of the moon and of the sky at various distances from it, to be compared, and a range of more than seventeen magnitudes was found to exist between the extreme values obtained. During the period covered by the report Mrs. Fleming classified the spectra and measured the light of 3506 stars, situated south of declination $-60°$, for the Southern Draper Catalogue. It is hoped that this zone will be completed shortly, and a catalogue containing nearly 4000 stars, all fainter than the ninth magnitude, published.

A large number of photographs have been obtained with the 13-inch Boyden and the 8-inch Bache telescopes at Arequipa, and a number of excellent light curves of Eros (from March 30 to August 19), showing a range of 0.5 to 1.0 magnitude, were obtained with the former instrument by Prof. Bailey. Four hundred and thirteen photographs, including eighty-seven of Eros, were obtained at the same station with the Bruce photographic telescope.

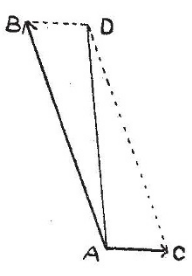
The meteorology of the upper air has been studied at the subsidiary observatory at Blue Hill, where fifteen kite flights, twelve of which were the monthly flights for the international series, were performed. The average height above sea-level attained by the meteorograph was 6450 feet, and the maximum height was 12,070 feet.

It is hoped that in a few months the Revised Harvard Photometry, containing the photometric magnitudes of all stars brighter than magnitude 6.5, about 9000 in all, together with the spectrum class of each star and its designation in other catalogues, will be published.

A set of fifty-five $8'' \times 10''$ contact prints from the original negatives, taken with the Harvard and Arequipa anastigmatic lenses, which cover the whole sky and contain all stars down to the twelfth magnitude, may be obtained by astronomers from the director for the sum of 15 dollars.

THE DIRECT AND RETROGRADE ROTATIONS OF THE PLANETS.—In a paper communicated to No. 3925 of the *Astronomische Nachrichten*, Prof. W. H. Pickering discusses the various theories which have been promulgated in explanation of the direct and retrograde rotations of the planets. Dismissing the theories of Laplace, Kirkwood, Faye and Trowbridge as insufficient, on the grounds that they presuppose abnormal conditions in the case of Neptune, and do not account for the perpendicular rotation of Uranus, he points out that the different motions may be explained by the tidal action of the sun in the following manner:—

Taking the case of Uranus as an example, let the line AB in the diagram represent the plane of the equator when this plane passes through the sun, let AC represent the plane of the planet's orbit and imagine the planet beyond the sun. Then the point A on the equator of the planet would, in the rotation, travel in the direction AB. The sun's attraction, in producing an annual tide, will produce a force AC acting on the particle A, with the consequence that A will travel along the resultant AD instead of along AB. This force AC will diminish during the planet's revolution until, after a quarter of a revolution, it will be zero. After half a revolution, when the plane of rotation again passes through the sun, the senses of both AB and AC will be reversed, but the effect on the planet's rotation will be the same as in the first case. This process will continue until ultimately the two planes will coincide when a direct rotation has been established.



THE "INVARIABLE PLANE" OF THE PLANETARY SYSTEM.—In No. 3923 of the *Astronomische Nachrichten*, Prof. T. J. J. See publishes the results of a detailed discussion of the accuracy of the data now available for the determination of Laplace's "Invariable Plane" of the planetary system. The elements of this plane are dependent upon the masses of the planets and the elements of their orbits, and the plane, when determined, would form a constant reference plane of great utility for the orbits of planets and comets. The transformations necessary to reduce star-places to this plane would be too cumbersome for practical utility.

Prof. See, in the first place, explains the mathematical process by which the elements of the plane are obtained when the planetary data are known, and then gives the results previously obtained. In the second part of his paper he reviews and discusses the values hitherto obtained for the mass of each of the planets, and deduces that for the mass of Jupiter, which, owing to its relatively large magnitude, acts as the most important factor of the reduction, the uncertainty does not amount to more than 0.0001 of the whole.

The elements obtained by Prof. See are as follows:—

$$\gamma = 1^\circ\ 35'\ 7''{\cdot}74, \quad 5☊ = 106^\circ\ 8'\ 46''{\cdot}688 \left\{ \begin{array}{l} \text{Ecliptic and mean} \\ \text{equinox 1850} \\ \text{Jan. 0·0 G.M.T.} \end{array} \right.$$

where γ = the inclination of the plane, and ☊ = the longitude of its ascending node on the fixed ecliptic of 1850.0.

In a subsequent table the author gives the longitudes of the ascending nodes and the inclinations of the planetary orbits on this "Invariable Plane," and, from a computation based on the relative positions of the planets at the epoch of 1850.0, he concludes that the actual shifting of the plane due to improvement in the data of the masses is not likely to exceed $1''$ for γ and $1'$ for ☊, a degree of accuracy approximating to that of our knowledge of the ecliptic and equator. He considers that a value for the inclination of which the probable error did not exceed $\pm 0''{\cdot}20$ would suffice for all practical considerations, and points out the importance of further work on the determination of the planetary masses, which only need to be a little more certain in order to produce this ideal result.

SIMULTANEOUS SOLAR AND TERRESTRIAL CHANGES.[1]

THERE are very many cases recorded in the history of science in which we find that the most valuable and important applications have arisen from the study of the ideally useless. Long period weather forecasting, which at last seems to be coming into the region of practical politics as a result of the observation of solar changes, is another example of this sequence.

The first indications of these changes on the sun, to which I have referred, are matters of very ancient history, and so also is the origin of some of the branches of observation on which the study of them depends.

I will begin by referring to these and to the conclusions arrived at in relation to simultaneous solar and terrestrial changes previously to the last twenty-five years.

The facts that there are sometimes spots on the sun, and that there is a magnetic force which acts upon a needle, seem to have been known to the ancient Chinese. In more modern times the inquiries, with which we are now concerned, date from the times of Galileo (1564–1642) and Kepler (1571–1630).

