Chapter IV

4. DISCUSSION

4.1. CONDUCTIVITY AND PRESSURE

One of the primary aims of this study was to find the cause of the inverse relationship of conductivity variation with the diurnal variation of atmospheric pressure. As has been mentioned earlier the well known or accepted relationship of mobility and hence conductivity with pressure and temperature cannot explain the relationship being discussed here. The results obtained from the present investigations will be analysed to find interrelationships or cause effect relationships of different weather elements with conductivity. The discussions presented here address these aspects.

4.1.1 Establishment of Conductivity- Pressure Inverse Nature.

This seems to be the first report of a simultaneous measurement of polar conductivities and atmospheric pressure. Data given in Fig 3.1 is the unprocessed GC output from both sensors. The unprocessed data show very close similarity in diurnal patterns. The exception is in the finer time scale variations of the order of minutes. The similarity in diurnal patterns indicates (sec 3.1) that the system for measurement is reliable. Fig.3.4 is the data processed as described in sec 3.2 for negative and positive polar conductivities. The polar conductivity data show a diurnal pattern of
variation that is closely similar for both negative and positive polar conductivities. Here also exceptions in similarity can be seen in minutes order variations. In Fig.3.5 is shown the polar conductivity and atmospheric pressure measured simultaneously. The most important aspect that can be easily noticed from the graphs is that the diurnal pattern of variation in atmospheric pressure is inverse in nature to the diurnal variations of both the polar conductivities. The significance of the present data is that the diurnal variations seen in data from both GCs are similar in nature but opposite to that of pressure variation. The 6th degree polynomial trend fit drawn over the conductivity and pressure graphs point out this inverse relationship readily.

Finer variations during small time intervals in pressure and conductivity can be seen in both curves but these variations of the order of minutes or an hour in pressure and conductivities have no similarity or inverse nature with each other. The order of magnitudes of conductivity agrees well with the published results (Sasi Kumar et al., 1995). However the magnitudes of polar conductivities are found to be different. Figures 3.7, 3.8 and 3.9 represent pressure and conductivity variation for three consecutive days during the month of April. The nature and pattern of variation seen in both conductivities over a day is seen to be similar. The inverse nature in diurnal pattern of conductivity and atmospheric pressure variations are readily observed.

While the inverse nature of conductivity and pressure is observed in the pressure and conductivity data discussed, the conductivity data in Fig.3.4
show a difference. That is, in Fig.3.4 the morning maxima in conductivity is seen to be higher than the evening maxima while in Fig.3.7,3.8 and 3.9 the evening maxima is seen higher. The morning minima and evening minima in conductivity are seen almost equal. Graphs (a), (b) and (c) in Fig.3.12 represents conductivity during a day in the month of January, February and March respectively. The diurnal pattern of variation in conductivity seen is similar to that discussed above. Here also the evening maxima in conductivity are higher than the morning maxima.

Mean value of atmospheric pressure at a place is determined by the pressure system or meteorological condition at the place at that time. For example it is known that India gets copious rain during South West monsoon season and during the season pressure over land is less than that over sea. That is, after say June 1st, the time the South West monsoon sets in, the pressure over land will show a decrease. Hence mean pressure will have a variation with season and its effect will be reflected in the diurnal pattern also.

![Graph showing atmospheric pressure variation between March 11 and April 10 2010.](image)

**Figure 4.1**

Atmospheric pressure variation between March 11 and April 10 2010.
That is, if it is decreasing trend the day’s pressure should have the first peak higher than the second one. This is seen in the pressure data collected during the present investigation also. A sample of pressure data for a month is shown in Fig. 4.1.

The figure shows pressure data recorded at CESS during March - April 2010. In the pressure data of March 22 it can be seen that the first peak of pressure is higher than second as the pressure is decreasing. On March 28 the pressure is increasing and the first peak is the lower one. The possibility of this change in pressure being reflected in the conductivity variation is not ruled out. However as the present investigation was concentrated on diurnal variation, the relationship between pressure and conductivity for a longer time scale has not been addressed.

The variation in conductivity and pressure is seen to be opposite to each other. The data presented in Fig.3.13 are the conductivity variations on a day during different months in a year. In all the conductivity data the diurnal pattern of variation is clear. The conductivity variation seen on all days of measurement throughout this investigation showed a diurnal pattern similar to the pattern seen in all graphs presented and discussed here. Also this diurnal pattern of variation in conductivity is seen, always opposite to the universally known diurnal variation pattern of atmospheric pressure (Nieuwolt, 1977).

