the fluctuations in temperature and pressure respectively.

The instrument will be found, after the observer has had some experience with it, a valuable aid in foretelling changes in weather conditions. For instance : a marked rise in temperature, detected by a glance at the thermograph, if associated with a shift of wind to an equatorial (in this country, southerly) quarter, will frequently give warning of the approach of an atmospheric disturbance before the barometer has commenced to fall.

In most thermographs the thermometer consists of a slightly curved metal tube filled with spirit. One end of this tube is fixed rigidly to a bracket on the frame of the instrument, while the other is attached to the system of levers which actuates the recording pen.

Thermographs for meteorological use must be well protected from rain and sun, at the same time, of course, they must be exposed out of doors, hence it is necessary to clean and oil their bearings from time to time.

The instrument may be set by comparing its indications with the reading of a standard mercury thermometer, placed beside it, and adjusting the pen accordingly. The setting should be effected only when the temperature is constant or changing slowly, and when the pen is near the middle of its range. As the metal tube containing spirit, which constitutes the thermometer, is in thermal contact with other parts of the instrument as well as its frame, all of which take an appreciable time to alter in temperature, the instrument is apt to respond somewhat sluggishly to rapid changes of temperature.

The readings of the thermograph require frequent checking by comparing them with those of a standard thermometer.

The Hygrometer.

For measuring the amount of water vapour in the atmosphere an instrument is used which is called a hygrometer (from two Greek words: *hygros*, wet; and *metron*, a measure).

Among a large variety of hygrometers, differing in form and construction, the one best adapted for general use consists of a pair of delicate thermometers placed side by side. Over the bulb of one of these instruments a single thickness of cambric or fine muslin is secured, and this covering is kept damp by means of a few strands of cotton wick, the bight of which is hitched round it, while the ends are immersed in water, contained in a small receptacle placed near the bulb, but not under it (Fig. 24). The water is conveyed to the muslin by capillary attraction, and, even though the temperature of the air should be below the freezing point of fresh water (273a, 32° Fahr.), the readings of the wet bulb will be trustworthy so long as there is a coating of ice on the muslin, for evaporation takes place from ice as well as from water. A thermometer fitted in the manner described is called a *wet-bulb thermometer*. The other instrument is in all respects an ordinary thermometer, which without the muslin covering is called the *dry-bulb thermometer*. This apparatus, known generally as a wet and dry-bulb hygrometer, is also called a psychrometer.

It is essential that the two instruments, while freely exposed to the air, should be protected from sun and rain, and from the effects of radiation. It is usual, therefore, to suspend them in a specially constructed screen, called a Stevenson Screen, the sides of which are louvred (Fig. 25).

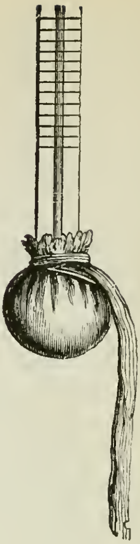

Fig. 24.

Arrangement of the Thermometers in the Screen.*

In arranging the thermometers in the screen the following points must be borne in mind :—

(1.) There should be a space of at least three inches between the bulbs of the thermometers and the top, bottom or sides of the screen.

(2.) The thermometers should be so arranged that all parts of their scales can be read without the necessity for moving any one of them.

(3.) The maximum and minimum thermometers should be clamped down so that strong winds cannot shake them, as jolting often leads to displacement of the indexes. The instruments require to be moved once a day for setting, and hence cannot be screwed in position.

A suitable arrangement is shown in Fig. 25.

The action of the wet bulb is as follows :—The temperature of the bulb is lowered by evaporation from the moistened muslin in the same manner as the temperature of the water in a canvas or earthenware water cooler is lowered by the evaporation of moisture percolating through the canvas or earthenware, as the case may be. When the air is dry evaporation proceeds rapidly, and the difference between the wet and dry bulb thermometer is relatively large ; when the air is damp evaporation takes place slowly, and the difference referred to is small. When the air is completely saturated with vapour the two thermometers, corrected for instrumental error, will indicate exactly the same temperature.

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* From the "Observers' Handbook." Meteorological Office Publication No. 191.

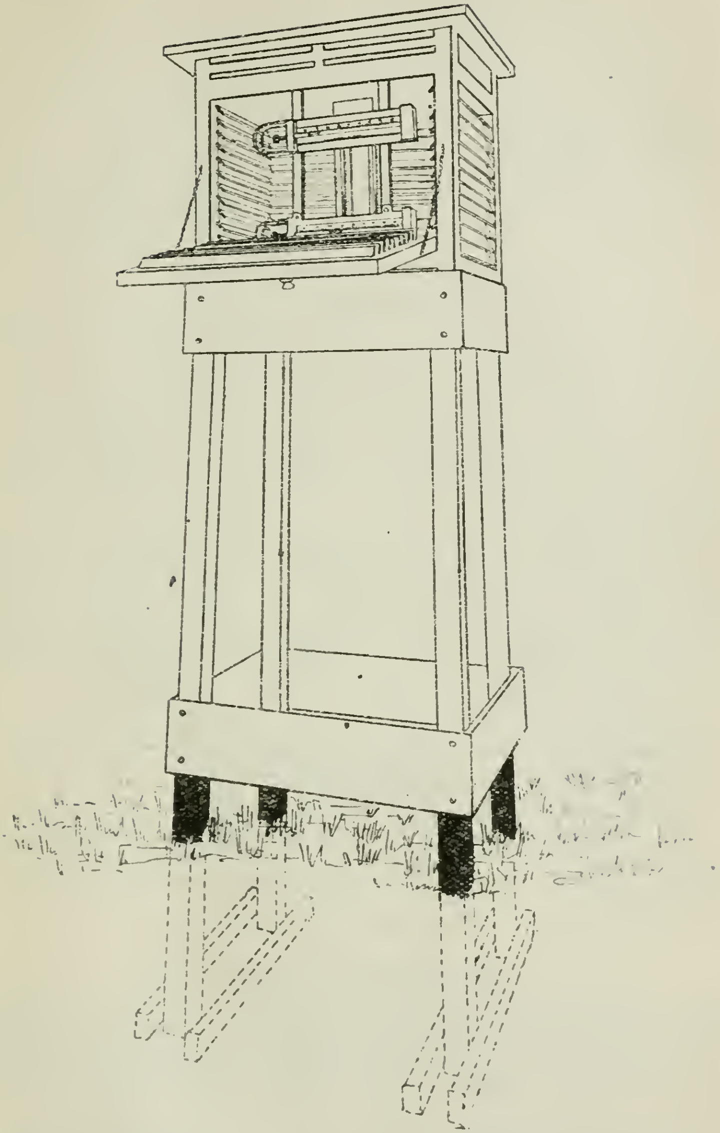


Fig. 25. Stevenson Screen with Thermometers.

The difference between the readings of the wet and dry bulb thermometers is occasionally considerable, and the *depression* of the wet bulb, as this difference due to evaporation is termed, may amount to as much as 20° Fahr. in our islands, and to more than 20° in some parts of the world. The difference is usually less near the sea than it is inland.

The muslin and wick for the wet-bulb thermometer should be well washed before being applied, and in order to secure trustworthy results from readings of the instrument these should be changed or cleansed frequently—say, every two weeks—for accuracy depends much on the care taken to ensure cleanliness. Rain or distilled water only should be used for moistening the muslin, because river and spring water leave a deposit of lime on the bulb, and this impairs its sensitiveness. Even rain water is not entirely free from impurities, containing as it does alkalis, salts, &c., which in time form a thin coating on the bulb. Should any encrustation be found on the bulb when the muslin is removed it should be carefully scraped off with a sharp penknife.

By means of observations of the dry and wet-bulb thermometer the following can be deduced :—The dew point ; the elastic force of aqueous vapour, or vapour pressure ; and the relative humidity.

In connexion with any investigation relating to climate, it is of great importance to know the highest temperature which occurs during the day and the lowest temperature during the night. For this purpose specially constructed self-registering thermometers have to be used, for it is only by continuous observations that such records can be obtained by means of an ordinary thermometer, and this will be found to be impracticable.

