elevation as they extend towards the E. These mountains, except the loftier summits, are, for the most part, covered with thick forests of pine, oak, cork, white poplar, wild olive, and other trees. The inferior ranges seem to be principally composed of Secondary limestone, which, at a greater elevation, is succeeded by micaceous schist and quartz-rock; and the higher chains are said to consist of granite, gneiss, mica-slate, and clay-slate. The Secondary and Tertiary formations are frequently disturbed and upraised by trap-rocks of comparatively modern date. Lead iron copper. antimony, sulphur, and rock-salt occur frequently; and in the Marocco portion of the range gold and silver are said to exist. In the Algerian division are mines of copper, lead, silver, and antimony. The lion, hyena, boar, and bear are common throughout the mountains. None of the rivers which take their rise in the system are of any great importance. The Tafilet is absorbed in the sands; the Tensift and Draa flow into the Atlantic; and about five or six find their way to the Mediterranean. Dr Hooker has explored the botany of many parts of the range, and the travels of Rohlfs have added largely to our general knowledge of it.

ATMOSPHERE

ATMOSPHERE is the name applied to the invisible elastic envelope which surrounds the earth, the gaseous matter of which it is composed being usually distinguished by the name of air. Storms and weather generally, solar and terrestrial radiation, the disintegration of rocks, animal and vegetable life, twilight, and the propagation of sound, are some of the more striking phenomena which are either to a large extent or altogether dependent on the atmosphere. That air possesses weight may be shown by the simple experiment of taking a hollow globe filled with air and weighing it; then removing the contained air by means of an air-pump, and again weighing the globe, when it will be found to weigh less than at first. The difference of the two results is the weight of the air which has been removed. From Regnault's experiments, 100 cubic inches of dry air, or air containing no aqueous vapour, under a pressure of 30 English inches of mercury, and at a temperature of 60° Fahr., weigh 31·03529 grains; and since 100 cubic inches of distilled water at the same pressure and temperature weigh 25,252½ grains, it follows that air is 813·67 times lighter than water.

Air as an elastic fluid exerts pressure upon the earth or any substance on which it rests, the action of a boy's sucker and of a water-pump being familiar instances showing the pressure of the atmosphere. When air is removed from a water-pump, the water rises in the pump only to a certain height; for as soon as the water has risen to such a height that the weight of the column of water in the pump above the level of the surface of the water in the well just balances the pressure exerted by the atmosphere on the surface of the well, it ceases to rise. If the pressure of the atmosphere be increased, the water will rise higher in the pump; but if diminished, the level of the water will sink. The height to which the water rises within the pump thus varies with the pressure of the atmosphere, the height being generally about 34 feet. Since a given volume of mercury weighed *in vacuo* at a temperature of 62° Fahr. is 13·569 times heavier than the same volume of water, it follows that a column of mercury will rise *in vacuo* to a height 13·569 times less than a column of water, or about 30 inches. If we suppose, then, the height of the mercurial column to be 30 inches, which is probably near the average height of the barometer at sea-level, and its base equal to a square inch, it will contain 30 cubic inches of mercury; and since one cubic inch of mercury contains 3426·7 grains, the weight of 30 cubic inches will be nearly 14·7304 ℔ avoirdupois. Thus the pressure of the atmosphere is generally, at least in these latitudes, at sea-level equal to 14·7304 ℔ on each square inch of the earth's surface. Sir John Herschel has calculated that the total weight of an atmosphere averaging 30 inches of pressure is about 11⅔ trillions of pounds; and that, making allowance for the space occupied by the land above the sea, the mass of such an atmosphere is about $\frac{1}{1200000}$ part of that of the earth itself. This enormous pressure is exerted on the human frame in common with all objects on the earth's surface, and it is calculated that a man of the ordinary size sustains a pressure of about 14 tons; but as the pressure is exerted equally in all directions, and permeates the whole body. no inconvenience arises in consequence of it.

A pressure agreeing approximately with the average atmospheric pressure at sea-level is often used as a unit of pressure. This unit is called *an atmosphere*, and is employed in measuring pressures in steam-engines and boilers. The value of this unit which has been adopted, in the metrical system, is the pressure of 760 millimètres (29·922 Eng. inches) of the mercurial column at 0° C. (32° Fahr.) at Paris, which amounts in that latitude to 1·033 kilogrammes on the square centimètre. In the English system, *an atmosphere* is the pressure due to 29·905 inches of the mercurial column at 32° Fahr. at London, amounting there to nearly 14¾ ℔ weight on the square inch. The latter atmosphere is thus 0·99968 of that of the metrical system.

