SOLAR AND TERRESTRIAL RELATIONSHIPS

A DISCUSSION on solar and terrestrial relationships had been arranged to take place on September 5 as part of the programme of Section A (Mathematical and Physical Sciences) of the British Association meeting at Dundee. The meeting was not held, owing to the international situation, and the following account contains the subject-matter of contributions from Dr. E. V. Appleton (radio effects), Mr. H. W. Newton (solar phenomena and terrestrial magnetism), Dr. A. D. Thackeray (solar phenomena), Prof. L. Vegard (auroral phenomena and the physics of the upper atmosphere), Prof. W. M. H. Greaves (the 27-day recurrence tendency of magnetic storms) and Prof. F. J. M. Stratton (general summary).

Many attempts have been made in the past to correlate solar and terrestrial phenomena. Until quite recently, the only one that was found to show a clearly measurable relationship was that between sunspot activity, auroras and magnetic activity. There is no direct meteorological effect of any serious importance, although in some climates tree-rings suggest a connexion of a complex type with the sunspot cycle not shown up by ordinary data. The recent study of the ionosphere has shown a new relation, involving an increase in ionization in the upper atmosphere accompanying increased magnetic activity at times of maximum sunspot activity; this relation appears in a peculiarly clear-cut fashion at times of chromospheric eruptions which closely coincide with short-wave radio fade-outs. The correlations so far found can all be attributed either to a stream of corpuscles ejected radially from the sun's surface or to an increase in ultra-violet solar radiation.

Nearly every type of solar activity is capable of emitting a stream of particles or high-frequency radiation which may ultimately strike the earth's upper atmosphere. In the lowest levels of the sun's atmosphere, direct observation reveals sunspots, faculæ and granulation; with the spectroscope, high-level flocculi and prominences are detected (chiefly in hydrogen or ionized calcium light); still higher, coronal streamers suggest a permanent outward flow of particles. Eruptive prominences, which may ultimately attain velocities of the order of 600 km./sec., form a spectacular example of the sudden expulsion of matter from the sun, presumably through radiation pressure; the motions of prominences, however, as revealed by cinematography, show many characteristics which are difficult to explain even in terms of a complex interaction of radiation pressure, gravitation and electrical forces.

Radiation pressure is insufficient to support the whole mass of chromospheric gases, but the dynamical concept of turbulence has partially solved this difficulty. A turbulent velocity of 15 km./sec. in the chromosphere is indicated; in the lower layers it is on a much smaller scale. The short-lived granules, with a life-time of only three minutes, represent permanent activity all over the sun's surface, *independent of the 11-year sunspot cycle*, while chromospheric eruptions represent temporary localized activity on a large scale. These eruptions consist of intense brightenings in hydrogen and calcium light which sometimes last only a few minutes. Thanks to the spectrohelioscope, perfected in 1924 by Hale, a practically continuous watch for these short-lived phenomena is now kept throughout all longitudes by international co-operation. It has been found that 50 per cent of the brightest eruptions are associated with *simultaneous* radio fade-outs; with the fainter eruptions the association is much less direct.

The statistical relationship between sunspots and magnetic storms may be summarized as follows: (*a*) there is a general similarity in the frequency curves of the two phenomena in the 11-year cycle; (*b*) the largest sunspots, at the time of their passage across the central solar meridian, are often associated with large magnetic storms; (*c*) the most favoured position of the associated sunspot at the time of the magnetic storm is about one day past the central meridian. The time-lag suggests the time of travel of a stream of particles from sun to earth. The relationship becomes progressively more obscure when smaller spots are studied.

It is natural to inquire whether this relationship is due to the presence of chromospheric eruptions, which are most commonly observed in or near large active sunspots. A distinct relationship has been established between eruptions and magnetic storms, similar to that with sunspots. Of the twenty-nine greatest eruptions observed since 1892, twenty-one were found to be followed within 4·0 days by a magnetic storm, and half of these storms were classified as 'great'. Magnetic storms do in fact appear to be more closely associated with chromospheric eruptions than with sunspots.

