Effect of surface radioactivity on vertical distribution of atmospheric electrical conductivities

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A balloon-borne force aspirated Gerdien condenser measurement carried out from Hyderabad, India, has given the conductivity profile from the surface onwards. The conductivity, instead of continuously increasing from the surface, decreases initially up to 2 km and then increases. This is due to the combination of the ionization due to galactic cosmic rays and surface radioactivity/radioactive gases. This feature has been presented and discussed.

Ionization in the lower atmosphere is caused mainly by galactic cosmic rays. The intensity of ionization increases downwards and reaches a maximum at about 15 km, below which it decreases. But, over places which have non-negligible surface radioactivity, the ionization tends to increase below a certain altitude and reaches a maximum at the surface. Close to the ground, the main ionizing agent is radioactivity, both radioactive minerals at the surface and radioactive gases released from the soil. The ionization due to radioactivity is maximum at the surface and decreases with altitude. This dominates up to about a few kilometres, beyond which cosmic rays take over. The decreasing effect of radioactivity with height and the increasing effect of cosmic rays combine to create a minimum in ionization at around 3 km (Ref. 1). The exact altitude at which the minimum appears, depends on various factors including the level of radioactivity at the surface. This minimum in ionization results in a minimum in ion density and, consequently, in conductivity. Thus conductivity does not increase continuously from the surface onwards, but decreases initially up to about 3 km.

There have been several balloon-borne measurements of atmospheric electrical conductivities and ion concentrations in the lower atmosphere. However, most of the measurements have given data only from about 4 km or above, except a few which could give from about 2 km upwards\(^2\). The balloon experiment carried out on 22 Apr. 1989, using a pumped Gerdien condenser, under the Indian Middle Atmosphere Programme (IMAP), namely IMAP-C05, gave conductivity data from the surface onwards. The data are presented and discussed below.

A pumped Gerdien condenser balloon payload was flown along with three other payloads from the TIFR balloon facility at Hyderabad, India, on 22 Apr. 1989. The balloon was launched at 0158 hrs IST and was cut off at 0800 hrs. This flight carried a pump with higher capacity compared to the first one\(^3\) and this helped in improving the strength of the signal. It was, therefore, possible to obtain the conductivity data right from the surface.

The conductivity profiles obtained from the flight are shown in Fig. 1(a). It can be seen that the conductivities decrease from the surface to about 2 km. It then increases above this altitude. Ion densities were derived from these conductivities, using the reduced mobilities obtained from earlier experiments\(^3\). The derived ion densities are shown in Fig. 1(b). The ion densities also show the same feature around 2 km.

The Hyderabad region has a background terrestrial (nuclear) radiation of about 75-114 mR/yr (Ref. 4). This is higher than the average background level and will influence the electrical structure of the atmosphere. The altitude up to which this can be effective is dependent on the distribution of radon and its derivatives with altitude. While gamma rays from the soil are the main ionizing agent at and near the surface, their influence falls rapidly with height and radioactive gases begin to dominate within a few tens of metres. Among the radioactive gases, only Rn and ThB are important, except in the vicinity of the ground. Their concentration (C) at any altitude (z) depends on the degree of turbulence and can be approximated by the expression:

\[
C = C_0 \exp \left[ -\left( \frac{\lambda}{k} \right)^{1/2} z \right]
\]
where, $C_0$ is the concentration at the surface, $k$ the eddy diffusion coefficient and $\lambda$, the radioactive decay constant of the concerned gas. However, the calculation of the corresponding values for intensity of ionization cannot be done easily. An approximate profile has been calculated by Israel\(^5\) for a $k$ value of 8 m\(^2\)/s. This profile shows that, for a surface value of ionization of 7.6 ion pairs/cm\(^3\)/s, the value at 2 km is about 1.5 and at 3 km about 0.9. These are close to the ionization due to galactic cosmic rays at these altitudes. Thus, the minimum occurs around these altitudes.

A typical result of a midlatitude experiment that could make measurements from about 2 km upwards\(^6\) is also shown in Fig. 1(b). It can be noticed that there is a tendency for the ion density to increase below 3 km. This launch site is also supposed to have natural background radioactivity above the average value\(^2\).

The measurement from Hyderabad has detected the effect of natural radioactivity on the near earth atmospheric electrical environment. It would give better insight if simultaneous measurements of ion production rates are carried out with the conductivity and ion density measurements. Measurement of conductivities at the surface during the flight also will be useful.

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**References**