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The Electron Diffusion Coefficient Tensor by Using the Real Geometry of the Earth's Magnetic Field in Ionospheric Plasma

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Abstract

In this study, the electron diffusion coefficients are calculated as depending on latitude, local time and seasonal in the ionospheric plasma by using the real geometry of Earth's magnetic field for north hemisphere. It is observed that if the earth's magnetic field is taken into account, the medium is anisotropic in ionospheric plasma. Due to this, the electron diffusion coefficients have tensorial form in the ionospheric plasma. As general, there is a harmony between change of the electron diffusion coefficient and the change of the electron density with local time in the ionospheric plasma

Keywords: Ionosphere, Diffusion, Ionospheric plasma

İyonosferik Plazmada Dünyanın Gerçek Geometrisi Kullanılarak Elektron Difüzyon Katsayısı Tensörünün Elde Edilmesi

Özet

Bu çalışmada, dünyanın gerçek manyetik alan geometrisi kullanılarak kuzey yarım küre için iyonosferik plazmada elektron difüzyon katsayıları yüksekliğe, yerel zamana ve mevsime bağlı olarak hesaplandı. Eğer dünyanın manyetik alanı hesaba katılırsa iyonosferik plazmada ortam anizotropik olur. Bundan dolayı iyonosferik plazmada elektron difüzyon katsayısı tensörel bir forma sahiptir. Genel olarak, elektron difüzyon katsayısının yerel zamanla değişimi ve elektron yoğunluğun yerel zamanla değişimi arasında bir uyum vardır

Anahtar Kelimeler:İyonosfer, Difüzyon, İyonosferik plazma

1. Introduction

Ionospheric Physics has a standing of over forty years as an experimental subject. Its origins, however, can be traced back for over a century on the existence of an electrically conducting layer in upper atmosphere. The scientific study of the ionosphere really began with the experimental determination of the height of the reflecting layers in 1925 by and Tuve and Appleton and Barnett. Later the stratified nature of the Ionosphere became apparent and naturally this raised the question of the physical origin the various layers that has taken decades to resolve. As is well known the symbols D, E, F are used to denote different regions the ionosphere with further notation (such as F1,F2) for distinct ionized strata within one region[1-4].

Ions and electrons diffuse under the influence of partial pressure gradients and gravity. This motion hindered by collisions with the neutral air. To within a good approximation the diffusion is ambipolar, in that ions and electrons are constrained by their electric charges to move with the same velocity. Were this not so, the separation of charge would create a polarization field to prevent further separation[5,6].

In this study, the electron diffusion coefficients are calculated as depending on latitude, local time and seasonal in the ionospheric plasma by using the real geometry of Earth's magnetic field for north hemisphere. It is observed that If the earth's magnetic field is taken into account, the medium is anisotropic in ionospheric plasma. Due to this, the electron diffusion coefficients have tensorial form in the ionospheric plasma.

2. Materials and Methods

If it does not has an impact outside, transport of particles in the ionosphere plasma from one place to place results from the pressure-gradient (∇P). This force occurs in any part of the plasma density to eliminate inhomogeneity. If **B**≠0, the medium is called the anisotropic. Due to this, the ionospheric plasma is anisotropic. The real geometry of Earth's magnetic field for the north-hemisphere is given as Figure 1. Where, $B_x = B\mathrm{Cos}I\mathrm{Sin}d$, $B_y = B\mathrm{Cos}I\mathrm{Cos}d$ and $B_z = -B\mathrm{Sin}I$. In which, I is the magnetic dip angle and d is the magnetic declination angle[1-3].

The flux density is described for both electron and ion as given in Equation (1):

$$\mathbf{\Gamma} + \frac{n_\alpha}{\nu_\alpha}\frac{D\mathbf{U}}{Dt} = \mu_\alpha(\mathbf{\Gamma}\times\mathbf{B} + n_\alpha\mathbf{E}) - D_\alpha\nabla n_\alpha \qquad (1)$$

