6.1 Summary of this thesis

The present thesis consists of the work done by the author during the last six years. The present work mainly deals with balloon-borne measurements of the stratospheric conductivity and electric field over the low latitude station of Hyderabad (India). Some of the results of rocket-borne conductivity measurement carried out at Thumba near Trivandrum (India) are also presented.

An instrument based on the relaxation method for conductivity measurement and double probe method for electric field measurement was developed by the author. Four balloon flights were successfully conducted from Hyderabad during the period 1984 to 1987.

The first balloon flight was conducted on 18th April
1984. We obtained the conductivity data at the ceiling altitude from 9.15 am to 12.00 am. The main observations were as follows: (1) The positive ion conductivity values obtained were between $7 \times 10^{-12} \text{ s/m}$ and $2.2 \times 10^{-11} \text{ s/m}$. (2) The negative ion conductivity values varied between $2 \times 10^{-12} \text{ s/m}$ and $6 \times 10^{-12} \text{ s/m}$. The positive ion conductivity was three to five times higher than the negative ion conductivity. (3) There was a large variation in the magnitudes of the two conductivities. The variations of the two polar conductivities were in phase.

The second balloon was launched on 28 October 1985. The measured positive ion conductivity was about $1.2 \times 10^{-11} \text{ s/m}$ while the negative ion conductivity was about $2.8 \times 10^{-12} \text{ s/m}$. Thus the positive ion conductivity was about four and half times higher than the negative ion conductivity. The result is similar to that of the previous flight, except that large fluctuations in the conductivity values were not observed during this flight.

The third balloon was launched on 29th December 1985. This time the positive ion conductivity was measured to be around $3.0 \times 10^{-12} \text{ s/m}$ while the negative ion conductivity was around $2.2 \times 10^{-12} \text{ s/m}$. The ratio between the two ionic conductivities was thus about 1.3 instead of 4.5 as in the case of the two previous flights. Compared to the October 1985 values, the observed positive ion conductivity was smaller by a factor of 4. The negative ion conductivity values were less by a factor of 1.2 only.

The fourth balloon was launched on 8th April 1987.
Conductivity measurement was done at two altitudes, 34 km and 29 km. At 34 km altitude, the positive ion conductivity was observed to be around $6 \times 10^{-12}$ s/m, while the negative ion conductivity was about $2.8 \times 10^{-12}$ s/m. The conductivity values at several places were observed to be lower than the mean value by almost a factor of three. The two polar conductivities measured at 29 km altitude showed large fluctuations. The average conductivity values at this altitude were $2.4 \times 10^{-12}$ s/m for $\sigma_+$ and $1.9 \times 10^{-12}$ s/m for $\sigma_-$. 

The balloons launched on 29 December 1985 and 8 April 1987 carried electric field probes also. During December 1985 flight, the vertical electric field was measured to be of the order of 0.4 to 0.5 volts per meter. The electric field was downward and the measured values showed a variation with time. They varied between around 0.6 to 0.7 volts per meter at 7.00 am and 0.4 to 0.5 volts per meter at 8.30 am.

The vertical electric field measured on 8 April 1987 was found to be reversed (upwards) and its magnitude was higher than 10 volts per meter. Such a condition is indicative of disturbed weather below the balloon trajectory. Since this electric field was larger than the signal handling capacity of the telemetry encoder, no measurements could be done.

Studies in mesospheric electrodynamics were also done by the author. Data from rocket borne measurements of electron and ion density from Thumba, Trivandrum (dip = $0.6^\circ$ S)
by Langmuir Probe technique was used to calculate the electron and positive ion conductivities in the altitude range between 60 and 100 km. A comparative study of stratospheric and mesospheric conductivities was done in order to get a consolidated picture.

The main conclusions derived from this study are given below.

1. A study of probe behaviour under in-situ conditions was done which showed that it is very little likely that the conductivity measurements are getting affected by photoelectron emissions from the probe.

2. At the balloon ceiling altitudes of around 32-35 km we obtained the ratio of the two polar conductivities, $\sigma_+/\sigma_-$ as roughly 4.5. Prior to this there had been no observations of this kind at this altitude. This ratio of 4.5 between the two polar conductivities implies that the average mobility of the positive ions is roughly four and half times higher than that of the negative ions under normal conditions in the altitude range of 30 to 35 km.

