p. 180. Francofurti, 1599; H. Billingsley, the first English translation of the "Elements of Euclid," Fol. 42. (London, 1570); N. Tartalea Brisciano, "Euclide," Fol. 32. (Venetia, 1565); J. Peletarius, "In Euclidis Elementa Geometrica Demonstrationum Libri sex." Prop. 32. *Appendix a Campano*, pp. 33, 34. (Lugduni, 1557).

It is much to be regretted that in this country so little importance is attached to the history of mathematics; otherwise, such mistakes as those mentioned by Mr. Tucker would not be repeated from one text book to another.

Galway, November 17. GEORGE J. ALLMAN.

Instruments of Precision at the Paris Exhibition.

IN your issue of November 15 (p. 61) is an account of "Instruments of Precision at the Paris Exhibition," in which it is stated that a catalogue of 250 pages has been prepared by the German Association of Mechanicians and Opticians. May I ask you to state in some future issue how that catalogue can be obtained, as I am anxious to get a copy of it?

E. T. WARNER.

H.M.S. *Britannia*, Dartmouth, November 21.

I AM much interested in the article in the number of NATURE for November 15, on optical and other instruments at the Paris Exhibition. Although I visited the exhibition, I did not see the exhibit, as I went too soon after the opening. I should much like to obtain the catalogue mentioned. Will you kindly tell me where I should be able to obtain one by writing for it?

H. DAVIDGE.

Seafield Park College, Crofton, Hants, November 17.

[For information as to the German Catalogue of Scientific Instruments, application should be made to Dr. Robert Drosten, Bureau de l'Exposition allemande des Instruments de Precision, Classe 15, Section 3, Exposition Universelle, Paris. If Dr. Drosten is not in Paris, letters will probably be forwarded. The secretary of the German Committee of Management is Prof. St. Lindeck, Reichsanstalt, Charlottenburg, Berlin, who no doubt would send a catalogue.—ED. NATURE.]

ON SOLAR CHANGES OF TEMPERATURE AND VARIATIONS IN RAINFALL IN THE REGION SURROUNDING THE INDIAN OCEAN.[1]

I.

THE fact that the abnormal behaviour of the widened lines in the spectra of sunspots since 1894 had been accompanied by irregularities in the rainfall of India suggested the study and correlation of various series of facts which might be expected to throw light upon the subject.

The conclusions already arrived at from bringing together the results of several investigations undertaken with this view may be stated as follows:—

(1) It has been found from a discussion of the chemical origin of lines most widened in sunspots at maxima and minima periods that there is a considerable rise above the mean temperature of the sun around the years of sunspot maximum and a considerable fall around the years of sunspot minimum.

(2) It has been found from the actual facts of rainfall in India (during the S.W. monsoon) and Mauritius, between the years 1877 and 1886,[2] as given by Blanford and Meldrum, that the effects of these solar changes are felt in India at sunspot maximum, and in Mauritius at sunspot minimum. Of these the greater is that produced in the Mauritius at sunspot minimum. The pulse at Mauritius at sunspot minimum is also felt in India, and gives rise generally to a secondary maximum in India.

India therefore has two pulses of rainfall, one near the maximum and the other near the minimum of the sunspot period.

(3) It has been found that the dates of the beginning of these two pulses on the Indian and Mauritius rainfall are related to the sudden remarkable changes in the behaviour of the widened lines.

(4) It has been found from a study of the Famine Commission reports that all the famines therein recorded which have devastated India during the last half century (we have not yet carried the investigation further back) have occurred in the intervals between these two pulses.

(5) It has been found from the investigation of the changes in (1) the widened lines, (2) the rainfall of India and (3) of the Mauritius during and after the last maximum in 1893 that important variations from those exhibited during and after the last maximum of 1883 occurred in all three.

It may be stated at the same time that the minimum of 1888-1889 resembled the preceding minimum of 1878-1879.

(6) It has been found from an investigation of the Nile curves between the years 1849 and 1878 that all the lowest Niles recorded have occurred between the same intervals.

(7) The relation of the intervals in question to the droughts of Australia and of Cape Colony, and to the variations in the rainfall of extra tropical regions generally has not yet been investigated. We have found, however, a general agreement between the intervals and the rainfall of Scotland (Buchan), and have traced both pulses in the rainfalls of Córdoba (Davis) and the Cape of Good Hope.

