JOURNAL GEOLOGICAL SOCIETY OF INDIA
Vol.78, September 2011, pp.199-210

Global Electric Circuit Parameters and their Variability Observed over Maitri, Antarctica

K. JEEVA[1], C. PANNEERSELVAM[1], K. U. NAIR[1], C. SELVARAJ[1], AJAY DHAR[2], B. M. PATHAN[2] and S. GURUBARAN[1]
[1]Equatorial Geophysical Research Laboratory, Indian Institute of Geomagnetism, Tirunelveli - 627 011
[2]Indian Institute of Geomagnetism, New Panvel, Navi Mumbai - 410 218
Email: 123.jeeva@gmail.com

Abstract: The global component of fairweather electricity is subject to special attention to watch the solar-terrestrial effects and secular changes in climate. It is generally considered that the diurnal variation of atmospheric electricity parameters, if they are not following the Carnegie pattern, are not representative of the global thunderstorm activity. Some of the results obtained from Maitri (70°45'54"S, 11°44'03"), are discussed here in context with global thunderstorm activity and space weather influences. The diurnal pattern of the Potential Gradient and current density strongly deviate from the Carnegie curve. We have showed that this deviation is not due to the local electrical influence but due to the global thunderstorm activity. During fairweather condition the parameters are representing the global thunderstorm activity and to some extent they respond to the upper atmospheric electro dynamic phenomenon. The mean value of the potential gradient (77.7 V/m) and current density (2.13 pA/m^2) well below the expected global mean but close to the value reported from the same location and season in the past years. The mean conductivity, 3.34 x 10^{-14} mhom^{-1}, is slightly at higher side and they exhibit a different diurnal trend comparing to the past measurements at this location.

Keywords: Conductivity, Conduction current, Potential Gradient, Global Lightning Flash numbers, Geomagnetic substorm.

INTRODUCTION

Monitoring of the Global Electric Circuit parameters (GEC) can be used as a tool to study the earth's climate and changes in it as it has direct implication with global lightning activity (Harrison, 2004). It is also suggested that the global component of fairweather electricity is subject to special attention because of the physical integration of the electrical circuit gives a possibility to watch Solar-Terrestrial effects and secular changes in global climate (Williams, 1994; Tinsley, 2000; Tripathi and Harrison, 2002). The physical correlation existing between the Solar originated disturbances on the climate changes suggests that an integrated approach in understanding the various electro dynamic processes at different regions of the atmosphere is required. Traditional Global Electric Circuit (GEC) do not involve the upper atmospheric electrodynamic process, where as, the New GEC model (Rycroft et al. 2000) treats the ionospheric and magnetospheric electrical parameter as passive systems of the global electric circuit. Since the atmospheric electricity parameters couple the upper atmosphere and the earth the investigation of the GEC parameters is expected to provide a plausible mechanism to understand the influence of solar activity and weather related problems.

The Global Electric Circuit is generated by the total global thunderstorms acting together at any time charges the ionosphere to a potential of several kilo volts with respect to the Earth's surface (Dolezalek, 1972). This potential difference generates a gradient of about 100-300 V/m close to the ground. With this electric field and the conductivity, in the order of 10^{-14} mho/m, caused by atmospheric molecular clusters ions formed by natural radioactive isotopes and cosmic rays, there flows a vertical current called the conduction current with the magnitude of about 2-3 pA/m^2. The conductivity of the atmosphere is bound to undergo spatial and temporal variations owing to dynamics within the Planetary Boundary Layer (PBL).

Interestingly, the studies from Antarctica shows the existence of correlation between the atmospheric electrical parameters and geomagnetic activity. During the geomagnetically disturbed conditions the dawn-dusk potential difference of magnetospheric convection pattern was found to clearly influence the vertical fair-weather field as it is intensified and presumably moved from its quiet time position to over balloon’s height (Mozer and Serlin, 1969; Mozer, 1971; Holzworth and Moser, 1979; Holzworth, 1981). Measurements of vertical electric field at Syowa station (69°.0S, 39.6°E) showed that the vertical field increased in response to a magnetospheric substorm. The geomagnetic substorm signature over the air-Earth current was observed by Belova et al. (2001). The possible explanation given for this relationship was the enhancement of vertical field at ground due to enhancement of ionospheric southward electric field during the substorm growth and expansion phase and redistribution of downward atmospheric electric current due to an increase in the atmospheric conductivity in the local D-region. More reports from Antarctica on the observation of the potential gradient, showed that there were significant changes in the electric field due to the Inter-planetary Magnetic Field (IMF) (Burns et al. 1998; Corney et al. 2003; Tinsley et al. 1998; Reddell et al. 2004). All these studies emphasize the need of more measurements towards understanding the Solar-Terrestrial weather relationship and electric field induced changes in the climatology.

In most of the cases, mentioned above, there was measurement of either current or potential gradient. The unique feature of this paper is to present the first results obtained from the simultaneous measurement of the Conductivity, Electric field and conduction current obtained all together from Maitri, Indian Scientific base, Antarctica during the austral summer 2006-2007. The results are discussed in context with meteorological weather condition and fair weather GEC environment and its modulation during geomagnetic disturbances. In recent years, some results emphasis on electricity parameters not being the true representative of thunderstorm activity if it does not follow the Carnegie pattern (Harrison, 2004; Kartalev et al. 2006). We have made an attempt to show that even the diurnal pattern which do not follow the Carnegie pattern have representation of global thunderstorm activity.

Measurements have been carried out by various groups from the location Amundsen-Scott base (90°00'S 139°16'W), (Reddell et al. 2004; Tinsley et al. 1998), Vostoc (78°28'00"S 106°47'59"E) (Corney et al. 2003). These stations are just below the polar cap region and most likely to be influenced by polar cap convection activity. Maitri is at the equatorward peripheral of the Auroral electrojet. When the geomagnetic condition is quiet station is under the influence of the Sq current system. During the geomagnetic stormy condition the station comes under the influence of the auroral electrojet which enables the field line currents to influence the upper space environment (Kalra et al. 1995; Rajaram et al. 2002). Thus, it is expected that during the quiet condition, the global electric circuit parameters are expected to provide the signatures of the global thunderstorm activity and during disturbed condition it might have the influence of the upper atmospheric current system which will alter the Vertical electric field and the current.

In this paper we bring out some results pertaining to the diurnal variation of the atmospheric electricity parameters and their response to the global thunderstorm activity and the space weather events. We have compared the values of the atmospheric parameters that were monitored form the same location and season during the past years. The mean value of the parameters has a close agreement with the past values. The diurnal variation of the conductivity, in the past years, did not show any significant pattern which is contradictory to the present observation and is discussed in detail.

