The wind direction during and immediately following the observation of a halo seems to play an important part in its verification as a rain prognostic. Of the 168 halos recorded, 94 were attended or followed by easterly winds and falling pressure. Of these, 82, or 87 per cent, were followed by precipitation within 48 hours. This result is important, in view of the fact that of the total number of halos recorded, but 99, or 59 per cent, were followed by rain or snow within 48 hours.

*Unusual displays, Fort Worth, Tex.*—Complex halos are rare indeed. Even the 46°-halo occurs but infrequently. From the time angular measurements were first made at this station, seven 46°-halos have been recorded. On the evening of May 23, 1901, two parhelia were noted as the sun was about 10° above the western horizon. They appeared on the edge of a bank of alto-stratus clouds. Between this edge and the horizon the sky was clear, while above the clouds were so dense as to obscure all evidences of the parhelic circle [?]. The parhelia were about 23° distant from the sun.

At about 6 p. m. on July 2, 1914, a complex halo with three parhelia was observed. The two brightest parhelia were vertically above and below the sun, while the parhelion to the south or left of the sun was but little more than an irregular splotch of light. The phenomenon lasted about 45 minutes, and occurred during a general rain over western Texas; for this reason it is supposed that this station was in the outskirts of the alto-stratus cloud region. No color was observed in the phenomenon, and no rain followed at Fort Worth within several days.

Many of the 22°-halos occur with a cirro-stratus overflow which precedes the incoming high. These halos are almost invariably followed by northerly winds and rarely by precipitation. Local thunderstorms are frequently preceded by halos, usually solar and occurring during the morning hours. These halos are followed by the usual meteorological conditions preceding a thundershower. It is also observed that halos occurring with brisk south winds and falling pressure will not be followed by rain if the wind shows a tendency to increase in velocity and shift to the southwest, but that halos followed by southwest winds and rising pressure will almost invariably be followed by rain within 24 hours.

Halos are not infallible weather signs, but when properly considered in conjunction with other features they serve as a material aid to the forecaster.

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## ORIGIN AND MAINTENANCE OF THE EARTH'S ELECTRIC CHARGE.[1]

By W. F. G. SWANN.

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[Author's abstract.]

The paper consists of two parts. Part I is devoted to a general discussion of certain broad principles which must be considered in the formation of any theory of atmospheric-electric phenomena, and to a consideration of former theories. In Part II a new hypothesis is provisionally formulated, and its consequences are traced.

Part I commences by considering the possibility of a general circulation in the atmosphere by which the negative electricity flowing upward at one place is conducted down at some other place. It appears that such an explanation is untenable, for no regions have been discovered presenting the phenomenon of a continual return current, and apart from this fact, the existence of a circulation of the kind depicted would necessitate that the electromotive forces around closed paths, in which the flow was taking place, would have to be of the order of magnitude of $10^5$ volts. *Electrostatic* forces can contribute nothing whatever to a line integral around a closed circuit. A consideration of such values of the line integral as could be obtained on the basis of the change of magnetic induction due to the earth's magnetic field through a closed circuit, or of the motion of the earth and atmosphere in the magnetic lines of force of the earth shows that, apart from the circumstance that they would be of a nature unsuitable to correspond to the facts, they would be of an order of magnitude entirely too small to play any appreciable part in the phenomena.

The various possible types of hypotheses which may be made to account for the maintenance of the earth's charge are capable of being grouped under three heads: (1) We may imagine that negative electricity is fed into the earth from the outside in some unspecified manner. In this case it will be necessary to assume that the vertical conduction current is dissipated again into space. (2) We may imagine that negative electricity is supplied continuously to the earth and positive electricity to the atmosphere at all places. (3) We may imagine that negative electricity is supplied continuously to the earth and positive electricity to the atmosphere, the supp taking place, however, over only a limited region at any one time.

Considering the hypotheses of the first type, it turns out that in view of the fact that the earth is a comparatively good conductor of electricity, the charge will distribute itself uniformly over the earth's surface. The known fact that the conductivity continually increases with altitude to a high value is all that is necessary to insure that things will arrange themselves so that the positive charge in the atmosphere is equal to the negative charge on the earth.

Considering the hypothesis of type 3, it turns out that in regions where the replenishment of charge to the earth and atmosphere is not taking place, the potential-gradient and earth-air current-density would, under ordinary conditions, quickly fall to an insignificant value. If, however, a very high value is assumed for the conductivity of the upper atmosphere, this difficulty to some extent vanishes, and the assumption of a replenishment of the charge at one place is sufficient to account for the maintenance of atmospheric-electric phenomena at all places.

A discussion of several former theories is given; among others, those of Elster and Geitel and of Ebert. In these theories a separation of positive and negative electricity takes place in such a way that negative electricity is left on the earth and positive is supplied to the atmosphere. The positive charge is carried upward by the ascending air currents, and in the steady state; the convection current so produced must be equal and opposite to the conduction current. Apart from the objections which have been raised by others against the Elster and Geitel theory, it is shown that, owing to the conductivity of the atmosphere, the rising positive electricity would become devoured, as it were, before it had reached any great altitudes, and the net result is that on such a theory the potential-gradient and earth-air current-density would be expected to diminish to practically a zero value at altitudes of the order of magnitude of 1,000 meters, which is contrary to the results of balloon experiments. The objection here cited applies to any form of theory in

[1] Reprinted from Carnegie Institution of Washington, Yearbook No. 14, for the year 1915, pp. 339–341. (Text of the paper appears in full in "Terrestrial Magnetism," September, *1915, 20:105–126.*)

which the convection current is supposed to balance the conduction current.

The hypothesis provisionally formulated in Part II consists in assuming that each cubic centimeter of the atmosphere emits negative corpuscles of a penetrating power sufficiently great to enable them to travel through considerable thicknesses of the atmosphere. The earth will absorb the corpuscles which fall upon it, and its potential will rise, in a negative sense, until the negative conduction-current back to the various parts of the atmosphere balances the charging effect due to the expulsion of the corpuscles. The total positive charge in the atmosphere will of necessity be equal to the negative charge on the surface of the earth. In the steady state the resultant downward corpuscular current at any altitude will just balance the upward conduction current at that altitude. A general consideration of the order of magnitude of the phenomena concerned shows that it is only necessary to assume an extremely small rate of emission of corpuscles per cubic centimeter, and though the degree of penetration necessary for these corpuscles is greater than any we are familiar with in laboratory experiments, a full consideration of all the circumstances shows that the assumption is not as unreasonable as might at first sight be supposed.

In the simplest case, where the rate of emission of corpuscles and the average range of a corpuscle are independent of the altitude, the corpuscular current-density and consequently the conduction current-density should decrease to practically a zero value at an altitude comparable with the average range of a corpuscle. In the more general case where the rate of corpuscular emission and the range of the corpuscles increases with the altitude, the variation of the conduction current-density with altitude becomes more complex, and it becomes possible in a natural way to explain on these lines the general features of the variations of the conduction current with altitude in so far as this variation is known. The argument in this connection is too involved to be made clear in an abstract, and a similar remark applies to a consideration of the question of annual and diurnal variation; it may be remarked, however, that the more prominent features of these variations fall into natural line with the conclusions resulting from the development of the hypothesis.

In conclusion, it is to be remarked that there is considerable latitude in the exact nature of the hypothesis which may be formulated in order to account for the general features of atmospheric-electric phenomena along the above lines.