SCIENCE

[Entered at the Post-Office of New York, N.Y., as Second-Class Matter.]

A WEEKLY NEWSPAPER OF ALL THE ARTS AND SCIENCES.

EIGHTH YEAR.
VOL. XVI. No. 389.

NEW YORK, JULY 18, 1890.

SINGLE COPIES, TEN CENTS.
$3.50 PER YEAR, IN ADVANCE.

SUN-SPOTS AND PREDICTIONS.

ATTEMPTS are continually being made to connect terrestrial weather and storms with the motions and positions of the moon, the planets, and the sun. It has been fairly well shown that at the time of full moon there is a tendency, in some parts of the world, toward a diminution of clouds. One computation has shown a slightly greater rainfall during new moon on the Atlantic coast, but precisely the contrary on the Pacific coast. There has also been a very slight evidence of the increase of thunder-storms at the new moon. The influence of the planets must be absolutely inappreciable. When we consider the sun, however, we see at once the intimate connection between his radiant energy and all activities upon the earth. The growth and well-being of every living thing are absolutely dependent upon the sun's light and heat. It is believed by many that the sun's heat is the only agent to be considered in seeking for an explanation of our storms and all our weather changes. It is undoubtedly true that some form of solar energy is concerned in our storms, but it would be quite hazardous to say that electric influences from the sun are not far more potent for producing storms than even its heat. As the sun's heat is the most prominent energy recognized by our senses, every attempt has been put forth to determine whether this is constant as regards our climate, or whether there are fluctuations at long intervals. It is plain that these changes, if they exist, cannot be appreciable to our thermometers for centuries. The difficulty of measuring the intensity of solar rays by direct observation has been practically insuperable; and we may say that the total amount of heat which we receive is so great, as compared with its fluctuation from the greatest to the least, that we cannot hope for any definite solution of that question for years to come.

Coincidences.

In seeking any relation between the sun's light, heat, rotation, or appearances, and terrestrial phenomena, it is unsafe to trust to mere coincidences; but some connection of cause and effect should be established. For example: on Aug. 3, 1872, while Professor C. A. Young was examining the solar prominences with a telescope, he saw a most violent outburst upon the sun, and noted the exact instant when it occurred. Afterwards he found that his assistant at that very moment had observed a violent agitation of his magnetic needle; and an examination of the records at Kew, England, revealed exactly the same disturbance of the needle there. This may safely be regarded as more than a mere coincidence, and proves, in connection with other observations of a like nature, the intimate relation between solar disturbance and terrestrial magnetism.

It is well known that the sun is periodically spotted; that is, once in about eleven years spots gradually appear, and increase near the sun's equator. A remarkable fact about these spots is that their motion very near the sun's equator appears to be faster than in higher latitudes They revolve or come in sight in a little over twenty-five days in the former position, and in about twenty-seven days in the latter. This single fact should lead a great many of those who believe that our tornadoes are produced just as the spots appear by rotation, or about twenty-six days apart, to doubt the sufficiency of the explanation, because any such periodicity would be entirely broken up from the variable rotation period of the spots. The cause of these spots has not been well established, but it is probable that they are the result of increased electric activity on the sun. The attempt to connect this eleven-year period with our weather has proved intensely fascinating, and volumes of researches have been published. Such comparisons have proved, in the main, very illusory. While an apparent connection would be found in a few periods, yet, as the number of observations increased, the supposed connection was disproved. A single illustration will suffice. The attempt has been made repeatedly to connect the sun-spot period with fluctuations in temperature. In the nature of the case, it is impossible, perhaps, to prove whether the spots show the sun to be hotter or cooler during their existence. The fluctuations of temperature on the earth certainly do not show a preponderance either way, when compared with the appearance of sun-spots. This does not necessarily prove, however, that the spots do not influence our temperature, or that they do not show increased heat in the sun; for this increased heat would tend to produce clouds from a greater evaporation, and these in turn would prevent the sun's rays reaching the earth, and this would result in a cooling rather than a heating, which would mask the spot influence (see *Monthly Weather Review*, January, 1888).

Auroras.

