ESSAY

ON

METEOROLOGICAL OBSERVATIONS.

BY

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The following essay on Meteorological Observations, was written by that distinguished scientific Gentleman, J. N. Nicollet, Esq., *in compliance with a wish expressed to him by the Honorable* J. R. Poinsett, *Secretary of the Department of War.*

It appeared to be so admirable a digest of what had been published on this subject, and to contain so many valuable suggestions from a highly philosophical mind, that lately, when it was a question to devise a system of instructions for observations of that kind, it was considered as probably the better course to publish this essay entire, as it was written. Accordingly, and in conformity with the directions of the Honorable Secretary, it has been printed for distribution to those officers whose duty it may be to make observations on the phenomena of which it treats, and for the benefit of others whose tastes and situations may induce them voluntarily to aid the cause of science and the useful arts.

Observations made by officers and agents of the Corps, will be regularly transmitted to this Bureau; those of others will be received with pleasure, and authors duly credited in any use that may be made of them.

J. J. ABERT,
Col. Topographical Engineers.

Bureau Topographical Engineers,
May 6, 1839.

METEOROLOGY.

Meteorology, as a branch of Natural Philosophy, comprehends not only the observation of those casual phenomena which occasionally appear in the atmosphere, and were formerly designated under the name of *Meteors*, but it embraces likewise an inquiry into all those phenomena, whether transcient or permanent, regular or irregular, which are brought about by the agency of heat, of electricity, of magnetism, or of light, either in the interior of the earth, upon its surface, or within the atmospheric ocean with which it is surrounded.

The object of the following remarks is to indicate the means of furnishing new and available data in reference to all these phenomena, and to enable observers to decide for themselves, and properly to appreciate *any condition of things* that might afford them opportunities to pursue their researches; and which, as they cannot always anticipate, they should at all times feel prepared to encounter with confidence.

In satisfying ourselves with the task of pointing out the manner of conducting each kind of observations, we leave it to the observer to choose his own mode of keeping a correct journal of the experiments that are made, and of drawing off tables and summaries of such as should be published, in order that men of science of all nations may consult them for the purpose of examining, elucidating, or verifying questions that have already been suggested, and that they may further serve to establish new and unquestionable facts in the science.

I.

OF BAROMETICAL OBSERVATIONS, OR THE MEASURE OF THE ATMOSPHERIC PRESSURE.

Our earth is surrounded by an atmosphere which presses upon it at all points, over its continents as well as over its oceans. By means of the *barometer*, we are enabled to estimate the pressure of the whole mass of this atmosphere, nearly with the same precision as if we were capable of actually weighing it; but we can see nothing of what is going on in the superior regions of the air. Placed upon the surface of the earth, we feel the winds and hurricanes; we experience changes of temperature; we distinguish those motions that are made evident by the passage of clouds at their ordinary elevations, and no more. With the assistance of the barometer, however, and from the property which that instrument possesses of marking at all times the *weight* of the column of air which it counterbalances, we can become aware of changes that take place in the whole of the ærial ocean at once.

It is easy to understand from this alone, that at any given spot the barometer will not remain stationary for a whole year, for a whole month, nay, nor for a whole day. In every place, accordingly, the mercury in the tube of the barometer continually oscillates between two points above and below a certain *mean elevation*, which is peculiar to that place; though sometimes, and apparently as if from a general concussion of the atmosphere, it is suddenly depressed below, and at other times as suddenly forced above this mean point.

These sudden changes in the height of the barometrical column, which are commonly called its *accidental variations*, are observed not to have the same extent in all climates, nor at all elevations above the surface of the ocean, but to be greater in proportion as the latitude is higher: so that such accidental variations must be less evident as we advance towards the equatorial regions. Accordingly the observations of Mr. de Humboldt show, that, in the torrid zone, the barometer is almost insensible to the great movements of the atmosphere. But this is not all. The action of the sun and moon before it reaches the ocean, to cause the phenomenon of its ebb and flow, must have previously passed through the atmospheric ocean, to which it will consequently have imparted a similar influence, and in which it will necessarily have produced phenomena analogous to those of the tides. Hence the occasion of winds and corresponding oscillations in the mercury of the barometer. But as winds occasioned by this cause are very inconsiderable, and almost insensible, compared with the great agitations to which the whole fluid mass is liable, it is at once apparent that the extent of the latter kind of oscillations will be very trifling; and that, consequently, the experiments by which they are ascertained, are of a very delicate nature. However, as it had been found that the oceanic tides are very much influenced by local causes, it was natural to suppose that analogous effects arising out of local causes also, would be produced in the atmospheric tides; and, therefore, it became a matter of much interest to ascertain the fact by direct observation.

The inquiry has been crowned with complete success. The observations made by Mr. de Humboldt in the equatorial regions, those that have been made in Europe, and more particularly those made at the Royal Observatory of Paris, demonstrate the existence of an *atmospheric tide*, which is very sensible, and which can be easily estimated by means of instruments now in use, and by adopting the method of observation indispensably necessary to be followed, in order that the great number of facts required for determining so curious a result, should be comparable with each other. It has been found that in the ordinary condition of the atmosphere, the barometer rises twice and falls twice during the twenty-four hours. The periods of these regular changes, called the *hourly variations* or *diurnal variations* of the barometer, occur at stated hours; and the amplitudes of the oscillations are very much the same in each given spot. Variations of this kind are thus very readily distinguished from the accidental variations, which are irregular in their appearance, and the extent of which cannot be foreseen.

The researches of Mr. de Humboldt further show, that at the equator, the *maximum* rise of the mercury in the barometer takes place at 9 o'clock, A. M.; after this time the mercury begins to fall until 4 to 4½ P. M.; and rises again until 11 P. M., when it arrives at its second maximum elevation, and returns finally until 4 A. M. to pursue a similar order of ascent and descent: so that every day the barometer reaches the two *maxima* of 9 A. M. and 11 P. M., and the two *minima* of 4 A. M. and 4. P. M. And such is the regularity with which these motions are effected within the equatorial zones, that they might there serve to give the true time of the day.

In the temperate regions, on the other hand, where the atmospheric changes are considerable and less regular, the diurnal variations are much concealed by the accidental variations. Fortunately, however, the usual changes of the barometer take place so slowly, as not to materially counteract the effects of regular causes. Observations carried on with precision, during one week only, are almost always sufficient to point out the general phenomenon. But to obtain an exact knowledge of the absolute mean value of each of the four diurnal variations, and of the precise time of the *maximum* and *minimum* of each period, requires a much longer series of observations. As regards this, it has been remarked, that from one place to another, the *mean* of the four diurnal variations diminishes from the equator to the poles; and that, for any given spot, this same *mean* result, and the time of the periods, change with the seasons, though they remain pretty nearly alike every year.

It is in respect to the latter considerations that Meteorology shows many *desiderata*. The phenomena depending upon the oscillations of the atmosphere, have fixed the attention of philosophers only since the beginning of the present century. Not that we are not already in possession of immense collections of meteorological observations that are very correct in themselves, but such labors are calculated only to prove the zeal and patience of those who have undertaken them; because their authors were not acquainted with the proper hours for making the observations, and that they did not know what conditions it was necessary to attend to, in order to render them comparable with those made elsewhere; and because, too, they were ignorant of the true methods which, by rejecting all arbitrary results, could alone serve as means of combining facts in the most advantageous manner, so as not to be exposed to the censure of laying down as laws of nature fortuitous occurrences, due, perhaps, entirely to accidental and irregular causes. It is owing to the imperfection of these early observations, that the progress of Meteorology has been so long retarded. The ablest Geometricians have at length, however, succeeded in establishing the theory of atmospheric oscillations; and the most accurate observers have repeatedly verified this theory upon the best authenticated facts.

We may now, therefore, guided both by theory and by experience, confidently engage in an inquiry into the data required for the solution of so many interesting questions; whilst we are enabled, at the same time, to discover the resources that can be derived from the barometer, in the way of obtaining accurate geographical levels, of ascertaining those between one sea and another, besides more immediately subserving the purposes of Meteorology. Hence, to avoid any unprofitable expenditure of time or labor, let us at once point out the proper methods which meteorologists should follow in recording the phenomena that depend upon the barometrical condition of the atmosphere. We shall, as regards this, conform ourselves to the instructions laid down by the most zealous observers.

The first, and at the same time the principal fact to be ascertained on any given locality, is that of its *mean diurnal barometrical height.*

Now, what is understood by the *mean diurnal height,* is the mean term of all the *degrees* to which the barometer has risen during each period into which the day may have been divided. Thus, if the period of one hour's interval be adopted, and that the state of the barometer be examined at each, *the sum of 24 barometrical indications, divided by 24, the number of observations made between two consecutive noons, or midnights, will give the mean diurnal barometrical height.* It may readily be imagined, however, that if it were indispensable to make these 24 observations every day, there would be great risk of never completing a sufficient number of them. Few co-operators could be found disposed to engage in so slavish and tedious an undertaking. It happens, therefore, fortunately, that a long series of experiments has shown, that there is *one* hour of the day when the height of the mercury in the barometer is within a fraction of the *diurnal mean*: This important event takes place at *noon.* Hence it becomes necessary only to take, every day, one accurate observation at this hour, to have with sufficient precision an equivalent of the *mean diurnal barometrical height sought.*

Being provided with the mean barometrical height of each day, if we add together the 30 indications thus obtained during the thirty days of the month, and divide this sum by 30, we shall have the *mean barometrical height for the month.* A similar calculation applied to the 12 mean heights of 12 months, will give us the *mean height for the year.* And, finally, the latter deduction having been made for a number of years in succession, will give, on an average, the mean *absolute* height of the barometer proper to the locality upon which the observations have been made. These are the first fundamental results which it is of the utmost importance to establish for every prominent spot upon our globe.

