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Surface measurements of atmospheric electrical parameters at Maitri, Antarctica: Preliminary results

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ABSTRACT

We are operating atmospheric electrical instruments like long wire antenna, electric field meter, wire antenna and passive antenna for atmospheric Maxwell current, electric field, conduction current and atmospheric potential gradient. This year (December 2008) we have installed Electric Field Meter (EFM-100) and wire antenna for measuring the atmospheric electric field and conduction current. This instrument is deployed at Maitri, Antarctica and will be operated under any weather conditions like snow fall and strong blizzard etc., The study has been carried out during austral summer for the period of 2008 and 2009 at the Indian station, Maitri (70.75° S, 11.75° E, 117 m above mean sea level). The present work has been to understand the new instrument system in response to different meteorological conditions and on fairweather days. The measured electric field from the Passive antenna and EFM-100 compared and is behaving similar variation.

Keywords: conduction current, electric field, Maxwell current, fairweather day, global electric circuit, displacement current.

INTRODUCTION

The global electrical circuit (GEC) is a large scale current system, formed by an aggregate of geophysical shells and electrical sources. Consequently, the GEC has the properties determinable by physical state of the magnetosphere, ionosphere, atmosphere and lithosphere. Atmospheric electricity is an integral part of the global electrical circuit . In this way, the global thunderstorm activity is able to maintain a time varying electric potential difference of ~ 300 kV, directed downward between the equipotential surfaces of the ionosphere and the ground (Adlerman and Williams

1996). The variations of vertical electric field and current are direct evidence for GEC action. The periodic electric 2 field variations, measured by Carnegie expedition over ocean, are considered as display of world-wide thunderstorm activity and are the classical standard of electrical global variations. The study of global electric circuit (GEC) can help in understanding the electrical environment of the earth's atmosphere. This approach can provide a good framework for exploring interconnections and coupling of various regions of the atmosphere (Rycroft 2006). The measuring site needs to be free of atmospheric aerosols and convective activity, otherwise these would obscure the weak signatures representing the global thunderstorm activity (Israel 1973). Measurements from Antarctica also allow us to investigate meteorological effects, such as blizzards, wind turbulence, snowfall and clouds, on local electrical processes and enable us to understand the electrical climate of the Antarctic plateau (Cobb 1977). The global circuit involves lower atmosphere generators and upper atmosphere generators, the latter being significant over the polar caps. The Antarctic plateau supports a desert-like climate with clear skies and very low atmospheric aerosol content (Tinsley B., A., and L. Zhou, 2006). In summer, the prevailing winds are light, moving in a nearly constant direction and the atmosphere is relatively free of turbulent and convective motions (Byrne et al 1993). The downward air-Earth current being delivered to the surface of the Antarctic plateau is larger than the global average owing to its location in high latitudes. Therefore, because of its orography, the Antarctica plateau is strongly coupled to the GEC.

