tudes, which blow from the ocean, countries that would otherwise be as bleak as Labrador. The better-known ocean currents are, the Gulf Stream of the North Atlantic and the Kuro Siwo of the North Pacific, both warm currents, flowing from the tropics toward the cooler waters of the poleward regions. There are other warm currents less popularly known flowing from the tropical waters. There are also cold currents from the Arctic regions that chill the coasts of the countries they wash. A cold current flows from Davis Strait along the coast of Labrador and even farther southward, influencing the temperature of the coast as far as Cape Cod. Humboldt's, or the Peruvian, current from the Antarctic lowers somewhat the temperature of the Chilian littoral.

Prevailing Winds.—As climatic factors the prevailing winds are the agencies by which the inequalities in temperature and the other climatic elements that result from the effects and distribution of the land and water surfaces of the earth are maintained within a measure of equilibrium, which though varying in different regions, yet remain on the whole constant for each region. To understand the climate of a region, the direction from which the wind of that region comes must always be taken into consideration. If the wind comes directly from over a considerable body of water, it will bring with it in a greater or less degree the temperature and humidity of the air over the water surface. Should, however, a mountain range intervene, the wind would be robbed of the greater part of its moisture, but would retain its temperature, as already referred to under the effects of mountain ranges. On the other hand, if the wind blows from the land, it brings with it the climatic conditions of the surfaces which it traverses.

Winds are classified as permanent, periodic, and variable. The permanent winds are those of general systemic circulation that prevail over the disturbing effects of the land and water distribution. They are well represented in the trades and the anti-trades of the oceans. The periodic winds are characterized by their prevalence from one direction in one season, and from the opposite direction in the opposite season. The Indian monsoons are the most popularly known of this class. The variable winds are members of the cyclonic and anticyclonic circulation systems of the atmosphere. The prevailing winds of a region can be predicted from a knowledge of the position of the region with respect to the general system of the atmospheric circulation, previously indicated, and from the relative position and distribution of the land and water areas of the region, the topography of the region and the consideration of the season of the year, and, in some instances, of the time of the day. From the facts already developed of land heating and cooling more rapidly and more extremely than water, the atmosphere over the land is subjected to greater extremes of temperature and density than that over the water. Air moves in the direction of least resistance, that is, from the denser toward the less dense. In the case of continents these conditions give origin to the class of periodic winds known as monsoons, from the Hindoostanee signifying season. The monsoon results, in the summer, from the overheating of the air over the interior of a continent, its consequent expansion, loss of density, rising and overflowing in upper air currents toward the [illegible] and the inflowing as surface currents of the [illegible] from the water to take the place of the heated. This form of exchange keeps up during the summer months. In the winter months the conditions are reversed. The air over the ocean is warm, that over the interior of the continent cold, for reasons that have been explained, and the exchange takes place just the opposite of that in summer. When the monsoon wind is in the direction of the general circulation of the latitude, it adds its force to that of the latter, which appears as a stronger wind than normal. If contrary, the monsoon must either overcome or be overcome by the general wind of the latitude. If the first, it appears as a feeble monsoon; if the latter, it is in evidence negatively as an enfeeblement of the systemic wind of the latitude. The effects of topography upon a monsoon can be inferred readily from what has been said regarding the influence of mountains on winds. Along the littorals of all large bodies of water a familiar illustration of the different effects of insolation on land and water is seen in a periodic wind of shorter period than the monsoon, the daily land-and-sea breeze.

The following broad generalizations as to the prevailing winds, and also ocean currents, of the globe may be of service. Within the warmer latitudes, the tropics and sub-tropics, the winds and ocean currents have a prevailing direction from the east; within the temperate latitudes, the winds and ocean currents have a prevailing direction from the west; within the polar latitudes, the wind and ocean currents have a prevailing direction from the poles toward the equator. There are a few winds that should be mentioned because of the frequent reference to them in climatic literature. These winds are all cyclonic in origin. The disagreeable *east wind* of Britain, referred to so often by Dickens in one of his novels, is dry and cold. The *mistral* of Southern France is a violent cold, dry, northwest wind, and is the *tramontana* of the Adriatic coast. The *northers* of Texas and the West are very cold and dry winds. The *sirocco* of the Mediterranean littoral is a torrid south wind, hot from the sands of the Sahara and damp from the moisture of the Mediterranean. The *khamsin* of Egypt, and the *Harmattan* of the west coast of Africa, are easterly and southeasterly winds, dry and hot from Sahara. The dreadful *simooms* of the Arabian and Persian deserts are but violent local whirlwinds, mixing the air and the heated sands of the desert together, with resultant temperatures that would be unendurable if continued longer than a few moments. The simoon passes over in about ten minutes.