Now, as regards the diurnal variations of the barometer, these should be investigated according to an analogous method. The principles which we have already laid down will enable us to determine these also, and in such a manner as to avoid as much as possible the errors occasioned by the great *accidental variations* of the barometer. Having said that there were four principal diurnal variations indicated at two *maximum* and two *minimum* points, it follows that the barometer should be observed at the periods of these greatest ascents and descents. In the equatorial regions we have already seen that these periods occur at 4 and 9 A. M. and at 4 and 11 P. M. But as these periods may, and do, vary in other regions of the globe, it will be necessary to determine, in the first place, the time when they are most likely in a given locality, to take place. For this purpose it will not require more than three or four select days of observations, made under the most favorable conditions of the atmosphere that will present themselves. The indications of the barometer must then be taken down every two hours, or, if possible, every hour. The rule of practice which should be followed is very simple. Generally speaking, the hours of 3 or 4 A. M., 9 A. M., 3 P. M. and 10 or 11 P. M. appear to be those most likely to give satisfactory results. To these, therefore, the attention should be first directed. Thus, in each station, strictly speaking, no comprehensive estimate can be made of the phenomena depending upon the pressure of the atmosphere, unless at least *five* barometrical observations be taken in every twenty-four hours, and for each day, as follows:—

At 3 or 4 o'clock, A. M.
At 9 " "
At noon,
At 3 " P. M., and
At 9 or 10 " "

In order to obtain a numerical estimate of the diurnal variations it is necessary to compare together all the observations of the same day: that is to say, we compare the observations made at 3 or 4 A. M. with that made at 9 A. M.; the latter with that of 3 P. M.; and so on; the mean of a number of estimates derived in this manner, from observations made for each period, enables geometricians to verify their theories by these experiments, and likewise to assign the meteorological causes to which the phenomena are due.

Observations conducted according to the above method, as they require so much punctuality and perseverance, will no doubt be thought by some tedious of execution; but this is the only way by which we can arrive at the most useful and satisfactory results in the science.

But to continue: The indications of the barometer being subjected to the influence of the winds, it follows that the mean heights deduced from observations made with that instrument, will have different values, according to the prevalence of certain winds.

As regards France and England, and on the coasts, experience has shown that the heights to which the barometric column ascends, taken under the influence of the S. and S. W. winds, are *cœteris paribus*, less than when observed under the action of the N. and N. E. winds. The former ascents are below, the latter above the mean absolute height of corresponding hours. It has, moreover, been discovered, that the average of observations thus influenced by opposite winds, is nearly a correct expression of the true mean height: a fact which is certainly very remarkable. It becomes necessary, therefore, to study the effects produced on the barometer by the predominant winds in each locality. When, then, a sufficient number of accurate observations will have been made along the shores of the oceans and inland seas, and that the important question of determining their respective level shall occur, the circumstance of having attended to the prevailing winds will come into play; for it is more than probable that the effects of the same winds are not the same in all countries. In the United States, for example, the results will probably be directly the reverse of what has been observed in France.

Finally: In order that barometrical observations may be comparable with each other, both as regards those made on the same spot and those obtained on other localities, there are two sorts of corrections to which they must be previously subjected. The first relates to the phenomenon of *capillary tubes;* the other consists in reducing the temperature of the barometrical column, at the moment of each observation, to some fixed degree of the thermometric scale; say 32° Fahrenheit. Tables intended to furnish these corrections, are to be found in most treatises on Natural Philosophy.

II.

OF THERMOMETRIC OBSERVATIONS, OR THE MEASURE OF TEMPERATURE.

The most prominent circumstance in the physical character of a climate is its temperature. Now, as meteorological phenomena are very much influenced by the thermometric condition of the atmosphere at the time they occur, it becomes a matter of indispensable necessity to inquire into the laws that regulate the distribution of heat on the surface of the earth.

This inquiry calls for a great number of observations, made, as in the case of the barometer, with the most accurate instruments, and throughout every climate. The meteorology of heat dates only from the commencement of the present century. It is only within thirty years that it can be said to have received a proper direction, by the united assistance of the most learned mathematical deductions and the laborious researches of the most experienced observers. Good and stationary observations have now been begun at several places; numerous scientific voyages have been performed in all directions over continents, over oceans, and to the summit of the highest mountains; very interesting results have been obtained, that have suggested some important questions with regard to the temperature of our globe, and that are calculated to throw much light upon the nature of meteorological phenomena and upon several points of physical geography, when the solution of these questions will have been rendered complete by a greater number of stationary and more diffused observations.

To co-operate usefully in an examination of such questions, it is necessary to determine, in each locality, 1st, the superficial temperature of the place; 2d, the temperature at various depths beneath the surface of the ground; 3d, the temperature at different elevations above the level of the country.

1st.—Of the superficial temperature, or the temperature of the atmosphere immediately above the surface of the ground.

We must define what is understood by *mean temperature*, as in the case of the barometer we explained what was meant by *mean height*. If observations be made with the thermometer every hour, or twenty-four times, from one midnight to another, the 24 numbers indicating the temperatures thus ascertained being added together and their sum divided by 24, the number of observations taken, we shall obtain precisely what is called the mean temperature of the day.

But, in respect to this, also, so tedious a labor is in general impracticable. The first subject of research, therefore, has been to discover an expression of the temperature which would be equivalent to the one sought and the means of finding which would not be so minute and fatiguing. The observations that have already been made, indicate to a certainity that the mean of the highest and lowest temperature of the day scarcely differs from the exact mean of the twenty-four hours; and that, consequently, one is an equivalent of the other. Moreover, the lowest or minimum temperature of the day is found to occur at sunrise; and the highest or maximum temperature takes place at 2 or 3 o'clock P. M. All that is required, therefore, is to observe the thermometer twice a day—1st, at sunrise, 2d, at 2 or 3 o'clock P. M.—and we obtain an exact equivalent of the mean temperature of the day, as defined above.

The comparison of a great number of observations has further pointed out, that the temperature indicated at sundown will *alone* give a very approximate equivalent of the mean temperature deduced from the combined observations made at sunrise and from 2 to 3 P. M. Thus, an observer, according to the circumstances in which he may be placed, may make use of either of these two modes of ascertaining the mean temperature of the day, or, what is much more satisfactory, employ them both to obtain the result desired. In a comprehensive system of permanent meteorological observations, we would decidedly recommend the practice of ascertaining the temperature at sunrise and from 2 to 3 P. M., as affording, at the expense of very little inconvenience, the most satisfactory data. In the next place, the mean temperature of the *month* is equal to the sum of the mean temperature of all the days in the month divided by the number of those days: and the mean temperature of the year is the quotient of the sum of the twelve monthly mean temperatures divided by 12; or that of the mean temperature of the days divided by 365 for the common year and by 366 for leap year.

It has been discovered, besides, that the mean temperature of the year could be determined by two other methods: 1st, by taking the mean temperature of the month of October only, which is very nearly its equivalent; 2d, by taking the annual mean temperature corresponding to some fixed hour of the day, which hour, even in pretty high latitudes, is found to be 9 A. M. But, as by these two methods we exclude the inquiry into the mean temperature of all the days of the year, (which is an important element in ascertaining the mean temperature of the months and seasons, and thus in arriving at a knowledge of the annual distribution of heat for the locality upon which the observations are made,) it is more rational and much more useful in a permanent establishment to adopt the mode of practice recommended above.

Finally, when an extensive number of the mean annual temperatures of any given spot shall have been collected, the mean of these all must be taken to establish the *absolute* mean temperature of the place. This last-mentioned element is the fundamental one, which it is of the utmost importance to determine for the greatest possible number of places on our globe. Many years of observations are required, before any result approximating to the truth can be obtained. The absolute truth is itself attainable only on the supposition that the changes to which a locality is subject are produced by some regular oscillations of its temperature: whilst the supposition seems corroborated by the circumstance that all observations heretofore made tend to prove the stability of climates and lead us to suspect that whatever vicissitudes or apparent perturbations they experience, are real oscillations, the periods of which, in consequence of their length, are yet unknown to us. But, had the fact been the reverse, and experience shown that the changes of temperature in any locality take place according to an indefinite progression, that the temperature of a climate goes on progressively diminishing or progressively increasing, the object of the research would not be to determine the mean temperature, but to ascertain the ratio of progression in which the temperature of a climate goes on thus increasing or diminishing. It is very probable that, in such case, the law would be very indefinite and complicated, but its existence could not be doubted: since every permanent phenomenon must necessarily be subservient to some law which is itself dependent upon the cause of the phenomenon. Such, however, we have seen, is not the case. Whenever a certain number of mean annual temperatures have been determined, it was feund that they vary from each other irregularly between any two years, but without ever exceeding (except by a very few degrees above or below) the limit which we have stated to be the absolute mean temperature of the place. No series of accurate observations has yet been produced, which could warrant the conclusion that the temperature of the locality upon which they were made undergoes changes that take place in any ratio of progression. On the contrary, every fact thus far tends to confirm the belief in the stability of climates. It will be felt, therefore, how powerful are the motives which should induce us zealously to persevere in the research of so important an element in our future calculations as the absolute mean temperature. A research of this kind will not have been completed for the different localities, until the deviations of each annual result from their absolute mean shall have been reduced to the lowest point possible. The more dissimilar the results, the more will it become necessary to multiply observations in order to neutralize the effects of the accidental causes of this dissimilarity. In some climates, (between the tropics for example,) where those causes are but trifling in their influence, a single year of observations will allow us to determine the exact mean temperature. This is not the case however in the climate of the temperate zones. At Paris, for instance, the means of twenty-one years of this century, during which observations have been made, differ from each other by as much as 2.7° centigrade, so that an error of this magnitude might result from adopting any one of these annual means as an expression of the absolute mean temperature of Paris. But, by taking the average of the means of these 21 years, the equivalent of the absolute mean temperature of Paris is found to be 10.8° cent.; in which most probably the error is reduced to 0.2° only.

A moment's reflection as to the great consequences to which labors of this kind, which are now being achieved everywhere, may lead, will make manifest the immense importance of similar researches undertaken in the United States, whose varied, extensive, and as yet unchanged natural surface is subject to vicissitudes of temperature at once so great, so sudden, and so frequent. The comparison of a great number of mean temperatures ascertained for many places, will enable us to determine the law of the decrease of heat for each meridian from the equator to the poles, as well as that for each vertical height according to its elevation above the level of the sea. The latitude of a spot and its absolute height are the two most general circumstances by which its mean temperature is affected; but the influence of these circumstances is greatly modified by a multitude of secondary and local causes, some of which are constant and others variable. Among the most prominent of these modifying causes, may be mentioned the distance of the locality from the ocean; from great lakes and large rivers; the vicinity of mountain chains; the inclination of the soil, its nature, its mode of cultivation; the prevailing winds; finally, all the phenomena dependent upon the barometric condition of the atmosphere.

It might seem, at first sight, that it would be impossible to establish any order amongst a mass of facts brought about in the midst of so many disturbing causes: science, nevertheless, by carefully analyzing and comparing their results, has succeeded in discovering the comprehensive law by which these varied phenomena are regulated. Humboldt has been the first to lay open this vast and interesting field of inquiry.

