THE CLIMATOLOGY OF THE UNITED STATES.

With especial reference to the difference existing between the climate of the Pacific slope and that of the country lying between the Rocky mountains and the Atlantic coast.[1]

[From a lecture delivered by FRANK R. KIMBALL in the rooms of the Essex Institute, January 18, 1886.]

THIS subject, owing to its comprehensiveness, can be treated only in a superficial way. The details and the differences existing between minor districts must be omitted. These of necessity would be included in a discourse devoted to the consideration of climate in regard to health, but in the present case we shall merely examine the chief characteristics from a meteorological point of view. The climate of a country has a greater influence upon the health and prosperity of the people than is generally realized. Man needs sunlight to maintain life, and air to breathe, food to eat and material for clothing. Next in importance to these fundamental necessities comes climate and this is an important element in the progress of mankind. None of the leading nations are situated in the torrid or frigid zones and no nation has advanced to high civilization without the concomitant advantages of a good climate and the foremost nations of to-day are those pos-

[1] In regard to the technical character of the following it should be stated that, in previous lectures on this subject, the speaker has omitted the elements of meteorology, considering at greater length kindred topics including a more detailed description of the Pacific coast climate; but, as questions which followed have shown a misunderstanding of important facts, it was thought best to devote a portion to these matters even though this should be done at the expense of a more popular treatment of the subject.

sessing the most favorable climatic conditions within the temperate zone. The greatest inventors, generals, statesmen and authors and the leaders of civilization are the product of the temperate zone.

The heat and the cold of the torrid and frigid zones enervate and stupefy men and retard development, so likewise, to a less extent, extreme variations of temperature in the temperate zone have an unfavorable influence. We appreciate the fact that the degrees of heat or cold and the dryness or dampness of the air affect invalids who are frequently sent to other localities, according to the nature of their trouble where these conditions are different; but it is also true that healthy persons are affected more or less by all weather changes. Many are affected by changes in temperature and others feel depressed during the passage of an area of low barometer though they may not be able to account for their feelings, therefore it becomes a matter of more or less interest and importance to know somewhat of other climates; and we find a great variety in different parts of the world. Some regions are very hot and others very cold; some have rain a large part of the year, in others it seldom rains; some are subject to great extremes of temperature while others have very little change throughout the year. In order to form an idea of the climate of any given place we must know a few of the laws governing weather changes, and then with the addition of whatever statistics we may have, a tolerably accurate knowledge of the climate can be obtained; but if we seek that knowledge blindly, by a few general reports, we are likely to be misled. It is frequently noticed that, in geographies, works of science and books of travel, the mean annual temperatures of places are given; such are worthless for our purpose. As an example we might take the mean annual temperatures of the two cities San Francisco and

Boston, these are very nearly alike and yet the climates of the two places are very dissimilar. In Boston, the thermometer in the heated spells of summer often marks one hundred degrees in the shade, while in the coldest winter weather the mercury often falls to zero and sometimes below, showing a variation during the year of over one hundred degrees; while in San Francisco, the variation from winter to summer is not much over forty degrees and the changes are much less abrupt. The same liability to error exists in judging of the rainfall, so we must know what figures we need and how to judge by the various statistics at our command. In order to explain the character of and the laws governing the various phases of the weather, I shall first describe our own climate and the operation of the United States Signal Service, and then the climate of the Pacific slope, supplementing the whole with a short consideration of the climatic changes which have been taking place throughout the world during the last few years.

Within the limits of the United States there exist three distinct meteorological regions. The first including that part of the country lying east of the Rocky mountains. This region has a precipitation of rain or snow at frequent intervals throughout the year; the greater part of the region has cold winters and hot summers; it is subject to variable winds at all seasons. The second region embraces the country lying between the Rocky mountains and the Pacific coast and north of New Mexico and Arizona. It has a wet and a dry season, the former occurring in the winter months; the precipitation is almost entirely in the form of rain, except in the mountains and is about one-half of that in the above-named region. The winters are mild and the summers cool on the coast and hot in the interior. The winds are variable in winter and westerly

in summer, appearing then like trade winds and are so called. These characteristics are more marked between the Sierra Nevada range and the Pacific coast. The elevated plateau between the Rocky mountains and the Sierra Nevadas, partakes somewhat of the character of the regions on either side; its rainfall is however less than either of these. The third region consists of New Mexico and Arizona; this like the last has a semi-tropical climate with a wet and a dry season, but these are reversed; the wet season occurring chiefly in July and August, the total rainfall, however, being very small. The winters are warm and dry and the summers hot except in the mountains.

Before proceeding to consider the Pacific climate we will note some of the chief features of our own variable climate. In the first place we shall notice that throughout the year, at intervals of every two or three days, especially in winter, we are visited by storms of large area occupying from twelve hours to two days in passing; these storms travel in about the same direction and act in about the same manner. A person who is an observer of nature and interested in the phenomena occurring about us from day to day, would naturally put the following questions? What causes these storms? Where are they developed? Where do they go? and what becomes of them? A few words and a few simple illustrations may make the subject plain in a general way.

It is often noticed on a summer day at the seashore, that the air will be quiet and warm, and in the afternoon the wind will start up from the eastward and refresh us with cool ocean breezes; this is owing to the air over the land becoming heated and rising, causing a current of cool air to flow in from the ocean to take its place; in this case we may have merely an afternoon breeze created which will go down with the sun. Again, we may take the case

of a great level plain heated by a summer sun till the air at some point commences to rise; as it rises air will flow in from all sides and will follow the upward current already created; in ascending, it will assume a spiral motion. This may be illustrated by taking a basin of water and allowing the water to run out through a hole in the bottom; the water will not flow in radial lines towards the hole, but in a curved line. And, again, if a column of smoke above a hot bonfire is noticed, it will be observed generally to rise in a spiral form; thus in the above case in the open plain, the air will rise in the same manner and currents will flow in from all sides, causing slight breezes along the surface of the ground. It is often noticed, on windy days, when the streets or roads are dusty, that little whirls of dust arise and travel for some distance; the action here is similar, but these, instead of being caused in a calm by the sun's action, are caused by conflicting currents of air; these of course being originally caused by the heat of the sun.

