minimum occurs at the hours of the day when the surface of the land is most highly heated, the ascending current of heated air rising from it therefore strongest, and the resulting breeze from the sea towards the land also strongest. Now it does not admit of a doubt that the diminution in the amount of the aqueous vapour noted on board the "Challenger" near the shore points to an intermixture with the air forming the sea breeze of descending thin air-filaments or currents to supply the place of the masses of air removed by the ascending currents which rise from the heated surface of the land. At Batavia, on the north coast of Java, and at Bombay, the aqueous vapour is also subject to a secondary minimum during the warmest hours of the day.

During the summer months this secondary minimum is best marked at inland places such as Peking, Nertchinsk, Barnaul, Tiflis, and Ekaterinburg, but the time of its occurrence is about two hours later than it is over the North Atlantic. Over all these places at this season the ascending current from the heated land in the interior of Asia is very strong. On the other hand the lowering of the amount of aqueous vapour scarcely if at all appears as a feature in the summer climate of St Petersburg, and not at all in that of Sitka, where the sea breeze is equally not a constant feature of the climate of the district.

In the excessively dry, rainless, and hot climate of Allahabad, in April the diurnal minimum of the aqueous vapour occurs from 11 A.M. to 6 P.M., the time of absolute minimum being 2 and 3 P.M. During all other hours of the day the amount of the vapour is above the mean, a secondary minimum occurring from 1 to 4 A.M. At Allahabad, at this time, the absolute maximum vapour pressure occurs at 8 A.M. Quite similar to this is the diurnal distribution of the aqueous vapour in July at Lisbon and Coimbra, the minimum occurring from 10 A.M. to 8 P.M. At this time of the year the climate of this part of the peninsula is hot and dry and the rainfall insignificant in amount. As this region lies between the high atmospheric pressure so characteristic a feature of the meteorology of the Atlantic in summer and the comparatively low pressure over the continents southward and eastward, the winds are almost wholly north-westerly. In this connexion it is instructive to note that the time of maximum vapour pressure is from 4 to 7 A.M., when the velocity of the wind is near the minimum, and the chief minimum vapour pressure from noon to 4 P.M., when the velocity of the wind and ascending currents reach the daily maximum. These results show that the diminution in the vapour pressure during the hours when temperature is highest, which characterizes the climates of large tracts of the globe, is due to descending air-filaments or currents, which necessarily accompany the ascending currents that rise from the heated land.

At Geneva during the summer months the vapour curve exhibits two daily minima very strongly marked, the one shortly before sunrise and the other from 2 to 4 P.M., and two maxima, one from 8 to 11 A.M. and the other from 6 to 10 P.M.; and with these the diurnal variations of cloud are in accordance. The peculiarly marked features of the vapour curve at Geneva are probably due to the size of the lake, which is large enough to give rise to a decided breeze during the day from the lake all round its shores and during the night to a breeze from the land all round upon the lake. On the setting in of the breeze, the mass of air composing it, having been for some time resting on the lake, is rather moist, and thus one of the daily maxima is brought about from 8 to 11 A.M. As the breeze continues the air supplying it is necessarily drawn from the higher strata of the atmosphere more copiously than in different situations; and, having thus acquired increased dryness in the descent, and having blown over the lake for too short a distance to materially influence its moisture, the air becomes constantly drier, till the minimum from 2 to 4 P.M. is reached. The lake breeze thereafter begins to diminish in force, and the air consequently becomes moister till the maximum vapour pressure of the day occurs when the lake breeze dies away and the land breeze has not yet sprung up. In the winter months, when these breezes do not prevail, the curve of diurnal vapour pressure shows only one maximum and minimum.

The *relative humidity* of the atmosphere must not be confounded with its vapour pressure or absolute humidity. The relative humidity, or, as it is more frequently called, the humidity, of the air is the degree of its approach to saturation. Complete saturation is represented by 100 and air absolutely free of vapour by 0, the latter state of things never occurring in the atmosphere, a humidity of 10 being of rare occurrence even in such arid regions as those of Arabia. The great significance of this element of climate is in its relations to the diathermancy of the air, and consequently to solar and terrestrial radiation. It is supposed that perfectly dry air would allow rays of heat to pass through it with at most only a very slight increase to its temperature therefrom. Let, however, a little aqueous vapour be added to it, a partial obstruction to the passage of radiant heat is offered, and the temperature of the mixture, or common air, is sensibly raised. Hence, other things being equal, the less the amount of vapour the more are the effects of radiation felt, or the greater the heat of the days and the cold of the nights. The mere amount of vapour in the air does not determine the degree of radiation, but it is the amount of vapour together with a certain temperature—in other words, the absolute and relative humidity of the air taken together—that determines the heating power of the sun and the degree of cold produced by terrestrial radiation.