The association of chromospheric eruptions with ionospheric disturbances is of a different character: (*a*) there is no time-lag; (*b*) the eruption can be effective wherever it occurs on the solar disk;

(*c*) the ionospheric disturbance is practically confined to the earth's sunlit hemisphere; (*d*) there is an accompanying small perturbation of the earth's magnetic field. These four facts are consistent with the suggestion that the solar agency is ultra-violet radiation emitted from active regions of the solar surface. The agency responsible for magnetic storms, however, is to be looked for in a radially ejected stream of high-velocity particles. The observations favour a common origin of radiation and particles in an active portion of the sun's surface, which may also but not necessarily be marked by a large sunspot. The association of terrestrial phenomena with sunspots must be regarded as an indirect one; it is only because they are so easily observed that sunspots have been taken as a convenient index of solar activity.

A further relationship between sunspots and terrestrial magnetism is shown by the fact, known for many years, that magnetic storms tend to recur at intervals of one synodic solar rotation (about 27 days). A catalogue of 403 storms based on Greenwich records for the years 1874–1927 has been used to study this relationship in detail. These were divided into five groups according to intensity, represented by the mean of the three components D, H and V. The history of storm-days following each storm was followed up and the tendency to recur after 27 days was found to be confined to the less intense storms (less than 180 γ); in the weakest storms (less than 150 γ), there is a definite additional tendency to recur at intervals of 54 days.

This result can be expressed in another way: if attention is confined to storms which tend to recur after 27 days, it is found that the ratio 'sequence storms' to all storms decreases progressively from 0·25 to 0·05 as one passes from weak to great storms. This result does not contradict the conclusion that magnetic storms are due to radial streams of corpuscles from active regions of the sun; it merely suggests that the most intense solar disturbances which eject such streams are comparatively short-lived and will not survive a solar rotation. The 27-day recurrence has been found to persist throughout spotless periods of minimum activity; thus, as implied previously, the spots themselves must not be regarded as the origin of the corpuscular streams.

The frequency of auroras has long been known to follow the cycle of solar activity; there is also a slight tendency for intense auroras to occur near the times of the equinoxes, when the earth lies in the plane of the equatorial belt of the sun where activity is greatest. The spectrum of auroras consists of bands (chiefly due to nitrogen) and lines (due to atomic oxygen and nitrogen, neutral and ionized). The wave-lengths of the strong green and red lines have been measured with great accuracy, and, with the help of knowledge of atomic energy levels, attributed to 'forbidden' transitions of neutral oxygen.

The presence of ionized oxygen and nitrogen indicates the action of particles of high energy. The work of Störmer has shown how the streamers may be identified with the paths of electrified particles entering the earth's magnetic field. Analysis of the intensity distribution within auroral bands yields a mean temperature determination of $-44°$ C. There is no evidence of any increase in temperature with height either from band analysis or from measures of interferometer fringes of atomic lines. Further, the observed light intensity along auroral streamers suggests that the density of atmospheric gases diminishes but slowly within the auroral region from 100 km. to 800 km. It is suggested that matter is driven to these heights by electric forces in an ionized or partially electrified atmosphere.

A theory proposed by Vegard in 1923 accounts for the main facts on the assumption of a stream of photon radiation, the wave-length of which corresponds to soft X-rays, in addition to the ordinary temperature radiation and corpuscular rays emitted by the sun. The incidence of this radiation on the extreme upper atmosphere produces a sort of terrestrial corona. The theory has been very successful in explaining the chief layers of ionization in the upper atmosphere. The soft X-rays will produce two ionization maxima; the first, formed at a high altitude by high-speed photo-electrons, is identified with the F_2 layer, which surrounds the whole earth, but is higher by night than by day; the second, at a low altitude where the absorption per unit length is a maximum, is identified with the E layer, which is confined to the sunlit hemisphere. The energy of the photons must be about 1000 volts to account for the observed heights of the E and F_2 layers. Finally, the absorption coefficient for rays in a large range of wave-length (100–1000 A.) is a maximum, so that these rays will produce an ionization maximum at about the same height—calculated to be 200 km.—which will be confined to the sunlit hemisphere. This maximum is identified by Vegard with the F_1 layer.