Research has shown conclusively that our auroras and magnetic storms have an eleven-year period, and this is coincident with spot fluctuations; that is, as activity in spots increases, our auroras increase, and *vice versa*. It has also been definitely settled that the aurora is an electric phenomenon, and is intimately connected with magnetic storms on the earth. Here we have practically a number of coincidences which may be said to prove a definite connection between these phenomena without a positive knowledge that

they are both produced by a common force, or that the spots produce the effect upon the earth. The coincidences here, however, are very marked, and there are practically no discordances. These points should be most carefully borne in mind in all our studies in this line.

Sun-Spots and Storms.

Meldrum of Mauritius was one of the first to study the relation between cyclones and sun-spots, and found that during the three maximum periods of the spots between 1848 and 1871 there were nearly twice as many cyclones as during the minimum periods. The evidence in 1871, however, was far less than in 1848, and the more recent spot maximum of 1884 showed no increase in cyclones; so that this proof, which has been *the* one that has been relied upon above all others, has gradually dwindled down to practically nothing. It should be noted, however, that we have no absolute proof one way or the other; for during the spot maxima of 1871 and 1884 there may have been other forces acting which tended to diminish the activity of cyclones, or to divert them from the track of ships whose records Meldrum examined. Poey examined the West India cyclones, going back to 1750, and he thought that there were more cyclones during spot maxima. This record is so long that I have deemed it worth while to give it a careful study. The spot curve is remarkably well defined, with very few irregularities. The maximum and minimum points are very easy to find, and one can have no doubt as to the exact year of each period. The cyclone curve, on the other hand, is exceedingly irregular, and fluctuates back and forth across the spot curve. Comparing the cyclone and spot curves, I find that in the twenty-four maximum and minimum periods there are eight coincidences, ten positive discordances, and six doubtful cases (that is, cases which showed a flat curve for cyclones at the time of either maximum or minimum spots). This is a very poor showing, and certainly proves no intimate relation. No one can compare these curves and consider that the relation is proved by them.

If it could be shown that our cyclones were due to special heat or electric action, and that sun-spots tended in the same direction, there might be some hope in establishing a relation between them. Under the circumstances, however, it is necessary either to obtain accordance or else to explain away the discordances. Coincidences for a few periods are very probable, and prove nothing. The weakness of this cyclone research lies in the fact that only very limited portions of the earth have been considered. The only proper way would be to determine the extent of storm activity over the whole globe each day of the year, and then to compare this with sun-spot action. The reasons that many sun-spotists have met with so much encouragement in their researches have been two: 1. A "coaxing," as Professor Young puts it, of the critical point of a sun-spot period (that is, if the cyclone maximum came two or three years earlier or later than the spot maximum, it has been regarded as a coincidence); 2. A consideration of all manner of terrestrial disturbances as fulfilling the prediction or establishing the coincidence. All manner of tornadoes, storms, blizzards, hot waves, cold waves, floods, frosts, earthquakes, etc., have been drawn into their nets. It would seem that this practice should be regarded as very unreliable. If a spot produces a cold wave one week or at one time, it can never produce a hot wave at any other time. The determination of such a relation, if there be one, is one of the simplest mathematical processes that can be imagined, after the data are at hand, and yet the sun-spotists are very anxious to make their own computations. One of them writes, "I am very much afraid you will coax the data to disprove my view." It is very plain that no accurate research of this kind can ever be made by any one that cannot be repeated by any other person, and the fear of sun-spotists to have the verification of their theories taken out of their hands is well grounded.

Tornadoes and Sun-Spots.

If we take such a very great territory as that of the United States, and have stations at every sixty or a hundred miles, then count the number of stations each day at which the wind velocity reached twenty miles or more per hour, we would have a partial view of the average storm activity each day of the year. Again: if we could get a record of every violent storm in this region, and give it a proper weight, we would have a fair idea of storm activity, and could compare it directly with the known and easily measured spot activity. This has been done with the 2,221 tornadoes that have visited this country. The following table shows the relative intensity of tornadoes by weight, and the relative sun-spot intensity:—

Year.	Tornadoes.	Sun-Spots.	Year.	Tornadoes.	Sun-Spots.
1873.....	8	701	1881.....	169	730
1874.....	15	601	1882.....	286	1002
1875.....	69	272	1883.....	589	1155
1876.....	68	122	1884.....	461	1079
1877	111	92	1885.....	374	811
1878.....	108	24	1886.....	243	527
1879.....	92	49	1887.....	183	[300]
1880.....	269	416	1888.....	259	[100]