With the assistance which is derived from having ascertained the mean temperature of places, we are enabled to determine the limits of all vegetation, and to draw a series of curves, called isothermal lines, (or lines of equal temperature,) all round the globe. Viewing the climates of the zones comprized between these lines, we detect the causes of the similarity or difference in their vegetable productions, as well as the influence they respectively exercise on the animal economy : and in reference to the distribution of heat over them, these zones come to be classed as *constant* climates; *variable* and *excessive* climates, which, when compared together, reveal to us many of the circumstances influencing the industry, the customs, and the progress of civilization among their inhabitants. For each climate, on the other hand, the mean temperature of the days, of the months, and of the seasons, and its extreme temperature, indicate the nature, facilities, and resources of the agricultural pursuits which can be carried on within it; while the marked difference in respect to temperature existing between one climate and another, likewise explains consequent varieties in those productions which promote the interest of agriculturists, excite industry, and serve to animate commerce.

Finally. Next to the solution of these questions, which are of such immediate interest, we are led to consider those of a more general character, viz: Is it true that the western coasts of the old and new continents have, on an average, in the same latitudes, a sensibly higher temperature than the eastern coasts? Is it true that the western coast of Europe has a higher average temperature than the eastern coast of the United States of North America? Is it true that the old continent is warmer than the new? &c.

2*d.—Of the temperature at various depths beneath the surface of the earth.*

From experiments which have been undertaken within a few years, it is inferred that there exists a *stratum* situated a certain depth beneath the surface of the earth, the temperature of which has remained the same during centuries. Observations made at the depth of 85 French feet in the cellars under the Royal Observatory of Paris prove that for more than fifty years back the temperature of that place has not varied the 0.25 of a degree above or below the constant mean, which is ascertained to be 10.82° cent. Unfortunately, Paris is perhaps the only place where observations as regards this subject have been as yet made in sufficient number and with sufficient precision. So constant and regular a phenomenon, however, could not be considered the effect of an accidental cause. Hence philosophers have been led to imagine that, everywhere, at a certain depth beneath the surface of the ground, there is a point at which the temperature remains constantly the same, whatever may be the changes that take place in the course of the year throughout the superincumbent soil and atmosphere. If, then, we suppose a section passing all round the earth, through all these points of constant temperature, we shall have an idea of that subterranean stratum called *the stratum of invariable temperature*, (couche invariable,) at which all the accidental and regular changes brought about by the alternation of day and night and the succession of seasons, on the superincumbent soil, vanish. But the question is, At what depth do we meet with this stratum of invariable temperature? As we lack appropriate observations made at various depths in different climates, this question cannot yet be decided experimentally; but we are warranted in concluding, theoretically, that in all localities the limit of invariable temperature cannot deviate much from the mean temperature of the superficial spot which is directly over the stratum where the observations are carried on; and that, in general, to find this correspondence, we must penetrate 2, 5, 10, 20, 40, 60, &c. feet below the surface, according to climate. It will readily be imagined that this stratum of invariable temperature must represent an irregular curve around the globe, determined by a thousand internal and external local causes, arising from the peculiar nature and configuration of the ground. What the direction of this curve is, must be deduced from future experiments.

There are other thermometric observations equally desirable to be considered in this section, viz: such as might be conveniently made at various depths between the surface of the ground and the probable limit of invariable temperature. So far we are acquainted with only few experiments of this kind; and these are mostly confined to moderate depths: they are nevertheless sufficient to indicate some very curious and remarkable circumstances as regards the movements of temperature according to seasons, from the surface of the ground to the stratum of invariable temperature. Thus it is observed that the oscillations of these temperatures diminish in extent as we descend, and thermometers sunk into the soil at equal depths in several localities where the mean temperatures are the same, still give very different results. The upper stratum of soil, taken from a few lines under the superfices to the depth of an inch only, always indicates a very different temperature from that of the ambient air: whereas the surface itself, during the day is much warmer, and during the night much colder, than the air. These results are, however, modified upon every locality, by many causes, the principal of which are, the sort of climate and the nature of the soil. Whenever the influence of these causes shall have been fully appreciated, it is evident that many important and useful facts, not only interesting to meteorology but subservient to the purposes of agriculture and domestic economy, will grow out of this knowledge.

Finally: if we penetrate beyond the stratum of invariable temperature, and measure, with the requisite precautions, the degrees of sensible heat at all accessible depths, we should thereby be enabled to throw some light upon one of the most interesting questions in the natural sciences, viz: that of the existence or non-existence of an internal heat—*a central heat*. This subject stands preeminent in modern theories of the earth, as serving to explain the phenomena of earthquakes, of volcanoes and the eruption of lava, the cause of the permanent high temperature of thermal springs, &c.

The fact that the temperature of the earth increases as we descend towards its centre, was ascertained nearly a century ago, by observing with the thermometer at successively increasing depths; but it was only some time after, that the important question to which this fact gives rise engaged the serious attention of philosophers, and took a proper direction. Observations tending to confirm the fact have been made in the principal mines of Europe, in France, Germany, and England. In Mexico, Humboldt was enabled to determine the temperature of the mines of that country, to the depth of 1713 English feet. The following are the principal consequences deduced from the experiments that have so far been made:

1. In all places where observations with the thermometer have been made beneath the *invariable stratum*, there is no known exception to the rule that the temperature increases with the depth.

2. Beneath the invariable stratum, the temperature peculiar to each stratum along the same vertical line is likewise invariable.

3. The proportion in which the temperature increases with the depth is often very different in different localities. The reason of this is readily found in the various causes that modify the distribution of heat throughout the dissimilar mineral strata of the globe. Enough is already known, however, to allow it to be stated approximately that to obtain an increase of 1° centigrade, it is necessary to penetrate from 82 to 98 feet below the stratum under examination.

If we take the data furnished by the observations made in the cellars of the Royal Observatory at Paris, it may be conjectured that, at the depth of about one mile and a half, the heat is about that of boiling water; and at a very small depth, compared with the radius of the earth, it must be sufficient to fuse lava and the greater number of rocks. What is it, then, that takes place in the centre of the terrestrial globe? Whence the origin of this internal heat? Is it produced by chemical combinations that are incessantly taking place at various depths, and might evidently thus give rise to the phenomena of volcanoes? Are we to understand it to be the *central fire* of the ancients; or is it not rather to be considered as the result of a *primitive heat*, imparted to the earth at its origin, which has mostly maintained itself at great depths, but has been partially diffused, according to definite laws, throughout the more superficial strata? This important question is at present reduced to the discussion of the two latter opinions: it awaits a system of observations more complete than any thing we as yet possess, to enable theorists to decide in favor of that which shall more satisfactorily account for the astronomical and geological phenomena connected with the physical constitution of our globe.

3d.—*Of the temperature at different elevations above the surface of the ground.*

We have already had occasion to state that the temperature decreases as we ascend in the atmosphere. This phenomenon is made evident by the perpetual snows that cover many high mountains of the old and new continent. Natural philosophers have been for a long time investigating the law by which this diminution of heat is regulated and the causes to which it may be ascribed. There still remains something to be done, and North America presents us, in relation to this subject, a region of inquiry as yet unexplored. The following is the principal observation that should be made: *to determine simultaneously the temperature of two or more stations the elevations of which are known.* A review of the observations of this kind that have been already made in Europe and within the equatorial zone, demonstrates the fact of a diminution of temperature as we ascend in the regions of the air. The mean of the actual results gives approximately a decrease of 1° cent. for every 541 feet of elevation. But it is also found that, in general, the diminution is not exactly in proportion to the elevation. This proportion is more indefinite, according as the temperature of the place happens to be influenced by the prevailing direction of the winds and the regularity with which the seasons succeed to each other. We cannot expect therefore to obtain a strictly accurate expression of the law, until observations shall have been made with sufficient precision, and in sufficient number to give us a fair estimate of the variable elements that enter into the calculation.

Many strange hypotheses were formerly imagined to explain the diminution of heat as we ascend, so as to discover, at the same time, the cause of the prevailing cold on the summits of high mountains and in the upper regions of the atmosphere. This phenomenon no longer presents any difficulty to natural philosophers, who more readily explain by well-known properties of heat and air susceptible of experimental illustration. The presence of perpetual snow on the summits of high mountains is evidently explained in the same manner. But it is the business of meteorologists to furnish observations enabling us to determine for all climates the height at which it is necessary to ascend the sides of mountains, to reach the line which separates the limit of perpetual congelation from the soils that are more or less adapted to the production of the different families of plants. At first sight it would appear that the mean temperature of the air at the beginning of the line of perpetual snow ought to be the degree of melting ice; but this is not the case. In some places the mean temperature of the air at the snow-line is about zero, while in others it is below. The limit of perpetual snow depends chiefly upon the temperature of the hotter months of the year: it is higher or lower, according as the temperature of these months augments or diminishes from one year to another. It thus experiences annual oscillations, the extent of which necessarily varies with the physical conditions of the locality. In fact, the temperature of the hotter months on any spot specified in reference to its height and geographical position, will depend upon the nature and inclination of the ground, the prevalence of certain winds, and the general condition of the atmosphere, clear, foggy, &c.; and all things otherwise equal, the limit of perpetual snow will besides be more or less elevated in proportion as the previous accumulation of snow will itself have been more or less considerable.

This brief outline of the phenomena to which we have just alluded, will, it is hoped, be sufficient to arrest the attention of observers wherever may be had an opportunity of studying all the circumstances that belong to them. The principal facts to be attended to, are, to determine the height above the sea of the limit of perpetual snow, and the extent of the annual oscillations of this line; to ascertain the mean annual temperature of the air at that elevation; to describe the locality in relation to its general configuration and the nature of its soil; and to fix its precise geographical position. In doing this we not only advance the progress of meteorology, but likewise furnish facts towards the interesting consideration of the geographical distribution of plants and animals.

The temperature of waters.

To complete the system of thermometrical observations which we are attempting to lay down, we have to consider some of the phenomena belonging to the temperature of waters in their various modes of distribution over the globe.

Of the temperature of springs.—It has been found that the temperature of surface springs which flow abundantly varies scarcely from 1° to 2° cent. through all the seasons of the year. In general their maximum degree of temperature is obtained towards the month of September and the minimum in March. The idea naturally suggested itself of comparing the mean temperature of those springs with that of the air over the spots whence they issue: and it has been found that, in the torrid zone, the mean temperature of the air is generally higher than that of the springs; whereas, in the temperate zones, the contrary is observed; the springs here are somewhat warmer than the air, the excess generally increasing with the latitude. From 30° to 50° latitude, the difference is about 1° cent. but from 60° to 70° the difference is as much as from 3° to 4° cent.

