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Recent studies in Atmospheric Electricity in the India Meteorological Department

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1. Introduction

In a previous article (Agarwala 1948) the author had given a review of the studies in atmospheric electricity undertaken in the India Meteorological Department upto that time. Further work in atmospheric electricity has been carried out in the department during the past decade and an attempt has been made to review briefly the work done during this period.

2. Measurement of surface electrical potential gradient, conductivity, mobility of small ions, air-earth current, etc.

The measurement of the electrical potential gradient of the air is of intrinsic scientific value. In the India Meteorological Department systematic registration of the atmospheric electric potential gradient at the surface is being made at the Colaba Observatory, Bombay and at the Meteorological Office, Poona, by means of Photographic Electrograph (Cambridge Instrument Co) maintained for the past many years. In connection with additional observations to be taken during the International Geophysical Year (1957-58), Electric Field Meters specially designed and constructed at the New Delhi laboratory on the principle of the field meter by Ross Gunn have also been installed in 1957-58 at New Delhi and Dum Dum (Calcutta) for continuous record of the surface potential gradient. In this electric field meter, an electric conductor is rotated in the electric field of the earth and is alternately exposed and shielded from the field. The electrostatic charge induced in the conductor which is proportional to the electric field, passes through a very high resistance and the voltage thus developed across the high resistance is fed to a vacuum tube amplifier. The amplified signal is then fed to a recording ammeter to record the variations of the electric field of the earth. Apart from the analysis and discussion of the atmospheric electrical potential gradient data on "quiet" days, made by Sil and Agarwala (1940) at Poona, and by Mukherjee (1938) at Bombay, a study of the variations in the potential gradient at Poona caused by special meteorological phenomena had been made by Sil (1933) and the changes of atmospheric potential gradient during monsoon rains at Bombay had been discussed by Pillai (1940). A detailed study of the patterns of the changes in the atmospheric electric potential gradient at Poona during disturbed weather has, however, been made recently by Sivaramakrishnan (1953) and he has found that if during rainfall, the potential gradient is negative but without rapid variations, the rainfall is associated with a "quiet" atmosphere whereas large and rapid changes in the potential gradient are usually associated with atmospheric disturbances having appreciable local ascending air currents just as rainfall occurring in showers. During this study, two main types of potential gradient patterns have been recognised— (*a*) wave patterns and (*b*) symmetrical patterns.

The diurnal variation of condensation nuclei and visibility at Colaba (Bombay) and related changes in the earth's electric field have been studied by Mukherjee (1949). Hourly observations of condensation nuclei, electrical conductivity and visibility of the air taken almost simultaneously on a few selected days and nights during November to May 1936-38 were analysed and compared with the corresponding values of potential gradient and winds. The variations of concentration of condensation nuclei and potential gradient during non-monsoon months were found to be nearly similar but inverse to the variations of conductivity and visibility. The principal variation of the earth's electric field was found to be directly related to the air contamination. During monsoon, however, the air supply over Bombay being mainly from sea, the effect of localised pollution was found to be practically absent, as seen from the variations of condensation nuclei and visibility, and the variation of potential gradient was essentially similar to that over the ocean.

A statistical analysis of the data of visibility and conductivity, based on a separate series of observations taken during 1935-36 was also made by Mukherjee (1942) and it was found by him that the conductivity increases as the visibility improves, and that the annual changes of visibility and conductivity went hand in hand. Thus the diurnal and annual variations of visibility are closely related to the diurnal and annual changes of the earth's electric field at this station.

Measurements of the surface electrical conductivity of the atmosphere and concentration of small ions and large ions (nuclei) were also made at Poona for sometime by means of Gerdien's apparatus, Eberts' ion-counter and Aitkens' nuclei counter. Agarwala (1951a) has discussed the mobility of the small ions of the atmosphere at Poona as derived from the simultaneous measurements of the conductivity and the ion-content of the air using the relation $K=\frac{\lambda}{ne}$; K being the mobility, λ the conductivity, n the ionic numbers and e the unit charge. The number of positive and negative small ions were obtained by means of Eberts' ion-counter while the polar conductivities were measured directly with Gerdien's apparatus. The frequency curves indicated different mobility-groups, the most prevalent group of the positive ions having mobilities ranging from 0·9 to 1·1 and the most prevalent group of the negative ions having a mobility of 1·1 cm^2 $volt^{-1}$ sec^{-1}. The mean value of the +ve and –ve mobility was found to be 1·06 and 1·09 respectively based on 151 determinations. The rate of atmospheric ionization and the air-earth current at Poona have also been discussed by Agarwala (1951b). The values of the rate of ionization were worked out by him from the concentration of small ions and large ions (nuclei) by making use of the relationship between these elements. As regards the air-earth current, the values were obtained by using the indirect method, *i.e.*, through the product of the observed electrical conductivity of the air and the potential gradient. The mean values of the rate of ionization and the –ve air-earth current at 1000 IST at Poona worked out to be 14·7 ion-pairs cc^{-1} sec^{-1} and $3\cdot7 \times 10^{-7}$ e.s.u. respectively.