As regards the distribution of atmospheric pressure over the globe, there was little beyond conjecture, drawn from theoretical considerations and for the most part erroneous, till the publication in 1868 of Buchan's memoir "On the Mean Pressure of the Atmosphere and the Prevailing Winds over the Globe."[1] By the monthly isobaric charts and copious tables which accompanied the memoir, this important physical problem was first approximately solved. Since then the British Admiralty has published charts showing the mean pressure of the atmosphere over the ocean.[2] The more important general conclusions regarding the geographical distribution of atmospheric pressure are the following:—

There are two regions of high pressure, the one north and the other south of the equator, passing completely round the globe as broad belts of high pressure. They enclose between them the low pressure of tropical regions, through the centre of which runs a narrower belt of still lower pressure, towards which the north and south trades blow. The southern belt of high pressure lies nearly parallel to the equator, and is of nearly uniform breadth throughout; but the belt north of the equator has a very irregular outline, and great differences in its breadth and in its inclination to the equator,—these irregularities being due to the unequal distribution of land and water in the northern hemisphere. Taking a broad view of the subject, there are only three regions of low pressure,—one round each pole, bounded by or contained within the belts of high pressure just referred to, and the equatorial belt of low pressure. The most remarkable of these, in so far as yet known, is the region of low pressure surrounding the south pole, which appears to remain pretty constant during the whole year. The depression round the north pole is divided into two distinct centres, at each of which there is a diminution of pressure greatly lower than the average north polar depression. These two centres lie in the north of the Atlantic and Pacific Oceans respectively. The distribution of pressure in the different months of the year differs widely from the annual average, particularly in January and July, the two extreme months. In January the highest pressures are over the continents of the northern hemisphere,—and the larger the continental mass the greater the pressure,—and the lowest pressures are over the northern portions of the Atlantic and Pacific, South America and South Africa, and the Antarctic Ocean. In the centre of Asia the mean pressure of the atmosphere in this month is fully 30·400 inches, whereas in the North Atlantic, round Iceland, it is only 29·340 inches, or upwards of an inch lower than in Central Asia. The area of high barometer is continued westwards through Central and Southern Europe, the North Atlantic between 5° and 45° N. lat., North America, except the north and north-west, and the Pacific for some distance on either side of 15° N. lat. It is thus an exaggerated form of the high belt of annual mean pressure, spreading, however, over a much greater breadth in North America, and a still greater breadth in Asia.

In July, on the other hand, the mean pressure of Central Asia is only 29·468 inches, or nearly an inch lower than during January; or, putting this striking result in other words, about a thirtieth of the pressure of the atmosphere is removed from this region during the hottest months of the year as compared with the winter season. The lowest pressures of the northern hemisphere are now distributed over the continents, and the larger the continental mass the greater is the depression. At the same time, the highest are over the ocean between 50° N. and 50° S. lat., particularly over the North Atlantic and the North Pacific between 25° and 40° N. lat., and in the southern hemisphere over the belt of high mean annual pressure, which in this month reaches its maximum height. Pressure is high in South Africa and in Australia, just as in the winter of the northern hemisphere pressures are high over the continents.

Over the ocean, if we except the higher latitudes, atmospheric pressure is more regular throughout the year than over the land. In the ocean to westwards of each of the continents there occurs at all seasons an area of high pressure, from 0·10 inch to 0·30 inch higher than what prevails on the coast westward of which it lies. The distance of these spaces of high pressure is generally about 30° of longitude; and their longitudinal axes lie, roughly speaking, about the zones of the tropics. The maximum is reached during the winter months, and these areas of high pressure are most prominently marked west of those continents which have the greatest breadth in 30° lat.; and the steepest barometric gradients are on their eastern sides. It is scarcely possible to over-estimate the importance of these regions of high and low mean pressures, from their intimate bearing on atmospheric physics, but more particularly from their vital connection with prevailing winds and the general circulation of the atmosphere. This relation will be apprehended when it is considered that winds are simply the flowing away of the air from regions where there is a surplus (regions of high pressure) to where there is a deficiency of air (regions of low pressure). Everywhere over the globe this transference takes place in strict accordance with Buys-Ballot's "Law of the Winds," which may be thus expressed:—The wind neither blows round the space of lowest pressure in circles returning on themselves, nor does it blow directly toward that space; but it takes a direction intermediate, approaching. however, more nearly to the direction and course of circular curves than of radii to a centre. More exactly, the angle is not a right angle, but from 45° to 80°. Keeping this relation between wind and the distribution of pressure in mind, the isobaric lines give the proximate causes of the prevailing winds over the globe, and through these the prominent features of climates. As regards the ocean, the prevailing winds indicate the direction of the drift-currents and other surface-currents, and thereby the anomalous distribution of the temperature of the sea as seen in the Chili, Guinea, and other ocean currents, and the peculiarly marked climates of the coasts past which these currents flow, are explained; for observations have now proved that the prevailing winds and surface-currents of all oceans are all but absolutely coincident.

