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The global variation of Air-Earth Current at Tirunelveli

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Air-Earth currents are expected to provide the most stable representation of the Global Electric Circuit system. Current density measurements carried out from the low Latitude Continental Station, Tirunelveli (8.7° N, 77.8° E, 30 m AMSL) have been used for this purpose in the present work. The effects produced by local sources have been identified, and variations on days when the expected global patterns are observed, are reported.

1. Introduction

The atmospheric global electricity is provided by a difference in electric potential (~300 kV) between the highly conducting ionosphere and the earth's surface, with a total current flow between the two of about 10^6 A (Roble *et al.*, 1991). The air-earth current is one of the components that links electric fields and currents flowing in the lower troposphere, the ionosphere and the magnetosphere and is part of a giant electric circuit called the Global Electric Circuit (GEC). An integrated approach in terms of global electric circuit has been emphasised for investigating the electrical environment of the earth's atmosphere. This approach can provide a good framework for exploring inter-connections and coupling of various regions of the atmosphere and also for explaining the solar-terrestrial relationship (Lakhina, 1993). The results from such studies are expected to generate relationships between climate and solar sunspot cycle, and also between solar wind and short-term weather changes. The existence of such correlations was recently reported by Tinsley and Heelis (1993), Bucha and Bucha (1997).

Ground-based measurements of electrical parameters pose difficulties in interpreting them in terms of the global air-earth current since they are essentially the superposition of currents from various sources, namely, conduction current linked to the existence of vertical electric field, convection current density, diffusion current due to the movement of charged particles, lightning current due to rapid lightning over the measuring site and precipitation current associated with showers. The sum of these currents is collectively called the Maxwell current. By suitable observation technique and site selection the air-earth current can be detected and investigated from the Maxwell current.

It is generally realised that the inadequacy of obtaining long period data-sets on air-earth current from any continental station is due to the fact that the current is more feeble in density, and is influenced by local processes within the Planetary Boundary Layer (PBL), apart from expensive experimental set-up and maintenance. The primary influences of the PBL are the drag, heat or evaporation, cooling or condensation (Hoppel *et al.*, 1986). The distribution of charges effected by these processes is detected as local changes in the observed current density.

After examining the influences of various physical processes, such as the local convection associated disturbances, local contributions to columnar resistivity changes and formation of mist and fog near the experimental site, on the Maxwell current, a few days have been identified that closely resemble the global variation of air-earth current that is expected to show a maximum at about 1900 UT and minimum at about 0300 UT. On some of these days there are differences in the occurrence times of the maximum and minimum. An attempt is being made to explain the causes for such differences using the complementary experimental set-up, namely, the microbarograph.

2. Experimental technique

Different types of sensors have been used in the past for the measurement of the air-earth current, like Wilson plate, spherical sensors, and the horizontal long-wire antenna. The horizontal long-wire antenna was used in the present work. The advantage of this sensor is that it suppresses local disturbances by averaging the vertical current over a large area (Ruhnke, 1969). In the present experiment, four long wires of length 37 m (effective area 144 m² calculated from the formula, F – hCe^{-1}), and 3 mm in thickness, one end of which are connected together, are used to shorten the antenna signal to the ground to pick up a certain amount of current from the air. A low noise differential amplifier (model AD 310) that has high impedance and permits extremely low input bias current (10^{-14} A) is used in the electric circuit. The output signal is run through a 100 m coaxial cable to the laboratory, where the current density is monitored and registered at the rate of 1 s. The antenna, placed in the atmosphere, not only picks up the atmospheric current, but also other signals of higher frequency. The high frequency current is filtered out by the low pass filter (4 Hz) provided in the circuit. The other current sources that would be picked up by sensor are due to (i) space charges, (ii) point charges, (iii) displacement current, (iv) precipitation current, (v) lightning current, (vi) radioactivity from rock which produces ionisation, etc. The currents imposed by these agents are superposed on the global conduction current that is of interest. In the present work, the effect of radioactive materials is not considered, as, so far, there have been no measurements of radioactive substances made at this station. The charge production due to point discharge is neglected as the sensor complex is periodically cleaned for any growth of grass or vegetation. While looking for the global signature, lightning current and precipitation current are eliminated by selecting fair weather days through careful visual observations. Hourly averaging of the raw data has been done for further analysis.

The current density is expressed in arbitrary units throughout this paper. Calibration of Maxwell current system is a major task involving shielding of the entire antenna system and will be undertaken in the near future.

The laboratory is in a remote place (8.7^0 N, 77.8^0 E, 30 m AMSL) situated about 15 km from the twin towns of Tirunelveli. It is a flat area free from dense vegetation. The Western Ghats are about 40 km to in west.

