

Terrestrial Magnetism *and* *Atmospheric Electricity*

VOLUME XII

SEPTEMBER, 1907

NUMBER 3

ATMOSPHERIC ELECTRICITY OBSERVATIONS AT BATTLE HARBOR, LABRADOR, DURING THE SOLAR ECLIPSE OF AUGUST 30, 1905.

BY J. E. BURBANK, CHIEF OF PARTY.

The eclipse party sent to Battle Harbor, Labrador, by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, in addition to observations of terrestrial magnetism embraced in its program such observations of atmospheric electricity as could be obtained without interfering with its principal work. The time available for this work being thus limited it was decided to observe only potential gradient and specific conductivity. These observations were entrusted to Messrs. Bowen and Homrighaus, members of the party, and it is greatly to their credit that so much was accomplished under the particularly difficult and trying conditions encountered.

Battle Harbor, the chief town on the Labrador Coast, has a permanent population of about 300 people scattered about on three islands. The principal part of the town is on Battle Island, which is about one-half mile wide from west to east and about one mile long. It is situated some six miles east of the mainland, and about thirty miles north of the upper entrance to the Straits of Belle Isle. It is in latitude $52^{\circ} 16'.6$ north, and longitude $55^{\circ} 34'.6$ west of Greenwich. The island is a mass of rock, covered in places with peat and devoid of any vegetation except grass and moss. Besides being exposed to storms and winds from the open sea, it is also in the course of the very violent and sudden storms which sweep up through the Straits of Belle Isle; this makes it an interesting place for the study of atmospheric electricity.

Battle Harbor is also in the belt of maximum polar light, and rarely does a night pass, even in summer, when some trace of this

[PLATE III.]



Weber.

phenomenon is not visible, generally as a low arch in the north, but often in the form of streamers covering nearly the entire sky. An especially brilliant auroral display accompanied by a violent magnetic disturbance occurred about 1 A. M., August 30. No attempt was made to study the relation between the aurora and atmospheric electricity.

The observations were made on the highest part of Battle Island near its center, and about 200 yards northeast of the town. This part of the island consists of a perfectly level place about 30 yards square, and contains a small fresh-water pond. Its elevation is about 100 feet above sea level, and about 75 feet above the town. The wind, except when west or southwest, blows from off the sea.

The weather conditions on days when observations were made may be summarized as follows:

WEATHER CONDITIONS AT BATTLE HARBOR, LABRADOR,
AUGUST AND SEPTEMBER, 1905.

August 23, strong south wind; hazy but clearing; 9:23 A. M., few clouds.

August 24, 5:00 A. M., sun just rising; low clouds; light sea breeze from northeast; light clouds all A. M., with sun occasionally breaking through.

August 25, 8:50 A. M., thick fog; light breeze; 10:03 A. M., light rain begins; 10:28 A. M., rain stops; 11:04 A. M., fog rises; 11:37 A. M., fog becomes dense again.

August 26, strong northwest wind; cloudy but sun breaking through occasionally during forenoon.

August 27, northwest wind, clear; sun rises 5:00 A. M.; perfectly clear day.

August 28, light northeast wind; dense fog; 9:14 A. M., sun comes out clear.

August 29, severe rain storm; clearing late at night; brilliant aurora about midnight.

August 30, light west wind; sun rises behind a cloud; sky nearly clear; 5:47 A. M., wind increasing; 6:34 A. M., clear bright sunshine, few clouds; 7:39 A. M., clouds begin to cover the sun; 7:51 A. M., clouds cover entire sky; sun under clouds until about 11:00 A. M.; after 11:00 A. M., sun comes out clear and remains so until nearly sunset.

September 1, moderate north wind; thick low clouds over entire sky.

September 2, light north breeze; thick clouds near horizon; thin clouds overhead; 10:19 A. M., light rain; 10:33 A. M., rain stops; 10:52 A. M., sun clear until noon; 4:47 P. M., increasing cloudiness; 5:42 P. M., heavy clouds in west.

September 3, 5:40 A. M., sun behind thick cloud; sky nearly clear; 6:45 A. M. to 8:00 A. M., thin haze over sky.

September 4, light haze and few clouds throughout forenoon; 2:24 P. M.; sun behind thick clouds; 2:45 P. M., sun clear; 3:50 P. M., only few thin clouds; sky nearly clear until sun set at 6:40 P. M.