1. Description of the instruments:

The most widely used ground-based sensors for the air-Earth current measurements are: Wilson plate (Israel 1973), the horizontal long-wire antenna (Ruhnke 1969), horizontal passive antenna (Harrison 1996) and spherical shell in the form of two hollow hemispheres (Burke and Few 1978). The horizontal long wire antenna, if placed in the atmosphere, will closely follow the electrical current variations of the atmosphere after the initial net charge on the antenna leaks off. When the antenna is shorted to the ground through a resistor, it will generate a voltage that is proportional to the air-Earth current. In the present experimental setup, a long wire of length 41.5m and thickness 3mm is kept horizontally stretched parallel to the ground at a height of 1.2 m. The wire is mechanically supported by means of masts. By using teflon rods at their ends it is ensured that the antenna wire is electrically insulated from the supporting masts. The input is fed through the electrometer (Model AD 549) that has high input impedance and permits extremely low input bias current (10-14 A). The electrometer measures the current up to 1 nA (corresponding to the output voltages whose limit is ±5V) with a feedback resistance of $5 \times 10^9 \Omega$. A unity gain operational amplifier (LM308) amplifies the electrometer output signal. The amplified signal is then taken in a shielded cable over a distance of 10m to the control room where it is fed to a PC-based data logger. The sensitivity of the digitized signal is 2.44mV that will correspond to a current of 0.5 pA. The data are recorded at a sampling interval of one second (Panneerselvam et al 2003). The atmospheric electric field has been measured with a horizontal passive wire antenna of 20 m in length and 3 mm in diameter made of tinned copper. The sensor is 3 supported 1 m above the ground by means of masts. At each end there are porcelain egg insulators, and a PTFE (Poly Tetra Flouro Ethylene) or teflon insulator under steady compression at the masts. The insulators are regularly cleaned with isopropanol. A guard potential, which is close to the potential on the wire, is applied to the support wires at each end. This is to minimize the leakage through the insulators, which would occur if the support were merely grounded. As a precaution against the guard potential influencing the potential sensed by the antenna, the parallel cable that carries the guard signal to the far end of the antenna has an earthed screen. The antenna makes contact with a short wire made of same material as that of the antenna, which is connected to a voltage follower electrometer (LMC 6042) with the unity gain that permits ultra low input bias current of nearly 1 fA. The amplified signals are filtered by the low pass filter at the input of data logger, which is 50 m away from the preamplifier. The filtered signal is fed to the PC at a sampling interval of one second (Panneerselvam et al 2007). This year we have installed Electric field meter (100) for the same atmospheric electric field measurements. After comparison work the passive antenna system was stopped for keeping it as a standby. The details are available in info@boltek.com. The sampling interval of this instrument is 0.5 seconds. It can be operated in any weather conditions with 12V DC.

The sources other than the air-Earth conduction current that contribute to the measured current density are (i) the convection current, (ii) the displacement current, (iii) the point discharge current, (iv) the precipitation current, and (v) the lightning current (Israel 1973). The sum of all these currents is collectively called the Maxwell current. Out of these, the convection current arises when the charge carriers are moved by the winds, and hence it is a possible source for the locally induced component in the measured current. The lightning and precipitation currents are not considered since the datasets selected are during fairweather periods. The location of the experimental setup on a barren land does not favour point discharge current because the sharp edges provided by plants and trees allow for point-discharge currents but in Antarctica there are no trees and plants hence, contribution of point-discharge current is negligible. The effective area of the present experimental setup is 66.1m2 calculated from the formula S = hC/ε (Kasemir and Ruhnke 1959; Tammet et al 1996, Panneerselvam et al 2007), ε being the dielectric constant of air, C the capacity of the antenna and h the height of the antenna above the ground. Here the value for C = 298.2pF ; h = 2m. Capacity is measured with Digital multimeter as well as calculated using the formula for C (Tammet et al 1996). The total current density can be estimated by dividing the measured current by the effective area of the antenna.

2. Site description:

The Indian Antarctic station, Maitri is located in the Schirmacher oasis in the Dronning Maud Land, East Antarctica (117m above the mean sea level). Antarctica has only around 2% of its area that is free from ice. The nearest steep cliff of the east-west trending glacier on the southern side of the station is more than 700m away from the station and is 300m in height. The snow-covered surface during summer season was more than half a kilometer away from the station. The instruments were installed on barren land near the station. The surface of the station area is mainly covered by sandy and loamy sand types of soil. The solar zenith angle at Maitri varies from 48° to 88° during summer months. There was no sunset till the third week of January, but periods of short nights slowly increased during February. The variations in surface meteorological parameters were measured by automatic weather station which is installed during this expedition. The cloud cover over the station occurs mainly under the influence of subpolar low-pressure systems and shows an alternating sequence of the sky changing from overcast to clear as the system moves away (Deshpande and Kamra 2001).

