THE MECHANISM OF A THUNDERSTORM

By G. C. Simpson

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Starting from his breaking-drop theory of the origin of electricity in thunderstorms and making use of the further meteorological knowledge of storms which has accumulated since 1909, Doctor Simpson has set out in the present paper, qualitatively and quantitatively, the complete theory of the thunderstorm.

Two diagrams [1] are first given showing the structure of the thunderstorm. The first figure shows the thundercloud in vertical section. The stream lines of the air flow enter the storm, passing under the forward end of the

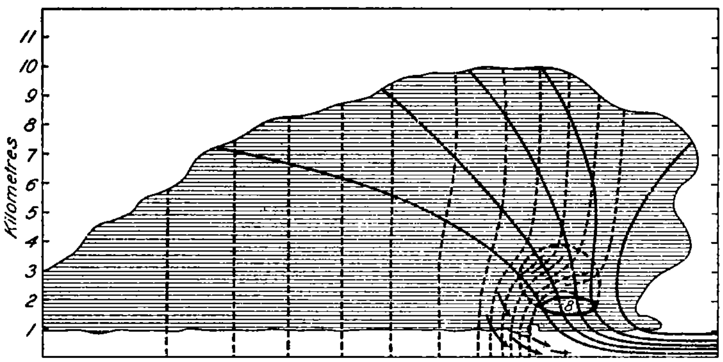

Fig. 1

cloud, and then rise into the cloud. The stream lines then spread out into the body of the cloud. The region where the vertical component of the rising air is more than 8 meters per second is marked. No rain can descend through this region, as the upward velocity of the air exceeds the terminal velocity of the largest possible stable raindrop (0.5 cm. diameter). Dotted lines show the course taken by falling raindrops in various parts of the cloud. In the rear parts of the cloud the rain falls almost

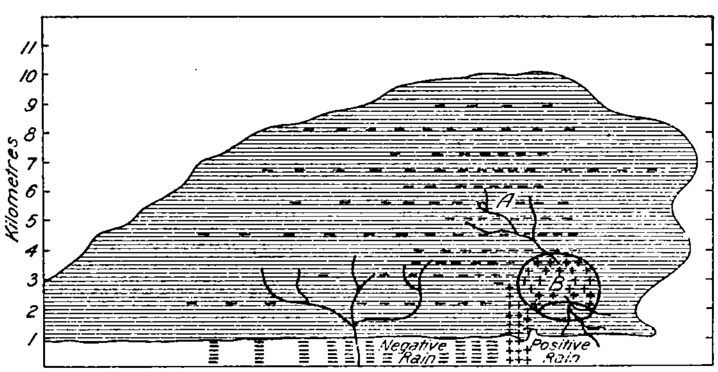

Fig. 2

vertically. In the front parts of the cloud the rain is deflected toward the rear by the air stream, the magnitude of the deflection depending on the size of the raindrops Over the region of maximum vertical velocity there will be accumulation of water. The largest drops will fall as the bounding surface of that part of the cloud where the vertical air velocity is 8 meters per second. Here they will be broken up and the little drops produced will be carried up again. They will recombine, descend again, and the process will be repeated, and so on.

The second diagram exhibits the electrical distribution produced by this set of conditions. In the region where breaking up of drops is taking place the water receives a positive charge and the air a negative charge. This negative charge is carried away into the main body of the cloud by the air current. The accumulating water soon becomes highly charged positively. The heavy rain which falls to the rear of the region of breaking drops is thus predominately positively charged and the lighter rain falling from the rear of the main cloud is preponderatingly of negative charge.

The second diagram also shows the characteristics of the lightning to be expected according to this theory. The main discharges start in the region where water is accumulating; that is, in the seat of the positive charge in the cloud. They branch upward into the main body of the cloud and downward toward the ground. It may also happen that there may be a strong enough field built up between the negatively charged part of the cloud and the earth. In this case a discharge starts on the ground and branches up into the cloud.

The next step is the examination of the theory to see if the quantities involved are all of the proper order of magnitude and whether the phenomena as a whole are in accordance with observation. First of all, the electrical quantities involved are examined. The necessary simplification is secured by assuming the region of accumulating water, and hence of positive electricity, to be a sphere of radius 1 kilometer and with a center 3 kilometers above the ground. The region of negative electricity is represented by another sphere, 3 kilometers radius, and center 7 kilometers above the ground. This latter sphere is vertically above the positive sphere and hence the two are tangential. In order to approximate to the nonuniformity of the distribution of electricity, each main sphere is divided into four smaller spheres, each of which is given an appropriate volume charge.

From these assumed data the field at any point due to the charges can be calculated. The total charge upon each set of spheres is 100 coulombs, this figure being suggested by some of Wilson's results. The distribution of volume charge as between the four spheres comprising each region is made upon a very likely basis, with a number of variants of position in the case of the positive spheres. In the three cases examined two had a sufficiently ample potential gradient to initiate a discharge.