EXPERIMENTAL SETUP

Atmospheric Electrical Conductivity

Positive and negative polarities of atmospheric electrical conductivity were simultaneously measured with a pair of Gerdien condensers. Its application is vast owing to the requirement of the measurement. In the present work, the Gerdien system used is U shape aspiration tube with a fan, two coaxial cylinders (condensers) with a shielding cylinder attached to the succession tube. The outer electrode is biased appropriately to measure the positive and negative ionic currents. The dimensions of the electrodes are as follows: the length of the central sensor is 0.2 m and the radius is 0.005 m. The radius of the outer electrode is 0.05m and length is 0.45 m. The flow rate of the air is 4m/s. Applied potential difference to the outer electrode is 36.7v. With these physical standard the apparatus constant the critical mobility (μ_c) is calculated using the equation

$$\mu_c = ku/V$$

k is the geometrical constant of the apparatus which can be obtained from the equation

$$k = (a^2-b^2)\ \ln(a/b)/2L, \text{ where}$$

a = radius of the outer electrode in meter; b = radius of the inner electrode in meter; L = Length of the inner electrode in meter; V = Potential applied to the outer electrode; u = flow rate of the air in m/s.

The above physical size of the apparatus is selected so as the critical mobility should be more than of the order of $10^{-4}\ m^2V^{-1}\ m^{-1}$. This means the system is capable of sensing the ions having mobility more than 10^{-4} m^2V^{-1} m^{-1}. Ions having less than this mobility are intermediate ions and large ions which do not contribute to atmospheric electrical conductivity. Elaborate theory on this aspect is discussed by K.L. Aplin (2000). The sensed ionic currents are measured by two separate electrometers consisting AD 549 electrometer. The final conductivity is arrived from the equation (Mac Gorman and Rust, 1998)

$$\sigma_{\pm} = \varepsilon_o i_{\pm}/CV_{\pm}$$

ε_o is the permittivity of the air (8.85 x 10^{-12} Fm^{-1}), i = ionic current, C is the capacitance of the apparatus 24 pF and V is applied voltage. Various reports show that the positive conductivity and negative conductivity are not equal. Mohnen (1974) defined mean mobility for the positive ions as 1.3-1.6 $cm^2v^{-1}s_{-1}$ and 1.3-1.9 $cm^2v^{-1}s^{-1}$ for negative ions. We also, in the present work, have observed that there is difference in magnitude between the positive and negative conductivity. Hence the conductivity in the present is termed as total conductivity which is obtained from the equation

$$\sigma = (\sigma_+ + \sigma\_)/2$$

Atmospheric Current Density

The atmospheric vertical current was monitored using long wire antenna (Kasemir and Ruhnke, 1959; Ruhnke, 1969). Increased attention to its measurement is expressed in Global Atmospheric Electricity Measurement (GAEM) (Ruhnke and Michnowski, 1991). Though there lays complication in using the effective area (Tammet et al. 1996) we obtained it from the equation A= hc/ε_o (Kasemir and Ruhnke, 1959). The long wire antenna senses the Maxwell current of the atmosphere. Freier (1979) presented a thunderstorm model which includes various electrical parameters at different stage of the atmosphere and the Maxwell current is termed as the sum of various currents.

$$J_M = J_E + J_L + J_C + \partial D/\partial t$$

Where J_M is total current; J_E is conduction current; J_L is lightning current J_C is convection current, J_P is precipitation current and $\partial D/\partial t$ is displacement current.

As per this model in the fair-weather region, far away from the thunderstorm, only conduction current flows. In addition to this an appropriate RC time constant, in the order of 20-30 minutes, was used and we considered only the conduction current part of the Maxwell current.

Measurement of Potential Gradient

It is commonly found that the measurement of the potential gradient is carried out using the mechanical field mill (Chalmers, 1967). The advantages in using the field mill are that it offers a more rapid time response and dynamic range (Chubb, 1990; MacGorman and Rust, 1998). At the same time it also has the disadvantages as the field mill is directly exposed to open atmosphere causing more heat or cold and it is to be prevented from precipitation. In the present study the vertical Potential Gradient (PG) is monitored using two different systems. One is the traditional field mill in which an electric motor rotates a grounded rotor and alternately exposes the sensing stator to the atmospheric electric field to generate an AC signal which is proportional to the electric field. From the response to a known electric field the unknown vertical electrical field can be calculated. The system is periodically calibrated to obtain the potential gradient. The second system we use to monitor the potential gradient is a Passive antenna system. The technical details and first results are presented by Pannerselvam et al. (2003)

Validation of Data

We have adopted various precautions in ensuring the quality of the data. The first precaution we adopted, to be free from errors, is to monitor the potential gradient using two different systems, the field mill and passive antenna. Any discrepancy can easily be brought out from the comparison of the potential gradient obtained from these experiments. One such example is presented in Fig.1 which shows the diurnal variation of potential gradient obtained from both the systems simultaneously on 23 February 2007. A long term comparison of PG obtained from both the systems has also been carried out and found to be satisfactory. To know the possibility of error in the measured components, the parameters are verified using atmospheric

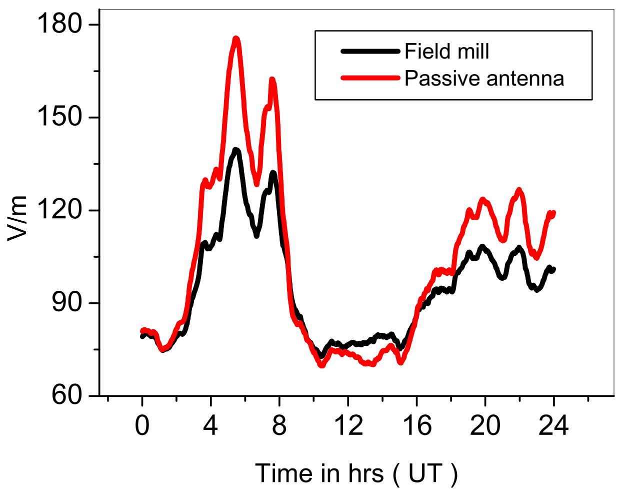

Fig.1. Comparison of the diurnal variation of potential gradient obtained on 23.2.07 from field mill and passive antenna system.

electricity Ohm's law j = σE. And the other two parameters are calculated from the following equations.

$$E_z = J_z/\sigma \quad \text{and} \quad \sigma = J_z/E_z$$

The result is presented in Fig.2 (the top panel, middle panel and bottom panel). There is fairly good agreement between the observed values and deduced values. However, during the course of 24 hours the potential gradient from both the system deviates from each other by 20% to 50%. The maximum deviation is during night hours and minimum deviation is during day hours. The deduced value is more than the observed value for the current density and the deduced value is less than the observed value for the other two parameters. The potential gradient will vary based on the sharp vertical gradients in the ion density in addition to the Earth-ionospheric potential difference. Whereas the observed current density is sensitive to the columnar conductivity. The major difference between the observed current density and calculated current density is that the observed current density is sensitive to the columnar conductivity. The calculated current density is obtained from the conductivity and the potential gradient. Both the parameters are sensitive to the surface conductivity. The same discussion is applicable for the differences in the deviation for the other two parameters.