September 5, clear all afternoon; sun set at 6:38 P. M.

September 12, stiff southwest wind at 1:41 P. M.; cloudy and foggy out at sea; light haze all P. M.

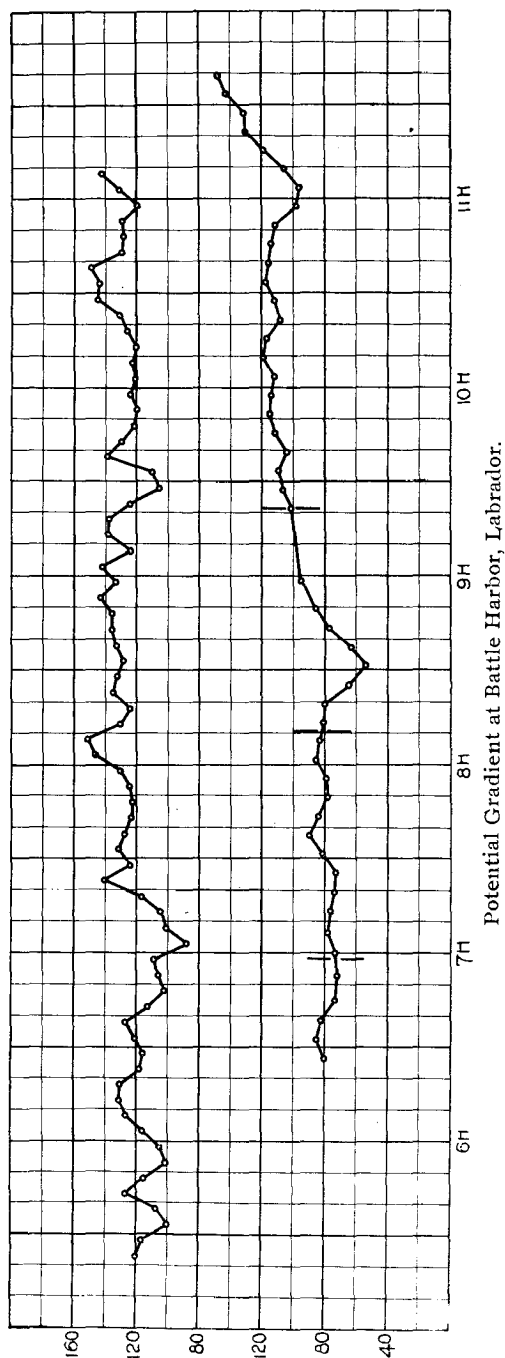
Of the above days August 27 and September 5 may be considered normal days. August 30th may be considered a normal day except for the cloudiness accompanying and following the eclipse.

POTENTIAL GRADIENT.

The potential observations were made with an ordinary portable Exner electroscope, which has leaves of aluminum foil. A copper rod coated with a deposit of radio-tellurium (polonium rod) was used as collector. This was mounted on the insulating cane in a special metallic holder in place of the flame collector, ordinarily used. The α rays emitted by the polonium ionize the air and render it highly conducting, so that the rod quickly reaches and follows the potential of the air surrounding it. This polonium rod had been previously tested and found to give satisfactory results. It was connected to the electroscope by a copper wire about 20 feet long, and always placed so that the wind blew at right angles to this wire, in order that none of the air ionized by the radio-tellurium would be brought near the electroscope.

For each series of measurements the distance from the ground to the polonium rod was measured and the observations reduced to volts per meter. Some difficulty was experienced by the condensation of moisture on the insulating cane. On August 25 the leaves of the Exner electroscope were injured, and from that date the electroscope of the Ebert ioncounter was used in its place, connection being made to the inner electrode. On September 4 one of the aluminum leaves became slightly injured and its scale was recalibrated on September 7. The electroscope used for potential always had its outer case grounded by a wire reaching down into moist earth. The scales of both the Exner electroscope and the Ebert ioncounter were calibrated by the writer at the United States Bureau of Standards on July 25, 1905.

During the periods of observation the readings were taken at one minute intervals. On account of inclement weather and duties in connection with the other work of the Expedition it was



not possible to obtain sufficient observations to deduce a diurnal curve.