The diurnal variation of the relative humidity is very different from that of the vapour pressure, and presents features of the simplest character. The following are the diurnal variations from the mean humidity 80 over the North Atlantic, from the "Challenger" observations in 1873:—

2 A.M.	+2	10 A.M.	−1	6 P.M.	−1
4 ,,	+2	Noon	−2	8 ,,	0
6 ,,	+1	2 P.M.	−3	10 ,,	+1
8 ,,	0	4 ,,	−2	Midnight	+2

Thus the maximum humidity occurs from midnight to 4 A.M., or when the daily temperature is at the minimum, and the minimum humidity at 2 P.M., when the temperature is at the maximum, the curve of humidity being thus inverse to that of the temperature. With two slight modifications this is the diurnal humidity curve for all climates and seasons. In the calm which intervenes in the morning between the land and the sea breeze the humidity continues high, or even increases, though at the time the diurnal increase of temperature has already set in. The other modification is seen in the humidity curves for Nertchinsk and Barnaul during winter, these curves being not inverse but coincident with the daily curves of temperature. In the climates of Central Asia in winter, the amount of vapour is very small, and the increase to the relative humidity during the day is probably occasioned by the more active evaporation from the snow during the day and the stillness of the air favouring the accumulation of aqueous vapour near the surface of the earth.

Next to the winds, the aqueous vapour of the atmosphere, in the diverse ways in which in different localities it is distributed through the hours of the day, plays the most important part in giving to the different parts of the globe its infinitely diversified climates.

Dew.—Dew is deposited over the earth's surface on comparatively clear and calm nights. As the cooling by terrestrial radiation continues, the temperature of objects on the surface is gradually lowered to the dew-point, and when this point is reached the aqueous vapour begins to be condensed into dew on their surfaces. The quantity deposited is in proportion to the degree of cold produced and the quantity of vapour in the air. Dew is not deposited in cloudy weather, because clouds obstruct the escape of heat by radiation, nor in windy weather, because wind continually renews the air in contact with the surface, thus preventing the temperature from falling sufficiently low. When the temperature is below 32°, dew freezes as it is deposited, and *hoar-frost* is produced. The dew-point practically determines the minimum temperature

of the night,—because if the temperature falls a little below the dew-point the liberation of heat as the vapour is condensed into dew speedily raises it, and if it rises higher the loss of heat by radiation speedily lowers it. This consideration suggests an important practical use of the hygrometer, it being evident that by ascertaining the dew-point the approach of frost or low temperature likely to injure vegetation may be foreseen and provided against.

Diurnal Oscillations of the Barometer.—The general character of the daily oscillations of atmospheric pressure is shown by the two curves of fig. 2. The solid line gives the mean oscillation for Bombay and the dotted line that for Vienna, these two curves being to a large extent typical of diurnal barometric oscillations in tropical and temperate regions as regards the two maxima and minima and the time of their occurrence.

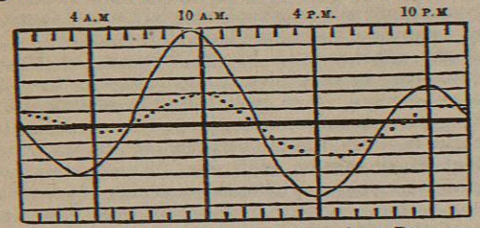

FIG. 2.—Daily Oscillations of Atmospheric Pressure.

A series of twelve maps of the globe were prepared for June, showing, for all stations whence observations have been obtained, the deviations at noon, 2 P.M., 4 P.M., &c., Greenwich mean time, from the mean daily pressure; and four lines were drawn indicating the positions of the two daily maxima and minima at these hours. For fully 30° north and south of the equator the lines of maxima and minima run north and south, but in higher latitudes these directions are changed, and the changes are chiefly conspicuous as regards the A.M. maximum and the P.M. minimum. Thus, for example, at 6 P.M. (G. M. T.) the line of P.M. minimum is for the latitude of London near 16° W. long.; in 30° N. lat. it is in 35° W. long., in which the line runs south as far as 30° S. lat.; its course thence turns south-westwards to near the Falkland Islands, 60° W. long. Hence in June the P.M. minimum occurs about three hours earlier in the Falkland Islands than to the south-west of Ireland, thus showing in a striking manner the influence of season on this phenomenon. In the middle and higher latitudes in summer, proximity to the sea delays the time of occurrence of the A.M. maximum and the P.M. minimum; whilst in continental situations the A.M. maximum occurs much earlier than in lower latitudes, and the P.M. minimum nearly as late as at places near the sea. In cases where the lines of maxima and minima cross a region such as southern and western Europe, whose surface is diversified by large tracts of land and sheets of water, the deflexions are of a remarkable character.