3. Results and Discussion:

Measurements of atmospheric electric currents and Electric field have been made at Maitri, Antarctica since 1999. This year we have installed EFM-100 and wire antenna for the measurements of electric field and conduction current. The selection of the fairweather days the days with 24 hours clear sky with low wind speed, less than 5m/s has been made with the standard procedure adopted in the past [Reiter, 1985]. In the present study, a set of days during which fairweather conditions prevailed all through the day were considered, and the hourly averages were computed to yield the diurnal variation. Features corresponding to the UT variation were then looked for. If thunderstorm activity was responsible for the generation of global electric circuit and its variation with time, one would expect in the average pattern a maximum in the measured electrical parameters near 19:00 UT and a minimum near 03:00 UT. To show the response of the sensors we have shown diurnal variation of the measured atmospheric electrical parameters as a raw data during fairweather condition as well as meteorologically disturbed day.

The diurnal variation of the hourly averaged values of the atmospheric electric field and current density for the period of November 2008 - February 2009 is depicted in Fig. 1. The diurnal variation of curve of electric field during fairweather days has a single period with a minimum at 04:00 UT and a maximum at 19:00 UT. The atmospheric current variation has minimum 03:00 UT and has a maximum for Maxwell current at 20:00 UT and 19:00 UT for the conduction current, which is very similar to the Carnegie curve. This variation has been widely observed, and according to classical theory, it is generally attributed to the variation with time of day of the number of thunderstorms across the globe (Roble 1985).

Hourly average value of the measured current and electric field variations using wire antenna and Electric field meter are shown in Fig. 2. The correlation coefficient for these parameters more than 0.9 during fair weather days and hence, during fair weather the conductivity is more or less stable. During fair-weather days the electric field and current variations are similar but during meteorologically disturbed days the variation of field and current always not similar because of atmospheric conductivity. During blizzard conditions due to high wind speed, falling and drifting snow brings different charges near to the sensor complex. And hence, the conductivity changes according to the polarity of the charged particles. Due to the change of the conductivity the current and field changes 5 occur. In figure 3 & 4. We have shown the diurnal variation of the field and current during fairweather day as well as meteorologically disturbed day.

From the measured Maxwell current density and conduction current density we have separated the displacement current density. Maxwell current measures conduction current and displacement current during fair weather condition. Subtracting the conduction current density from the Maxwell current density we will get the displacement current, which is shown in Fig. 5. During magnetic quiet period the upper atmospheric contribution to the measured Maxwell current is less compared with the magnetic disturbed days. Our observation made during sunspot zero days, fairweather and magnetic quiet day, and then also the measured Maxwell current has some displacement current. The measured Maxwell current follows the famous ""Carnegie curve" which implies the measured Maxwell current at Maitri, Antarctica dominated by the thunderstorm activity during magnetic quiet days.

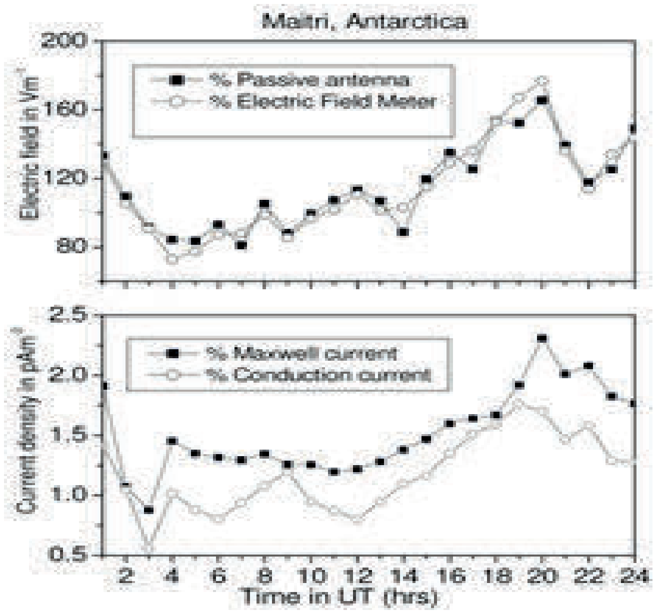

Fig : 1. Diumal variation of atmospheric electrical parameters during summer 2008 – 2009

