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Observations of Atmospheric Maxwell Current at Indian Antarctic Station, Maitri

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Abstract

Measurements of atmospheric Maxwell current, the fundamental parameter of the global electric circuit was commissioned at Indian Antarctic Station, Maitri, in December 1999. The horizontal long wire antenna is used as a sensor for picking up charges that constitute various currents collectively called the Maxwell current. The objective of the present work is to understand the response of the experimental setup to various atmospheric electrical and meteorological conditions and to explore the possibilities of detecting the global *DC* component believed to be the result of global thunderstorm activity. During the fairweather conditions i.e. days with low or moderate winds, no snowfall or snowdrift, no clouds and no fog effects, the diurnal variation of air-Earth Maxwell current has single periodic with a minimum at 0300 UT and a maximum at 1900 UT. The diurnal variation closely follows the trend of the Carnegie curve.

Introduction

The study of global electric circuit (GEC) provides a platform for understanding the solar-terrestrial relationship and offers possibilities for exploring one of the traditional scientific problems of mankind in the last few centuries, namely, that of associating changes in lower atmospheric weather with the solar output (Herman and Goldberg, 1978). In spite of several mechanisms having been proposed there still lie uncertainties in identifying the actual physical processes that govern the envisioned relationship between the sun and the changes in weather. Continuous measurements of atmospheric electrical parameters, namely, the vertical electric field, the conductivity and the air-earth current density, that characterize the GEC, are considered useful in any study aiming towards understanding fully the electrical environment of the Earth. Further, since the global circuital path links the lower troposphere, the ionosphere and the magnetosphere, the measurements of atmospheric electrical parameters will be handy in any integrated approach that involve all these regions. Long-term measurements would be considered useful for addressing some of the problems associated with global change.

The classical model of GEC proposed by Wilson (1920) considers the thunderstorm as the only generator and operates the GEC and neglects other sources. It is also hypothesized that the ionosphere is an equipotential surface and that the thunderstorm electric field cannot go beyond ionosphere. According to the new GEC model, the solar wind/ magnetosphere dynamo, the ionosphere dynamo and thunderstorms are the three main generators that operate the global electric circuit (GEC). Due to the variability of thunderstorm activity there are diurnal, seasonal, interannual variations in the potential differences and currents, as well as solar influences on the properties of the circuit (Israel, 1973; Markson, 1986; Roble and Tzur 1986).

The Antarctic station has been chosen as our instrument site for several reasons. Most importantly, the station sits on the Antarctica plateau; a region where the atmosphere is more suited for making measurements of GEC (Park, 1976). It is a desert-like climate with clear skies, very low atmospheric aerosol content. The prevailing wind which are light, flow in a constant direction, and are relatively free of turbulent and convective motions (Dalrymple, 1966). The continent is free of thunderstorm activity. Hence, atmospheric electrical measurements made at Antarctica are expected to be relatively unperturbed by local meteorological conditions. The ice surface is flat and void of obstructions, the electrical conductivity of the surface ice is several orders of magnitude higher than that of the air. In the present work, vertical air-Earth current measurements made at Maitri, Antarctica, are made use of to examine the possibility of detecting global signatures.

Experimental Technique

The Maxwell current in the air is the most informative parameter of the global atmospheric electric circuit (Ruhnke, 1969). Different methods for measuring the vertical electric current in the atmosphere were attempted in the past. Disturbances of local origin are unwanted signals for any method attempting to detect global signatures. The long-wire antenna is considered as a good alternative since it allows for the suppression of local disturbances by averaging the vertical current over a large area (Ruhnke, 1969). The horizontal antenna, if placed in the atmosphere, will closely follow the electrical variations of the atmosphere after the initial net charge on the antenna leaks off. When the antenna is connected to ground through a resistor it will pick up a certain amount of current proportional to the air-Earth current density. In our experiment a long wire antenna of 41.5 m long and 3 mm diameter is used to collect incoming charges from the atmosphere. The sensor is supported 1.5 m above the ground by means of masts that are electrically separated by Teflon rods. It is connected to an electrometer (Model AD 549) that has high input impedance pre amplifier in the order of $10^9\ \Omega$ and permits extremely low input bias current (10^{-14} A). The electrometer converts the current into voltage. The electrometer measures the current from pA to 2nA with the high feedback resistance ($5 \times 10^9\ \Omega$). A unity gain operational amplifier (LM308) amplifies the electrometer output signal. The amplified signals is filtered by the low pass filter, with a cut-off frequency of 1 sec (3dB) at the input of ADC, which is 100 m away from the preamplifier. The filtered signal is fed to the 12-bit ADC (AD574) with 2.44 mV resolution, which is mounted in the personal computer. The PC is recording the signal at a sampling interval of one second. The RC constant chosen to is 30 minutes, which is nearly equal of the order as the atmospheric relaxation time. The hourly averaging of the data samples carried out in the later stages may further eliminate any short-period variations in the measured current density.