The retardation of the time of occurrence of the A.M. maximum is greatest in situations which, while eminently insular in character, are at the same time not far from an extensive tract of land. Of this Holland presents the best example in Europe; and there the A.M. maximum, which at Paris occurs at 8 A.M., does not occur at Utrecht till 9.30 A.M., at Amsterdam till 12.30 P.M., and at Helder till 2 P.M. There is thus as regards the same diurnal phenomenon in June a difference of six hours between Paris and Helder. Sicily and the south of Italy on the one hand and Madrid on the other present also the most striking contrasts. Again at Sitka (56° 50′ N. lat., 135° W. long.), which has one of the most truly insular climates in the world, the A.M. maximum is delayed to 2.30 P.M.; whereas at Astoria, ten degrees to southward, it occurs at 9.30 A.M., and at Fort Churchill, in Nevada, as early as 7 A.M. There is thus as regards the same phenomenon a difference of 7^h 30^m between Sitka and Fort Churchill.

From hourly observations made in this month at the base, the top, and two intermediate points on Mount Washington (N. H.) it was found that the time of occurrence of the A.M. maximum at the base of the mountain, which is 2898 feet above the sea, was 8 A.M.; at 4059 feet, 10 A.M.; at 5533 feet, 11 A.M.; and at the top, 6285 feet, noon. Hence, as regards the time of occurrence, the influence of an isolated mountain like Mount Washington brings about a result similar to what is observed in insular situations. But the analogy is even closer. In insular climates the minimum in the early morning is very greatly in excess of that in the afternoon; and the same relation is observed on the top of Mount Washington, where the former is −0·020 inch and the latter −0·004 inch. Again in continental climates the minimum in the early morning is much the smaller of the two, and the same relation was observed at the base of the mountain, where the observed minima were respectively 0·006 inch and 0·020 inch. The differences presented by the daily curve of pressure at the top as compared with that at the base of the mountain have their explanation in the effects which follow the diurnal range of temperature. As the temperature is at the minimum at the time of least pressure in the morning, the atmosphere is more condensed in the stratum between the base and the top, and consequently the barometer at the top reads relatively lower. As the temperature continues to rise during the day, the stratum of air above the base of the mountain expands, thus placing more air above the barometer at the top, so that, while at the base pressure begins to fall at 8 A.M., at the top it continues to rise till noon, simply from the mechanical upheaval of the air owing to the higher temperature. In the afternoon, when the minimum at the base falls to −0·020 inch, it is only −0·004 inch at the top, this relatively higher pressure at the top being due to expansion from temperature. The peculiar feature of the pressure curve at the top is essentially a temperature effect.

The diurnal oscillations of the barometer occur alike over the open sea and over the land surfaces of the globe. The atmosphere over the open sea, as already shown, rests on a floor or surface subject to a diurnal range of temperature so small as to render that temperature practically a constant both day and night. This consideration leads to the vital and all-important conclusion that the diurnal oscillations of the barometer are not caused by the heating and cooling of the earth's surface by solar and terrestrial radiation and by the effects which follow these diurnal changes in the temperature of the surface, but that they are primarily caused by the direct and immediate heating by solar radiation, and cooling by nocturnal radiation to the cold regions of space, of the molecules of the air, and of its aqueous vapour. These changes of temperature are instantly communicated through the whole atmosphere from its lowermost stratum resting on the earth's surface to the extreme limit of the atmosphere, which the flight of meteors proves to be not less than 500 miles. There are important modifications affecting the amplitude and times of occurrence of the four prominent phases of the phenomena observed over land surfaces, the temperature of which is being superheated during the day and cooled during the night; but it is particularly to be noted that the barometric oscillations themselves are independent of any changes of temperature of the floor on which the atmosphere rests

Let us first look at the phenomena in the simplest form as found in the Pacific, or in the midst of the largest water surface of the globe. The following are the mean variations of pressure from observations made on board the "Challenger," September 1 to 12, 1875, in mean latitude 1° 8′ S. and long. 150° 40′ W., the mean being 29·928 inches:—

	Inch.		Inch.		Inch.
2 A.M.	−0·012	10 A.M	0·032	6 P.M.	−0·028
4 ,,	−0·022	Noon	0·006	8 ,,	0·004
6 ,,	0·003	2 P.M.	−0·043	10 ,,	0·013
8 ,,	0·028	4 ,,	−0·055	Midnight	0·012

The most striking feature in these oscillations is the amplitude of the range from the A.M. maximum to the P.M. minimum, amounting to 0·087 inch, and the rapidity of the fall from 10 A.M. to 2 P.M. The same feature appears in all means deduced from observations made at least 12° on each side of the equator.

From October 12 to 22, 1875, in mean lat. 35° 1′ S., long. 134° 35′ W., the mean atmospheric pressure was 30·298 inches, and the difference between the A.M. maximum and the P.M. minimum was only 0·036 inch; and from July 12 to 19, 1875, in mean lat. 36° 16′ N. and long. 156° 11′ W., the mean pressure was 30·328 inches, and the difference between the A.M. maximum and P.M. minimum was only 0·025 inch. Thus, with a mean pressure in the Pacific about lat. 35°–36° N. and S. much greater than near the equator, the oscillation is much less, being in the North Pacific less than a third of what occurs near the equator. Similarly, this oscillation is small (or even smaller) in the high-pressure areas in the North and South Atlantic as compared with the same oscillation near the equator.

