Terrestrial Magnetism *and* *Atmospheric Electricity*

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LE CADET'S TREATISE ON ATMOSPHERIC ELECTRICITY.¹

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Dr. Le Cadet has given in this volume of 200 pages a very general review of our knowledge of atmospheric electricity. Specifically, the chief aim of the work is to critically review present theories as to the origin of the electricity of the atmosphere in the light of certain modern determinations of the strength of the earth's electric field. Many years ago Sir William Thomson desired that we might have a general electrical survey, showing the surface density of the electrical charge on the earth's surface. If this were known, we could determine the normal values of the earth's field. It would also be shown whether masses of electrified air were the chief factors controlling the earth charge, and also what the upper limit of the air electrification might be. It is almost impossible to determine proper reduction coefficients for various points on the earth's surface, and so, lines of equal electrical potential are unknown. It is also evident that the relations existing between the potential and the various meteorological elements can only be imperfectly established by observation at the earth's surface. The study of the electricity of the air is restricted, as in Meteorology, by our inability to undertake work in the free air at a sufficient elevation, identical with that done at the surface. In common, then, with most workers of to-day, Dr. Le Cadet recognizes the necessity of reaching out from earth and studying the electrification of the air *in situ*. In brief, the purpose of this memoir is to direct attention to what may be called modern exploration of the earth's electrical field.

¹ *Étude du Champ Électrique de l'Atmosphère*, par GEORGES LE CADET. Annales de l'Université de Lyon. Paris. Librairie J. B. Baillière et Fils.

[PLATE V.]

L. W. Mumay

In the chapter devoted to instruments, there is given a full exposition of the errors peculiar to collectors as well as electrometers, and the chapter has evidently been written by one who is very familiar with the different types of instruments. Water-droppers, flame collectors, burning matches, and mechanical devices are discussed, and that the author's reading has been extensive is shown by references to devices not known except to those who are specially interested in this line of investigation. It is an open question whether our present instrumental equipments should not be regarded as provisional. Plates and points which lose their electrification upon exposure to certain solar rays may lead to collectors giving fixed values; but at present, it must be confessed, the experimenter is far from feeling confident that the values obtained by him in any piece of experimental work have not been vitiated by instrumental errors which he is powerless to eliminate. A small flame of illuminating gas is perhaps the handiest collector, since it takes but a few seconds to impart to the surrounding metal and needle the potential of the air. Morrill's flame collector is accorded high praise by Dr. Le Cadet, as it indeed deserves.

The portable apparatus used by Exner, and the different devices of Elster and Geitel, are discussed. A small metallic lamp, supported by an ebonite rod inclosed in a glass tube, makes a serviceable collector. In discussing the different forms of water collectors, attention is called to the methods employed by S. A. Andree at Cap Thordsen, Spitzbergen, in 1882-3, for use during low temperatures. Perhaps the collector of Rowland and Morrill—the so-called mechanical collector—will yield the most constant results.

The chapters dealing with the exploration of the atmosphere are full of detailed information. The two fundamental laws as given by Peltier are: 1st. That in clear weather the potential over conducting surfaces increases in general with elevation; 2d. If we consider only the rate of increase of potential with regard to height, this increase dV/dN , representing the intensity of the field, will vary, barring surface irregularities, proportionately with the density of a negative charge distributed over the earth surface, conformably to the equations of electrostatic equilibrium.

The chapters devoted to detailed accounts of the different attempts by means of balloons to measure the potential gradients, constitute a valuable contribution to our knowledge of this subject, and will prove very serviceable to future experimenters.

McAdie's experiments at Blue Hill with kites and electrometers, in 1891, are referred to as illustrating one of the few possible ways of obtaining accurate measurements of the potential gradient. Exner's experiments with small balloons carrying a match collector and fine copper wires are given at some length; and also the experiments of

Lemström, Semmola at Naples with captive balloons, Holmgren, Ch. André and Le Cadet. In the first ascension of the last named, made on September 27, 1892, two of the party of three were injured in the rapid descent, due to a storm. On September 15, 1892, Dr. Josef Tuma obtained the following values from 10 A. M. to 3 P. M.;

Height in meters	410	500	750	820	1000	1120	1300	1900
Potential fall in volts per meter	40	44	47	52	53	55	60	70

On August 1 and August 9, 1893, Dr. Le Cadet made some very successful ascensions, the results of which in brief were:

Mean height above ground	Fall of Poten- tial per meter.	Mean height above ground	Fall of Poten- tial per meter
August 1. 615 meters	75 volts	August 9. 824 meters	37 volts
740	45	830	43
790	35	1060	43
870	26	1255	41
1005	29	1290	42
1100	27	1745	34
1150	38	1940	25
1300	33	2080	21
		2120	19
		2310	18
		2520	16

The somewhat remarkable result appears from these observations, that during clear weather the field does not strengthen with altitude. Börnstein's observations in the balloon Phoenix, August 18 and September 29, 1893, also show a decrease in the potential gradient with elevation. Baschin's determinations, February 17, 1894, also confirm the above. In brief, it would seem that in middle latitudes, as a rule, the electricity of the air is positive, but that in the lower strata, up to 2,000 meters, the positive masses are offset by negative masses, sometimes feeble, sometimes strong; and the positive electricity predominating above is about neutralized at 5,000 meters by the negative charge of the earth and the lower layers of atmosphere.

On March 24, 1897, with new apparatus, a third ascension was made by Le Cadet, with the following results:

Altitude (meters)	dN (meters)	dV (volts)	dN/dV
1680	5	140	28
1700	5	158	32
1780	5	149	30
1810	5	155	31
1850	5	158	32
1880	5	145	29
1900	5	149	30
2200	5	149	30
2500	5	145	29

At the Observatory at Lyons the potential as registered on the electrometer gave a mean value for the field of 99 volts per meter for an altitude of 300 meters. The first deduction then is that the field was less

strong at 1,500 meters in the free air than near the ground. It is noteworthy that approximately the same value was obtained by all experimenters at an elevation of 1,800 meters.

The fourth ascension was made on September 11, 1897, and we shall give but a few of the many values then obtained:

Altitude (meters)	dN (meters)	dV (volts)	dN/dV
1120	5	220	44
1050	5	210	42
1120	5	220	44
1150	5	210	42
1260	5	206	41
1300	5	197	39
1370	5	188	38
1400	5	180	36
1550	5	201	40
1700	5	139	28
1800	5	133	27
2100	5	112	22
2200	5	110	22
2500	5	112	22
3000	5	95	19
4000	10	134	13
4150	10	112	11
3900	10	148	15

Taking the mean of 26 observations made when the balloon was fairly constant at an elevation of 4,000 meters we have $dV/dN=150\pm 20$ vm.

Following Exner, the relation between the distribution of the water vapor and the electrification of the air is discussed at length.

Le Cadet advances a new view concerning the origin of the positively electrified masses of the atmosphere. He holds that the field is the result of the negative electrification of the earth surface and the equivalent positive electrification of the free carbon dioxide. Carbon dioxide being a constituent of the atmosphere, the general distribution would conform to the general pressure distribution. Both the production and absorption of carbon dioxide occur at the earth surface, and it is in the lowest levels that we find the most marked variations.

Excellent curves showing the perturbations recorded during dust storms and the apparent relationship between the dustiness of the atmosphere and its electrification are given from the records of the Observatory at Lyons.