Rainfall.—The effect of rainfall as a factor is rather passive than active. Rain itself is the result of the operation of the other climatic factors and elements. To save a certain amount of repetition, its further consideration is deferred to rain as an element of climate.

Soil.—The nature of the land surface, apart from the great irregularities that have been considered under mountain ranges, exerts a considerable influence upon the climate of the region. The physical construction and chemical composition of the soil affect in no inconsiderable degree the quantities of insolation and of moisture that remain for a greater or less time in its surface. The general relation of the kind of soil to the absorption and radiation of heat is approximately about as follows:

ABSORPTION AND RADIATION OF HEAT IN PERCENTAGE.

Sand, with some limestone	100
Pure sand	96
Light clay	77
Gypsum	72
Heavy clay	71
Clayey earth	68
Pure clay	67
Fine chalk	62
Humus	49

From this table it will be observed that a sandy limestone soil absorbs practically all the heat falling on it. The absorptive and the emissive thermal powers of a body being equal, it follows that the same soil radiates under given conditions all the heat it absorbs. Observation has shown that sandy deserts are subject to the greatest ranges in temperature. Earth containing much humus shows less range of temperature than any other kind of soil. The quantity of moisture taken up by the different kinds of soil varies greatly. Sand and sandy soils absorb moisture quickly and in great quantity, but retain it badly. Humus may take up from forty to sixty per cent. of its own volume of water and will retain it strongly. Rain falling, therefore, on sandy soil is quickly absorbed and quickly lost, the loss is mostly by percolation; falling on humus it is slowly absorbed, but what is taken is strongly retained. The damper the soil the more nearly it approximates the behavior of a water surface with respect to temperature and humidity. Frost

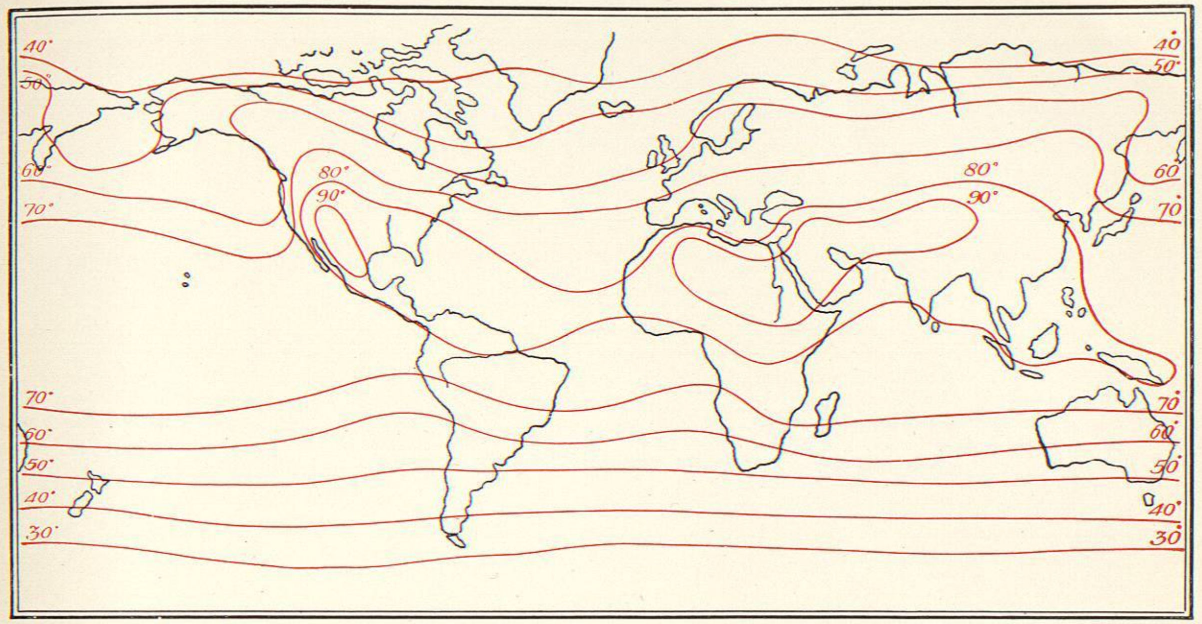

FIG. 1.