To Galileo, Fabricius, and Scheiner we owe the first telescopic observations of the spots on the sun; to Kepler, the basis of spectrum analysis, which has not only revealed to us the chemistry of the sun and of its spots, but enables us to study daily other phenomena, the solar prominences, which will in all probability turn out to be more important for practical purposes than the spots themselves.

It is only quite recently that the importance of the study of the prominences in this direction has been indicated, so that we have to deal, in the first instance, with a long period of years in which only the spots and their terrestrial echoes were in question.

According to Prof. Wolf (as quoted by Prof. Köppen), Riccioli, in 1651, shortly after the first discovery of sunspots, surmised that some coincidence might exist between them and terrestrial weather changes (Blanford, Bengal Asiat. Soc. *Journ.*, lxv., part ii., 1875, p. 22).

In the first year of the last century, Sir Wm. Herschel directed attention to this subject (*Phil. Trans.*, 1801, p. 265). He wrote:—

"The first thing which appears from astronomical observations of the sun is that the periods of the disappearance of spots on the sun are of much greater duration than those of their appearance.

1 Paper presented to the International Meteorological Committee at Southport, September 11, 1903. By Sir J. Norman Lockyer, K.C.B., F.R.S.

"With regard to the contemporary severity and mildness of the seasons, it will hardly be necessary to remark that nothing decisive can be obtained. An indirect source of information, however, is opened to us by applying to the influence of sunbeams on the vegetation of wheat in this country. I do not mean to say that this is a real criterion of the quantity of light and heat emitted by the sun, much less will the price of this article completely represent the scarcity or abundance of the absolute produce of the country.

"On reviewing the period 1650–1713, it seems probable, from the prevailing price of wheat, that some temporary scarcity or defect of vegetation has generally taken place when the sun has been *without* those appearances which we surmise to be symptoms of a copious emission of light and heat.

"To those acquainted with agriculture who may remark that wheat is well-known to grow in climates much colder than ours, and that a proper distribution of rain and dry weather are probably of much greater consequence than the absolute quantity of light and heat derived from the sun, I shall only suggest that those very circumstances of proper alternations of rain and dry weather and wind, &c., favourable to vegetation, may possibly depend on a certain quantity of sunbeams being supplied to them."

Herschel's suggestion was a daring one, for however perfect our national statistics may have been in relation to the price of wheat, there was nowhere kept up a continuous record of the changes observable on the sun's surface, nor had there been any serious attempt made to determine the law underlying them.

In 1825 this serious attempt was made, and by Schwabe of Dessau, who discovered a cycle of about eleven years in the solar changes. Wolf afterwards took up the question.

Herschel had associated the variation in the number of spots with that in the price of corn, the connecting link being sunshine or weather. It was to him a question of meteorology.

A year after the publication of Herschel's papers, Wollaston extended the early spectrum work of Kepler and Newton by discovering that in the solar spectrum there were many dark lines, these were for the first time mapped by Fraunhofer in 1814.

Soon after 1850 it became a question of the connection of sun-spots with terrestrial magnetism as well as with meteorology. A new idea was introduced.

Lamont, Sabine, and Allan Broun discovered that there was a well marked coincidence between the variations of magnetic effects, as observed on the surface of our planet by delicately suspended magnets, and the quantity of spotted area observed on the sun. This in later telegraphic days is not merely a pious opinion which does not interest anybody, because, when the magnetic changes are very considerable and the disturbances arrive at a maximum, it is very difficult to get a telegram from London to Brighton.

The period around the year 1860 was rendered ever memorable by a still further extension of Kepler's and Newton's work, which at once explained the dark lines observed in the solar spectrum by Wollaston and Fraunhofer.

Hitherto undreamt-of attacks on the nature of the sun became possible. The names of Kirchhoff, Bunsen, Ångström, Stokes, Balfour Stewart will go for very long down the stream of time, because they showed us that in spectrum analysis we had the power of practically conversing, chemically, with the distant worlds in space, and these distant worlds, of course, included the sun, although it is practically our neighbour.

It was now established that the solar radiation came from the incandescence of metallic vapours and gases in the sun's atmosphere, the metals and gases being for the most part those with which we are familiar on the earth. Not only was a high temperature demonstrated in this way, but it was further shown that above the sun's apparent surface there was an absorbing atmosphere, consisting of vapours cooler than those below, but yet hot enough to be composed of the steam of iron and other metals.

In 1865, De la Rue, Stewart, and others, in an attempt to get the periodicity of the solar phenomena still more accurately determined, started work at Kew; while the former observations were carried on by Schwabe and Wolf by the eye, photography, which was then being introduced into astronomical work by the labours of Warren De la Rue, was for the first time now utilised, and a picture of the sun was taken each day.

In 1866 a new method of observing solar changes, which consisted in throwing an image of the sun on the slit plate of a spectroscope, revealed the fact that the spectra of spots differed from that of the photosphere generally; certain lines were widened in the spot spectrum (Lockyer, *Proc.* Roy. Soc., October 11, 1866).

In 1867 a connection between changes in spotted area and in terrestrial temperatures was pointed out by Baxendell (*Memoirs* of the Manchester Lit. and Phil. Soc., third series, vol. iv., pp. 128 *et seq.*). He noticed a distinct and very striking relation between the number of sun-spots and the ratio which exists between the difference of the mean maximum temperature of solar radiation and the mean maximum air temperature on the one hand, and that of the mean temperature of the air and of evaporation on the other.

In 1868 a spectroscopic method was discovered of observing in full daylight the "prominences" or "red flames" which hitherto had only been glimpsed during eclipses, and it was established that, closely surrounding the sun ordinarily seen, there was an envelope, named the chromosphere, of incandescent gases and vapours, hydrogen, and a new substance named helium chief among them (Lockyer, *Proc.* Roy. Soc., October 20, 1868).

Many spectroscopic observations made on the spots and prominences about this time indicated great changes in the solar temperature in different regions, and possibly, therefore, changes in the amount of heat radiated earthwards. From the changes thus actually seen it was easy to imagine that there might be a cycle of terrestrial changes depending no longer on the sun's presentation to us in its daily and yearly rounds, but on physical changes in the sun itself, requiring, perhaps, many years to accomplish.

