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# Studies of atmospheric electrical potential gradient near the ground at Poona during the IQSY

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ABSTRACT. A detailed study of the diurnal and seasonal variations in the atmospheric electrical potential gradient near the ground during the IQSY has been made from the records of photographic electrograph installed in the Meteorological Office at Poona. The results are compared with earlier values obtained at Poona during the IGY, and at Bombay both during the IGY and IQSY. The electric field at both Poona and Bombay shows a large increase since the IGY and these are attributed to the increase in sources of atmospheric pollution in the region during the last few years.

## 1. Introduction

Over the oceans and in regions well removed from sources of pollution, the electrical field strength and air-earth current have a 24-hour period and show parallel variations, while electrical conductivity is practically constant throughout the day. Over the continents, the electrical potential gradient generally shows a double oscillation during the day, while the air-earth current and conductivity have a parallel 24-hour period. Paramanoff (1950) was able to show that over non-polar continental stations also the oceanic type is present, but is superimposed by local influences. The local perturbations were earlier considered to be an unwelcome noise, but are now known to give information on the relation between certain weather conditions and atmospheric electricity parameters and to enable one to draw conclusions about meteorological conditions in the lower layers of the atmosphere.

Israel (1953) attributed the daily variations of potential gradient over the continents to "vertical atmospheric mass *austausch*" and to changes in the number of atmospheric condensation nuclei. Muhleisen (1955) has, however, shown by actual measurements that the diurnal variations of potential gradient near towns are caused mainly by positive space charges, produced chiefly by urbanization, industry and traffic. Haze, which is the collective name of atmospheric suspensions, is mainly confined to the lower layers of the atmosphere. Whipple (1929) found that the daily variations of atmospheric pollution and potential gradient at Kew are very similar, both showing a closely parallel 12-hour oscillation. Whipple explained the double fluctuation at Kew as a joint result of production and vertical transport of pollution particles.

The abundance or scarcity of condensation nuclei and dust or particulate matter in the air is of great importance to the physics of precipitation and in the heat balance of the earth. Electrical conductivity even over the oceans, as measured during the cruises of Carnegie from 1915 to 1929, showed a gradual decrease, which was attributed to a gradual increase in the particulate content in the lower layers of the oceanic air (Wait 1946). At land stations all over the world, wherever more or less continuous records of atmospheric electrical conductivity or potential gradient have been kept, a diminution appears in conductivity and an increase in potential gradient.

Atmospheric potential gradient measurements have been made at Poona since 1930 and it seemed worthwhile to study the nature of the variations in electric field strength at the ground at Poona during the IQSY and to compare the observations with those made during the IGY and earlier during 1930-38; and to compare these results with those obtained at Bombay during the IQSY and IGY. Earlier data at Poona have been studied and the results published by Sil (1938), Sil and Agarwala (1940), Sivaramakrishnan (1953) and Sivaraman and Banerji (1962) and at Bombay by Mukherjee and Pillai (1940) and Yacob (1962).

## 2. Data

The instrumental arrangement is exactly that described by Sil and Agarwala (1940) and has not been changed since 1930, as far as is known from available records, except for periodic replacement of the radium collector and overhauling of the driving clock and recorder. The radium collector in the form of a helix is exposed at a mean distance of 50 cm from the zero potential surface. This is reduced to 25 cm in disturbed weather. The

TABLE 1

**Mean monthly values of electrical potential gradient (V/m) near the ground at Poona**

| | Period | | |
|---|---|---|---|
| | (1930-38) | IGY (1957-58) | IQSY (1964-65) |
| Jan | 79 | 116 | 145 |
| Feb | 72 | 62 | 90 |
| Mar | 63 | 50 | 75 |
| Apr | 59 | 48 | 42 |
| May | 59 | 16 | 43 |
| Jun | 57 | 14 | 47 |
| Jul | 59 | 32 | 60 |
| Aug | 59 | 48 | 70 |
| Sep | 65 | 36 | 57 |
| Oct | 68 | 83 | 95 |
| Nov | 75 | 120 | 154 |
| Dec | 88 | 129 | 175 |
| Mean | 67 | 63 | 84 |

apparatus is calibrated periodically and periodical tests made for leak in the electrometer system. The correction for imperfect exposure is determined every year, from control observations taken in the open field about 5 km from the observatory.