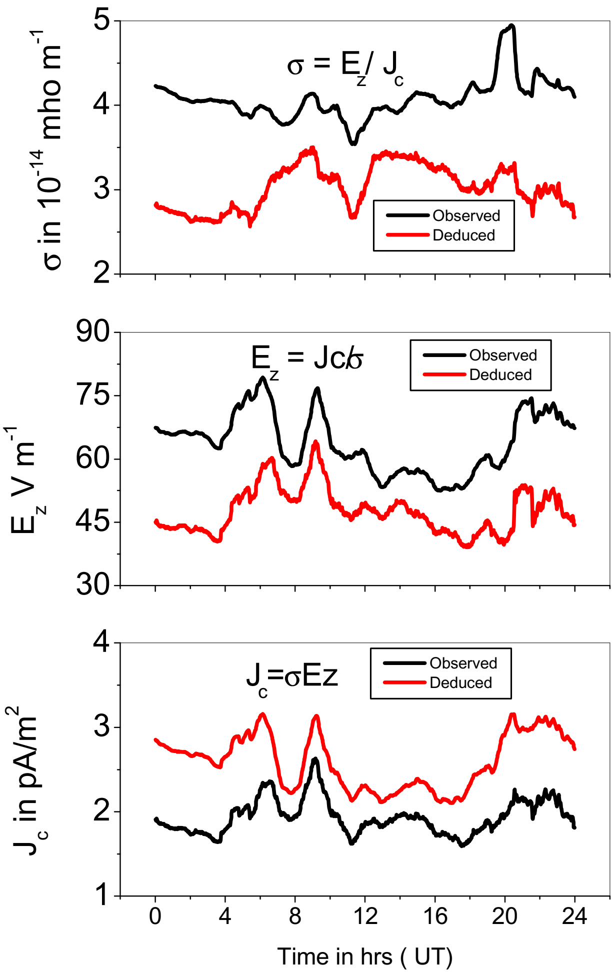

Fig.2. Comparison of the diurnal variation of the observed and calculated atmospheric parameters for the day 4.2.07.

Data Selection

During the fair weather days the atmospheric current and potential gradient are expected to follow the trend of global thunderstorm activity. The fair weather condition is generally defined as the days with no precipitation (snowfall/ rain) wind speed less than 10ms^{-1}, high clouds are less than 3 octas through the day (Deshpande and Kamra, 2001). Since the continent is free from thunder clouds and anthropogenic pollution the threshold limits of the above mentioned meteorological parameters are reconsidered. Visual observation showed that strong wind associated with snow and sand alone distorted the regular and smooth variation of the measured parameters. Clouds with more than 3 octa also found to be not disturbing the smooth display of the variation. Hence, in the present work data sets are selected by omitting large and rapid fluctuations due to weather conditions like strong wind with drifting snow/sand, fog and low cloud conditions which used to disturb be the smooth recording of the parameters.

RESULTS

Conductivity

The diurnal variation of the total conductivity displayed various patterns during the observation period. On few occasions the conductivity is not displaying any systematic pattern. The most common diurnal patterns observed are presented in Figs.3a and 3b. There are two prominent peaks during post- and pre-mid night hours and a minimum during noon hours. This pattern is observed on days Jan 28, 29, 31, Feb 9, 17 and 21. The other pattern is just opposite to the former one. It displays a peak around noon hours. The days are Jan 8, 9, 13, 15, 17, 20, Feb 2, 16, 20, 23, 26 and 27.

Potential Gradient and Current Density

The diurnal variation of the potential gradient and current density display various trend over the season of austral summer. In order to study their diurnal characteristics they have been averaged for every ten days and 30 minutes smoothed curve is considered to study the diurnal pattern. They are presented in Figs. 4a to 4e. Figure 4a shows the mean diurnal variation for the days from December 17th to

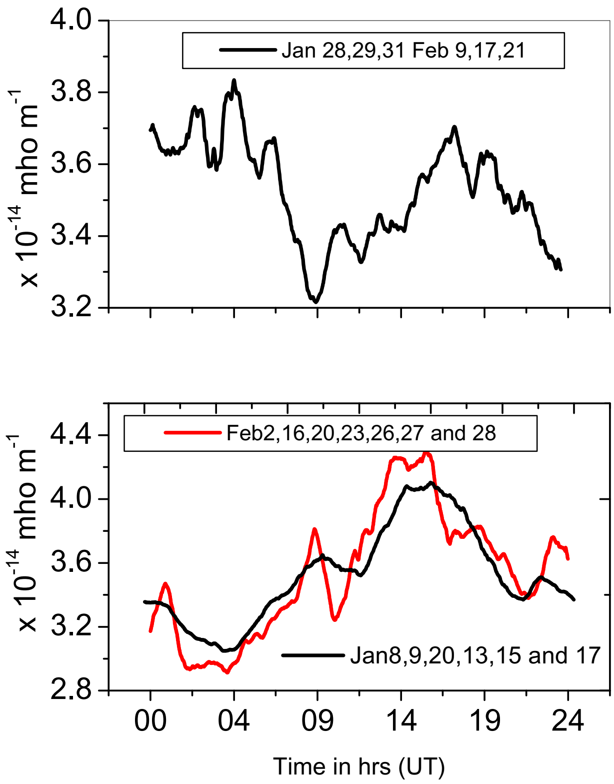

Fig.3. Different pattern of Diurnal variation of total conductivity obtained from the days mentioned.

31st. Figure 4b is from the month of January from 12th to 15th. Figure 4c shows for the first ten days of February, followed by 8 days mean from 13th to 20th February (Fig.4d) and last eight days of February in the Fig.4e. The first common signature found in all the figures is that both the parameters, the potential gradient and current density, are exhibiting identical trend except a small deviation from each other for short periods. Secondly, the diurnal variation of the potential gradient and current density, in majority cases, show two prominent peaks, one during the post mid night hours and the other one centered around 19 hrs UT. A broad minimum is observed around noon hrs

DISCUSSION

Conductivity

The atmospheric conductivity is directly proportional to the total ion density (n) and it is also subject to the ion mobility (ì) i.e. $\sigma = \mu n$. The ions in the atmosphere are generally categorized into small ions, intermediate ions and large ions. The atmospheric electrical conductivity is controlled by the small ions due to their smaller in size and so the mobility (more than 1 x 10^{-4} $m^2v^{-1}s^{-1}$) (Dhanorkar and Kamra 1997; Aplin, 2000). It can also be clearly explained from the equation that the conductivity can vary owing to the density of ion number and its mobility. In a given location and time the ion density is the net reaction of the production and destruction of ions. The loss can take place chiefly by attachment ions with aerosol pollution number concentrations. This will be insignificant in places like Antarctica. However another common source to deplete the ion concentration is the electrode effect (Hoppel and Gathman, 1971; Tuomi, 1981, 1982; Hoppel et al. 1986; Israelsson et al. 1991) in which the ions are transported upward due to the increased updrafts after the enhancement of solar energy during the morning hours. The stable atmospheric condition during night hours causes more accumulation of radon and hence the conductivity is expected to be more during the morning hours. This phenomenon is very common over the land surface the variation can be called as continental type. Such an observation from the same location and same season in 2005 was reported by Kamra et al. (2007). Interestingly Aumento (2001) made a study on the Radon tides on an active Volcanic Island in which he showed the radon emanation, one of the major ionizing source at the surface level, showed two prominent peaks one at dawn hours and the other at the sunset hours. He has also showed a close correlation between the sun's elevation angle and the emanation of the radon gas. From this it can clearly be mentioned, from our study, that the ground based ionizing source dominates in the Maitri location on those days where the two maxima occur on the pre-mid night hours and post midnight hours.