The instruments used for registering the highest and lowest temperatures are called *maximum* and *minimum* thermometers (from the Latin *maximum*, greatest ; and *minimum*, least).

The Maximum Thermometer.

The form of instrument commonly used is a mercury thermometer, the bore of which is much constricted close to the bulb (Fig. 26). When the mercury expands with a rise of temperature it is forced past this constriction up the stem, but when it contracts with a

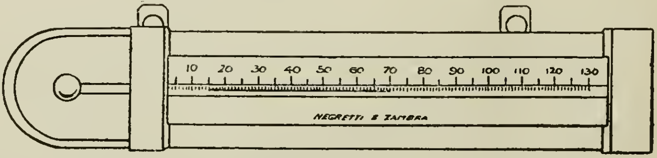


FIG. 26.
Maximum Thermometer.

fall of temperature that portion of it which is within the stem is prevented, by the constriction, from returning into the bulb and remains in the position to which it was forced, thus registering the highest temperature attained (*see* Fig. 26). To set the instrument, it is held bulb downwards and shaken; this causes the mercury within the stem to unite with the mercury in the bulb. The thermometer is then hung horizontally.

Minimum Thermometer.

The most serviceable form of instrument for registering the lowest temperature is a spirit thermometer having a small metallic index, which does not move freely within the stem (Fig. 27). When the index is at the end of the column of liquid and the temperature falls, the column contracts and draws back the index with it in consequence of adhesion until the temperature ceases to fall. When the temperature rises the spirit expands, and, flowing past the index, does not displace it. The index thus registers the lowest temperature that has been reached.

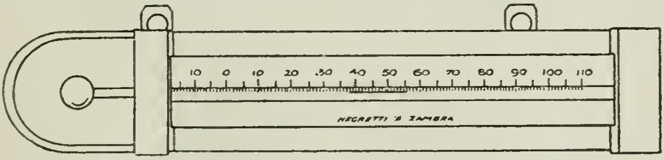


FIG. 27.

Minimum Thermometer.

The thermometer is set by sloping it, bulb uppermost, until the index is made to run down to the end of the column of spirit. The instrument is then hung up horizontally.

Like the dry and wet-bulb thermometers, the maximum and minimum thermometers should be exposed in the Stevenson's screen, and should be clamped to the battens in the screen from which they are suspended.

The arrangement of the thermometers in the screen recommended is described on page 162 and is shown in Fig. 25.

There should be a space of at least three inches between the bulb of the thermometers and the top, bottom or sides of the screen.

The thermometers should be so arranged that all parts of their scales can be read without the necessity for moving any one of them.

Stevenson's Screen.

The screen which has been found most suitable for the exposure of thermometers in this climate, and has therefore been generally adopted in the British Islands, was originally constructed by Thomas Stevenson, Engineer of the Northern Lighthouse Board ; it has already been referred to (Fig. 25). The two sides as well as the front and back of this screen are double louvre-boarded, the louvres sloping in opposite directions. It has a double roof, the main one being perforated to give additional ventilation, and the battens, which form the base of the screen, are separated for the same purpose.

Thus, while the thermometers in the screen are protected from radiant heat and rain, they are nevertheless exposed to a free circulation of air.

The screen should be well supported on four legs which are buried sufficiently deep in the ground to ensure steadiness in strong winds. It should stand over short grass, its base raised 3 feet 6 inches above the level of the ground. The face of the screen should open towards the true north, so that at any time when observations are being taken the instruments may not be exposed to the sun's rays.

Sea Water Thermometer.

Observations of sea surface temperature are taken for the Meteorological Office, twice daily : at about sunrise and at 4 p.m., at a large number of places on our coasts. The thermometer used for this purpose is protected by a metal case, having at its base a receptacle for water, capable of holding sufficient to cover the bulb of the instrument.

To observe sea temperature at a shore station a convenient place is selected where the water is not less than six feet deep because shallower water responds too quickly to changes in air temperature, to increase of heat due to solar radiation, and to diminution of heat through cloudiness. Consequently it does not represent fairly the surface temperature of the coatsal water. The thermometer, secure in its metal case, is plunged under water, kept there three minutes, and then promptly read off. If a canvas bucket and line are available the bucket is thrown into water, not less than six feet deep, and left there for five minutes ; it is then hauled in, full of water, the thermometer is placed in it, and after three minutes' immersion is read, while the instrument is held upright, with its bulb still immersed.

A canvas bucket is recommended because of its portableness: it is easily thrown to a considerable distance, and easily carried when full of water. It should be about 14 ins. deep and 7 ins. in diameter.

Anemometers.

Many devices have from time to time been suggested for measuring the velocity or the pressure of the wind. The first, of which there is any authentic record, is that described by Dr. Hooker in the first volume of the Philosophical Transactions (1667). It consisted of a plate hinged in such a way that it could swing upward under the pressure of the wind. The extent of its upward movement was measured upon a graduated arc, and " the force or strength of the wind in proportion to the resistance of the flat side of the instrument " was thus determined.

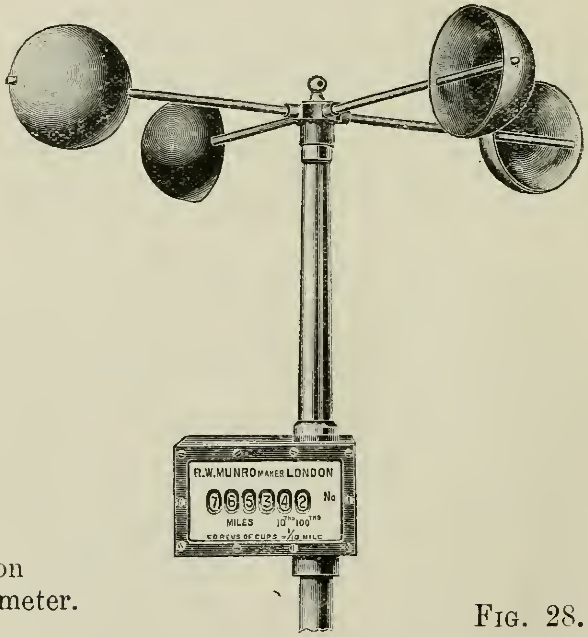
Osler's Pressure Plate.

The form of pressure anemometer which until recently was generally used, was introduced by the late Mr. Osler of Birmingham, and bears his name. It had a vertical plate, generally of one or two square feet area, which was kept facing the wind, and by the wind was driven back against the resistance of a spring. The deflection of the plate from the perpendicular, thus produced, was registered upon a sheet of paper, indicating the force exerted by the wind upon the plate. The chief defect of this instrument lies in the unchecked momentum of the plate; and the exaggerated pressures which the instrument not infrequently recorded may probably be attributed to this cause. A modified form of this instrument, in which the plate has been prevented from oscillating after being struck by a gust of wind, has been made and used. A pawl is employed for this purpose and the plate is thus retained at the extreme limit to which it is pushed in a gust, and it can move no further back until a stronger gust arrives. It moves, therefore, step by step, up to the highest force attained by the wind; and it is this maximum wind pressure alone, and not a continuous record of the variations of wind pressure, from moment to moment, which is obtained.

The mechanical arrangements required by most forms of recording anemometers necessitate the placing of such an instrument upon a building of some kind, and the result frequently is that its exposure to the wind becomes seriously impaired, the record being marred in consequence of eddies to an extent which cannot be accurately estimated.

Robinson's Cup.

In the year 1846 Dr. Robinson introduced an anemometer for giving the velocity of the wind, which is commonly known as the Cup Anemometer. Fig. 28. It consists of four hemispherical cups fixed to the ends of a horizontal cross which can revolve upon a vertical spindle. The force exerted by the wind upon the cups causes the cross to rotate, and its revolutions are registered either upon dials or upon a sheet of paper round a drum the rotation of which is effected by clockwork. With this instrument it is obviously necessary, first of all to determine the relation between the speed at which the cups move, and the speed of the wind which drives them, and it is found that this relation depends upon the size of the cup, and also upon the length of the arm to which it is attached; it is consequently different for instruments of different pattern.