Atmospheric disturbances, similar to the above cases, occurring when the air is dry, will continue only so long as the sun remains above the horizon to heat the surface of the earth and the air. After sunset these will cool and the air will have no tendency to rise, hence such disturbances cannot develop into storms; but where there is moisture in the air the case is different.

It is a well-known fact that when water evaporates, heat is absorbed; hence we say evaporation causes cold. When the molecules of water separate and assume the vaporous condition, they need energy and so absorb all the heat they can. When condensation takes place, the molecules come together again and assume the cold, sluggish condition of a liquid, hence they do not need the energy to keep them in activity and the heat is given off again.

This latent heat plays a most important part in the production of storms.

In the above cases we have assumed that the air was dry. We will now suppose it to contain moisture to a considerable amount. Where the layers of air next to the surface of the earth become heated, the air rises and in so doing it expands and cools. The moisture condenses and we have clouds formed; but in condensing heat is given out which prevents the air from cooling as much as it would otherwise, therefore it continues to rise till it reaches a high altitude and overflows, passing off from the central spiral of ascending air; greater quantities follow and an activity is started by the new supply of heat which maintains the action after the sun has ceased to exert a direct influence; thus we have the development of a typical storm which continues day and night. Now, if we cut through this storm and take a horizontal section or ground plan, we shall see that in the centre is a calm of ascending air; about this a rain area and beyond this an area of clouds and we shall see that the winds rush in towards this centre. Therefore, on the north side of the storm we shall notice northerly winds, on the east side, easterly winds and so on, the storm appearing like a great wheel, with the exception that the winds, instead of following radial lines to the centre, as the spokes of a wheel do, tend to reach that centre by a more or less curved line, this curve changing according to the distance of the centre. At great distances from the centre the winds are drawn towards it in nearly radial lines, while of course at the centre the motion is nearly circular. This motion of the winds towards the centre is always in the opposite direction from the hands of a watch (that is, from right to left) in the northern hemisphere and from left to right in the southern hemisphere. Such are ordinary storms in all parts of the

world; they are called cyclones on account of their form, though many people improperly restrict the term cyclone to a tornado or a very severe cyclonic storm, whereas a cyclone may be of very slight energy and may only manifest itself to ordinary observers as a slight shower.

Having now noticed the formation of storms the next question would be, Where do they come from? In answering this question we may suppose two lines to be drawn, one just north of the United States running east and west, and another running south from the eastern point of the United States. From some point within these lines all our storms come; that is, all the storms in the north temperate regions travel in an easterly or northeasterly direction, therefore every storm which passes over New England comes from a westerly or southwesterly point. No storm ever comes from the northeast or east; the majority come from the region extending from the Gulf States to the northwest states. A few come from west of the Rocky mountains, but whether they come up the great Mississippi valley or across the centre of the country, or from the northwest, they almost always pass to the lake region and thence down the St. Lawrence valley. Besides these, there are what are known as the West India cyclones which come from a southwestern or sometimes nearly a southern point, following the coast to Cape Hatteras or Cape Cod and then passing off to the eastward over the gulf stream. These occur most frequently from August to December and are very apt to be severe. By bringing to mind the horizontal section of a cyclonic storm before described, it will be readily seen that as these storms approach New England and pass off to sea that the northern side is usually the only one felt, therefore as it passes away and the weather clears, the winds will back from northeast to north and northwest

instead of passing around to the south, southwest and west, as in the case of a storm passing down the St. Lawrence valley to the north of us. The majority of storms after leaving our coast travel to the northeastward, across the Atlantic and pass north of England. When a storm first develops it is of small area; but as it progresses from day to day its diameter increases and in high latitudes it disappears from this very fact; for when the diameter of the centre becomes so great that the ascending air does not overflow, but cools and sinks back into the centre again, the storm dies out.

Tornadoes are very destructive storms of small area and tremendous energy which frequent the centre of the country, being most destructive in Kansas, Illinois, Missouri and neighboring states. The South Atlantic states have also been visited by very disastrous ones, especially in February, 1884, when a great many people were killed and wounded and thousands of dollars' worth of property destroyed within a few hours. Until within the last few years very little has been known about the nature of these storms or the laws governing them; and it is only within the last two years that the Signal Service has attempted to give any daily indications of their probable occurrence for different localities. Their sudden development, narrow paths and short courses, together with their destructive force, have prevented very accurate observations until lately. What appears to be a thunder storm rises in the west and in the midst a funnel-shaped cloud appears suspended above the earth, moving up and down and swaying from side to side. The clouds above appear in greatest commotion, while an indescribable roaring is heard in the air. The storm travels like others, generally in a northeasterly direction, sometimes veering toward the north at the rate of about thirty miles an hour. They are liable to occur

at any time of the year, but are mostly confined to the summer months and are most frequent in June in the latter part of the afternoon.

The path of great destruction varies from 300 or 400 feet to a quarter of a mile in width, and the course of the tornado ranges from a few miles to 100 or 200 miles. When one occurs in the daytime it can be seen on the western plains a long distance away and its roar can be heard in time for the inhabitants in its path to escape. When it is seen approaching from the southwest a flight to the southeast will soon take one beyond the limits of its devastating path; but when one occurs at night the inhabitants either awake to find it already upon them or are often so terrified as to lose their self-possession and judgment, and thus lose the opportunity for escape to a place of comparative safety. For this reason, it is common to have "dug-outs" in the ground connecting with the cellar or close at hand, to which a family may quickly resort in case of danger. The Signal Service has enlisted the coöperation of town officers, postmasters and others in the regions liable to these visitations, and these parties act practically as voluntary assistants to the regular signal office observers in different parts of the country in collecting information and statistics in regard to every tornado visiting their locality.

After a tornado has occurred, the United States' observer at the nearest station will often make a series of personal observations, going over the course of the storm and taking the observations and accounts of eye-witnesses, and combining them with his own observations make out a report which is forwarded to Washington. In this way much valuable information is obtained and the Signal Service has been enabled to give within the last year or so indications of the probable occurrence of tornadoes in

which the percentage of verification has been very large considering the great difficulty of the subject, and very likely in this short period many lives have been saved. Many people in the east consider that the large destruction of property in the west by tornadoes is partly due to the light construction of the wooden houses there; but it should be borne in mind that brick and stone buildings succumb to these blasts almost as quickly as those of wood.