In this table, numbers in the sun-spot column are taken from the Greenwich photographs, and show the relative area covered by spots in millionths of the sun's surface. The earlier tornado records are in some doubt, as they are quite meagre. The enormous increase in both tornadoes and sun-spots during 1883 and 1884 is very striking, and seems to be a fact, though it will require several more eleven-year periods to establish the coincidence. There was an increased activity in collecting tornado data in 1882, but this continued through till 1887; so that the great increase in the two years above cannot be ascribed to this cause. Moreover, the list of 2,221 tornadoes was made up chiefly from the same source throughout all the years. There is a quite strong proof that the sun-spots are due to the action of electricity. Now, it has been shown that our tornadoes have an abundance of electric action, so that there is no inherent improbability in the supposition of a relation between these phenomena, aside from a mere coincidence in their phases.

Specific Influence of Spots.

If such a relation exists, some have thought that there ought to be a synchronism between the appearance of spots and resulting storms. The view has been strenuously sup-

ported, that within two or three days after the appearance of a spot on the eastern limb of the sun, or by the rotation of the sun, storms break forth or greatly increase in violence on the earth, and that it would be possible to use this fact in making predictions of violent storms. It will be easily seen that this view, if true, is of the extremest importance. No attempt is made to explain why it is that after two or three days this spot influence dies down, while the spots are still in full view of the earth for ten days. Since electric energy is transmitted at once from the sun, why should it not begin its action at once upon the earth? We must remember that this action is not a direct one, but electricity must act first upon the clouds or atmosphere, and possibly these upon the earth in turn, before the storm is produced or influenced; so that there need not be a direct connection between the two. The reason that this hypothesis has gained in favor has been already explained, and lies in ignoring discordances and emphasizing coincidences. Our curve of tornado activity furnishes a most extraordinary means of determining this specific effect of spots, if there be such.

The Greenwich, India, and Mauritius photographs of spots show exactly the appearance of each spot by solar rotation, and its area, or, as we may say, its relative intensity. We can easily determine, then, the activity of spots on the eastern limb of the sun during any day. It will be seen that this process is very dissimilar to the one adopted in obtaining the annual intensity; for that used the spotted area over the whole sun each day, while this method uses the area of a spot for three days only, and immediately after its first appearance by rotation. The years 1874 to 1886 were used, and the tornado months March to September. Curves were constructed showing both the spot and tornado activity for each day of the above period. An examination of the curves showed, (1) 46 tornadoes coincident with spots, (2) 156 spots without tornadoes, and (3) 393 tornadoes without spots: 46:593, or 8 per cent, which is insignificant. Next there were compared three successive days of spots, and the same days of tornadoes, during the extremely abundant tornado years 1882 to 1885 and the months April to August. It will be seen that in this comparison every thing was in favor of the tornado and spot-rotation hypothesis. There were 43 coincidences, 30 spot groups without tornadoes, and 79 tornado groups without spots: 43:109, or twenty-eight per cent. It is plain that this hypothesis breaks down completely under this investigation.

General Influence of Spots.

On observing the sun-spots carefully, we find that there are marked periods during which the spot activity increases and diminishes. In order to compare such periods with tornado activity, curves of both were drawn; and it was found that while a rise in the tornado curve occurred during the greatest activity of spots, yet the converse of this proposition was not true, for there might be a rise in the spot curve without a response from the tornado curve. This may have been due, as has already been suggested, by the masking of the spot effect at the earth's surface. The evidence, while showing a tendency to increased tornado action during an abundance of spots in at least one eleven-year period, does not show any marked specific action or relation between any definite spot phenomenon and a corresponding response by storms on the earth. The subject is exceedingly complex, and merits further study, especially in the line of a removal of any outside influences which would tend to mask the influence of spots at the earth.

Predictions.