The Robinson Anemometer.

FIG. 28.

In the standard instrument, adopted by the Meteorological Office, which has cups of 9 inches in diameter, fixed to arms measuring 2 feet from the centre of the cup to the spindle, the mechanism should be such as to make it necessary to multiply the distance travelled by the cups by 2·2 in order to obtain the corresponding travel of the wind. In a smaller instrument, which has cups 3 inches in diameter, carried on arms $7\frac{5}{8}$ inches long, the factor has been found to be 2·733 instead of 2·2.

Dines' Pressure Tube.

A more recent form of anemometer, and the one which gives information not only of the pressure and velocity of the wind, but also the way in which the velocity varies from moment to moment, is the pressure-tube anemometer invented by Mr. W. H. Dines, F.R.S.

This anemometer depends on measuring the small differences of pressure that are produced in the air when the wind passes over an obstacle.

In general, when moving air meets with a fixed obstacle there is an excess of pressure on the windward side, and a decrease of pressure on the lee side, but with light winds the differences are small, and difficult to measure.

In the tube anemometer a tube with one end closed and one open is kept by a vane with the open end facing the wind, and in consequence there is an excess of pressure inside the tube ; also, of course, inside any closed vessel with which the tube is put into airtight communication by means of a pipe. It was found by experiments conducted by Mr. Dines, that the wind when it blows over a vertical tube of one or two inches diameter, having a ring of small holes round it, exerts a sucking action, and produces a decrease of pressure inside. This fact is made use of in connexion with the construction of the tube anemometer ; and the difference in pressure causation is measured between a tube with its open end facing the wind, and a tube, with a ring of holes round it, in a position roughly vertical : for the exact angle is not of any consequence.

For a wind of 100 miles an hour this difference amounts to 7·31 inches of water ; the value depends on the square of the velocity, and thus for 10 miles an hour it is $\frac{1}{100}$ of the above value, namely ·073 inch ; for 20 miles an hour it is 4 × ·073 inch : for 30 miles, 3 squared or 9 × ·073 inch, and so on.

This form of anemometer is very convenient since the head, or part exposed to the wind, when once fixed will run for years without oiling, and the registering part may be under cover at any reasonable distance from the head.

If automatic registration be not required ; also if observations of light winds may be excluded, the simplest form of registration is an ordinary U glass tube. With such a tube partially filled with water, the force of winds equal to or above a fresh breeze, can be read off on a scale suitably adjusted.

For continuous registration the recording apparatus shown in Fig. 29, and the head of the anemometer in Fig. 30 were invented by Mr. Dines. In connexion with the former the

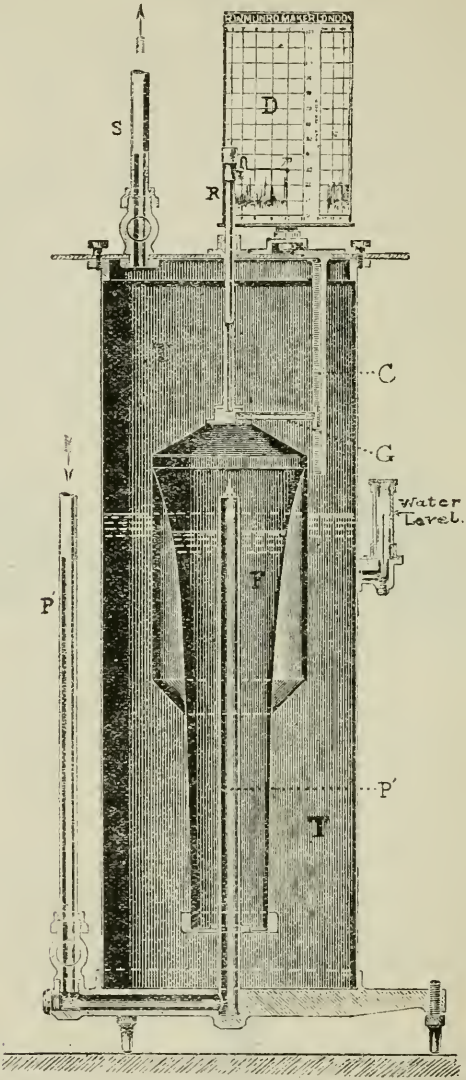


Fig. 29.

Recording Apparatus.

Dines' Pressure Tube Anemometer.

clock drum D is employed, and a fine pen, P, which traces a record on a chart adjusted round the drum, as is the case with the barograph, and thermograph already described. The pen is carried by the rod B, which is attached to a floating cylinder F called the *float.* The rod is prevented from rotating by the guide G, to one end of which it is connected, while the other end moves in a vertical slot C. This float is shaped in a special manner, and in its position of equilibrium a very small force acting upwards on it will raise it a considerable height out of the water in which it floats. Its open end or rim is downwards like a diving bell, and the air enclosed between the water and its upper part is in communication with the open tube P on the head, Fig. 30,

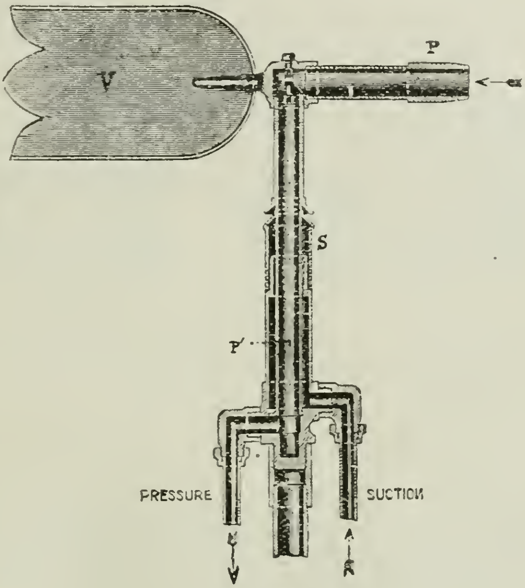


Fig. 30.

The Head.

which is kept facing the wind by the vane V. The communication is effected by a tube (P′) of about $\frac{5}{8}$ inch in diameter, which runs down from the head and up through the water in the float, its mouth opening inside the enclosed air space. The float, and the water which buoys it up, are contained in a sealed vessel T, the rod carrying the recording pen passing out through a hole which it fits closely enough to be air-tight or nearly so, but not so closely that there is any appreciable friction. It is obvious that the wind blowing into this tube, will raise the float, and with it the pen. The top of the sealed vessel T is connected with the vertical tube S, which has been referred to as having a ring of holes at the head, by a pipe so that the sucking action of the wind, produced by its passage across the holes, may take effect.

The action of the instrument depends chiefly on the excess of pressure produced by the wind against the mouth of the tube P; the second communicating pipe S is introduced, not to increase the difference of pressure caused in the two tubes, but for the following reason. The tube anemometer has to measure very small differences of pressure, and, if one connecting pipe only came from the head to the registering apparatus, the registration would depend on the pressure of the air in the room where the apparatus was placed. In windy weather it would in fact depend largely upon what windows and doors were open or shut, so that the registration of correct values would not be possible. Supposing the suction tube to be absent, and the registering apparatus to be placed in a small hut, then the act of opening the door of the hut to windward, if the hut were well exposed, would, during a gale, reduce the recorded values from gale force to that of a fresh breeze or possibly even to that of a light breeze. The suction tube removes this source of error, by confining the wind's action upon the instrument to that which is communicated through the two pipes on the head of the anemometer. In the "Observers' Handbook" the following instructions are given in regard to the management of this instrument :—

(1.) It should be kept clean, so as to admit of the free working of its parts.

(2.) It must be kept level. To test the level remove the collar through which the pen rod passes, and note whether the latter passes through the centre of the circular hole in the top of the recorder. If not, adjust by means of the levelling screws. Replace the pen carriage on the rod before making the adjustment. The screws should bear on a metal surface and not on wood.

(3.) The level of the water in the tank should be kept up to the fixed mark in the gauge which projects from the side of the apparatus.