As regards the annual march of pressure through the months of the year, curves representing it for the different regions of the earth differ from each other in every conceivable way. It is only when the results are set down in their proper places on charts of the globe that the subject can be well understood. When thus dealt with, many of the results are characterised by great beauty and simplicity. Thus, of all influences which determine the barometric fluctuation through the months, the most important are the temperature, and through the temperature the humidity. Comparing, then, the average pressure in January with that in July, which two months give the greatest possible contrasts of temperature, the following is the broad result:—

The January exceeds the July pressure over the whole of Asia except Kamtchatka and the extreme north-east, the greatest excess being near the centre of the continent; over Europe to south and east of a line drawn from the White Sea south-westward to the Naze, thence southward to the mouth of the Weser, then to Tours, Bordeaux, and after passing through the north of Spain, out to sea at Coruña; over North America, except the north-east and north-west. On the other hand, the July exceeds the January pressure generally over the whole of the southern hemisphere, over the northern part of the North Atlantic and regions immediately adjoining (the excess amounting in Iceland to 0·397 inch), and over the northern part of the North Pacific and surrounding regions. Thus the pressure which is so largely removed from the Old and New Continents of the northern hemisphere in July is transferred, partly to the southern hemisphere, and partly to the northern portions of the Atlantic and Pacific Oceans.

Atmospheric pressure is more uniformly distributed over the globe in April and October than in any of the other months. In May and November, being the months immediately following, occur the great annual rise and fall of temperature; and since these rapid changes take place at very different rates, according to the relative distribution of land and water in each region, a comparison of the geographical distribution of May with that for the year brings out in strong relief the more prominent causes which influence climate, and some of the more striking results of these causes. This comparison shows a diminution of pressure in May over tropical and sub-tropical regions, including nearly the whole of Asia, the southern half of Europe, and the United States. An excess prevails over North America to the north of the Lakes, over Arctic America, Greenland, the British Isles, and to the north of a line passing through the English Channel in a north-easterly direction to the Arctic Sea. The excess in the southern hemisphere includes the southern half of south America and of Africa, the whole of Australia, and adjacent parts of the ocean. The influence of the land of the southern hemisphere, which in this month is colder than the surrounding seas, brings about an excess of pressure; on the other hand, the influence of land over those regions

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[1] *Trans. Roy. Soc. Edin.*; vol. xxv. p. 575.

[2] *Physical Charts of the Pacific, Atlantic, and Indian Oceans*, Lond. 1872.

which are more immediately under the sun brings about a lower pressure, interesting examples of which occur in India, the Malayan Archipelago, and the Mediterranean, Black, and Caspian Seas. In many cases the lines of pressure follow more or less closely the contours of the coasts. Thus the diminution is greater over Italy and Turkey than over the Adriatic and Black Seas. The greatest diminution occurs in Central Asia, where it exceeds 0·200 inch, and the greatest excess round Iceland, where it exceeds 0·200 inch. It is to the position of Great Britain, with reference to the deficiency of pressure on the one hand and the excess on the other, that the general prevalence of east winds at this season is due. These easterly winds prevail over the whole of Northern Europe, as far south as a line drawn from Madrid and passing in a north-easterly direction through Geneva, Munich, &c. To the south of this line the diminution of pressure is less, and over this region the winds which are in excess are not easterly, but southerly. Crossing the Mediterranean, and advancing on Africa, we approach another region of lower pressure, towards which easterly and north-easterly winds again acquire the ascendency, as at Malta, Algeria, &c.

This, in many cases great, variation of the pressure in the different months of the year must be kept carefully in view in deducing heights of places from observations made by travellers of the pressure of atmosphere, by the barometer or the temperature of boiling water. In reducing the observations, it is necessary to assume a sea-level pressure if the place is at a considerable distance from any meteorological observatory. Previous to the publication of Buchan's *Mean Pressure of the Atmosphere*, it appears that a mean sea-level pressure of 29·92 or 30·00 inches was in such cases universally assumed. The mean pressure at Barnaul, Siberia, being 29·536 inches in July, 30·293 inches in January, and 29·954 inches for the year, it follows that, by the former method of calculating the heights, observations made in January to ascertain the height of Lake Balkash would make the lake 350 feet too high, and observations made in July would make it 330 feet too low,—the difference of the two observations, each set being supposed to be made under the most favourable circumstances, and with the greatest accuracy, being 680 feet. This illustration will serve to account for many of the discrepancies met with in books regarding the heights of mountains and plateaus