Where, α=e,i , $\mu_\alpha = \frac{q_\alpha}{m_\alpha \nu_\alpha}$ is the electron and ion mobility, $D_\alpha = \frac{k_b T_\alpha}{m_\alpha \nu_\alpha}$ is the diffusion coefficient, B is the magnetic field and **Γ** the flux of density is as follows:

$$\mathbf{\Gamma} = n_\alpha \mathbf{U} \qquad (2)$$

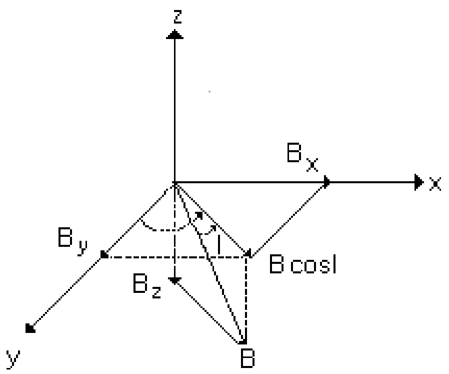

Figure1. The geometry of the Earth's magnetic Field (for the North-hemisphere)[1]

If **E**=0, the diffusion tensor for the steady-state is obtained from Equation (1)

$$D = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix} \qquad (3)$$

From here; the tensor elements of diffusion coefficients for both electron and ions are given as follows.

For the electron;

$$D_{xx} = K^{-1}D_e\left[\omega_{cx}^2 + \nu_e^2\right]$$

$$D_{xy} = K^{-1}D_e\left[\omega_{cx}\omega_{cy} - \omega_{cz}\nu_e\right]$$

$$D_{xz} = K^{-1}D_e\left[-\omega_{cx}\omega_{cz} + \omega_{cy}\nu_e\right]$$

$$D_{yx} = K^{-1}D_e\left[\omega_{cx}\omega_{cy} - \omega_{cz}\nu_e\right]$$

$$D_{yy} = K^{-1}D_e\left[\omega_{cy}^2 + \nu_e^2\right]$$

$$D_{yz} = -K^{-1}D_e\left[\omega_{cy}\omega_{cz} + \omega_{cx}\nu_e\right]$$

$$D_{zx} = -K^{-1}D_e\left[\omega_{cx}\omega_{cz} + \omega_{cy}\nu_e\right]$$

$$D_{zy} = K^{-1}D_e\left[-\omega_{cy}\omega_{cz} + \omega_{cx}\nu_e\right]$$

$$D_{zz} = K^{-1}D_e\left[\omega_{cz}^2 + \nu_e^2\right]$$

$$K = \left[\omega_{cx}^2 + \omega_{cy}^2 + \omega_{cz}^2 + \nu_e^2\right]$$

and for the ion;

$$D_{xx} = L^{-1}D_i\left[\omega_{cx}^2 + \nu_i^2\right]$$

$$D_{xy} = L^{-1}D_e\left[\omega_{cx}\omega_{cy} - \omega_{cz}\nu_i\right]$$

$$D_{xz} = L^{-1}D_e\left[-\omega_{cx}\omega_{cz} + \omega_{cy}\nu_i\right]$$

$$D_{yx} = L^{-1}D_e\left[\omega_{cx}\omega_{cy} - \omega_{cz}\nu_i\right]$$

$$D_{yy} = L^{-1}D_e\left[\omega_{cy}^2 + \nu_i^2\right]$$

$$D_{yz} = -L^{-1}D_e\left[\omega_{cy}\omega_{cz} + \omega_{cx}\nu_i\right]$$

$$D_{zx} = -L^{-1}D_e\left[\omega_{cx}\omega_{cz} + \omega_{cy}\nu_i\right]$$

$$D_{zy} = L^{-1} D_e \left[-\omega_{cy}\omega_{cz} + \omega_{cx}\nu_i \right]$$

$$D_{zz} = L^{-1} D_e \left[\omega_{cz}^2 + \nu_i^2 \right]$$

$$L = \left[\omega_{cx}^2 + \omega_{cy}^2 + \omega_{cz}^2 + \nu_i^2 \right]$$

3.Numerical Analysis and Results

In this study, the electron diffusion coefficients in F-region of the ionospheric plasma are calculated at geographic coordinates of (38.7°N, 39.2°E, R=10) for year 1996 for different seasons. The ionospheric parameters used for calculation are obtained from the IRI model. For a given location, time and date, IRI describes the electron density, electron temperature, ion temperature, and ion composition, electron content in the altitude range from about 50 km to 2000 km. It provides monthly averages in the non-auroral ionosphere for magnetically quiet conditions.