The data from the present simultaneous measurement confirms that the diurnal variation pattern presented always in local time and the diurnal
pattern of polar conductivities plotted in local time have an inverse nature. This rather conclusively proves that the conductivity at a place is not determined by local sources and sinks of ions alone. In other words the factor or phenomenon that causes the pressure variation, which is a global one, could cause directly or indirectly the conductivity variations also.

4.1.2. Conductivity- Pressure Inverse Nature and Seasons.

Since an inverse nature of conductivity and pressure variation has been established through simultaneous measurement, it is important to ascertain whether such inverse nature in pressure and conductivity is exhibited in climatologically different days or seasons. Conductivity data presented as graph (b), (c), (d) and (e) in Fig.3.14 is that of a few days during the pre-monsoon season from February to May. In this set of curves showing conductivity variation the general pattern of variation seen by the trend fit are similar to the pattern seen during the south west monsoon period of June to September [graphs (g) and (h) in Fig.3.13 and graphs (f), (g), and (h) in Fig.3.14]. The nature of variation of conductivity is found to be similar and inverse to pressure variations. Conductivity data during the winter and post monsoon periods are also given in Fig.3.13 and 3.14. Here also the same diurnal pattern of variation can be seen. In other words, both polar conductivities and pressure, measured simultaneously and continuously for three years in this region of study indicates strong inverse relationship between each other. Hence it may be concluded that irrespective of the
seasons and meteorological condition of the atmosphere, the diurnal variation in electrical polar conductivity and atmospheric pressure are inverse to each other as pointed out earlier with known pressure variation by Sasi Kumar (1995). Probably this is the first report of an inverse relationship of conductivity and pressure being seen in all seasons for three years.

Referring to the conductivity data presented in Fig.4.2, an unusual change in conductivity values are seen between 12:00 h to 16:00 h during many days in the pre-monsoon seasons. The reason for this unusual increase in conductivity values may be due to the local electrical climate. That is during the pre-monsoon periods, convective thunderstorms are frequent during afternoon in this region (Murali Das et al., 2009; Vishnu et al., 2010) which could have given rise to a different local electrical climate. In other words, a local electrical phenomenon like occurrence of thunderstorm may result in augmentation in conductivity over the basic diurnal pattern as seen here.
4.1.3. Conductivity-Pressure Variation and Their Relative Magnitudes

The percentage variation in pressure about their mean on 8/6/01 is found to be about +0.31% and -0.22%. The simultaneous variation in
positive polar conductivity is +135% and -98% over the mean, while that for
the negative polar conductivity is +146% and -96%. In earlier report of Sasi
Kumar (1995), the percentage variation of conductivity observed was around
±50%. The present investigation points to a variation in conductivity from
±14% to around ±270% and the pressure variation around +0.22% to -0.19%.
Such a very large variation in conductivity could not be explained on the
basis of its known linear dependence on atmospheric pressure, temperature
and ion mobility. Here the possibility that the presence of atmospheric
aerosols and its variation can influence the polar conductivity is not ignored
(given in sec 4.3.) since atmospheric electrical conductivity has shown some
variation with seasons (Sasi Kumar et al., 1994; Israel 1971). The data also
indicate that percentage variations in conductivity are higher in the pre-
monsoon period than that during the monsoon period.

Even if the data
presented here were obtained only for one day, it must be focused because a
simultaneous measurement showing inverse relationship of conductivity and
pressure is a phenomenon to be investigated. During monsoon and pre-
monsoon period and at all other periods or in other words, irrespective of the
environmental conditions, magnitude in conductivity variation is two to three
orders higher when compared to the pressure variation. During the year 2003
the percentage variation in both polar conductivity is found to be less of the
order of +79% and -14% while the percentage variation about the mean
varied between +270% and -80% in the previous two years. The reason for
this is not known. The influence of solar activity in modulating the
atmospheric electrical behaviour close to the surface of earth cannot be ruled
out. After 1989 the incidence of strongest solar activity occurred in the ear
[Accessed on 29/11/2010]. But the reduction in percentage variation has
been found well before the said occurrence of solar activity in October 2003.
Another reason may be sought in aging of the GC due to continuous
operation. Periodic cleaning of the GC sensor assembly and its Teflon
insulator parts might not have been sufficient in preventing surface leakage.
That is even with periodic cleaning, continuous operation for months and
years might have reduced surface resistance of insulator parts due to residual
deposits. Even if the magnitude of variation in conductivity during the third
year is less compared to previous two years, the observed variation in
conductivity itself could not be explained with its known relationship with
pressure.