Of the periodical variations of atmospheric pressure, the most marked is the daily variation, which in tropical and sub-tropical regions is one of the most regular of recurring phenomena. In higher latitudes the diurnal oscillation is masked by the frequent fluctuations to which the pressure is subjected. If, however, hourly observations be regularly made for some time, the hourly oscillation will become apparent. The results show two maxima occurring from 9 to 11 A.M. and 9 to 11 P.M., and two minima occurring from 3 to 6 A.M. and 3 to 6 P.M. The following are the extreme variations for January, April, July, and October from the daily mean pressure at Calcutta, deduced from the observations made during six years, viz., 1857–62:—

	A.M.				P.M.			
	Min.	Hour.	Max.	Hour.	Min.	Hour.	Max.	Hour.
	Inch		Inch		Inch.		Inch.	
January	– ·023	3	+ ·079	10	– ·053	4	+ ·010	10
April	– ·020	3	+ ·070	9	– ·071	4	+ ·016	10
July	– ·019	3	+ ·040	10	– ·051	4	+ ·029	10
October	– ·026	3	+ ·064	9	– ·047	4	+ ·018	10

Similarly the maxima and minima at Vienna, with the hour of their occurrence, are as follows:

	A.M				P.M.			
	Min.	Hour.	Max.	Hour.	Min.	Hour.	Max.	Hour.
	Inch.		Inch.		Inch.		Inch.	
January	– ·008	6	+ ·018	10	– ·020	3	+ ·012	10
April	– ·003	5	+ ·021	10	– ·027	5	+ ·014	11
July	+ ·003	3	+ ·022	9	– ·028	5	+ ·009	11
October	– ·010	6	+ ·020	10	– ·015	4	+ ·008	10

These two illustrations may be regarded as typical, to a large extent, of the diurnal barometric oscillations in tropical and temperate regions. At Calcutta the amounts are large, and the dates of the occurrence of the maxima and minima very regular from 3 to 4 and 9 to 10 A.M. and P.M. respectively. On the other hand, the oscillations at Vienna are much smaller and more variable in amount, and the dates of occurrence of the critical phases take place through a wider interval, viz., from 3 to 6 and 9 to 11 A.M. and P.M. respectively.

Though the diurnal barometric oscillations are among the best-marked of meteorological phenomena, at least in tropical and sub-tropical regions, yet none of these phenomena, except perhaps the electrical, could be named respecting whose geographical distribution so little is really known, whether as regards the amount of variation, the hour of occurrence of the critical phases, or, particularly, the physical causes on which the observed differences depend. This arises chiefly from the want of a sufficient number of ascertained facts; and to remedy this deficiency, observations have, in the preparation of this present article, been collected and calculated from upwards of 250 places in different parts of the globe, and the data set down on charts. The chief results of this inquiry are the following, attention being entirely confined to the chief oscillation, viz., that occurring from the A.M. maximum to the P.M. minimum.

The A.M. *Maximum.*—In January this occurs from 9 to 10 in tropical and temperate regions as far as 50° N. lat.; in higher latitudes the time of occurrence varies from 8 A.M. to noon. In July it occurs from 9 to 10 everywhere only as far as about 40° N. lat.; the time at Tiflis (41° 42′ N. lat.) being between 7 and 8 A.M. In higher latitudes the time varies from 8 to 11 A.M., the last hour being general in north-western Europe.

The P.M. *Minimum.*—In January this occurs from 3 to 4 P.M. nearly everywhere over the globe, a few exceptions occurring in north-western Europe, the extremes being 2 P.M. at Utrecht and 6 P.M. at St Petersburg. It is quite different in July, when the time from 3 to 4 P.M. is regularly kept as far north as about 40° N. lat. In higher latitudes the hour is very generally 5, but at some places it is as early as 4 P.M., and at others as late as 6 P.M.

In the northern hemisphere, in summer, the afternoon minimum falls to a greater extent below the mean of the day than the forenoon maximum rises above it, at 82 per cent. of the stations; but in winter the percentage is only 61. In the southern hemisphere the same relation is observed in the summer and winter months, thus showing that in the summer of both hemispheres the influence of the sun tends to lower the minimum at 3 to 4 P.M. to a greater extent than to raise the 9 to 10 A.M. maximum.

