AURORAS AND LUMINOUS NIGHT CLOUDS*

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Auroras

SCOTLAND is well situated for observing auroras for they may be seen there on the average on about forty nights in the year, compared with seven to ten nights in the south of England. Since 1946, four stations—at Abernethy and Blairgowrie in Perthshire, Newton Stewart in Wigtownshire and Roseneath in Dumbartonshire—equipped with specially designed cameras ($f/1.25$ and focal length 5 cm.) and linked by telephone, have been used to record the forms and to determine the positions and heights of auroras that have occurred in association with the last sunspot maximum of 1947.

It is impossible to predict precisely the course of a great aurora, but what usually happens is as follows. At first, a glow, much like dawn (hence the name aurora borealis, northern dawn, which was first used by the French philosopher, Gassendi, in 1621), appears on the northern horizon, often with a warning by day 24–36 hours beforehand of a solar flare. The glow then ascends from the horizon to form an arc, the lower border of which is at a height of about 100–110 km. Of all the auroral forms, the quiet arc is the only one of which the lower border appears always at about the same height; there is no significant variation either with latitude or with local time. This fact, together with the tendency of the arc to remain quiescent for a long time, allows the determination of its geographical position by photographs from a single station. In fact, when such an arc appears, there is an arrangement at the Scottish stations to photograph simultaneously according to a prearranged time scheme with Prof. Carl Störmer's Scandinavian network. The geographical position of the arc may then be plotted from mid-Atlantic to western Russia, thus providing information that may be of value to the theoretical worker.

The true colour of most arcs is probably green, for a predominant line in the spectrum is the green forbidden line 5577 Å. of atomic oxygen, and this happens to be in the region of maximum sensitivity of the retina. But, except in the case of very bright arcs, it appears to the eye to be grey-white, since the light intensity is below the threshold of colour perception. The arc may then brighten suddenly to an intensity above the threshold such that patches of vivid greens and reds can be seen here and there along its length. Simultaneously the lower border becomes extraordinarily sharply defined and is appreciably lower, all of which are signs that the arc is about to lose its regular shape and to show ray structure. It may then undulate to appear like the folds of a huge waving curtain, or it may take the form of a wide band, stretching irregularly across the sky. The base of these draperies may come as low as 90 km.; the minimum height tends to occur at about 0300 hr. local time, so that the particles which cause auroras appear to penetrate most deeply into the atmosphere about this time. There is some evidence, too, that the bases of curtains and bands are lower in lower latitudes. Indeed, one of the aims of low-latitude stations, such as those in Scotland, is to investigate these latitude variations.

* Substance of a paper read on August 9 before Section A (Physics and Mathematics) at the Edinburgh meeting of the British Association.

When the rays pass overhead into the southern sky, they then form what is undoubtedly the most spectacular of auroral forms—the corona. The rays appear to converge to a point, approximately the point in the sky to which the south pole of a magnetic dip needle would point—in Scotland it is about 20° south of the zenith. Thus the direction of the auroral streamers coincides approximately with the lines of force of the earth's magnetic field. This is what would be expected if the aurora is caused by charged particles emitted from the sun at the time of the flare, for, when they eventually enter the earth's magnetic field after their journey of a day or so through space, the particles would be deflected to travel ultimately either directly down the lines of force or in close spirals round and down them. The auroral light is produced along their path by the excitation of atmospheric atoms and molecules, probably mainly by collisions with secondary electrons ejected by the primary auroral corpuscles. The light streamers are therefore closely parallel and their apparent convergence in the corona is merely the effect of perspective.

When the display is at its height, the total illumination may be greater than that of full moon. During the great display of January 25, 1949, it was possible to pick out trees and fields on a hillside three miles away. At one point during this display the illumination suddenly ceased as if the lights had been switched off; but a great display usually fades out in what is called 'flaming'—waves of light, generally of low intensity, surge upwards, one after the other, towards the zenith. Sometimes this whole sequence may be repeated. There is a fairly well-marked diurnal variation with a main maximum at 2200 hr. and a secondary one at 0400 hr. Usually, luminosity is greatest and the auroral forms are most active and well defined at the time of the main maximum, and it is then that the display is likely to reach its most southerly limit. At the time of the secondary maximum, the forms are often diffuse and weak.

The method of determining the height and position of aurora is due to Prof. Störmer, who, besides making important contributions to the theory of aurora, has, during the past forty years, made a very thorough investigation of auroral forms seen from Norway. A certain part of the aurora is photographed simultaneously by the observing stations, and then, on comparing the plates, the relative parallax of the star background is measured and the location of the aurora computed. During the great aurora of January 25, 1949, a base line of 169.8 km. was used between Abernethy and Newton Stewart to measure the height and position of red diffuse surfaces, which were found to be situated at heights of 500–700 km. over northern Germany. As might be expected, the main difficulty has been cloud and fog, which have completely obscured at least two great auroras, and often obscure an aurora at one of the stations when the others are able to make an exposure.

Luminous Night Clouds

The auroral cameras and plates are suitable for the photography of the rare noctiluent or luminous night

clouds, so that when the brilliantly blue clouds were observed on July 10–11, 1949, parallax photography was immediately begun and continued until the clouds slowly vanished in the growing light before dawn. Measurements showed that the whole mass of cloud was situated at heights between 84 and 89 km. and was confined within the twilight circle. (The greatest height at which ordinary clouds appear is about 12 km.)