When a tornado strikes a building it generally tears it in pieces, carrying the débris aloft within the funnel-shaped cloud and throwing it out from the top to either side as it advances, leaving the wreckage of a homestead scattered along in a northeasterly line for distances, varying from a few yards to one or two miles.

It sometimes, however, happens that a house will explode by the expansion of the air within, as the rarefied air of the funnel passes over it, and the four walls will be thrown out in as many directions. This may occur frequently without being observed, as the parts may be carried away by the in-blowing currents and thus all trace of this action may be obliterated. Tornadoes have been found to travel in connection with some cyclonic disturbance to the north and their courses are generally parallel with the course of the main storm, though generally from 200 to 500 or 600 miles away. The theory which is now generally accepted is, that when a body of cool air flows southward and meets a mass of warmer air, it sometimes flows over instead of under the warmer air and in seeking a condition of stable equilibrium the warm air forces an opening through the stratum of cool air above, an interchange of positions thus taking place. Taking account of the temperatures, amount of moisture in the air and barometric pressures at the time, the Signal Service has

succeeded in sending out very correct indications in regard to the results likely to follow such given conditions; and during the last summer western farmers were enabled to go about their work without being needlessly alarmed at the sight of every ordinary thunder shower.

These storms within the past five or six years have been spreading over a greater area and becoming more severe. This is in part merely apparent from the spreading of the population over hitherto unpopulated districts and the greater number of reports received of these storms; but aside from this there seems to have been a greater display of this form of atmospheric disturbance than formerly. Besides cyclones and tornadoes, we have thunder showers and local showers which need no special explanation after what has already been said.

Having now noticed the principles of weather changes in our climate, we will devote a few moments to the consideration of the United States Signal Service and its work in collecting reports of the weather and deducing therefrom the bulletins and indications which are daily sent out to the principal cities of the country. When meteorologists and scientific men found that storms moved and acted in a somewhat orderly way and travelled in about the same direction, it became apparent to them that some plan might be adopted whereby vessels about to leave port might be appraised of the approach of severe storms, especially those from the West Indies, and, accordingly, a movement was set on foot with this object in view. On February 9, 1870, Congress passed a joint resolution authorizing the Secretary of War to put this scheme into operation and a weather bureau was established in the Signal Service to collect weather reports and issue warnings and probabilities of weather changes for the benefit of commerce and agriculture.

On November 4, 1870, the first weather bulletin was issued. On that day twenty-four stations sent simultaneous reports to the office in Washington and the bulletins were prepared and sent to more than twenty cities. There are now nearly five hundred stations scattered over the country from the Atlantic to the Pacific, and from the Great Lakes to the Gulf of Mexico. These are classed as those of the first order, second order, cotton region, mountain, river and seacoast stations. The main office at Washington keeps a continuous record by means of self-registering instruments. Stations of the second order like Boston and other principal points take six observations and send three telegraphic reports to Washington daily and one monthly by mail. Other stations take five observations and send three reports daily; still others take only one observation daily. The river stations report the height of the water at various points on the great rivers as indicated on a gauge which is placed on the bank and extends from the extreme low water line to the danger line; thus, the central office is kept informed of the condition of the great rivers and their tributaries, and is able to give notice of any probable rise or of any approaching flood in the river valleys, and river commerce is quite dependent on these reports. The cotton region stations, numbering between 100 and 200, take one observation, daily at five P. M. The seacoast stations take various observations, including the character of the waves, or the approach of swells which indicate the presence of a storm at sea and are often forerunners of cyclones coming up the coast. These stations also work in connection with the life-saving stations and are connected by a coast telegraph line and with the central office.

Storm signals were first displayed on October 24, 1871, a red flag with a square black centre by day, and a red

lantern by night is called the cautionary signal and denotes that a storm of considerable energy is approaching and that the wind will probably blow at the rate of twenty-five miles or more per hour. In this connection it should be noted that when the wind blows twenty-five miles per hour in Boston it may blow forty miles per hour off Cape Cod; therefore when a person in the city considers the warning not justified he should remember that it is displayed for the benefit of mariners, owing to the large number of vessels trading between ports scattered over an immense coast line extending from the provinces to the Gulf of Mexico. The display of signals at various points on that line is a matter of interest to a great many people having the care of a large amount of property, and when a very severe cyclone is coming up the coast the signal officer in a port like Boston, for example, not only displays the signal when he receives orders to that effect from Washington, but sends the police boat about the harbor to notify officers of vessels about to leave port of the character of the approaching storm. When the wind is expected to blow very strongly from the west or northwest the cautionary off-shore signal is displayed. This consists of a white flag with a black centre above the red flag already mentioned by day and a white light above the red light by night. The white flag alone indicates a cold wave. Of the display of these signals it may be said that about ninety per cent have been justified. When the wind does not attain a velocity of twenty-five miles per hour within the district the display of the signal is considered unjustified, yet the wind may attain nearly that velocity and so we may consider a larger proportion correct in a general way. The inland weather signals consist of three white flags, one with a red ball, one with a red crescent, and one with a red star denoting respectively higher temperature, lower temperature, and

stationary temperature, and three white flags, one with a blue ball, one with a blue crescent, and one with a blue star denoting general rain or snow, clear or fair weather, and local rain or snow. These are not displayed by the government but are recommended for use, and responsible parties willing to display them regularly will be furnished with daily telegraphic reports from the signal office for that purpose.

In the preparation of the daily weather bulletins a number of charts must first be made out and when it is considered that several hundred stations send in their reports it is not surprising that a large force is necessarily employed at the main office. Seven graphic charts in all are prepared showing the barometric pressures, the temperature, direction and velocity of the wind, moisture in the air, etc., at the various stations throughout the country. These charts then pass into other hands and the bulletin giving a synopsis of the weather throughout the country is prepared and the indications are made out and telegraphed to all the principal cities in the United States. The per cent of verifications of these indications has averaged a little higher than that of the storm signals. In addition to these telegrams there are the Farmer's Bulletins which are printed and sent to the smaller places by rail. In this work some forty railroad companies assist in distributing two-thousand or more bulletins daily; these are posted in conspicuous places by station agents, postmasters, etc.

