

Studies of fair weather atmospheric electrical potential gradient in the free atmosphere over Poona during IQSY

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ABSTRACT. The results of upper air soundings made during the IQSY (1964-65) at Poona to study the fair weather potential gradient in the free atmosphere are presented. The variations in the troposphere are large and shown to be mainly meteorological in origin. Small but significant variations are also noticed in the stratosphere. Values of ionospheric potential integrated from vertical profiles of the electric field, range from 260-360 kv, with a maximum during December-February and a minimum during June-August.

1. Introduction

The main electrical generators in the atmosphere, the thunderstorms, are driven by solar energy and in consequence, their total global activity is related to solar activity. Since the conductivity of the atmosphere at high levels is also influenced by solar radiation, this would again affect the path and the strength of the electric currents in the complete electrical circuit, by which thunderstorms control the electrical phenomena in fine weather regions.

The main reason for the present ambiguity in fair weather electricity studies is the superimposition of local meteorological effects on world-wide effects, particularly near the ground. Two spheres of quite different behaviour, have therefore to be considered separately, the troposphere, characterised by vertical turbulent convection and the stratosphere-mesosphere, by horizontal motion. The electric behaviour of the stratosphere-mesosphere is essentially governed by the world-wide steering effects of the main generator and by variations of ionization, which depend mainly on the variations of cosmic radiation with latitude. The tropospheric variations are controlled by the influence of 'Austausch' on the aerosol conditions. The processes and problems are quite different in the two regions from the meteorological as well as the electric point of view.

2. Measurement of the fair weather potential gradient

Fairly extensive measurements of atmospheric electric potential gradient in the free atmosphere have been made at a number of stations in the world but the measurement of the electrostatic field in the regions above the tropopause has naturally received little attention. Eighty per cent of the total atmospheric potential lies below 6 km and the contribution of high-altitude fields to the total earth-ionosphere potential is extremely small. Stratospheric measurements are essential,

however, for a systematic study of the total potential difference V , between the surface of the earth and the ionosphere and its variations in time. Electric field and conductivity measurements could be a valuable index of the time variations of global electrical activity and provide a better insight into the mechanism of the world-wide atmospheric electrical circuit and particularly changes in thunderstorm activity in different parts of the world. But to be meaningful they have to be essentially free from the interference of the local meteorological factors, which make interpretation of low level data so difficult.

The main reason for the lack of observations in the stratosphere, is the inherent limitations of present-day techniques for sounding the stratosphere, particularly with balloon-borne sondes. The field itself is distorted by free and induced charges on balloons. The sondes are designed for low altitude, high-field measurements, and are not sensitive enough for measuring accurately the very small potential gradient which occur at high levels. The radioactive collectors used are also of limited or no value at these levels. Aircraft measurements at very high levels are not possible.

3. Atmospheric electricity measurements during the IQSY

In view of the importance of information on the distribution and temporal variation of global thunderstorm activity and of the details of the mechanism by which its control of fine weather effects is achieved, the Joint Committee on Atmospheric Electricity of the International Association of Meteorology and Atmospheric Physics and the International Association of Geomagnetism and Aeronomy, formed a working group in 1963, for planning and organizing systematic world-wide observations of atmospheric electricity during the IQSY. Under the auspices of this working group, weekly soundings on all

