Twenty Fifth Indian Antarctic Expedition 2006-2007
Ministry of Earth Sciences, Technical Publication No. 23, pp 179-186

Measurement of Atmospheric Potential Gradient in Antarctica Using Indigenously Developed Passive Antenna System

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ABSTRACT

Several techniques are available to measure the atmospheric vertical potential gradient. During the austral summer of the 25th Indian Scientific Expedition to Antarctica (2005-06), an indigenously fabricated passive antenna system was installed at Maitri, Antarctica to monitor the potential gradient continuously. The potential gradient observed by the passive antenna is compared with the observations taken by the conventional field mill. The signature of the potential gradient is further verified using the global lightning activity obtained by the LIS instrument onboard TRMM satellite.

INTRODUCTION

Monitoring of atmospheric vertical potential gradient has important implication in the Earth's Electrical Environment. The natural spherical condenser formed by the base of the ionosphere, surface of the earth and the atmosphere is continuously charged by the global thunderstorm activity to a potential of a few hundred kilovolts (Roble and Tzur, 1986). Using the Global Electric Circuit (GEC) concept the electrodynamic coupling between the upper atmosphere and the lower atmosphere can effectively be investigated (Bearing III et al., 1995, Rycroft et al., 2000, Singh et al., 2005). With this primary objective, we have started monitoring the atmospheric electricity parameters at Maitri (Indian Scientific Station), East Antarctica from 1999 onwards (Panneerselvam et al., 2003, Anil Kumar 2008, 2009).

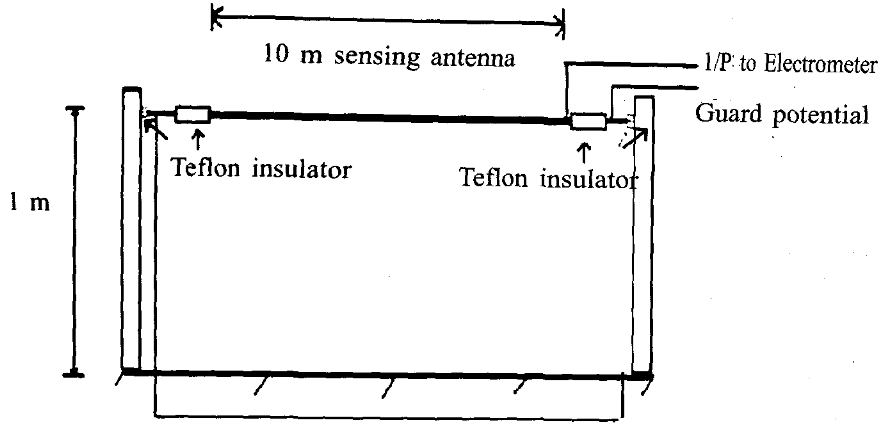
The basic approach of the measurement of the potential gradient (PG) is to connect an antenna acquiring the static charges from the atmosphere and discharge them through an electrometer. The antenna can be a plate, a wire, an alpha or a rotating vane. The most familiar one is the rotating field mill (Chalmer, 1967) in which an electro mechanical device measures the strength of a static electric field. One or more electrodes are alternately exposed to and then shielded from the field to be measured. The electric current which flows to and from the electrode is proportional to the strength of the electric field. The advantage of using field mill is that it offers more rapid time response and dynamic range. At the same time it also has some disadvantages as the field mill is directly exposed to open atmosphere, causing more heat during low temperatures and has to be prevented from precipitation. The continuous rotation is likely to have drift in its speed, resulting in drift of the measured parameter (MacGorman and Rust, 1998).

In order to overcome the disadvantages of the field mill and to have a back up measurement of the potential gradient and to cross examine the potential gradient signatures, the passive antenna technique was implemented at Maitri during the 25th Indian Scientific Expedition to Antarctica. A direct method for sensing the potential of passive antenna system has been described by Harrison (1996). The indigenous electrometers used in this work were fabricated based on the technique of Harrison (1997). The system was kept under operation throughout the year. The data were logged to a PC with a sampling rate of 30 seconds.