Undisturbed days in Poona are few, despite the fact that thunderstorms occur only during the pre-monsoon and post-monsoon months, March to May and October to November. The monsoon season extends from June to September, when the skies are generally overcast and it drizzles or rains occasionally. The winter, December to February, is characterised by mist or fog in the morning and haze in the evening. During the summer months the atmosphere is dusty and the visibility low.

The data studied in this paper pertains to the IQSY period (*i.e.*, 1 January 1964 to 31 December 1965) excluding period of rain and thunderstorm during a day but including the rest of the day when there was no rain, shower or thunderstorm.

### 3. Results

The mean values of electrical potential gradient for the IQSY (1964-65), IGY (1957-58) and the period 1930-38 are given in Table 1. In the absence of an agreed definition "of an undisturbed day" the IQSY and IGY values given are for "undisturbed periods", *i.e.*, they exclude periods of rain and thunderstorms during a day, but include rest of the day when there was no rain, showers or thunderstorms. Though periods of thick dust and haze should also have been normally excluded, this has not been done, as it would have led to the exclusion of much of the summer and winter days. The eight years' data discussed by Sil and Agarwala (1940) contained only about 416 'undisturbed days' since even days of dust and haze had been excluded. The IGY and IQSY data are, therefore, not strictly comparable with the 1930–38 data presented.

Fig. 1 shows the diurnal variation of the potential gradient at Poona during the different months of the IQSY. Fig. 2 shows the diurnal variations during the four main seasons, summer (March to May), monsoon (June to September), post-monsoon (October and November) and winter (December to February) for both the IGY and IQSY. The mean hourly values of the potential gradient for the different seasons during the IQSY and IGY are tabulated in Table 2.

An examination of Figs. 1 and 2 shows that there is a seasonal as well as a diurnal variation in the mean hourly values of the potential gradient. The values are in general low and the diurnal variation almost absent during the monsoon months. Both the absolute values of the potential gradient and the variations are large during the other 3 seasons, being highest during winter from November to January. The afternoons during the summer months, especially April and May, experience thundery conditions and the potential gradient fluctuates violently. These being both positive and negative, tend to lower the summer values somewhat. The diurnal variations show prominent 12-hour oscillations during the non-monsoon seasons, with minima at 0500 and 1600 IST and maxima at 1000 and 2100 IST.

Fig. 2 summarises these results for both the IGY and IQSY. The two sets of curves are similar, except that the maximum at 2100 IST during the IQSY is flatter than that during the IGY. There is also a slight shift in time by one hour both in the maxima and minima. Since the exposure has remained unchanged there seems little doubt that local conditions play an important part in the diurnal variation and the times of maxima and minima now appear later than during the IGY.

The mean monthly values of potential gradient for both the IQSY and IGY at Poona are plotted in Fig. 3. IQSY values are throughout 30–60 per cent higher than the IGY values, except in April. In the upper half are plotted monthly values of the Angstrom atmospheric turbidity coefficient $\beta$ for both the IQSY and IGY. The increase in turbidity since the IGY is roughly double and the increased atmospheric pollution is probably caused by increased urbanization and industrialisation in Poona.