(8) We have had the opportunity of showing these results to the Meteorological Reporter to the Government of India and Director-General of Indian Observatories, John Eliot, Esq., C.I.E., F.R.S., who is now in England, and he allows us to state his opinion that they accord closely with all the known facts of the large abnormal features of the temperature, pressure and rainfall in India during the last twenty-five years, and hence that the inductions already arrived at will be of great service in forecasting future droughts in India.

Solar Physics Observatory, October 26.

ADDENDUM.

Since Meldrum and one of us called attention, in 1872 to a possible connection between sunspots and rainfall, there has been a large literature upon the subject which it is not necessary for us to analyse; it may be simply stated that, in spite of the cogent evidence advanced since, chiefly by Meldrum, and in later years by Mr. Hutchins,[1] it is not yet generally accepted that a case for the connection has been made out.

What has been looked for has been a change at maximum sunspots only; the idea being that there might be an effective change of solar temperature, either in excess or defect, at such times; and that there would be a gradual and continuous variation from maximum to maximum.

At the same time, it is possible that the pressure connection, first advanced by Chambers, is now accepted by meteorologists as a result of the recent work of Eliot.

The coincidence, during the last few years, of an abnormal state of the sun with abnormal rain in India, accompanied by the worst famine experienced during the century, suggested to us the desirability of reconsidering the question, especially as we have now some new factors at our disposal. These have been revealed by the study, now extending over twenty years, of the widened lines in sunspots, which suggested the view that two effects ought to be expected in a sunspot cycle instead of one.

[1] By Sir Norman Lockyer, K.C.B., F.R.S., and W. J. S. Lockyer, M.A. (Camb.), Ph.D. (Gött.). Paper read before the Royal Society on November 22.

[2] This period was selected because the Kensington observations of widened lines only began in 1879, and the collected rainfall of India has only been published to 1886.

[1] "Cycles of Drought and Good Seasons in South Africa, 1889."

The Widened Lines.

It will be gathered from previous communications to the Royal Society[1] that, on throwing the image of a sunspot on the slit of a spectroscope, it is found that the spectrum of a spot so examined indicates that the blackness of the spot is due, not only to general, but to selective absorption,[2] and that the lines widened by the selective absorption vary from time to time.

Since the year 1879, the *selective* absorption in spots has been observed for every spot that was large enough to be spectroscopically examined; the method adopted being as follows:—

The regions of the spectrum investigated lie between F—*b* and *b*—D, and an observation consists in observing the six most widened lines in each of these regions. These lines are then identified on the best solar spectrum maps available and their wave-lengths determined.

An examination of many years' records of these widened lines has shown that at some periods they are easily traceable to *known* elements, while at others their origins have not been discovered, so the latter have been classed as "unknown" lines. If we compare these two periods with the sunspot curve as constructed from the measurements of the mean spotted area for each year, it is found that when the spotted area is greatest the widened lines belong to the "unknown" class, while when the spotted area is least they belong to the "known" class.

The majority of the lines traced to some terrestrial origin belong to iron, but the lines of other elements, such as titanium, nickel, vanadium, scandium, manganese, chromium, cobalt, &c., are also represented in a less degree.

It is quite likely that some of the "unknown" lines are higher temperature (enhanced) lines of known chemical elements.

In our laboratories we have means of differentiating between three stages of temperature, namely, the temperature of the flame, the electric arc, and the electric spark of the highest tension. At the lowest temperature, that of the flame, we get a certain set of lines; a new set is seen as the temperature of the electric arc is reached. At the temperature of the high tension spark we again have many new lines, called enhanced lines, added, while many of the arc lines wane in intensity.

It is found that at sunspot minimum, when the "known" lines are most numerous, the lines are almost invariably those seen most prominent in the arc. Passing from the sunspot minimum towards the maximum the "unknown" lines gradually obtain the predominance. As said before, they may be possibly "enhanced lines"—that is, lines indicating the action of a much higher temperature on *known* substances.

Unfortunately the records of enhanced lines at South Kensington, having been obtained from photographs, are chiefly confined to a region of the spectrum not covered by the visual observations of widened lines in sunspot spectra.

We can only point to the evidence acquired in the case of one metal—iron, for which photographs of the enhanced lines in the green and yellow parts of the spectrum have been obtained.

This evidence quite justifies the above suggestion, for the enhanced lines of iron can be seen revealing themselves as the number of unknown lines increases.

We are, therefore, quite justified in assuming a very great increase of temperature at the sunspot maximum when the "unknown" lines appear alone.