(4.) When the pressure is identical on both sides of the float, the float should be quite free, *i.e.*, it should not be supported on the base of the tank. If it is, there will be a "dead" interval within which the upthrust on the float produced by wind is not sufficient to raise it.

The float is so constructed that it rests in contact with the base of the recorder in its zero position without exerting any pressure on it. If the adjustment is not perfect, it should be altered by adding or withdrawing shot from the cup which will be found on the pen carriage.

(5.) The position of the pen should correspond with the zero of the scale when the air pressure is the same on both sides of the float, *i.e.*, when both taps are turned so that communication with the head is shut off. A screw motion is provided for making this adjustment.

Pressure tube recorders are primarily graduated upon an empirical basis by Mr. Dines's experiments,* but the indications of different instruments can be compared with a pressure gauge.

Rain Gauges.

There are several different forms of this instrument but the majority of rain gauges in use at the present time are those of the Snowdon pattern or a modified form of that pattern to which the principle of the former is applied.

The Snowdon, Fig. 31, is a 5-inch gauge and consists of cylindrical funnel (*f*) having a rim 4 inches deep, to the edge of which a stout brass ring (*r*) is firmly fixed ; a vertical cylinder with closed base (*c*), and shoulder (*s*) upon which the lower edge of the funnel-cylinder rests when in position, and a can (*b*), which rests on the bottom of the lower cylinder.

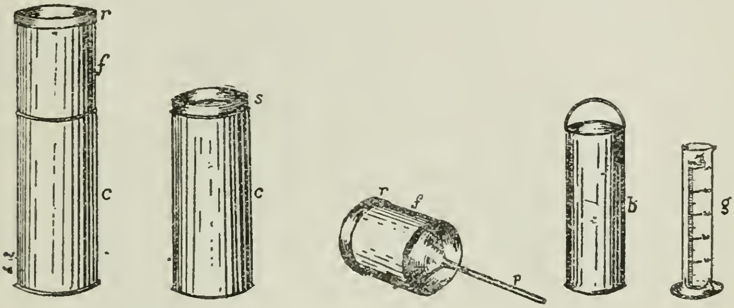


Fig. 31.

Precipitation is directed from the funnel to the glass bottle by means of a pipe (*p*) attached to the former, reaching almost to the bottom of the latter :

The brass ring, the inside measurement of which is exactly 5 inches in diameter, is bevelled on the outside so as to form a knife edge upon which no rain can rest. The rim of the cylindrical funnel is made 4 inches deep in order to prevent loss of precipitation by splashing ; also to facilitate its collection when in the form of snow.

With the exception of the ring, the instrument is usually made entirely of copper, on account of the durability of that metal.

The rain collected is measured by pouring it into a measuring glass (*g*) graduated to indicate either millimetres or hundredths of an inch.

Meteorological Office Pattern.

The gauge adopted by the Meteorological Office is eight inches in diameter ; and the rim of the funnel is six inches deep. The lower half of this gauge has a splayed base as shown in Fig. 32, where (*f*) is the cylindrical funnel; (s) the splayed base; (c) the can, and (*g*) the measuring glass.

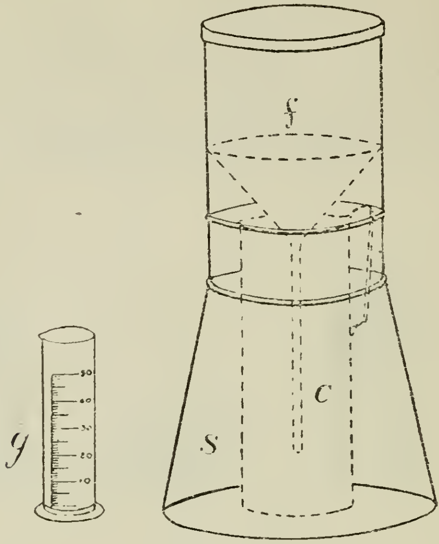


Fig. 32.

The measuring glass will hold half an inch of rainfall, an amount which corresponds with a weight of 14·50 oz. avoirdupois when collected in an 8-inch gauge or with 5·67 oz. when collected in a 5-inch gauge.

Rain gauges should be sunk into level ground, and their rims should be one foot above the surface. They should be fixed firmly in the ground; the object of the splayed base is to contribute towards its stability when in position.

The Meteorological Office pattern of gauge is made of five inches diameter also; it differs from the Snowdon only in having a splayed base.

APPENDIX I.

Displacement of the Horizon.

The conditions which occasion displacement of the horizon through refraction are analogous to those under which the phenomenon of mirage occurs, and result from unequal density of the different layers of air by contraction or expansion through contact with chilled or heated surfaces.

The air generally diminishes in density with height. Rays of light traversing a medium of varying refractive index proceed obliquely upwards from an object, becoming more and more horizontal, but usually passing away into space. Assuming the density of the air to diminish with height unusually quickly, as it does when it is cooler the nearer it is to the surface; commonly the case in the Red Sea, for instance, where hot air from the land passes over relatively cool water, then the angle of incidence is increased from one layer of the atmosphere to another, so that the obliquely ascending rays may become very nearly horizontal. When this critical angle is reached, as at A, Fig. 33, reflection succeeds refraction, the rays are bent downwards, and again undergo a series of refractions, but in a contrary direction, until they reach the surface at a distant point.

The horizon at this point, as seen, is too high; and erect images of objects, such as O, that are below the horizon, may thus be observed.

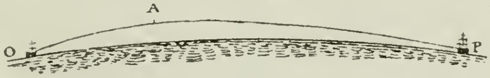


Fig. 33.

Fig. 34.

The faint indications of coast line, sometimes noticeable beyond the limits of direct vision, which sailors speak of as *the loom of land*, are produced in this manner.

Should the density of the air increase with height, as when cold air passes over the surface of relatively warm water, and such conditions frequently obtain in temperate latitudes of the North Atlantic that come under the influence of the Gulf Stream, the lower stratum of air becomes warmer, and therefore less dense than the strata above it. Under these circumstances a ray of light from a distance suffers refraction that diminishes with lessened density and is convex towards the sea surface; with the result that the apparent horizon is seen too low; and a distant object, such as O, Fig. 34, is seen at P inverted, appearing to come from the direction P A D.

APPENDIX II.

The following notice with reference to the supply of Telegraphic Information to the public is taken verbatim from Circular 001 of the Meteorological Office : "Provisions for the supply of information to the public." During the continuance of hostilities, however, the provisions for the supply of information to the Public have been modified and are subject to further modifications :—

DAILY WEATHER REPORTS. FORECASTS AND STORM WARNINGS.

Between 7.15 a.m. and 9.30 a.m. telegraphic messages are received daily, reporting meteorological observations at 29 stations (marked T in list of stations, Section I) in the British Isles, chiefly on the coast, at 39 stations on the Continent of Europe, including Gibraltar, and at the Azores, at five stations in Iceland, and one in the Færöe Islands. The observations are now made at 7 a.m. at all stations, except Oxford, Lisbon, and the Azores. A certain number of stations report evening observations (6 p.m.), also by telegram, and those that do not report in the evening include the evening observations with the following morning reports, so that a complete schedule of morning and evening observations is drawn up daily. The information refers to the readings of the barometer, dry bulb thermometer, maximum and minimum thermometers, rainfall, and in some cases, sunshine, with estimates of the direction and force of the wind, and reports of the weather and state of the sea. The observations received from Iceland give only the readings of the barometer and the dry bulb thermometer, the direction and force of the wind, and the state of the weather.

These reports are supplemented by a number of additional observations made at various stations in the United Kingdom, and sent either by telegram or by post, by private persons or local officials. Moreover, the "Bulletin International" published in Paris, reproducing meteorological telegrams from the whole of Europe, is received by post on the morning of the day after publication, and supplements the information previously received in the Office by telegram.

Through the courtesy of the Lords Commissioners of the Admiralty occasional reports of observations at sea off our southern and western coasts are transmitted by wireless telegraphy from the ships of H.M. Navy. Wireless reports are also received almost daily from ocean liners crossing the Atlantic.