The present work deals with the validation of the data and to some extent to establish the merits and demerits of the system. For this purpose we have selected data for a fortnight from the data set of April 2006. The reason for selecting this period was that the global thunderstorm activity is expected to be at its lowest during the austral summer. Southern hemisphere summer does not produce sufficient number of severe thunderstorm activity. During the month of April the Sun is over the equator and the thunderstorm activity is expected to be more than that of the austral summer months. 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.

System Description

The passive antenna system was installed at about 30 m away from the field mill and close to the lake where we could find fairly plain terrain. A schematic diagram of the installation is shown in the figure below. The sensing antenna is of 2 mm thickness and 10 m long tinted copper wire. The antenna is separated by two Teflon rods to minimise



the leakage of the current. The antenna wire, suspended horizontally between two short metal masts and the electro meter is kept in a thermally insulated box near by the mast. All the insulators are regularly cleaned using isopropyl alcohol. A guard potential close to the potential on the wire is applied to support wires at each end, to minimize the leakage through the insulators which would occur if the support wires were merely grounded.

The signal pick up cable is soldered to the antenna and connected to the electrometer through a Teflon insulated wire. The electrometer is powered by a 12 V battery kept in the laboratory at a distance of nearly 30 m away from the experimental set up. The lab test characteristics of the system have been discussed by Panneerselvam et al., (2003).

Validation of Data Obtained from the Passive Antenna System

The data acquired at the sampling rate of 30 seconds for the days 1 - 15 April 2006 are shown in Figure 1. The 2880 sample points of one day are smoothed to 60 points, which is equivalent to 30 minutes or about the relaxation time of atmosphere.

In Figure 1 the potential gradient in Volts/m is presented for the days from 1 April to 15 April 2006. The purpose of presenting these data is to examine the behaviour of the passive antenna system to the condition of fair weather electrical environment and disturbed weather condition. During this period, the weather was meteorologically stable from 1st to 6th April. On 9th April and 10th April, the weather was disturbed. Again 11th and 12th April were fair-weather days and deteriorated again between 13th to 15th April.

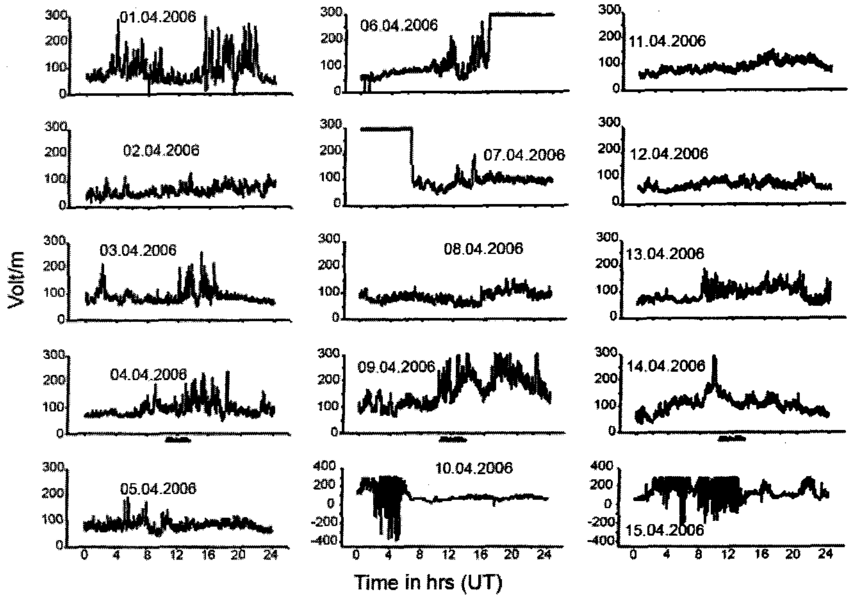


Fig. 1: Diurnal variation of the potential gradient for the period April 1-15, 2006, as measured by the newly installed Passive antenna system