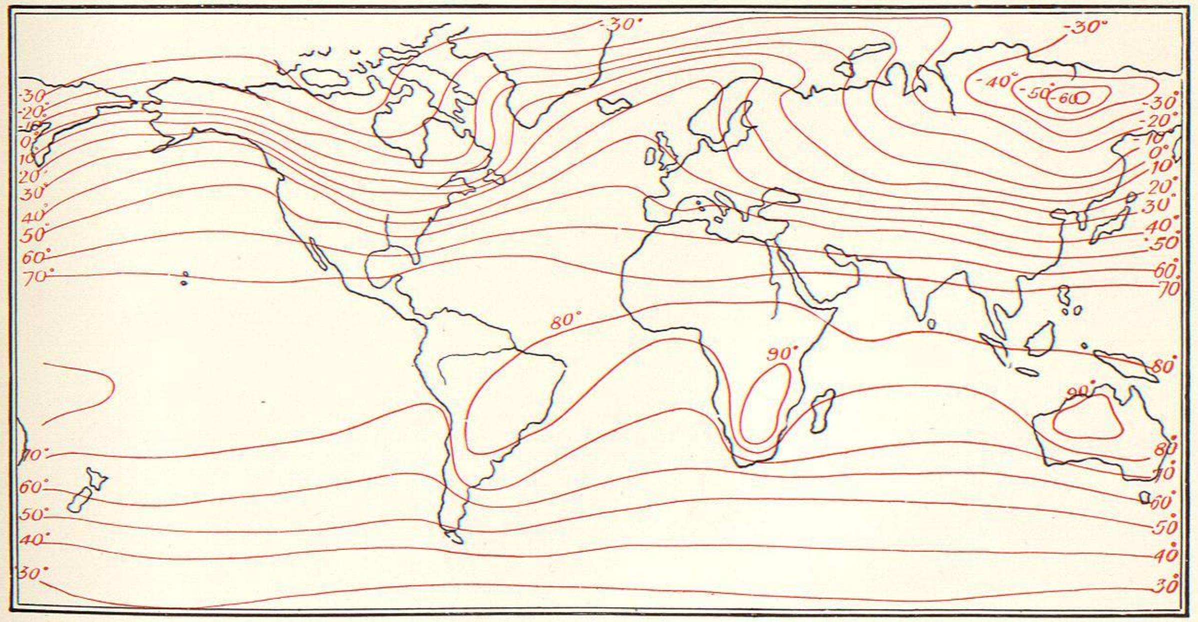

FIG. 2.

CHART OF ISOTHERMS OF THE WORLD

(Degrees Fahrenheit)

Fig. 1, for July; Fig. 2, for January.

Climate.

does not form readily on marshy lands, while on well-drained lands it may occur on any night when the atmospheric temperature falls to 40° F. The damper the soil, the damper will be the atmosphere over it; the drier the soil, the drier the atmosphere—that is, so far as the moisture content of the air is dependent on the evaporation from the soil. Drainage of the soil will raise the temperature in the day and lower it at night. Water-logging will restrict both the day and the night ranges. Vegetation, though not strictly a part of the soil, is intimately associated with the latter and may be considered in connection with it. The effect of vegetation will depend upon whether it simply covers the soil as grass, or extends above and shades it as forest. The general effect of vegetation is to cool the soil by affording an increased radiating surface. Only a relatively small part of the foliage surface of plants is exposed to the sun's rays and absorbs heat, while all the foliage surface radiates heat; hence, the lower temperature of vegetation compared with that of the soil. In grass-covered fields the night temperature falls lower than in the forests; this is undoubtedly due to the interference with soil radiation by the elevated foliage. The average temperature, however, of forests is lower than that of woodless plains, but the temperature variations are less. The average humidity of the air of forests is usually about four to five per cent. above that of the open. The effect of forests upon rainfall is a much debated question, but the general consensus appears to be that deforestation decreases the amount, and that where treeless regions have been reforested the amount of precipitation has increased. That reforesting has an appreciable influence upon the surface run off of water, checking the rate, seems undoubted. Forests may serve to a certain extent as wind breaks. These influences are obviously local in operation. The effect of forests on the climate of a region in general is a matter awaiting further inquiry. The local slope of the ground has a considerable influence on the local climates of a region. A hillside sloping toward the sun receives the solar rays more nearly vertically than one sloping away from the sun. As a consequence the surface temperature of a sunward incline will be higher than that of an antisolar incline. The effect of inclination upon soil drainage is obvious and needs no comment.