In 1873 General Myers, chief signal officer, attended the Meteorological Congress at Vienna, a gathering composed of the officers of the various national weather bureaus of Europe, and representatives of scientific organizations. On this occasion he submitted a plan for united work, whereby a simultaneous record of meteorological conditions in differ-

ent parts of the world might be obtained from time to time or at regular intervals. The idea was favorably received and at the present time meteorologists are gaining considerable knowledge on the subject from the bulletins of the International Weather Bureau.

Before leaving the subject of forecasting weather changes, I will say a few words in regard to those who are known as weather prophets, men like Mr. Vennor and Mr. Wiggin who have enjoyed quite a notoriety at times. These men were not in the habit, as some have intimated, of sending out predictions, based upon nothing but the caprice of their own imaginations simply to attract public attention. On the contrary, they each had systems more or less worthy of scientific investigation and they themselves believed in their systems and at the same time endeavored to gain a reputation for accuracy in foretelling meteorological events. The late Mr. Henry G. Vennor, of Montreal, was a gentleman of learning, a Fellow of the Geographical Society, a naturalist and an author, having completed a record of meteorological observations extending over a period of many years. He found what appeared to be a series of recurring weather changes; that is, a period in which the weather would repeat itself, or go through the same changes as occurred in a former period: cold winters, hot summers, wet and dry seasons, etc., occurring in a certain order, through a certain number of years; these changes then being repeated throughout the next period of years, and so on. Mr. Vennor, however, did not disdain to seek aid for his predictions from other sources; and his knowledge in the field of natural history was of great advantage in enabling him to judge of the character of coming seasons from the migrations and appearance of birds, and the actions of animals and insects. He published a monthly bulletin and an almanac; these

contained a great deal of matter more or less interesting and instructive in regard to the weather, agriculture, etc.

Mr. Wiggin, who has been connected with the finance department of the Canadian Government at Ottawa, is an astronomer, and though not devoting so much time to meteorological work as did Mr. Vennor; yet he has made a number of predictions, some of his earlier ones proving correct and creating for him quite a notoriety. His predictions, however, are based not on the recurrence of weather changes, but upon the influence exerted upon the earth with its elastic envelope of atmosphere by the superior planets and other heavenly bodies. Without doubt there is much in such a system and although we might not be able to rely upon it entirely, yet not only the sun and moon, but the other heavenly bodies, exert an influence to a greater or less extent upon us, or the earth and air. The chief difficulty with which we should meet would be the reduction of these general facts to any practical system. In order to use them, we should know how much influence is exerted under certain conditions, and how that influence would manifest itself. In making predictions, weather prophets, on whatever system they work, refer to conditions which have not at the time begun to manifest themselves; whereas the Signal Service, as a general rule, draws indications of the increase and progress of conditions already developed.

Having now considered the principal features of our eastern climate, and the operation of the Signal Service, we will cross to the Pacific and note some of the peculiarities of that climate. After crossing the Rocky Mountains we find ourselves in what is called the great enclosed American basin, a plateau of 4000 to 5000 feet elevation, extending westward to the Sierra Nevada range. This region is mountainous, dry and barren in general, with a

few productive spots like the great Salt Lake Valley, which lies in the eastern part at an elevation of about 4000 feet above sea level. This valley is about the only locality here, capable of supporting at present any large population. Passing on to the west, we cross the great Alkali Desert; a region producing very little in the way of vegetation but sage brush. The rainfall in this section of the country is very light, ranging from eighteen inches at Ogden to four inches at Humboldt per annum, as compared with an annual precipitation in Boston of forty-eight inches; and as more water is lost here by evaporation than is furnished by the rainfall, the lakes, including Great Salt Lake, are gradually diminishing in size. The winters here are cool and the summers quite warm, but the extremes are not so great as in much of the country east of the Rocky Mountains, nor are the changes in temperature as great or as sudden. This condition appears to be the result of the relative position of the plateau with regard to the Rocky Mountains and the Pacific Ocean. We should expect to find it somewhat cooler than the lowlands of the great Mississippi Valley, but we also find that it is less subject to the violent fluctuations of temperature which we experience when warm areas of barometric depression are rapidly followed by cold waves from the west or northwest. The majority of these cold waves sweep down into the United States in a southeasterly and easterly direction from the northwest states and the region to the north, along the eastern slopes of the Rocky Mountains which here trend in a southeasterly direction. The region to the west of these mountains is subject to more or less change, but in a less degree; and again, the character of atmospheric changes, advancing from the west, would be influenced by the proximity of the Pacific Ocean which is milder than the Atlantic in the same latitudes, a matter which will be

considered later. Having reached the Sierra Nevada range, we find the western slopes very much more abrupt than those of the Rocky Mountains, and we descend very rapidly into the valleys of California. We are now in a region which possesses well marked climatic peculiarities.

The state of California is about eight hundred miles long and two hundred miles wide, with a coast line of a little over one thousand miles. Its surface is cut up by mountain ranges running parallel with the coast, and dividing the state into numerous long narrow valleys.

The prominent features of the climate are, first, a wet and a dry season; the former occurring in the winter months, while from May to October rainfalls are rare, and a shower in June, July or August, is of very unusual occurrence. Secondly, a small rainfall, the amount of precipitation in the rainy season being no greater than that of the corresponding period in New England. Thirdly, mild winters, snow being a rarity except in the mountains, and the climate in the southern part of the state being of a semi-tropical character.

The first question which would naturally arise would be in regard to the cause of the dry season. A person in the east is very apt to consider that the same causes tend to produce precipitation either in the form of rain or snow in all seasons, and when one finds a region where the rain ceases in the spring and does not begin again until fall, curiosity is aroused as to the peculiar conditions which cause a cessation of rainfall during a part of the year. In considering this question, several important facts must be borne in mind. In the first place, there is a tendency for weather changes to move in an easterly direction; and, secondly, the western sides of the continents are milder than are the eastern sides in the same latitudes. This may be partly due to the influence of warm oceanic cur-

rents coming from southern latitudes, flowing in a northeasterly and easterly course and striking the western coasts with a temperature above that of the surrounding water.