Another pattern of diurnal variation of total conductivity is just opposite to the continental pattern (bottom panel of Fig 3b). The number of days on which such pattern occurs is more frequent than the continental pattern. In this pattern there is a maximum around noon hours and minimum during the pre mid-night and post mid-night hours. On examination of the general pattern of the potential gradient, from Figs. 4a to 4e, it is found that the conductivity and potential gradient are inversely related. The inverse relationship is unique and is known since the beginning of the 20th century and it indicates that the parameters hold the atmospheric Ohm's law.

Potential Gradient and Current Density

The vertical atmospheric potential gradient and vertical current are well studied atmospheric phenomena. A common global diurnal variation results from a diurnal variation of the ionospheric potential which modulates the vertical air-Earth conduction current in the absence of local effects (Mulheisen, 1977). Takaji and Iwata (1980) observed that

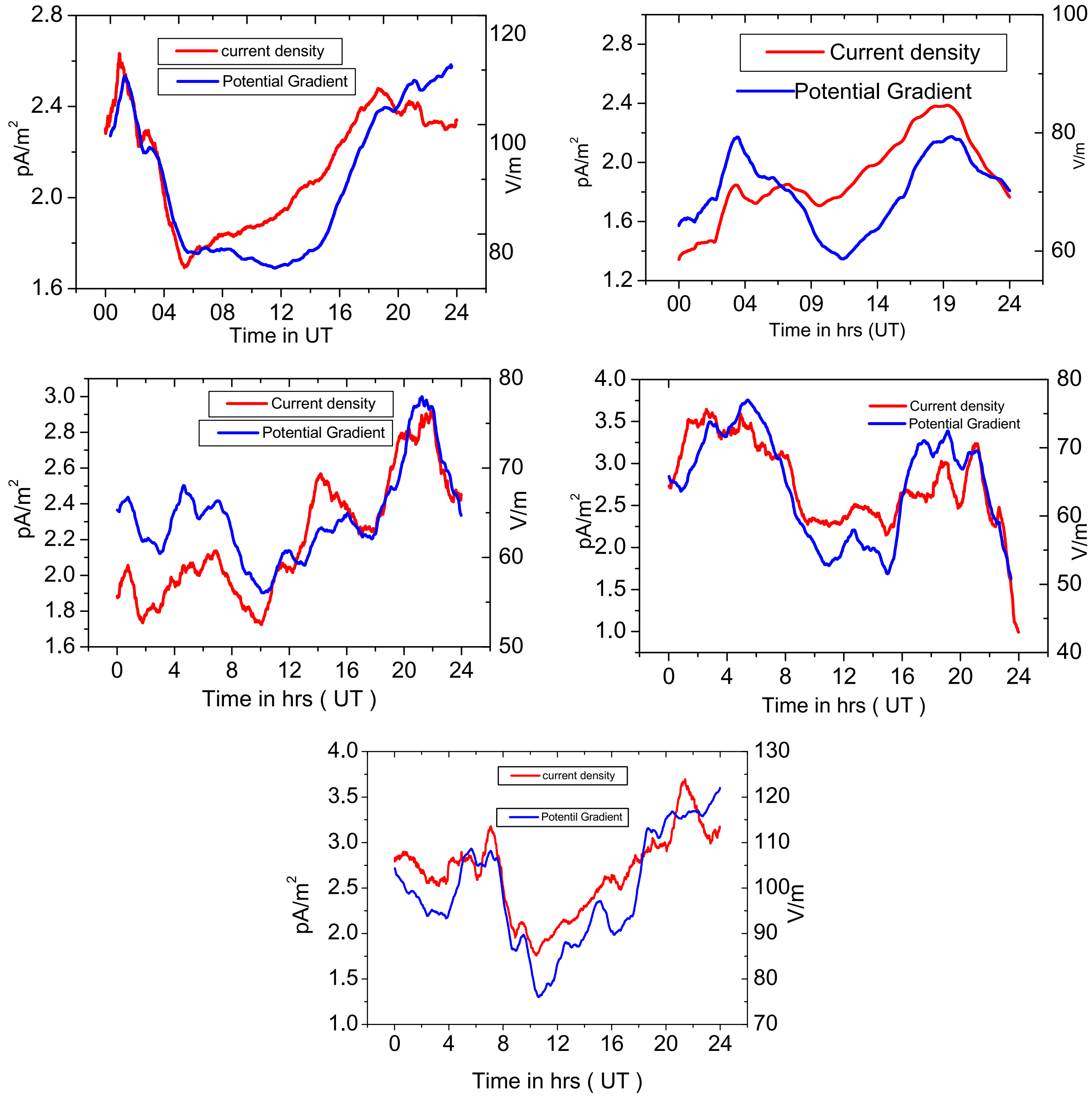

Fig.4. Mean Diurnal variation of potential gradient and current density for the period **(a)** 17-31, Dec, 2006; **(b)** Jan 12-15, 2007; **(c)** 1-10 Feb 2007; **(d)** 13-20 Feb 2007; **(e)** 21-28 Feb 2007.

the characteristics of the Potential Gradient regularly alter with the season. In winter period it has the same diurnal pattern as that observed at globally representative stations and it exhibits a pattern depending on the variation of local conductivity during summer periods. Dolezalek (1972) found a diurnal maximum at 16UT. Deshpande and Kamra (2001) observed at Maitri, Antarctica a maximum around 12 UT. Williams and Satori (2004) reported large current contributions from South American shower clouds around 20 UT. All the above studies indicate that the maximum is during the universal afternoon hours.

