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The study of the electrical conductivity of air in the lower stratosphere at Poona

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ABSTRACT. A series of measurements of the electrical conductivity of air in the atmosphere up to a height of 20-25 km was made at Poona during 1971-72 using balloon borne conductivity sondes developed and constructed in the Instrument Research Laboratories of the Meteorological Office at Poona.

During July and September conductivity increases monotonically with height in agreement with theory, while during winter months it shows a sharp fall after about 18 km. The main cause for the differences in conductivity would appear to be the changes in aerosol content in the lower stratosphere due to changes in the circulation patterns.

1. Introduction

Gish and Sherman (1936) during the Explorer II manned balloon flight observed that the electrical conductivity of air increased with height upto 18 km, after which it decreased up to 22 km, the maximum elevation attained by the balloon. They explained the decrease as due to the presence of Aitken nuclei in this region of the stratosphere. Kroening (1960) also noted the derease of conductivity after about 12 km. Mani *et al.* (1971) found at Poona a similar decrease of conductivity after about 18 km in March 1971, and this was attributed to the presence of stratospheric dust at this height. Israel (1969) had reported a similar drop in conductivity above 18 km and associated it with the ozone layer, ascribing a certain connection between ozone production and nuclei formation.

Stergis *et al.* (1955), Woessner *et al.* (1958) and Bourdeau *et al.* (1959), on the other hand, did not observe any decrease in the conductivity at high altitudes and reported that the measured values of conductivity were in good agreement with the calculated values based on cosmic ray intensity data. A series of conductivity soundings were made at Poona during 1971-72, to check whether the sharp decreases observed by Mani *et al.* (1971) at Poona were a regular feature of the conductivity profiles over the region. This paper summarises the results of the Poona soundings which confirm the earlier observations and gives a plausible explanation for the observed changes in conductivity.

2. Experimental method

The instrument used for measuring the conductivity of the atmosphere is a modified Gerdien condenser which has been described previously by Venkiteshwaran *et al.* (1953). The condenser is charged to —45 volts every 2 minutes by means of a motor driven switch. As the instrument ascends in the atmosphere, at an average rate of about 20 km per hour, the discharge rate of the condenser is measured by an electrometer and telemetered to the ground where the data is continuously recorded. The electrical conductivity of the air is computed using the usual formula. To minimise the electrostatic effects of the balloon, the conductivity chamber is suspended about 25 metres below the balloon and is isolated by a teflon insulator.

3. Results

Regular soundings were made every fortnight at the meteorological observatory at Poona during 1971-72. Ascents were made generally in the afternoon. Only soundings which crossed the 20-km level are discussed in the persent paper. Figs. 1and 2 show the vertical profiles of electrical conductivity at Poona obtained on 22 July, 29 July and 8 September 1971, 23 February, 20 October and 16 December 1972.

It will be observed that (*i*) during July and September, while minor fluctuations are observed, the conductivity increases monotonically with height, (*ii*) during October, December and February the conductivity increases with height upto about 18 km, after which it shows a marked decrease, between 18 to 20 km, followed by an increase at about 25 to 28 km. This confirms the earlier observations by Mani *et al.*, made in March 1971. Unfortunately good soundings could not be made in April, May and June.

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TABLE 1

Computed values of electrical conductivity of air at Fccna

Ht. (km)	Pressure (mb)	Mean temp. (°C)	$I_\circ$	α ($\times 10^{-6}$)	λ ($\times 10^{-4}$ e.s.u.)	λ ($\times 10^{-14}$ MKS Ω^{-1} m^{-1})
1·5	850	19·7	3·0	1·550	3·298	3·670
3·1	700	10·0	6·0	1·570	4·336	4·825
5·9	500	—5·2	15·0	1·580	7·775	8·652
9·7	300	—30·0	43·0	1·594	8·132	13·66
12·4	200	—50·2	72·5	1·612	17·76	19·76
14·3	150	—63·1	88·0	1·594	19·91	22·16
16·7	100	—74·6	97·0	1·415	23·82	26·51
20·6	50	—61·0	86·0	0·8042	48·98	54·50
25·0	25	—54·0	65·0	0·3155	103·40	115·00
29·0	15	—45·0	48·0	0·1712	165·70	184·40

4. Theoretical calculations

In this analysis, it is assumed that cosmic rays are the only source of ionization in the atomosphere. Since this is not exactly true, the following expression is applicable only for regions several kilometres above the earth where pollution is considered to be small.

The theoretical value of conductivity, λ, as a function of the cosmic ray intensity I, the pressure P and the tempeature T, is given by Callahan *et al.* (1951).

$$\lambda = ek_0(I_0/\alpha_{T=273})^{1/2}\,(P_0/P)^{1/2}\,(T/T_0)^{9/4} \quad (1)$$

where k is the mobility, α, the recombination coefficient, e, the electric charge, and the subscript 0 refers to the standard temperature and pressure. Using values of I from the data of Neher and Pickering (1942) and temperature and pressure data from the 'Normals of climate and temperature' published by the India Meteorological Department, the above equation is solved for λ as a function of altitude. These values are given in Table 1.

