crop was fruiting generally. The crop is in an excellent state of cultivation but needs rain. The plant is small, irregular, and, as a rule, ten days late. Cotton on upland is suffering, while on lowland the crop is holding out well. The dry weather has been very unfavorable for corn. Early corn has matured a good crop in some localities over the State, but, as a rule, it is very light. In some places much of the crop was cut for forage. The yield will be considerably below the average. Water for irrigating rice has not been sufficient for the needs of the crop in all localities, and in some places it has suffered. Rice which was dependent on rainfall for water is almost a failure.—*I. M. Cline.*

*Utah.*—The mean temperature was 63.3°, or 2.4° below normal; the highest was 109°, at Green River on the 30th, and the lowest, 19°, at Loa on the 14th. The average precipitation was 0.25, or 0.15 below normal; the greatest monthly amount, 0.97, occurred at Frisco, while none fell at Cisco, Promontory, St. George, and Terrace.

Dry farm wheat was badly damaged by the drought of the latter half of the month. Irrigated crops made fair advancement and were in good condition at the close of the month.—*L. H. Murdoch.*

*Virginia.*—The mean temperature was 72.3°, or 1.1° above normal; the highest was 103°, at Stephens City on the 30th, and the lowest, 40°, at Burkes Garden on the 1st. The average precipitation was 5.05, or 1.10 above normal; the greatest monthly amount, 14.37, occurred at Dale Enterprise, and the least, 1.40, at Ashland.

The month opened with wet weather prevailing and soil sodden. This was followed by bright, warm weather, during which crops made excellent growth and farm work was much advanced. After the 20th the weather became hot and the month closed with a heat wave of great severity prevailing. Wheat matured and harvesting was general during the latter half of the month.—*Edward A. Evans.*

*Washington.*—The mean temperature was 56.3°, or 3.8° below normal; the highest was 99°, at Pasco on the 18th, and the lowest, 26°, at Lind on the 5th. The average precipitation was 1.94, or 0.22 above normal; the greatest monthly amount, 8.33, occurred at Montecristo, and the least, 0.25, at Pasco.

The extraordinary coolness of the month prevented rapid growth and made corn and vegetables very backward, but the ample supply of rain and cool weather at filling season was very favorable for wheat. There was no good haying weather except in the eastern section.—*G. N. Salisbury.*

*West Virginia.*—The mean temperature was 70.7°, or 0.2° above normal; the highest was 104°, at Creston on the 30th, and the lowest, 32°, at Philippi on the 2d. The average precipitation was 5.67, or 1.38 above normal; the greatest monthly amount, 11.10, occurred at Spencer, and the least, 1.37, at Magnolia.

At the close of month wheat was filling well, although rather thin on the ground, and was beginning to turn with prospect of fair yield; meadows had improved but were weedy; oats were heading and corn was growing fast, but needed cultivation; early potatoes were promising, but late ones were not so good; apples had deteriorated considerably by dropping, but the prospect for peaches was excellent.—*E. C. Vose.*

*Wisconsin.*—The mean temperature was 67.4°, or about normal; the highest was 103°, at Brodhead on the 25th, and the lowest, 26°, at Medford on the 8th. The average precipitation was 4.17, or 0.16 below normal; the greatest monthly amount, 8.68, occurred at Ashland, and the least, 1.12, at Milwaukee.

Month moderately cool until last decade when extremely high temperatures occurred generally. Precipitation largely in excess of the normal over central and northern sections, while in the southern section the lack of rain was a serious menace to crops. Crops generally satisfactory, except along southern border, where the drought was becoming quite serious at the close of the month.—*W. M. Wilson.*

*Wyoming.*—The mean temperature was 57.5°, or 2.4° below normal; the highest was 98°, at Fort Laramie on the 29th, and the lowest, 20°, at Fort Yellowstone and Evanston on the 5th. The average precipitation was 1.79, or 0.19 above normal; the greatest monthly amount, 3.92, occurred at Parkman, and the least, 0.20, at Hyattville.—*W. S. Palmer.*

## SPECIAL CONTRIBUTIONS.

### SUN SPOTS AND THE WEATHER.

By H. H. KIMBALL, U. S Weather Bureau.

