First Results from the measurements of atmospheric Maxwell currents at an Indian Station, Maitri, Antarctica

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Abstract

An instrument to measure the atmospheric air-Earth current, the fundamental parameter of the global electric circuit was commissioned at an Indian station, Maitri, Antarctica 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 the diurnal variation closely follows the trend of the Carnegie curve.

1. Introduction

The study of global electric circuit (GEC) provides a platform for 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. It can provide information on the solar-terrestrial weather relationship (Lakhina, 1993). 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 GEC links the electric field and currents flowing in the lower atmosphere, the ionosphere and the magnetosphere, and the measurements of atmospheric electrical parameters will be handy for any integrated approach involving all these regions. Long-term measurements would be considered useful for addressing some of the problems associated with global change.

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 winds 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

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is several orders of magnitude higher than that of the air. In the present work, air-Earth current measurements made at Maitri Antarctica, is made use of to examine the possibility of detecting global signatures.

2. Experimental technique

The vertical 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 2 m above the ground by means of masts that are electrically separated by Teflon rods. It is connected to an electrometer amplifier that has high input impedance and permits extremely low input bias current (10-14 A). The output signal is run through a coaxial cable to a personal computer where the current density is monitored and recorded at a sampling interval of one second. The RC time constant chosen is 200 sec., which is of the same order as the atmospheric relaxation time. The output signal in the form of voltage is further amplified and passed through a low pass filter, with a cut-off frequency of 4Hz, employed in the detection circuit. This permits variations in the air-Earth current time scale down to 250 ms. The hourly averaging of the data samples carried out in the later stages may further eliminate any short-period variations in the measured current.

3. Results and Discussion

Measurements of atmospheric current at an Indian station, Maitri, Antarctica 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 daily pattern of atmospheric air-Earth current during fair-weather conditions is depicted in Fig. 1. The measured current is presented in arbitrary units. The diurnal variation of the atmospheric air-Earth current may be noticed with a maximum around 1800 UT and a minimum around 0300 UT. 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 of the number of thunderstorms across the globe (Roble, 1985).

In the present study the data sets were selected for analysis during the fairweather conditions prevailed during the entire day was considered, and the hourly averages of the air-Earth current are computed to yield the diurnal variation. The observed features are close 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 1800 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-Saharan African region is active around 1600 UT and the Americas, 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.

4. Conclusion

From the limited data set available and examined so far, the atmospheric electric current density sensors used at an Indian station, Maitri, Antarctica 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 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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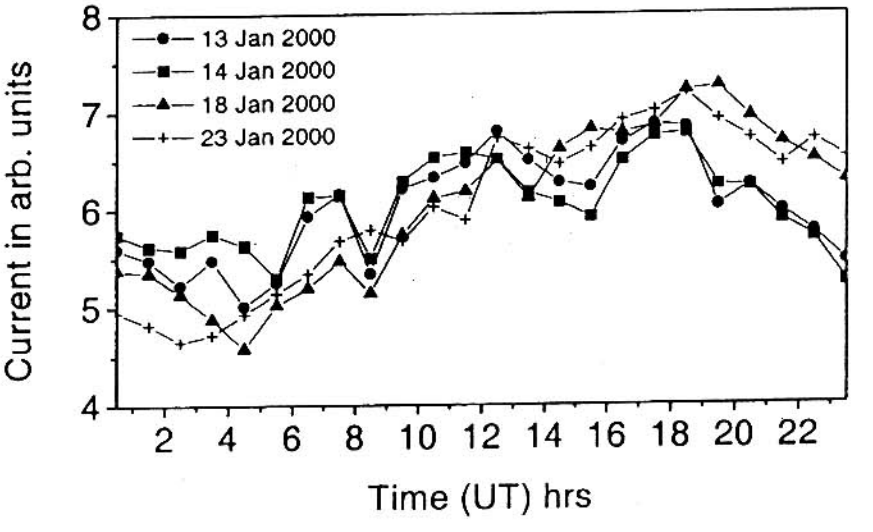

Fig. 1. Current variation on selected fairweather days during January 2000