Climatic Elements.—The items, or elements, of climate will now be considered briefly in detail.

Pressure.—Atmospheric pressure, though of the utmost importance in the causation and the explanation of the general and the local circulation of the air, is not usually classed among either the climatic factors or the climatic elements. It is not a climatic factor in the sense that latitude, or altitude, land, and water are, because it has nothing of their fixity. As an element of climate it is not perceptible to the senses like temperature, moisture, and the other climatic elements, hence it is generally left out of this category. Whether factor or element or neither, it is, however, a matter of importance to the student of climatology to know something of the general distribution and effects of atmospheric pressure. In the introduction to the general atmospheric circulation, the statement was made that in the region of latitude 30°, both north and south, there resulted from the banking up of the poleward moving currents a belt of high pressure that was sufficiently great to cause a poleward outmoving current at the surface strong enough to overcome the equator-seeking surface current from the poles. The pressure in this belt (speaking now of the one in north latitude) is not uniformly distributed around the earth. In winter, the pressure is greatest in those portions of the belt that cross the great continental areas of America, Europe, and Asia, and lowest in those over the Atlantic and Pacific Oceans. In summer, the pressure is greatest in those portions of the belt over the Atlantic and Pacific Oceans and lowest in those over the continents. This shifting of pressure gives rise to the monsoon winds; it is itself due to the unequal effects of insolation on land and water. In the southern hemisphere these changes are less striking, because of the relative preponderance in area of the water over the land, but they are still in evidence. As a climatic element the pressure changes from day to day are usually so slight that their effects escape detection except by closest observation. To a certain extent the effects usually attributed to altitude are those that belong properly to diminished atmospheric pressure.

Temperature.—If other influences be ignored, it may be stated that the temperature is highest under the vertical sun and decreases as the sun declines from the vertical. The rate of this decrease with regard to latitude has been explained and is, as previously stated, approximately as the cosine of the latitude. If we read altitude for latitude, the same ratio will hold good for the intensity of the insolation with a clear sky at any hour of the day. When the sun is just on the horizon its rays are tangent to the surface, and practically all its caloric radiant energy is absorbed by the great depth of the atmosphere through which the rays have to pass. As the sun rises above the horizon this depth of atmosphere becomes less and less, in the ratio stated, and less and less heat is absorbed, till under a vertical sun seventy-five per cent. of radiant energy, as heat, reaches the earth's surface. As the sun declines from the vertical the reverse operation takes place. Under the equator, or within the tropics generally, it is estimated that on a clear day sixty-five per cent. of the total radiant solar energy incident on the outer limits of the atmosphere reaches the earth's surface. From the different effects produced by the solar rays on land and water, taken in connection with the great increase in the length of the summer day (that is, of the time the sun is above the horizon) in the higher latitudes, one is prepared to understand that the highest temperatures are not necessarily confined to the tropics. The lengthened sunlighted day of the summer in extra-tropical regions, and the relatively great absorption of heat by the land, cause the temperature of the continents in these regions to be from 10° to 20° F. higher than the theoretical normal for their latitudes. On the contrary, the long nights of these regions in winter and the enfeebled insolation due to the low meridian altitude of the sun, and also to the great radiating powers of the land, bring the temperature of these continental areas correspondingly below their theoretical normals. The following table, calculated by the late Prof. William Ferrel, shows in F. degrees the average temperature over the combined land and water surface for each tenth parallel as far as 80° north and 60° south latitude, for January, July, and for the year.