In 1869 Janssen showed (*Comptes rendus*, vol. lxviii. (1869), pp. 367 *et seq.*) that by a special arrangement of the spectroscope an image of the sun, showing the prominences both on the disc and surrounding it, might be obtained

It was not very long before it was found that the reaction of these solar changes on the earth was not so limited as had formerly been thought. This was an idea started by Dr. Stone, of the Royal Observatory at the Cape of Good Hope, Piazzi Smyth, of the Royal Observatory of Edinburgh, and others, about the years 1870 and 1871, but the most striking Imperial contribution to the matter we owe to the labours of a distinguished meteorologist, Dr. Meldrum, director of the observatory at Mauritius, which has since become the Royal Alfred Observatory. He showed that the number of wrecks which came into the harbour of the Mauritius and the number of cyclones observed in the Indian Ocean could enable anyone to determine the number of spots that were on the sun about the time. The Mauritius is most admirably suited for the making of these observations, because the tropics are really the right region in which to try and estimate the possibilities of this solar action. Meldrum found, in fact, that the maximum number of cyclones was associated with the maximum number of sun-spots. He wrote (NATURE, vol. vi. p. 357, 1872):—

"During the period 1847–72 it is found that some years have been remarkable for a frequency, and others for a comparative absence of cyclones.

"1847–51	were characterised by	cyclone frequency.
"1852–57	,, ,,	,, comparative calm.
"1858–63	,, ,,	,, cyclone frequency.
"1864–68	,, ,,	,, decrease.
"1868–72	,, ,,	,, great increase.

"It will be seen that the years correspond with the maxima and minima epochs of sun-spots. It appears to me that there is more than a mere coincidence as to time.

"The numbers of wrecks during these periods also show a similarly regulated frequency."

Poey, investigating shortly afterwards the cyclone condition in the West Indies (*Comptes rendus*, November 24, 1873, p. 1222), found that the greater number of years of maxima of storms fall from six months to two years, at the most after the years of maxima of solar spots.

Out of twelve maxima of storms, ten coincide with maxima periods of spots. Out of five minima of storms, five coincide with minima of spots.

It will be seen that the results from both the East and West Indies are the same. Next came the question of a rainfall cycle corresponding to the solar spots ("Solar Physics," Lockyer, 1874, p. 425).

When I was preparing to go to India, in 1871, to observe the eclipse, Mr. Ferguson, the editor of the *Ceylon Observer*, who happened to be in London, informed me that everybody in Ceylon recognised a cycle of about thirteen years or so in the intensity of the monsoon—that the rainfall and cloudy weather were more intense every thirteen years or so. This, of course, set one interested in solar matters thinking, and I said to him:—"But are you sure the cycle recurs every thirteen years, are you sure it is not every eleven years?" adding, as my reason, that the sun-spot period was one of eleven years or thereabouts, and that in the regular weather of the tropics, if anywhere, this should come out.

It afterwards turned out that the period in Ceylon was really of eleven years, five or six years dry and five or six years wet, and that a longer period of about thirty-three years was recognised.

Mr. Meldrum passed from cyclones to rainfall by a very obvious step, because cyclones are generally accompanied by torrential rains. A study of the rainfalls of Port Louis, Brisbane, and Adelaide led him to the conclusion that a case had been made out for a supposed periodicity.

On my return from India I looked up the Cape and Madras records for the periods available, and found that they followed suit, hence I quite agreed with Dr. Meldrum that investigations were desirable, and I wrote as follows ("Solar Physics," pp. 424–5):—

"Surely in meteorology, as in astronomy, the thing to hunt down is a cycle, and if that is not to be found in the temperate zone, then go to frigid zones, or the torrid zones and look for it, and if found, then above all things, and in whatever manner, lay hold of, study it, record it, and see what it means. If there is no cycle, then despair for a time if you will, but yet plant firmly your science on a physical basis, as Dr. Balfour Stewart long ago suggested, before, to the infinite detriment of English science, he left the Meteorological Observatory at Kew; and having got such a basis as this, wait for results. In the absence of these methods, statements of what is happening to a blackened bulb in vacuo, or its companion exposed to the sky, is, for research purposes, work of the tenth order of importance."

With reference chiefly to Dr. Meldrum's paper, I added:—

"Surely here is evidence enough, evidence which should no longer allow us to deceive ourselves as to the present state of meteorology. A most important cycle has been discovered, analogous in most respects to the Saros discovered by the astronomers of old, indeed, in more respects than one, may the eleven yearly period be called the Saros of meteorology, and as the astronomers of old were profoundly ignorant of the true cause of the Saros period, so the meteorologists of the present day are profoundly ignorant of the true nature of the connection between the sun and the earth.

"What, therefore, is necessary in order to discover the true nature of this nexus? Two things are necessary, and they are these. In the first place, we must obtain an accurate knowledge of the currents of the sun, and secondly, we must obtain an accurate knowledge of the currents of the earth. The former of these demands the united efforts of photography and spectrum analysis, and the second of these demands the pursuit of meteorology as a physical science, and not as a mere collection of weather statistics. When these demands are met—and in spite of the Mrs. Partingtons who are endeavouring to prevent this, they will soon be met—we shall have a science of meteorology placed on a firm basis—the meteorology of the future."[1]

At this time the Indian authorities were quite alive to the importance of such investigations as these. India is in the tropics, India is a child of the sun, the inhabitants depend almost entirely upon the beneficent rains which seemed, in some way or another, to depend upon solar action. India also had then the germs of one of the best equipped meteorological organisations which exist on the surface of the planet, and the meteorologists felt that there was something behind their meteorological registers which might be assisted by taking a very official step and going to headquarters, headquarters being the sun. When I was in India in 1872, Lord Mayo, the then Viceroy, did me the honour to ask me to go to Simla with the view of choosing a site for a proposed solar physics observatory. That is thirty years ago! Unfortunately, I was secretary of the Duke of Devonshire's Commission, which was then sitting, and I could not get leave, and therefore could not go; the scheme, which was then before the Indian authorities—which, if I may say so, was altogether grandiose and extravagant—fell through.