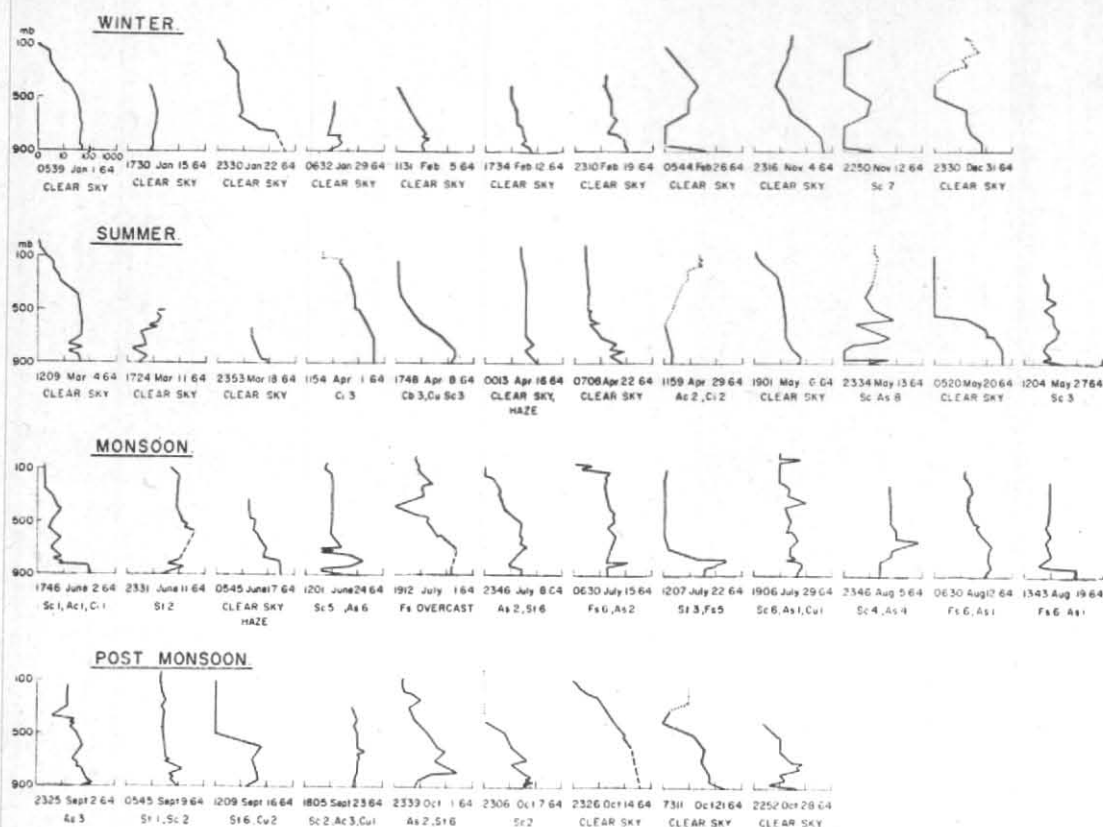


Fig. 1. Vertical distribution of atmospheric potential gradient—1964
Horizontal scale of each graph is logarithmic from 1—1000 volts/metre; Time of observations in IST

Regular Geophysical Days were made at a number of stations in the world according to an agreed joint programme, using sondes developed in each country. To ensure world-wide comparability of atmospheric electricity data, potential gradient sondes taking part in the IQSY programme, were inter-compared at Weissenau, Germany in May 1965, under the auspices of the World Meteorological Organisation Working Group on Atmospheric Electricity. The results showed surprisingly good agreement among the different sondes.

The potential gradient sonde used at Poona during 1964 was the original sonde designed by Venkiteswaran and his colleagues (1953). This had certain drawbacks and improvements were made during 1964-65 to improve its stability, reliability and accuracy and to reduce the response time. The modified sonde (Srivastava *et al.* 1966) was used in the soundings during 1965.

4. Results

The results of the soundings made during 1964 and 1965 are summarised in Figs. 1 and 2, where the

potential gradient in volts/metre is plotted against pressure in mb for the years 1964 and 1965. The horizontal scale is logarithmic, with potential gradient from 1-1000 v/m. The soundings are grouped under four main categories for the four main seasons of the year, winter, summer, monsoon and post-monsoon.

(a) *Troposphere: Exchange layer*—The exchange layer as explained earlier, is the region of small scale convection currents and turbulent mixing, characterised by high and variable values of the electric field. It is confined to a thin layer extending from the ground to about 3 km in winter and about 6 km in summer. The large diurnal and day-to-day variations are clearly caused by local changes in the number and types of condensation nuclei and the consequent variation in electrical conductivity, in the lower layers of the atmosphere. The results are similar to those obtained earlier during the IGY.

A rather interesting new feature observed, is the secondary exchange layer that appears at about