It is well known that aqueous vapour absorbs the heat rays of the sun considerably more than does the dry air of the atmosphere; how much more physicists have not yet accurately determined. Consequently air heavily charged with aqueous vapour will be heated directly by the sun's rays as they pass through it in a greater degree than comparatively dry air is. Now it is shown further on that the prevailing surface winds outflow in every direction from the areas of high mean pressure in the Atlantic and Pacific about lat. 36° N. and S. Since, notwithstanding, the pressure continues high, it necessarily follows that the high pressure is maintained by an inflow of upper currents, and as the slow descending movement of the air connects the inflowing upper currents with the outflowing prevailing winds of the surface, it follows that the air over high-pressure areas is very dry, and that it is driest where pressure is highest and the high-pressure area best defined. Hence over the best-defined anticyclonic regions the air will be least raised in temperature through all its height by the heat rays of the sun.

On the other hand, between these high-pressure areas of the great oceans there is a belt of comparatively low pressure towards which the north and south trades pour their vapour unceasingly. The atmosphere of this belt of low pressure is thus highly saturated with aqueous vapour which rises in a vast ascending stream of moist air to the higher regions of the atmosphere. These equatorial regions thus present to the sun a highly saturated atmosphere reaching to a very great height. It is in these regions therefore that the atmosphere will be most highly heated by the sun's heat rays as they pass through it. One of the most striking facts of meteorology is the suddenness with which this barometric oscillation increases in amplitude on entering on these parts of intertropical regions; and the rapidity with which its amplitude diminishes on advancing on the high-pressure regions of the horse latitudes is equally striking. The following are the mean oscillations in the middle regions of the four great oceans about lat. 36° from the A.M. maximum to the P.M. minimum about the time of the year in each case when the sun is highest in the heavens:—South Pacific, 0·036 inch; North Pacific, 0·025 inch; South Atlantic, 0·024 inch; and North Atlantic, 0·014 inch. These amplitudes diminish as the ocean becomes more land-locked with continents, or as the anticyclonic region becomes better defined and currents of air are poured down more steadily from the higher regions of the atmosphere.

If the temperature of the whole of the earth's atmosphere were raised, atmospheric pressure would be diminished, for the simple reason that the mass of the atmosphere would thereby be removed to a greater distance from the earth's centre of gravity. Quite different results, however, would follow if the temperature of only a section of the earth's atmosphere were simultaneously raised, such as the section comprised between long. 20° and 60° W. The immediate effect would be an increase of barometric pressure, owing to expansion from the higher temperature; and a subsequent effect would be the setting in of an ascending current more or less powerful, according to the differences between the temperature of the heated section and that of the air on each side. These are essentially the conditions under which the morning maximum and afternoon minimum of atmospheric pressure take place.

The earth makes a complete revolution round its axis in twenty-four hours, and in the same brief interval the double-crested and double-troughed atmospheric diurnal tide makes a complete circuit of the globe. The whole of the diurnal phenomenon of the atmospheric tides is therefore rapidly propagated over the surface of the earth from east to west, the movement being most rapid in equatorial regions, and there the amplitude of the oscillations is greater than in higher latitudes under similar atmospheric, astronomical, and geographical conditions. Owing to the rapidity of the diurnal heating of the atmosphere by the sun through its whole height, some time elapses before the higher expansive force called into play by the increase of temperature can counteract the vertical and lateral resistance it meets from the inertia and viscosity of the air. Till this resistance is overcome, the barometer continues to rise, not because the mass of atmosphere overhead is increased, but because a higher temperature has increased the tension or pressure. When the resistance has been overcome, an ascending current of the warm air sets in, the tension begins to be reduced, and the barometer falls and continues to fall till the afternoon minimum is reached. Thus the forenoon maximum and afternoon minimum are simply a temperature effect, the amplitude of the oscillation being determined by latitude, the quantity of aqueous vapour overhead, and the sun's place in the sky.

All observations show that over the ocean, latitude for latitude, the amplitude of the oscillations is greater in an atmosphere highly charged with aqueous vapour and less in a dry atmosphere. It is also to be noted that in very elevated situations, particularly in tropical regions, the amplitude is greater proportionally to the whole pressure than at lower levels. This is what is to be expected from the law of radiant heat by which more of the heat rays of the sun is absorbed by the air, and particularly by its aqueous vapour, mass for mass, in the higher than in the lower strata.