Global Maximum and Minimum

In the measurement of electricity parameters, it is generally believed that they are not the representative of thunderstorm activity if they are not following Carnegie pattern (Harrison, 2004; Kartaleva et al. 2006). The Carnegie curve is considered to be the representation of the global thunderstorm activity from three major thunderstorm regions, the Asian sector, African sector and the American sector with the timing of around 09 UT, 14 UT and 19 UT respectively and a minimum at about 03 UT. This curve is obtained from the measurement of the vertical potential gradient data averaged over 130 fairweather days spread over several years (Wilson, 1920). The observation of potential gradient, for a short term, rather than a long term, significantly deviates from the Carnegie pattern due to various factors like temporal and spatial distribution of the thunderstorm from all over the globe (Kamra et al. 1994; Deshpande and Kamra, 2001). The diurnal variation of the potential gradient and current density in the present work exhibits a strong deviation from the Carnegie pattern and they are shown in Figs. 4a to 4e. There two prominent maxima, one during the post midnight hours and the other one at about 19 UT hrs. There is a broad minimum (except .c) centered on noon hours. It is to be mentioned here that the measurement of potential gradient from the same location, Maitri, during the austral summer 1997 (Deshpande and Kamra, 2001) showed a prominent maximum around 12 UT followed by a secondary maximum at about 19 UT. The measurement during the austral summer 2001 (Panneerselvam et al. 2003) showed that the diurnal pattern closely followed the Carnegie pattern. Rather than comparing with Carnegie pattern to know whether the variation is the global thunderstorm activity or it appropriate to compare with global lightning activity. The global lightning flash numbers obtained from the space based Lightning Imaging Sensor (LIS) onboard TRMM is examined for the corresponding the period of the observation of the electricity parameters and they are depicted in Fig.5. It is to be mentioned here that the flash events used in the analysis are obtained from the orbit summary of the satellite hence the flash numbers is available about every 96 minutes (http://thunder.msfc.nasa.gov/data/lisbrowse.html). Whereas the data of potential gradient and current density are sampled at 30 second (Dec 2006-Jan 2006) and 1 second (Feb 2007).

The comparison of the potential gradient and current density with the global lightning activity reveals that both of them are not following the Carnegie pattern. The lightning

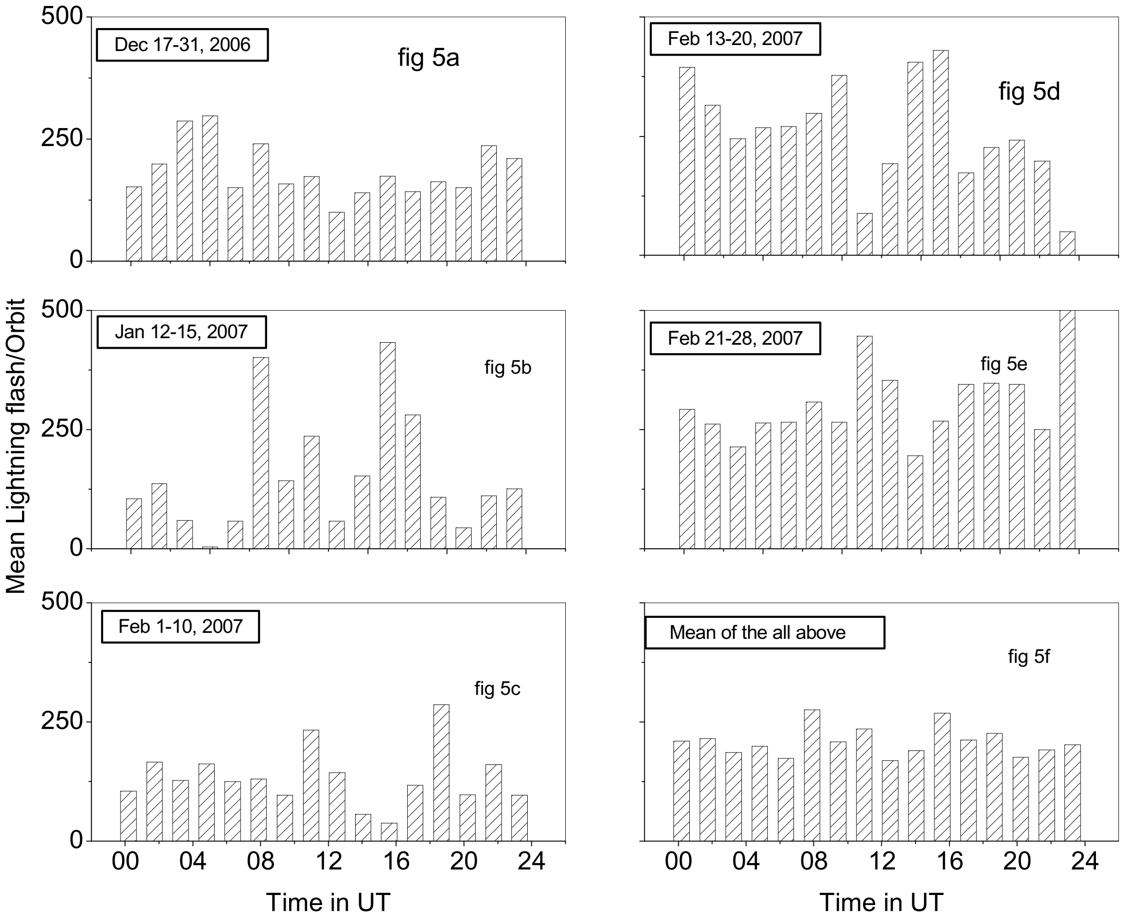

Fig.5. Diurnal variation of mean lightning flash numbers per orbit for the corresponding period of the atmospheric electricity measurement.

activity exhibit maximum activity, similar to the potential gradient and current density, near about post mid night hours (Fig.5a, c, d and e) and noon minimum (Figs.5a and b). The mean variation of the flash numbers show there is a steady lightning activity over the twenty four hours and there is hardly any decrease in the lightning activity around noon hours as seen in the electricity parameters. Thus the minimum could be due to the enhancement of the atmospheric conductivity (Fig.3) as per the Ohm's law of atmospheric electricity. From this it is inferred that the observed variation in the potential gradient and the current density is contributed by the global thunderstorm activity and to some extent the local PBL activity.

Geomagnetic Field and Potential Gradient

The year 2006 followed by 2007 are the solar minimum years. We have selected three magnetically disturbed days based upon the maximum SKp on 19 Dec 2006 was +22, 20 December 2006 with -30 and 28 February 2007 with -29. One of the most severe storms recorded in this decade was on 29 Oct 2003 with SKp -58. Figure 6 shows the diurnal variation of the atmospheric potential gradient and total geomagnetic field observed on 19 December 2006. In the beginning, when there was a sharp decrease in the total field, a sharp increase in the PG was observed. Afterwards the

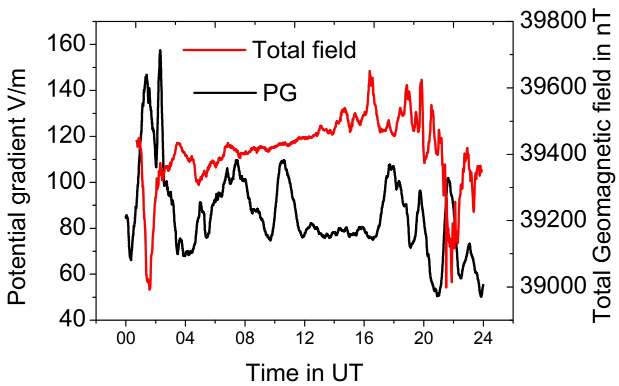

Fig.6. Diurnal variation of potential gradient and total geomagnetic field observed on 19 December 2006

disturbance appears to have identical variation to each other. Similarly Fig.7 depicts the diurnal variation of the geomagnetic field disturbed during the post mid night and pre mid night hours on 20 December 2006. Figure 8 shows another significant geomagnetic disturbance on 28 February 2007, the season's maximum, on which the potential gradient and current density is compared. In all the above comparison it is found that the potential gradient has significantly increased during the geomagnetic disturbed condition. Similar variation is also observed with the current density.