The telegraphic information is tabulated and charted by about 9 a.m. for the morning observations, and 7 p.m. for the evening ones. A general report is then drawn up, and forecasts of the weather, *for the twenty-four hours following the next noon, or midnight, as the case may be*, are formulated ; a note as to the further outlook is added if the meteorological conditions are such as to justify an anticipation for more than twenty-four hours ahead.

At a selection of stations additional observations are taken and telegraphed to the Office at 1 p.m., and occasionally modifications are made in the morning forecasts as a result of these observations. This information is usually available by 2 p.m.

Forecast Districts.—For the purposes of forecasts of weather the region of the British Isles is divided into land districts and sea districts, as indicated in the accompanying map.

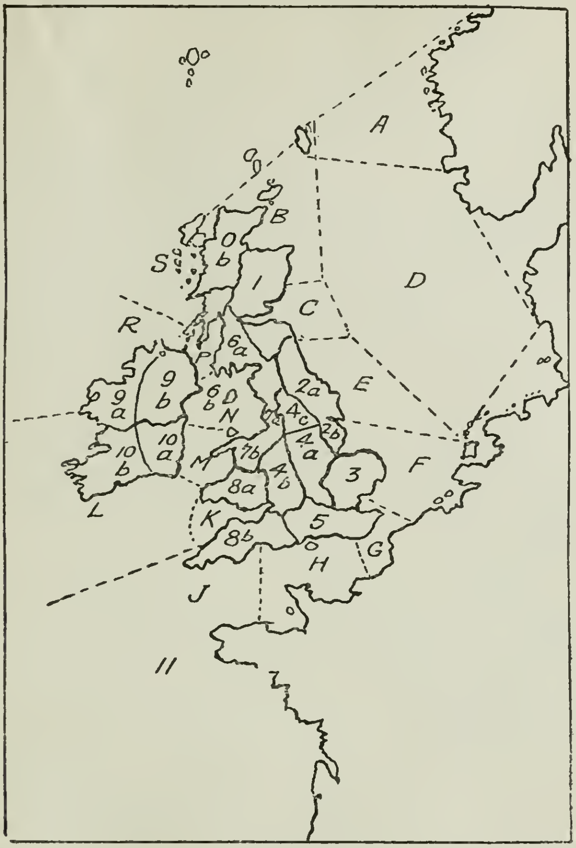


FIG. 35.

FORECAST DISTRICTS.

LAND.*

0. SCOTLAND, NORTH. (a) Islands. (b) Mainland.
1. SCOTLAND, EAST.
2. ENGLAND, NORTH-EAST. (a) North. (b) South.
3. ENGLAND, EAST.
4. MIDLAND COUNTIES. (a) East. (b) West. (c) North.
5. ENGLAND, SOUTH-EAST.
6. (a) SCOTLAND, WEST. (b) ISLE OF MAN.
7. (a) ENGLAND, N.W. (b) NORTH WALES.
8. (a) SOUTH WALES. (b) ENGLAND, S.W.
9. IRELAND, NORTH. (a) West. (b) East.
10. IRELAND, SOUTH. (a) East. (b) West
11. MOUTH OF CHANNEL and Bay of Biscay.

SEA.

A. SHETLAND TO THE NAZE
B. SHETLAND AND ORKNEY.
C. EAST OF SCOTLAND.
D. GREAT FISHERY AND DOGGER BANKS.
E. NORTH SEA, North of the Humber.
F. NORTH SEA, South of the Humber.
G. STRAITS OF DOVER.
H. ENGLISH CHANNEL, Central Reach.
J. ENGLISH CHANNEL, Western Portion.
K. BRISTOL CHANNEL.
L. SOUTHWARD AND SOUTHWESTWARD OF IRELAND.
M. ST. GEORGE'S CHANNEL.
N. IRISH SEA.
P. NORTH CHANNEL.
R. NORTHWESTWARD OF IRELAND.
S. THE MINCH.

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* For the grouping of the counties to represent approximately the forecast districts, *see* List of Stations (Section I)

Although from 4,000 to upwards of 5,000 wireless reports have been received yearly from Atlantic liners since March, 1910, only a small percentage reach the office in time to be included in the map of the Daily Weather Report for the day to which it relates, i.e., within about four hours of the time of taking the morning observation; and rather less than half have reached the office in time to be included in one of the two maps for "yesterday" shown in the Daily Weather Report. The forecasts are prepared within about two hours of the time of observing, therefore very few messages reached the office in time to be of direct and immediate application in the preparation of forecasts or the issue of storm warnings. Nevertheless there were a number of occasions on which messages were of great assistance to the forecaster. They often gave the earliest observations of the westerly or north-westerly winds in rear of a depression, and so put him in a position to forecast the early extension of these winds to our western districts. On other occasions the extension of southerly winds to some distance from our western coast increases the probability of a continuance of southerly winds over the British Isles for the 24-hour period covered by the forecast.

Wireless reports have also proved valuable in connection with the issue of a "further outlook," especially when it has taken the form of a notification or a probable spell of fair weather. Such a notification would not be issued if wireless reports showed the existence of important disturbances over the ocean.

Moreover, wireless reports from liners are of use in connexion with a series of maps, included in the Weekly Weather Report which is issued by the office, showing the distribution of pressure, air temperature, and wind over Asia, Europe, Iceland, the North Atlantic, the United States, and the Dominion of Canada, at 7 a.m. on each day during the week.

They are utilised also in connexion with seven daily synoptic Charts, three of them covering the same area and the remainder relating to Europe and the North Atlantic only, which are included on the backs of each weekly issue of the Monthly Meteorological Charts of the North Atlantic and Mediterranean, giving the distribution of pressure and other elements each day of the week ended on the day before the issue of the chart.

THE DISTRIBUTION OF FORECASTS AND TELEGRAPHIC INTELLIGENCE.

The arrangements for the distribution of telegraphic intelligence have been suspended during the war. The Grouping of the Stations at which gale signals were exhibited, is shown in the following list :—

I. *Scotland, N.E.—A. Northern Section, Shetland, Orkney and North Coast of Scotland.*—Lerwick, *Scalloway, *Dunrossness, Sumburgh Head L.H., Fair Isle L.H., Noup Head L.H., Stromness, Kirkwall, Cantick Head L.H., Thurso, Dunnet Head, Wick.

B. Southern Section. East Coast from Harril Head to Stonehaven.—Tarbet Ness L.H., Cromarty, Inverness, Nairn, Burghead, Lossiemouth, Buckie, Port Knockie, Cullen, Portsoy, Banff, Fraserburgh, Peterhead, Aberdeen, Girdleness L.H., Scurdy Ness L.H., Montrose, Stonehaven.

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* Telegrams only exhibited.

II. *Scotland, E.—Stonehaven to the Tweed.*—Broughty Ferry, Dundee, St. Andrews, Anstruther, Buckhaven, Methil, Wemyss West, Burntisland, Grangemouth, Bo'ness, Granton, Newhaven, †Leith, Fisherrow, Dunbar, Cockburnspath, St. Abb's Head, *St. Abb's, Eyemouth, Berwick-on-Tweed.

III. *Scotland, N.W.—Kyle of Durness to Firth of Lorne.*—Cape Wrath L.H., Stoerhead L.H., *Port of Ness, Stornaway, Island Glass L.H. (Scalpay).

IV. *Scotland, W. and North Channel.—From Firth of Lorne to Barrow Head, and from Fair Head to Strangford Lough.*—*Glasgow, Greenock, *Rothesay Lamlash, Carradale, Campbeltown, Mull of Cantire L.H., Rhuvaal L.H., Rhinns of Islay L.H., Ardrossan, Ballantrae, ‡*Cairn Ryan*, Corsewall Point L.H., Mull of Galloway L.H., Belfast, Donaghadee.

V. *Ireland, N.—Fair Head to Galway Bay.*—Killybegs L.H., Mulroy, Fanad Point (Lough Swilly) L.H., Rathmullen, Malin Head, Portrush.