The temperature of springs is certainly affected by that of the mineral strata which they traverse; but there is a very important distinction to be made between those springs that are small and rise slowly, and those that flow abundantly. The waters of the former will impart but very little heat to the mineral beds through which they percolate, while, on the contrary, their own temperature may be greatly changed by the extent of the mass which they traverse; and they will carry to the surface the temperature which has thus been imparted to them. The waters of springs that rise quickly and flow abundantly, on the other hand, heat the colder or cool the warmer strata through which they pass, and reach the surface with a temperature very nearly equal to that of the subterranean basins from which they are derived. Whatever changes they may experience from this cause will be less in proportion to the greater quantity of water emitted.

These conclusions, to which we are naturally led, are fully confirmed by the experiments made in France on the temperature of waters in artesian wells. The greater the depth of these wells, the higher the temperature of the water flowing from them; but the temperature of the water brought to the surface in each is invariable. And this condition of the water, at its issue, must be very nearly that of the deep reservoir by which it is furnished. This subject, likewise, offers an illustration of the increase of heat from the surface to the interior: for if there were not a constant source of heat below, it is evident that the alternate descent of the cooler and ascent of the warmer columns would gradually bring the water to the temperature of the surrounding medium. We see, therefore, how well-deserving the attention of meteorologists this subject of ascertaining the temperature of springs has become. In the natural sciences every isolated fact has its value: the most simple fact the observation of which at the time appears the most indifferent, never fails in the end to assume some degree of interest and of usefulness; we have only to wait the time when it can be made available. Thus, with respect to springs which flow rapidly and abundantly, the depth of their source is indicated by the temperature of their waters. It may be affirmed of those that undergo slight changes with the seasons, that their origin and subterranean flow is between the surface of the earth and the *station of invariable temperature*. Their sources cannot be lower than 60 or 80 feet. When the law of the diminution of temperature from the surface to the invariable stratum shall have been correctly laid down, it will then become possible to state the precise depth of the source of a spring whose variable temperature within certain limits has been ascertained.

Finally, the mean temperature of surface springs may serve to give approximately, at least between the parallels of 28° and 58° latitude, the mean temperature of the places where they occur. It may be stated, also, that springs of a constantly uniform temperature, have their origin below the invariable stratum. This temperature being ascertained, the depth of the well may be calculated; and *vice versa*, the temperature of the water may be predicted from the depth to which the well is bored.

The preceding remarks apply to natural springs only, and do not relate to *thermal springs*, nor those sudden eruptions of water, mud, or gas, observed in different countries, and particularly in the neighborhood of active volcanoes. The source of the heat, in thermal springs, has greatly occupied the attention of meteorologists and geologists. The facts in relation to them appear to be complicated. We are not yet able to say whether those waters owe their elevated temperature to the depths at which they take rise, or to some particular processes going on in the strata through which they percolate. This subject still presents an ample field for beautiful researches: meteorologists should neglect no opportunity which may offer itself of ascertaining the temperature of these springs, and noting the geological particularities of the spots at which they issue.

Of the temperature of lakes and rivers.—The surface water of lakes experiences very considerable changes of temperature: in winter it freezes; in summer it is heated as high as 20° to 25° cent. At certain depths below the surface such variations are no longer perceptible. It would seem, therefore, from this fact alone, that the law of the distribution of heat, in a *liquid* mass, operates very differently from what it does in a solid. Here, then, is another interesting question to be examined, requiring thermometrical observations of great accuracy, to be made as much as possible simultaneously, at the surface and at various depths in each lake. The experiments that have hitherto been made in Europe, lead to this remarkable conclusion: that the temperature of the water at the bottom of all lakes is nearly constantly the same, and much lower than the mean temperature of the country. This circumstance, taken in connexion with the fact that the maximum density of water is *fixed*, has furnished the fundamental principle which serves to explain the mode by which an equilibrium of temperature is established in large masses of water, and all the peculiarities in the phenomenon of their congelation. In respect to *rivers*, the mode in which the distribution of heat takes place is not precisely the same.

The motion imparted to the watery molecules produces a constant intermixture of the upper and inferior layers, the effect of which is to establish an equality of temperature in the whole mass. Nevertheless, as this motion is not of the same kind in the middle as on the sides, and as it appears, moreover, to be different at the surface from what it is at the bottom of the river, it gives rise to a multitude of interesting contingent phenomena. Of these, the phenomena of congelation are the only ones that have been so far examined with care. Science claims a system of observations upon which to found a general theory of the whole subject.

The best mode of conducting the observations under this head, appears to us to consist in making thermometrical ones, once a month, at an interval of 30 days each, during several years. Those experiments are to be made at the surface and at the bottom of lakes and rivers. In summer it will be necessary to ascertain more particularly at what depth the heat will reach. In winter, the same interest should be attached to ascertaining the temperature of the surface water at the moment of freezing. For deep lakes, it is required to verify whether the process of congelation commences always at the surface, without ever penetrating to any considerable depth. For rivers, it will be proper to state the proofs that, under certain circumstances, the surface waters are the first to freeze, whilst under other circumstances, the process commences at the bottom, &c. These subjects of consideration are merely hinted at, to awaken the interest which such important researches must necessarily excite.

Of the temperature of the ocean.—This subject is alluded to in this place as a complement to the general theory with regard to the distribution of heat over our globe.

For many years back, the most skilful navigators of different nations have traversed the ocean in all directions, and have instituted, in relation to its temperature and the phenomena attendant upon it, a system of observations of the greatest importance to meteorology. These observations lead to some singular conclusions on the subject of the distribution of heat throughout the agitated mass of waters enclosed within the extensive limits of the ocean. We must waive the consideration of this subject, but we cannot refrain from the desire of raising the emulation of the officers of the United States Navy to this additional opportunity of acquiring honorable distinction by taking an active part in researches which at present engage the attention of scientific navigators of all nations.

Such, then, are the various sorts of thermometrical observations with which meteorologists should occupy themselves. When a great number of aggregate results shall thus have been obtained, it may then become possible to discover the causes that co-operate in maintaining through the entire mass of our planet, its proper distribution of heat, and even all the varieties of temperature to which it is subject; but this great desideratum cannot be filled up without a final appeal to the mathematics. The grand result must be yielded up into the hands of the geometrician, to be dealt with according to the principles of his analysis; from which ordeal it must return to us enriched with the most valuable consequences.

III.

OF THE OBSERVATIONS OF ACCIDENTAL PHENOMENA IN METEOROLOGY.

The fundamental principles of meteorology are established upon the two systems of observations that have been illustrated in the preceding sections. It is hoped that the details there laid down will have been sufficient to afford a proper estimate of the usefulness of such investigations. It must, however, be borne in mind that their utility is altogether dependent upon the care, the regularity, and the constancy with which the experiments will have been conducted. We took pains to insist on the necessity of these conditions; for without them the whole labor becomes fruitless, and loses all claim to that public regard which is attached to scientific productions. If we have succeeded in treating a subject yet so novel with that logical precision which it was our wish and endeavor to bestow upon it, it will be perceived that the two systems of observation are almost always inseparable from one another, and that they serve mutually to elucidate the results obtained by each. We need refer to the principles only on which the barometer and thermometer have been constructed, to understand that the phenomena which those instruments are respectively intended to illustrate, being intimately connected, will on most occasions require the simultaneous indications of both.* It is by thus attending to the joint intelligence which they impart, that, from being objects of merely common use, or simple ornaments of the drawing-room, the barometer and thermometer have become the most indispensable requisites in philosophical

* There is generally, and always should be, a thermometer in the mounting of the barometer, called the *thermometer attached*, which should always be observed with the barometer; and at the same time observation should be made on a detached thermometer, so that a complete barometrical observation must have associated with it observations of the thermometer attached and the thermometer detached.

researches. Considering the simple mode of construction of these instruments, and the ease and convenience with which they are used, we have indeed reason to be filled with surprise that, with apparently such slender means, philosophers should have succeeded in making discoveries alike astonishing by their number and importance.

It remains for us to treat of those *accidental* phenomena that relate to meteorology.

Of the observation of winds.

It is not contemplated, under this head, to treat of the theory of winds. This extensive and complicated subject, about which so much has been written, embraces as yet no general law to which its accompanying phenomena can be referred. We must confine ourselves to some remarks concerning the influence of winds upon the barometer, and the necessity of observing and registering their direction and velocity. In this manner we may also remotely assist in elucidating the general theory of the meteorological agent. We have already said that the direction of the wind has a great influence in determining the correct expression of *mean height* derived from barometrical observations. It is necessary, therefore, to take account of this direction, every time an observation is made. To this effect we may direct attention to the course of the clouds, or, in their absence, to any of the well-known indexes constructed for that purpose.

It will be frequently remarked of the clouds, that they move in different and even opposite directions. This appearance indicates the action of superposed and co-existing currents, contending, as it were, against each other for the mastery. Such occurrences, perhaps so far too much neglected, should not fail to be noted. In general, the true direction of the wind is not easily ascertained; hence it is proper to register only those currents that are strongly marked, in order to avoid the introduction of any doubtful elements in the discussion of the observations afterwards. The direction of the wind being well defined, it is next required to state as accurately as possible its strength, which is estimated by its velocity. For this purpose, the annexed table, exhibiting the classification according to velocity, and the terms generally used to designate their character, may be consulted.

Wind barely perceptible,	whose velocity is	0′.4	inches	per second.
perceptible,	do.	3′.3½	do.	do.
moderate,	do.	6′.6	do.	do.
brisk,	do.	17 feet		do.

Wind, strong,	whose velocity is	33	feet	per second.
very strong,	do.	66	do.	do.
storm	do.	74	do.	do.
great storm,	do.	88.′6″	do.	do.
hurricane,	do.	118′	do.	do.
violent hurricane,	do.	147.′6″	do.	do.