**TABLE 2**

**Mean hourly values of potential gradient (V/m) at Poona for different seasons during IGY and IQSY**

| Hour (IST) | SUMMER | | MONSOON | | POST-MONSOON | | WINTER | | ANNUAL | | MAUNA LOA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | IGY | IQSY | IGY | IQSY | IGY | IQSY | IGY | IQSY | IGY | IQSY | 1960-61 |
| 00 | 31 | 50 | 28 | 45 | 97 | 125 | 103 | 153 | 65 | 93 | 130 |
| 01 | 31 | 49 | 28 | 43 | 86 | 110 | 85 | 139 | 57 | 85 | 135 |
| 02 | 29 | 48 | 28 | 44 | 71 | 97 | 75 | 120 | 51 | 77 | 142 |
| 03 | 26 | 44 | 26 | 44 | 57 | 79 | 59 | 99 | 42 | 67 | 147 |
| 04 | 28 | 39 | 24 | 45 | 56 | 69 | 52 | 83 | 40 | 59 | 146 |
| 05 | 32 | 39 | 29 | 47 | 56 | 69 | 55 | 79 | 43 | 59 | 142 |
| 06 | 48 | 48 | 42 | 53 | 79 | 83 | 81 | 99 | 63 | 71 | 138 |
| 07 | 59 | 68 | 51 | 65 | 106 | 115 | 112 | 135 | 82 | 96 | 131 |
| 08 | 68 | 85 | 49 | 74 | 154 | 159 | 175 | 161 | 111 | 120 | 118 |
| 09 | 74 | 89 | 46 | 77 | 170 | 199 | 224 | 183 | 129 | 137 | 107 |
| 10 | 59 | 83 | 39 | 74 | 142 | 215 | 201 | 201 | 111 | 143 | 101 |
| 11 | 49 | 71 | 36 | 71 | 114 | 197 | 148 | 207 | 87 | 137 | 99 |
| 12 | 39 | 60 | 34 | 69 | 99 | 163 | 104 | 188 | 69 | 120 | 101 |
| 13 | 34 | 51 | 33 | 69 | 79 | 128 | 75 | 150 | 55 | 99 | 103 |
| 14 | 22 | 37 | 28 | 63 | 74 | 103 | 63 | 119 | 47 | 83 | 104 |
| 15 | 11 | 25 | 30 | 56 | 69 | 91 | 57 | 104 | 42 | 69 | 105 |
| 16 | 16 | 21 | 31 | 53 | 66 | 84 | 54 | 95 | 42 | 63 | 106 |
| 17 | 17 | 19 | 33 | 52 | 77 | 89 | 64 | 98 | 48 | 65 | 111 |
| 18 | 18 | 27 | 38 | 57 | 104 | 109 | 104 | 111 | 66 | 76 | 115 |
| 19 | 25 | 45 | 42 | 61 | 143 | 131 | 149 | 137 | 90 | 93 | 119 |
| 20 | 37 | 59 | 45 | 63 | 157 | 145 | 168 | 155 | 102 | 105 | 121 |
| 21 | 32 | 61 | 39 | 64 | 138 | 147 | 156 | 153 | 91 | 106 | 123 |
| 22 | 29 | 55 | 34 | 59 | 131 | 145 | 138 | 158 | 83 | 104 | 123 |
| 23 | 31 | 51 | 28 | 51 | 114 | 140 | 120 | 161 | 73 | 101 | 125 |

The last column in Table 2 gives the values of the potential gradient at Mauna Loa observatory for 1960-61 (Cobb and Phillips 1962). Mauna Loa in the island of Hawaii, 3394 m above sea level, is considered as an 'atmospheric bench mark' of the suspended particulate matter within the earth's air envelope, on account of its location well above the *austausch* layer and its consequent freedom from local pollution. The differences between the Poona and Mauna Loa values can be taken as an index of the local convection and pollution effects at Poona.

#### 4. Discussion

4.1. *Poona* — Israel (1953) has reported that over continents both types of variations in potential gradient occur, the single 24-hr oscillation and the double 12-hr oscillation and that as a rule, the former is present in winter and changes gradually into the latter type by summer. In some stations the variation during the entire year is of the single periodic type and in some the double periodic. At Poona the variations are throughout of the double 12-hr oscillation type with the prominent variations of winter being almost wiped out during the monsoon months. The reason for the low values and lack of daily variation in the potential gradient during the monsoon must be ascribed to the fact that the monsoon air being maritime in origin is more moist and is already thoroughly mixed. The atmospheric pollution due to suspension of dust is also less during the monsoon. The air is also more stable and the *austausch* effect less prominent.

Israel (1953) also showed the diurnal variations in potential gradient and vapour pressure and atmospheric pollution to be almost identical and explained the double-periodic daily variation to arise through the superposition of a 'depression' around noon time upon the simple daily 24-hr basic fluctuation due to the atmospheric mass *austausch*. In Fig. 4 are plotted the hourly values of vapour pressure for the different months. It will be seen that in agreement with Israel's observations, a double periodic daily variation almost identical with that in potential gradient, is present in the vapour pressure curves. The close similarity in the two sets of curves indicate that the two are parallel phenomena having a common origin.