Figure 2-5 show variations with local time of the electron diffusion coefficient having the tensorial structure as seasonal. For all seasons, the electron diffusion coefficients are order about 10^8 (m^2/sn) with respect to local time in F-region of the ionosphere. The elements of electron diffusion coefficient tensor increase at sunrise, they have been doing maximum about 8.00 LT, the all of tensor elements increase between 16.00-18.00 LT at sunset but D_{xx}, D_{xz}, D_{zz} are greater than other tensor elements for all of seasons.

Finally, it could be showed that the electrical conductivity of ionospheric plasma increase between 7.00-10.00 LT at sunrise and 16.00-18.00LT at sunset for all of seasons. Besides, it is observed that the electron plasma oscillation frequency is greater than other local time as the electron plasma oscillation frequency depend on the electron density.

4. Discussion

In this study, the variationof the electron diffusion coefficient is investigated with local time as seasonal. It is observed that when the earth's magnetic field is taken into account, the electron diffusion coefficient does not become single-valued and it has tensor form. The higher electron density means the greater the elements of the electron diffusion coefficients in ionospheric plasma, especially at sunrise and sunset.

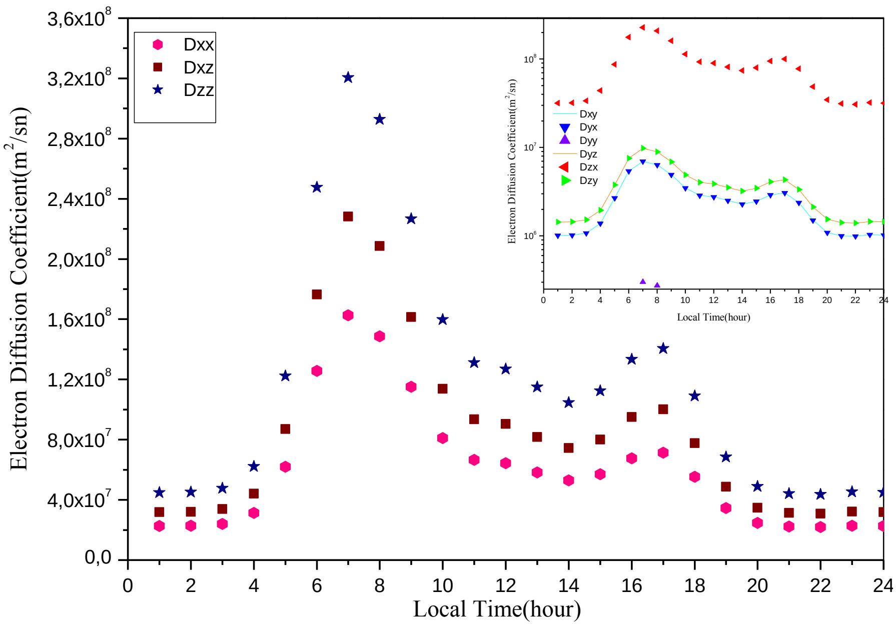

Figure 2. Variation with local time of the electron diffusion coefficient in F-region of the ionosphere (21 March)

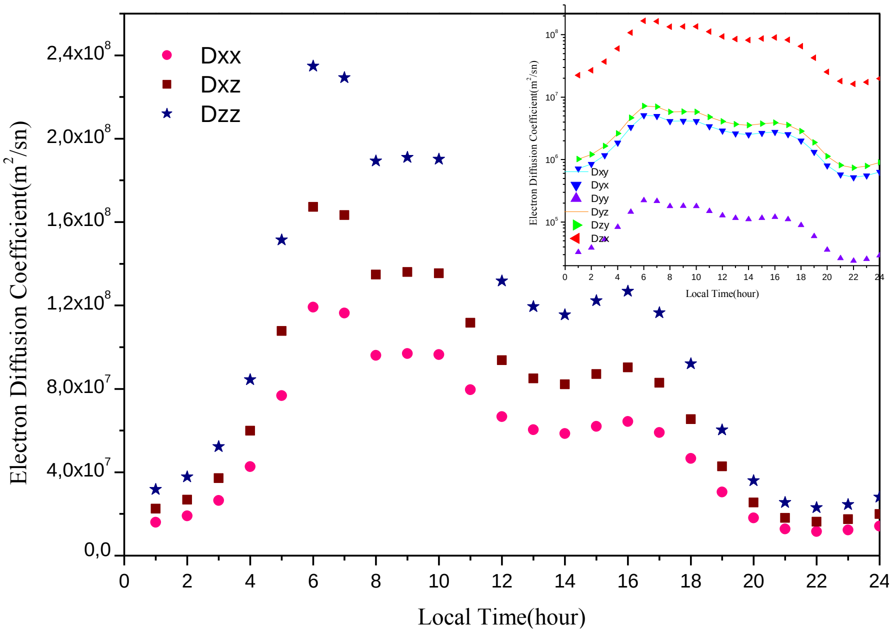

Figure 3. Variation with local time of the electron diffusion coefficient in F-region of the ionosphere (21 June)