The variations in ionization in these three layers may be very efficiently studied by means of the radio sounding method, developed by Appleton and others. The ionosphere may, in fact, be regarded as a solar laboratory in which the effects of high-frequency radiation and particles emitted by the sun may be analysed. By timing echoes of vertically transmitted waves, a relation is obtained between equivalent height of reflection and radio-wave frequency. At a critical frequency, echoes from the ionosphere are lost, and this gives a clue to the maximum electron density in any layer. Layers E and F_1 show comparatively smooth diurnal, seasonal and sunspot-cycle variations, all of which confirm the supposition that these layers are produced by high-frequency solar radiation. The long-scale variations in ionospheric reflectivity do, in fact, give a very perfect reproduction of the 11-year cycle of solar activity. The ionization in layer F_2, however, suffers remarkable irregularities, particularly during magnetic storms, when the ionization maximum is less than normal. The most striking type of ionospheric irregularity is that known as an irruption or fade-out, which is usually associated with a chromospheric eruption. Here the absorption is so great that the echo may be entirely lost, but the height of reflection is not usually greatly affected.

The question of the ultimate character of the short-wave solar radiation associated with these disturbances (for example, its frequency and whether it consists of continuous or line-emission) is still quite unsettled. The spectrum of chromospheric eruptions in the observable range has been found to consist of lines due to H, He and Ca^+. Photometric measures show that during an eruption, the total Hα radiation from the sun increases by only a few tenths of one per cent; it is quite clear that what the spectrohelioscope observer sees is a secondary effect, and that the primary disturbance consists in the leakage of unobservable ultra-violet radiation. As Milne has pointed out, given an increase of radiation, the ejection of a stream of high-speed particles is easily accounted for by radiation pressure. Lyman emission of hydrogen is insufficient to account for all the observed effects, and it is probable that we have to deal with a mixture of line and continuous radiation. Continuous emission is not normally observed in the visible region, although a small increase at wave-length 3220 A. has been detected in one exceptional eruption.

Further analysis of ionospheric disturbances by radio sounding probably holds out greater hopes for the ultimate solution of the problem than the observation of secondary solar effects in the visible spectrum. Finally, the spectra of 'sunlit auroras' recently observed by Störmer promises a fruitful field for research into the uppermost regions, where the solar rays first strike the earth's atmosphere.

OBITUARIES

Sir William Pope, K.B.E., F.R.S.

WILLIAM JACKSON POPE, the great chemist, was the eldest son of William and Alice Pope who at the time of his birth (March 31, 1870) lived in New North Road in the City of London. On leaving the Cowper Street Endowed School, Pope proceeded to the Finsbury Technical College, where he was one of H. E. Armstrong's earliest pupils. He followed Armstrong to the Central Institution (now the City and Guilds' College of the Imperial College of Science and Technology), where the scheme of scientific studies having no reference to outside examining bodies did not lead to a university degree but gave Pope a rigorous training in chemistry, classical crystallography (under H. A. Miers) and in research methods admirably suited to his genius. From that time dated the unique friendship between Armstrong and Pope which was only broken by the former's death in 1937.

While still a student, Pope began his own crystallographic investigations of organic compounds. He also collaborated with F. S. Kipping, then Armstrong's assistant, in important investigations in the chemistry of camphor and on the constitution and characterization of externally compensated compounds.

Pope's first appointment (1897) was that of head of the Chemistry Department of the Goldsmiths' Institute at New Cross, and at the same time he was lecturer on crystallography at the "Central". In 1901 he became professor of chemistry and head of the Chemistry Department at the newly built School of Technology, Manchester, becoming professor of chemistry in the University of Manchester in 1905, when the School was made the centre of the Faculty of Technology, and on that occasion Pope received his first university degree; he had been elected to the fellowship of the Royal Society in 1902. Pope was elected to the professorship of chemistry in the University of Cambridge in 1908 in succession to J. D. Liveing, who had held the chair for forty-seven years, and in the following year he was elected to a professorial fellowship at Sidney Sussex College.

Pope's enduring fame will rest chiefly on his work on molecular dissymmetry. Pasteur had laid the foundations of stereochemistry in 1849, and up to the time of Pope's work at the Goldsmiths' Institute, all the optically active compounds studied by Pasteur and his successors contained in the molecule at least one carbon atom having an asymmetric environment. The presence of this 'asymmetric carbon atom'—a carbon atom united to four different atoms or groups tetrahedrally arranged round it—in the molecule was up to then regarded as being essential for the particular compound to be capable of exhibiting optical activity. As Pope has frequently pointed out, it is probable that the use of this