The curves of the "known" and "unknown" lines have been obtained by determining for each quarter of a year the percentage number of known and unknown lines and plotting these percentages as ordinates and the time elements as abscissæ. Instead of using the mean curves for all the known elements involved, that for iron is employed, as it is a good representative of "known" elements, and has been best studied. When such curves have been drawn they cross each other at points where the percentage of unknown lines is increasing, and that of the iron or known lines are diminishing, or *vice versâ*.

We seem, therefore, to be brought into the presence of three well-marked stages of solar temperature.

When the curves of known and unknown lines cross each other, that is, when the number of known and unknown lines is about equal, we must assume a mean condition of solar temperature. When the unknown lines reach their maximum we have indicated to us a + pulse or condition of temperature. When the known lines reach their maximum we have a − pulse or condition of temperature.

The earliest discussion showed that, generally speaking, the unknown-lines curve varied directly, and the iron-lines curve varied inversely with the spot-area curve. The curves now obtained for the whole period of twenty years not only entirely endorse this conclusion, but enable more minute comparisons to be drawn.

The "widened line" curves are quite different from those furnished by the sun-spots. Ascents and descents are both equally sharp, changes are sudden, and the curves are relatively flat at top and bottom. The crossings are sharply marked.

During the period since 1879 three such crossings have occurred, indicating the presence of mean solar temperature conditions, in the years 1881, 1886-7,[1] and 1892. It was expected that another crossing with the known lines on the rise would have occurred in 1897, indicating thereby the arrival of another mean condition of solar temperature, but as yet no such crossing has taken place.

The following tabular statement shows the years of those crossings, together with the probable dates, in brackets, of the two previous crossings, as determined by the time of occurrence of the preceding sun-spot maximum.

Rise of	Years		
Unknown lines ...	(1869)	1881	1892
Known lines ...	(1876)	1886–7	?

Comparison of Solar and Terrestrial Weather.

It has long been known that a cycle of solar weather begins in about lat. 32° N. and S., and in a period of 11 years ends in about lat. 5° N. and S.

Just before one cycle ends another commences. The greatest amount of spotted surface occurs when the solar weather-changes produced in the cycle reach about lat. 16° N. and S.

It becomes, therefore, of the first importance to correlate the times of mean solar temperature, and of the + and − heat pulses, with the solar weather cycle, in order to arrive at the temperature-history of the sun during the period which now concerns us. This may be done as follows:—

Solar cycles				→				→		→
Lat. of spots	19°	16°	12°	9°	18°	17°	10°	7°	19°	18°
Heat condition	mean	+	mean	−	mean	+	mean	−	mean	+
Years	1869	1870–5	1876	1877–80	1881	1882–6	1886–7	1888–91	1891–2	1892–

[1] *Proc. Roy. Soc.*, vol. xl. p. 347, 1886; vol. xlii. p. 37, 1887; vol. xlvi. p. 385, 1889; vol. lvii. p. 199, 1894.

[2] *P.R.S.*, Lockyer, 1866, October 11.

[1] According to the observations the mean was reached in December 1886, or January 1887.

Connection of the Spots with Prominences.

In 1869, when a sun-spot maximum was approaching, the prominences were classified by one of us into *eruptive* and *nebulous;* the former showing many metallic lines, the latter the hydrogen and helium lines chiefly. This conclusion, which was published in 1870, was subsequently confirmed and adopted by Secchi, Zöllner, Spörer, Young and Respighi.

In the same year prominences on the sun's disc were also observed by one of us by means of the C and F lines.[1]

The eruptive prominences, unlike the nebulous ones, were not observed in all heliographic latitudes; but, according to the extended observations of Tacchini and Ricco, had their maxima in the same latitude as the spots. This is especially well shown by the diagrams illustrating the distribution of spots, faculæ, eruptions and protuberances which are given by Tacchini for 1881–1887 in the *Memoria della Soc. degli Spettroscopisti Italiani*, 1882–1888. These curves show in the most unmistakable manner that the spots, faculæ and eruptive or metallic prominences have their maximum frequency in the same solar latitudes while the nebulous or quiet prominences are more uniformly distributed, and even have maxima in zones where spots are rarely observed. This is corroborated by what Prof. Respighi many years ago stated:

"In correspondence with the maximum of spots, not only does the number of the large protuberances increase, but more than this—their distribution over the solar surface is radically modified."