It has been remarked of winds that they are produced in two ways—by *propulsion*, and by what has been termed *aspiration*. It is only when they blow *strongly*, that it can be determined by which of those two modes they take place. The wind is said to be produced by *propulsion* when the blast and current are in the same direction. This is of most usual occurrence. It is said to be produced by *aspiration* when the blast is in one direction and the current in an opposite one. In this latter case it appears to *begin* at that point *towards* which it blows. There are many instances of the kind. The sudden condensation of vapors existing in the bosom of the atmospheric ocean, is no doubt one of the principal causes in the production of wind. This condensation occasions the fall of rain, which produces a vacuum, and originates the wind. The annals of meteorology are encumbered with the accounts of disasters occasioned by those violent winds more particularly designated as storms and hurricanes. The chief characteristic of these is their excessive velocity. The N. E. storms on the coast of North America furnish us unfortunately but too frequently with opportunities of observing them. It has been remarked that, in general, they begin over the Gulf of Mexico, and move on towards the north, by *aspiration*. Whenever an occasion presents itself of observing and describing the phenomena that accompany these storms, it should never be neglected; for a comparison of all the circumstances appertaining to an event of this nature, when collected in various stages of its progress, is extremely useful in leading us to the discovery of the origin and causes. We might cite a great many examples of such storms, but we shall content ourselves with recalling the leading particulars of a very memorable one observed by Dr. Franklin. This distinguished philosopher relates (Letters and Papers on Philosophical Subjects) that, in 1740, he was prevented from observing an eclipse of the moon, at Philadelphia, by a N. E. storm, which came on about 7 o'clock in the evening, and which he was surprised to find afterwards was not felt in Boston until 4 hours later. Comparing subsequently many accounts of this storm, as it manifested itself at various localities, Dr. Franklin discovered that although it blew from the N. E. it was advancing all the while from the S. W. at the rate of about 99 miles per hour, or nearly 145 feet per second. It was, consequently, *a violent hurricane*, which, blowing in one direction while it advanced in another, was produced, as we have said, by *aspiration.* Dr. Franklin supposed that it was owing to some great rarefaction of the air in or near the Gulf of Mexico. But, every thing being considered in relation to phenomena of this sort, there is nothing to be concluded of them farther than that they are great movements of a body of the atmosphere, acting with a momentum proportioned to its velocity.

There are other phenomena, fortunately more rare, but much more destructive in their effects, which ought likewise to be observed and described by meteorologists. Among these we may mention *water-spouts.* These meteors often make their appearance on land, where they overset trees and houses and destroy every thing which opposes itself to their violent impetuosity. They are more frequently met with at sea, where they appear as enormous clouds of a columnar form, or that of an inverted cone, several hundred feet high. The cause of these phenomena has not yet been satisfactorily assigned; we are entirely at a loss for so formidable an agent taking its origin in the midst of the air. Before we can pretend to explain the nature of water-spouts, then, we must have collected with care a detail of all the circumstances by which they are accompanied.

Does electricity perform any part in the production of water-spouts? A categorical answer to this question would possess great interest; therefore, whenever this phenomenon is presented, it should be closely examined if thunder and lightning be then engendered.

Trade winds.

The trade winds may yet be objects of research, as the practice of navigation often limits itself to single perception, with which science is not satisfied. Thus, it is not true, whatever may be said to the contrary, that, to the north of the equator, these winds blow constantly from the N. E. and to the south of the equator constantly from the S. E. The phenomena are not the same in the two hemispheres; and, moreover, in each place, they change with the seasons. Daily observations of the real directions, and, as near as possible, of the strength of the oriental winds which prevail in the equinoctial regions, would be a useful acquisition to meteorology.

The vicinity of continents, above all that of the western coasts, modifies the trade winds both in force and direction. It sometimes happens that even a *westerly* wind replaces them. Wherever this change of wind is manifested, it is proper to note the epoch of the phenomenon, the bearing of the neighboring coast, its distance, and, when it can be done, its general aspect. To show the utility of this last recommendation, it will be sufficient to say that a sandy region would act much sooner and much more powerfully than a country covered with forests or other vegetable substances.

The sea which bathes the western coast of Mexico between the 8th and 22d degrees of north latitude, will give to observers occasion to remark a complete inversion of the trade wind. They will find an almost permanent westerly wind there, in the equinoctial regions, where we should expect to see an easterly wind prevail. In these parallels, it will be curious to note to how great distance from the coast the anomaly exists, and at what longitude the trade wind resumes its general direction.

According to the most generally adopted explanation of trade winds, there should constantly be, between the tropics, a *superior wind*, blowing in a contrary direction to that at the surface of the earth. There have already been collected divers proofs of the existence of this counter current of air. The observation of clouds, and particularly of those called *dappled clouds*, ought to furnish special indications from which meteorology would derive advantage. The time, strength, and extent of trade winds form, in short, a subject of study in which, notwithstanding the multitude of important observations, there is much to glean.

Of hygrometric observations.

A large class of atmospheric phenomena which fall within the province of meteorology, are occasioned by foreign substances suspended in the air; in which they accumulate with greater or less rapidity, and from which they may be removed either quickly or slowly, according to circumstances. It is necessary to inquire into the origin, the properties, and the various appearances of these meteoric substances. Hence we have a new series of difficult questions to examine in relation to the following phenomena: *dew*, (*serein*); *white and hoar frost; fogs; clouds; rain; snow; spicular snow*, (*gresil*); *sleet; hail;* also, the fall from the atmosphere of certain singular substances, and of *aerolites*, properly so called.

The watery vapor suspended in the atmosphere under the different forms in which we find it, appears, of all the substances thus suspended, to exert the greatest influence in producing the phenomena we have just enumerated. The principal property of this vapor, which it is necessary for us to examine, is its *elasticity:* it therefore becomes necessary to indicate the means used to measure the *elastic force* of atmospheric vapors.

The instruments that serve for this purpose are the *hygrometers*. They are of different classes: one class giving immediately the measure, while another class affords the result only indirectly and by means of inductions more or less uncertain. Those of the first kind are generally constructed on the principle of the condensation of vapor gradually cooled by some convenient arrangement: the second kind depend upon the absorption of moisture by different substances. Of all the hygrometers of this class, there is none which experience has not demonstrated to be too inexact to warrant a recommendation of its use; and we do not even except from this proscription *the hair hygrometer of Saussure,* notwithstanding the important labor of Gay-Lussac to give to this instrument all the exactitude of which its construction is susceptible. On the other hand, the first-mentioned instruments being constructed on a simple and rigorous principle, give, by a short manipulation, the exact value of the element sought after. Of these, we indicate in preference, *the hygrometer of Daniel,* already extensively known in Europe and to the philosophers of the United States. The arrangement of parts which the inventor has given to it, has rendered it quite portable, easy of observation, and precise in its indications: it is therefore a valuable meteorological instrument. In using this hygrometer, the observation consists merely in noting carefully the temperature of what is termed the *dew-point;* and to find in tables calculated for this object the corresponding elastic force. By this method we obtain a comparison of the quantities of vapor diffused through the atmosphere. These results are entirely independent of the temperature of the surrounding air: but, on the other hand, the air, though containing the same quantity of vapor, does not on this account necessarily possess the same degree of moisture; for this last quality depends upon the temperature of air at the time of observation. To obtain, therefore, the degree of humidity of the air, it becomes necessary farther to compare the temperature of the dew-point with that of the surrounding air. If these two temperatures are nearly equal, the air is nearly *saturated with vapor*: if, on the contrary, the temperature of the surrounding air exceeds considerably that of the dew-point, we pronounce that the air is *very dry.* It is necessary that the observer should have a clear notion of the rationale of this phenomena, in order that he may be able to give to this simple but useful experiment the entire interest and attention that it deserves. The only results which it is necessary to enter on the register are, the temperature of the dew-point and the temperature of the surrounding air. The first of these two data enables us, by reference to the proper tables, to determine the elastic force of the vapor, and its weight, as contained in any given volume of air taken as unity. The comparison of the first of these data with the second, gives the degree of humidity of the air at the time of observation. In this manner, we obtain all the elements required to assist in explaining those meteorological phenomena which depend on the presence of elastic vapor in the atmosphere.

1st. We can explain directly and easily the *dew*, (*serein*, Fr.) which offers the singular appearance of a rain extremely attenuated, without any sign of clouds; and which is often observed in summer, and most usually at the setting of the sun. The different phenomena presented in the formation of *dew*, which seem at first sight so complicated, are found to be natural consequences of the above-cited hygrometric laws of the atmosphere, combined with the laws (now well known) of the nocturnal radiation of caloric. On this subject we cannot do better than refer to the admirable work of Dr. Wells, who was the first person to discover and develop these deductions in a long series of experiments, as conclusive as they are ingenious. In this work he has indicated a number of useful precautions, which his observations have enabled him to apply to the cultivation and preservation of fruits, plants, and flowers.

2d. *White* or *hoar frost*, which is frequently observed during the cold mornings of spring and autumn, is nothing more than dew congealed. The same cause, therefore, which produces the one occasions the other. Hail, which ordinarily occurs in the spring and autumn, and which often proves so destructive to the crops, may also be considered as the same phenomenon carried to a higher degree of development. The same circumstances which favor the formation of dew and frost, are also those which tend to produce hail: so, on the other hand, all the precautions indicated as proper to turn aside the injurious effects of dew and frost, become identically the same with those it is proper to employ against the action of hail.

3d. *Fogs*, like the preceding phenomena, depend on the same theory: whether they take place during the light of day or in the darkness of night, in the quiet of a still and serene atmosphere or when the air is all commotion from the effects of a storm; whether at sea, on the shores of lakes, or over rivers—still this phenomenon may always be traced to the laws of hygrometry and the radiation of caloric already alluded to.

4th. *Clouds* owe their first origin to the collection of fogs more or less dense, suspended at different heights in the atmosphere, sometimes immoveable, but generally following the direction of the prevailing wind. Those fogs which are formed at the surface of the earth, over damp grounds, in the bottom of valleys, on hills, or around elevated peaks or snowy summits, become so many clouds when carried off by winds.

We here see that all these questions depend, more or less remotely, upon the same causes; and the same theory extends to and explains them all.

These phenomena, apparently so different, are only the consequences of the same laws, more or less developed; and it would appear that we have only to follow out these consequences to obtain the explanation of other questions of the same class. But in proportion as these phenomena become more extensive they also become more complicated. Other causes come in and concur to produce them: and the laws alone of hygrometry and the radiation of heat are not sufficient of themselves to account for all the circumstances observed. For instance, with respect to clouds, it is well known that they must proceed necessarily from the same cause that produces fogs: they may be formed directly in the atmosphere, either by the meeting of two currents of moist air of unequal temperatures, or otherwise by the condensation of vapors, when these rise in abundance into regions too cold to permit them to retain their elastic state. We must admit, in this case, that the vapors which form clouds assume the *versicular* form; i. e. the condensation which the cold produces on them reduces them to the state of a collection of minute globules, filled with moist air. Observation does not disprove the existence of these globules, under certain physical states of the atmosphere; but the laws of equilibrium applicable to this case render it difficult to conceive in what manner such a collection of versicular vapors can remain suspended in the air. There is, therefore, on this subject, something which is yet hidden from us. In order to ascertain it, it is necessary for us to accumulate all the data in our power relating to the properties of vapors, and of the different elements which compose them, to study the composition of clouds, their form, extent, elevation, color, and, in fine, all the variegated appearances which they assume.

5th. *Rain* has its origin from the clouds. Let the formation of these be once satisfactorily explained, and there remains only one step, easy to be made, to determine the causes which produce rain. While awaiting the determination of these causes by the aid of *theory*, let us, in the mean time, examine into facts, the knowledge of which may aid us in the search.

