Electrical conductivity and electric field measurements in the stratosphere by balloon-borne probes from Hyderabad

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During the IMAP period (1980-89), several balloon flights had been carried out for measurement of ion conductivity and electric field in the stratosphere. The balloons were launched from TIFR Balloon Launching Facility at Hyderabad. Measurements were done in the altitude region of 15-35 km. The results from four of the six balloon flights done for conductivity measurements are reported here. While most of these measurements were carried out during daytime, one balloon flight made early morning measurements (IMAP-C2) and one flight extended from late night (IMAP-C9) to daytime. The measurements show higher values of conductivity during day as compared to those during night. A larger variation of positive conductivity as compared to the negative conductivity is also observed.

1 Introduction
Measurements at stratospheric altitudes provide us the means to understand stratospheric ionization behaviour\(^1\)\(^-\)\(^3\) as well as the global electric circuit\(^1\)\(^,\)\(^3\)\(^-\)\(^6\). There have been several measurements of height profile\(^1\)\(^,\)\(^3\)\(^,\)\(^7\)\(^,\)\(^8\) of conductivity in the past. Long duration measurements at balloon-float altitudes are not many\(^2\)\(^,\)\(^4\)\(^,\)\(^6\). Such measurements carried out over a period of several hours or days provide data useful for understanding the behaviour of stratospheric ionization. We have carried out several extended measurements, mostly during the morning hours (Table 1), and these have given us some interesting results. This paper deals with some of the observations made during the measurements of electrical conductivity and vertical electric field, extending over a period of six years. Results of the earlier balloon flights were reported by Gupta and Narayan\(^2\). Some of these data have been used in the present discussion.

We came across some unexpected difficulties in instrumentation due to the charging of the balloon-gondola system. This has been described elsewhere\(^6\).

2 Measurement principles and instrumentation
We use balloon-borne instruments for making conductivity and electric field measurements in the altitude region of 15-35 km of the atmosphere. The method for conductivity measurement is based on the discharge of a capacitor through the ambient medium\(^4\). The details of instrumentation have been described by Narayan\(^10\). We employ a 0.1 m radius metallic sphere as sensor. This is coated with aquadag to reduce the photoelectron emissions during daytimes. The sensor is used as a spherical capacitor, the reference conductor (also called the return current electrode) being the outer surface of the gondola. If we apply a certain voltage to the sensor with respect to the gondola and allow it to discharge through the ambient air, then the sensor potential will decrease exponentially with time. The time constant will give the air conductivity according to the following expression:

\[
\tau = \frac{C_0}{\sigma}
\]

<table>
<thead>
<tr>
<th>Flight No.</th>
<th>Date</th>
<th>Time of launch hrs LT</th>
<th>Float altitude km</th>
</tr>
</thead>
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<tr>
<td>IMAP 4</td>
<td>19.4.1984</td>
<td>0610</td>
<td>35</td>
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<tr>
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<td>0100</td>
<td>34</td>
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<tr>
<td>IMAP 9</td>
<td>22.10.1985</td>
<td>0600</td>
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</tr>
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<td>0100</td>
<td>34</td>
</tr>
<tr>
<td>IMAP-C6</td>
<td>11.4.1988</td>
<td>0608</td>
<td>36</td>
</tr>
<tr>
<td>IMAP-C7</td>
<td>17.10.1989</td>
<td>0030</td>
<td>34</td>
</tr>
</tbody>
</table>
If we charge the sensor positive, it will attract negative ions and we get negative ion conductivity, and if we charge the sensor negative, we will get positive ion conductivity. The total conductivity is the sum of these two.

A pulse of +5 volts and -5 volts is alternately applied to the sensor every 2 min for a duration of 2s. The subsequent exponential decay of the sensor voltage gives the conductivity. Within one minute the sensor potential becomes steady and the sensor voltage during rest of the 2-min period is used for electric field measurement.

The electric field is measured using double probe technique. The electric field is given by the ratio of the potential difference between two vertically separated sensors and separation distance. A correction due to the influence of the gondola is applied as explained by Narayan10.

3 Results

Figure 1 shows the results of conductivity measurement during IMAP-C2 flight at the float altitude of 34 km during early morning hours. The positive ion conductivity around 0645 hrs LT is $5.5 \times 10^{-12}$ mho/m and is roughly twice in magnitude compared to the negative ion conductivity which is $3 \times 10^{-12}$ mho/m. We observe fluctuations in both positive and negative conductivity. We also observe a small increase in positive conductivity with time which is around $7 \times 10^{-12}$ mho/m at 0715 hrs LT. This increase in early hours has also been observed during other flights2.

Figure 2 shows conductivity measurements from several balloon flights. A hand-fit done to these data is also shown (continuous curve). We have used negative conductivity data, as this appears to remain more stable throughout the day. Also, error due to photoelectric emission is believed to be less during negative conductivity measurements11.

4 Discussion

The values of positive conductivity and negative conductivity measured during IMAP-C2 flight at float altitude of 34 km are shown in Fig. 1. The float altitude could vary by 1 km; however, the vertical velocity is < 0.3 m/s.

We observe that the measured values of negative conductivity are fairly stable while positive conductivity increases from dawn to mid-day. Such an increase has also been observed by other scientists5,11,12. As to the possible cause for such an observation, we believe that there are at least two alternatives: (i) It is possible that sunlight dissociates some of the positive ions so that they become less massive. The decreased mass would cause an increase in mobility13 which could cause increase in conductivity; and (ii) The possibility of electron emission from the probe in the presence of solar UV radiation falling on the probe. This might cause photoelectric emissions11,14. Our data from various flights do not rule out either of these two possibilities. We need some more experimental data to resolve this problem.

Figure 2 shows a height profile of conductivity compiled from several IMAP flights. Comparing with various measurements done at high latitudes3-6, we find that our values of conductivity are lower by a factor of about 2. This factor can be attributed to
lower ion production rates at tropics as measured by Neher\textsuperscript{15}, which is related to the conductivity through the relation, $\sigma = ne\mu$, where $n$, the ion production rate is a factor of 2 lower at Hyderabad latitude (11° magnetic north) as compared to high latitudes, while the mobility $\mu$ can be considered nearly the same.

A very distracting problem throughout this IMAP ionization campaign has been the so-called 'gondola charging effect'\textsuperscript{16,17}. A detailed appraisal of this problem as related to our measurements has been done by Narayan et al\textsuperscript{9}. Any measurement of atmospheric electrical parameters must consider the effect of charging of the balloon-gondola system during the flight\textsuperscript{16}. For our latest flight (17 Oct. 1989), modifications were done for electrically decoupling the gondola from anything higher up along the loadline. After doing this we could get good conductivity data from 15 km to 35 km altitude. On this flight, vertical electric fields were measured from 15 km onwards during ascent. This field was directed downwards and was 2 V/m at 20 km altitude. During descent when the balloon was cut-off and parachute was deployed, we could get some measurements down to 8 km. At this altitude the electric field was 30 V/m. This is in accordance with theory\textsuperscript{18}. The detailed results will be published later on.

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References