Latitude.	Temperature.		
	January.	July.	Mean of Year.
North 80°	−25° F.	34° F.	4° F.
" 70	−16	44	14
" 60	−2	57	29
" 50	21	66	43
" 40	40	73	56
" 30	55	80	68
" 20	71	84	78
" 10	79	83	81
" 0	81	79	80
South 10	82	75	79
" 20	80	69	75
" 30	73	60	67
" 40	64	52	58
" 50	52	44	48
" 60	38	32	35

The approximate actual distribution of temperature around the world for January and July, as deduced from the accumulated meteorological records of the world, is shown in the two accompanying charts (Plate B). A comparison of the deflection of the actual isotherms from the position of the calculated isotherms shows most strikingly the effects of the different climatic factors. The influence of the ocean currents and the general heat-retaining properties of water cause the extra-tropical parts of the great oceans to be from 5° to 10° F. cooler in summer than the calculated normals for the latitudes, and from 10° to even 40° F. warmer in winter, as in the North Atlantic. The interior of continents is subjected to the greatest extremes of heat and cold, while the temperature of their shores may be greatly modified by that of the surrounding oceans. Though many irregularities exist in the falling-off of temperature with increasing latitude, nevertheless the decline is positive. But latitude is not alone necessary for low temperature; even under the equator, if the elevation be sufficient (about fifteen thousand feet), freezing temperatures and snow may be found. Going toward the poles this elevation declines till at the Arctic circles it is at sea level. The line of the altitudes of this freezing temperature in the different latitudes is called the snow line. In the free air, the temperature falls about 1° F. for every three hundred feet ascent. In ascending high mountains, the decline is slightly less. Over elevated plateaux the fall in temperature due to the altitude of the region is very much less, not more than 2° to 3° F. to the thousand feet, and this amount varies with the season, being less in summer and greater in winter. In estimating, therefore, what will be the decrease in temperature due to the altitude of a place, regard must be had to whether it be a rapidly rising mountain or a slowly rising plain.

The temperature of the air is controlled more or less in its degree and in its fluctuations by the state of the atmospheric humidity. Water in the gaseous state is as diathermanous as dry air; but when condensed as cloud, even though the condensation be too slight to be visible, it offers great obstruction to the passage of heat. Hence in cloudy regions, and on cloudy days, the temperature is usually more uniform, that is, it is subject to less pronounced extremes of heat than it is in clearer regions or on cloudless days. Air expands or contracts $\frac{1}{491}$ of its volume for each change of 1° F. Warm air is, therefore, lighter and rises; cold air, heavier and falls. The effect of this is seen in the phenomena of hill and valley winds. In the daytime the warm air flows up the hillside, and at night the cool air flows down the slope into the valley, where it is felt sometimes as an intensely cold wind. These cold night winds are very common in the deep valleys of the Swiss Alps. The average temperature of the air is highest both seasonally and diurnally, not at the time of the greatest solar altitude, but at a period a little subsequent thereto. The warmest part of summer is about a month after the æstival solstice; and the warmest part of the day is about one or two hours after noon. The coldest part of the winter is about a month after the winter solstice, and the coldest part of the day is about an hour before sunrise.

Humidity.—The relation between temperature and humidity is an intimate one. The amount of water that can exist in the gaseous state depends on the temperature. The higher the temperature the greater the possible humidity; the lower the temperature the lower the possible humidity. Water exists in the gaseous state at all observed temperatures. The following table shows the actual weight of water that can exist as a gas at some of the ordinary atmospheric temperatures:

Temperature.	Number of grains of aqueous vapor in a cubic foot.	Temperature.	Number of grains of aqueous vapor in a cubic foot.
100° F	19.8	30° F	1.9
90	14.8	20	1.2
80	10.9	10	.8
70	8.0	0	.5
60	5.7	−10	.3
50	4.1	−20	.2
40	2.8		

The amount of moisture in the atmosphere in any given locality will be governed, first, by the temperature of the region; secondly, by the nature of the evaporating surface of the place, whether land or water; thirdly, by the rate at which the humidity is carried away; and finally, by the rate at which humidity is brought to the region by the prevailing winds. As the temperature declines with altitude, it is evident that the humidity possibilities of elevation must likewise decline. The humidity of the atmosphere is referred to under two captions, absolute and relative humidity. By absolute humidity is meant the real amount of water existing as vapor in a unit of space. In English measures this amount is stated usually as grains of water per cubic foot. The table just given shows the absolute humidity in a saturated cubic foot at the temperatures indicated. By relative humidity is meant the ratio that the amount of vapor actually present bears to the amount required to saturate the space at the given temperature. Relative humidity is usually stated as a percentage, saturation being taken as 100. Absolute humidity is a physical entity. Relative humidity is simply a relation between the temperature and the absolute humidity. The statement of the relative humidity conveys no practical information unless the temperature or the absolute humidity be given also. The absolute humidity of the air, though limited in its quantity by the temperature, varies but slowly from day to day and from season to season. The variation is less with a rising temperature, because the increase of temperature does not affect in any way the form of the humidity. But as the temperature falls a point is reached when the space will be saturated, and then a change of form of the moisture takes place, condensation occurring, and heat, the so-called latent heat of evaporation, is set free, which raises the temperature somewhat and checks its fall for a while. This process may go on indefinitely till either the moisture be all precipitated or some accidental cause comes in to raise the temperature. This fact of moisture liberating heat during condensation is an important factor in the retardation of cooling. In passing from the liquid to the vapor state, water takes heat from the surroundings; that is, evaporation lowers temperature.