In 1873 the idea of the possible connection of solar and magnetic changes had got so far that the magnetic and meteorological department of the Royal Observatory at Greenwich, which had been established in 1838, received an important addition. A photoheliograph was set up in order to continue the daily photographic record of the sun's surface, begun at Kew in 1865.

In the same year Köppen found that the maximum temperature occurs in the years of sun-spot minima and the reverse; years with many spots are cool years.[1]

Of special importance for the connection between the temperature on the earth's surface with the sun's spotted area is the fact that the temperature curve (mean number for the whole earth) and the curve representing the sun-spotted area are identical in all the irregularities.

In the tropics in the

Year before the sun-spot *Min.*, the temperature is 0·41° higher than the mean.

Year before the sun-spot *Max.*, the temperature is 0·32° lower than the mean.

The variation is thus 0·73°

By this time spectroscopic observations of the solar changes had proved that the sun was hottest when there were most spots, thereby upsetting the old idea that the spots acted as screens and reduced the radiation at sun-spot maximum. Köppen's result, therefore, was a paradox, and was thus explained by Blanford (Bengal, Asiat. Soc. *Journ.*, 1875):—

"The temperatures dealt with by Prof. Köppen are of course those of the lowest stratum of the atmosphere at land stations, and must be determined *not by the quantity of heat that falls on the exterior of the planet, but on that which penetrates to the earth's surface, chiefly to the land surface of the globe.* The greater part of the earth's surface being, however, one of water, the principal immediate effect of the increased heat must be the increase of evaporation, and, therefore, as a subsequent process, the cloud and the rainfall. Now a cloudy atmosphere intercepts the greater part of the solar heat, and the re-evaporation of the fallen rain lowers the temperature of the surface from which it evaporates and that of the stratum of air in contact with it. The heat liberated by cloud condensation doubtless raises the temperature of the air at the altitude of the cloudy stratum; but at the same time we have two causes at work, equally tending to depress that of the lowest stratum. As a consequence, an increased formation of vapour, and therefore of rain, following on an increase of radiation, might be expected to coincide with a low air-temperature on the surface of the land" (see also Blanford, NATURE, April 23, 1891, vol. xliii. p. 583).

The next important advance had to do with atmospheric pressure. In 1875 Mr. F. Chambers, the director of the Bombay Observatory, found that

"The variation of the yearly mean barometric pressure at Bombay shows a periodicity nearly corresponding in duration with the decennial sun-spot period" (Meteorology, Bombay Presidency, August, 1875, S. 26, p. 12).

The years round 1875 were rendered very important by the number of new organisations established to record and

[1] I very much regret that, in the article quoted, my reference to Carlyle's German "Dry as dust," as a patient inquirer who would eventually apportion credit to all meteorological workers, has been misunderstood by some of my German friends. Relying on imperfect dictionaries, which have told them that a mere "bookworm" was meant, they have missed the high compliment I intended to pay them.

[1] W. Köppen, "Über mehrjährige Perioden der Witterung" (*Zeitschrift. f. Meteorologie*, Bd. viii., 1873, pp. 241–248 and 257–268).

demonstrate various classes of observations with which we are concerned in this short history. Meteorological inquiries on a large scale were organised at home and in India, and observatories were established at Potsdam, Paris, and London, with the main object of studying solar changes. At the same time steps were taken to resume observations in the tropics. It is not out of place here to make a brief reference to what was done in Britain and in India.

The Government took this action in consequence of a strong recommendation of the Royal Commission on Science, presided over by the late Duke of Devonshire, for the establishment by the State of an observatory of solar physics in which inquiries relating to the nature of the sun and its changes should be fostered, and various investigations which were necessary should be carried on.

The commission also proposed that similar institutions should be established in various parts of the Empire.

The ground on which the Royal Commission, and subsequently a memorial presented to the Government by the British Association, urged this new departure was that, in the opinion of a considerable number of scientific men, there was a more or less intimate connection between the state of the sun's surface and the meteorology of the earth, and they directed attention to the fact that recent independent investigations on the part of several persons had led them to the conclusion that there was a similarity between the sun-spot period, periods of famine in India, and cyclones in the Indian Ocean. The memorialists concluded by saying:—

"We remind your Lordships that this important and practical scientific question cannot be set definitely at rest without the aid of some such institution as that the establishment of which we now urge."

The Lords of the Committee of Council on Education referred this memorial to a committee, consisting of Prof. Stokes, Prof. Balfour Stewart, and General Strachey, for their opinion as to whether a commencement might not be made to give effect to the proposals of the memorialists by utilising the chemical and physical laboratories at South Kensington, as the proposed observatory must be more chemical and physical than astronomical. The following paragraph appeared in the terms of reference:—

"Although we are not at present in a position to consider the establishment of a physical observatory on a comprehensive scale, we believe that some advantage can be gained if a new class of observations can be made with the means at command, since the best method of conducting a physical laboratory may thus be worked out experimentally, and an outlay eventually avoided which, without such experience, might have been considered necessary."

While the discussion as to the establishment of a solar physics observatory in this country was going on, Lord Salisbury, who was then Secretary of State for India, permitted me to send him a memorandum on this subject. In it I pointed out that what we wanted, especially in reference to solar inquiries, was to learn, day by day, what the sun was really doing, which India and other tropical countries always could tell us, while it seemed almost impossible that we should ever get sufficiently continuous records in England.

I gave the following extracts:—

"Solar research is now being specially carried on in Europe at—

"(1) Potsdam, in the new Sonnenwarte.

"(2) Paris, in the new physical observatory.

"(3) Rome and Palermo.

"(4) South Kensington, in connection with the Science and Art Department.

"(5) At Greenwich, Wilna, and other places it is carried on in a less special way.

"In these European observatories, however especially in the more northern ones, we are attempting to make bricks without straw, that is, the climate is such that the observations are often interrupted, at times for weeks together, while, in addition to this, in winter the sun's altitude is so small that fine work is impossible.