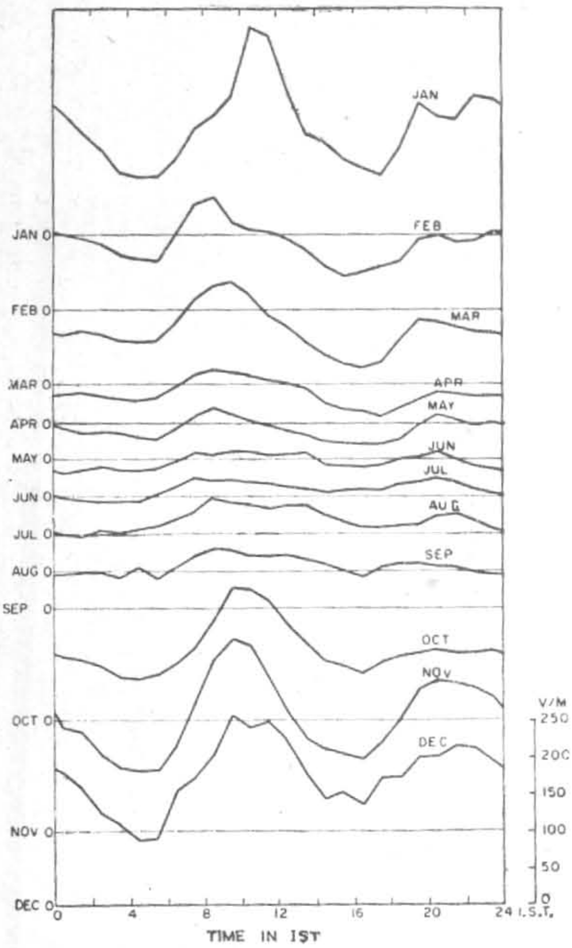


Fig. 1. Diurnal variation of potential gradient near the ground at Poona during IQSY (1964-1965)

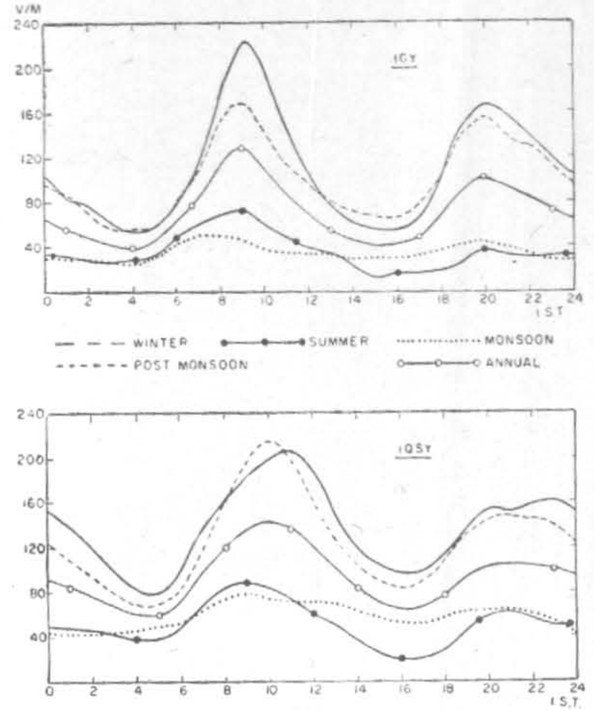


Fig. 2. Diurnal variation of surface potential gradient (V/m) at Poona during different seasons