The mild climate of the British Isles is attributed to the influence of the gulf stream. There may be other causes, but these currents certainly have a considerable share in producing the effects which we notice. The gulf stream flows northeasterly at some distance from our coast, while a cold current from the Arctic regions passes southward between the coast and the gulf stream, consequently much of the influence of this latter stream is here counteracted. In the Pacific, a great ocean current exists similar to the gulf stream; it is called the Kurosiwo or Japan current, and flows from the coast of Japan in a northeasterly course towards the Aleutian Islands and Alaska, a small part passing into Behrings Sea and the balance sweeping down the Pacific coast of the United States. Owing to its great size, it preserves a very even temperature throughout its long course, both in winter and summer, and consequently has a marked influence upon the climate, not only of Alaska but of British Columbia and the regions to the south, giving these places very mild winters. Sitka, in the southern part of Alaska, corresponds in latitude to the northern part of Labrador, and yet its winter climate is not much colder than that of New York.

The average temperature of this current, as it reaches San Francisco, is about fifty-five degrees, and as it tempers the cold of winter it also mitigates the heat of summer; but here another feature of this climate, the trade wind as it is called, presents itself. This is in reality a continual indraught of air from the ocean during the summer season, caused by the rising of the air in the great

interior valleys to the eastward, which are very dry and hot at this season of the year. We may include in the list of localities contributing to this, the regions even to the east of the Sierra Nevada range, for it seems quite probable that the great enclosed basin before referred to may constitute quite an important factor in the case. It is true that in a large part of it the heat is not excessive, but the aggregate of thermal energy throughout such a large area would amount to considerable, and in the southern part the heat is quite sufficient.

The most favorable conditions, however, for producing this summer wind are to be found in the great valleys of the Sacramento and the San Joaquin; these two in reality forming one continuous valley, running north and south between the Sierra Nevada and the coast ranges. The temperature is very high here in summer and the coast mountains are comparatively low and a number of openings in the range admit a flow of air at a low level from the sea to the valley.

The principal opening through which this wind reaches the valley is that through which the Sacramento flows, on its way to the Bay of San Francisco; hence this bay and the adjacent localities are subject to much stronger summer winds than other parts of the coast north or south. Now, as we have seen, the temperature of the sea along the coast is quite low, and the winds passing over it are cool and do not absorb much moisture; and when they strike the land which at this latitude is quite warm, whatever moisture they may contain is absorbed rather than condensed; consequently rain is impossible as long as these conditions continue.

When, however, the interior regions cool in the fall, there is no longer a continued demand for this cool ocean breeze, and winds, more or less variable, take its place.

Rain occurs and the climate assumes characteristics more or less like our own, with the exception of the cold, as the Japan current still exercises its influence on the temperature, causing, as above stated, mild winters. Such is a brief explanation of the causes operating to produce the dry season in California. The dry summers and the mild winters are the distinguishing features of this climate; but, in addition, the claim is reasonably made that no other region of equal area offers such a variety of climates as the State of California. This might seem somewhat contradictory, especially when applied to the summer season, but even then a great change in temperature may be found by travelling from the coast inland or from the valleys up into the mountain ranges. It may be argued that various climates in one sense may be found in New England in summer, by travelling from the coast inland or among the White or the Green mountains. It is true that in New England as elsewhere, it is likely to be cooler near the seashore than inland, but aside from this the two regions are quite dissimilar. In New England, on the coast, it is at times as warm or nearly so, as in the interior, and places in the interior are at times as cold as those on the coast, while the moisture in the air causes mugginess in warm weather and chilliness in cold weather; hence all localities here partake more or less of the same characteristics. In California, though there may be slight changes, the permanent climatic features of different localities are more marked: for example, in San Francisco, although it has a somewhat disagreeable climate, we may expect about the same weather from day to day throughout the summer season; while if we pass a few miles to the south into the Santa Clara valley, we may, likewise, expect about the same weather from day to day, but it will be unlike that of San Francisco, and although

we may find disagreeable features in both, we may be very sure that they will not exchange places.

We should hardly expect to find in Santa Clara the fogs and the strong cold winds of San Francisco, while at the same time San Francisco was basking in the hot, clear air of Santa Clara. I have spoken of the dry air, especially in the interior, but we find along the coast a fog bank which encroaches on the land at night and retreats in the daytime; this is particularly noticeable at San Francisco. In the morning it extends some miles inland, the distance varying with the character of the country, the mountains offering a barrier to its progress. During the forenoon the land radiates sufficient heat to dissipate it and the rest of the day is bright. The fog bank, however, is likely to remain over the sea, appearing like a huge cloud rolling in towards the shore but not reaching it till sunset, when it spreads inland and a clear evening is uncommon. As we pass along the coast, away from San Francisco, the winds and the fogs become less noticeable, while if we go back into the Sacramento or San Joaquin valley we get beyond the reach of the fog, but we also lose the benefit of the cool breezes; consequently, the pleasantest climate is found nearer the coast, but at some distance from San Francisco.

The coast range sends out numerous spurs which form a broken line of hills or low mountains along the shore in many cases rising quite abruptly from the sea. Among these are many little valleys which are quite sheltered from the fogs and winds and yet are comparatively cool. Here we find small fruit ranches nestled at the foot of the hills or climbing the sides which are in some cases so steep as to necessitate terraces, and here and there are mineral springs and pleasure resorts on a small scale for summer and

winter. The position of these mountain ranges running north and south in connection with the steady westerly wind produces (as has been stated) a great variety of temperatures. In San Francisco the thermometer registered 80° not more than five or six times in the summer and the average would be about 75°. When the interior valleys become a little cooler the trade wind becomes weaker and the weather warmer. On this account July and August are the coolest months and June and September are generally a few degrees warmer.

What are called dog days in the east are scarcely known on the Pacific Coast. When we reach Sacramento we experience a summer heat of 90° and as we go north or south towards the heads of the two great valleys we get beyond even the slight influence of the trade wind which Sacramento feels, and the temperature rises to 100° and over, and occasionally the mercury registers 110° in the shade; but, owing to the dryness of the air, a temperature of 100° is no more trying than one of 85° in New York, and this region has the advantage of cool nights; though the people of Sacramento have a mid-day heat of 90° they find blankets necessary at night.