It has been said that one of the best tests of the advancement of a science is its power to make predictions. Unfortunately, weather science has easily lent itself to all classes of wise or simple persons, and has suffered by their ignorant attempts at foisting upon it crude and imperfect forecasts of the future weather. An interest attends some of these efforts, however, from their curious and incongruous medley. Witness, for example, the famous lines of Dr. Jenner, beginning

> "The ass begins to bray,
> We shall have rain to-day,"

now so universally quoted. Many of these signs have a real significance: for example, the very old saying, "When it is evening, ye say, 'It will be fair weather, for the heaven is red;' and in the morning, 'It will be foul weather to-day, for the heaven is red and lowering.' " It has been suggested already that much may be learned from cloud appearances to assist in determining the probability of a tornado. A peculiar livid and greenish color is often seen, or ragged and angry-looking clouds in the west announce the greater disturbance. The appearance of lightning and heavy thunder usually precedes the tornado, though of course both these may be followed by an ordinary thunder-storm. The loud indescribable roar is unmistakable as a precursor of the funnel-cloud.

The question is often asked, however, "Can there be a prediction of a tornado a day, week, year, or even a century, in advance?" This problem has been most exhaustively studied by so-called weather prophets, and the public have been not a little mystified by the varying claims put forth by each prophet, and especially by the extraordinary success in such predictions that these men insist they have had. The scope of this paper will not permit more than an outline of these theories; but we may lay down certain rules that should guide us in estimating the value of such predictions, and in putting our faith in them. The moon, the planets, and the sun have been the most potent factors in these theories of storm-formation.

The Moon's Influence.

The comparative nearness of this body, and the fact that its phases occur in about seven days, which is approximately the interval for the occurrence of storms, have made it one of the most popular influences for weather changes. Soon after the death of the elder Herschel there appeared a singular set of weather tables ascribed to him, and purporting to give weather predictions according to the age of the moon. These tables have been scattered broadcast over this country. It is needless to remark that Herschel had nothing to do with them, as has been shown by his son. The moon is an inert mass, and can have no influence on our weather, except, as we have just seen, it has a very slight tendency to drive away clouds. Observations have shown that the tide produced by the moon in our atmosphere is only four-thousandths of an inch of mercury.

Planetary Hypotheses.

If the moon, only 250,000 miles away, has no marked influence on our weather, what must we think of the effect of the planets, millions of miles away? It is no wonder that at least one of these prophets, after giving the whole subject careful study, was forced to abandon the planetary hypothesis for the lunar theory. There is nothing which shows the utter absurdity of these planetary theories more forcibly than the introduction of the hypothetical planet Vulcan. This is needed in order to have a body revolving around the sun frequently enough to make his position relative to the earth coincident with our numerous storms. One of these prophets, an American, thought he saw Vulcan passing across the sun, and published a careful computation indicating, that, according to Le Verrier's orbit, the planet should have been exactly at that point; but, unfortunately for this hypothesis, it was shown by Professor Proctor, that, owing to a slight inaccuracy, this computation was wrong, and that this prophet, if he saw Vulcan at all, must have seen it directly *through the sun*, on the opposite side from the earth. Granting that there is a planet only 8,000,000 miles from the sun, and about 85,000,000 from us, is it not perfectly plain that its influence on terrestrial weather would be most completely overshadowed by the all-powerful sun behind it?

It is not a little remarkable that these prophets are entirely disagreed as to how this planetary effect is produced. One would have our storms and tornadoes coincident with the equinoxes of the planets, another with their oppositions and conjunctions; and so on. It is easy to see, that, under these circumstances, no two of these prophets agree on the dates of storms, but they are distributed quite uniformly for about half the days in the year. How does it happen, that, though these dates disagree, all these prophets are perfectly satisfied as to the exact fulfilment of their predictions? This is very simple to explain; for the man who predicts a storm on the 1st of the month, for example, verifies by a storm, say, in Illinois, while the one who has put his storm on the 3d of the month verifies by the same storm, which has now moved to Maine. There is just one crucial test by which we may satisfy ourselves of the worthlessness of these theories. It has been outlined in the last chapter. Let these prophets make a careful study of all the influences they can muster, and put down, no matter whether for the past or the future, the dates when they would expect the worst storms, and also the dates of fewest disturbances, then take the whole extent of this country, and establish the dates of most and least atmospheric disturbance. A comparison of these dates would quickly prove the value of such predictions. It is needless to add, that frequent and continued attempts to obtain these dates from at least four of these prophets, and to get any one of them to agree to this comparison, have lamentably failed.