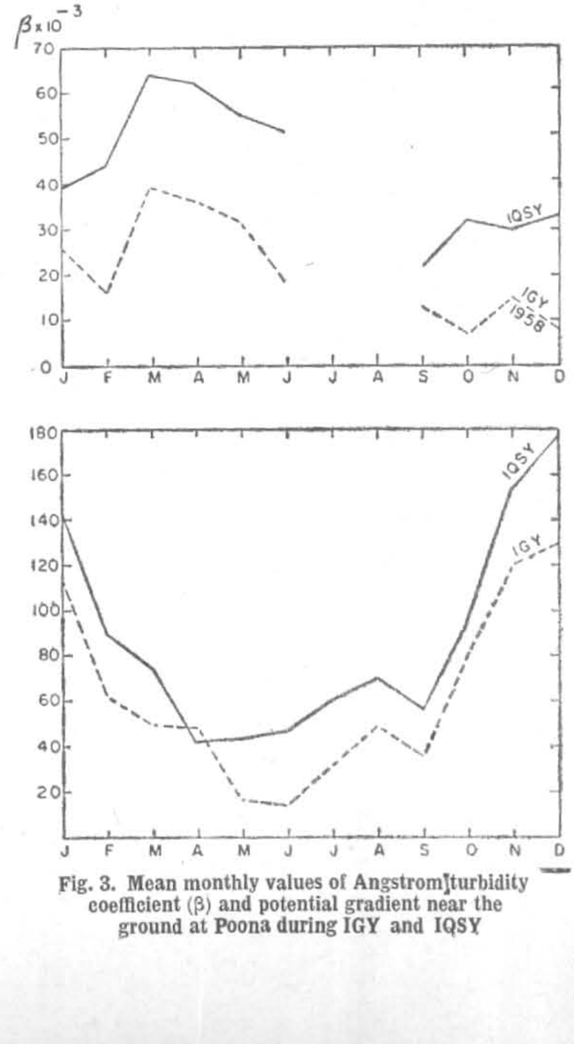


Fig. 3. Mean monthly values of Angstrom turbidity coefficient (β) and potential gradient near the ground at Poona during IGY and IQSY