VI. *Ireland, S.—Galway Bay to Carnsore Point.*—Tuskar L.H., Dunmore East, Dungarvan, Helvick Head, Minehead L.H., Youghal. Queenstown, Cork, Passage, *Kinsale*, ‡Kinsale (Old Head), Galley Head L.H., ‡*Castletownshend*, Brow Head, Dingle, Tralee (Fenit), Limerick, Loophead L.H.

VII. *Irish Sea. South of a line from Strangford Lough to Barrow Head and North of Lat.* 53° *N.*—Howth, Kingstown, Point of Ayre, Ramsey, Douglas, Silloth, Maryport, Workington, Whitehaven, Barrow, Walney Island L.H., Morecambe, Fleetwood, Blackpool, Lytham, Preston, Southport, Formby, Liverpool, Runcorn, New Brighton, ‡*Hoylake*, New Ferry, Rhyl, Port Penrhyn, Point Lynas L.H., Holyhead, South Stack L.H., Carnarvon, Port Dinorwic.

VIII. *St. George's Channel.*—Aberystwyth.

IX. *Bristol Channel, St. David's Head to River Camel.*—Smalls L.H., *Milford, St. Ann's Head, Caldy L.H., Tenby, Pembrey (Burry Port), Llanelly, Swansea, Briton Ferry, Porthcawl, Nash L.H., Penarth, Cardiff (Bute Dock and Barry Dock), Newport, Weston-super-Mare, Burnham, Bridgewater, ‡*Minehead*, Ilfracombe, Bull Point L.H., Barnstaple, Appledore, Hartland Point L.H., Lundy Island.

X. *England, S.W.—River Camel to River Exe.*—Port Isaac, Newquay, ‡*Godrevy* L.H., ‡*Hayle*, St. Ives, St. Sennen, Newlyn West, Padstow, Penzance, Porthleven, Scilly, the Lizard, Looe, Falmouth† (Pendennis Castle), Fowey, Plymouth, Devonport (Mount Wise and the †Dockyard), Prawle Point, Salcombe, Teignmouth, Exmouth.

XI. *England, S.—River Exe to Beachy Head with Channel Isles.*—Guernsey,† Jersey (St. Helier's), Portland Dockyard, Portland L.H., Weymouth, Anvil Point L.H., Poole, Hurst Castle L.H., Southampton, Yarmouth (I. of W.), Cowes, Ryde, St. Catherine's Point, Portsmouth (Dockyard and Horse Sand Fort), Littlehampton, Brighton, *Newhaven.

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* Telegrams only exhibited

† Arrangements made for showing signals or illuminating the cone at night.

‡ Stations of which the names are printed in italics are in abeyance during the war.

XII. *England, S.E.—Beachy Head to Shoeburyness.*—Beachy Head, Eastbourne, †Hastings, Rye, ‡*Sandgate*, Dover, Deal, Ramsgate, Faversham, Sheerness, Chatham, Greenhithe, Shoeburyness.*

XIII. *England, N.E.—From the Tweed to the Humber.*—Blyth, Tynemouth, South Shields, Souter Point L.H., Sunderland, Hartlepool, †Middlesbrough, Redcar, Whitby, Filey, Flamborough, Bridlington.

XIV. *England, E.—From the Humber to Shoeburyness.*—Hull, Goole, Grimsby, Boston, Sutton Bridge, Lynn, Sheringham, Cromer, Great Yarmouth, Gorleston, Southwold, Orford Ness L.H., Ipswich, Harwich, Gunfleet L.H., West Mersea.

C.—STATISTICAL INFORMATION.

THE BRITISH METEOROLOGICAL AND MAGNETIC YEAR BOOK.

Terms of Subscription.—The Statistical Publications of the Office have been grouped together under the general title "British Meteorological and Magnetic Year Book." For 1913, 1914, 1915 and 1916 the Year Book consists of four parts, as follows :—

Part I.—**The Weekly Weather Report.** Issued on Friday of each week. Price 6*d.* per number. Annual subscription (which includes the Monthly Weather Report, *see* below) 30*s.* postage paid. The appendices to the report can be obtained separately, price from 4*d.* each.

Part II.—**The Monthly Weather Report** with an annual summary. Issued on the 27th of each month as a supplement to the Weekly Weather Report. Price 6*d.* each issue.

Part III.—(1) **Daily Readings** at Meteorological Stations of the First and Second Orders. Issued in monthly parts, within about five weeks of the close of each month. Price 6*d.* each issue. Annual Volume consisting of 12 monthly numbers with Introduction, Annual Supplement, Title Page and Map, price 5*s.*

(2) **The Geophysical Journal.** Daily observations (Meteorology, Terrestrial Magnetism, Atmospheric Electricity, Seismology, &c.) at the Meteorological Office Observatories (Valencia, Kew, Eskdalemuir) and principal Anemograph Stations, together with records of Temperature, Humidity and Wind in the free atmosphere, obtained by means of kites, balloons and pilot balloons. Price 1*s.* each issue. Annual Volume consisting of 12 monthly numbers, with Introduction, Annual Supplement and Title Page, price 10*s.*

Part IV.—(1) **Hourly Values** from Autographic Records. **Meteorological Section. Hourly Readings** of Pressure, Temperature, Wind, Rainfall, Humidity and Sunshine, at the Meteorological Office Observatories (Valencia, Kew, Eskdalemuir). Issued in monthly sections for each observatory. Price 6*d.* each section. Annual volume, 20*s.*

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* Telegrams only exhibited.

† Arrangements made for showing signals or illuminating the cone at night.

‡ Stations of which the names are printed in italics are in abeyance during the war.

APPENDIX III.

The following notice with reference to the supply of Barometers which the Office lends for the use of fishing communities is taken verbatim from Circular 001 of the Meteorological Office, "Provisions for the Supply of Information to the Public."

FISHERY BAROMETERS.

The Office possesses a number of Barometers which it lends for the use of fishing communities, where it is shown that the instrument will be of material service. As a condition of the loan the community is required to provide for the housing of the instrument and to keep and forward to the Office a record of daily readings. Forms on which the record may be plotted are supplied by the Office. Simple instructions concerning the use of the barometer are given on these forms (M.O. 4150). A picture of a frame containing one of them is shown on p. 186.

LIST OF STATIONS SUPPLIED WITH FISHERY BAROMETERS.

District and Port.	No.	Custodian.	District and Port.	No.	Custodian.
ENGLAND.			ENGLAND—*continued.*		
Lancashire and Western.			Cornwall—*continued.*		
Morecambe ...	67	Sanitary Inspector.	St. Ives	2	Pier Head Light Keeper.
Fleetwood ...	140	Marine Supt. L. & N.W. & L. & Y. Railway.	Porth Guarra ...	265	Mr. T. Joyce.
			Penberth Cove ...	241	Mr. A. Jeffery, Carrier.
Carnarvon ...	135	Customs Officer.	Mousehole ...	7	Harbour Master.
Aberystwyth ...	221	R. Kenrick, Esq.	Newlyn Town ...	23	Mr. R. Pollard, Trinity Pilot.
Milford Haven.			Newlyn	137	Mr. E. Morrish.
			Coverack	153	Coast Guard.
Milford	58	Mr. H. Lewis.	Falmouth... ...	62	Customs Officer.
Angle	180	Mr. Davies, Grocer	Porthallow ...	38	Coast Guard.
			Durgan	84	Mr. E. Downing, Fisherman.
Glamorgan.					
	379		Penryn	63	Customs Officer.
Swansea	126	Customs Officer.	Portscatho ...	146	Mr. Wesley Collins.
Briton Ferry ...		Dockmaster.	Devoran	77	Hon. Sec. of Reading Room.
Somerset.			Gorranhaven ...	49	Coast Guard.
			Mevagissey ...	41	,, ,,
Burnham	52	Customs Officer.			
			Devon.		
Cornwall.					
			Bideford	218	Miss A. M. Braund.
Port Isaac ...	45	Coast Guard.	Exmouth	191	Customs Officer.
Hayle	97	Customs Officer.	Budleigh Salterton	47	Coast Guard.