The quantity of rain which falls in the course of the year on any point of the surface of the earth is a meteorological element, the determination of which is of the greatest importance. The instruments which are used for this purpose are known by the name of *udometers* or *rain-gauges*.

The local circumstances of the place, such as its latitude, its elevation above the sea, its exposure, and the mountains, woods, &c. in its neighborhood—all these seem to exert a powerful influence over this phenomenon. Nevertheless, in comparing the observations of this kind which have been made under each zone parallel with the equator, we are led to draw the following results:

1. The mean annual quantity of rain increases in proportion as we approach the equator, so that it follows in fact the temperature of the zones.

2. The mean number of rainy days is in an inverse ratio to the above; that is to say, the number of such rainy days appears to be greater in proportion as we depart from the equator.

3. The quantity of rain is greater in summer than in winter; although, in this latter season, there is the greater number of rainy days. In some climates, the rain which falls during the months of June, July, and August, is equal to that which falls during all the other nine months of the year.

4. Rain falls more abundantly during the day than the night.

5. Other circumstances equal, more rain falls in mountains than in champaign countries.

6. At any given place the quantity of rain received in the course of the year is less in proportion as the receiving vessel is elevated above the surface of the earth. This last fact is put beyond all doubt by the experiments made at the Royal Observatory, Paris, and continued for more than 14 successive years. The mean of the annual result of this series shows that the mean quantity falling yearly at Paris, in the court of the Observatory, is 56 centimetres: while the mean quantity which falls at any elevation of 28 metres above this point, on the roof of the building, is only 50 centimetres. Every year this excess takes place on the same side, and differs but little in its amount. It has been satisfactorily ascertained that a difference of only 4 or 5 metres in the height of the receiving vessels is sufficient to produce a sensible difference in the annual quantities of water falling upon each.

This remarkable fact has been too uniformly observed to allow of its being referred to accidental circumstances. It is probable it depends in a great measure on the condensations which the drops of cold rain produce in passing through the lower strata of the atmosphere, and perhaps also from the circumstance that fogs and vapors are always more dense near the surface of the ground, and of themselves deposite a quantity of water sufficiently observable. Hence the necessity that rain-gauges should be near the surface of the ground.

It is probably to this cause that we should attribute the difference of opinion so warmly contested in Europe of late years, whether the climates of different countries are susceptible of gradual amelioration by the clearing of the ground, changes of cultivation, or, in one word, by any of the extensive alterations produced on their surface by the labor of man.

One of the first indications that such a change has taken place, is, certainly, either an increase or diminution in the mean quantity of rain which falls in the course of the year: but it is readily understood, after what has been said, that, in order to render these comparisons conclusive, this quantity must be measured by gauges constantly kept at the same height above the surface of the ground, and whose situation shall not be changed during the whole number of years that the experiment continues. Without this precaution we run the risk of attributing to a change of climate a difference of result which is only owing to a difference in the height of the instrument.

It is scarcely necessary to remark how important it is to ascertain all these facts in different climates. The observers should not only determine the mean *annual* quantities of rain, but also the mean quantities for each month—these last having the most direct influence on the production of different fruits and crops.

Heavy rains also merit particular attention; as a careful study of the circumstances which accompany them may lead to the discovery of the true causes in the formation of rain, and thus afford a link in the chain of reasoning to conduct us to the true theory of the constitution of clouds.

6th. *Snow.* We know but very little on the subject of the formation of this substance. Are the clouds which produce it composed of versicular vapors, or of particles already frozen? Are the flakes formed at once, or are they gradually enlarged in passing through the lower stata of the air? These are questions which are yet unanswered. The only set of observations, relating to snow, which can be considered at all complete, refer merely to the different forms of crystallization which the flakes assume. It is to the observations made by Captain Scoresby, in the polar regions, that we are indebted for the most satisfactory information on this subject. His work contains the delineation of about 100 figures, generally very remarkable and curious.

It is necessary, however, that we study, more minutely than has been done, their temperature, and the different circumstances which influence their form and volume, before we can be prepared to form a theory on the subject.

Whatever may be the causes that produce snow, its occurrence is invested with the greatest interest on another account. It is well known that it prevents the descent of the frost into ground covered by it; and that the cold of severe winters penetrates less deeply into the earth in proportion as the quantity of snow on its surface is greater. This property, so favorable to the preservation of the seeds intrusted to the earth, has been known to the husbandman from time immemorial, but it is only of late that science has been able to afford the explanation of all the circumstances of this phenomenon. Snow being a very bad conductor of heat, performs, when present, the double office of intercepting the passage of the cold of the atmosphere into the ground, and also prevents the ground from losing its natural heat by the radiation into space which would otherwise be constantly going on. It will be useful in promoting our knowledge of climates to remark, every year, the time of the first appearance of snow, the period of its entire disappearance, and the quantity also which has occurred.

7th. *Spicular snow* (gresil, Fr.) consists of water in the form of minute needles, grouped and intermingled so as often to present the appearance of delicate vegetable products, skilfully united in a *bouquet*. In many climates it is observed almost every year in the first months of spring. This phenomenon probably owes its origin to a cause analogous to that which produces snow; but on this head we are unable to advance any thing definite or certain.

8th. *Sleet* is formed by rain which freezes as it falls upon the ground. It is observed in winter covering the surface of the earth and of other objects with a uniform thin and transparent layer of ice. The cause is very simple. When the ground is sufficiently chilled to congeal the rain as it falls, it is only required that the air should have at the same time such a degree of warmth as to produce rain.

9th. *Hail* consists of small frozen balls, which are formed in the atmosphere, and which fall to the surface of the earth. Under certain circumstances of the atmosphere, these *frozen balls* or *hail-stones* assume very varied forms. Their ordinary size is about that of a nut acorn. They are, however, sometimes very small, and occasionally sufficiently large to measure three or four inches in diameter. The weight of these hail-stones, according to the different sizes, varies from the fractional part of an ounce to 9 or 10 ounces; they have even been found as heavy as 12 or 13 ounces. Their internal structure, also, offers a variety of appearances. In Europe, it is in the spring and summer and during the warmest part of the day, that hail is most abundantly formed. It takes place more generally during the day than during the night; and it does not continue to fall for more than a few minutes, very rarely extending to a quarter of an hour. It generally precedes the rain of a storm; it is sometimes mingled with it, but it never succeeds a rain of any duration. Notwithstanding these circumstances, the quantity of ice which falls from the clouds in these short periods, is so g at as frequently to cover the ground to the depth of several inches. Hithei ; we have considered in this meteoric substance only the combined effects of the laws of hygrometry and of the laws which regulate the production of cold. Let us continue our examination, to see what facts will teach us.

The clouds that bring hail, appear to have great extent and great breadth. They are but little elevated in the atmosphere, and may be distinguished from other clouds by a remarkably ashy color. Their edges are very rugged, and their lower surface is swollen and undulating, with enormous protuberances which hang down from it. The fall of hail is often preceded by a peculiar hurtling sound in the air, which has been compared to the noise which we may imagine to be produced by a number of bags of nuts suddenly emptied together on a floor. Sometimes thunder is heard mingled with the noise we have just described; at other times it is heard before and even after it.

Lastly: The presence of hail is always accompanied by *electrical* phenomena. An *atmospheric electrometer*, properly exposed at the approach of this meteor, shows that the fluid changes frequently in intensity, and that it is passing alternately from positive to negative and from negative to positive states.

We have here given a rapid sketch of the circumstances which accompany this phenomenon, so formidable to the interests of the husbandman. The terrible effects it produces are universally known, and they are of too much importance to the agriculture of a country to permit philosophers to neglect inquiry into the causes which occasion it. To give a satisfactory explanation, we must ascertain in what manner the cold is produced which forms the first nucleus of each ball of hail; by what process these balls augment in size, and what is the force which sustains in the air masses of ice whose weight amounts sometimes to half a pound;* and, lastly, we must assign the reason why the electricity of the atmosphere is so intense, and why it passes so rapidly from one state to another whenever the sky is covered with clouds charged with hail.

All the phenomena of which we have given a sketch above, under the head of *hygrometric observations*, are intimately connected with one another, and depend, undoubtedly, on the same fundamental cause whose action is disclosed more or less with regard to each one of them. Profound theories have been stated to explain them, but none of them satisfy yet the rigor of science. We will dispense with even a mention of these various theories here, in order to give place to the following subject, which is recommended to the zeal and attention of meteorologists by the Philosophical Society of Philadelphia. The phenomena in question are there considered under a new point of view, which merits being put to the test of observation.

Formation of clouds.

There is a certain kind of cloud which forms only in the day, when the heavens are not overspread with other clouds, and when the dew-point is not too low, which, when well formed, generally appears with a broad dark base and narrow top, something in the form of a cone, with sides as white as snow. There is no cloud ever seen below the base of this cloud, but it frequently rises

* Are they sustained? Do they not fall as they form, and form as they fall?

with its top above the highest clouds, which it pierces with its snow-white top. As it passes through this uppermost or feathery cloud, it seems to lift the thin cloud before it, and condense it into a semi-transparent veil, which at first appears at some distance above the top of the columnar cloud; but finally, as the columnar one moves upwards, its well-defined top reaches the thin veil and penetrates it. Very soon afterwards, by the upward motion of the columnar cloud, the veil coalesces with the cloud, and can no longer be distinguished from it. The same phenomenon frequently takes place when no feathery clouds are to be seen in the higher strata of air. When the top of the columnar cloud reaches a great elevation, it is seen to form above it, at a short distance, a similar veil or cap, which it gradually overtakes and coalesces with, as before mentioned. The basis of these clouds are probably all on the same horizontal level; and if the theory which has been lately advanced in the Journal of the Franklin Institute be correct, the height of these bases is as many hundred yards as the temperature of the air is above the dew-point at the moment of observation, in degrees of Fahrenheit.