Decrease between Morning Maximum and Afternoon Minimum.—Of the four daily oscillations, this is the most important. When the amounts at different places are entered on charts of the globe, it is seen that the amplitude of this fluctuation is, speaking generally, greatest in the tropics, diminishing as we advance into higher latitudes; greater over the land than over the sea, increasing greatly on proceeding inland; nearly always greater with a dry than with a moist atmosphere; and generally, but by no means always, it is greatest in the month of highest

temperature and greatest dryness combined. The regions of largest amplitude include the East India Islands, Eastern Peninsula, India, Arabia, tropical Africa, and tropical South and Central America, where it either closely approaches or exceeds 0·100 inch. At Silchar, in Assam, it is 0·133 inch. In the tropical parts of the ocean the oscillation is from 0·020 to 0·030 inch less than on land. The influence of the Mediterranean Sea in lessening the amount over all regions bordering it is very strongly marked. The line showing an oscillation of 0·050 inch crosses North America about lat. 44°, curves southward at some distance from the east coast to lat. 23°, then north-eastward along the coast of Africa, passes eastwards near the north coast of that continent, thence strikes northwards, cutting the eastern part of the Black Sea, and eastward across the Caspian to a point to northward of Peking, and then bends southward to the Loo Choo Islands. The line of 0·020 inch cuts the N.W. of Spain and N.W. of France, and runs northward through Great Britain as far as the Tweed, thence to Christiania, then southwards to Copenhagen and to Cracow, the latitude of which it follows eastward through Asia.

The more marked seasonal changes are these:—In India the oscillations during the dry and wet seasons, or in January and July, respectively, are—Bombay, 0·120 and 0·067 inch; Poonah, 0·133 and 0·059 inch; and Calcutta, 0·132 and 0·091 inch. At Madras, where the rain-bringing characters of the monsoons are reversed, the numbers are 0·114 and 0·115 inch, and at Roorkee, where rain falls all the year round, 0·088 and 0·079. Again, at Aden, in Arabia, where the weather of July is peculiarly hot and dry, the oscillation in December is 0·106, but in July it rises to 0·137 inch. The point to be insisted on here is, that, whatever be the cause or causes to which the daily barometric oscillation is due, the absolute amount is largely dependent on comparatively local influences.

While illustrations similar to the above may be adduced from many other parts of the globe, showing the influence in the same direction of prevailing dry or wet, hot or cold seasons on the amplitude of the oscillation, the North Atlantic and regions adjoining present an apparent exception to the law which seems to be indicated by these results. The whole of the North Atlantic, particularly north of lat. 20°, and the sea-boards which bound it, to which the Mediterranean and its immediate sea-board may be added, are strikingly characterised by a small summer oscillation; and this diminution is most strongly marked along the eastern part of the ocean. Thus, in July, at Ponta Delgada, in the Azores, the oscillation is only 0·06 inch; at Angra do Heroisma, also in the Azores, 0·010 inch; at Funchal, Madeira, 0·011 inch; at Oporto, 0·018; Lisbon, 0·030; and Lagos, 0·021; at Naples and Palermo, 0·008; and at Malta, 0·020 inch. Now, with reference to this extensive region, it is to be noted that the rainfall of July is either zero or very small; and yet with this dry state of the atmosphere and high temperature (the annual maximum occurring at the time), this oscillation is extraordinarily diminished, being exactly the reverse of what takes place during the dry and wet seasons in India. The diminution on the western half of the Atlantic, though not so great, is also striking, the January and July oscillations being 0·056 and 0·036 inch in Barbadoes, 0·080 and 0·056 at Jamaica, 0·082 and 0·054 at Havanna, 0·053 and 0·024 in the Bahamas, and 0·054 and 0·022 in Bermuda. Over the whole of the region here indicated the rainfall of July is largely in excess of that of January. The apparently exceptional character of this region is probably due to the circumstance, that at this time of the year the sun's rays fall perpendicularly over a more diversified surface of the earth, that is, on a greater extent of land, than at any other season. At this time the Mediterranean which is completely shut in by land, and the Atlantic, which is bounded by two great continents, show a much smaller oscillation than prevails over the land adjoining them, and the lines of equal oscillation now attain their annual maximum. On the other hand, in January, when the sun's rays fall perpendicularly over the most uniform surface, or over the maximum extent of ocean, the lines are almost everywhere parallel with the parallels of latitude.

Again, on advancing inland from the Atlantic, the effects of comparatively local influences are very striking, as the following mean July oscillations, from places situated in lines running in different directions, show:—Dublin, 0·012; Oxford, 0·022; Ostend, 0·009; Brussels, 0·019; Vienna, 0·049; Odessa, 0·024; and Tiflis, 0·077: Limerick, 0·010; Helston, 0·007; Paris, 0·020; Geneva, 0·045; Turin, 0·052; Rome, 0·036; Palermo, 0·008; and Malta, 0·020. But the most remarkable illustration is the following, the places being all situated between 38° and 42° N. lat.: San Francisco, 0·068; Fort Churchhill, 0·091; Washington, 0·063; Angra do Heroisma, 0·006; Lisbon, 0·030; Campo Maior, 0·054; Palermo, 0·008; Tiflis. 0·077; and Peking, 0·060.