The next question to be considered is whether there is sufficient breaking of drops to produce the required quantities of electricity. A direct calculation is out of the question, but an estimate can be found by considering the amount of electricity which has been found to be brought down by the positively charged rain. In some observations made at Simla this varied from 0 to 7 e.s.u. per cc. The order of magnitude may be taken as 1 e.s.u. per cc. On this as a basis, the 100 coulombs of electricity signifies that the amount of water present in the positive region is about 3 by 10^{11} grammes. Spread uniformly over the cross section of the region, this will yield a layer of water 10 cm. deep, a very possible amount of water from a meteorological point of view. An estimate of the time needed for such an amount of water to accumulate works out at 17 minutes, a reasonable period. Also an estimate of the amount of electricity produced if all drops available for breaking broke simultaneously

[1] Both diagrams are reproduced from Proceedings Royal Society of London, volume 114, series A, 1927, pp. 377 and 379.

is 3.5 coulombs. Ten breakings would thus produce 35 coulombs, the average amount required for an average lightning flash, again a reasonable result. Thus the proposed theory is in conformity with the facts and the amount of breaking of drops and the quantities of electricity involved are not out of harmony with what might be expected from observed facts.

The three possible types of lightning discharge are denoted as follows:

(1) Discharge from the seat of positive charge upward into the cloud—type U.

(2) Discharges downward from the same region—type D. These may be further subdivided into types D_1 and D_2, according as to whether the discharge reaches the ground or not.

(3) Discharges from the ground up to the negatively charged cloud—type N.

Schonland and Craib, from their observations of storms and the field changes resulting upon the lightning discharges, arrived at conclusions which they thought to be definitely inimical to the breaking drop theory. Doctor Simpson reexamines their results and finds that the discrepancy is due to the fact that Schonland and Craib ignored the possibility of a lightning flash directed downward toward the ground, but failing to reach the ground (*i. e.*, type D_2). Taking this important point into consideration, it is shown that the results of Schonland and Craib and Wilson fit excellently with the present theory.—*C. E. Britton.*

THE CARACOLES METEOROLOGICAL STATION AND ITS IMPORTANCE FOR THE TRAFFIC OF THE TRANSANDINE RAILWAY AND AVIATION

By JULIO BUSTOS NAVARRETE, Director

[Observatorio del Salto, and professor in the aviation school, Santiago de Chile, May, 1928]

The great storms that frequently blow, year after year, over the Andes Mountains have not been properly studied, and all the observations available, as force of the wind; nebulosity; amount of clouds, forms, velocity, and direction; visibility; height of snow; rainfall and hydrometeors, where only dispersed observations were made by different persons. The need for scientific data about the storms over the Andes Mountains has been clearer since Transandine Railway and aviation require to be in possession of reliable facts about the weather, not only for the development of their traffic but also before crossing over on each passage.

At the beginning of the year a letter was written from the Observatorio del Salto to the manager of the Transandine Railway Co. asking them for their cooperation in the installation of a meteorological station in Caracoles. As the railway company is the most affected by the storms on the cordillera, our solicitude was favorably acknowledged and the necessary instruments for the installation were immediately bought.

The Caracoles meteorological station was finally installed on the 15th of May; and by its instruments as well as by its position it is called to provide observations of great interest. The meteorological shed or pavilion is located near the Caracoles Railway station and it is formed by double-latticed sides to prevent the snow from getting in, and it is also 4 meters from the ground, to prevent it being covered by the great snowstorms. Inside there is a Lambrech meteorograph apparatus of high precision, which was previously controlled by comparing it with the standard instruments of the Observatorio del Salto. This apparatus gives a continuous record of the pressure, temperature, and humidity. The pluviometer is located at a certain distance away from the railway station and the vane is on the station itself.

The following observations are made daily and transmitted by telegraph to the Observatorio del Salto: Atmospheric pressure, reduced to sea level; relative humidity; temperature of the air, maxima and minima; wind's direction and force; clouds, amount, forms, velocity, and direction; visibility; height of snow; rainfall; hydrometeors.

It remains for us to say that the Caracoles meteorological station is situated on the highest point of the Transandine Railway, near the Cumbre, and at the side of the entrance to the international tunnel that joins Chile with the Argentine Republic. The station is approximately at 3,200 meters altitude.

The first diagrams received from the registering apparatus of the Caracoles meteorological station immediately revealed certain peculiarities of remarkable interest; the oscillations of the atmospheric pressure are not simultaneous with those of the central zone of Chile; they produce themselves 24 hours later, and seem to be intermediate with those of the Argentine Republic; the oscillations of the temperature exceed the values which had been estimated for them before. For example, on the week from the 14th to the 21st of May, minima of 15° C. below zero were registered, etc.

In our monthly bulletin we will publish a résumé of the meteorological observations of the Caracoles station, which, as before stated, is situated on the limit of two meteorological systems or régimes; these observations will be very important for the proper study of the meteorological conditions in Chile and in the Argentine Republic. In Chile we have a system of winter rains and storms, while in the Argentine Republic they have a system of summer rains and storms.

All storms are produced in Chile by depressions coming from the Pacific Ocean, and in consequence with a falling barometer; while over in the Argentine all storms are produced when an anticyclonic area advances from the south, with the existence of a relative depression over the north central part of the country; in consequence, they are produced with a high barometer.

The most severe storms over the Chilean side very rarely reach any farther than Tierra Amarilla, and the most intense Argentine storms scarcely come any farther this way than Juncal. The greater part of the water vapor condenses and precipitates itself over the cordillera.

Serious doubts have risen regarding the displacements of the depressions. Not long ago, it was discussed, if the depressions that come from the Pacific Ocean, that affect Chile's central zone, could really cross over the cordillera, and influence the weather over Argentine's central zone; nevertheless, the Caracoles observations seem to infer that certain depressions coming from the Pacific Ocean occasionally manifest themselves 24 hours later over the cordillera and afterwards over Argentine's central zone.