When the daily maximum temperature is past, and the temperature has begun to fall, the air becomes more condensed in the lower strata, and pressure consequently at great heights is lowered. Owing to this lower pressure in the upper regions of the air, the ascending current which rises from the longitudes where at the time the afternoon pressure is low flows back to eastward, thus increasing the pressure over those longitudes where the temperature is now falling. This atmospheric quasi-tidal movement occasions the P.M. increase of pressure, which reaches the maximum from 9 P.M. to midnight, according to latitude and geographical position. This maximum is therefore caused by accessions to the mass of the atmosphere overhead, contributed by the ascending currents from the longitudes of the afternoon low pressure immediately to westward.

As midnight and the early hours of morning advance, these contributions become less and less and at length cease altogether, and pressure continues steadily to fall. But between the time when the increase of pressure from the overflow through the upper regions of the atmosphere ceases and the time when pressure increases from the heat rays, direct or indirect, of the returning sun, or during the hours of the night when the effects of nocturnal radiation are the maximum, pressure is still further reduced from another cause. Radiation towards the cold regions of space takes place, not only from the surface of the globe, but also directly from the molecules of the air and its aqueous vapour. The effect of this simultaneous cooling of the atmosphere through its whole height is necessarily a diminution of its tension. Since this takes place at a more rapid rate than can be compensated for by any mechanical or tidal movement of the atmosphere from the regions adjoining, owing to the inertia and viscosity of the air, pressure continues to fall to the morning minimum. This minimum is thus due, not to the removal of any of the mass of air overhead, as happens in the case of the afternoon minimum, but to a reduction of the tension or pressure of the air consequent upon a reduction in the temperature through radiation from the aerial molecules towards the cold regions of space. In the open ocean the morning minimum is largest in the equatorial regions, and it diminishes with latitude; but the rate of diminution with latitude through anticyclonic and other regions is generally less and more uniform than in the case of the afternoon minimum.

The amplitude and times of occurrence of the phases of the diurnal barometric tides are subject to great modifications over the land. The amplitude of the oscillation from the morning maximum to the afternoon minimum is greatest where the atmosphere is driest and the sky clearest, and least where the atmosphere is highly saturated and the sky more frequently and densely covered with clouds, being thus generally the reverse of what is observed to take place over the open sea. The meteorology of India affords the most striking illustrations of this remark. At Bombay in April during the dry atmosphere and clear skies of the north-east monsoon, the oscillation is 0·118 inch; but in July during the humid atmosphere and clouded skies of the south-west monsoon it falls to 0·067 inch. In the Punjab, where the air is drier, it is much greater, rising in exceptional years, such as 1852, to 0·187 inch. The much greater amplitude of this oscillation on land as compared with the open sea is entirely due to the heating of the earth. By this heating of the surface the lower strata of the air become also highly heated and the tension is increased; and, since the air does not expand freely, vertically and laterally, from its inertia and viscosity, the barometer rises. When, however, the resistance is overcome, the ascending current which sets in is stronger owing to its higher temperature. Since this higher temperature which has its origin in the superheated surface is in addition to the direct heating of the air by the heat rays of the sun as they pass through it, the morning maximum and the afternoon minimum over land are both more extreme than over the open sea. It follows that this oscillation is much larger over land, and largest in climates where insolation is strongest.

In places already referred to where the morning maximum is greatly retarded, such as Helder, Sitka, Valentia, and Falmouth, the afternoon minimum in the summer months is singularly small,—so small indeed that it does not fall so low as the mean pressure of the day. This peculiarity in the diurnal barometric tide is in all probability due to their insular position to the westward of a more or less extensive tract of land, by which a tidal overflow is propagated through the upper regions from the continental towards the insular situations. This tidal overflow receives its impulse from the ascending current from the land, which rises sooner and stronger from inland than from insular situations. On the other hand, on the open sea, and away from land in regions where the morning maximum and afternoon minimum are both small, the minimum always falls below the mean of the day, and the time of occurrence of the maximum is not retarded as is the case in insular situations. A map of deviations from the daily mean pressure of the morning minimum in summer shows, as regards the middle and higher latitudes, that it is greatest near the sea, and least in inland continental situations. Indeed in the interior of the Old-World continent the dip in the curve in the early morning is so small that the minimum does not fall below the daily mean pressure, but at most places remains considerably above it. The same relations are seen in north-western Europe, where the morning minimum is −0·020 inch at Valentia and Falmouth, −0·018 inch at Helder, and −0·012 inch at Amsterdam, whilst at Kew it is only −0·002 inch. From its compact form and relations to the surrounding ocean, the Spanish Peninsula well illustrates the peculiarities of this phase of the pressure. The deviations from the daily mean pressure of the morning minimum are at Lisbon −0·022 inch and Coimbra −0·011 inch, but at Madrid in the interior +0·009 inch,—pressure in the last case, just as happens in the interior of Asia, not falling so low as the daily mean.