Numerous attempts have been made to show a relation between the variations in sun-spot frequency and the departures from normal weather conditions on our globe. Of these we need for the present only mention the following:

In 1880, Mr. Fred. Chambers[1] presented tables and diagrams showing that at certain stations within the Tropics there exists a periodicity of about eleven years in the curve representing the secular variations in the barometer, corresponding to the 11-year period in the curve of sun-spot frequency, the maximum of the pressure curve occurring at the time of minimum sun-spot frequency, and vice versa. He also undertook to show that a maximum of pressure was followed by a minimum of rainfall, and consequently by famines in India, but his deductions were questioned by Mr. E. Douglas Archibald, who showed that winter rains were quite apt to be abundant in northern India after a period of maximum pressure, and that no one rule could therefore be applied to the whole of India.

In 1894, Mr. W. L. Dallas,[2] after first accepting the theory that years of maximum sun spots are years of maximum solar radiation, advanced the theory that these years should also be years of increased activity in the atmospheric circulation, since, as is well known, the general circulation depends primarily upon a difference of temperature between the equator and the poles. Likewise, since years of maximum heat should be years of maximum evaporation, they should also be years of maximum rainfall, and this latter circumstance would exert such a modifying influence on the temperature of a country like India that the relative heating effect of the sun for the different years of the cycle might be entirely obliterated. Since the effects of the variations in the radiation from the sun could apparently best be studied in a tropical region as little under the influence of local conditions as possible, he selected for discussion observations taken on shipboard in the Bay of Bengal, and presented tables and diagrams showing in general the existence of a cycle of eleven years in the pressure and temperature variations. His pressure curve has the same general characteristics as that of Chambers, and his curve of temperature fluctuations coincides in a general way with the sun-spot curve, in that the years of maximum and minimum temperature occur at about the same time as the years of maximum and minimum sun spots.

In 1898, Prof. F. H. Bigelow presented a diagram[3] showing the relations between areas of sun spots, terrestrial magnetism, and certain elements of American weather for the years 1878–1893. His curves, showing the variations in sun-spot areas, terrestrial magnetism, and the barometric pressure for selected American stations, agree quite closely in their phases and characteristics, but the temperature curve is the reverse of these, the years of maximum temperature occurring during years of minimum sun spots, and vice versa. This is contrary to the relation found by Chambers in the Tropics, but is consistant with the modifications that Dallas pointed out might be introduced by local influences. Bigelow's theory of the relation between sun spots and the weather is, however, very different from the others we have mentioned.

In 1900, Sir Norman Lockyer and his son Dr. W. J. S. Lockyer presented to the Royal Society some conclusions[4]

[1] Abnormal variations of barometric pressure in the Tropics, and their relation to sun spots, rainfall, and famine. Nature, Vol. XXIII, pp. 88, 107, and 399.

[2] The relations between sun spots and weather as shown by meteorological observations taken on board ship in the Bay of Bengal during the years 1856 to 1879. Indian Meteorological Memoirs, Vol. VI, Part I, No. 1.

[3] Abstract of a report on solar and terrestrial magnetism in their relation to meteorology. W. B. Bulletin No. 21, p. 125.

[4] On solar changes of temperature and variations in rainfall in the region surrounding the Indian Ocean. Nature, volumn 63, pp. 107 and 128.

on the relations between sun spots and rainfall, based upon a study of the lines in the spectrum of sun spots and of the rainfall data of India, which may be summarized as follows:

(1) The sun is warmest at sun-spot maximum and coolest at sun-spot minimum.

(2) In India there is a maximum of rainfall at about the time of sun-spot maximum, and a secondary maximum at about the time of sun-spot minimum. In Mauritius there is a maximum of rainfall at the time of minimum sun spots.

(3) The dates of the beginning of the pulses in the rainfall of India and the Mauritius are related to the sudden remarkable changes in the behavior of the widened lines in the spectrum of sun spots.

(4) All the famines that have devastated India during the last half century have occurred in the intervals between the two pulses.

(5) Important variations are found in (1) the widened lines, (2) the rainfall of India, and (3) the Mauritius in connection with the maximum of 1893 as compared with the maximum of 1883; but the minimum of 1888–89 resembles the previous minimum of 1878–79.

(6) The lowest stages of the Nile have occurred between the same intervals as the Indian famines.

(7) The relation of the intervals in question to the droughts of Australia and Cape Colony and to the variations in rainfall in extra-tropical regions generally has not yet been investigated.

(8) Mr. John Eliot states that these deductions accord closely with the known facts of the abnormal features of the rainfall, temperature, and pressure of India during the past twenty-five years, and will be of great service in forecasting future famines.