LIST OF STATIONS SUPPLIED WITH FISHERY BAROMETERS—*continued.*

District and Port.	No.	Custodian.
ENGLAND—*continued.*		
Southern.		
Portland	93	Mr. R. Cox.
Weymouth ...	100	Coast Guard.
Poole	96	Customs Officer.
Yarmouth (I.o.W.)	231	Harbour Master.
Brixton	206	Coast Guard.
Atherfield ...	204	" "
Ventnor	118	Mr. J. H. Blake.
Bembridge ...	173	Coxswain of Lifeboat.
Ryde	60	Mr. Whitewood.
Sussex.		
Bognor	115	Pier Master.
Kent and Essex.		
Dover	13	Superintendent of Sailors' Home.
Kingsdown ...	33	Mr. W. Sutton, Vicar's Gardener.
Deal	57	Borough Surveyor.
Margate	92	Caretaker of Seaman's Institute.
Leigh*	174	Coast Guard.
Maldon	224	Edmund Gowers, Ltd.
West Mersea ...	249	Coast Guard.
Brightlingsea ...	211	Customs Officer.
Harwich	88	Coast Guard.
Suffolk and Essex.		
Walberswick ...	245	Mr. F. E. Debney.
Lowestoft ...	214	Mr. J. Moore.
Gorleston	42	Harbour Master.
Eastern.		
Wells	82	Harbour Master.
King's Lynn (Dock).	195	Dock Manager.
" " (Fisher Fleet).	56	Eastern Sea Fisheries Committee.
North-Eastern.		
Hull	17	Foreman at Humber Dock.
Withernsea ...	76	Mr. J. Ward.
Bridlington ...	31	Harbour Master.
Flamborough ...	40	Mr. Fell.
Filey	22	Coast Guard.
Scarborough ...	171	Harbour Master.

District and Port.	No.	Custodian.
ENGLAND—*continued.*		
North-Eastern —*continued.*		
Staithes	54	Coast Guard.
Sunderland (Roker).	148	" "
Northumberland.		
North Shields ...	99	Quay Master.
Blyth	131	Clerk to Harbou Commissioners.
Berwick	136	Customs Officer.
ISLE OF MAN.		
Douglas	155	Customs Officer.
Port St. Mary ...	108	Harbour Master.
Peel	184	" "
"	32	" "
CHANNEL ISLANDS.		
Gorey (Jersey) ...	5	Harbour Master.
SCOTLAND.		
Shetland Isles.		
Uya Sound ...	186	Mr. S. J. Sandison Merchant.
Sumburgh ...	116	W. L. McDougall Esq., Estat Office.
Lerwick	8	Harbour Master.
Sandwick... ...	27	Mr. T. T. Anderson Merchant.
Scalloway ...	190	Mr. J. Scott, Jun.
Symbister (Kholsay)	192	Mr. D. J. Williamson.
Hamnavoe ...	263	Mr. J. Jameson. Shop Manager.
Walls	240	Messrs. Inteste & Co.

* Station closed.

LIST OF STATIONS SUPPLIED WITH FISHERY BAROMETERS—*continued.*

District and Port.	No.	Custodian.
SCOTLAND—*continued.*		
Orkney Isles.		
Westray	205	Mr. J. Hewison, Merchant.
Papa Westray	215	Mr. J. Petrie.
Burray	29	Mr. R. Sutherland, Postmaster.
Kirkwall	125	Harbour Master.
Barswick	14	Mr. J. Annal.
East Coast.		
Duncansbay	217	Mr. W. Manson, Merchant.
Freswick	202	Mr. J. Mowat, Crofter.
Auchengill	203	Mr. J. Nicholson, Farmer.
Keiss	167	Mr. M. E. Mowat, Merchant.
Ackergill	103	Mr. D. Thain, Fisherman.
Staxigoe	50	Mr. W. Plowman, Cooper.
Wick	133	Mr. A. Sinclair, Fishery Offices.
Lybster	1	Harbour Master.
Dunbeath	270	Mr. J. McPherson, Cooper.
Hilton	74	Mr. A. Wood, Fisherman.
Inver	237	Mr. A. Fraser, Fisherman.
Portmahomack	4	Harbour Master.
Ballintore	264	" "
Cromarty	95	A. McDonald, Fisherman.
Avoch	101	Mr. D. McLeman, Coal Merchant.
Nairn	16	Harbour Master.
Burghead	64	" "
Portessie	269	
Port Knockie	81	Harbour Master.
Portsoy	102	Harbour Master.
Whitehills	12	Mr. G. Findlay.
Gardenstown	26	Mr. G. Watt, Merchant.
Rosehearty	79	Harbour Master.
Pitullie (Sandhaven).	85	" "
Fraserburgh	200	" "
Inverallochy	141	Mr. J. Duthie, Fisherman.
Pointlaw	150	Mr. B. Tuck, Ferryman.
Portlethen	61	Mr. J. Craig, Fisherman.
Skateraw	164	Mr. W. Christie, Fisherman.
Stonehaven	138	Harbour Master.
Arbroath	210	Mr. T. Swankie, Ship Chandler.
SCOTLAND—*continued.*		
East Coast—*continued.*		
Broughty Ferry	24	Mr. J. B. Gall, Fisherman.
St. Andrews	21	Harbour Master.
Crail	53	" "
Cellardyke	34	Mr. W. Allan, Merchant.
St. Monance	230	Mr. J. Dunn, Merchant.
Burntisland	194	Mr. J. Isles.
Newhaven	11	Harbour Master.
South-West Coast.		
Port Patrick	106	Coast Guard.
Cairn Ryan	129	" "
Port William	193	Harbour Master.
West Coast.		
Lamlash	247	Police Inspector.
Tarbert (Loch Fyne).	178	Mr. D. McMillan, Quay Porter.
Loch Ranza	105	Piermaster
Campbeltown	169	Harbour Master.
Carradale	168	Piermaster.
Portnahaven	143	Mr. M. McNeill, Fisherman.
Port Wemyss	248	Mr. J. McKinnon, Fisherman.
Gruinard	222	Mr. J. Brown, Merchant.
Bowmore (Islay)	251	Mr. J. Kirk, Hotel Keeper.
Mallaig	259	Station Master.
Portree, Isle of Skye.	70	Piermaster.
Armadale, Isle of Skye.	213	Mr. N. Kennedy, Merchant.
Isle of Soay	235	Mr. Kennedy, Schoolmaster.
Kyle of Lochalsh	260	Mr. N. C. Macintosh.
Plockton	89	Mr. J. Gillies, Fisherman.
Ardneaskan	252	Mr. D. Mackay, Fisherman.
Shieldaig (Applecross)	239	Mr. J. Grant.
Badachro	244	Mr. J. Mackenzie, Fishcurer.
Ullapool	151	Mr. W. Urquhart, Grocer.
East Mey	124	Mr. J. Mackay, Fisherman.
Gills	238	Mr. J. Geddes, Crofter.
Stroma, North	114	Mr. W. Allan, Fisherman.
" , South	75	Mr. A. S. Robertson, Postman.

LIST OF STATIONS SUPPLIED WITH FISHERY BAROMETERS—*continued.*

District and Port.	No.	Custodian.
SCOTLAND—*continued.*		
Hebrides.		
Ness	69	Mr. J. McLeod, Postmaster.
Carloway	271	Harbourmaster.
Marvaig	262	Mr. W. Kerr, Schoolmaster.
Crossbost	266	Postmistress.
Stornoway ...	68	Harbour Master.
Portnaguran ...	207	
Valtos	209	
Obb	94	Mr. W. Stewart.
Bernera	255	Mr. F. Paterson, Merchant.
Boreray	208	Mr. D. McDonald, Merchant.
Lemreway ...	199	Mr. A. McLeod.
Loch Boisdale ...	*	Mr. A. MacLennan.