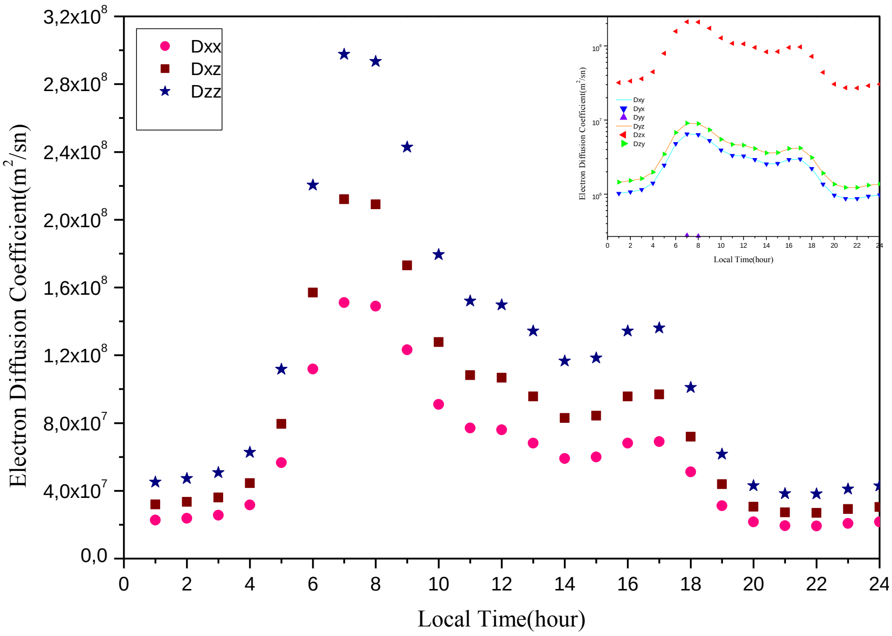

Figure4. Variation with local time of the electron diffusion coefficient in F-region of the ionosphere (23 Sempt.)

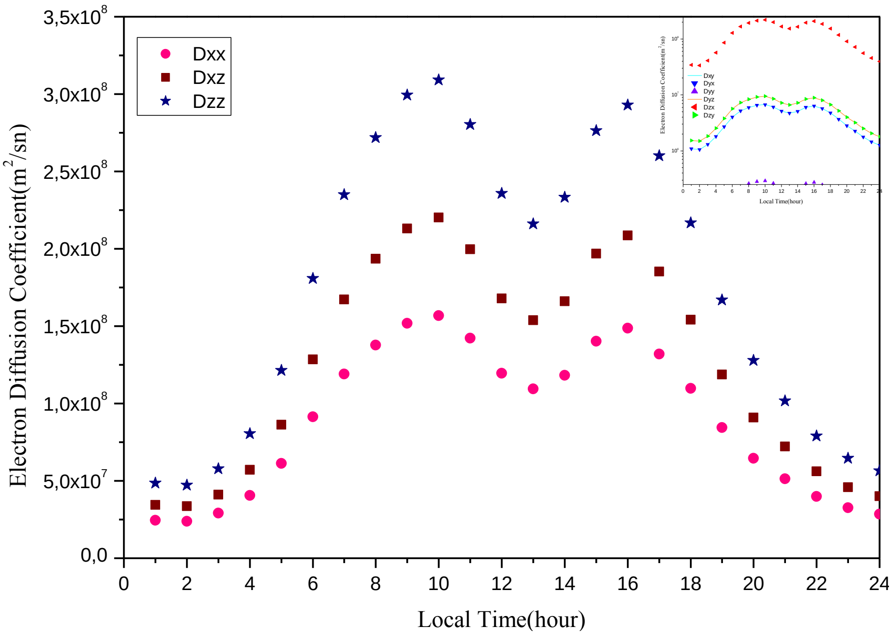

Figure 5. Variation with local time of the electron diffusion coefficient in F-region of the ionosphere (21 Dece.)

5. References

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