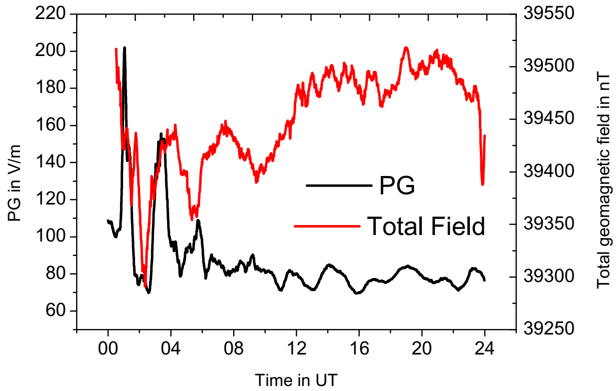

Fig.7. Diurnal variation of potential gradient and total geomagnetic field observed on 20 December 2006.

The variation of the atmospheric conductivity shows opposite trend to that of the potential gradient and the current density which can be explained from atmospheric Ohm's law.

The geographical location of Maitri is unique from geomagnetic studies point of view. Under quiet geomagnetic conditions the stations is under the influence of the mid-latitude ionospheric Sq current system. As the magnetic disturbances grow due to the enhanced solar wind-magnetospheric interaction, the auroral oval expands equator wards and Maitri comes under the influence of auroral electrojet. Many important processes occur on the night side of the Earth wherein the geomagnetic field is stretched into a long tail by the streaming charged particle flow from the Sun. The field lines forming the tail are energized whenever the interplanetary magnetic field (IMF) turns southward as this favors magnetic field reconnection on the dayside of the earth. The energy extracted from the solar

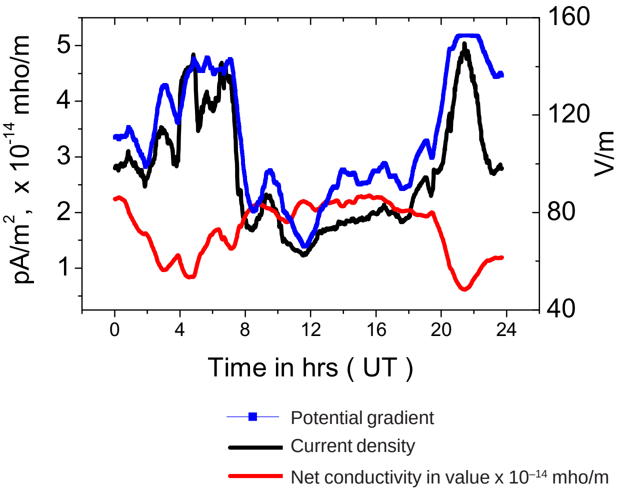

Fig.8. Diurnal variation of all the three atmospheric electricity parameters observed on a severe geomagnetically disturbed day on 28.02.2007.

wind may be dissipated in the ionosphere through the directly driven process leading to an enhancement of the convection driven auroral electrojects in the dawn and dusk sectors (Rostoker, 1999). The energetic charged particles precipitating from the Earth's inner and outer magnetospheric radiation belts interacts with the middle atmosphere by increasing the ionization directly or via bremmstrahlung radiation, by altering its chemistry (Jackman et al. 1995) or by affecting the nucleation by the electro freezing of droplets from clouds, thereby influencing the dynamics of storm and atmosphere (Tinsley and Heelis, 1993; Tinsley, 1996, 2000). Freier (1961) and Lobodin and Paramanov (1972) reported auroral effects on vertical electric field measured on the ground. In general, they reported a decrease in the electric field that later recovers to pre auroral condition.

Using atmospheric potential gradient and current density data, obtained in 2003 from the same location Anil Kumar et al. (2009) showed that the solar wind-magnetosphere energy coupling function (e) enhances the potential gradient and current density. It is also discussed that during the magnetic storm activity there is usually a decrease in the cosmic ray flux which in actual increases in the columnar resistance (Tinsley and Zhou 2006, Devendra Singh and Singh, 2009). Figure 6 clearly shows the enhancement in the potential gradient and current density in the atmosphere on 28 February, a geomagnetically disturbed day.

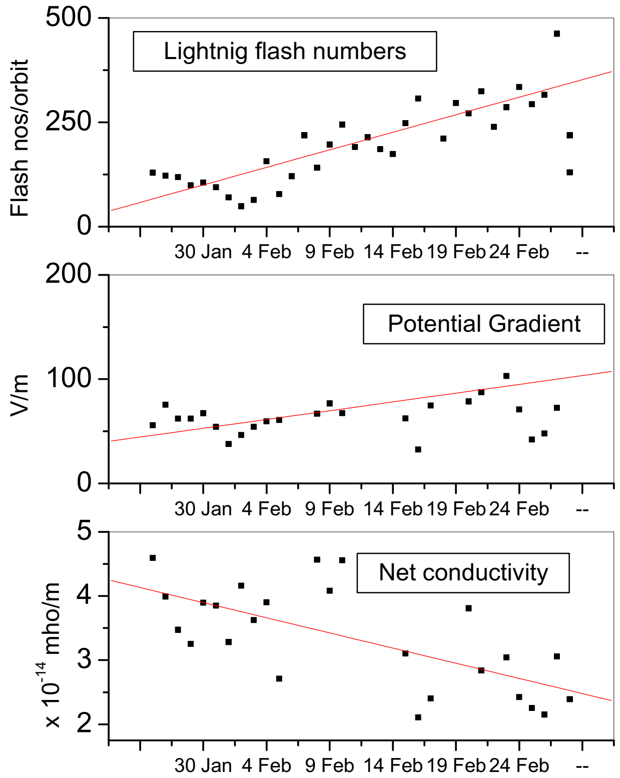

Fig.9. Relationship between the potential gradient, Global lightning flash numbers and the conductivity.