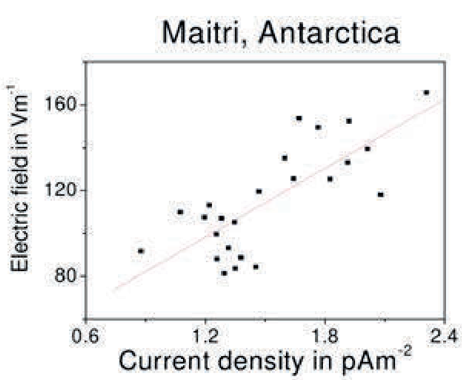

Fig : 2. Conduction current Vs Electric field during summer 2008 / 2009

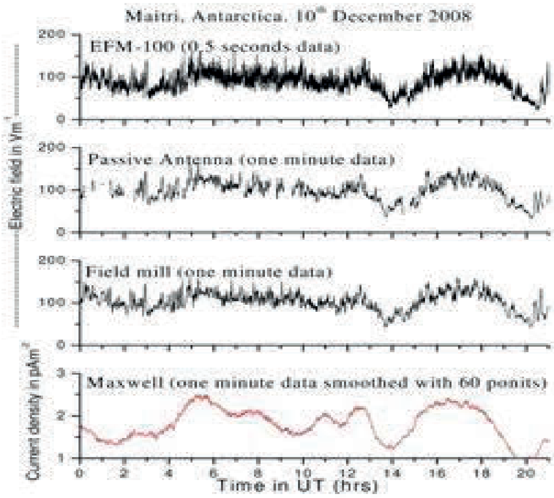

Fig : 3. Dirunal variation of atmospheric electrical parameters during clear sky day (raw data)

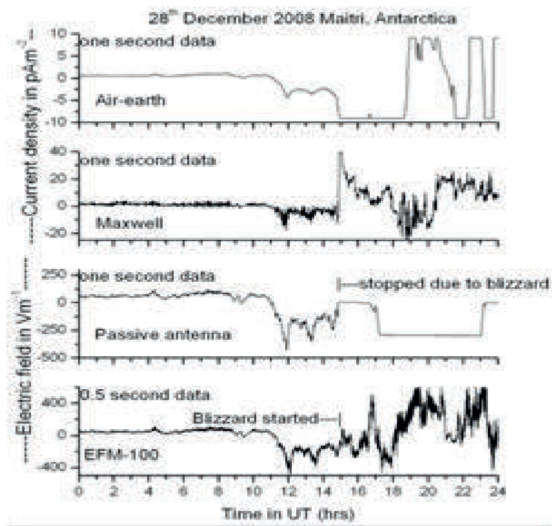

Fig : 4. Dirunal variation of GEC parameters during Blizzard days on 28 December 2008

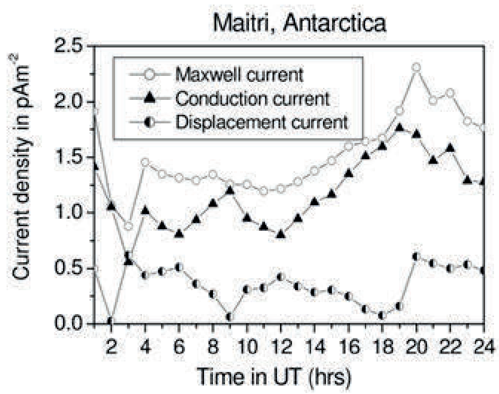

Fig : 5. Diurnal variation of different currents during summer 2008 / 2009

Conclusion:

The variations of measured atmospheric electrical parameters are similar to the famous fair-weather 'Carnegie curve' during fair-weather days. And also the days were selected during magnetic quiet conditions. The upper atmospheric contribution to the measured electrical parameter is very low because the observation made during sunspot zero days, hence the measured the atmospheric electrical parameters are to the contribution of the global thunderstorm activity. The conductivity more or less stable during fairweather days and it is varying during meteorologically disturbed days. Detailed study about the upper atmospheric contribution will be carried out after reaching to the mainland. With the continuous measurements of atmospheric electrical parameters and geomagnetic field variations, there is scope for addressing the problems related to the modulation of GEC by the influence of magnetosphere-ionosphere -lower atmosphere coupling processes on the near-surface electrical parameters in the polar caps.

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