We invite the special attention of the meteorologist to be directed to this cloud. Let him watch it from the moment of its beginning to form in the morning, taking drawings of it through all its stages, noting the length of time from one stage to another, until it dissipates or produces rain. If it dissipates without raining, let him try to ascertain the cause. Did its top rise into a current of air, moving in a different direction, and preventing it from rising perpendicularly, slicing off its top, and dissipating it in air not saturated with vapor? Or did it spread out in all directions, and thus dissipate? Or did the failure depend upon the dew-point? Or what were the circumstances in which it differed from columnar clouds producing rain? In case of producing rain, let the top of the cloud be particularly noted. Did it change its appearance about the time or a little before the rain is seen to descend from its base? And in case the cloud becomes very lofty, does the base of the cloud sometimes descend to a lower level, and appear convex below? and is an extention of this appearance the water-spout? Does the cloud also swell out sometimes above, so as to form a shape something like an hour-glass, or double cone, with the apices together? What kind of cloud does this columnar or hour-glass rain-cloud form after the rain is over, and how does it differ from the cloud which dissipates without raining? Does it become the feathering cloud, sinking a little at the top and rising at the base, and spreading out in the direction of the upper current? What is the direction of that upper current at the equator? Is it towards the west? If so, do storms travel in that direction; and with what velocity? Near the equator, on the north side, do the storms recede a little from the equator as they travel westwardly; and so on the south side of the equator? Or is there any general law on this point? During the rapid formation of a columnar cloud, is the wind affected? If the theory alluded to above is correct, it should blow in all directions towards the forming cloud, and upwards, in the region of the cloud itself. Is there such a thing as a white squall, without any cloud, formed or about to be formed over the region of the squall?

In case of a great storm or hurricane, does the wind near the equator always set in from some western point; and do tornadoes always travel in the direction of the stratum of air which the tops of columnar clouds penetrate? or is there any law on this point? Do columnar clouds more frequently form over islands than in the open sea? and do they only form in the day when the heavens are not overcast with other clouds, and do they disappear in the night as they do on land? Are columnar clouds formed every day not overcast? if not, what is the cause? Is it because the dew-point is too low when compared with the temperature of the air? What is the greatest depression of the dew-point below the temperature of the air when columnar clouds form? How soon do they begin to form after sunrise, and when do they cease forming in the afternoon? And when do they disappear entirely in the evening? Or is there any law on this point?

Mr. Redfield, of New York, has shown that the storms which visit the West Indies, travel northwestwardly while in the torrid zone. Does the wind in these storms which sets in from the N. W., change round on the N. E. side by the north, and on the S. W. side by the west, in such a manner as to show that the wind blows towards the centre of the storm? Or what is the general law upon this point? Are these storms always attended with electrical phenomena; and is there any thing peculiar in the appearance of the lightning? When the observations are made on land, note whether the lightning descends vertically, as has been asserted, and rolls over the ground like melted metal. Inquire, when these tornadoes occur, whether they sometimes lift up large trees and set them down in a different place on the broad base of their roots, without overturning them; whether they lift off the roofs of houses and prostrate the walls outwards as if by explosion, and tear up the floors of others and leave the walls standing? Are they ever attended with hail? Do these storms remain for some time stationary on reaching an island, and what evidence is there of a lull or calm in the centre of the storm? Has the barometer ever been observed at the moment of this lull, and what is the greatest depression recorded by a credible witness? Does the rain cease at the moment of the lull of the wind, and are the clouds seen at the same time to move on all sides towards the zenith?

In case of violent storms in the torrid zone, do they always set in from some western point, and terminate from some eastern point? If they set in from a point far north of west, does the wind veer round by the north; and if from a point far south of west, does the wind veer round by the south? If this question should be answered in the affirmative, the importance of the discovery will be of immense advantage to navigation, for it will afford an indubitable proof that the wind blows towards the storm; and the knowledge of this fact will enable the mariner to avoid the storm by sailing in a direction from the point to which the storm is advancing.

Suppose, for example, that it has been discovered that near the equator the storms travel towards the west, and that the wind, in great storms, blows towards the centre of the storm, and a violent gale sets in from the N. W., it is manifest, if the mariner sails towards the N. E., he will soon be out of reach of the storm; whilst, on the contrary, if he should direct his course southwardly, he would penetrate the very heart of the storm, and thus be exposed to all its violence. It is then a matter of high importance to ascertain the course which storms travel in all the different latitudes. If the uppermost current of the atmosphere gives direction to violent storms, it is highly probable that near the equator they travel towards the west. For as the air at the equator is lighter than the air at high latitudes, both on account of greater heat and greater moisture, it will ascend, and, in ascending, it will recede to the west, in consequence of the earth's rotation.

This upper current may probably be detected by the direction in which the lofy columnar clouds lean; for their tops, when they rise to a great height, will be bent over in the direction of the upper current. Besides, as the feathery or hazy cloud spoken of above is probably formed out of the tops of columnar clouds, which have rained, this upper current will most likely be indicated by the hazy clouds. Let these clouds be carefully noticed and described. Is their velocity uniform or various? Does their acceleration indicate rain? Does their increase in number indicate rain? Is their direction uniform in the same latitude? Is this direction towards the W. near the equator; N. W. near the tropic of cancer; S. W. near the tropic of capricorn; nearly towards the N. about 30° north latitude, and nearly towards the S. about 30° south latitude; then gradually turning towards the N. E. in higher north latitudes, and towards the S. E. in higher south latitudes? For these are the directions the uppermost current must take, as it flows down the inclined plane of the upper part of the atmosphere from the equator towards the poles. Or is there any general law on this point?

The observer will be careful to distinguish between violent storms and ordinary rains: for it may be that ordinary rains are very irregular in the direction of their motion, the tops of the clouds producing them not reaching into the uppermost current, which is probably nearly uniform in its direction, while the tops of clouds producing tornadoes may all reach into the uppermost current, and thus great uniformity in the direction of their motion may be produced. Mr. Redfield has shown that there is a remarkable uniformity in the progressive motion of storms or hurricanes which traverse the West India islands, all moving in the direction which theory would seem to give to the uppermost current as it passes off from the equator towards the pole. The greater heat and higher dew-point of the intertropical air will cause it to be about one-sixth lighter than the air in the frigid zones; and, of course, it will stand proportionably higher, and will therefore roll off towards the poles, carrying with it, in some measure, the diurnal velocity which it had at the equator; and so moving faster east than the earth at the latitude which it has reached. In confirmation of this theoretical result, it is known that the highest of all our clouds, in the latitude of Philadelphia, come constantly from near the west or southwest; and all the tornadoes which have been observed by scientific men, travel from a little south of west in that latitude. It may be added, that of eleven land-spouts or tornadoes which passed through New York, Pennsylvania, and New Jersey, every one had the trees thrown drown with their tops inwards and forwards, not one tree being ever discovered with its top lying out at the side. Thus proving, beyond a doubt, that in land-spouts the wind blows towards the centre of the spout. How is it at sea? In several great storms in the United States, of several hundred miles in diameter, which have been investigated with great care by the joint committee of the American Philosophical Society and the Franklin Institute of the State of Pennsylvania, the wind has been discovered to blow for many days in succession towards the storm, on all sides round the storm. Is this the case at sea? It is known, however, that rains of moderate size, produced by columnar clouds, where the base is not too low to permit it, cause, by their cooling effect on the air below the base of the cloud, and also by their weight, the wind to blow outwards at the surface of the earth on all sides from the rain. It is true, that in many cases of this kind, the lower parts of the cloud have been seen at the same time moving in from the circumference towards the centre; which proves that, in this case too, the air at some distance above the surface of the earth blows towards the cloud. It is highly desirable to investigate all the causes producing this variety of effect, so that it may be predicted by the appearance of a cloud, whether the wind will blow from the rain or to it, at the surface of the sea.

Do columnar clouds at sea generally disappear at night as early as they do on land; and what time of day do they form most rapidly? If, as is probable, opportunities be presented of observing volcanoes, let it be seen whether they ever produce rains immediately after they break out; first in the neighborhood of the volcano, and afterwards extending to greater distances. Are these rains ever attended with violent tornadoes, and sometimes with hail? Are the smoke and ashes carried in all directions above to a great distance, or are they carried farther on one side than on another?

The fluctuations of the barometer, in connexion with storms, will of course be noted. Much knowledge is yet wanted to be able to read the indications of this valuable instrument; observe whether it ever rises before the depression which always takes place in great storms, and at the moment of the calm, which may probably be experienced in the middle of the storm; mark the greatest depression.

The four diurnal fluctuations of the barometer should also claim particular notice. Very laborious and highly interesting observations on these fluctuations have lately been made in India, which are recommended to the attention of the meteorologist.

If these fluctuations depend on the increase and diminution of the elasticity of the air by heat and cold, according to a theory published in the Journal of the Franklin Institute, the morning maximum of a considerable elevation ought to be greater than on the plain below, and the afternoon minimum should not be so low as on the plain below. Again, the night maximum should be less, and the minimum greater than on the plain. These predictions have been verified by observations. If time and opportunity should be found, they might be repeated. The theory, however, goes farther: it indicates that at very great elevations there are but two fluctuations in a day—a maximum at about 12 or 1 in the day, and a minimum at about daybreak. To verify or refute this inference from theory, simultaneous observations at an elevation of 14,000 or 15,000 feet, and on the plain below, continued for a few days, will be sufficient, if the fluctuations on the plain are regular.

If a cloud is produced by the cold generated by the expansion of air as it ascends, it is manifest that the base of the cloud will be low in proportion as the dew-point approaches near to the temperature of the air, and high in proportion as the dew-point recedes from that temperature. Let the dew-point therefore always be carefully taken on the approach of a storm, and the character of the cloud observed with regard to the dew-point; the height of the base from the surface of the ocean; the rapidity of the formation; the final perpendicular height of the cloud above the base, and if it forms the hour-glass shape, let the relative size of the two parts be noted, and the height of the narrow part of the cloud. Does this hour-glass cloud only form when the dew-drop is high; and is the rain ever seen descending from the upper inverted cone into the clear air? If so, has this fact any connexion with hail? as the air on the outside of the cloud is much colder than the air on the inside, in consequence of the latent caloric given out in the condensation of the vapor in the formation of the cloud; or does hail depend entirely on the great height to which the drops of rain are carried up by the upward motion of the air in the cloud itself? In calm days, when a sudden breeze springs up over a very limited space, which is seen by the ruffling of the water, observe whether the wind blows towards that space by aspiration or from it by impulse.

The Franklin Kite Club, at Philadelphia, have lately discovered that in those days when columnar clouds form rapidly and numerously, their kite was frequently carried upwards nearly perpendicularly by columns of ascending air; and they say, in their report, that this circumstance became so familiar during the course of their experiments, that, on the approach of a columnar cloud just forming, they could predict whether it would come near enough to affect their kite; for, if the cloud did not pass directly over the kite, the kite would only move sideways towards the cloud. Now these upward columns were probably formed of air heated from contact with the ground. Is the same effect produced at sea? Is there any connexion between these sudden and very limited breezes at sea and the formation of columnar clouds?

If thunder-storms occur at night, endeavor should be made to find out whether they originate at night, or whether they are continuations of storms originating in the day. If they form at night, note whether the columns ascend from the stratum of middle clouds, or whether they rise from below them. Observe where the electricity first appears in them, and at what stage of their advancement, and the whole phenomena as contrasted with storms or rains in the day.