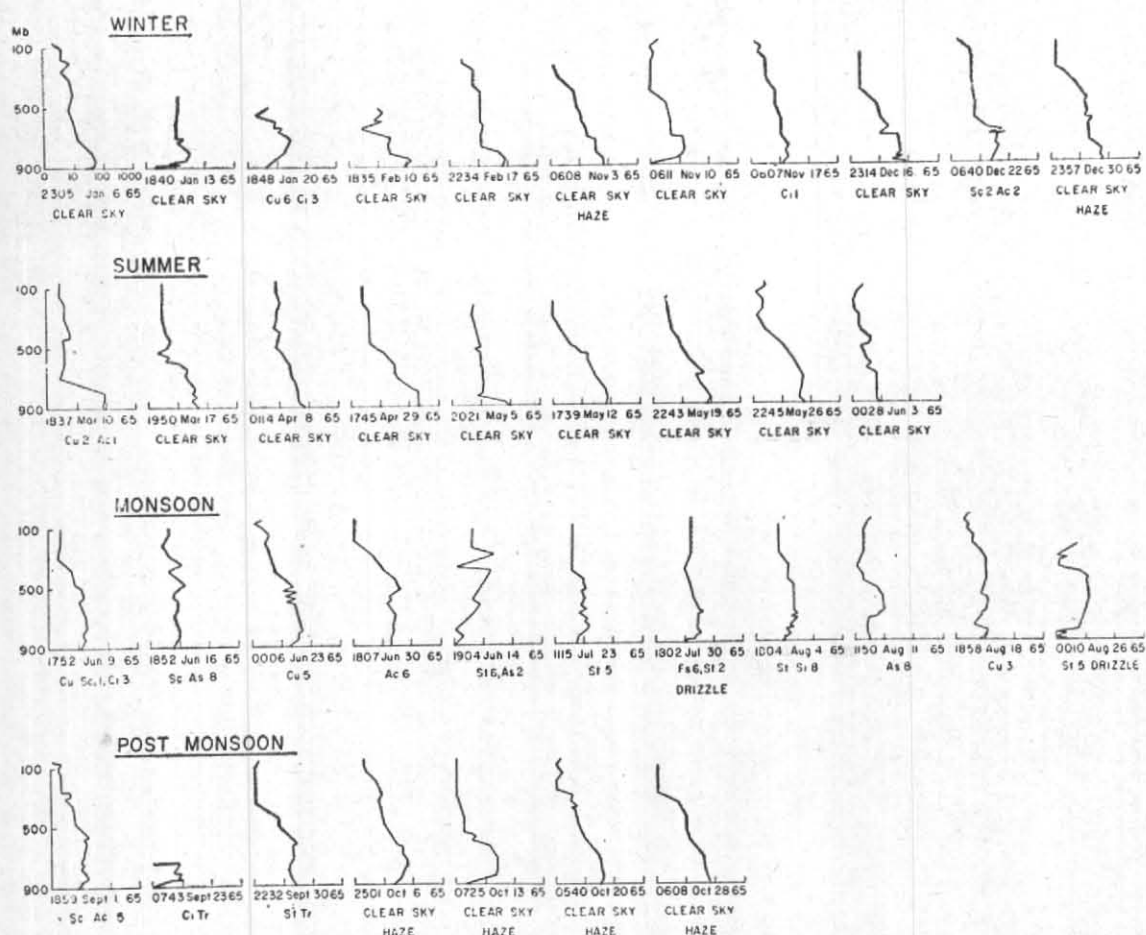


Fig. 2. Vertical distribution of atmospheric potential gradient—1965

Horizontal scale of each graph is logarithmic from 1—1000 volts/metre; Time of observations in IST

800-700 mb (2-3 km), in addition to the surface layer, during the winter months in almost all the soundings. The sharp increases in potential gradient are invariably accompanied by similar peaks in relative humidity profiles, but are not always associated with temperature inversions. This is illustrated in Fig. 3, where potential gradient values in exchange and cloud layers in the lower troposphere, are shown. Potential gradient in volts/metre, temperature in degrees centigrade and relative humidity are plotted against height in millibars.

Another feature of interest is the increased heights to which Austausch extends during summer due to increased heating and turbulence in this season (Figs. 1 and 2) and increased dust contents and consequent high values of potential gradient in the atmosphere during the premonsoon months over the area. Turbidity observations using

potential methods (Mani and Chacko 1963) have indicated high dust content in summer and a practically clean atmosphere during the monsoon.

(b) *Upper troposphere*—Above the exchange layer, the atmospheric potential gradient normally decreases exponentially with altitude. Departures from theoretical values are observed during the winter and summer months when abrupt increases in potential gradient are observed in the upper troposphere. During winter, field values show a marked increase at about 300—200 mb (9—12 km) when jet streams are present over Poona. Fig. 4 illustrates the 'jet stream effect' during the winter of 1965. Winds and potential gradient are plotted against pressure in mb. Marked increases are noticed on the first three days when winds are strong, in contrast to the last two. These observations confirm those made during the IGY (Mani and Huddar 1965).