It is most surprising that the first records of these remarkably lovely blue clouds appeared as late as 1885. Their spectrum is similar to that of the day sky and shows Fraunhofer lines; the particles constituting the cloud then are so high that those within the twilight circle are in sunlight, revealing their presence by the sunlight they scatter. Their blue colour indicates that the diameter of their particles is small compared with the wave-length of light.

The conditions necessary for observation of the clouds are as follows: the sun must be at least 10° below the horizon in order that the sky background may be sufficiently dark; it must not be more than 18° below the horizon, for an appreciable part of the atmosphere above 80 km. must be in sunlight; normal clouds must be sparse or absent and visibility excellent. Thus they can be seen only in the summer months and only within latitudes 45° – 62° .

The first accurate measurements were made in Germany by Jesse about 1890. He found their height to be about 79–90 km., and on one occasion recorded the remarkable velocity of 177 m. per sec. or 400 m.p.h. He observed that they travelled from the north-east before midnight and from east-north-east after midnight. They occurred frequently, and in brilliant forms during 1885–88. Ormond saw them from Ben Nevis Observatory on every clear night from June 4 to July 2, 1888. From then until 1932 they were seen only occasionally. During 1932–34 the clouds again appeared in brilliant forms to give Prof. Störmer the opportunity of applying the technique that he had used so successfully in studying auroras. He confirmed Jesse's measurements, finding the mean value of their height to be 82 km. and their velocities to lie in the range 48–83 m. per sec. The clouds were rarely seen between 1934 and 1949, but during and since 1949 several fine displays have been photographed and measured both in Norway and Scotland. On July 24–25, 1950, the rare coincidence occurred of luminous night clouds in association with an aurora. On this occasion the clouds soon became so brilliant that they extinguished the aurora. By 0100 hr. they extended along the horizon between azimuths 345° and 85° and reached an elevation of 25° ; at this time, so brilliant were they, that it was possible to make notes and observe the stop watch by cloud light.

The nature and origin of the clouds is still uncertain. Jesse thought them to consist of the products of condensation of matter projected into the high atmosphere at volcanic eruptions; the magnificent displays of 1885–86 were ascribed to residual dust from the Krakatoa eruption of 1883. But Vestine has pointed out that just at this time there occurred a remarkable number of meteor appearances, showers and great comets. Moreover, no marked increase in the frequency of the clouds succeeded the eruption in 1912 of Katmai, Alaska, whereas the great Siberian meteor of 1908 was followed immediately by a brilliant display. So he concludes, and Prof. Störmer agrees, that the clouds consist of material of cosmic origin.

On the other hand, Vegard believes that the clouds may be formed by the condensation of water vapour on sodium oxide nuclei formed by the combination of sodium and atmospheric oxygen. He suggests that the presence at this great height of water vapour, in the concentration necessary to account for such extensive clouds, may result from the combination of atmospheric oxygen, perhaps in the form of ozone, and hydrogen, projected into the atmosphere from the sun. There is evidence that a temperature minimum of the order of 200° K. exists at a height of 80 km., and, as the pressure there is of the same order of magnitude as the vapour pressure of water, conditions may be favourable for condensation. During the display of July 24–25, 1950, portions of the clouds were observed to change colour from vivid blue to white, suggesting growth of the particles.

Now that Whipple's meteor observations and the theoretical work of others on atmospheric tides indicate that temperature falls rapidly from a maximum at 60 km. to a minimum at 80 km., the problem of explaining the occurrence of the clouds always at about 80 km. is resolved. Meteoric dust, for example, would tend to drift to and remain below the base of the inversion at 80 km., and if these are water clouds, then condensation is most likely at the temperature minimum at 80 km. Indeed, the presence of the clouds always at this fixed level is itself evidence of the existence there of a temperature minimum.

Wave formation is a characteristic of the clouds, and measurements show that the distance between the wave crests is about 9 km. Recalling the great speeds with which these clouds may travel, the wave formation is no doubt generated in the wind shear at the inversion, as in ordinary billow clouds.

These clouds are naturally of great interest to the meteorologist for, with meteor trains and now the new radio methods, they provide a direct means of measuring air movement at these high levels.

STORAGE OF FARM PRODUCTS

IT is often not realized that an increase in the yield of a farm crop which has taken many years of selection and improved culture to achieve may be much less than the losses during storage of the crop. For example, it has been estimated that a fifth of the total production of potatoes in France is lost during storage because of respiration, water-loss, disease and sprouting. There seems no reason for believing that the overall loss in Great Britain is much less, in which case the weight lost during storage would be sufficient to supply the whole human population of the United Kingdom for nearly four months. Admittedly potatoes are one of the more impermanent farm crops; but for most products the development of more efficient means of storage is a matter of great importance, and clearly merited the discussion devoted to it at Edinburgh by Section M (Agriculture) of the British Association during the morning of August 10 under the chairmanship of Dr. E. M. Crowther, president of the Section.

Prof. S. J. Watson, of the Department of Agriculture and Rural Economy, University of Edinburgh, speaking first, discussed the storage of grass. The traditional method—by making hay—is extremely wasteful of the feeding potential of the grass. In a wet year as much as half the feeding value may be