3. In the premonsoon period we have found large fluctuations in the conductivity values.

4. A comparison of the conductivity values measured in October 1985 with those measured in December 1985 shows a drastic decrease in the December 1985 value. This is expected because of the injection of a large
number of aerosol particles in the stratosphere by the volcanic eruption in Colombia. The decrease in the positive ion conductivity is about four times more than the decrease in the negative ion conductivity. A similar decrease was observed in April 1987 measurement of conductivity. Compared to the October 1985 value, the positive ion conductivity was smaller by a factor of 2. The negative ion conductivity was only marginally smaller.

5. The stratospheric conductivity is lower by a factor of 4 in the December 1985 flight, and the electric field is higher by roughly the same factor. It appears that the presence of aerosol in the stratosphere does not affect the air earth current significantly.

6. The two polar conductivities observed during 8 April 1987 flight show a ratio of $\sigma_+/\sigma_- \approx 1.25$ at 29 km altitude and $\approx 2.35$ at 34 km altitude. Thus the ratio of the polar conductivities was found to be altitude dependant.

7. The vertical electric field was observed to be upwards during thunderstorm period on 8 April 1987. Its magnitude was more than 10 volts per meter. During fair weather, the electric field is in the downward direction.

8. Rocket borne measurements in the mesosphere show that at 60 km altitude the positive ion conductivity is of
the order of $1.1 \times 10^{-9}$ s/m. This is higher than the stratospheric conductivity values at 30 km altitude by a factor of $10^2$.

9. It was observed that the balloon-borne gondola gets positively charged during the balloon ascent. The potential developed on the gondola was measured. It was found that during ascent, the gondola acquires potentials of the order of a hundred volts.

10. It was observed that rocket bodies acquire floating potentials of the order of a few volts when they pass through the mesosphere. This phenomenon has been observed at altitudes around 80 km and exists over a narrow altitude range of about 5 km.

6.2 Suggestions for follow-up actions

The present work, while it gave a number of new and good results, it also exposed some of the areas where more work is required, either in the form of understanding the measurement process, or in the form of follow-up action based on the results obtained during the present work.

The behaviour of the charging of the gondola is one of those aspects of instrumentation which deserves a serious study. In the present experiment, we could not get ascent-time data due to this problem. The gondola potential was measured during two of the balloon flights and was
found to be of the order of a hundred volts. The cause of this large potential developing on the gondola has not been properly understood. This problem is a serious one and it should be investigated thoroughly as it affects the balloon-borne measurements of conductivity related parameters. Its cause has to be understood and methods aimed at rectifying this problem have to be developed, so that one can obtain reliable conductivity data both during ascent as well as during float periods.

Another point which emerged during the present work is that although there have been some attempts of modelling the probe behaviour in the past, the actual measurement environment is more complex than what these models have considered. Several aspects of the probe behaviour are still to be understood. For example, the effects of photoemission on probe current is not understood properly. It has been shown through simple calculation of the solar ultraviolet flux at the balloon altitudes that one should expect very large probe currents during daytime, several orders of magnitude higher than the conductivity currents measured by the probes. Yet it is not so in practice. The question of why the photoemission from the probe surface is not as high as the theoretically expected value is indeed interesting. Another interesting problem to be looked into is the current collection by a probe in flowing medium. The author has investigated this problem to a certain extent, but a rigorous numerical modelling of the probe behaviour under typical measurement conditions remains to be done.
The author feels that it is important to study the temporal and spatial variation of conductivity and electric fields in the stratosphere. Although long duration measurements have not been conducted from Hyderabad due to several constraints, the author feels that measurements spanning over a period of one full day conducted in different seasons will provide answers to a number of questions which have arisen during the present work. At the same time, such a work will help in a better understanding of the global electric circuit.

The large fluctuations measured in conductivity during April 1984 appears to be related to some yet unknown phenomenon. This observation merits a systematic follow-up action in the form of observation of stratospheric conductivity together with in-situ measurements of water vapour and particulate matter concentration.

The changes in polar conductivity values observed before and after volcanic eruptions poses an interesting problem for theoretical modelling. As an input to such a model, measurements are required of conductivity and number density of ions. The author feels that a simultaneous measurement of several parameters like conductivity, ion density and aerosol concentration will be more useful for studying the volcanic effects.

In view of the observations of rocket body potential in the mesosphere, the author feels that investigations as to whether these potentials are a manifestation of the mesospheric electric fields or due to some other cause
should be done.

In the above paragraphs, some of the questions and unsolved problems that came up during the present work are described. Apart from it, it was felt that the electrodynamics of the middle atmosphere at low latitudes offers a number of interesting problems to be solved. The intimate relation between the stratospheric electricity and chemistry should be investigated. Future experiments should be planned towards measurement of ion composition together with electrical parameters in the low latitudes.