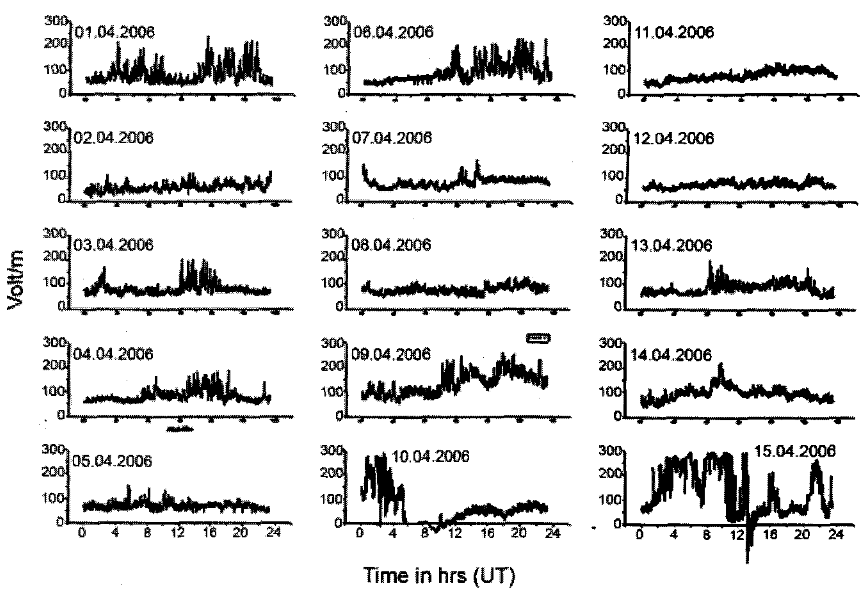


Fig. 2: Diurnal variation of the potential gradient for the period April 1-15, 2006 as measured by the conventional field mill.

Similarly, Figure 2 shows the potential gradient variation in Volts/m observed by the field mill. The comparison of these two set of figures indicates that there is a good agreement in all aspects when the weather is stable i.e. during fair weather condition. However, the signature varies from each other during the disturbed weather condition (e.g. 10th and 15th April 2006).

DISCUSSION

By comparing the behaviour of the field mill and passive antenna, it was observed that they have the same signature during the fair-weather condition. They largely differed during disturbed weather conditions as seen on 10th and 15th April 2006.

It was difficult to bring out the diurnal pattern of the potential gradient from the 30 second data. The raw sets were smoothened to 60 points which is equivalent to 30 minutes. The selection of 30 minutes smoothing was done considering the atmospheric relaxation time. They are displayed in the top panels of Figures 3 and 4.

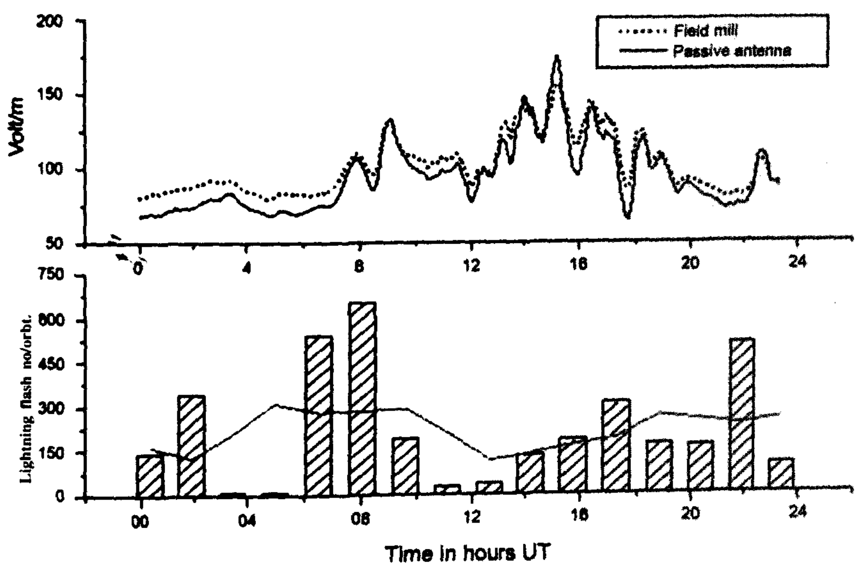


Fig. 3: Comparison of the potential gradient measured by passive antenna and field mill with the global lightening activity for the day of April 4, 2006