The amount of evaporation depends on the temperature of the space into which the vapor escapes. The higher the temperature of the space the more vapor it can contain. The rate of evaporation depends on the temperature of the evaporating surface, the humidity, and the velocity of the wind. The temperature of the evaporating surface determines the velocity with which the vapor molecules escape from the surface; the higher the temperature the greater the velocity. The lower the atmospheric humidity the more rapidly will the molecules escape into the space, and the higher the velocity of the wind up to a certain limit the more rapidly will the escaped molecules be removed out of the way of others.

It is customary to say that the atmospheric pressure influences the rate of evaporation; this is only true if by it we mean the partial pressure of the aqueous vapor in the atmosphere. Water evaporates in a dry atmosphere of oxygen or any other dry gas under twice the ordinary barometric pressure as rapidly as it does in one of like kind under but one-fourth the same pressure. It is the pressure of the water vapor that controls the rate of evaporation, for the well-known physical fact that all gases are to each other as vacuums holds good with regard to the gases of the atmosphere. The fact that evaporation is usually more rapid in elevated regions is simply due to the lesser atmospheric moisture of these regions. The wind facilitates evaporation by removing the layer of vapor formed over the evaporating surface, thereby lessening the vapor pressure on the surface. Under the most favorable conditions, a certain definite time is required to convert water into vapor. When the velocity of the wind reaches a rate of movement equal to the rate of vapor formation, no further increase in the movement of the wind affects the rate of evaporation. This velocity is about thirty miles per hour; that is to say, that wind velocities of more than thirty miles per hour have no more effect on the rate of evaporation than a thirty-mile wind has.

The following table shows in inches the average depth of water evaporated annually from a free water surface at several places where such records have been kept:

Place.	Latitude.	Evaporation.
Madras	13 N.	91
St. Helena........................	17 S.	84
Dijon........................	47 N.	26
London........................	51 N.	21
Boston........................	42 N.	39
Lake Michigan	44 N.	22
Great Salt Lake........................	41 N.	80
Fort Conger	82 N.	9

The atmosphere contains always more or less foreign solid particles, or dust, which radiate their heat during the night more rapidly than the air. The temperature of many of these particles will generally fall below that of the atmospheric dew-point at the time—that is, the temperature at which the air would be saturated with moisture. As a result vapor will condense upon them, they will become heavier and heavier, and many of them will fall to the ground. The occurrence of this phenomenon explains why the air is, as a rule, so much clearer in the mornings than at other parts of the day.

Wind.—The movement of the atmosphere, or simply the wind, results from a difference in the density of the atmosphere. The wind is merely the effort to restore or maintain an equilibrium. The atmospheric density is disturbed in two ways: by difference in temperature and by difference in humidity. The effect of temperature on the density of the air has been mentioned. Aqueous vapor is specifically lighter than either oxygen or nitrogen, the two chief constituents of dry air; hence an equal volume of moist air is lighter than a like volume of dry air, temperature and pressure being equal. The movement of the air is impeded by friction at the surface of the earth; and it increases with elevation up to a certain height.

Atmospheric movement is of two kinds, vertical and horizontal; the latter are those familiar to us as winds. The vertical circulation is, however, an important element. It is by the vertical movement of the air that the uniform ratio of mixture of the different permanent gases of the atmosphere at all observed elevations is maintained. The upward vertical movement is greatest in the region of the equatorial calms. A downward vertical movement takes place in the region of variable winds about latitudes 30°, also in the regions of the poles. The winds are generally stronger during the day and increase in velocity up to noon or a little after, and then decrease gradually to a minimum during the night. This does not apply, of course, to the wind velocities of accidental storms.

