Diurnal variation of potential gradient and current density observed at Maitri and their relevance to Carnegie curve

K. Jeeva[1], K.U. Nair[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*

Monitoring of the Global Electric Circuit (GEC) parameters has recently been shown that it 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. Obtaining the global signature of the global thunderstorm activity from the GEC observation is a challenging job as the signals are very weak and are easily masked due to Planetary Boundary Layer (PBL) process. The diurnal pattern of the GEC parameters could be anything owing to the local weather condition and orography. It is generally believed that to have the diurnal variation of the potential gradient and current density should show similarity with the Carnegie curve to have the representation of the global thunderstorm activity.

We have examined the diurnal variation of the potential gradient and current density for the year 2006 and 2007 and conductivity for the year 2007 obtained from Maitri, Antarctica. We avoided averaging the data with large number of days. Comparison of the individual days and weekly averaged data show disagreement with Carnegie pattern. However they show agreement with global lightning flash numbers obtained from TRMM satellite. As the season progress towards austral winter (summer in the northern hemisphere) the fortnight average show agreement with Carnegie curve and global lightning flash numbers.

To explain the above feature the time schedule and duration and the cruises of seven Carnegie expeditions are considered.

1. Introduction

The global component variation of fair weather electricity is subject to special attention because the physical integration of the electrical circuit gives a possibility to watch Solar-Terrestrial effects and secular changes in global climate (Williams 1994; Tinsley et al., 2000; Tripathi and Harrison, 2002). The study atmospheric electricity is expected to provide answers to some of the intriguing questions like how does atmospheric electricity affect man and his technological systems? Is our electrical environment changing significantly as a result of air pollution, the release of radioactive materials, the construction of high-voltage power lines, and other activities, or by energetic charged particle effects in the atmosphere? (Rycroft et al. 2000). In recent years there are some results emphasis on electricity parameters are not the representative of thunderstorm activity if they are not following Carnegie pattern (Harrison, 2004, Kartaleva et al. 2006). The diurnal variation of atmospheric potential gradient and current obtained from the locations at Antarctica are expected to resemble the Carnegie curve. But there are some reports from Antarctica, Amundsen Scot base (Byrne et al 1993), Maitri (Deshpande, 2001) show a significant deviation from the Carnegie curve particularly during the austral summer months. The suggested reason for such deviation is that the variation pattern depends upon the domination of thunderstorm activity from the major thunderstorm zones like America, Africa and Asia.

In the present work we too have observed that the diurnal variation of the potential gradient and current density obtained from Maitri during austral summer is significantly deviating. We attempted to give explanation for such deviation using the global lightning data obtained from LIS instrument onboard TRMM satellite. The data considered for this study is potential gradient measured by field mill, current density measured by long wire antenna for the year 2006-2008.

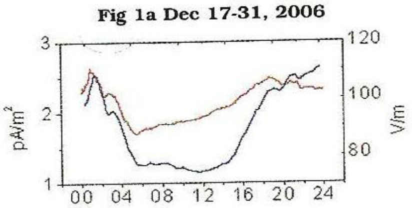
2. Observation

The potential gradient is measured using two different techniques. One is the field mill and the other is Passive antenna. Current is measured using long wire antenna. Fig 1a to 1h are the diurnal variation of potential gradient and current density. They are averaged for a small number of days and smoothed curve is presented. The diurnal variation is expected to coincide with the trend of the Carnegie curve as the measurement is made from Antarctica a pollution free zone. But the obtained pattern is strongly deviating from Carnegie curve. We attempted to examine the global lightning flash numbers pertaining to this season.

The three panels of Fig 2d shows the seasonal flash numbers/orbit for all the four seasons for the year 2001,2002,2003. This shows that the lightning flash activity is least during the winter months of northern hemisphere (austral summer). Fig 2e shows the daily mean value of current density from the fair-weather days of each month which is also showing leas number for the same period. It is to be remembered here that of three major thunderstorm regions the American sector is the largest contributor of the thunderstorm. A greater percentage of the Earth's continental land mass is located in the Northern

Mean smoothed diurnal variation of current density and potential gradient, grouped in small number of days, for the austral summer months 2006-2008