The winters here are colder than on the coast but the rainfall is less, averaging about nineteen inches only; these valleys sometimes have nearly two hundred and fifty clear days in the year without fog or clouds. The rainfall increases from the southern part of the state towards the north. It is greatest near the coast, and is generally more on the western sides of the mountains than on the eastern; the amount is however quite variable from year to year. It averages in San Francisco twenty-three and one-half inches, at Santa Barbara fifteen inches, at Los Angeles twelve inches, at San Diego ten inches, and at Colton nine inches per year. The Los Angeles region

like Nevada and Arizona is subject to occasional cloud bursts when the water comes down in a deluge carrying everything before it. These generally occur in the mountain canyons and small valleys and have not been known near the large towns, though the railroads and towns suffer from the rapidly rising streams at such times. Sand storms also occur here as they do in the San Joaquin valley. To the east of southern California lies the Arizona meteorological region in which the small rainfall occurs in summer; this season is excessively hot except in the mountains. The mercury in a few places sometimes reaching 120° in the shade, and the hot days are followed by hot nights; the southern part, however, has a fine winter climate the mountain districts being cold. The mean July temperature of Yuma, which is in the lowlands, is one hundred and four degrees and the rainfall at this place is only four inches. Between this region and southern California lies a desert which is influenced by the dry winters of the former and the dry summers of the latter. A year or more has often passed without rain, but an occasional cloud burst supplies the country with an unwelcome amount in a few minutes; coming in this way little good is done, and no vegetation is produced here. As I have stated Nevada and Utah differ somewhat from California in climate, so also Colorado and the western parts of Texas partake somewhat of the climate of the Arizona region, but the classification of the three principal regions of the United States already made is sufficient in a general way.

It remains to be stated that the above characteristics and statistics refer to the weather in its normal condition, but a change has been taking place throughout the world during the last five or six years, which the majority of meteorolo-

gists have as a general rule refrained from considering with the exception of some of the phenomena resulting therefrom. We may consider that somewhere about the years 1880, 1881 or 1882, we entered a cycle of astronomical disturbance, and this fact has manifested itself in the unusual terrestrial and atmospheric phenomena which we have witnessed in this period. The climatic changes occurring in various localities have been noticed and commented upon, but no general explanation has been given by the leading meteorologists to whom people look for information in such matters. Local changes have been attributed to local causes, and peculiar phenomena like the "Yellow Day" have been explained to the satisfaction of many, but not in a way to comply with the conditions in the case. The "Yellow Day" occurred in New England in September, 1881. I was at Marblehead Neck at the time and had a fair opportunity of observing the phenomenon. When I awoke on that morning I discovered the harbor and the surrounding landscape bathed in a most peculiar yellow light. This continued throughout the day. The grass appeared blue and all colored objects had a strange appearance and the atmosphere was very still and oppressive. People were at first unable to give any explanation or form a theory in regard to it. Men who went to their business in Boston returned with accounts of the peculiar aspect of the city where gas was used in many places throughout the day. The papers gave descriptions of it, but no adequate explanation. The superstitious believed the end of the world was near at hand, and the members of one religious sect prepared to ascend, and waited patiently all day. More practical people, particularly those who had been in tropical regions, expected that an earthquake or a hurricane would follow, but nothing of the kind took place; and when the sun had set, the strange light

lingered but a little while and the moon and sky then appeared as clear as usual.

A theory was then evolved and adopted to explain this appearance. It was to the effect that owing to the extensive forest fires then raging to the north of New England, a great quantity of smoke had drifted to the south and east over the country, thus producing the yellow light; and in support of this theory it was stated that many persons noticed an odor of smoke and that in New Hampshire it was particularly strong. As no better explanation was offered it was accepted generally. Nevertheless, it would not satisfactorily stand a test.

The ordinary ruddy glow of sunset is simply caused by the way in which the rays of light penetrate the atmosphere which is apt to contain considerable moisture; but when we have to deal with a phenomenon like the Aurora Borealis (or northern lights) we find we have a more complicated subject to analyze. We can scarcely say that the light is caused by the presence of gross foreign matter in the air, unless we class magnetism and electricity as such. This light at times appears in the form of a few streamers or an arch of white light. At other times it will rise to the zenith and even stretch over towards the south. Occasionally, it spreads over a large part of the distance between the east and the west, and at times it assumes a reddish hue, and the flickering and darting motions of the streamers or rays are very common. It has been noticed that a brilliant display of this kind often accompanies or follows a sun storm, that is, a disturbance in the envelope of the sun, such as may be witnessed in the development and expansion of a so-called sun spot. A change of weather or of temperature is also looked for, after a display of northern lights. This subject is little understood, yet we can but feel that a bond of sympathy exists throughout the

solar system and that oftentimes unexplained phenomena are but the manifestations of reactions between the members of that system. Now to revert to the subject under discussion; it appears to me quite necessary to attribute the cause of the "Yellow Day" to something higher than smoke in the air, and I will mention a few facts which seem to make the smoke theory untenable.

In the first place, it is granted that in the neighborhood of an extensive fire the sky assumes a murky hue from the smoke; but there have been many forest fires of great magnitude in the regions to the northeast, north, northwest and west of New England without being followed by any such conditions as were present on the "Yellow Day." It is claimed that the wind was not in the proper direction on these occasions, but that on the "Yellow Day" it was.

Now let me say that though there may possibly have been a little smoke in the air in northern New Hampshire and Vermont, yet the yellow light of that day appeared over other parts of New England nearly simultaneously. If smoke had been the cause, we should have had a gradual thickening of the sky, as the smoke advanced from one district to another southward and it would have passed away in the same gradual way. Such was not the case; it appeared in a short space of time and disappeared with the sun. Furthermore, if the wind had been violent enough to have brought such an immense volume of smoke down over New England and carried it away so suddenly, then that wind, even if at a high altitude, must have caused some motion in the air next to the earth. But the air was calm on that day, and, again, if such an amount of smoke had been carried along over so large a territory in so short a time, it would have presented more the appearance of masses of clouds

driven before a strong wind, whereas there was very little appearance of that kind.