At the time of maximum sun spots many of the widened lines of the spectrum of the spots can not be identified by means of charts of the lines of the solar spectrum, perhaps because they are enhanced, or high temperature lines. At any rate, the coincidence in the time of the occurrence of the maximum of sun spots and the maximum of these unknown lines, together with the increase in the number of eruptive prominences in the lower latitudes of the sun, is considered evidence that at this time the solar temperature reaches a maximum. The known lines of sun-spot spectrum reach a maximum when sun spots and eruptive prominences are at a minimum and when the solar heat is also supposed to be at a minimum. The curves representing the frequency of the known and unknown lines are very much flattened at the time of their maximum and minimum phases, and at some intermediate point they cross at quite a sharp angle. It is after these crossings, when either the known or unknown lines are on the increase, that the rainfall pulses have occurred, and it is previous to this, when the number of known and unknown lines is not changing perceptibly, that the Indian famines have occurred.

Ordinarily the crossings occur every five or six years, or twice during each 11-year cycle, as will be seen from the following table, which also shows the relation between the rainfall pulses for India and such crossings as have occurred since the known and unknown lines have been carefully observed and plotted.

| | Years. | | | |
|---|---|---|---|---|
| Crossings | 1881 | 1886 | 1892 | ..... |
| Rain pulses | 1881–84 | 1887–90 | 1892–94 | ..... |
| Indian famines | 1879–81 | 1884–86 | 1890–92 | 1896–97, 1899 |

The crossing that we would expect in 1897 has not yet occurred, showing that the interval between crossings is by no means regular. But the unprecedented famine of 1899 accords with the theory that the rain pulses commence at about the time of a crossing of the known and unknown lines and are of limited duration, and that in consequence famines may be expected during the years just preceding a crossing, and will be especially severe whenever the crossings are delayed.

A popular presentation of these facts, by Sir Norman Lockyer, in the North American Review for June, 1901, appears to have attracted a great deal of attention, and some inquiries and many clippings on the subject have found their way to the Weather Bureau. As is so often the case, many of the newspaper correspondents appear to have misunderstood the real object of these scientific investigations, which was, as stated by the Lockyers, to see if sun spots would aid in predicting the occurrence of famines in India. Except in a few cases they have not been able to study the relations between the crossings of the known and unknown lines of the spectrum of sun spots and the rainfall outside of India. In the valleys of the Nile and the Mississippi rivers they found evidence of rain pulses such as occur in India, while at other places no such pulses could be detected. Evidently, therefore, it is claiming too much, and certainly more than the Lockyers intended, to say that any general relation between sun spots, temperature, and rainfall, has been discovered that will apply to all regions of the globe. Neither are the claims that have been advanced by others consistent, since in one case we find the excessive heat of the summer of 1900 attributed to the general absence of sun spots, while in another case the absence of these spots is advanced as an indication of a cool, wet summer for this year.

That a very conservative attitude is maintained by Weather Bureau officials toward this question, is indicated by the following reply by the Chief of Bureau, dated June 13, 1901, to a letter from Maj. Henry Hammond, Beech Island, S. C., inquiring if the cold and wet weather of that section during the present season can be attributed to the 11-year sun-spot cycle:

*June* 21, 1901.

DEAR SIR: * * * I beg to advise you that the only relation between sun spots and terrestrial weather that appears to be definitely fixed is an increase in the number and violence of magnetic storms corresponding to years of maximum sun spots. No connection has thus far been shown between the spottedness of the sun and the fall of rain on this planet.

The low temperatures and the preponderance of rain in the South Atlantic States are due mainly to the paths taken by areas of low pressure moving across the United States from west to east. If in winter and spring these traveling areas of low pressure take a southerly course or move from the Gulf northeastwardly over the South Atlantic States, the weather will be cold and showery. If, on the other hand, the pressure is such that areas of high pressure move southeastwardly from the Lake region and lodge off the South Atlantic States, forming a semipermanent high in that region, warm, pleasant weather will result. During the month of May and thus far during June pressure has been remarkably low over the South Atlantic States, and there has been a relatively large number of rainy days. This condition is not a permanent one. In the ordinary course of events it should give way to the normal conditions for the season and the latitude.

## AN INSTANCE OF BALL LIGHTNING AT SEA.

By ROBERT SEYBOTH, U. S. Weather Bureau.

The description in a local paper of a recent display of ball lightning near Cumberland, Md., has induced the present writer to relate his personal experience with this rare phenomenon, of whose strange vagaries no satisfactory explanation has as yet been offered, and the actual occurrence of which has sometimes been doubted. It is indeed difficult to formulate a theory that will cover all the peculiar manifestations attributed to ball lightning, especially as regards shape, color, slow and erratic movement, and, finally, explosive effects.

But whether all its visual manifestations are physical realities, or whether they are partly the result of an optical illu-