EQUATORIAL ELECTROJET PARAMETERS AND THE RELEVANCE OF ELECTROMAGNETIC DRIFTS (EMD) OVER THUMBA

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Abstract. The thermal imbalance in the E-region heights is inescapable and an undisputed fact. The equatorial electrojet parameters are being evaluated for an Indian Equatorial station of Thumba, making use of the observed electron density, electron temperature, and current density profiles for two rocket flights on 3 March, 1973 and 7 April, 1972 around local noon, corresponding to low and medium solar active conditions. The computed Joule heating due to Equatorial Electrojet Current (EEC) does not account for the observed difference between the electron and neutral gas temperatures. The discrepancy of about 6 km in the peaks of the observed and computed current density profiles may be attributed to the presence of the Electromagnetic Drifts (EMD). In order to see whether or not EMD plays an important role, the photoionization balance between production and loss rates have been computed by making use of the latest available solar flux and cross sections and chemical reaction rate constants for the appropriate solar epoch conditions including the transport term due to EMD. There is an excellent agreement between the observed and computed electron density profiles indicating its relevance.

1. Introduction

The Earth’s ionosphere owes its origin due to the balance of two processes, production of ionization of atmospheric particles by solar XUV radiation and loss of ionization due to photochemical and transport processes (Balachandra Swamy, 1991a, b). The equatorial latitude is distinctly different from other latitudes, because of the unique geometry of the magnetic field and anisotropic nature of conductivities. The equatorial electrojet is an intense and localized electrical current flowing in the ionospheric E-region at the dip equator. Under normal conditions, the direction of this current is eastward during the day and westward at night. The equatorial Electrojet current (EEC) has been described in terms of Pederson, Hall, and Cowling conductivities, known as equatorial electrojet parameters. These parameters are being evaluated for an Indian Equatorial station at Thumba, making use of the observed electron density, electron temperature, and current density profiles (Prakash et al., 1972; Sampath et al., 1974) for two rocket flights on 3 March, 1973 and 7 April, 1972 around local noon, corresponding to low and medium solar active conditions. Joule heating due to EEC is also being estimated. The importance of the variation of the electric field intensity below 100 km plays an important role in matching the observed and computed current density profiles. The importance of the collision frequency profiles in the E-region heights is also being highlighted. The total electron collision frequency consists of the sum of electron neutral and electron-ion collision frequencies. Both of them depend on the electron temperature ($T_e$). The total ion collision frequency consists of the sum of the ion neutral
and ion electron collision frequencies. The latter depends on the electron temperature and the former on the neutral gas concentrations.

In order to see whether or not EMD plays an important role, the photoionization balance between production and loss rates have been computed by making use of the latest available solar flux and cross sections and chemical rate constants for the appropriate solar epoch conditions for the above-mentioned flights, including the transport term due to EMD (Balachandra Swamy, 1991a). The vertical ion drift velocity is also estimated.

2. Equatorial Electrojet Parameters and Joule Heating

Equatorial Electrojet has been studied extensively in the past both from the theoretical and experimental points of view (Untiedt, 1967; Richmond, 1973; Maeda, 1981; Reddy and Devasia, 1981; Raghava Rao and Ananda Rao, 1987). The most outstanding feature of the models is that there is a discrepancy between the observed and theoretically computed current density profiles (of about 6 km). Several explanations have been given by several workers in the past (Maeda, 1981; Reddy and Devasia, 1981, Raghava Rao et al., 1987). The equatorial electrojet (Chapman, 1951) is an intense and localized electrical current flowing in the ionospheric E-region at the dip equator. The equatorial electrojet current (EEC) is described in terms of Pederson, Hall, and Cowling conductivities known as equatorial electrojet parameters. If the electric field is applied in the X-direction, there are in general components of velocity in the X- and Y-directions. The conductivity in the direction of the applied electric field is the Pederson conductivity: i.e.,

\[
\sigma_1 = \left[ \frac{N_e}{m_e v_e} \left( \frac{v_e^2}{v_e^2 + \omega_e^2} \right) + \frac{N_i}{m_i v_i} \left( \frac{v_i^2}{v_i^2 + \omega_i^2} \right) \right] |e|^2,
\]

(1)

and that perpendicular to the applied field is the Hall conductivity

\[
\sigma_2 = \left[ \frac{N_e}{m_e v_e} \left( \frac{\omega_e v_e}{v_e^2 + \omega_e^2} \right) - \frac{N_i}{m_i v_i} \left( \frac{\omega_i v_i}{v_i^2 + \omega_i^2} \right) \right] |e|^2,
\]

(2)

The conductivities and the applied electric field are all in a plane perpendicular to the magnetic field. The conductivity along the magnetic field due to a parallel electric field is the direct or longitudinal conductivity: i.e.,

\[
\sigma_0 = \left[ \frac{N_e}{m_e v_e} + \frac{N_i}{m_i v_i} \right] |e|^2,
\]

(3)

where \( \omega_e = |e| B/m_e \) and \( \omega_i = |e| B/m_i \); while all other symbols have their usual meaning. If the electric field is written as a vector

\[
E = \hat{i} E_x + \hat{j} E_y + \hat{k} E_z,
\]