There are not a few people who put great faith in such predictions, though a moment's thought would show how preposterous the claim is. For example: the Louisville tornado, on March 27 of the present year, was heralded as a perfect verification of a prediction for storms from March 28 to 30, and pains were taken to spread this fact from Maine to California. Suppose some one in the tornado district had read this prediction on March 27, and put faith in it: would he not have been misled? Again: if some one in Maine had read the prediction, would a storm in Kentucky apply to his locality? It is so easy to make a storm prediction, and so easy to verify it if one is allowed his own way, that there is no immediate prospect of silencing these prophets; but it is to be hoped that our citizens will study this matter for themselves, and before long obtain right views. It is plain that such a prediction made years beforehand can have no influence on right-thinking persons, for we know that it is impossible to predict the weather with certainty for even twenty-four hours.

Since 1872 it has been known that tornadoes and severe storms occur in the south-east quadrant of a depression system as it traverses the country, and in the history of the Signal Service frequent predictions of such storms have been made. A great deal of discussion has arisen as to the possibility of extending this system, and of giving ample warning of these outbursts. The most that can be said at present is, that the occurrence of such a storm is exceedingly rare; and in a very small space, while we may be able to indicate a region of several thousand square miles where such local outbursts may be expected, yet little more than this can be hoped for. People living in such districts, when they hear of the prediction, should not be disturbed, but simply take it as a probable occurrence at possibly one or two places, and in any particular locality should be guided by the appearance of clouds and other threatening signs which have become familiar. In fact, the question frequently arises as to whether it would not be better to omit such a prediction entirely; but if the right view be taken of it, that it is a warning to look out, and not a positive statement, no one should be unduly disturbed.

There are times when there seems to be an unusual amount of electricity present in the atmosphere, and when these severe storms occur without presenting any indication whatever on our maps or in our reports. It is impossible, from our present telegrams and knowledge of these storms, to make any predictions in such cases, though we may hope that in the future we may have a clearer idea of disturbed conditions at one or two thousand feet above the earth, which will enable better predictions. Such storms are not very severe as a general thing. A storm region like that in Kentucky on March 27, 1890, is plainly indicated on our maps, and predictions of severe local storms were sent all through that region nearly twelve hours in advance.

There has been a gradual development in these predictions as the conditions have become more familiar. One of the later attempts was made in 1884, and in this case the whole country east of the 102d meridian was divided into eighteen districts, and private predictions were made each day during the tornado season as to whether or not a tornado would occur in any district. The claim was made that in this case 97 per cent of the predictions were successful, but a serious fallacy in these attempts was soon pointed out. To say that on any day in New England, for example, there would be no tornado, was no prediction at all; for only under most extraordinary conditions, occurring once in three or four years, are any tornadoes experienced there. Several verifications of these predictions according to mathematical principles gave from 13 to 20 per cent of success. This does not indicate, however, the measure of skill that has been at-

tained in tornado prediction, but was due primarily to an injudicious system of predicting, and secondarily to an improper estimate of the nature of the problem. It would be impossible, of course, to say that such a tornado as that at Grinnell in 1882, and the recent one at Louisville, would occur in any district. All that we can do is to predict a disturbed region. In verification, it would hardly be fair to adopt principles which could be used in determining the skill of a marksman shooting at a target, for example; but we must take into account the knowledge we have already gained of the relative violence and the manner of occurrence of such storms. We must determine, on a scale, the number of violent storms occurring in any district where such storms were predicted, and not confine attention to the most violent alone. To draw an imaginary line, and say that if a storm occurs within five miles of that line, in a district where it was predicted, it shall count fully as a success, but if it occurs five miles on the other side of that line it shall count as a total failure, is to impose restrictions upon the problem which seem entirely unreasonable.

In a study of tornado predictions made by Mr. Finley for June, 1885, the present writer assumed "that violent storms occurring, in any district predicted for, half way between the centre and edge, shall have weight 1; in the rest of the district, $\frac{3}{4}$; to the centre of the next outlying district, $\frac{1}{2}$; to the edge of that district, $\frac{1}{4}$; all outside of these, 0" (see *American Journal of Science*, August, 1887, p. 129). The percentage of skill attained as thus measured was 49. Mr. Curtis, taking the same predictions and discussing them mathematically, found 14 per cent. Mr. Curtis has more recently (1887) adopted somewhat the method suggested above, and obtained 40 per cent. These percentages, however, mean very little as to showing a real knowledge of the probable occurrence of tornadoes, for it is necessary to radically change the system of predicting. It would seem wiser to determine as nearly as possible the central point of any probable disturbance, three hundred or four hundred miles to the south-east of a general storm, and then give boundaries more or less definite to the violence of the storms. This we are able to do from what is known of the behavior of such storms. In verifying, we should consider all the storms that occurred, and give weights corresponding to their distance from the centre of the disturbed region, and to their intensity.