4.2. Conductivity and Weather Elements

Weather data measured simultaneously with polar conductivities
were presented in Fig.3.6 and in Fig.3.10. It can be seen that only
atmospheric pressure has a double oscillation type diurnal variation pattern
inverse in nature to that of conductivity variation. All weather elements such
as temperature, humidity, wind speed, wind direction and rainfall does not
have a variation either similar or opposite to the variation in conductivity.
Temperature, relative humidity, wind direction and wind speed do have a
pattern of variation as explained in section 1.2.2 but they have no similarity
that can be connected with the pattern of variation seen in polar conductivity or atmospheric pressure.

A sharp fall in both polar conductivities around 16:00 h is seen during many observations. The variations in pressure at the corresponding time on all such days are seen to be smooth with no abrupt variation and seen to be same as that for any other days. Rainfall data on those days shows intermittent rain around the times at which sudden decrease in conductivity is seen. That is, during all occasion when a sudden reduction in both polar conductivities are seen, occurrence of rainfall are also seen. This is expected because splashing of rainwater (Blanchard, 1963) can produces very large number of small droplets to which small ions can get attached. This will reduce the ion mobility and hence conductivity also will reduce.

Thus the patterns of diurnal variation in conductivities seem to have no relation to weather elements other than pressure to the extent being evident from the patterns of variations of weather elements.

### 4.3. Conductivity - Source and Sink for Ions

The main ionising agency close to the surface of earth being the γ radiations, the intensity of γ radiations monitored for a few days were presented in Fig.3.15. The variations in radiation intensity does not have a pattern either similar or opposite in nature to that of polar conductivities. Hence it can be stated that surface radioactivity does not play a role in the diurnal pattern of variation seen in polar conductivity.
The influence of aerosols in modulating polar conductivities also was studied by measuring aerosol count of different spectral mode. Counts of all the three types of aerosols show an increase in the evening starting from about 16:00 h to 18:00 h. The pressure shows an increase during the corresponding time and conductivity shows its characteristic reduction from 16:00 h in Fig.3.20. The variation of 0.3μm aerosols count in the Fig.3.19 is somewhat similar to the pressure variation which decreases up to about 16:00 h and shows an increase after that. The reason for this increase is not known. Measurements by Parameswaran et al., (2001) show variation of aerosol mass loading over several hours at Trivandrum. Here also increase after 04:00 h and 16:00 h is clearly seen.

The trend fit of 6th degree polynomial in Fig.3.20 shows similarity to diurnal variation of pressure and inverse similarity to conductivity. The mean inverse variation of conductivity and aerosol is found to be two fold. The pattern of variation seen in mass loading measurement and that in 0.3 μm has not been explained except for a relationship with sea and land breeze at a coastal station (Parameswaran et al., 1999).
Black Carbon (BC) is a component in the aerosol spectrum. In Fig.4.3 is shown the variation of BC at two stations namely Kharagpur and Trivandrum reproduced from Abhish (2005). The Kharagpur measurement was done when the wind patterns showed a direction towards the sea. A clear change in the slope can be seen at 04:00 h and at 16:00 h in the relatively inland location of Kharagpur. The variations shown here point out that aerosols and black carbon also show a variation similar to that of atmospheric pressure variation. The indication that aerosols might have diurnal variations similar to those of atmospheric pressure is an observation worthy of further investigation.
4.4 Conductivity and Pressure-Cause Effect Relationship