Fig 1a Dec 17-31, 2006



Dif 1(b) Jan 12-15, 2007

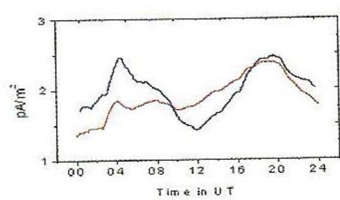


Fig 1 (c) Feb 1-10, 2007

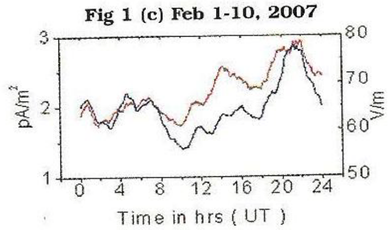


Fig 1 (d) Feb 13-20, 2007

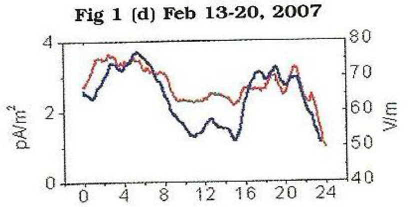


Fig 1 (e) Feb 21-28, Feb 2007

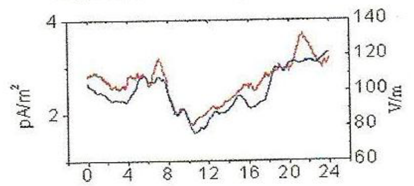


Fig 1 (f) Dec 9-15, 2007

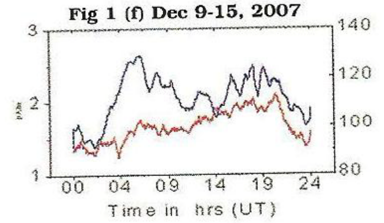


Fig 1 (g) Dec 16-31,

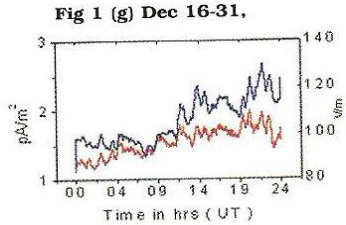
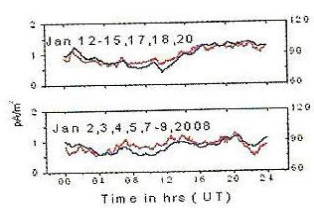
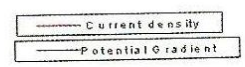


Fig 1 (h) 1-31 Jan 2008





Comparison of global lightning flash numbers with atmospheric current density

Fig 2a Monthly pattern of Current density of each month's fairweather days

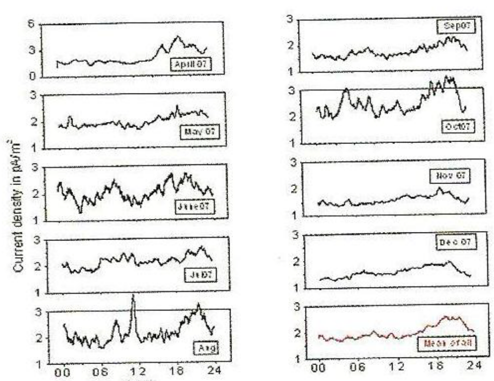


Fig 2c Monthly FW days

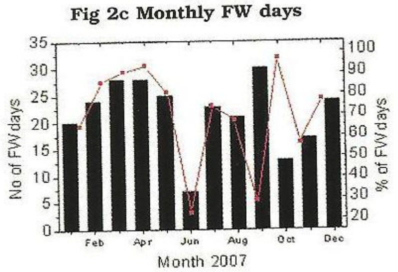


Fig 2b Seasonal pattern of Lightning flash for 2006,07

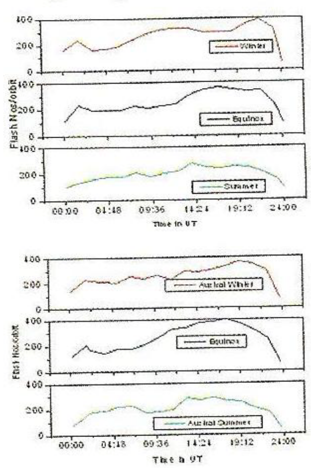


Fig 2d Seasonal variation in lightning flash numbers

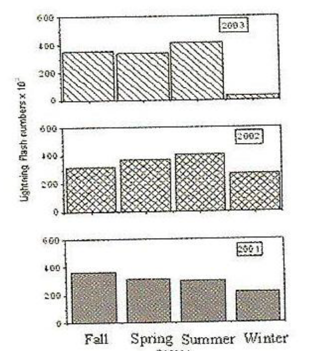
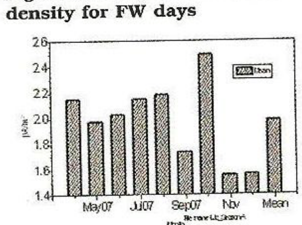


Fig 2e Monthly mean current density for FW days



Hemisphere and most convective electrical activity occurs over land, as manifested by the fact that lightning occurs _10 times more frequently over land than ocean (Orville and Henderson, 1986; Price and Rind, 1992; Williams and Heckman, 1993). So as the temperature and moisture content drop and the occurrence of thunderstorms decreases in the northern hemisphere winter, the Earth-ionosphere potential also goes down. Simultaneously, the electrical convective activity in the Southern Hemisphere is at its strongest, but because of the greater percentage of ocean, the Southern Hemisphere increase cannot make up for the Northern Hemisphere decrease (Reddell, 2004).