The yellow light seemed to be equally diffused over the heavens and at rest, though there occurred now and then whitish spots or what appeared to be breaks or openings in the yellow expanse, but no definite outlines were visible and the difference in the tints was so slight as to amount to no more than the variations in the sunset glow or the breaks in the white expanse of the northern lights.

A number of persons claimed to have noticed the odor of smoke in the air, but I think they may have remembered such a fact after being informed of the smoke theory, and one might quite readily imagine smoke in the air when it was so close and oppressive as on that day. In the northern part of New England I doubt not, there may have been more or less smoke in the air, not only on that day but for some time, not, however, in sufficient quantities to cause such a sudden and extensive combination of atmospheric conditions. Such facts we may consider as negative proofs. Let us now see if there are any cases in which such appearances occur without the presence of smoke. We have only to seek such information from a sea captain or some one who has been in tropical regions, and we shall find that a calm, sultry air and a brassy appearance of the heavens often occur before elemental disturbances of great violence, and even here in New England we have occasionally noticed such appearances before the breaking of a heavy thunder shower; and when we find that in some regions a calm, sultry air with a yellow light in the heavens continues for some time without the presence of smoke and is generally followed by atmospheric disturbances, we are led to believe that such conditions are produced by the same agencies, and that as these are variable, it is possible for the above appearances to exist

under certain circumstances without the attendant disturbances.

Another fact in connection with the "Yellow Day" is that the same yellow light was observed within a day or two after, in Virginia and then in Iowa. In the latter state the light had a flashing appearance like the northern lights in activity. It certainly seems quite unreasonable to suppose that smoke came down to New England, then passed to Virginia and then over to Iowa. The only satisfactory way to account for it is, as above stated, on the supposition that it was caused not by the mere interference of gross matter held in suspension in the air, but by the same forces and conditions which are concerned in the production of many other singular terrestrial and aërial phenomena, and which may have much to do with the aurora borealis and the red afterglows at sunset which have attracted so much attention within the last two or three years. These brilliant results began in the fall of 1883, appearing in India in September, and being very marked in October, November and December, not only in Asia, but in Europe and America. The display began when the ordinary ruddy glow of sunset had faded; then a deep red light illumined the western sky, extending at times even to the zenith. A writer, describing the appearance in New England, says: "The display was almost startling and there was something almost bewilderingly grand in the evidences of the red glow. It was at almost six o'clock that the most peculiar phase of the phenomenon was witnessed, when in the starlit sky the peculiar ruddy glow came and went. The coldly brilliant stars seemed blue and green by contrast with red and their brilliancy was fantastically magnified." Astronomers and meteorologists here and abroad advanced different theories and each seemed plausible. Prof. Piazzi

Smyth, Astronomer Royal for Scotland, maintained that there must have been an excessive amount of vapor in the higher atmosphere caused by unusual meteorological conditions. The "New York Herald" also strongly supported this theory, while other leading astronomers claimed that the cause was to be found in the volcanic dust thrown up by the great eruption in the Island of Java. This theory has perhaps been more generally received than any other. Mr. Norman Lockyer, Professor Ball of Dublin and Mr. Raynard being among its supporters. Professor Loomis was not inclined to endorse either of these theories. It has also been claimed by several scientists of high standing, that the earth passed into a stream of meteoric dust about the time of the beginning of these displays, and others have sought the cause in the attenuated matter of a comet's tail in the atmosphere. The theory of volcanic dust from Java has, however, as above stated, been the one most universally accepted, and yet that seems scarcely adequate to explain the matter fully, for the eruption took place August 27, and three days later these afterglows were seen in Brazil, over nine thousand miles from the disturbance, and if the wind had borne the dust thither it must have travelled at a great speed; and, furthermore, it must have travelled rapidly in various directions to have produced such results in Asia, Europe and North America as well, and there have been reports of such appearances before the earthquake. And, again, if the upper atmosphere had become so permeated with foreign matter, it seems very strange that the effects should not have been noticed every day. As it was, several days often passed without the display, followed by one or a number of successive brilliant afterglows, which at times assumed the motions of the northern lights, streamers of red darting upwards, and then retreating in a man-

ner different from the ordinary changes of sunset hues, and scarcely to be accounted for on the mere supposition of light passing through a veil of suspended volcanic dust.

On the whole it appears quite as reasonable to suppose that the cause which produced the great earthquake of Java also produced atmospheric phenomena at the same time, and it does not particularly affect the case whether, as is generally supposed, the causes of earthquakes exist within the earth or whether, as is not improbable, outside influences are largely concerned in their production, or both. In referring to the matters above my object has been to show that unusual phenomena have occurred within the period before mentioned, and numerous other cases might also be cited; one or two of the principal ones I will hastily consider in order to make the case more distinct. The eruption of Krakatoa in Java in the summer of 1883 was the most powerful convulsion on record. Other great catastrophes have occurred within the last century or so, such as the great Lisbon earthquake of 1755; the Java earthquake of 1815, and that which devastated the western coast of South America in 1868; but the one we are considering destroyed more human beings and its disastrous action continued for a longer time—one-hundred thousand persons were killed. A range of mountains disappeared beneath the sea and the topography of the whole country and the neighboring regions was changed, so that mariners knew not where they were; waves rolled where dry land had formerly been, and land appeared where vessels had sailed, while the sea for a long time after was covered for miles upon miles with a layer of pumice stone and ashes. To this may be added the earthquake of England, which though slight in comparison with the above, was an unusually severe one for the country in which it occurred. The disastrous floods and tornadoes in the United States

within the last five years have been unparalleled in the history of the country, and the frequency of severe storms all over the world has been very unusual. In January, 1884, a paper was read before the Academy of Sciences at Paris, giving a review of the year 1883. The following lines are taken from a synopsis of this paper.