"While this state of things holds in Europe, in India, on the other hand, one has an unlimited and constant supply of the *raw material*, by which I mean that here one can, if one chooses, obtain observations of the finest quality in sufficient quantity all the year round. I may even go further, and say that, limiting my remark to English ground, we have in India a *monopoly* of the raw material."

The prayer of the memorandum was granted, and shortly afterwards I had the pleasure of sending out one of my assistants to India. Unfortunately, he died soon after the first series of daily photographs of the sun had been commenced, but eventually the Trigonometrical Survey Department took the matter up, an observatory was built at Dehra Dun, and India began its work, and I am thankful to say that it has gone on continuously ever since.

It was not until 1879, and after a letter from the Duke of Devonshire, that a sum of 500*l.* was taken on the estimates to replace the assistance formerly obtained by myself from the Government Grant Fund administered by the Royal Society, and to allow of more research work being undertaken. At the same time the Solar Physics Committee was appointed. The object sought was to make trial of methods of observation, to collect and discuss results, to bring together all existing information on the subject, and to endeavour to obtain complete series of observations along the most important lines.

This State action was taken because the sun has to be studied, if studied at all, continuously, because it is ever changing, and the more we study it the longer are the cycles which we find to be involved; hence, all inquiries into its nature must be on an Imperial basis. Individuals die, nations remain. Nor is this all. Observatories are not only wanted in the centres of intellectual activity where research can be conducted in a scientific atmosphere, but there must be others to obtain the necessary observations in those favoured regions of our planet in which the maximum of sunshine can be depended upon.

The then Astronomer Royal, Sir George Airy, was most sympathetic, and as a result of this State action the little observatory at South Kensington was shortly afterwards enlarged; it has considerably grown since then, but it is still in the experimental stage. Although, perhaps, I am not the one to say it, I am prepared to take the responsibility of stating that it is now one of the best equipped for its special work in the world. It certainly is the shabbiest to look at. Irreverent comparisons have been made even in the House of Commons, the general appearance of its wood and canvas huts having been likened to that of a more or less disreputable looking travelling menagerie, but, at all events, it is instrumentally efficient, and that for the present must be sufficient.

During the last quarter of a century a great deal of work has been going on, and the colonies and dependencies of Britain have also been doing yeoman service; very little has been said about it, because not all departments are in the habit of advertising themselves, and Blue Books are not as a rule light reading. In the first place, the Indian daily photographic record, which was weak during a month or two during the south-west monsoon, was supplemented by the erection of a duplicate instrument at the Mauritius, and I am again thankful to say that the work has gone on at the Mauritius continuously since. Thus we have now two tropical records, which, taken together, may be described as absolutely continuous, of solar changes sent to us in the most Imperial fashion by two observatories. Another appeal was made to Australia. For a time records were sent us, but I am sorry to say that after a time they ceased.

These records are sent regularly with every precaution against loss to the observatory at South Kensington, and for the days when no photographs have been taken at Greenwich the necessary photographs are transmitted there, where they are reduced in continuation of the record commenced in 1873 there, in succession to Kew.

What has been the result of this? The late Astronomer Royal took up this work at Greenwich in 1873. In 1874, 1875, 1876, 1877, 1878, the average number of days on which it was possible to obtain photographs in each year was a little more than 160, the exact figures being 159, 161, 167, 171, 149. This was Greenwich working alone, national work.

Next, we come to the Imperial work. Selecting years at random, and dealing with 1889 to 1893, I find that we obtained photographs of the sun in 1889 for every day in the year except five, in 1890 for every day except four, in 1891 for every day except two. It is easy to understand that with such a magnificently complete record as this the study of solar physics was enormously improved.

Very fortunately for science, even before these steps were being taken to secure a continuous record of the spotted area, Prof. Respighi (1869) and Prof. Tacchini (1872) had commenced at Rome a daily record of the solar prominences and of the latitudes at which they appeared at different times.

I pass on to some of the most important work done during the last quarter of a century, only referring to the results obtained which bear upon the connection between solar and terrestrial changes.

Many important advances were made in 1878.

Mr. F. Chambers, in continuing his studies on the Indian barometer, found (NATURE, vol. xviii. p. 567) a remarkable degree of resemblance in the progression of barometric pressure during summer, winter, and year, and sun-spots from year to year, but he noted that the barometric curve *lags* behind the sun-spot curve, particularly in the years of maxima of sun-spots. The winter curve is more regular than the summer one, probably because the weather generally in India is more settled in the winter than in the summer, but on the whole the two curves support each other in having a *low pressure* about the time of *sun-spot maximum*, and a high pressure about the time of sun-spot minimum. We may therefore conclude that the *sun is hottest* about the time when the *spots are at a maximum*. He added that these results appear to harmonise well with the decennial variations of the rainfall in India, and to throw light upon the inverse variation (compared with the sun-spots) of the winter rainfall of northern India.

Dr. Allan Broun also, in a discussion of Indian barometric readings, found that the years of greatest and least pressure are probably the same for all India, and that, therefore, the relation established by Mr. Chambers for Bombay holds for all India (NATURE, vol. xix. p. 6).

I next pass to rainfall. Dr. Meldrum, returning to his rainfall studies, found that (NATURE, vol. xviii. p. 565)

"There is a remarkable coincidence between the rainfall and sun-spot variation at Edinburgh, much more remarkable than that at Madras. The years of maximum and minimum rainfall, and sun-spots for the mean cycles, coincide, and on the whole there is a regular gradation from minimum to maximum, and from maximum to the next minimum."

The minimum rainfall occurred, on an average, in the year immediately preceding the year of maximum sun-spots.

The results of these investigations show that the rainfall of fifty-four stations in Great Britain from 1824–1867 was 0·75 inches *below mean* when sun-spots were at a minimum, and 0·90 inches *above mean* when sun-spots were at a maximum.

For the thirty-four stations in America, the corresponding numbers were 0·94 inch and 1·13 inch.

In the report of the Meteorological Department of the Government of India, published this year (1878), the following reference to solar action occurs:—

"The following are the main important inferences that the meteorology of India in the years 1877–1878 appears to suggest, if not to establish:—

"There is a tendency at the minimum sun-spot periods to prolonged excessive pressure over India, and to an unusual development of the winter rains, and to the occurrence of abnormally heavy snowfall over the Himalayan region. . . . This appears also to be accompanied by a weak south-west monsoon."