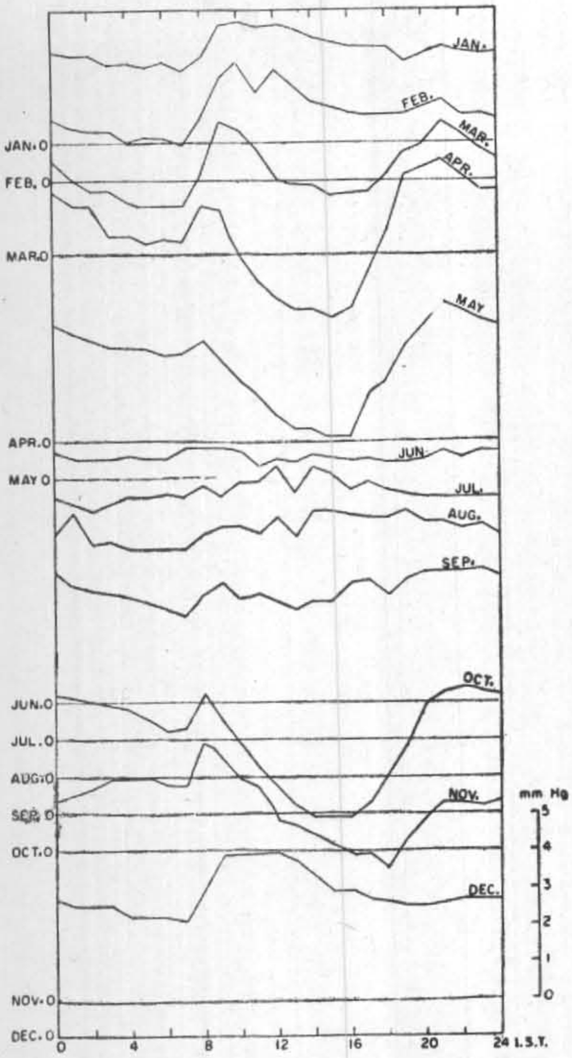


**Fig. 4. Mean diurnal vapour pressure (mm of Hg) at Poona during IQSY (1964-65)**

NOTE : Base line =6 mm Hg for Jan-Apr, Nov and Dec =12 mm Hg for May-Oct

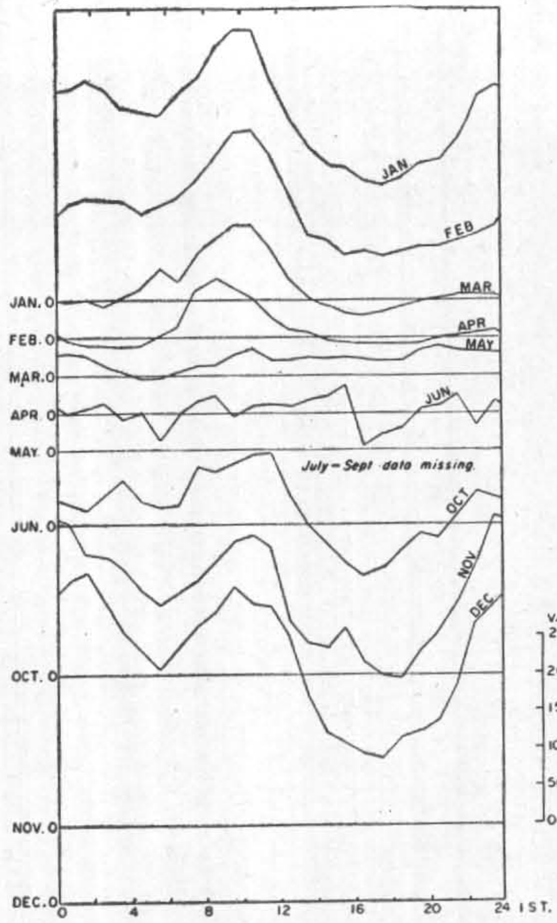


**Fig. 5. Diurnal variation of potential gradient near the ground at Colaba, Bombay during IQSY (1964–1965)**

4.2. *Bombay* — In Figs. 5 and 6 are presented the hourly mean values of potential gradient at Colaba (Bombay) during the IQSY and IGY. The mean monthly values are given in Fig. 7. The main features are the same as those at Poona with a 12-hr period, but the maxima occur at about 0200 and 1000 IST and minima at about 0600 and 1800 IST. They do not also occur at the same time during the year as at Poona but vary from month to month. The maximum variations occur during the months November to February and there are little or no diurnal variations during May to September as at Poona.

Mukherjee and Pillai (1940) had observed the effect of dust on potential gradient at Bombay and reported that with the occurrence of dust raising winds the air becomes visibly charged and the field shows a sharp reversal. The values of the potential gradient were seen to fluctuate violently from a few to several hundred volts, depending on the strength and direction of the winds. They found that during the pre-monsoon months, no less than 95 per cent of the days on which potential gradient was negative, was due to dust in the air. The low values at both Bombay and Poona during both the IGY and IQSY during April-May support these observations.

4.3. *Variation with air masses* — Israel (1953) has shown that electrical conductivity and field strength are good criteria of air mass types, since atmospheric stability is also an air mass criterion.

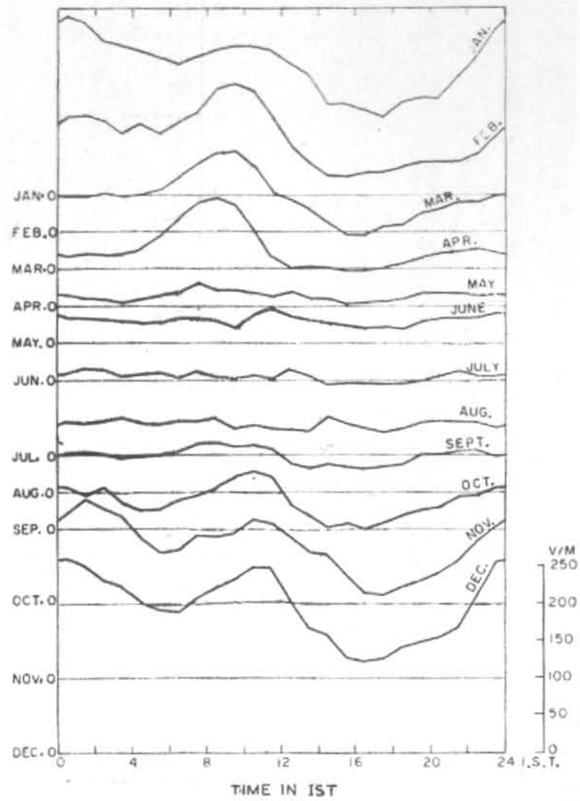


Fig. 6. Diurnal variation of potential gradient near the ground at Colaba during IGY (1957-1958)