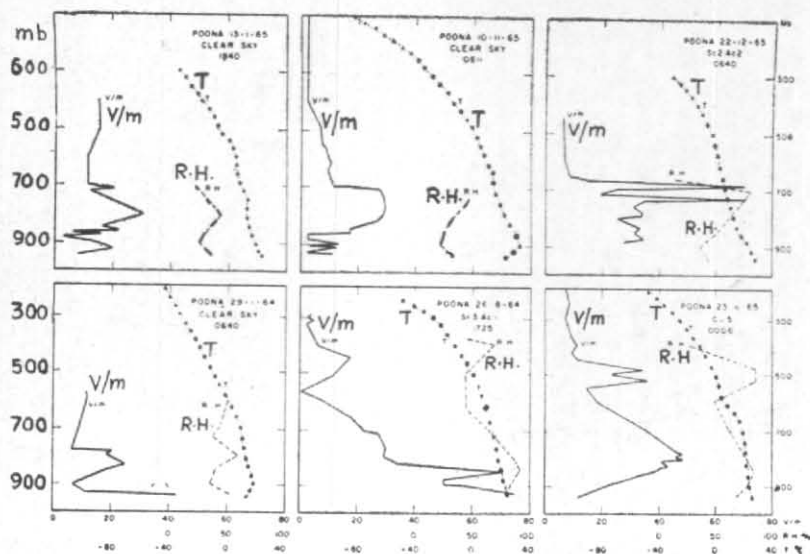


Fig. 3. Potential gradient in exchange layers and clouds

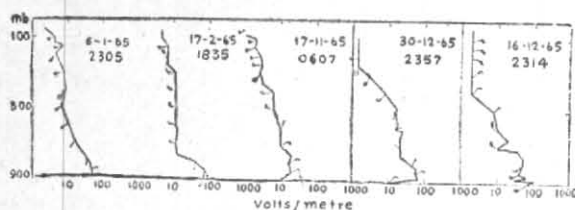


Fig. 4. Potential gradient and Jet stream

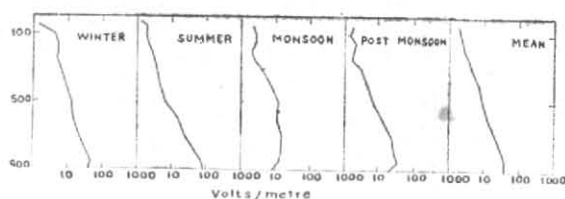


Fig. 5. Mean potential gradient over Poona—1965

Because of their vertical circulations, the jet streams become a very important factor of mass exchange, which brings particles originally suspended in the stratosphere and in the upper troposphere, to lower levels in a short time. Opinions regarding the causes of stronger electric fields in the vicinity of jet streams are widely divergent. Falconer (1952) assumed positive charges found in iced up parts of cumulus clouds to be transported over wide areas where they cause increased electric fields. The increase could also be caused by particles of extra-terrestrial origin, descending to the upper troposphere, through breaks in the tropopause. When jet streams are active over the region, injections of dust from volcanic eruptions cannot also be ruled out. Similar variations in vertical profiles of radiation and ozone have also been observed during the IQSY over Poona.

(c) *Stratosphere*—Fig. 5 shows the mean potential gradient profiles from the surface to 30 km over Poona during the IQSY, for the whole year and for the four main seasons. The effect of increased mois-

ture and clouding during the monsoon and austausch during summer in the lower troposphere and 'jet stream effect' in winter in the upper troposphere are clearly indicated.

In the stratosphere the field is not always negligible as one would expect from theoretical considerations. Sudden increases are occasionally observed as on 15 July 1964 at 19 km and 29 July 1964 at 24 km (Fig. 7). These are presumably caused by dust at high levels and deserve direct observation and study. Increased pollution in the stratosphere due to atomic explosions cannot also be ruled out. Hatakeyama *et al.* (1958), while carrying out conductivity measurements in the atmosphere did find rapid fluctuations in the stratosphere.