3. Measurement of point discharge current, rain charges, etc.

Mention had been made in the previous article (Agarwala 1948) of the work of Chiplonkar (1940) at the Colaba Observatory

(Bombay) on the measurements of point discharge current, etc. Chiplonkar had measured the current through a point 8·3 metres high and recorded the field simultaneously using a radio-active collector. A study of the electric charge on rain drops was undertaken at Poona with a special apparatus designed for the purpose and Sivaramakrishnan (1957) has made a detailed study of the point discharge current, the earth's electric field and rain charges during disturbed weather at Poona. An analysis of measurements of the current flowing to earth through an insulated point set up at a height of 17·8 metres together with simultaneous measurements of potential gradient by a quick-run photographic electrograph during fourteen thunderstorms in 1955 made by him showed that point discharge currents of either sign can be represented as increasing with the square of the field as found by Whipple and Scrase for Kew, Hutchinson for Durham and Chiplonkar for Colaba (Bombay). A paper on "The generation of Electric charge by disruption of Rain drops" has also been contributed by Das and Banerji (1956); they, in this paper, have computed the charging current due to disruption of falling rain-drops assuming a given drop-size spectrum and have found that the values obtained are one order less than those obtained by Chapman which were based on a number of simplified assumptions such as that all drops in the cloud were of equal size and that the drops could be treated as rigid spheres akin to molecules in the kinetic theory of gases.

4. Observations of electrical potential gradient and conductivity of the free atmosphere

While measurements of the surface electrical potential gradient and conductivity have been recorded in India for many years, similar measurements in the upper air have been made in this country only in recent years with the development of a technique for the measurement of the electrical potential gradient in the upper air with the audio frequency modulated type of radiosonde; experimental soundings were first obtained using this technique at the Meteorological Office, Poona (India met. Dep. 1955). Details of the technique for potential gradient measurements have been published in a paper by Venkiteshwaran, Dhar and Huddar (1953). In these measurements of the potential gradient the valve electrometer of Koenigsfeld and Piraux (1951) has been adopted with the audio frequency modulated type of radiosonde used in the U.S.A. The HL 23 valve which works as an electrometer is coupled to the modulator circuit of the American radiosonde transmitter by disconnecting its temperature and humidity elements and replacing them by a wire wound resistance of about 350 ohms. The above technique has been improved and simplified subsequently by dispensing with the specially wound load resistance by utilising the internal resistance of the HL 23 valve between the grid and the cathode (Venkiteshwaran, Gupta and Huddar 1954).

The above method has later been successfully extended to the measurement of the electrical conductivity of the air in the upper atmosphere by Venkiteshwaran, Gupta and Huddar (1953), who were the first to employ this technique.

The study of the variation of electrical potential gradient with height at Poona during a few consecutive days in October-November 1953, was made by Venkiteshwaran and Huddar (1956). The observations made by them indicate that in clear weather there is a rapid decrease in the field with increasing height above the ground, attaining almost a steady value of about 20 to 30 volts per metre at levels above 15,000 ft approximately and that there are appreciable variations, both diurnal and seasonal, in lower layers of the atmosphere upto about 10,000 to 15,000 ft even in clear weather. These are obviously due to local changes in the space-charge and the conductivity of the air. During the winter season, strong ground inversions prevail, particularly during the night and in the early morning and as a result, there is an increase in the condensation nuclei, in the lower layers of the atmosphere resulting in mist or even fog, which decrease the conductivity of the air by raising the proportion of the slow ions, causing corresponding increase in the potential gradient. As regards the diurnal variation of potential gradient with height, they found that on most days the potential gradient increased sharply just above the ground to nearly 600 volts per metre and this value rapidly decreased above approximately 850 mb (4760 ft above ground). This level corresponds to the level above which there is an increase in the lapse rate of temperature. The pontential gradient distribution and the tephigrams also showed that although the level at which the fall of the potential gradient approximately corresponds to the region of increasing lapse rate (about 850mb), the lowest value of the potential gradient is reached at 750—700 mb, where there is a sharp inversion associated with the drier air mass above. The value of the potential gradient in the upper drier air mass is low, being of the order of about 30–50 volts per metre, and there appears to be no change in this value at all heights above, extending even upto 100 mb. These are the important features about the variations in the potential gradient for tropical latitudes.

It may be added that special observations of potential gradient and conductivity of the free atmosphere are being made at Delhi and Poona on a limited number of "World Days" during the International Geophysical Year (1957-58). It is hoped that all the data of observations on atmospheric electricity collected by the Department during the International Geophysical Year will be analysed, discussed and published as soon as possible.

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