Since there is no regular radiosonde station at Poona, the normal temperatures and pressures were taken from radiosonde data from Bombay (Lat. 19° 07′N, Long. 72° 51′E) very near to Poona (Lat. 18° 32′N, Long. 73° 51′E). Again, in the absence of cosmic ray data for Poona, we have assumed Bangalore data from Neher's published results in 1942 to be applicable to Poona. This is valid since there is very little variation in cosmic ray intensity below λ =10° (Here λ is the geomagnetic latitude).

5. Discussion on results

The experimental and theoretical curves for the different soundings are also given in Figs. 1 and 2. It will be seen that the observed values of conductivity in the troposphere are in general lower than the expected values. In the lower stratosphere, the conductivity decreases with height after about 18-20 km during October, December and February. In July and September it increases with height upto all heights measured.

The value of the small ion conductivity is smaller than the expected values calculated from Neher's cosmic ray intensity data and the Thomson theory for ion—ion recombination. This low value may be due, in part to the attachment of small ions to aerosols and this accounts for most of the reduction in the values of conductivity below the expected value, particularly as stratospheric aerosols are polydisperse, whereas the attachment theory has considered only the monodisperse case. Morgan (1972) in his investigation of the small ion conductivity, has found that the value is smaller than the expected values at Adelaide.

A probable reason for the decrease of conductivity after about 18-20 km during October-March may be the movements of aerosols in this region. Studies of aerosols below 60 km by Gambling *et al.* (1971) at Adelaide show that there is a marked annual variation in the stratospheric aerosol back scattering coefficient with maximum values occurring in mid-winter (July). The annual effect is interpreted as a seasonally dependent poleward transfer of aerosols from an equatorial reservoir. The mean scattering ratio profiles for each month show that the peak ratio is a minimum in April and then increases to a maximum in July after which it again decreases. In the northern hemisphere, Schuster (1970) has found a decreasing trend in the peak value of the scattering ratio from April to July, and hence it is very probable that the annual variation of aerosol is in fact a seasonal trend.

The annual variation in the stratospheric aerosol concentration found by Gambling *et al.* (1971) is in agreement with the well known seasonal variation of transport processes in the lower stratosphere and these are very similar to those of ozone; since the aerosols and ozone are transported by the same mechanism. The aerosols are more numerous in winter in the lower stratosphere and hence the recombination coefficients for the small ions will be more than the Thomson theory predicts. So the small ion conductivity will be less and

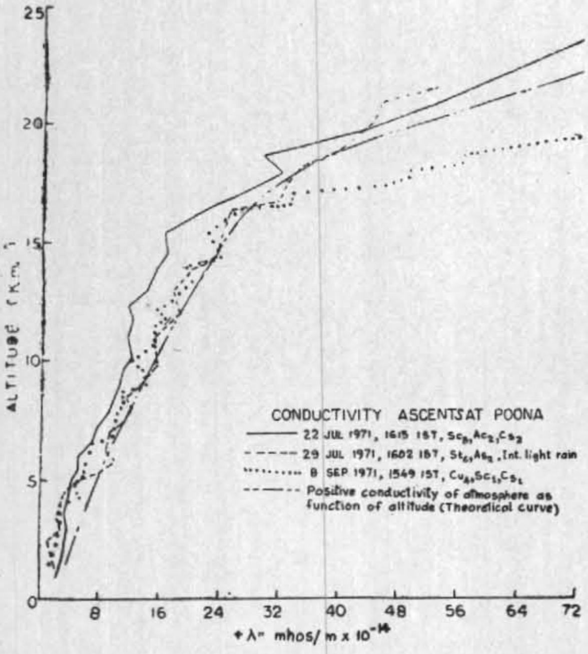

Fig. 1

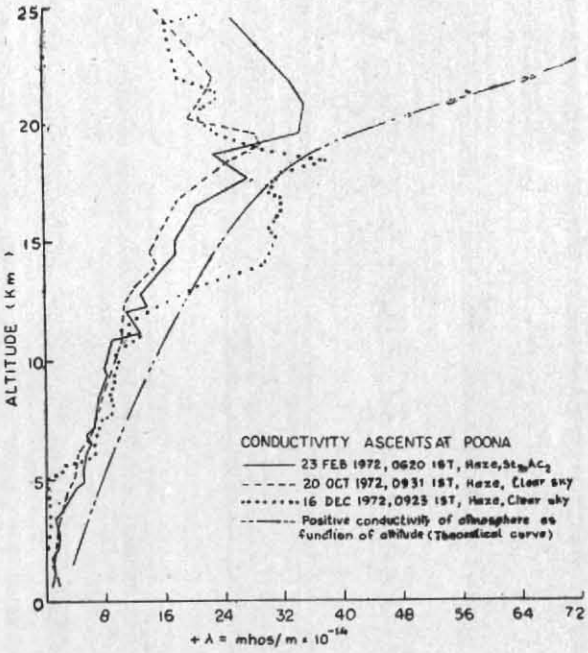

Fig. 2

hence the conductivity decreases at this height rather than increase in this season. Similarly, in the summer stratosphere the aerosol content will be smaller and the recombination coefficients will be smaller and the conductivity will be more and will increase with height as shown in Fig. 1.

7. Conclusions

The positive small ion conductivity increases with height upto 18-20 km during October, December and February and then decreases with height, while it increases monotonically with height in July and September.

The observed differences in the conductivity profiles in the lower stratosphere during the two periods probably arise from differences in the circulation pattern in the tropics and the variation in aerosol content in different seasons.

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