3. Conclusions

1. The diurnal variation of potential gradient and current density for the austral summer months of 2006 and 2007 is analysed and it is found that their pattern is strongly deviating from the Carnegie curve suggesting that it may not be representing the global signature of the thunderstorm activity. However the analysis of the global lightning flash numbers, obtained from LIS instrument onboard TRMM satellite, suggest that global lightning flash numbers pertaining to this period too show a distinct deviation from other seasons. This suggests that during the austral summer months the sun is in the southern hemisphere and the thunderstorm contribution from the Northern Hemisphere have come down drastically. This is also seen from the seasonal variation of the thunderstorm activity for the three consecutive years 2001,2002,2003 in which the winter months use to have approximately 30% of the summer months.
2. The diurnal variation of the current density for the months April to December 2007 and mean of all these months show that there is good resemblance with Carnegie curve. Similarly the lightning flash numbers for the seasons winter and equinox (NH). When the data sets are averaged for large number of days, excluding the austral summer months, there is similarity with the Carnegie curve.
3. The concept "Electricity parameters are not the representative of thunderstorm activity if they are not following Carnegie pattern" has to be reviewed. It may be appropriate for the summer vernal solstice and equinox. But may not be suitable for autumn solstice. Since the sun is over the southern hemisphere where there is majority of ocean there can be no sufficient convection activity to generate large number of thunderstorm activity. The thunderstorm activity which occur during the northern hemisphere and southern hemisphere may be different in magnitude and occurrence of time.

Acknowledgements. We convey our sincere thanks to our Director, Prof. A. Bhattacharyya, for extending all support in conducting the experiments at Maitri Antarctica. We thank Director, National Centre for Antarctic and Ocean Research for providing an opportunity to participate in the 26the Indian Antarctic Expedition during the year 2006-008. The measurement of potential gradient was carried out using the Field mill provided by IITM, Pune.

We acknowledge the GODDARD Space Flight Centre, NASA for providing the LIS data through internet services. We express our sincere thanks to all the scientists and engineers from EGRL, IIG for the continued effort in making the experiment and expedition success.

References

Anderson, R.V., Universal diurnal variation in air-Earth current density, J.Geophys. Res., 1697-1700,1969.

Byrne, G.J., J.R. Benbrook, E.A.Bearing, A.A.Few, G.A Morris, W.J. Trabucco, and E.W.Paschal, Ground-based instrumentation for measurements of atmospheric conduction current and electric field at the South Pole J.Geophys, Res., 98,2611-2618,1993.

Deshpande C.G, and A.Kamra, Diurnal variation of atmospheric electric field and conductivity at Maitri, Antarctica, Journal of Geophys, Res Vol 106, No D13, Pages 14,207-14,, Jul 16, 2001.

Dolezalek, H., Discussion of the fundamental problem of atmospheric electricity, Pure and Applied Geophysics 100, 8-43,1972.

Harrison , R.G., JASTP September 2004, Pages 1127-1133, M.D. Kartaleva et al 2006, Journal of Atmospheric and Solar Terrestrial Physics 68 (2006) 457–468.

Price C, Rind D. A simple lightning parameterization for calculating global lightning distributions, J Geophys Res., 1992.

Reddell , B.D., J.R. Benbrook, E.A. Bering, E.N. Cleary and A.A. Few, Seasonal variations of atmospheric electricity measured at Amundsen-Scott South Pole station, Journal of Geophysical Research 109 (2004), p. A09308.

Rycroft, M. J., S. Israelsson and C. Price,The global atmospheric electric circuit, solar activity and climate change Journal of Atmospheric and Solar Terrestrial Physics Vol 62 , issue 17-18, Nov 2000 Pages 1563-1576.

Takgi, M., and M. Kanada, Global variation in the atmospheric electric field, Pure Appl. Geophys., 100,44-53,1972.

Tinsley, B.A.: 2000 'Influence of solar wind on the global electric circuit and inferredEffects on the cloud microphysics, temperature and dynamics in troposphere'. Space sci. Rev 94, 231-258.

Tripathi, S. N. and Harrison, R.G., 2002. Enhancement of contact nucleation by scavenging of charged aerosol particles. Atmos. Res. 62, pp. 57–70.

Williams E.R., and S.J. Heckaman, The local diurnal variation of cloud electrificationand the global diurnal variation of negative charge on the Earth, J. Geophys. Res., 98, 5221-5234, 1993.

Williams E.R. 1994: "Global Circuit response to seasonal variations in Global surface air-temperature- Month weather Rev., 122,1917-1929.