Since an inverse nature between conductivity and pressure variation has been established and their magnitudes shows a difference, it would be good to determine whether pressure is the cause for conductivity variation. The data presented here as Fig.4.4 is to analyse the influence of pressure on conductivity variation. The data show that the pressure variation has a range from +0.19% to +0.31% and the conductivity variation has a range from +271% to -95%. In the figure pressure data shows a departure from the usual pattern of variation for a short period, that is an increase in magnitude can be seen between 00:37 h and 02:07 h which is well before sun rise. At about the same time and for the same duration, temperature also is seen to increase. Correspondingly the humidity is also seen to show a decrease. This indicates that the effect of pressure increase is seen correctly in the temperature and humidity data. It is possible that the changes in pressure, temperature and humidity were caused by atmosphere effect (Fleagale and Bussinger 1963; Vishnu et al. 2010) possibly due to presence of a cloud overhead. The overhead cloud seems to have impeded the vertical circulation resulting in pressure increase, temperature increase and a consequent relative humidity decrease. The small differences in time of the order of minutes may be ignored because of many reasons like time constants of the weather elements, time constants of measurement sensors, the averaging interval of 5 minutes etc. However this increase in pressure is not seen reflected in the conductivity data of both polarities. No change is seen at the corresponding times either in the reduced data shown here or in the raw data.
Fig. 4.4.
Pressure, conductivity, temperature and relative humidity on a day in April
Fig. 4.5
Conductivity, pressure, temperature and humidity during a day
The data presented in Fig.4.5 along with humidity data is that during a day in the pre-monsoon period. The pressure data shows an unusual decrease in pressure between 08:39 h and 11:54 h. This pressure decrease is seen reflected in the temperature and humidity graph at the corresponding time. If pressure were the driving force for conductivity variations, an unusual increase in conductivity can be expected during the corresponding time. But the conductivity values seen in the graph does not show such unusual increase and shows a steady increase like any other day. The variations in atmospheric pressure is seen to be smooth on all days while the variation in conductivities are not so. Thus it can be stated that variation in atmospheric pressure due to local phenomena like atmosphere and other causes, are not seen influencing the polar conductivities of atmospheric air. Stated more explicitly atmospheric pressure seems to be not the cause for the changes in electrical conductivity of air.

4.5. Reference Estimation – Significance

In Fig.4.6 the unprocessed GC data on the left hand side and processed GC data on the right hand side are presented. One striking aspect that can be seen is the difference in diurnal pattern of variations of the unprocessed GC output and the processed conductivity data. That is, of the two conductivity maxima during a day on the right hand side, the highest peak is around 02:00 h.
Fig. 4.6.

Unprocessed and processed GC data on a day.

The graphs representing the unprocessed GC data shows that the peak GC output at this time is the lowest among the two peaks on that day. In other words when the morning maxima in the unprocessed GC data is less compared to the afternoon maxima, the morning maxima in conductivity is higher than the afternoon maxima.

This difference between unprocessed and processed data was seen in all the data collected in the study for three years. The difference in the data clearly indicates the usefulness of reference estimation by grounding of the driving electrode.
4.6. **HIGHLIGHTS OF RESULTS AND CONCLUSION**

The data from the simultaneous measurement of polar conductivities, weather parameters, source and sink of ions, close to the surface of earth indicate the following.

(i) The Gerdien condenser sensor and the electronic circuit designed and developed for the study is suitable for continuous monitoring of electrical polar conductivities in all environmental conditions.

(ii) Reference estimation by grounding the Driving Electrode of the Gerdien condenser is necessary for continuous monitoring of conductivity.

(iii) Polar conductivity close to the surface of earth at the study location has a double oscillation type diurnal variation pattern.

(iv) Positive and negative polar conductivities have exactly same pattern of variation

(v) Atmospheric pressure and polar conductivity variations are opposite in nature and this is the first report of an inverse relationship between conductivity and pressure through simultaneous measurement.

(vi) Percentage variation in conductivity is two to three orders higher in magnitude to that of pressure variation.

(vii) Variation in pressure experienced locally does not cause a variation in conductivity.
(viii) Percentage variation of conductivity during the pre-monsoon period is more than that in the monsoon period.

(ix) Polar conductivity seems to increase during thunderstorm activity.

(x) Air temperature, Relative humidity, Wind speed, Wind direction and also Rainfall does not have double oscillation type variation pattern.

(xi) The variation of surface radioactivity does not have pattern similar or inverse nature to the pattern seen in conductivity or pressure variation. Hence surface radioactivity does not seem to influence conductivity variations.

(xii) The variation of aerosol in the atmosphere is seen to have pattern similar to the pressure variation and opposite to conductivity variation.

(xiii) Aerosol variation does not seem to be the cause of very large variation in conductivity.

(xiv) The diurnal pattern of polar conductivity variations are opposite to the variations seen in atmospheric pressure and aerosol.
4.7. CONCLUSION

Simultaneous measurement of polar conductivities, atmospheric pressure and other weather elements show that,

(i) irrespective of the weather and seasons or environmental condition the diurnal variation of polar conductivities and atmospheric pressure are inverse in nature.

(ii) diurnal variation in polar conductivity is not caused by the variation in atmospheric pressure.