In 1880 the relation of Indian famines and the barometer was first fully treated by Mr. F. Chambers, the meteorological reporter for western India (NATURE, vol. xxiii. p. 109). He concluded from his inquiry that there is some intimate relation between the variations of *sun-spots, barometric pressure*, and *rainfall*, and as famines in general are induced by a deficiency of rain, it is probable that they also may be added to the above list of connected phenomena.

Commencing with the daily abnormal variations observed at several stations in western India, it was found that as the time over which an abnormal barometric fluctuation extended became longer and longer, the range of the fluctuation became more and more uniform at the various stations, thus leading to the conclusion that the "*abnormal variations of long duration affect a very wide area.*" For testing this, the conditions of Batavia were compared with those at Bombay, and the results showed a striking coincidence, the curves obtained for the two places being almost identical in form, but with this remarkable difference, the curve for Batavia was found *to lag* very persistently about one month *behind* the Bombay curve.

Similar results were then worked out for other stations, St. Helena, Mauritius, Madras, Calcutta, and Zi-ka-wei. On comparing the curves obtained for these various places, though a strong resemblance in form between all the curves is observed, there is also strong evidence of a want of simultaneity in the barometric movements at different stations, and as a rule the changes take place at the *more westerly stations* several months *earlier than* at the more *easterly ones*.

Thus on comparing the curves for St. Helena and Madras from 1841–1846, the latter sometimes lagged behind the former as much as six months, and for Bombay and Calcutta the corresponding difference was often upwards of six months.

The facts suggested to him long atmospheric waves (if such they may be called) travelling at a very slow and variable rate round the earth, from *west to east*, like the cyclones of the extra-tropical latitudes.

With special reference to famines, he remarked that, on comparing the dates of all the severe famines which have occurred in India since 1841, widespread and severe famines are generally accompanied or immediately preceded by waves of high barometric pressure. He suggested, therefore, that intimation of the approach of famines might be obtained in two ways:—

(*a*) By regular observations of the solar spotted area and early reductions of the observations, so as to obtain early information of current changes going on in the sun.

(*b*) By barometric observations at stations differing widely in longitude, and the early communications of the results to stations situated to the eastward.

In the same year, Dr. H. F. Blanford discovered that (NATURE, vol. xxi. p. 480)

"Between Russia and Western Siberia on the one hand, and the Indo-Malayan region on the other, there is a reciprocating and cyclical oscillation of barometric pressure, of such a character that the pressure is at a maximum in *Western Siberia* and *Russia* about the epoch of maximum sun-spots, and in the *Indo-Malayan area* at that of minimum sun-spots."

Up to 1881, the general idea had been that there was a great difference between the meteorological conditions at the maximum and minimum of the sun-spot curve, but the more numerous and more accurate series of observations available in the year in question revealed to Meldrum "extreme oscillations of weather changes in different places at the turning points of the curves representing the increase and decrease of solar activity."

This was a most important change of front. Not the maximum only, but both the maximum and minimum had to be considered ("Relations of Weather and Mortality, and in the Climatic Effect of Forests").

In relation to these pressure changes Blanford wrote as follows (NATURE, vol. xxi. p. 482):—

"Among the best established variations in terrestrial meteorology which conform to the sun-spot cycle, are those of tropical cyclones, and the general rainfall of the globe, both of which imply a corresponding variation in evaporation and the condensation of vapour. Now the variation of pressure with which we have to deal evidently has its seat in the higher (probably the cloud-forming) strata of the atmosphere. This is not only illustrated in the present instance by the observed relative excess of pressure at the hill stations as compared with the plains, but also follows as a general law from the fact established by Gautier and Köppen, viz., that the temperature of the lowest stratum varies in a manner antagonistic to the observed variation of pressure. It is then a reasonable inference that the principal agency in producing the observed reduction of pressure at the epoch of sun-spot maximum is the more copious production and ascent of vapour, which may operate in three different ways. First, by displacing air the density of which is three-eighths greater; second, by evolving latent heat in its condensation; and thirdly, by causing ascending currents, and thus reducing dynamically the pressure of the atmosphere as a whole. The first and second of these processes do not indeed directly reduce the pressure but only the density of the air stratum while they increase its volume. In order, therefore, that the observed effect may follow, a portion of the higher atmosphere must be removed, and this will necessarily flow away to regions where the production of vapour is at a minimum, viz., the polar and cooler portions of the temperature zones, and more especially those where a cold dry land surface radiates rapidly under a winter sky. Such an expanse is the great northern plain of European Russia and Western Siberia north of the Altai."

In 1886 we got the first fruits of the observations of the widened lines in sun-spots, which had been obtained on a definite plan, since 1879. The changes which occurred from a spot-minimum to a spot-maximum, and some distance beyond, had therefore been recorded. The changes were most marked, showing a great change in the chemistry of the spots at these times. At minimum the lines chiefly widened were those of iron and some other metals, but at the maximum the lines widened were classed as "unknown," because they had not been recorded in the spectra of the terrestrial elements. It was reasonable to suppose, therefore, that the sun was not only hotter at maximum, but hot enough to dissociate iron vapours (*Proc.* Roy. Soc., 1886, p. 353).

In 1891 Janssen's suggestion of 1869 was brought into a practical shape for observatory work by Hale and Deslandres (*Comptes rendus*, August 17, 1891), and the prominences on the sun's disc and surrounding it were photographed in full daylight by using only the light radiated by the calcium vapour, which they always contain.

By the year 1900 we had accumulated at South Kensington observations of the widened lines for a period of more than twenty years. There was a curious break in the regularity of the results obtained after 1894, and the Indian meteorologists reported contemporaneous irregularities in the Indian rainfall.

I determined, therefore, to make a connected inquiry into both these classes of phenomena. Thanks to the establishment of the Indian Meteorological Department in 1875, we had rainfall tables extending over a quarter of a century, and in the tropics, where the problems might be taken as of the simplest, to compare with the new solar data.