3. Results

Hourly mean values are most commonly used for the investigation of the global electric circuit, since the electric charge generated by a thunderstorm somewhere on the globe is distributed along the equalising layer around the globe within 10 to 15 minutes. Mean values of at least 30 minute duration would be sufficient for identifying signatures associated with the global thunderstorm activity (Reiter, 1992). Fig. 1 depicts the hourly average of Maxwell current density in arbitrary units for a few selected fair-weather days in the month of October. There is a clear maximum at 1930 UT and a minimum near about 0300 UT. A secondary maximum occurs at about 0730 UT. Fig. 2 depicts the hourly average for a few selected fair-weather days for the month of July. The time is represented in IST to show the minimum trend, which is split when the time is represented in UT. The maximum is observed at about 1630 UT and

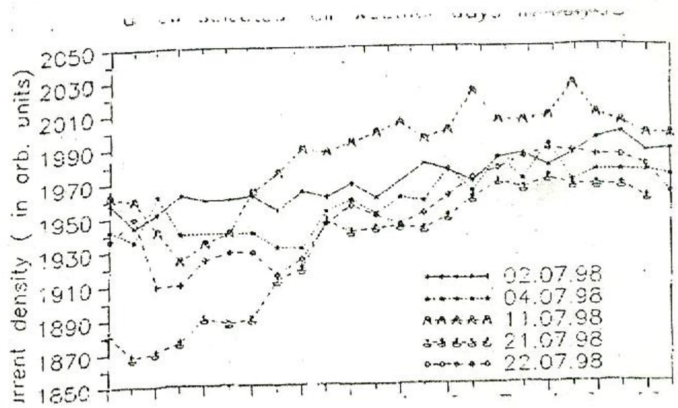

Fig. 2. Air-Earth current variation for a few selected fair weather days in July '98.

the minimum at about 0130 UT. The occurrences of the minimum and maximum in the air-earth current density are about two hours earlier in the month of July than in the month of October.

Fig. 3 depicts the hourly average of the Maxwell current density for a few selected fair-weather days for the month of August. A sharp minimum has been found at around 0300 UT in contrast to the minimum for July and October, which is a shallow one, but the maximum occurs at different times in the UT evening.

On many occasions the Maxwell current density reveals a steady upward or downward drift within a few

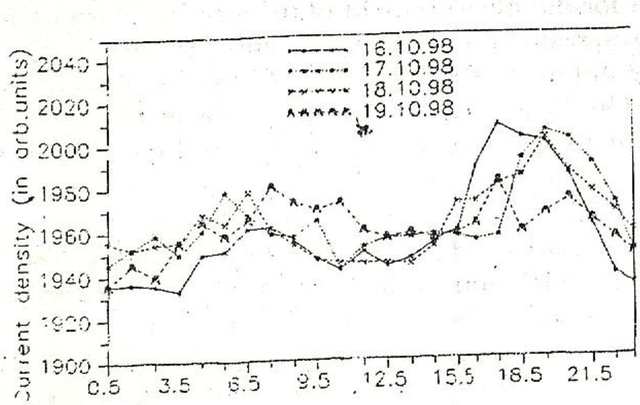

Fig. 1. Air-Earth current variation for a few selected fair weather days in October '98.

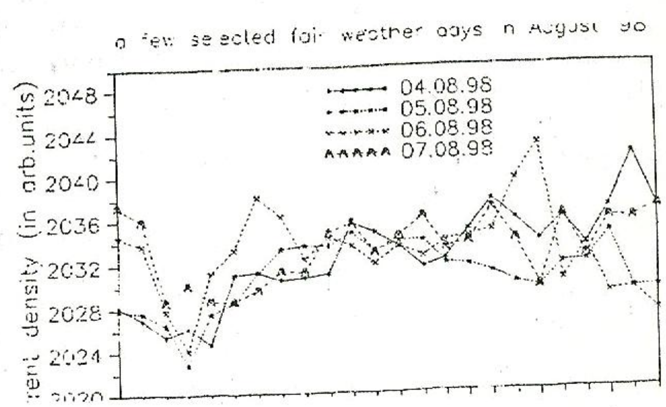

Fig. 3. Air-Earth current variation for a few selected fair weather days in August '98.

days. Such a drift could possibly be either due to the systematic errors in the basic measurement technique or the variability of the weather parameters. Understanding of this drift and application of proper correction is very essential for any meaningful interpretation of the air-earth current measurements. Fig. 4 shows the hourly average of Maxwell current density for three consecutive days, namely, 2nd, 3rd and 4th December 1996. A non-cyclic correction has been applied to the observed data set and the variation for 3rd December 1996 is depicted in Fig. 5 along with its original value. Time is represented in IST to show the day to day upward drift.