It follows from what has been stated that much which has been written regarding these fluctuations, and in explanation of them, does not rest on facts; and nearly everything yet requires to be done in the way of collecting data towards the representation and explanation of the daily oscillations of atmospheric pressure which are, as regards two-thirds of the globe, perhaps, as already stated, the most regular of recurring phenomena, and an explanation of which cannot but throw much light on many of the more important and difficult problems of the atmosphere. The data chiefly required are—barometric data from which the amplitude of the four daily oscillations can be represented in their distribution and times of occurrence for each of the months; temperature data, comparable *inter se*, from which the diurnal march of temperature for each month can be ascertained; hygrometric data for hourly values; rain data also for the hours; wind observations conducted on a satisfactory and uniform plan; together with magnetic and electrical observations. It is singularly unfortunate that the disposition of meteorologists of recent years has been to recommend as hours of observations for places which observe only twice or thrice daily, hours which do not correspond with the times when the great barometric and thermometric daily phases occur; hence these phases cannot be noted except at the great observatories, which are too few and far apart to give sufficient data for the proper discussion of many of those questions.

Since the two maxima of daily pressure occur when the temperature is about the mean of the day, and the two minima when it is at its highest and lowest respectively, there is thus suggested a connection between the daily barometric oscillations and the daily march of temperature; and similarly a connection with the daily march of the amount of vapour and humidity of the air. The view entertained by many of the causes of the daily oscillations may be thus stated:—The *forenoon maximum* is conceived to be due to the rapidly increasing temperature, and the rapid evaporation owing to the great dryness of the air at this time of the day, and to the increased elasticity of the lowermost stratum of air which results therefrom, until a steady ascending current has set in. As the day advances, the vapour becomes more equally diffused upwards through the air, an ascending current, more or less strong and steady, is set in motion, a diminution of elasticity follows, and the pressure falls to the *afternoon minimum*. From this point the temperature declines, a system of descending currents set in, and the air of the lowermost stratum approaches more nearly the point of saturation, and from the increased elasticity, the pressure rises to the *evening maximum.* As the deposition of dew proceeds, and the fall of temperature and consequent downward movement of the air are arrested, the elasticity is again diminished, and pressure falls to the *morning minimum.* Since the view propounded some years ago, that if the elastic force of vapour be subtracted from the whole pressure, what remains will show only one daily maximum and minimum, has not been confirmed by observation, it follows that the above explanation is quite insufficient to account for the phenomena; indeed, the view can be regarded in no other light than simply as a tentative hypothesis.

Singularly enough, Lamont and Broun, a few years ago, were led, independently of each other, to form an opinion that the daily barometric oscillations were due to the magneto-electric influence of the sun. It admits of no doubt, looking at the facts of the case so far as they have been disclosed, that the daily barometric oscillations originate with the sun, and that more than the sun's influence as exerted on the diurnal march of the temperature and humidity of the atmosphere is concerned in bringing them about. But from the facts adduced, it is equally certain that, be the originating cause what it may, its effects are enormously modified by the distribution of land and water over the globe, by the wind, and by the absolute and relative humidity of the atmosphere. The smallness of the amount of the summer oscillation from the forenoon maximum to the afternoon minimum over the North Atlantic as far south as lat. 30°, and its diminished amount, as far south at least as the equator, will no doubt play an important part in the unravelling of this difficulty.

One of the most important steps that could be taken would be an extensive series of observations from such countries as India, which offers such splendid contrasts of climate at all seasons, has a surface covered at one place with the richest vegetation, and at others with vast stretches of sandy deserts, and presents extensive plateaus and sharp ascending peaks—all which conditions are indispensable in collecting the data required for the solution of this vital problem of atmospheric physics

The ancients thought that air was one of the four elements from which all things originated, and this doctrine continued to prevail till 1774, when Priestley discovered oxygen gas, and showed it to be a constituent part of air. Nitrogen, the other constituent of air, first called *azote,* was discovered soon after, and the marked differences between these two gases could not fail to strike the most careless observer. It is remarkable that Scheele independently discovered both oxygen and nitrogen, and was the first to enunciate the opinion that air consists essentially of a mixture of these two gases. From experiments made by him to ascertain their relative volumes he concluded that the proportions are 27 volumes of oxygen and 73 volumes of nitrogen. It was left to Cavendish to show from 500 analyses that the relative proportions were practically constant, and that the proportion is 20·833 per cent. of oxygen. The results obtained by Cavendish, though not attended to for many years after they were published, have been shown by recent and more refined analyses to be wonderfully exact. The most recent analyses of specimens of air collected under circumstances which ensure that it is of average purity, give as a mean result the following:—

	Volume.	
Oxygen	20·96	per cent.
Nitrogen	79·00	„
Carbonic acid	0·04	„
	100·00	

The circumstances under which these proportions vary, and the other gases and substances which are found in the air, will be afterwards adverted to.