The larger minimum near the sea arises from the higher temperature there during the night as compared with more inland situations, from which results a tidal overflow through the upper regions from the sea towards the land, as the temperature of the latter falls lower than the sea during the night. The effect of this overflow is to reduce the pressure over those regions whence it proceeds and to increase it in those regions over which it advances. The shallowing of the morning minimum is greatest in the higher latitudes of continental climates and most complete at great elevations, where in some cases the minimum vanishes,—in other words, where the amount of aqueous vapour is small and the time is short during which no part of the atmosphere overhead is touched by the sun's rays. Since the peculiarity is observable in the curves over nearly the whole continent, appearing even in the low latitudes of Calcutta and Madras, it might be suggested whether we have not evidence here of a vast tidal movement propagated through the higher regions towards that trough-like section of the atmosphere as it moves westwards over the continent where the temperature of the lower strata of the air is about the minimum of the day and pressure also about the minimum.

Reference has been made under ATMOSPHERE to the smallness of the range from the A.M. maximum to the P.M. minimum in the North Atlantic during summer. This phase in the diurnal distribution of pressure is represented in fig. 3, which shows for June the mean amount of the oscillation by lines of 10, 20, 40, 60, 80, and 100 thousandths of an inch, or 0·010 inch, 0·020 inch, &c. This abnormality begins in March, attains the maximum in June, and terminates in October. It is thus confined to the warmer months of the year, and, unlike most meteorological phenomena, is not cumulative, but follows the sun, so that its maximum occurs in June, and not in July as that of the temperature of the air, or in August as the temperature of the sea. The smallness of this range over the North Atlantic, which is less than occurs in any other ocean in the same latitudes, is to a large extent caused by the small dip in the diurnal curve of the afternoon minimum.

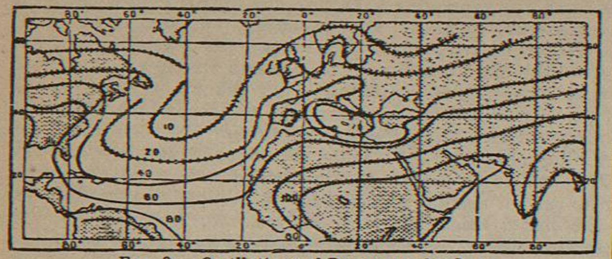

FIG. 3.—Oscillations of Barometer for June.

If the map of the distribution of pressure over the globe for July be examined (fig. 17) it is seen that this part of the Atlantic is occupied by a well-defined area of high mean pressure,—higher indeed than occurs at any season over any ocean; and it is shown below that out of this area the surface winds blow in all directions. But, since air is constantly being drained out of this region by the wind without diminishing the pressure, it follows of necessity that the high pressure must be maintained by accessions of air received from above through the upper currents. Now the regions whence such accessions can come are the upper currents which have their origin in the ascending currents that rise from the heated plains of Africa, Europe, the belt of calms, and the two Americas surrounding the North Atlantic. It is evident that the major portion of each day's overflow of air from the continents through the upper regions of the air upon the Atlantic, whether this overflow takes place by convection currents or from a tidal movement similar to what has been already described, will take place during mid afternoon. In other words, the overflow will occur about the time of the afternoon minimum of the Atlantic, thus diminishing the dip of this minimum, and so producing the abnormally small range now under examination. It is in favour of this view that the abnormality follows the sun's course and is not cumulative, and is felt also on both sides of the Atlantic, even although the weather on the east side is dry and all but rainless, and on the west moderately moist and characterized by a rather copious rainfall. It is also full of significance that the peculiarity is most strikingly seen in that part of the ocean of the globe which is closely hemmed in by large masses of land.

Influence of the Moon on Atmospheric Pressure.—Fifteen years' hourly observations have been made at Batavia and discussed by the late Dr Bergsma in their relation to the lunar day, which was assumed in the calculations to commence with the time of the upper transit of the moon. The result of the inquiry is that atmospheric pressure at Batavia has a lunar tide quite as distinctly marked as the ordinary diurnal barometric tide, except that its amplitude is much less. The four phases are these:—

1st max.	+ 0·0022	inch at lunar hour	1
1st min.	− 0·0021	,, ,, ,,	7
2d max.	+ 0·0025	,, ,, ,,	13
2d min.	− 0·0024	,, ,, ,,	19

The lunar tide has the important difference that its phases follow the moon's apparent course much more closely than the ordinary diurnal fluctuations of the barometer follow that of the sun. The two maxima occur about the 1st and 13th, and the two minima about the 7th and 19th, whereas these four daily phases of the diurnal barometric fluctuation occur with respect to the sun's apparent course from one to six hours later. It is interesting to note that in the higher latitudes in inland situations during winter, or at times and in situations where the disturbing influences of temperature and humidity tend towards a minimum, the times of occurrence of the four phases of the daily oscillation of the barometer approximate to those of the daily lunar atmospheric tide.