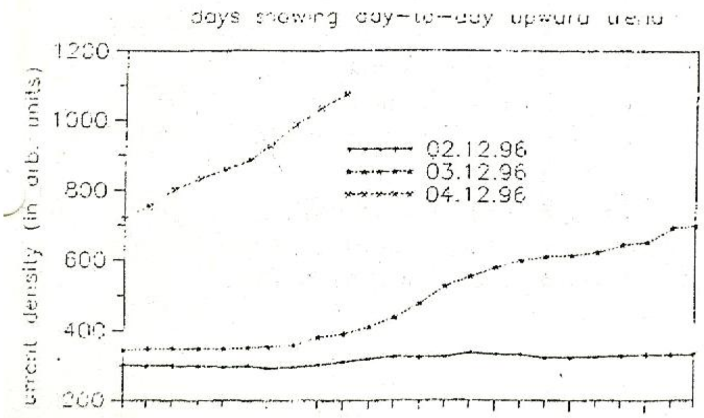

Fig. 4. Maxwell current density variation for three consecutive days 2nd, 3rd and 4th December 1996, days with day-to-day upward drift.

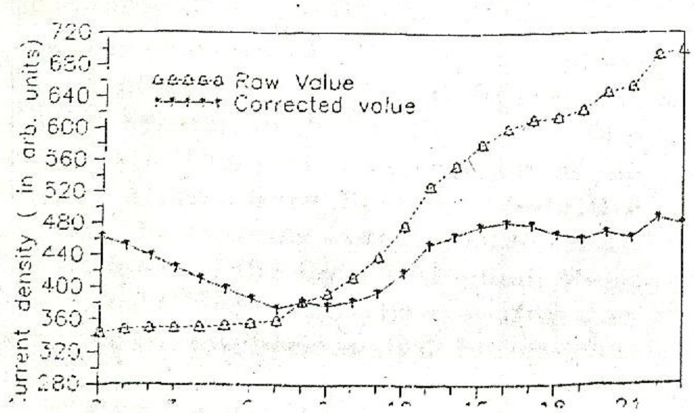

Fig. 5. Maxwell current density variation after removing non-cyclic correction for the days 2nd, 3rd and 4th December 1996.

4. Discussion

The global UT variation is clearly evident in the Maxwell current density measured from the low latitude continental station. The occurrence of minimum is not pronounced on certain days, viz. examples shown in Figs. 1 and 2, whereas it is remarkable on certain other days, viz. example shown in Fig. 3. The occurrence of the minimum for the global variation of air-earth current is expected to be around 0300 UT. This corresponds to 0830 hours IST, about 2 hours after sunrise. Immediately after sunrise, the land gets heated and convection activity sets in. This convection current is one of the principal sources of the Maxwell currents causing a morning rise named sunrise effect (Kasemir, 1956; Israel, 1958; Burke and Few; 1978). The data from the microbarograph, continuously run from near the experimental site, have been used to study the convection activity. The short period fluctuations observed in the microbarograph records are often associated with changes in the wind speed, atmospheric density and atmospheric pressure. The changes in these parameters arise from either convective plume activity or ground-based inversion in the transition hours (Krishna Reddy *et al.*, 1998). A parallel analysis of the microbarograph data reveals that during periods when the convective activity started late in the morning, no clear minimum in the Maxwell current density at about 0830 IST has been observed. The mixing associated with convection might have dispersed the space charges whatsoever present near the surface to be picked up by the antenna sensor. The absence of minimum in the current density is hypothesised to have been caused by this sunrise effect. On the other hand, whenever there was a minimum in the Maxwell current density at about 0830 IST, the convective activity, as revealed by the microbarograph records, had set in well in advance. The secondary maximum around noon is inferred to be associated with the convective activity as revealed by microbarograph records. It could also be due to the contribution of any other thunderstorm zones active around this time.

On some of the days it has been noticed that the measured current density does not undergo the cyclic variation if the global DC component is believed to be the principal source. In Fig. 4 the maximum value on 2nd December is the minimum for 3rd December and the maximum of 3rd December is the minimum for 4th December. This clearly indicates that there is a non-cyclic contribution to the measured current density. Since these contributions are pronounced during the transition period of seasons, it is expected that the changes in atmospheric variability like the contents of aerosol particles, change in the columnar resistivity, etc., might have had a role to play. The columnar resistance is influenced by the vertical mixing of the atmosphere. The slow change in the rate of mixing during the transition periods causes the change in the height of the boundary layer, which in turn is expected to produce a slow change in the background current density levels through its influence on the columnar resistivity. The non-cyclic variation due to these local processes, once eliminated, leads to the detection of global trend as depicted in Fig. 5.

5. Conclusion

The present work demonstrates the potential of the Maxwell current experiment in detecting the variations of atmospheric electrical parameters associated with the global DC circuit. Complementary experiments like an automatic weather station supported by cloud observations and the microbarograph are very essential to study the day to day drift and to adopt proper correction while removing the contributions from the convection currents which could be one of the primary sources even on fair-weather days as often observed during the course of the present work.

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