A mean curve has, however, been plotted (see figure, upper curve, in which circles represent the means of five mean readings at minute intervals) from the values obtained on August 24 and 27, and September 3 and 4 for the hours 6 to 11 A. M., local mean time. All of these days were nearly normal for the hours considered. The observations on September 3 and 4 *together* covered the period mentioned, so that the curve really amounts to a mean for three days. It appears from this curve that there is a slight tendency of the potential to rise from morning toward noon. The ordinates represent volts per meter.

The lower curve of the figure shows the observations of August 30, each point plotted being the mean of six readings taken, in general, at intervals of one min-

ute. The potential oscillated about a mean value of 80 volts per meter until about 8:20 A. M., some 10 minutes after maximum obscuration, when it fell rapidly to a minimum value of 23 volts at 8:32 A. M. It then rapidly rose to about 70 volts at 8:40 A. M., and continued to rise from that point to about 140 volts per meter at 11:40 A. M. The morning was clear, and, except for the cloudiness during and after the eclipse, the day might be called normal. An examination of the curve will show that the potential was steadily rising throughout the cloudy period, 7:40 A. M. to 11:00 A. M., except for the depressions at about 8:30. Relative humidity observations, taken with a sling psychrometer, show a decrease of relative humidity during the eclipse period and the subsequent cloudiness.

In view of the fact that the cloudiness was no greater at 8:30 A. M. than during the period 9:00 A. M. to 10:00 A. M., while the relative humidity was also decreasing, it is difficult to understand why the sudden temporary decrease in potential should be ascribed to the cloudiness. It would, however, be unsafe to draw any definite conclusions.

SPECIFIC CONDUCTIVITY.

The specific electric conductivity of the air was measured in absolute electrostatic units by means of a form of instrument devised by Dr. H. Gerdien, of the Geophysical Institute Göttingen, Germany. The theory of this method is given in the journal "*Terrestrial Magnetism and Atmospheric Electricity*," June 1905.¹ The instrument is somewhat similar in principle to Ebert's ion-counter. It is, however, not designed to measure all the ions which enter, but only a fraction of them, this fraction remaining constant within a wide range of velocities of the entering air current. Experiment shows that this theoretical condition is fulfilled.

The principal portion of the instrument consists of a cylindrical condenser, the outer part of which is 16 centimeters in diameter and about 55 centimeters long. A current of air is drawn through the apparatus by means of a fan wheel mounted in its rear part, and driven by a hand gear. The inner cylinder consists of a thin brass tube 1.4 centimeters in diameter and 24 centimeters long with hemispherical ends connecting, through a suitable side tube in the

¹ Gerdien, H., *Die absolute Messung der spezifischen Leitfähigkeit und der Dichte des verticalen Leitungstromes in der Atmosphäre.* Terr. Mag., Washington, D. C., v. X. No. 2, June, 1905, pp. 65-80.

outer cylinder, with the leafholder of an Exner electroscope. The fan is driven by hand at a uniform speed of about 16 revolutions per second. A wire screen of fine mesh directly in front of the fan wheel serves to produce a fairly uniform velocity of air current over the entire cross section of the apparatus.

Inasmuch as the results do not depend on the velocity of the air currents, the effect of the wind could be neglected and the instrument was always pointed toward the wind during observations. Great care was taken not to get in front of the apparatus and thereby contaminate the air before it entered. Observations were always made on the windward side of the potential apparatus and at least 30 feet from it in order to avoid the effects of the air ionized by the radio-tellurium. The instrument was generally mounted on a small wooden stand about two feet high near the southeast corner of the level place above described. Some of the observations were made with the instrument resting on the ground. A special series of comparisons indicated no difference between the observations on the table and on the ground.

An observation is made as follows: The inner cylinder is given a positive charge and its potential observed by reading the divergence of the electroscope leaves, the fan is then revolved for 5 minutes and the potential of the inner cylinder again observed. From the fall in potential and the known constants of the instrument, the specific conductivity of the air for positive electricity can be computed. In a similar way when the inner cylinder is charged negatively the specific conductivity of the air for negative electricity is determined.