Tornado Photographs.

One of the most recent developments in tornado studies has been a strong desire to photograph this extraordinary appearance. It is very unfortunate that this desire has become so strong that unscrupulous persons have resorted to photographing sketches of tornadoes, and selling them for the real article. It is also unfortunate that all these alleged photographs have been made at distances of from ten to twenty miles. It is a great desideratum that we have many photographs taken at much closer quarters, and this is not so impossible as might at first sight appear. It would be useless for any one to attempt a photograph on the south side of a tornado within a thousand or fifteen hundred feet; but on the north side we have repeated authentic observations of persons who stood within one hundred and fifty feet, and did not feel any violent wind. It is much to be hoped that a photographer will catch, by his instantaneous flash, one of these monsters as it passes just south of his position. It will require more than the usual amount of bravery to do this, however, as is very plain.

Alleged Photograph.

While nearly all these photographs show quite plainly their origin, yet there is a single exception in a picture representing an alleged tornado near Jamestown, Dak., on June 6, 1887, recently published in a prominent magazine. There is no doubt that this is a genuine photograph. There exist most serious difficulties in regarding it a tornado-cloud, however. The picture shows a dense mass of cloud extending from the trees at the earth up to the uniform veil of cloud above, with clear sky on either side. This mass has a thickening on the right-hand side, and this is supposed to be the tornado. The appearance is exactly that of a cloud-burst, as has been often witnessed, and not at all of a tornado. The dimensions of the camera and the distance of the cloud give the height between two and three miles. The distance of the cloud was variously estimated from eighteen to twenty miles. There was no destruction, and no one saw it, at the spot where the tornado was supposed to be. The only way it could be located was by following two lines of sight of persons from ten to fifteen miles away until they crossed. Drawings of a sand-whirl, not far from the alleged tornado, showed a funnel-cloud, and nothing at all like this indefinite mass in the picture. The evidence is quite conclusive that on this day there were in this region several appearances simulating cloud-bursts, tornadoes, and sand-whirls. It is very probable that this photograph was that of a cloud-burst within two or three miles of Jamestown. It is highly improbable that either a cloud-burst or a tornado ever had a height exceeding two or three thousand feet. A photograph of a funnel-cloud showing details, and especially two or three photographs taken as the cloud comes up and passes by, would be of the highest interest, and invaluable at this stage of our studies.

H. A. HAZEN.

NOTES AND NEWS.

THE Norwegian Storthing, by 73 votes against 39, has voted a grant of 200,000 kroner for Dr. Nansen's north pole expedition, says *Nature*.

—The third international shorthand congress will be held at Munich from Aug. 7 to 17, says *Nature*. The centenary of F. X. Gabelsberger, the originator of modern German shorthand, will be celebrated by those who attend the meetings, and a bronze statue of him will be unveiled.

—The Entomological Club of the American Association will meet at 9 A.M., on Wednesday, Aug. 20, in the room of Section F, State House, where members of the club will register and obtain the club badge. The president is Professor A. J. Cook, Agricultural College, Mich.; secretary, F. M. Webster, Lafayette, Ind. Members of the club intending to contribute papers will send titles to the secretary. The Botanical Club will hold a meeting, as usual, on Thursday, Aug. 21, at the State House. Communications should be sent to the president, Dr. N. L. Britton, Columbia College, New York, or to the secretary, Dr. Charles R. Barnes, University of Wisconsin, Madison, Wis. The Society for the Promotion of Agricultural Science will hold its eleventh annual meeting in Indianapolis, beginning on Monday evening, Aug. 18, in the room assigned to Section I in the State House, and continuing on Tuesday. For further information address Professor W. R. Lazenby, secretary, Ohio State University, Columbus, O. The