Of different meteoric substances.

With regard to those extraordinary rains known under the name of *showers of blood, showers of ashes, rain of manna, &c.*, in one word, all those substances, whether soft or in a state of powder, which fall from the atmosphere, and of which the catalogue is already extensive, and also with regard to the *red snow* which is sometimes found scattered about on the mountains and in other situations, lying in sheltered cavities, and almost always on the surface of the ordinary snow, we can only recommend to observers to describe with care the characters of those meteoric substances, the atmospheric circumstances accompanying their fall, &c. If they judge that the substance observed is susceptible of being analyzed, either chemically or in any other point of view, they should gather as much of it as possible, with all the precautions necessary for its preservation, in order to place it, as soon as can be, in the hands of persons specially skilled in making its examination.

Aerolites deserve particularly that no pains be spared to keep an exact account of their fall. When not informed of the occurrence till after it has taken place, which must necessarily be the case frequently, the observer should make diligent inquiry into the circumstances accompanying it; but, above all, he must obtain, if possible, the meteoric body itself or its fragments, in order that analysis may determine its composition.

The origin of these stones is yet a mystery. Calculation has demonstrated that it is possible that they may be ejected from the volcanoes of the moon, to such a distance as to come within the sphere of the earth's attraction. This possibility would become a probability could we determine certainly that there are volcanoes in the moon. It is also possible that these meteors exist already formed in the celestial space, in which they move with great velocity, by virtue of the planetary actions, and only fall to the ground when the earth's attraction preponderates over their centrifugal force. Again, it is possible that these aerolites may be the fragments of rocks thrown up to a great height by the volcanoes of the earth, and which fall back again after having performed several revolutions around the globe.

In the midst of these uncertainties, we can at least pronounce that the existence of stones which fall from the air is well ascertained both on the old and new continent; but it is only within the last thirty or forty years that they have been carefully observed in Europe.

For many ages before, the Chinese and Japanese have paid particular attention to these phenomena. These nations have a descriptive catalogue of all the *falls of stones* which have come to their knowledge, much more complete than ours, since it extends back as far as the seventh century before the Christian æra. A fact so well established as this we are considering, must have some general cause, which we should endeavor to discover. Several learned and industrious men are now engaged on this subject, and are uniting together all the documents that can be collected relating to every period and every place. We should be careful, therefore, not to lose any opportunity that may offer of aiding their researches.

Earthquakes.

According to the general received opinion in South America, earthquakes should be more frequent in certain seasons than in others. Such a result, if proven, would be of extreme importance for the physical theory of the globe. A complete collection of the journals which have been published in Chili during twenty years, if carefully examined, would certainly throw some light on this subject. We will recommend this matter to all observers and travellers; and we beg them to ascertain if the phenomena which are asserted* to have accompanied the earthquake that destroyed Arica and Saena, on the morning of the 18th September, 1833, have been observed in other places.

A visit to the coast of Chili will afford an opportunity of examining the phenomena so much spoken of, that, in the month of November, 1822, and after an earthquake which had overthrown the cities of Valparaiso and Quillata, a large portion of the country was found to be elevated from four to six feet above its former level. The earthquake of 1834 appears to have been stronger than those of 1822. It is important, then, to ascertain whether it did not also cause a raising of the country, as did the latter.

Of luminous meteors.

Much time need not be devoted to the observation of the mirage, whose causes are now well known, and theories upon which are laid down in the best treatises on natural philosophy. Nor will we now stop to discuss the subject of *parhelia,* or *mock suns,* of which the science of optics affords a sufficient explanation, under all the various and fantastic forms which those phenomena sometimes assume, although the opportunities for observing them are comparatively rare. We will mention, however, more particularly, *haloes,* the theory of which merits the attention of observers.

The name of *halo* is given to any one of those crowns or bright and often colored circles which are occasionally seen to surround the sun or moon. The space comprised between the interior border of the ring and the nearest edge of the sun or moon, forms the breadth of the *halo.* This space is distinguished by tints of color differing from the rest of the sky more or less, according as the transparency of the atmosphere is more or less affected by vapors. A commencement has been made of measuring the apparent diameter of these haloes; it has generally been found to be from 45° to 46°.

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* By Mr. John Reid, an English traveller.

Under some circumstances, a second halo is seen, concentric with the first, but of a diameter nearly double. The brightness of this second is more feeble, and the colors more pale, than those of its interior halo.

Attempts have been made at different times to render a satisfactory reason for this phenomenon. Of all the explanations offered, the most probable is one of old date, which attributes it to small, transparent, prismatic needles, which float in the upper regions of the atmosphere, and have some analogy with those composing snow. The laws of polarization, discovered within a few years, prove, in fact, that the light of haloes is a refracted light: therefore, the condition necessary to produce this phenomenon is the presence of icy particles in the higher regions of the air. Philosophers will be able to submit this theory to a decisive test, when they shall possess a sufficient number of good observations. Unfortunately, it is very rare that this phenomenon takes place with sufficient distinctness and regularity to enable us to define with precision its exact dimensions. We would, therefore, insist on the importance of observers watching for the most favorable circumstances. When these occur, by the aid of a small sextant or other instrument for measuring angles, the apparent diameter of the halo can be determined in several directions, but principally in a vertical and a horizontal plane, in order to determine if the figure of the halo is not rather an ellipsis than a circle, as some philosophers maintain. Care should also be taken to mark the temperature of the air whenever a halo is observed, whether round the sun or round the moon, even though there should be no opportunity of measuring the diameters: for this temperature becomes a term of comparison with that which prevails in the elevated regions where this phenomenon takes place; and by these means the theory of haloes leads to a conclusion the more important, as it furnishes an additional datum in relation to the temperature of the air at great heights.

Aurora borealis.

It is now sufficiently well established that the aurora is as frequent in the southern as in the arctic regions; and every thing induces us to believe that the appearance of austral auroras is governed by the same laws that regulate those of which we are witnesses in North America. However, this is but a conjecture. Observations on this subject will be looked for with great interest. Every appearance of this kind should therefore be noted and carefully described: the observations to include the position of the central part at the horizon; the height and amplitude of the arches when formed; the position of the vanishing point of the streamers, and, when practicable, the effect on the magnetic needle. In Europe *the most elevated point* always appears situated in the magnetic meridian of the place of the observer. Is it the same elsewhere?

Rainbow.

Its theory is not yet complete. When we attentively regard this magnificent phenomenon, we perceive under the red of the interior bow, many series of green and purple, forming narrow arcs, contiguous, well-defined, and perfectly concentric with the principal one. Of these *supplementary* bows, the theory of Descartes and Newton does not speak, nor may it ever be applied. The supplementary arcs appear to be an effect of *luminous interferences.* These interferences can be engendered only by drops of rain of a certain smallness: and it is also necessary that these drops, besides the condition of size, should be, at least the greater number, of an equality almost mathematical; for, without it, the phenomenon could have no brilliancy. If, then, the rainbows of the equinoctial regions never present supplementary arcs, it will be a proof that the drops of water there detached from clouds are larger and more unequal than in the northern climate. This fact, well observed and minutely described, will not be without much interest in explaining the causes of clouds and rain by the aid of theory. If supplementary arcs are formed in the equinoctial regions, it is almost certain that they can never attain the horizon: therefore, the comparison of the angle of elevation under which they there cease to be perceived, with the angle of disappearance observed in other climates, would lead to meteorologic results which no other method can give at the present day.

Zodiacal light.

The study of this phenomenon requires observations to be made in the equinoctial regions, to decide whether Dominique Cassini has made sufficient allowance for the causes of error to which we are exposed in our variable atmosphere, and has given due consideration to the purity of the air, when he announced that the zodiacal light is constantly more bright in the evening than in the morning; that in a few days its length may vary between 60° and 100° &c. It is desirable, then, that informed travellers, during their sojourn between the tropics, and after the setting and before the rising of the sun, when the moon does not illumine the horizon, take note of the constellations traversed by zodiacal light, of stars that its point attains, and of the angular breadth of the phenomenon at a determined height near the horizon. Note must be kept of the time of observation.

Falling stars.

Every one is now aware how much these long-neglected phenomena deserve attention. It appears that their parallax has already proved them much higher than the limits of our atmosphere, and that they do not originate in it, but come from beyond; and that their most constant direction seems diametrically opposite the revolutionary motion of the earth in its orbit. This result requires to be established upon the discussion of a great number of observations. The time of the appearance of each shooting star should be noticed, its angular height at its nearest approach to the horizon, and, *above all, the course of its motion.* By comparing these meteors with the principal stars of the constellation which they traverse, those divers questions may be solved by a glance of the eye. It is desirable that particular attention should be paid to these appearances on the nights of the 10th, 11th, 12th, 13th, and 14th of November, and also from the 20th to the 24th of April, in order to ascertain whether the remarkable appearance which has on several occasions been observed at those periods will recur. It is not necessary to refer to the interesting speculations of Professor Olmstead on this subject. There are many reasons to contemplate that a new planetary world is about being revealed to us: it would be a triumph to our nation, should his ingenious views be proved to be correct.

Lightning.

M. Fusiniere has studied the effect of lightning in a point of view which depends upon a new method of investigating electric phenomena. He thinks himself authorized to conclude, from his experiments, that the atmosphere contains, at every height, or at least to the region of stormy clouds, iron, sulphur, and other substances; that the electric sparks impregnate themselves with these matters, and transport them to the surface of the earth, where they form very minute depositions around the points stricken. This theory attracts the attention of natural philosophers, and, in fact, deserves to be followed with the exactitude the present state of science permits. Witnesses of the phenomena of lightning would do well to collect with care the black or colored matter which the fluid may seem to have deposited over different portions of its route. A scrupulous chemical analysis may lead to discoveries unexpected and of great importance.

NOTE.

In the foregoing essay, the centigrade or Celcius thermometer is referred to. In this country, thermometers of Fahrenheit's divisions are generally used, and occasionally of Reaumur's. It may probably afford some facilities to have the differences pointed out.

In Reaumur (R.) the point of melting ice is 0; that of boiling water 80°.

In the centigrade (C.) the point of melting ice is 0; that of boiling water 100°.

In Fahrenheit (F.) the point of melting ice is 32°; that of boiling water 212°.

Degrees may be converted from one to the other by the following formula:

$$\frac{R \times 9}{4} + 32 = F, \text{ and } C = \frac{(F - 32) \times 5}{9}$$

The head of the column of all observations by the thermometer should be marked with the characteristic letter of the instrument, R., F., or C.

The barometer used should also be described; and it should be particularly noted with what standard barometer it has been compared.