(iii) since a pattern is seen in conductivity, aerosols and atmospheric pressure there is a possibility that another global agency is responsible for all variations.

(iv) results confirmed the total lack of influence of surface radioactivity in modulating the diurnal pattern of conductivity variation.

(v) aerosol indicates a variation pattern similar to pressure variation and inverse to conductivity variation.

(vi) weather elements other than pressure does not have pattern of variation similar or opposite to the conductivity variation and hence, no influence in modulating polar conductivity.

Considering the variation in polar conductivity, atmospheric pressure and aerosol, it is probable that a fourth global element or agency is responsible for the cause behind the diurnal variation of all the three. Hence, it may be concluded that with out considering the role of a fourth global agency, it is difficult to explain the
diurnal variation pattern of atmospheric electrical conductivity, pressure and aerosol.

4.8. Suggestions for Further Studies

The investigation presented in this thesis was done at a time when continuous measurement of aerosol concentration or concentration of any spectral component of it was not common. Data on diurnal variation of aerosols for several days were not freely available. The institute where the investigations were carried out, namely the CESS, did not have an aerosol laboratory. Hence aerosol measurements were done, as had been mentioned, with collaboration of another laboratory. They had acquired the aerosol counters at a time close to the time of the investigations. The limitation of the equipment was mentioned earlier in this thesis. Presently the technology on aerosol counters have improved and equipment which can measure continuously at least some spectral components are commercially available. M/s TSI Instruments USA is one manufacturer which makes counters of different kinds. One such instrument capable of doing continuous measurement is available at CESS also. This is a water based condensation particle counter capable of measuring particles from 5nm to 3μm in diameter.

The equipment draws ambient air through a column saturated with water vapour. Water condenses on the particles in the drawn sample and those particles are counted using laser excitation in an optical chamber. Shown in Fig.4.7 is a sample of diurnal variation obtained from the equipment. The changes in the variation pattern near 04:00 h and 16:00 h is noticeable. Shown in Fig.4.8 is the pressure variation for the same day. The similarity between the two diurnal patterns
can be readily seen. The minima in condensation nuclei count seem to be occurring at 04:00 h and between 12:00 h to 17:00 h. The second maximum also is close in time to that of pressure. One of the features observed on most days in the diurnal pattern of condensation nuclei is the steady decrease to reach a minimum near 04:00 h.

Fig.4.7. Diurnal variation of condensation particle concentration measured at CESS
Fig. 4.8.

Pressure variation on 31/12/09 the day condensation nuclei concentration was measured.

Summing up there seems to be a pattern of condensation nuclei variation over a day. Hence it is suggested that simultaneous measurements of aerosol concentration, atmospheric electrical conductivity and weather elements are done.

4.8.1. Influence of Latitude on Pressure and Conductivity Variations:

It is known that diurnal variation in pressure is seen predominantly near equator. In other words the diurnal variation is less predominant at higher latitudes. This offers an opportunity to investigate the amplitude of pressure variation over the mean at different latitudes and do the same for atmospheric electrical conductivity too. This will serve as cross check on the interrelationship. That is if diurnal variation in pressure reduces in amplitude at higher latitudes the magnitude of variation of atmospheric electrical conductivity can be checked for sympathetic reduction. A marine cruise with simultaneous monitoring of weather elements,
aerosols and conductivity at different latitudes also can throw more light on their interrelationship.

4.8.2. Negative Values of Collector Current during Reference Estimation

As has been explained earlier reference value for collector current during measurement was estimated by grounding the driving electrode of GC periodically to reduce the error due to leakage current. According to the established theory of GC such grounding of the collector cannot give a negative value. To be more explicit a positive GC cannot give negative value and visa versa for a negative GC. However on many occasions it has been observed that both positive and negative GCs have been found to have opposite polarity during grounding.

![Positive GC Data 21/2/01](image)

**Fig.4.9.**

**GC Data showing negative values during zero estimation**

An explanation for such behaviour could not be found or is not found in literature. Such data was not used for the investigations presented in this thesis. However it seems to be an observation which should be reported in. Processed data of one such observation is presented in Fig.4.9. Between 00:00h and 10:00h during
reference estimation the output can be seen to be more than the normal value. Investigations on the reason for such behaviour were not taken up as the attempt can dilute the effort towards investigations on the main issue. Even though the GC sensor is capable of giving reliable output, resurfacing and polishing of Teflon insulators occasionally to yield better results during continuous monitoring is also suggested.