The current sources other than the conduction current that contribute to the measured current density are: (i) the convection current; (ii) the displacement current; (iii) the point charge 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 other than electrical force like winds, eddy and due to gravity. As far as the long wire antenna is concerned, it does not favor convection current (Tammet et al., 1996), and is not affected by the locally induced component in the measured current density. The lightning and precipitation current contribution is not possible since the data sets are selected during fair-weather periods. The location of the experimental setup is on barren land and does not favour point charge current. Choosing the RC time constant can eliminate the displacement current (short period variations). The sensor complex is free from any growth of grass or vegetation. The meteorological parameters are measured with standard meteorological instruments.

Site Description

The Indian Antarctic Station, Maitri, is located in the Schirmacher Oasis in the Dronning Maud Land, East Antarctica (117 m above mean sea level). Antarctica has only *2%* of its area as free of 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 300 m in height. The snow-covered surface during summer season was more than 0.5 km 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 varied form 48° to 88° during our observation periods (January and February 2001). There was no sunset till January third week, but the period of short nights slowly increased during February. The variations in surface meteorological parameters like wind speed, wind direction, snowfall, pressure, visibility and all other parameter is systematically monitored by the India Meteorological Department. Antarctica has a desert like climate with clear skies, very low atmospheric aerosol content. In summer the prevailing winds are light, flowing in a nearly constant direction, and are relatively free of turbulent and convective motions. The cloud cover over the station occurs mainly under the influence of sub polar low-pressure systems and shows an alternating sequence of clear sky changing over to the overcast and then again clearing as the system moves away (Deshpande and Kamra, 2001)

Results and Discussion

Measurements of Atmospheric Maxwell Current at Indian Antarctic Station, Maitri, were started in December 1999. The data for the period of this Antarctic summer are available for analysis. The selection of the fair-weather days is the same as the standard procedure adopted by Reiter (1992). India Meteorological Department systematically recorded observations of local weather conditions. The hourly averaging is most suited for the identification of the signatures of global electric circuit. Since the charge generated by a thunderstorm somewhere on the globe is distributed in the equalizing layer (ionosphere) within 10-15 minutes, mean values of at least 30 minute duration would be required if the global thunderstorm activity is to be adequately represented (Reiter, 1992). One-hour averages are considered for examining the diurnal variation in the measured current. The measured current is discussed in arbitrary units.

In the present study the data sets were selected for analysis during the fairweather conditions that prevailed during most of the summer period, and the hourly averages of the air-Earth current are computed to yield the diurnal variation. The observed features are identical to the "classical" Carnegie curve. If thunderstorm activity was responsible for the generation of global electric circuit and its variation with time, one would expect a maximum in the measured current around 1900 UT and a minimum around

0300 UT. The day-to-day variability is attributed to the different thunderstorm regions active at different times worldwide. The thunderstorm processes over the Malaysian Archipelago and the adjoining maritime continent extending from South Asia across the Philippines, Indonesia and Borneo into Northern Australia are active around 1000 UT. The sub-Sahara African region is active around 1600 UT and the America, principally, the Amazon basin in South America, around 2200 UT. The other agencies that might influence the occurrence of this maximum are the ionospheric wind dynamo process and the solar wind-magnetosphere interaction. Both these processes lead to a large potential drop within the upper atmosphere thereby contributing to significant changes in the spatial and temporal behavior of the global air-Earth current (Roble, 1985). A detailed study on the effects of these processes will be taken up in the near future.

The daily pattern of atmospheric air-Earth current during fair-weather conditions is depicted in Fig. 1. The diurnal variation of the atmospheric air-Earth current may be noticed with a maximum around 1900 UT and a minimum around 0300 UT. Considering that it was summer in the Southern Hemisphere this diurnal trend is consistent with the familiar "Carnegie curve" variation. This variation has been widely observed, and according to classical theory, is generally attributed to the variation with time of day to the number of thunderstorms across the globe (Roble, 1985).