If ϵ is the ionic charge, v the mean value of the specific velocities of the ions in centimeters per second in an electric field having a potential gradient of one volt per centimeter, n the number of ions per cubic centimeter, and λ the total conductivity, then $\lambda = \lambda_n + \lambda_p$ where λ_n is the conductivity of the air for a positive charge of electricity, and is produced by the negative ions present. Hence, $\lambda_n = \epsilon n_n v_n$ and $\lambda_p = \epsilon n_p v_p$. (The subscripts p and n refer to positive and negative electricities respectively.) The computation formula then becomes:

$$\lambda_n = \epsilon n_n v_n = \frac{\log(\text{nat.}) \frac{V''_p}{V''_n} \times C \log(\text{nat.}) \frac{r_a}{r_i}}{T 2 \pi l}$$

in which V'_p and V''_p are the initial and final potentials of the inner cylinder for a positive charge. For the instrument used C , the capacity of the apparatus in electrostatic units, is 12.9; r_a , the inside radius of the outer cylinder, is 8.0 centimeters; r_i , the outside radius of the inner cylinder, is 0.71 centimeters l , the length of the inner cylinder, is 24.0 centimeters, and T , the time in seconds is 300 seconds.

Since all of the above, except V'_p / V''_p and T are constant quantities, we have

$$\lambda_n = \epsilon n_n n_v = \log (\text{nat.}) \frac{V'_p}{V''_p} \times \frac{K}{T} = 0.208 \log (\text{nat.}) \frac{V'_p}{V''_p} \times \frac{1}{T}$$

$$\text{If } T \text{ is 300 seconds: } \lambda_n = K' \log \frac{V'_p}{V''_p}, \text{ and}$$

$$\lambda_p = K' \log \frac{V'_n}{V''_n}$$

$$\text{in both of which } K' = 1.6 \times 10^{-4}.$$

The scale of the electroscope was calibrated at the United States Bureau of Standards on July 25, 1905.

From simultaneous values of the conductivity and the potential gradient, the vertical currents are computed in amperes per square centimeter, as observed at the surface of the Earth on the assumption that the Earth's surface is the plane of zero potential. The currents are composed of a stream of positive ions, moving toward the Earth's surface, and a similar stream of negative ions moving away from the Earth's surface.

Owing to the limited number of the observations it is not possible to obtain any idea of the diurnal range of the vertical currents. The values obtained, however, show a high conductivity of the air and a correspondingly large vertical current. The values of the vertical current, in electro-magnetic units, range from about 2.7×10^{-16} amperes per square centimeter to 12.0×10^{-16} amperes per square centimeter.

The results clearly show the greater conductivity of the air for negative electricity. The observations of August 30 present an interesting feature in that the conductivity of the air was practically the same for both positive and negative electricities at the beginning and end of the observations, and while the conductivity for negative electricity remained nearly constant throughout the entire period, that for positive electricity decreased appreciably during the latter part of the eclipse period, and then

rose slowly until noon, when it reached a value equal to that for negative.

Inasmuch as the conductivity for positive electricity is measured by the product of the number and mean velocity of the negative ions present in the atmosphere, while that for negative electricity is measured in a similar way by the number and velocity of the positive ions, an inspection of the results for August 30, when plotted shows that the product of the number and velocity of the positive ions of the air remained fairly constant during the entire period of observation, while the corresponding quantity for the negative ions decreased appreciably during the latter part of the eclipse, and did not recover its normal value until nearly noon.

It is generally accepted that the condensation of moisture decreases the velocity of the negative ions to a greater degree than it does that of the positive ions. The effect of moisture is practically the same on the conductivity of both positive and negative electricity. (See also observations at sea.²) Inasmuch as the observations of relative humidity show a decrease during the eclipse period it is difficult to explain the observation of August 30 on the ground of a decrease in the mean velocity of the negative ions.

Observations of conductivity were made under various conditions of weather, during fogs and rain, to determine their effect, if any. Some of the results show both kinds of ions to be similarly affected, and others that the two kinds of ions are not affected to an equal extent. Some observations near the surf were made in order to compare the relative conductivities for positive and negative electricity near the water, where considerable spray was present in the air, with the values at the usual place of observation. Observations were made on September 4 and 5 for the purpose of studying the effect of sunset on the conductivity. No definite results were obtained. The results indicate very plainly the different values of the conductivity on different days.

In view of the uncertainty regarding the conditions of atmospheric electricity in the immediate neighborhood of the ground, it is not thought advisable to place much dependence on the absolute values of the vertical currents. The results indicate that these currents vary greatly from day to day, as also from time to time during the same day. The curve for August 30 shows a marked depression immediately after maximum obscuration; the exact significance of this decrease is not clear.

² Burbank, J. E.; Specific Electrical Conductivity of Air at Sea. *Terr. Mag.*, Washington, D. C., v. X., Sept., 1905, pp. 128-129.