Besides these three constituents of air, there is a fourth, viz., the vapour of water, from which no air, even at the lowest temperatures yet observed, is wholly free, so that absolutely dry air does not exist in the free atmosphere. The dry air of the atmosphere—oxygen (inclusive of ozone), nitrogen, and carbonic acid—is always a gas, and its quantity is constant from year to year; but the vapour of water does not always remain in the gaseous state, and the quantity present in the atmosphere is, by the processes of evaporation and condensation, varying every instant. Water evaporates at all temperatures, even the lowest, and rises into the air in the form of an invisible elastic gas called aqueous vapour. The elasticity of vapour varies with the temperature. At 0° Fahr. it is capable of sustaining a pressure equal to 0·044 inch of the mercurial barometer, as calculated from Regnault's experiments; at 32° (freezing), 0·181 inch; at 60°, 0·518 inch; at 80°, 1·023 inch; and at 100°, 1·918 inch, being nearly $\frac{1}{15}$ the average pressure of the atmosphere.

In investigating the hygrometry of the atmosphere, the chief points to be ascertained are—(1), the temperature of the air; (2), the dew-point; (3), the elastic force of vapour, or the amount of barometric pressure due to the vapour present; (4), the quantity of vapour in, say, a cubic foot of air; (5), the additional vapour required to saturate a cubic foot of air; (6), the relative humidity; and (7), the weight of a cubic foot of air at the pressure at the time of observation. The vapour of the atmosphere is observed by means of the hygrometer (see HYGROMETER), of which it is only necessary here to refer to *Regnault's* as the most exact, and *August's* as the most convenient, and, consequently, the one in most general use. August's hygrometer consists of a dry and a wet bulb, with which are observed the temperature of the air and the temperature of evaporation. Of these two observed data, the formula of reduction, as deduced from Apjohn's investigations, is as follows:—Let F be the elastic force of saturated vapour at the dew-point, f the elastic force at the temperature of evaporation, d the difference between the dry and wet bulb, and b the barometric pressure, the

$$F = f - \frac{a}{88} \times \frac{b}{30}$$

when the reading of the wet bulb is above 32°; and

$$F = f - \frac{d}{96} \times \frac{b}{30}$$

when below it. From Regnault's values of the elastic force of vapour, f is found, and d and b being observed, F is calculated. From F the dew-point is found. In calculating relative humidity, saturation is usually assumed to be 100, perfectly dry air 0. The humidity is found by dividing the elastic force at the dew-point by the elastic force at the temperature of the air, and multiplying the quotient by 100.

The elastic force may be regarded as representing approximately the absolute quantity of vapour suspended in the air. It may be termed the absolute humidity of the atmosphere. Since the chief disturbing influences at work in the atmosphere are the forces called into play by its aqueous vapour, a knowledge of the geographical distribution of this constituent through the months of the year is of the utmost possible importance. Hence every effort ought to be made to place the observation of the hygrometry of the air, and the reduction of the observed data, on a sounder basis than has yet been done. As regards geographical distribution, the elastic force is greatest within the tropics, and diminishes towards the poles; it is greater over

the ocean, and decreases on advancing inland; greater in summer than in winter; and greater at midday than in the morning. It diminishes with the height generally; but in particular cases, different strata are superimposed on each other, differing widely as regards dryness and humidity, and the transitions from the one to the other are often sharp and sudden.

The relative humidity of the air may be regarded as the degree of approach to saturation. It is greatest near the surface of the earth during night, when the temperature, being at or near the daily minimum, approaches the dew-point; it is also great in the morning, when the sun's rays have evaporated the dew, and the vapour is as yet only diffused a little way upwards; and it is least during the greatest heat of the day.

Between the humidity, both absolute and relative, of the air and the temperature there is a vital and all-important connection. Observation shows that when the quantity of vapour in the air is great, and also when the relative humidity is high, temperature falls little during the night, even though the sky be perfectly clear; but when the quantity of vapour is small, or the relative humidity is low, temperature rapidly falls. On the other hand, during the day the temperature rises slowly, when the quantity of vapour is great, or relative humidity high, even though the sky be clear, but when the quantity of vapour is small, and humidity low, temperature rapidly rises. These facts are explained by the circumstance that perfectly dry air is diathermanous, that is, it allows radiant heat to pass through it without being sensibly warmed thereby. Add vapour to this air, and its diathermancy is diminished. The diathermancy is also reduced if the temperature approach nearer to the dew-point; in other words, if the relative humidity be increased. Hence, with an increase of vapour or with increased humidity, the effects of both solar and terrestrial radiation are much less felt on the surface of the earth—the vapour screen performing, in truth, one of the most important conservative functions of the atmosphere.