5. Atmospheric potential

The total atmospheric potential is the most important index of world-wide atmospheric electric variations, just as conductivity is the most important measure of local atmospheric conditions

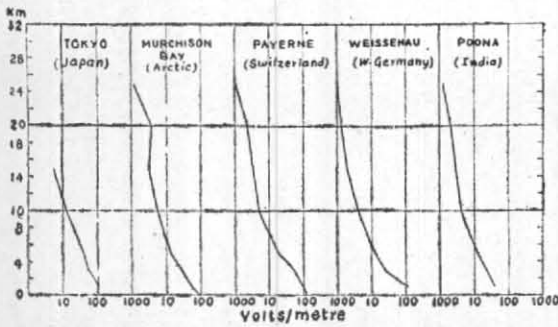


Fig. 6. Mean potential gradient in the free atmosphere

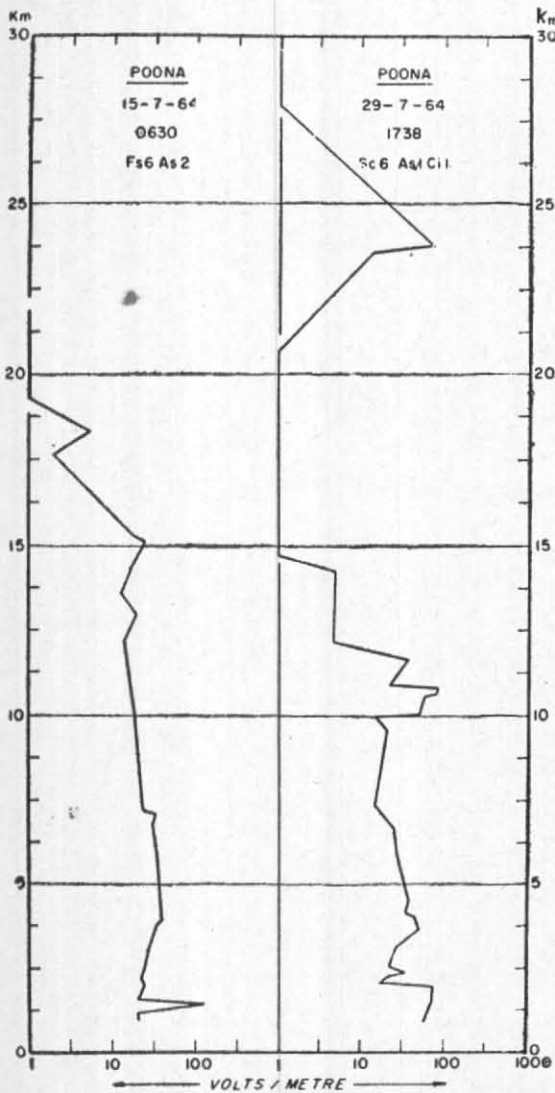


Fig. 7. Potential gradient with height

in the troposphere. The atmospheric potential values over Poona have been calculated by integration of the electric field values, from the surface to ionospheric levels for all the soundings. The mean values for the four seasons are as follows—

Season	Mean values
December—February	311 kv
March—May	357 kv
June—August	258 kv
September—October	281 kv

The mean for the whole year is 300 kv with an accuracy of ± 10 per cent. This compares well with 290 kv obtained by Clark (1958) over the USA and 282 kv obtained by Fischer (1962) at Weissenau. Gish (1951) obtained values of 360 kv over the USA and Israel (1953) 270 kv over Germany. The summer values over Poona are clearly influenced by the presence of dust in the lower troposphere and are abnormally high. The monsoon values are the least, since the atmosphere is washed clean of dust at this time. If we neglect the meteorological effects in the lower troposphere, the ionospheric potential is seen to be least during June—August and highest during December—February. Fischer (1962) also found a seasonal maximum in the northern winter, corresponding to maximum global thunderstorm activity.

Diurnal variations show a maximum (366 kv) at about 1800 GMT and a minimum (271 kv) at 0600 GMT. The total atmospheric potential has a stable value, about which it varies diurnally. Whipple (1929) has pointed out that this diurnal variation in the electric field of the earth is due to global thunderstorm activity, which is a maximum at 2000 GMT and a minimum at 0400 GMT.

6. Comparison with other stations

The vertical distribution of potential gradient at different stations in the world is shown in Fig. 6. The agreement upto 25 km at stations as far apart as Murchison Bay in the Arctic, Payerne and Weissenau in Central Europe, Tokyo and Poona in Asia and the USA is remarkable and indicate that one can justifiably expect worldwide comparability of data to exist even in this very difficult field of measurement,

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