Electrification.—As an element of climate the electrical state of the atmosphere deserves mention; but as to its effects little can be said. The atmospheric electrification is, as a general rule, positive with respect to that of the earth, but it is subject to great and sudden variations. During rain storms the atmosphere is often if not generally negatively electrified. There appears reason to think that the atmospheric potential of elevated regions is greater than that of sea-level regions.

Sunshine or Sunlight.—The effect of the sun cognizable as light undoubtedly is a most important consideration in climate in relation to the organic world, but as an item of the state of the atmosphere sunlight is not appreciable. What impress it may make or leave upon the air is yet to be ascertained. As a climatic element, it is measured by its photographic effects. Observation has shown that the photographic effects are stronger in summer than in winter, and in the forenoon than in the afternoon. This is probably the result of the greater freedom of the air from clouds and dust in the morning hours, and to the lessened atmospheric depth traversed by the light rays in the summer.

Rain.—Like sunlight, rain makes no continuous impress on the atmosphere. It cannot be regarded strictly as an element, yet it performs an important function in the purification of the air. According to the researches of Aitkin and others, the formation of rain begins by condensation on the dust particles of the atmosphere; in falling to the earth, rain washes down many more; this is why the air is always clearer after precipitation. Rain also brings in solution some of the constituent gases of the air. An important one, and one that exists in such small quantities as to be characterized in amount by the chemist's "trace," is ammonia. But small as is the ammonia content of the air, it is indispensable in the vegetable economy. The relation of rainfall to the humidity of the air is almost that of effect and cause; without sufficient humidity, rain cannot occur. The time of rainfall varies with the cause of its precipitation. Within the tropics, rain falls most often in the afternoons and in the form of heavy downpours. Shortly after the precipitation ends the clouds break up and disappear, leaving the nights cloudless. In the extra-tropical regions, when the rain comes as one of the consequences of a thunder storm, it is most frequent in the afternoons. In the rains of cyclonic storms, the precipitation may, and does, occur at all hours of the day. The clouds do not break up, as a rule, till some time after the rain has ended, except in the case of thunder storms, after which the clearing is generally more rapid.

The seasonal distribution of rainfall is a most important climatic consideration in connection with vegetation and habitability. Many regions having comparatively large amounts of rainfall in the year are yet unsuitable for vegetation, because the precipitation either does not fall during the spring or summer seasons, or falls all in one or two torrential downpours, instead of being distributed in smaller quantities over the growing season. On the other hand, regions that have but a comparatively small yearly rainfall are yet fertile because the precipitation occurs during and throughout the growing seasons.

The present knowledge of the causation of rain may be summarized as follows: To produce abundant rain the temperature of the air must be suddenly brought below that of the dew-point. Air cooled below its dew-point condenses its moisture into minute cloud or fog particles. These particles may float away or be re-evaporated should some cause raise their temperature; or, if in sufficient number and in such motion as to bring them into collison, they may coalesce and form larger and larger drops till they attain sufficient weight to overcome the atmospheric resistance and fall to the ground as rain, snow, or hail, according to the temperature and conditions of condensation. This cooling of the air may be effected, so far as present knowledge goes, by the air being forced up the side of a mountain, as happens when a mountain runs transversely to the direction of the wind: the surface air may become, under the effects of intense insolation of a region, warmed to a degree that will cause it to expand rapidly and thus give rise to ascensional currents, which carry the moisture upward till its dew-point is reached, with resulting condensation and precipitation; and lastly, but most important, at least outside the tropics, by the circulation of the air in cyclonic storms in which there is a surface inflow radially from all sides and a central ascensional movement.

The following broad rules are convenient as indicating the general distribution of rain: Rain is more abundant in warm than in cold countries, that is, its quantity decreases from the equator toward the poles. Rain is more abundant in coast regions than in the inland countries; provided that there be no mountains, or the mountains be far in the interior. Rain is more abundant in hilly and mountainous districts than in lowland regions. Rain is more abundant on windward shores and exposures than on leeward shores and exposures. Rain is more abundant in summer than in winter. It increases in amount up to 5,000 feet above sea level; above this altitude it begins to decrease. Rain in falling washes down many of the impurities, especially dust particles, floating in the air. Regions that have frequent rains have clear and clean atmospheres. The humidity of the