Since ascending currents fall in temperature as they ascend, through diminished pressure and consequent dilatation, they increase their relative humidity; and since descending currents increase in temperature, and consequently reduce their relative humidity, it follows that, over a region from which ascending currents rise, solar and terrestrial radiation is very considerably obstructed, but over a region upon which currents descend, radiation is much less obstructed. Most of our exceptionally hot summer and cold winter weather is to be explained in this way, on which occasions there is generally observed a high barometric pressure overspreading a comparatively limited region, on which a slow downward movement of the air proceeds.

Of the solar heat which reaches the surface of the globe, that part which falls on the land may be regarded as wholly absorbed by the thin superficial layer exposed to the heating rays; and since there is no mobility in the particles of the land, the heat can be communicated downwards only by conduction. On the other hand, the solar heat which falls on water is not, as in the case of land, arrested at the surface, but penetrates to a considerable depth, the heating effect being in the case of clear water appreciably felt at a depth of from 500 to 600 feet. Since the heat daily received by the ocean from the sun is diffused downwards through a very considerable depth, the surface of the ocean on which the atmosphere rests is much less heated during the day than is the surface of the land. Similarly it is also less cooled during the night by terrestrial radiation.

This points to a chief acting force on which the great movements of the atmosphere depend, viz., simultaneous local irregularities in the distribution of temperature in the atmosphere. The local expansion of the atmosphere by heat during the day is greatest over land, where the air is clear, dry, and comparatively calm, and least over the ocean, where the sky is clouded, and the air loaded with moisture. On the other hand, the local contraction by cold during night is greatest over land, where the air is clear, dry, and calm, or nearly so, and least over the ocean, where the air is clouded, and loaded with moisture. As familiar illustrations of atmospheric movements resulting from local expansions by heat and contractions by cold, we may refer to the land and sea breezes, and what depend upon exactly the same principle, the dry and rainy monsoons in different parts of the globe. But the illustration of the principle on the broadest scale is the system of atmospheric circulation known as the equatorial and polar currents of the atmosphere, which originate in the unequal heating by the sun of the equatorial, temperate, and polar regions.

The other principal motive force in atmospheric circulation depends on the aqueous vapour. The many ways in which this element acts as a motive force will be seen when it is considered that a large quantity of sensible heat disappears in the process of evaporation, and reappears in the process of condensation of the vapour into rain or cloud; that saturated air is specifically lighter than dry air; and that the absolute and relative amount of the vapour powerfully influences both solar and terrestrial radiation. The question to be carefully considered here is, how in these ways the vapour produces local irregularities in the distribution of atmospheric pressure, thus giving rise to aerial movements which set in to restore the equilibrium that has thus been disturbed.

It is from these local irregularities—using the word local in a very wide sense—in the distribution of atmospheric pressure, whether the irregularities originate in the temperature or aqueous vapour, that all winds, from the lightest breeze to the most destructive hurricane, take their rise; for, as already stated, wind is merely the flowing away of the air from where there is a surplus of it to where there is a deficiency.

In examining weather charts embracing a considerable portion of the earth's surface, such, for instance, as those published in the *Journal of the Scottish Meteorological Society,* vol. ii. p. 198, which include a large part of the northern hemisphere, there are seen two different systems of pressure changing their forms and positions on the globe from day to day—one set being systems of low pressure marked off by concentric isobarics enclosing pressures successively lower as the central space is approached, and the other set being systems of high pressure marked off by roughly concentric isobarics bounding pressures successively higher towards their centres. These two systems are essentially distinct from each other, and without some knowledge of them the circulation of the atmosphere cannot be understood.

1. *Areas of Low Pressure, or Cyclones.*—The annexed woodcut, fig. 1, is a good representation of a cyclone which passed over north-western Europe on the morning of 2d November 1863. The pressure in the central space is 28·9 inches, from which it rises successively, as shown by the isobarics, to 29·1, 29·3, 29·5, 29·7, and 29·9 inches. The arrows show the direction and force of the wind, the force rising with the number of feathers on the arrows. The two chief points to be noted are the following:—(1.) The *direction* of the arrows shows a vorticose motion of the air inwards upon the space of lowest pressure, the motion being contrary to that of the hands of a watch. It will be observed that the winds blow in conformity with what is known as Buys-Ballot's "Law of the Winds," already