The Carnegie curve is the diurnal variation of potential gradient obtained during the Carnegie expeditions (1915-29). This curve is considered to be the representation of global thunderstorm activity. Its general behaviour is to have a minimum around 03 UT and a broad maximum thereafter followed by peak at about 19 UT hours. This broad peak is contributed by the regional thunderstorm activity in the Asian sector (around 0800 UT) and African sector (around 1600 UT). We attempt to explain the diurnal variation of potential obtained by the passive antenna and field mill. In Figure 3, we find two peaks centred around 0900 UT and 1600 UT. This appears to be contributed by the thunderstorm activity from Asian sector and African sector. In Figure 4 a peak is seen around 0700 UT and 2000 UT. This appears to be contributed by the thunderstorm activity from Asian Sector and American Sector.

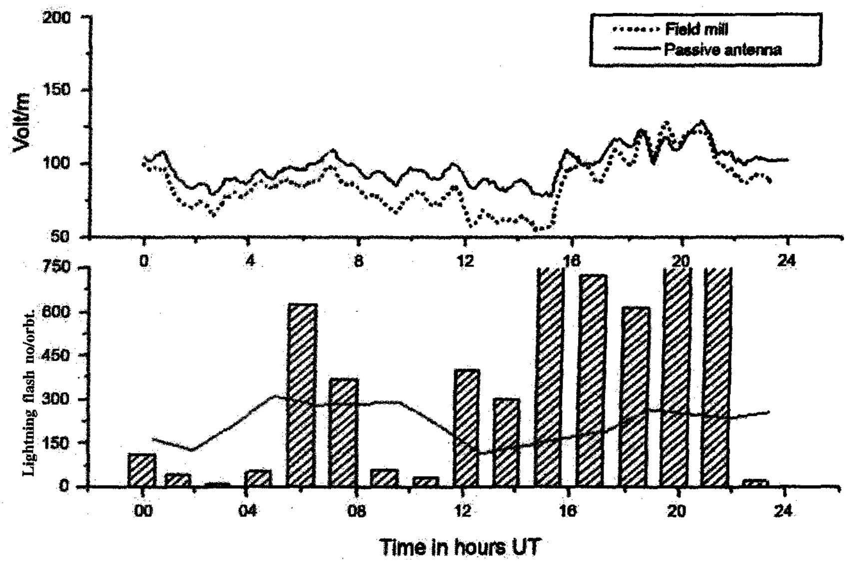


Fig. 4: Comparison of the potential gradient measured by passive antenna and field mill with the global lightening activity for the day of April 8, 2006

In order to have the real time global lightning activity, the global flash numbers observed by the LIS instrument onboard TRMM satellite, were plotted at the bottom panels of Figures 3 and 4. They are in total agreement with the observed potential gradient by the passive antenna and field mill. Thus the parameters observed by both the systems are confirmed to respond to the global lightning activity.

CONCLUSIONS

The diurnal variation of measurement of the potential gradient at Maitri using the passive antenna is compared with that of field mill and their signatures are having a good agreement with each other. The values at any given time differ by about ±10 volts/m.

The measured diurnal variation is compared with the global thunderstorm activity and that too is in good agreement with each other.

The disadvantage of using the passive antenna is that its dynamic range is about 300 v/m. whenever, the potential gradient exceeds this level the output turns to saturation. However, this will not affect the monitoring of fair-weather electrical environment, which is expected to be around 150 v/m.

Since the sensing element is a long wire it is bound to respond to even moderate winds causing large fluctuations in the measured parameter. As such, the set up is reliable for fair-weather days. Such a fluctuation is not seen in field mill even when the wind is very strong. Hopefully, with further improvement in the antenna system, the set up will be useful to monitor the electrical environment in all weather conditions in future.

ACKNOWLEDGEMENTS

We express our sincere thanks to the Director, NCAOR for the invaluable support in providing all the infrastructure and facilities at Maitri to conduct the experiments. We sincerely acknowledge Indian Institute of Tropical Meteorology, Pune, for providing us with 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 Director, IIG for her support and guidance in conducting this experiment at Antarctica. We would like to acknowledge the suggestions and comments of the reviewer, which helped in improvement of the manuscript.

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