"At the last January session of the Paris Academy of Sciences, M. Foye gave a rather startling summary of recent physical commotions both on the earth and on the sun. Among the numerous exceptional phenomena noted for some time such as the frightful volcanic explosion of Krakatoa, the immense sea waves and air waves which swept round the globe, and the strange celestial lights and colorations, he mentioned that the month of January in Europe resembled in temperature the month of April, while systematic observations disclose singular variations in sun-spot frequency and no less singular behavior of the magnetic needle. During the present summer in the southern hemisphere extraordinary heat has been recorded, the thermometer at Buenos Ayres rising in the shade to 101° and in Queensland to 106°. In consonance with the disturbed state of the earth, M. Wolf of Zurich reports two pronounced sun spot maxima in April and October last, and only four days in 1883 in which the sun was not spotted. Though these maxima were not so high as that of April, 1882, and there are now indications that the sun's activity is decreasing, physicists will not be slow to connect the terrestrial disturbances with the solar storms. The French scientist may now add to his list of strange phenomena the late unparalleled Ohio floods, the extraordinary southern tornadoes of recent date, with the reported death roll of several hundred persons and the phenomenally early and extensive efflux of Arctic ice upon the Atlantic." The above extract points quite plainly to the fact

already mentioned, that is, the relation existing between the members of the solar system. If a sympathy exist between the sun and the earth, it must also exist between the sun and the other planets, and if changes in the sun affect these it is not unreasonable to suppose that they in turn may exert some influence upon the sun, and if they ever do, we should expect the effects increased when the superior planets occupy such positions with regard to one another as they have within the last five years. Now after these superficial observations, I will refer to my former statement that the characteristic climates of the different sections in the United States which I have described, have not within the last few years been in their normal condition. As an example the dry season in California has been growing shorter, the rains have continued later into the spring, and commenced earlier in the fall, and light showers have occurred in June and last summer a light one occurred the first of July, and in some localities in the state thunder and lightning accompanied it, a remarkable event for that region. A Spaniard who had resided in Monterey most of his life stated that he had never seen lightning until two years ago. The Californians boast of their freedom from thunder showers; light ones occur though very rarely but the state is subject to eight or ten earthquake shocks a year. These, however, are generally light, and in the majority of cases are scarcely noticeable, and the residents prefer them to thunder showers. In support of this preference they bring up the undeniable fact that in twenty years only forty deaths from earthquakes have occurred in the state, and these mostly by the falling of old adobe houses, while in the rest of the United States subject to thunder showers the deaths by lightning amount to nearly one hundred and fifty a year, and if the deaths by tornadoes be added, the total would

be from 250 to 300 a year and sometimes more. Of course there always exists in California the liability of a severe earthquake, but though showers have taken place there lately, they are not likely to develop into any such severe and frequent electrical storms as are experienced elsewhere. Changes in our own climate are also quite plain: for several years our proverbial April weather has been a stranger. We have not had mild days with typical April showers and bright blue skies alternating in rapid succession, as formerly, but instead, we have had cold rainy Aprils more like November, with a few instances of unseasonable heat; and again, our winter season formerly preserved its characteristics in a regular and orderly manner. The snow came and the cold came and remained in quite an even way. We were accustomed to have sleighing through a large part of the winter, and we expected a short thaw of two or three days in the early part of January known as the January thaw, but of late years we have had very little continuous sleighing here, some years having very little snow and at other times having the larger part of it in one or two heavy storms. Our thaws have occurred every few days, nearly every snowstorm being followed within a day or two by one; cold waves and warm spells alternating in rapid succession. The present season has possessed more or less the true winter features, but we have had an alternation of many very severe storms, very cold waves, and warm spells. On the whole, the winter has been a cold one with considerable of the old time regularity in its snow falls, but nearly as changeable as others of late. This changeable and uncertain weather of the last few years has caused an unusual amount of sickness everywhere. The influences bringing about these changes have also manifested themselves in other ways.

The most important agents of climatic change within the

control of man are the forests. These have an important bearing on the climate of a place and their wholesale destruction is apt to create an unfavorable change. This is confined chiefly to the temperature and the prevalence of droughts and floods. In the case of the latter in a deforested region, the effect, so far as the destruction of the forest is concerned, is not produced by an extra amount of precipitation but by the water reaching the streams more rapidly; and it often happens that barren regions suffer most from floods, other things being equal. It should be noted, however, that many of the unusual floods of late years have been caused by very heavy rainfalls on account of the abnormal conditions which we have been considering, but the results have been more marked in scantily wooded regions than they would have been had the hills been covered with a heavy growth of timber. It has been quite strongly maintained by some authorities that forests do not actually cause more rain; but if they do not in a direct way, they do indirectly, and numerous examples are afforded us for observation while the evil effects of forest destruction are too common. Whole districts which once were rich and productive have become dry and barren, their streams have dwindled to mere brooks, except after heavy rains, when they rise rapidly and sometimes overflow and the soil is gradually washing away from the hills. The effect in temperature varies somewhat with the surrounding conditions. The clearing of forest lands in Germany had the effect of raising the temperature. In England the same result followed, but in Iceland the temperature has been lowered. It may be said, however, as a rule that a forest equalizes the annual temperature as well as the distribution of the rainfall.

About ten years ago I wrote an article, calling attention to the importance of united work for the preservation

of our already rapidly decreasing forests; and localities, which I then had in mind, have since been denuded of their timber, and the changes, above mentioned, to a certain extent, have been the result. The destruction of forests could not cause all the varied and unusual meteorological phenomena which we have been considering, yet a corresponding influence is contributed to exaggerate all abnormal weather changes. The "arbor days," instituted of late in a number of our states, are the result of excellent ideas, and if they are generally observed will be of great benefit in creating an interest in the subject.

I think many would find a source of recreation in the subject if their interest were once aroused. It is not only important from a climatic and sanitary point of view, but it is a very instructive and interesting study in other ways; and the organization of local societies, composed of both sexes, devoted to the study of forestry in all its branches, including botany, with the intention of making practical use of the knowledge thus gained by means of united work, would eventually bear as much fruit as many of the other societies organized for various purposes in our different cities and towns. But the subject of forestry is too vast to be considered at any length within the limits of the present discourse, and as I have been expected to confine myself to meteorology I have not digressed from that subject, and I will close with the hope that the questions which I have endeavored to explain have been made clear.