Conclusion

From the limited data set available and examined so far, the atmospheric electric current density sensors used at an Indian Antarctic Station, Maitri, have shown the capability of providing high quality and high resolution data for monitoring the global electric circuit. These initial results encourage us to continue the experiment in future. With the simultaneous measurements of atmospheric electrical parameters and the geomagnetic field variations, there is scope for addressing to the problems related to the modulation of global electric circuit by other terrestrial and extraterrestrial sources.

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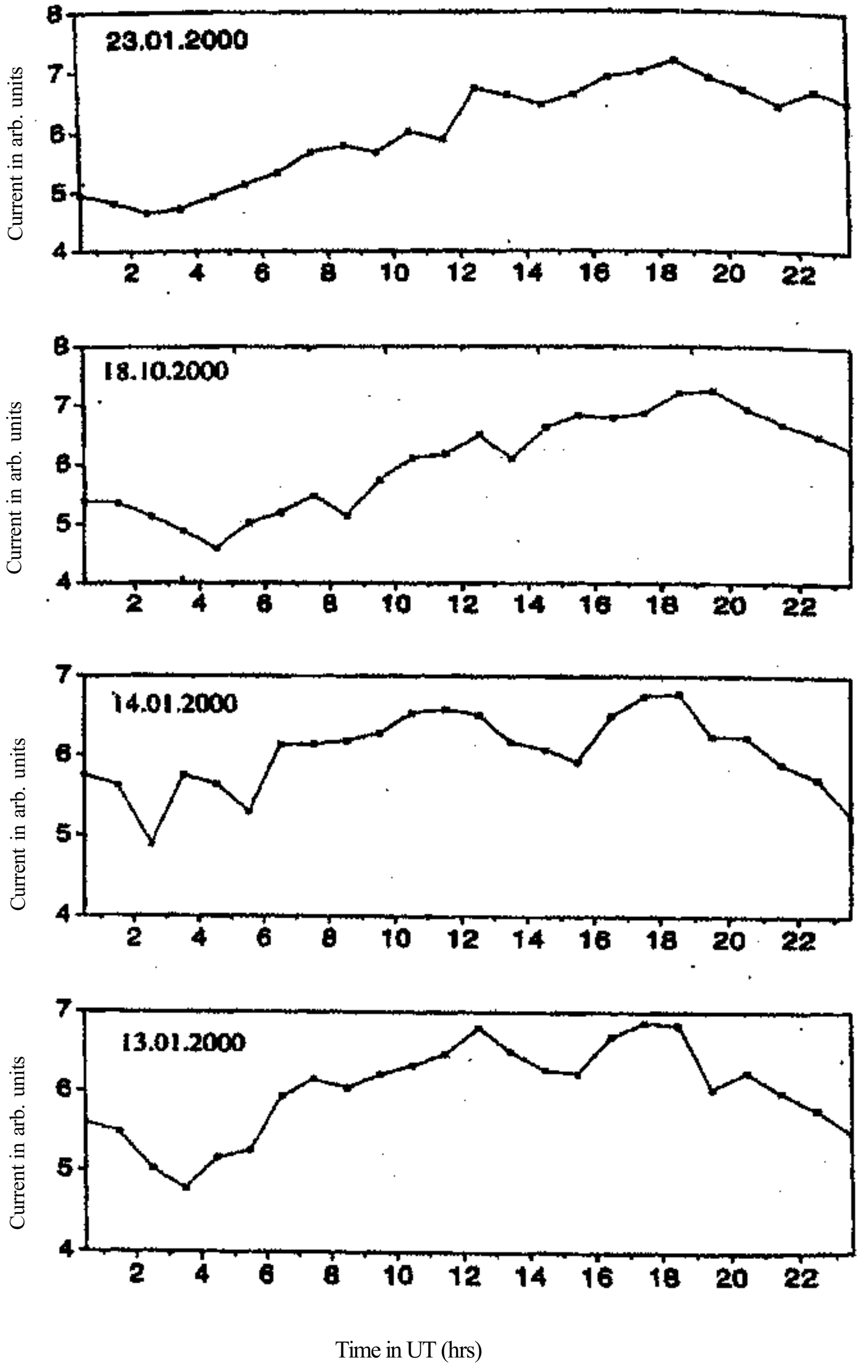

Fig. 1: Maxwell current for the selected fair weather days during January 2000

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