Since a distinct lunar tide is traced to the attractive influence of the moon, it follows that the attractive influence of the sun will enter as one of the several causes which determine the phases and amplitude of the diurnal barometric curve. It also follows from the much less attractive influence of the sun than that of the moon on the earth's atmosphere that the effects of the sun's attraction on the pressure will be wholly concealed by the much larger effects of the other forces concerned in determining the diurnal oscillation, except in the case or cases where the variation in the fluctuation is small at 1 and 7 A.M. and 1 and 7 P.M. Now at places north of lat. 45° N. the variation at 1 A.M. is small during the winter, and it is a singular fact that some years ago Rykatchew of St Petersburg drew the attention of meteorologists to the existence at these northern stations of a faintly marked third maximum; and it is further of importance to remark that, at many places where on the mean of years the third maximum is scarcely or not at all marked, it appears in the mean of some of the separate years. Thus, though it does not appear in the mean of the twenty years ending 1873 at Greenwich for January, it appears in nine of the individual years. It is highly probable that this maximum, which may be named Rykatchew's maximum from its discoverer, is due to the attractive influence of the sun, its amplitude and time of occurrence being in accordance with such a supposition.

Diurnal Variation of the Force of the Wind.—During the three and a half years' cruise of the "Challenger," ending with May 1876, observations of the force and direction of the wind were made on 1202 days, at least twelve times each day,—650 of the days being on the open sea and 552 near land. The observations of force were made on Beaufort's scale 0–12, being the scale of wind-force observed at sea. The mean diurnal force of the wind on the open sea and near land respectively is shown in fig. 4, where the figures on the left are Beaufort's scale, and those on the right the equivalents in miles per hour. The solid line shows at the different hours of the day the mean force on the open sea, and the dotted line the mean force near land.

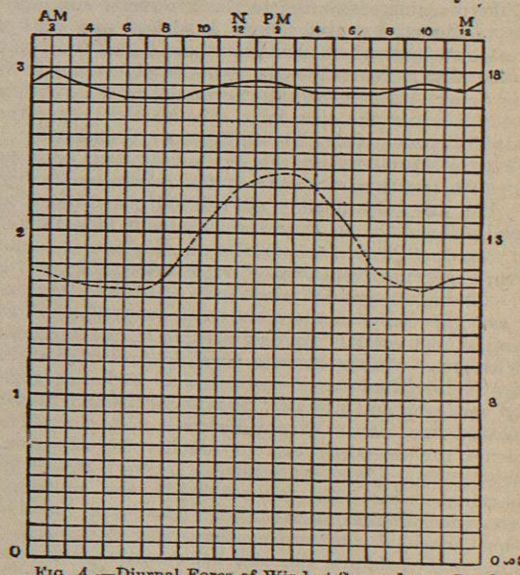

FIG. 4.—Diurnal Force of Wind at Sea and near Land.

As regards the open sea it is seen that the diurnal variation is exceedingly small, there being two apparent slight maxima, about midday and midnight respectively. On examining, however, the separate means for the North and South Atlantic, North and South Pacific, and the Southern Ocean, there is no uniform agreement observable among their curves, the slight variations which are met with being different in each case. It follows therefore that the force of the winds on the open sea is subject to no distinct and uniform diurnal variation. The difference between the hour of least and greatest mean force is less than a mile per hour.

Quite different is it, however, with the winds encountered by the "Challenger" near land, the force of the wind there giving a curve as pronouncedly marked as the ordinary diurnal curve of temperature. The minimum occurs at 2 to 4 A.M. and the maximum from noon to 4 P.M., the absolute highest being at 2 P.M. The curves constructed for each of the five oceans from the observations near land give one and the same result, or a curve closely accordant with the curve of diurnal temperature. The differences between the hours of least and greatest force are as follows:—Southern Ocean 6½ miles, South Pacific 4½ miles, South Atlantic 3¼ miles, and North Atlantic and North Pacific 3 miles per hour.

In the case of each ocean the velocity of the wind on the open sea is considerably in excess of that near land, but in no case does the maximum velocity near land, attained about midday, reach the velocity of the wind on the open sea. The 650 daily observations on the open sea give a mean hourly velocity of 17½ miles, whereas the 552 near land give a velocity of only 12½ miles per hour. The difference is greatest at 4 A.M., when it amounts to upwards of 6 miles an hour, but is diminished by the rising temperature till at 2 P.M. it is less than 3 miles an hour.