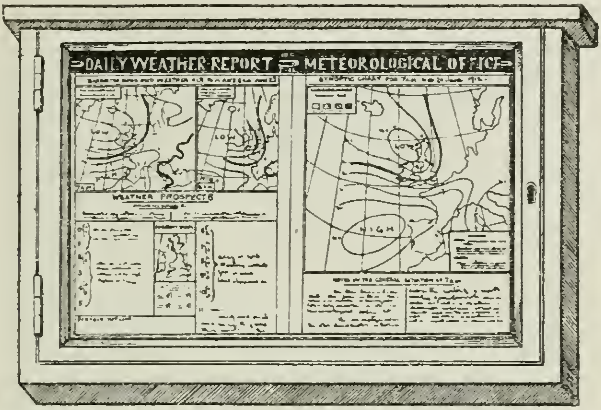
*Large Barograph No. 137.

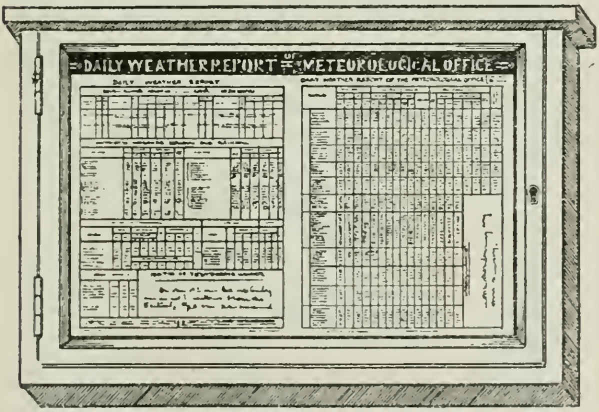
District and Port.	No.	Custodian.
IRELAND.		
East Coast.		
Belfast	73	Customs Officer.
Bangor	51	Coast Guard.
Groomsport ...	172	
Portavogie ...	28	Coast Guard
Donaghadee ...	189	Station Master.
Ballyhalbert ...	187	Harbour Master.
Cloghy	251	Coast Guard.
Ardglass	72	,, ,,
Carlingford ...	120	,, ,,
Glenarm	130	,, ,,
Greenore	127	,, ,,
Dundalk	36	Town Clerk.
Loughshinney ...	170	Coast Guard.
Clogher Head ...	242	,, ,,
Malahide	122	,, ,,
Howth	59	,, ,,
Kingstown (H.M.S. Ranger).	98	Coast Guard.
Kingstown (Sailors' Home).	123	Harbour Master.
Bray	179	Coast Guard.
Wicklow	198	,, ,,
Rosslare	113	,, ,,

District and Port.	No.	Custodian.
IRELAND—*continued.*		
South Coast.		
Dunmore East ...	163	Coast Guard.
Dungarvan ...	78	Harbour Master.
Kinsale	107	Coast Guard.
Union Hall ...	228	,, ,,
Castletownshend...	9	,, ,,
Baltimore ...	197	,, ,,
Schull (2)	3 185	,, ,,
Crookhaven ...	154	,, ,,
Castletown (Berehaven).	227	,, ,,
Lawrence Cove ...	234	,, ,,
Ballydonegan ...	232	,, ,,
Ballycrovane ...	229	,, ,,
West Coast.		
Valencia	246	Coast Guard.
Dingle	39	,, ,,
Tralee (Fenit)	71	Mr. A. Board.
Kilronan	25	Coast Guard.
Galway	236	Customs Officer.
Spiddal	196	Coast Guard.
Cleggan	220	,, ,,
Elly Bay	250	,, ,,
Ballyglass ...	226	,, ,,
Ballycastle (Mayo)	20	,, ,,
Mullaghmore ...	15	,, ,,
Donegal	166	,, ,,
Tribane	145	,, ,,
Killybegs	104	,, ,,
Teelin	144	,, ,,
Malinmore ...	225	,, ,,
Port Noo	176	,, ,,
Burton Port ...	65	,, ,,
Kincashla ...	201	,, ,,
Bunbeg	83	,, ,,
Inniscoo Island ...	258	Captain J. O'Donnell
North Coast.		
Dunfanaghy ...	46	Mr. W. T. Auld.
Rathmullen ...	48	Harbour Constabl
Buncrana... ...	132	Coast Guard.
Malin Head ...	139	,, ,,
Moville	147	,, ,,
Greencastle ...	256	,, ,,
Port Stewart ...	159	Harbour Master.
Portrush	128	Coast Guard.
Port Ballintrae ...	233	,, ,,
Ballintoy	142	,, ,,
Ballycastle (co. Antrim).	216	,, ,,

FRAMES FOR EXHIBITING WEATHER INFORMATION AT FISHING PORTS, &c.

In accordance with the tradition initiated 50 years ago, the Meteorological Office has lent barometers to about 230 fishing villages, and in peace time sends storm warnings by telegraph to 250 seaports. These provisions have for their object the diminution of the loss of life and property at sea. The regulations under which the loans have been made and the telegrams sent provide that the incidental cost of exhibiting the barometers and hoisting the signals have to be borne by the locality.



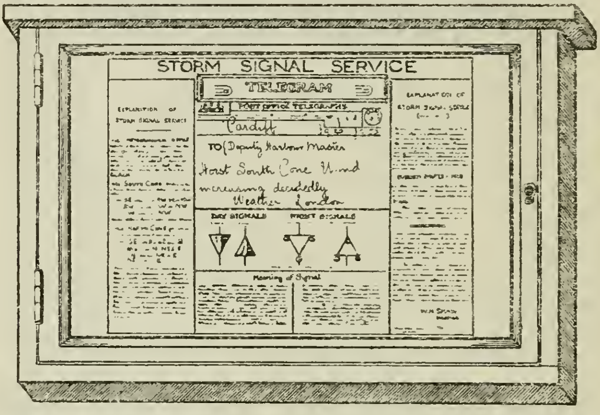


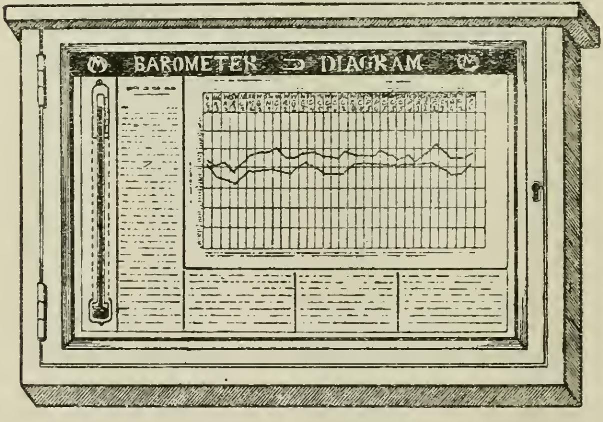
To enable fishermen and others to take advantage of these facilities for making use of our increasing knowledge of the laws of weather, the barometer diagram and the storm warning telegram, together with the explanation of the meaning of the warning, should be exhibited where they can be seen by all. From the fact that the several localities have been left to make their own arrangements for exhibiting the Weather Information there has been no organised system for providing suitable frames, and in consequence, in many cases, the information has not been accessible to the people for whom it is intended.

The Office has also made a practice of sending post free to a number of seaports copies of the "Daily Weather Report."

This Report gives detailed observations as received by telegram from the United Kingdom, Atlantic Islands, and European countries, and by "wireless" from ships at sea, together with the charts and the forecasts based on these observations. Both sides of this Report should be visible to the public, but the local provision for exhibiting it is often inadequate and sometimes fails altogether.

In order as far as possible to meet this want, a teak frame has been designed of the proper size. It is strong and waterproof. A sliding bolt to catch the sheets of paper which are to be exhibited has been devised, and, on trial, has been found serviceable.





Frames of this pattern can now be sent out from the Meteorological Office ready for fixing; they can be secured directly to wood-work or to wall plugs. For the exhibition of the whole of the information sent out by the Office in the forms mentioned above, four frames would be required, as shown in the accompanying sketch, but they may be obtained separately to meet the requirements of individual localities. The cost of the frames is £1 10*s*. 0*d*. each (carriage to any railway station in the British Isles included). Applications for supply should be addressed to the Director, Meteorological Office, South Kensington, London, S.W.

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