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Diurnal variation of surface currents at a tropical station

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ABSTRACT

The surface measurements of different atmospheric electrical and meteorological parameters made at a tropical station were analyzed, to study their diurnal variation pattern with specific emphasis on convection current and the meteorological conditions responsible for its generation. The analysis shows that most of the time the displacement current is very small. The convection current is positive for most of the time of the day indicating transport of negative charge to the earth by convection. In spite of very low winds during night, the convection current is found to be more during night than during day. Large space charge density gradient near the earth's surface during stable and stratified atmosphere at night may be a reason for large convection current during that time. This study demonstrates that eddy diffusion during day time and large space charge gradient during night time are responsible for generation of convection current at this location.

1. Introduction

It has been widely accepted that the thunderstorms are the main current source for the global electric circuit (GEC). However, recent studies have raised objection for this widely accepted theory (Kasemir, 1994; Kundt and Thuma, 1999). According to Kasemir (1994), transport of fair weather space charge by turbulence in the boundary layer is the main current source for GEC. Williams (1996) emphasizes that the magnitude of convection current and its global diurnal variation should be studied to find its contribution to GEC. Kundt and Thuma (1999) propose that the negative charge transferred to the earth by settling of heavy aerosol is the main current source for GEC. However, their hypothesis has not been supported by observations. Contribution of convection current to the air–earth current has been studied very rarely over land as well as over ocean. Law (1963) has found that even during quiet nights, contribution of convection current to the air–earth current can be substantial.

The measurements should be considerably free from any local effects to study the global atmospheric electric circuit (Israelsson, 2007). This distinction in global, regional and local effects can also be achieved by making measurements of atmospheric electric field (E), atmospheric electrical conductivity (λ) and total air–earth current density (J). If Ohm's law is fulfilled as $J=E\lambda$, one can use these measurements as global representatives. However, if the measured J and calculated $E\lambda$ are different, then the degree of deviation determines the suitability of the site for making measurements of global importance. Earlier observations (Law, 1963; Raina, 1984) suggest that convection current generated by eddy diffusion is responsible for such deviation from Ohm's law in the atmosphere. Bhartendu (1977) discusses deviation of the parameter Ω which is a measure of degree of deviation from Ohm's law at two different land stations. Dolezalek (1978) also emphasized that the best method to provide information on the reliability of the air–earth current determination is to measure E and J simultaneously and determine the degree of fulfillment of Ohm's law. Therefore, it is important to study the atmospheric conditions responsible for generation of convection current.

Simultaneous measurement of all fair weather electrical parameters as reported in this study is rare and is the first of this kind over Pune (18° 32′N, 73° 51′E, 559 m AMSL). Here, we analyze the data of atmospheric electric field (E), atmospheric electrical conductivity (λ), air–earth current density (J) and space charge density (ρ) measured during fair weather days and discuss the results on the basis of convection current.

2. Instrumentation

The Atmospheric Electricity Observatory is located at the campus of Indian Institute of Tropical Meteorology (IITM), Pune, on the outskirts of the city and is relatively free from air pollution produced by vehicular traffic and human activities in the city. There is no direct source of air pollution in the immediate vicinity of this location. The observatory is a specially prepared plain land of bare soil of about 100×100 m area and free from any raised objects, which is the essential requirement for the measurement of atmospheric electrical parameters.

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Atmospheric electric field (E) is measured by a vertical field mill as described by Pawar and Kamra (2004) and Kamra and Pawar (2007). It consists of two stators and rotor plates of symmetric shape and size. The stator plates are periodically shielded and exposed to the atmospheric electric field by the rotor plate, which is fixed with the shaft of an ac motor (1400 rpm, 12 W) and connected to ground by dipping the shaft into a small metal cup containing mercury. The sensor and rotor plates are 10 cm in diameter and made up of non-magnetic stainless steel. The stator and rotor plate are separated by Teflon bushes. The signals from the stator plates are amplified by using IC-8007 and demodulated by IC-1496. The field mill is kept in a pit of 30 cm depth so as to keep the sensor plates flushed to ground level. The time constant of the field mill is adjusted to 1 s for the fair weather measurements. The field mill is calibrated by directly placing it in a uniform electric field produced by applying known voltages across two parallel plates, of which one is flushed to the ground and another is at 10 cm height. The field mill can measure the electric field in the range ± 5 kV/m and the response of the field mill in this range is found to be linear during the calibration. The sensitivity of the field mill is ± 2 V/m and the noise level is well below ± 2 V/m. The electrical zero of the field mill is checked every day by applying ground potential to a plate at 10 cm above the sensors and it is found to be constant during the observational period.