I have already stated that in the preliminary discussion of the most widened lines observed in the sun-spots up to the year 1885 a most remarkable difference was observed in the lines observed at sun-spot maximum and minimum. This continued until about 1895, another ten years. As the curve of iron lines went up, the curve of "unknown" lines came down; there were therefore *crossings* of the curves which might, on the hypothesis before referred to, be taken as the times at which the temperature of the sun had a mean value. These crossings turned out to be about half-way between the maxima and minima of the spotted area which had to be considered as the times at which the sun was hotter and colder than the mean.

We were then brought into the presence of three well-marked stages of solar temperature—it was no longer a question merely of spots and no spots, but of heat pulses.

The next point was to study these heat pulses in relation to the Indian rainfall, and it was found that in many parts of India the plus and minus heat pulses on the sun, which, of course, occurred immediately after the time of mean temperature, when the sun was getting either hotter or colder, were accompanied by pulses of rain in the Indian Ocean and the surrounding land. It was next found, from a study of the Indian Famine Committee's reports, that the famines which have devastated India during the last half century have occurred in the intervals between the pulses.

In 1902, with the view of getting more light on the important issues raised by the comparison of the solar heat pulses and the Indian rainfall, I determined to reduce the observations of prominences made by Tacchini at the Observatory of the Collegio Romano since 1874, and to compare the Indian meteorological conditions with them. The reason for this step was that the admirable photographs of the prominences on the solar disc, published by Hale and Deslandres, showed the extensive area over which they were distributed. An argument which has been used against the possible connection between solar and terrestrial changes was based upon the small area covered by spots. In 1877 Eliot wrote as follows (Report on the Meteorology of India, 1877, p. 2):—

"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 mathematical principle, the effect on the elements of meteorological observations for the whole earth ought to be small."

Now the photographs to which I have referred exhibited broad bands of prominences extending almost across the whole disc, and if we assume two belts of prominences, north and south, 10° wide, with their centres over latitude 16°, a sixth of the sun's hemisphere would be in a state of disturbance. Hence it followed that the prominence effect, when fully studied, might be much more striking and important than that produced by spots.

The prior work in connection with the Indian rainfall had shown not only that there was a close connection between pressure and rainfall, but that the pressure was much the more constant element over the different areas. The comparison with the prominences obtained from the discussion of Tacchini's results was in the first instance compared with the Indian pressure curve.

The result was magnificent In addition to the well-marked prominence maximum at the maximum of the spotted area, there were others corresponding approximately with the "crossings" of the widened lines, and all were re-echoed by the Indian barometers!

The sun-spot cycle of eleven years gave way to a prominence cycle of about 3·7 years, and by this interval, as a rule, are the Indian pressures separated.

To see whether such a striking and important result as this was limited to Indian ground, the important series of pressure observations obtained at Cordoba in South America were studied. Here the same effect was also most marked, but with the important difference that the curves were inverted, that is, high pressure years in India were represented by low pressure years in Cordoba.

In order to extend the Indian and Cordoba areas and to see how far these conditions prevailed, the pressure variations of stations as widely distributed as possible were examined. The result of this inquiry showed that the world might be divided roughly into two portions. The Indian area was found to extend to Australia, East Indies, Asiatic Russia, Mauritius, Egypt, East Africa, and Europe, while the Cordoba region might be said to include not only South and Central America, but the United States and Canada, extending further west than Honolulu.

The discovery of this barometric surge, which has been corroborated since by Prof. Bigelow, was an important advance, and will enable the investigator to connect up regions that undergo similar pressure changes.

In addition to the two periods, namely, 11 and 3·7 years, mentioned above, Brückner ("Klimaschwankungen," Eduard Brückner, Vienna, 1890) has pointed out that there is a long period weather variation. His discussion of all the available data of pressure, rainfall, temperature, &c., led him to conclude that there is a periodical variation in the climates over the whole earth, the mean length of this period being about thirty-five years.

Since this work, a recent discussion of the sun-spot data by Dr. W. J. S. Lockyer (*Proc.* Roy. Soc., vol. lxviii. pp. 285–300) has brought to light a similar long period, and this has taught us that each eleven-year cycle is different from the one immediately preceding and that following it.

A further inquiry into the distribution of the solar prominences, as observed by Respighi, Secchi Tacchini, Ricco, and Mascari (*Memorie* della Societa degli Spettroscopisti Italiani), has resulted in increasing our knowledge of the circulation of the solar atmosphere. The centres of prominence action, or the centres of the prominence belts, have a tendency to move from low to high latitudes, the opposite of spots; generally speaking, two belts in each hemisphere exist for some time, then they couple up and move towards the solar poles, while in the meantime a new belt begins to form in low latitudes (*Proc.* Roy. Soc., vol. lxxi. pp. 446–452).

The existence of prominences in the polar regions is coincident with great magnetic disturbances on the earth just previous to or about the time of sun-spot maxima (*ibid.*, pp. 244–250). Further, these polar prominences are responsible for the existence of large coronal streamers near the solar poles, as seen during solar eclipses about the time of sun-spot maximum. In fact, recent research seems to indicate that this prominence circulation is intimately associated with all the different forms of the corona (*Monthly Notices* R.A.S., vol. lxiii., 1903).

There seems little doubt, therefore, that we must look to the study of the solar prominences not only as the primary factors in the magnetic and atmospheric changes in our sun, but as the instigators of the terrestrial variations.

In dealing with solar phenomena, especially from a meteorological point of view, it is of great importance that the solar disc be treated in zones and not as a whole.

Just as it has been shown that the prominences sometimes exist in three zones in one hemisphere at one time, so is this the case with spots, but unfortunately it is only very recently that the phenomena occurring in each hemisphere have been treated in this manner.

It has already been pointed out that a possible connection existed between changes in the spotted area of the sun and terrestrial temperatures. Quite recently this question has been studied by Charles Nordmann (*Comptes rendus*, No. 18, May 4, 1903, vol. cxxxvi.), who finds that

"The mean terrestrial temperature exhibits a period sensibly equal to that of solar spots; the effect of spots is to diminish the mean terrestrial temperature, that is to say, the curve which represents the variations of this is parallel to the inverse curve of the frequency of solar spots."