Absolute Value of the Atmospheric Electricity Parameters

The mean fair weather atmospheric electricity parameters are obtained from 34 days from the months January and February 2007. Figure 9 shows the relationship between the potential gradient, lightning flash numbers and the conductivity. There is positive correlation between the global thunderstorm activity and the potential gradient suggesting that the PG monitored over here is the true representation of global thunderstorm activity. The increasing trend in the potential gradient and lightning flash numbers indicate that the excursion of the global thunderstorm activity towards southern hemisphere, where there use to be least thunderstorm activity had come an end and it is advancing towards the northern hemisphere. The mean values of the observed and calculated parameters are presented in Table 1. The season's mean potential gradient we obtained is 77.7 V/m which is far lower than the mean global potential gradient (130 v/m Markson, 1978). Some of the measured atmospheric electricity parameters, from the same location and season in 2005 (Devendraa Singh et al. 2007) showed relatively lower value comparing to the value from a tropical station in Northern hemisphere. Such low values were also reported from different stations shown in Table 2. The

Table 1

Parameter	Value
Air-Earth current density	2.13 pA/m^2
Vertical potential gradient (Field mill)	77.7 V/m
Vertical potential gradient (passive antenna)	72.7 V/m
Positive conductivity	3.89 x 10^{-14} mho/m
Negative conductivity	2.78 $^{-14}$ mho/m
Net conductivity	3.34 x10^{-14} mho/m
Air-Earth current density calculated using Ohm' law (Jz=Ezσ)	2.47 pA/m^2

Table 2

Station name	Year of observation	Mean PG V/m
McMurdo Sound	1902-1903	93
Trieste	1902-1905	73
Davos	1908-1910	64
Cape Evans	1911-1912	87
Upasala	1912-1914	70
Scoresby Sound	1932-1933	71
Fair Bank	1932-1933	97

decreased value for the PG is also an indication that the southern hemisphere summer do not produce sufficient number of sever thunderstorm activity. By comparing the northern and Southern hemisphere PG data, Alderman and Williams (1996) found a maximum in PG in June/July consistent with the maximum in lightning occurrence.

CONCLUSIONS

There are several salient features in the present work and the first to mention here is that we monitored all the global atmospheric electricity parameters simultaneously.

There is a general opinion that the diurnal variation of the electricity parameters which do not follow the Carnegie pattern are not the representative of global thunderstorm activity. In the present work we have shown some of the diurnal trends that do not follow the Carnegie pattern but represents the global thunderstorm activity that is observed by the TRMM.

We observed that the current density and potential gradient are lower than the mean global values. The cause for the reduced magnitude is that the northern hemisphere, which is the major contributor to the global thunderstorm activity, is undergoing the winter season. This fact is established by the increasing trend of the potential gradient and decreasing conductivity as the global thunderstorm activity is moving from southern hemisphere to northern hemisphere where its activity is relatively stronger than the southern hemisphere.

The different pattern of diurnal variation in the net conductivity indicates that there could be large variability in the continent. Our observation introduces two different pattern of atmospheric electrical conductivity of which one appear to have the influence of the electrode effect and the other is global thunderstorm activity. The latter part is the dominant one.

We have been undergoing the minimum phase of the solar activity due to which we were not able to have enough severity of geomagnetic disturbances. However, in couple of cases available, they appear to have significant influence over the atmospheric electricity parameters but unable to come to a conclusion whether the values are increasing or decreasing. During geomagnetically quiet conditions the variation of the atmospheric current density and potential gradient is displaying the signature of global thunderstorm variability. When the station comes under the influence of auroral activity, i.e. during the equatorward shift of the auroral electrojet, the global variation of the atmospheric electricity is strongly influenced. It is interesting to note that the conductivity is also strongly influenced by the geomagnetic activity which suggests the Planetary Boundary Layer’s electrical environment is also significantly altered during the geomagnetic disturbances.

The large variability in the conductivity suggests that the ionization due to the rock and soil might be containing a large quantity of radioactive elements which will emanate radon gas.

Acknowledgements: We express our sincere thanks to the Director, NCAOR for providing all the infrastructure facilities at Maitri to conduct the experiments. We sincerely acknowledge IITM, Pune, for providing field mill to measure the potential gradient. We acknowledge NASA for providing the TRMM data over internet services which is used in this work. We are greatly thankful to the two anonymous referees for their valuable suggestions.

References

Alderman, E.J. and Williams, E.R. (1996) Seasonal variation of the global electric circuit. Jour. Geophys Res., v.101, D23, pp.29679-29688.

Anil Kumar C.P., Panneerselvam, C., Nair, K.U., Johnson Jeyakumar, H., Selvaraj, C., Gurubaran, S. and Venugopal, C. (2009) Apposite of atmospheric electric parameters with the energy coupling function (μ) during geomagnetic storms at high latitude, Atmospheric Res., v.91, pp.201-205.

Aplin, K.L. (2000) Instrumentation for atmospheric ion measurements, PhD Thesis, Department of Meteorology, The University of Reading, UK.

Aumento, F. (2001) Radon tides on an active volcanic Island. Presented at 6th International Rare Gas Conference, Cuernavaca, Mexico.

Belova, E., Kirkwood, S. and Tammet, H. (2001) The effect of magnetic substorms on near-ground atmospheric current. Ann. Geophys., v.18(12).

Burns, G.B., Frank-Kamenetsky, A.V., Troshichev, O.A., Bering, E.A. and Papitashvili, V.O. (1998) The geoelectric field: A link between the troposphere and solar variability. Annals of Glaciology, v.27, pp.651-654.

Chalmers, J.A. (1967) Atmospheric Electricity, 2nd ed., Pergamon Press, Oxford.

Chubb, J.N. (1990) Two New Designs of “Field Mill” Type Fieldmeters not Requiring Earthing of Rotating Chopper. IEEE Trans. on Industry Applications, v.26, no.6, pp.1178-1181.

Cobb, W.E. and Wells, H.J. (1970) The electrical conductivity of oceanicair and its correlation to global atmospheric pollution.

Jour. Atmos. Sci., v.27, pp.814-819.

Corney, R.C., Burns, G. B., Michael, K., Frank-Kamenetsky, A.V., Troshichev, E.A. Bering, O.A., Papitashvili V.O., Breed, A.M. and Duldig, M.L. (2003) The influence of polar-cap convection on the geoelectric field at Vostok, Antarctica. Jour. Atmos. Solar-Terrestrial Physics, v.65, pp.345-354.

Deshpande, C.G. and Kamra, A.K. (2001) Diurnal variations of atmospheric electric field and conductivity at Maitri, Antarctica. Jour. Geophys. Res., v.106(D13), pp.14, 207-14,218.

Dhanorkar, S. and Kamra, A.K. (1997) Calculation of Electrical Conductivity from ion Aerosol balance equation. Jour. Geophys. Res., v.102, D25, pp.30147-30159.

Dolezalek, H. (1972) Discussion of the fundamental problem of atmospheric electricity, Pure and Applied Geophys., v.100, pp.8-43.

Freier, G.D. (1961) Auroral effects on the Earths Electric field. Jour. Geophy. Res., v.66, pp.2695-2702.

Freier, C.D. (1979) Time dependent fields and a new mode of charge generation in severe thunderstorms. Jour. Atmos. Sci., v.36, pp.1967-1975.

Harrison, R.G. (2004) The global atmospheric electric circuit and climate. Survey in Geophys., v.25, pp.441-484.

Holzworth, R.H. and Mozer, D.F.S. (1979) Direct evidence of solar flare modification of stratospheric electric fields. Jour. Geophys. Res., v.84, pp.363-367.

Holzworth, R.H. (1981) High latitude stratospheric electrical measurements in fair and foul weather under various solar conditions. Jour. Atmos. Terr. Phys., v.43, pp.1115-1125.

Hoppel, W.A. and Gathman, S.G. (1971) Determination of eddy diffusion coefficients from atmospheric electric measurements. Jour. Geophys. Res., v.76, pp.1467-1971.