Air–earth current density (J) is measured with a plate antenna of 1 m^2 size, mounted flush to the ground on four porcelain insulators. The porcelain insulators are chosen because of their high electrical resistivity and low affinity to moisture. The porcelain insulators are regularly cleaned to avoid leakage currents. The signal is fed to an electrometer amplifier (AD-311K) with the time constant of 40 min. This time constant is chosen to avoid the displacement current caused by variation in the electric field (Chalmers, 1967; Bennett and Harrison, 2008). The electrical zero of this instrument is checked by shielding it by an isolated grounded metal plate kept 10 cm above the sensor.

Both polarities of conductivity (λ_+ and λ_-) are measured with a Gerdien apparatus placed at 1 m height. The design and working of the instrument are described by Dhanorkar and Kamra (1992). It consists of two identical cylindrical condensers connected with an U-tube. The air is drawn through the condensers with a common fan fixed in the U-tube. The sensor rods inside the cylinders are insulated from the outer cylinder by Teflon bushes. The critical mobility of the apparatus is adjusted at 3.6×10^{-4} $m^2\,V^{-1}\,s^{-1}$. The signals from both the condensers are amplified with AD-311K.

The space charge density (ρ) is measured with Obolensky filter apparatus placed at 1 m height similar to that of Moore et al. (1961). It consists of a metal tube with a steel wool pre-filter and a glass wool absolute filter. The air is drawn through this tube at the rate of 120 lpm using a blower. The filter tube is connected to an electrometer amplifier (AD-311K). The details of this instrument are given in Pawar and Kamra (2000).

Electrical zero of all the instruments are checked periodically and there is no appreciable shift observed during the period of observations. All these signals are fed to a computer based data acquisition system. The signals are sampled at 1 Hz rate, averaged for 1 min and stored in the computer. This data is again averaged for 30 min and used for the analysis in this study. The meteorological parameters are measured using a weather monitor system which records dry-bulb temperature, wet-bulb temperature, wind speed and wind direction at the level of 1.2 m at every half an hour interval.

3. Criteria for fair weather day and sign convention

A day with low-level clouds of less than 3 octas, winds less than 10 m s^{-1} and no precipitation is taken as a fair weather day (Kamra et al., 2001). Measurements of all these parameters were made for three months, i.e. December 2000 to February 2001. From these measurements 40 days data have been analyzed for this study. The other days are excluded either on the basis of fair

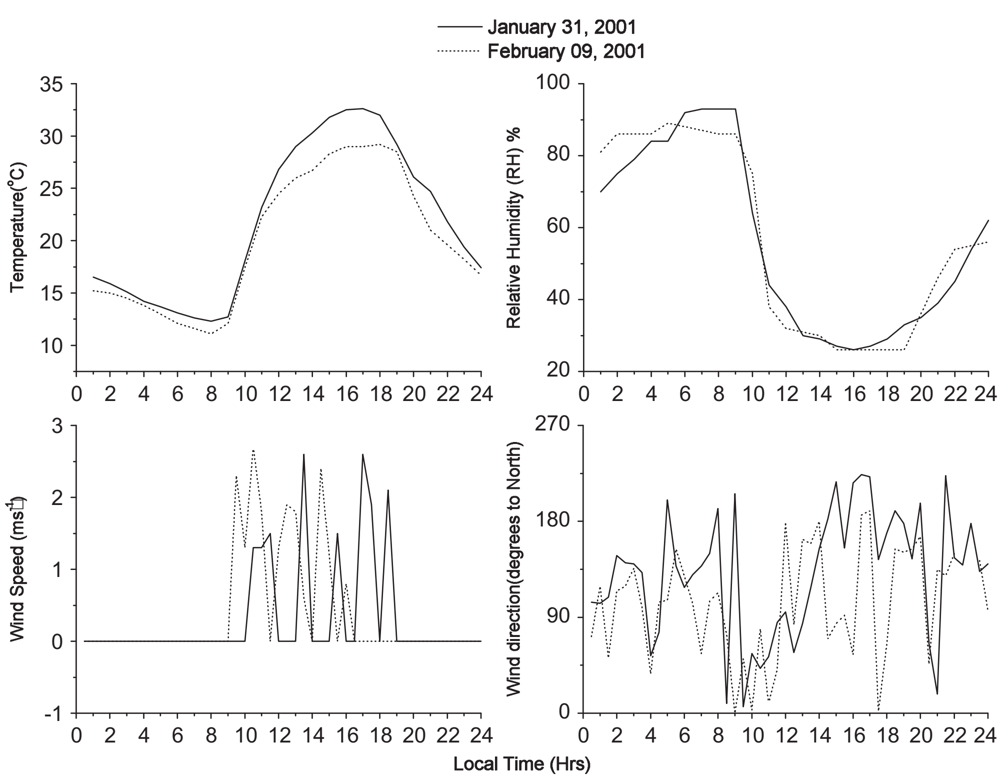

Fig. 1. Typical diurnal variation of meteorological parameters.