At Mauritius, which is situated within the south-east trades, the minimum velocity of the wind is 9·7 miles per hour, occurring from 2 to 3 A.M., from which it rises to the maximum 18·5 miles from 1 to 2 P.M., the influence of the sun being thus to double the wind's velocity. At Batavia, situated in a region where the mean barometric gradient is much smaller, the differences are still more decided. From 1 to 6 A.M. 85 per cent. of the whole of the observations are calms, whereas from noon to 2 P.M. only 1 per cent. are calms. In all months, the minimum velocity occurs in the early morning, when the temperature is lowest, and the maximum from 1 to 3 P.M., when the temperature is highest, the mean minimum and maximum velocities being to each other as 1 to 21. At Coimbra the mean maximum hourly velocity is five times greater than the minimum hourly velocity in summer, whereas in winter it is only about a half more. At Valentia, in the south-west of Ireland, one of the windiest situations in western Europe, the three summer months of 1878 gave a mean hourly velocity of 13·3 miles per hour, the minimum oscillating from 10 to 11 miles an hour from 9 P.M. to 6 A.M., and the maximum exceeding 16 miles an hour from 11 A.M. to 5 P.M. The absolute lowest hourly mean was 10 miles at 11 P.M., and the highest 18 miles at 1 P.M., the velocity about midday being thus nearly double that of the night. Many observations might be added to these, including those published by Hann, Köppen, Hamberg, and others, which go to establish the fact that the curves of the diurnal variation of the velocity of the wind generally conform to the diurnal curves of temperature. The curves are most strongly marked during the hottest months; and the maximum velocity occurs at 1 P.M. or shortly thereafter, being thus before the time of occurrence of the maximum temperature of the day, and the minimum in the early morning, or about the time when the temperature falls to the lowest. The rule also holds good with all winds, whatever be their direction. The exceptions to this rule are so few and of such a kind that they are probably to be attributed to causes more or less of a local character.

Hann has shown, for a number of places in northern Europe, that with a clear sky the velocity is doubled from the minimum to the maximum, with a sky half covered the velocity is three-fourths greater, and with a sky wholly covered the velocity is only a half more. On the other hand at the strictly inland situation of Vienna, with a clear sky the velocity is double, and with a sky half covered it is two-thirds greater, but with a covered sky the diurnal variation in the wind's velocity becomes irregular and faintly marked. Hann has also examined the winds at Vienna, and found that winds of a velocity not exceeding 30 kilometres an hour show a mean diurnal increase from 11 kilometres at 6 A.M. to 16·8 at 1 P.M., but that winds of velocity exceeding 30 kilometres an hour exhibit only a faintly marked and irregular increase of velocity during the day.

In offering an explanation of this remarkable fact regarding the diurnal variation in the velocity of the wind in all climates, it is to be remarked that the minimum velocity occurs when terrestrial radiation and its effects are greatest, but the increase of the velocity closely follows the sun, and the maximum is reached nearer the time the sun crosses the meridian than perhaps any of the other maxima or minima of meteorology which are dependent on the sun's diurnal course. It is also to be noted that the winds over the open sea are practically uninfluenced by solar and terrestrial radiation, for there the diurnal curve of variation in the force of the wind is all but a straight line. On nearing land, however, the wind's force exhibits a diurnal curve of variation as distinctly marked as, and bearing a close resemblance to, the analogous curve of temperature; while on the land itself these features become still more decidedly pronounced. Lastly, the amount of the diurnal variation of the temperature of the surface of the sea is less than a degree, whereas over all land surfaces the diurnal variation of the temperature is large, even where the ground is covered by vegetation, and enormously large over sandy wastes.

From this it follows that, so far as concerns any direct influence on the air itself, solar and terrestrial radiation exercise no influence on the diurnal increase of the velocity of the air with the increase of its temperature,—or, if any influence at all, such influence must be altogether insignificant, as is conclusively shown by the wind observations of the "Challenger" over each of the five great oceans of the globe. The same observations show that on nearing land the wind is everywhere greatly reduced in force. The retardation is greatest during the hours when the daily temperature is at the minimum; and it is particularly to be noted that, though the temperature rises considerably, no marked increase in the velocity sets in till about 9 A.M., when the temperature has begun to rise above the daily mean. From this time the increase is rapid (see fig. 4); the maximum is reached shortly after the period of strongest insolation; and the velocity falls a little (but only a little) during the next three to five hours, according to season, latitude, and position, and falls again to near the minimum shortly after the hour when the temperature is at the mean. Even at the maximum, the velocity near land falls considerably short of the velocity which is steadily maintained over the open sea by night as well as by day.

The period of the day when the wind's velocity is increased is practically limited to the hours when the temperature is above the daily mean, and the influence of this higher temperature is to counteract to some extent the retardation of the wind's velocity resulting from friction and from the viscosity of the air. The increase in the diurnal velocity of the wind is in all probability due to the superheating of the surface of the ground and to the consequent ascensional movement of the air, tending to counteract the effect of friction and of viscosity between the lowermost stratum of the air and the ground. It is of importance in this connexion to keep in view the fact that in cloudy weather a temperature much higher than might have been supposed is often radiated from the clouds down upon the earth's surface,[1] which accounts for the phenomenon of the

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[1] *Journal of Scottish Meteorological Society*, vol. ii. p. 280