Hoppel,W.A., Anderson, R.V. and Willett, J.D.J.C. (1986) Atmospheric Electricity in the Planatary Boundary Layer, in Earths Electrical Environment, National Academy Press, Washington D.C.

Israelsson, S. (1991) Report series in aerosol science no.19, Dept. of Physics, Helsinki, Finland.

Jackman, C.H., Cerninglia, M.C., Nielsen, J.E., Allen, D.J., Zazodny, J.M., Mc Peters, R. D., Douglass, A.R., Rosefield, J.E. and Rood, B. (1995) Two dimensional and three dimensional model simulations, Measurements and interpretations of the influence of the October 1989 Solar proton events on the middle atmosphere. Jour. Geophys. Res., v.100, pp.11641-660.

Kamra, A.K., Deshpande, C.G. and Gopalakrishnan, V. (1994) Challenge to the assumption of the unitary diurnal variation of the atmospheric electric field based on observations in the Indian Ocean, Bay of Bengal, and Arabian Sea. Jour. Geophys. Res., v.99(D10), pp. 21043-21050.

Kartalev, M.D., Rycroft, M.J, Fuellekrug, M., Papitashvili, V.G. and Keremidarska, V.I. (2006) A possible explanation for the dominant effect of South American thunderstorms in the Carnegie Curve. Jour. Atmos. Solar Terrestrial Physics, v.68, pp.457-468.

Kasemir, H.W. and Ruhnke, L.H. (1959) Antenna problems of measurement of the air-Earth current. *In:* L.G. Smith (Ed.), Recent advances in Atmospheric Electricity. Pergamon, New York, pp.137-147.

Lobodin, T.V. and Paramanov, N.A. (1972) Variation of Electric field during aurorae. Pure Appld. Geophys., v.100, pp.167-173.

Markson, R. (1978) Solar modulation of atmospheric electrification and possible implications for the Sun-weather relationship. Nature, v.273, pp.103-109.

MacGorman, D.R. and Rust, W.D. (1998) The Electrical Nature of Storms. Oxford University Press, New York, 403p.

Mohnen, V.A. (1974) Formation, nature and mobility of ions of atmospheric importance. Proc. V International Conference on Atmospheric Electricity, Garmish-Partenkirchen, Germany.

Mozer, F.S. and Serlin, R. (1969) Magnetospheric electric field measurements with balloons. Jour. Geophys. Res., v.74, pp.4739-4755.

Mozer, F.S. (1971) Balloon measurement of vertical and horizontal atmospheric electric fields. Pure Appld. Geophys., v.84.

Muhleisen, R. (1977) The global circuit and its parameters. In: Dolezalek, H., Reiter, R. (Eds.), Electrical Process in Atmospheres. Steinkopff, Darmstadt, p.467.

Panneerselvam, C., Nair, K.U. Jeeva, K., Selvaraj, C., Gurubaran, S. and Rajaram, R. (2003) A comparative study of atmospheric Maxwell current and electric field from a low latitude station, Tirunelveli. Earth Planets Space, v.55, pp.697-703.

Rajaram, Girija, Arun, T. and Ajay Dhar (2002) Diagnostics of magnetosphere-ionosphere coupling over Indian Antarctic station Maitri, from magnetometer and riometer observations during the optical auroral event of 4–5 March 1999. Adv. Space Res., v.30, no.10, pp.2195-2201.

Rajesh Kalra, Ajay Dhar, Unnikrishnan. K, Jeeva. K, Daga. D.M. and Girija Rajaram (1995) Changes in the Auroral Electrojet Currents Inferred from Geomagnetic Field Variations at Maitri and Northern Conjugate Stations. Eleventh Indian Expedition to Antarctica, Scientific Report, 1995 Department of Ocean Development, Technical Publication No.9, pp. 87-101

Reddell, B.D., Benbrook J.R., Bering E.A., Cleary E.N. and Few, A.A. (2004) Seasonal variations of atmospheric electricity measured at Amundsen-Scott South Pole station. Jour. Geophys. Res., v.109, pp.A09308.

Rostoker, G. (1999) The evolving concept of a magnetospheric substorm. Jour. Atmos. Solar Terestrial Physics, v.61, pp.85-100.

Ruhnke, L.H. (1969) Area averaging of atmospheric current. Jour. Geomagn., Geoelectr., v.21, pp.453-462.

Ruhnke, L.H. and Michnowski, S. (Eds.) (1991) Proceedings of the International Workshop on Global Atmospheric Electricity Measurements, Madralin, Poland, September 10–16, 1989. Publ. Institute of Geophysics, Polish Academy of Sciences D-35 (238).

Rycroft, M.J., Israelsson, S. and Price, C. (2000) The global atmospheric electric circuit, solar activity and climate change. Jour. Atmos. Solar Terrestrial Physics, v.62, pp.1563-1576.

Takaji, M. and Iwata, A. (1980) A seasonal effect in diurnal variation of the atmospheric field on the Pacific coast of Japan. Pure Appld. Geophys., v.118(2).

Tammet, H., Israelsson, S., Knudsen, K. and Tuomi, T.J. (1996) Effective area of a horizontal long-wire antenna collecting the atmospheric electric vertical current. Jour. Geophys. Res., v.101, pp.29671–29678.

Tinsley, B.A., Weiping, L., Rohrbaugh, R.P. and Kirkland, M.W. (1998) South Pole electric field responses to over-head ionospheric convection. Jour. Geophys. Res., v.103 (D20), pp.26,137-26,146.

Tinsley, B.A. (2000) Influence of solar wind on the global electric circuit and inferred effects on the cloud microphysics, temperature and dynamics in troposphere. Space Sci. Rev., v.94, pp.231-258.

Tinsley, B.A. (1996) Correlations of atmospheric dynamics with solar-wind-induced Changes of air-Earth current density into cloud tops. Jour. Geophys. Res, v.101, pp.701-714.

Tinsley, B.A and Heelis, R.A. (1993) Correlations of atmospheric dynamics with solar Activity. Evidences for a connection via the solar wind atmospheric Electricity and microphysics. Jour. Geophys. Res., v.98, pp.275-384.

Tripathy, S.N. and Harrison, R.G. (2002) Enhancement of contact nucleation by scavenging of charged aerosol particles. Atmos. Res., v.62, pp.57-70.

Tuomi, T.J. (1981) Atmospheric electrode effect, approximate theory and winter time observations’. Pure Appl. Geophys., v.119, pp.31-45.

Tuomi, T. J. (1982) The atmospheric electrode effect over snow. Jour. Atmos. Terr. Phys., v.44, pp.737-745.

Williams, E.R. (1994) Global Circuit response to seasonal variations in Global surface air-temperature. Month Weather Rev., v.122, pp.1917-1929.

Williams, E.R. and Satori, G. (2004) Lightning, thermodynamic and hydrological comparison of the two tropical continental chimneys. JASTP, v.66.

Wilson, C.T.R. (1920) Investigation on lightning discharges and on the electric field of thunderstorms. Philos. Trans. Royal Soc. London, v.A221, pp.73-115.