In his observations, Prof. Young found that the H and K lines of calcium were reversed in the chromosphere as constantly as *h* or C, and the same lines "were also found to be regularly reversed upon the body of the sun itself, in the penumbra and immediate neighbourhood of every important spot."[2] This result was confirmed by the early (1881) attempts of one of us to photograph the spectra of the chromosphere and spots, and also by eclipse photographs. In the photographic spectrum, the H and K lines are by far the brightest of the chromospheric lines, and this fact has been utilised by Hale and Deslandres acting on a suggestion due to Janssen, for the purpose of photographing at one exposure the chromosphere and prominences, as well as the disc of the sun itself, in the light of the K line.

These photographs thus give us in K light the phenomena which one of us first observed by the lines C and F of hydrogen, and thereby present a record of the prominences across the whole disc of the sun as well as at the limb.

In such photographs near sunspot maximum, the concentration of the prominences in zones parallel to the equator is perfectly obvious at a glance. Eruptive or metallic prominences are thus seen to cover a much larger area than the spots, so that we have the maximum of solar activity indicated, not only by the increased absorption phenomena indicated by the greater number of the spots, but by the much greater radiation phenomena of the metallic prominences; and there seems little doubt that in the future the measure of the change in the amount of solar energy will be determined by the amount and locus of the prominence area.

Spots are, therefore, indications of excess of heat, and not of its defect, as was suggested when the term "screen" was used for them. We know now that the spots at maximum are really full of highly heated vapours produced by the prominences, which are most numerous when the solar atmosphere is most disturbed.

The Indian meteorologists have abundantly proved that the increased radiation from the sun on the upper air currents at maximum is accompanied by a lower temperature in the lower strata, and that with this disturbance of the normal temperature we must expect pressure changes. Chambers was the first to show that large spotted area was accompanied by low pressures over the land surface of India ("Abnormal Variations," p. 1).

[1] *P.R.S.*, 17, p. 415.

[2] "Catalogue of Bright Lines in the Spectrum of the Chromosphere" (1872).

Passing, then, from the consideration of individual spots to the zones of prominences, with which they are in all probability associated, it is of the highest interest to note the solar latitudes occupied when the crossings previously referred to took place, as we then learn the belts of prominences which are really effective in producing the increased radiation. The area of these is much larger, and therefore a considerable difference of radiation must be expected.

The greater disturbance of certain zones of solar latitude seems to be more influential in causing the + pulse than the amount of spotted area determined from spots in various latitudes.

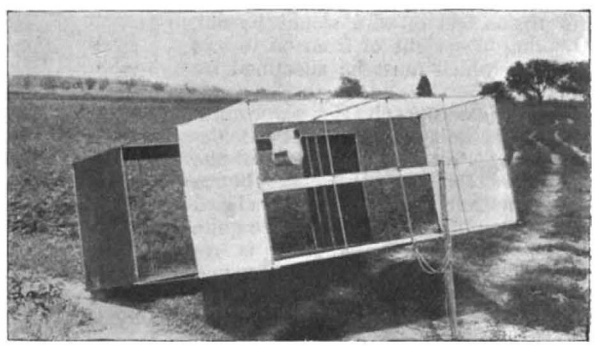
It is all the more necessary to point this out because the insignificance of the area occupied by the spots has been used as an argument against any easily recognised connection between solar and terrestrial meteorological changes.[1]

Assuming two belts of prominences N. and S., 10° wide, with their centres over Lat. 16°, a sixth of the sun's visible hemisphere would be in a state of disturbance.

(*To be continued.*)

THE KITE WORK OF THE UNITED STATES WEATHER BUREAU.

EARLY in the year 1898, the Congress of the United States granted a sum of money, to be expended under the direction of the Chief of the Weather Bureau, for the establishment and maintenance of a series of stations at which observations of the upper free air were to be made by means of automatically recording mechanisms attached to kites. This work was to be undertaken primarily in the hope that daily simultaneous



observations might be obtained at definite altitudes, thus permitting the construction of daily synchronous charts of pressure, temperature, and wind direction and velocity, which, when studied in connection with corresponding surface charts, would admit of some advance being made in the present system of weather forecasting, both in accuracy and in the duration of the periods forecasted for.

Seventeen stations were established in the spring of

[1] "So far as can be judged from the magnitude of the sun-spots, the cyclical variation of the magnitude of the sun's face free from spots is very small compared with the surface itself; and consequently, according to mathematic principle, the effect on the elements of meteorological observation for the whole earth ought also to be small" (Eliot, "Report on the Meteorology of India in 1877," p. 2).