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—Four resolutions referring to compulsory Greek were submitted to Congregation on Tuesday. The resolution permitting candidates intending to read for the honour school of natural science to offer a substitute for Greek was carried by a majority of 2, the voting being 164 in favour and 162 against. The second resolution, giving the same option to honours students in mathematics, was approved by a majority of 29—the voting being 131 and 102. The two remaining resolutions providing alternative subjects for Greek in the examination in Holy Scripture, and in Responsions, were agreed to without a division. The resolutions will now be embodied in a Statute by Council, and will be submitted to Congregation and Convocation in due form.

The 255th meeting of the Oxford University Junior Scientific Club was held at the museum on Wednesday, February 3. Mr. J. F. Hornsey, Wadham, read a paper on "Photographic Films," with numerous exhibits. The following are the officers elected for this term:—President, Mr. W. E. Smith, Balliol; biological secretary, Mr. P. T. Spencer-Phillips, New College; chemical secretary, Mr. B. M. Jones, Balliol; treasurer, Mr. C. P. D. A. Pereira, Keble; editor, Mr. G. P. Poulton, Balliol.

CAMBRIDGE.—It is announced that when His Majesty the King visits the university on March 1 for the purpose of opening the new museums and medical school, he will be accompanied by the Queen and by Princess Victoria.

Mr. C. E. Inglis, King's, and Mr. A. H. Peake, St. John's, have been reappointed demonstrators in mechanism and applied mechanics.

Recent donations to the benefaction fund have raised the total to 71,658*l*. A number are specially ear-marked for various scientific departments.

The Balfour studentship, vacant by the untimely death of Mr. J. S. Budgett, will be filled up in the Easter term. The studentship is of the value of 200*l*. a year; the student need not necessarily be a member of the university, and he must devote himself to original research in animal morphology. Application is to be made to the registrary, Mr. J. W. Clark.

Dr. Guillemard, Prof. Darwin, Dr. Marr, Prof. Bury, and Dr. A. W. Ward have been appointed members of the newly created Board of Geographical Studies.

The following have been appointed electors to the chairs respectively named:—Prof. Thomson, F.R.S. (chemistry), Prof. Larmor, Sec.R.S. (Plumian of astronomy), Sir M. Foster, F.R.S. (anatomy and Downing of medicine), Prof. Allbutt, F.R.S. (botany and physiology), Mr. A. C. Seward, F.R.S. (geology), Sir William Ramsay, F.R.S. (Jacksonian of chemistry), Prof. Liveing, F.R.S. (mineralogy and agriculture), Mr. J. W. Clark (zoology), Prof. R. B. Clifton, F.R.S. (Cavendish of physics), H. Darwin, F.R.S. (mechanism), Sir Frederick Treves, Bart. (surgery), Prof. Muir (pathology).

Prof. Marshall Ward, Prof. Hughes, Mr. R. H. Adie, Mr. T. B. Wood, Prof. Middleton, Mr. A. E. Shipley, Mr. J. H. Widdicombe, and Mr. W. McCracken have been appointed examiners for the diploma in agriculture.

DR. H. KENWOOD has been appointed professor of hygiene at University College, London, in succession to the late Prof. W. H. Corfield.

IT is stated by *Science* that by the will of the late Mr. Charles F. Doe, of San Francisco, more than 100,000*l*. is bequeathed to the University of California for a library.

AMONG the names of those upon whom the Senatus Academicus of the University of St. Andrews has resolved to confer the honorary LL.D. at its annual graduation ceremony in March next are those of Prof. A. H. Keane and Prof. J. N. Langley, F.R.S.

MR. FREDERICK PURSER, fellow of Trinity College, Dublin, has, says the *Lancet*, presented a sum of 2000*l*. to the equipment fund of Queen's College, Belfast, to found a studentship in mathematics in memory of his brother, the late Prof. John Purser, of Queen's College, Belfast.

IN a pamphlet published by Messrs. Ginn and Co., Prof. J. W. Adamson, professor of education in King's College, London, deals with what he calls our defective system of training teachers. He argues that "professional training is a post-graduate business. The general, as distinct from technical, studies of the teacher are admittedly part of his professional equipment, since he cannot teach what he does not know, and mental gymnastic is at least as necessary for him as for the layman. Nevertheless, it remains true that purely technical instruction is also requisite, while the teacher's general culture, whether of the university or other type, should not be inferior in range or depth to that of the layman of similar intellectual status." He consequently urges that the general education of the teacher should be separated from technical instruction, the first being more or less completed before the second is begun.

THE following appointments are announced in the current number of the *Physikalische Zeitschrift*:—Dr. Ludwig Berend, professor of chemistry at the University of Kiel Dr. Paul Spies, professor of physics at the Royal Academy of Posen; Prof. H. Berg, professor of mechanical engineering at the Stuttgart Technical School; Dr. Eberhard Rimbach and Dr. Georg Frerichs, professors of chemistry at Bonn; W. Wendelin, of Vienna, professor of electrotechnics and applied mechanics at Leoben; and Dr. Frederik Carl Mulertz Strömer, professor of mathematics at Christiania in succession to the late Prof. C. A. Bjerknes. Prof. Herrmann Struve is to succeed Prof. Wilhelm Förster as professor of astronomy at the University of Berlin, and Dr. Robert Freiherr Daublebsky von Sterneck has been transferred from Vienna to the chair of mathematics in the University of Czernowitz. The course of lectures at Bonn on chemistry of foodstuffs has been placed in the hands of Prof. Karl Kippenberger. The following teachers in technical high schools have been raised to the standing of professor:—R. Lutz, professor of mechanical engineering at Aachen; Dr. Carl Frenzel, professor of electrochemistry at Brünn; and Dr. Bernhard Neumann, professor of chemistry at Darmstadt.

THE first volume of the report for 1902 of the Commissioner of Education of the United States Bureau of