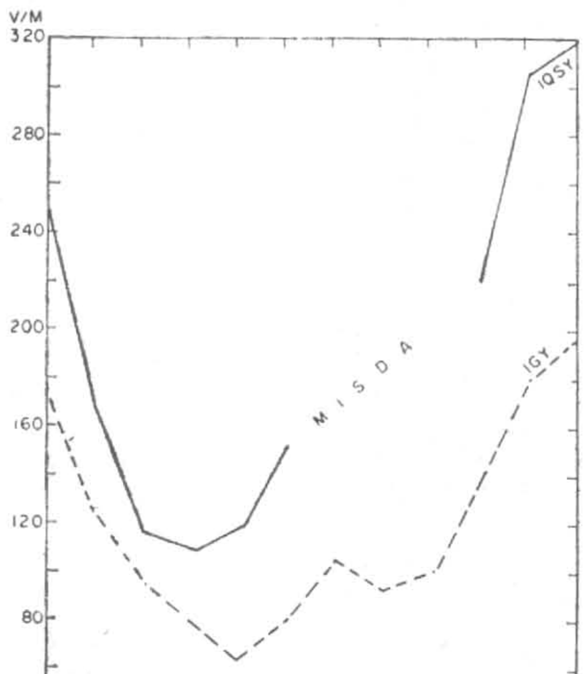


Fig. 7. Mean monthly values of potential gradient near the ground at Colaba during IGY and IQSY

TABLE 3

Potential gradient values (V/m) and Ångstrom turbidity coefficient (β)

| Air mass | Poona | | | | Bombay | |
|---|---|---|---|---|---|---|
| | IQSY | IGY | 1930-38 | β (IGY) | IQSY | IGY |
| Winter *Pc* | 137 | 102 | 80 | ·016 | 246 | 165 |
| Summer *Tc* | 53 | 38 | 60 | ·035 | 115 | 79 |
| Monsoon *Tm* | 59 | 43 | 60 | ·012 | (152) | 126 |
| Post-monsoon | 125 | 101 | 71 | ·009 | 263 | 158 |

Koenigsfeld (1953) found the following potential gradient values in different air masses at Uccle —

| | |
|---|---|
| Arctic | 282 V/m |
| Polar continental | 201 V/m |
| Continental | 159 V/m |
| Polar maritime | 117 V/m |
| Maritime | 79 V/m |

The mean value of the potential gradient over the oceans given by Mauchly is 113 V/m.

Over Poona and Bombay the air mass is tropical maritime during the monsoon months, June to September, and tropical continental during the summer months, March to May. The monsoon air is cool and highly humid and convectively indifferent, while the tropical continental air is the hottest and driest air over India, with marked instability and turbulence leading to the development of dust raising winds and duststorms. The modified cold air over central India in winter is of continental polar origin, characterized by pronounced convective stability. The values of potential gradient for the three seasons are given in Table 3 along with the Angstrom turbidity coefficients $\beta$ (Mani and Chacko 1963).

It is obvious that the air masses become considerably modified in their travel over various regions, and are especially influenced by local pollution and exchange. The values at Bombay and Poona barely 120 km apart differ by a factor of 2. The values of potential gradient for 1930–38, in which even days of haze and dust were excluded, show that variations in different air masses are less significant.

## 5. Conclusions

(1) At Poona and Bombay, similar 12 hour oscillations in both the diurnal and seasonal variation of potential gradient during IGY and IQSY are present. The values are relatively large and the variations prominent during the winter season, while during monsoon they become very small with little or no variation.

(2) The potential gradient values during IQSY show an increase of about 30-60 per cent over those during IGY both at Poona and Bombay.

(3) A slight shift of about an hour in the time of occurrences of maxima and minima between IQSY and IGY period is noticed at Poona. The similar shift is not quite perceptible at Bombay.

(4) The diurnal variation of potential gradient and vapour pressure at Poona show marked similarity indicating a close relationship between the two.

(5) The overall increase in the values of potential gradient both at Poona and Bombay during IQSY as compared to IGY is presumably due to increased atmospheric pollution as a result of increased industrialisation, urbanization and traffic. The increased atmospheric pollution (about 2 times) during IQSY as compared to IGY period is also supported by the observed turbidity measurements during the two periods.

(6) Secular variations in potential gradient over the oceans reflect variations of electric parameters on a global scale and to gradual changes in the global electrical circuit. Low level land surface observations are, on the other hand, normally dominated by local environmental conditions, as a result of the injection of particulate matter into the lower air strata and continuing but irregular convective and diffusion processes. The observed secular variations in potential gradient at Poona and Bombay would appear to be due to the effects of increased pollution in these regions.

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