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Araştırma Makalesi / Research Article

The Behavior of the Classical Diffusion Tensor for Equatorial Ionospheric Plasma

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Abstract
In this study, the relationship between the classical diffusion tensor's coefficients (D_0, D_1 and $D_2$for steady-state case) and the equatorial anomaly is investigated by taking the geometry of Earth's magnetic field as $B=B_0z$ for both solstices of ionospheric plasma. The effective heights used here is made for the altitudes (280,300,340,390 and 410 km) where the observations are predominantly referenced to the equatorial anomaly. It is seen that the classical diffusion coefficients calculated value at 12.00 LT is greater than 24.00 LT in both solstice seasons. This means that no anomaly is observed in the classical diffusion coefficient for the electron density at night. All values of diffusion coefficients (D_0, $>D_1$ $>D_2$) are higher at 12:00 LT than the values at 24:00 LT for both solstices. This means that the classical diffusion coefficient relates with the night anomaly which is observed with the electron density. Seasonal (winter) anomaly in the equatorial region (-10^0S, -15^0N) corresponds to 390 and 410 km for D_0, 280, 300 and 340 km for D_1 and similar condition to the seasonal anomaly for all altitudes for D_2 (the measured values at December 21 are higher than the measured values at June 21) at 12:00 LT. D_0 and D_2 values show seasonal anomaly for all altitudes while D_1 does not show any values for any altitudes at 24:00 LT.

Keywords: Ionosphere, Diffusion Tensor, Equatorial, F- Region

1. Introduction

The ionosphere is defined as a part of the upper atmosphere of Earth, which spreads from 50 km to approximately 1000km[1,2,3,4,5,6]. The region called as ionosphere is filled with ionized gas, called plasma. The natural plasma "ionosphere" is a function of electron density as vertical but it is horizontally very complicated that called equatorial anomaly in the low latitudes, equatorial region and reaches to middle and high latitudes. Equatorial anomaly ranges on both sides of the magnetic equator between 17^0S-17^0N latitudes. There is many theory to have been explaining equatorial anomaly. The most important of them is Martin's theory dragged upwards by diffusion of plasma. Besides, at this theory the equatorial anomaly spreads on both sides of the magnetic equator between 30^0S-30^0N latitudes [1,9,10,12].

Most of ionospheric plasma events could be investigated by using momentum transport equations which it is considered as plasma a multi-constituent fluid or a single conducting fluid.

For some cases; at the plasma phenomena must be done the approximation of kinetic theory. If the pressure gradient term is take into accounted in Newton's motion equation, It generates a force that tends to eliminate the change in plasma density perturbations. Then ions and electrons move under the influence of partial pressure gradients and gravity. As general, the diffusion of plasma due to the difference both density and temperature results from pressure gradient force. The momentum equation for the electrons are used with electron-neutral collision frequency for the electron diffusion coefficient for a weakly ionized plasma.

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Because the electrons have lower masses than ions ,they moves faster with respect to ions at fixed temperature and the velocity of electrons are much more easily changed : the electrons are more mobile than ions. Consequently, the electrons are responsible for the transport of heat and charge through plasma. Transport equations of ionosphere plasma can be obtained by including the electric conductivity, electromagnetic drift, plasma diffusion and thermal conductivity[1,3,6,10].

The equation for plasma diffusion is obtained by take into accounting the forces acting both ions and electrons. As the force resulting from the gravity term for electrons is very small as magnitude ,it is negligible. The diffusion coefficients, called diffusivity such as electrical mobility are the most important indicator of plasma diffusion movement. The diffusion coefficients could be obtained in many ways. One of them is Fick's law but is also used others equations in physics and chemistry. The diffusion coefficients in ionosphere plasma for each different type " both ions and electrons" can be calculated. In a multi-component gas system, it is arranged for each species in the ionosphere plasma. The diffusion coefficient is proportionally constant between the diffusion flux and gradient in the concentration of the diffusing species "electrons and ions, and it based on both temperature and pressure[11,12,13].

In this study, the relationship between the classical diffusion coefficients (D_0, D_1 and D_2 for steady-state case) and the equatorial anomaly is investigated by taking the geometry of Earth's magnetic field as $\mathbf{B}=B_0\mathbf{z}$ for both solstices in the ionosphere plasma.

2. The Classical Diffusion Tensor

If the medium is adiabatic, the transport of particles in the ionosphere plasma from place to place results from the pressure-gradient (∇P). This force happens in any part of the plasma density to eliminate inhomogeneity. If $B\neq 0$, the medium is named the anisotropic. Hence, the ionospheric plasma can acceptable anisotropic[5,11].

The force affecting the electron with respect to Newton's law is given by:

$$m\frac{d\mathbf{U}}{dt} = -e(\mathbf{U}\times\mathbf{B}) - m\nu\mathbf{U} \tag{1}$$

Where $\nu = \nu_{ei} + \nu_{en}$

and, $\nu_{ei} = N\left[59 + 4.18\log\left(\frac{T_e^3}{N}\right)\right]\times 10^{-6} T_e^{-3/2}[m.k.s]$ and $\nu_{en} = 5.4\times 10^{-16} N_n T_e^{1/2}[m.k.s]$

are the electron-ion and electron-neutral collision frequencies velocity and fields vary as $e^{i(\mathbf{k}\cdot\mathbf{r}-\omega t)}$ where ω is angular wave frequency, and ω_c is electron angular gyro frequency and is expressed follows: $\omega_c = \frac{-eB}{m}$

The z-axis of the cartesian coordinate system shows vertical upwards. When the real geometry of the earth's magnetic field is used for the steady-state ($\partial/\partial t=0$, that is, $\omega=0$), the diffusion tensor of the solution of eq.(2) is obtained as the diffusion coefficient, depending on the real geometry of the earth[13,14].

$$\mathbf{\Gamma} = \mu(\mathbf{\Gamma}\times\mathbf{B}) - D\nabla n \tag{2}$$

where, $\mu = \frac{-e}{m\nu}$ is the electron mobility, $D = \frac{k_b T}{m\nu}$ is the electron diffusion coefficient, and $\mathbf{\Gamma}=(n\mathbf{U})$ is the flux of density. The flux of density in terms of the current density is as follow.

$$D\nabla n = \mu(\boldsymbol{\Gamma} \times B) \qquad (3)$$

the diffusion tensor;

$$D = \begin{bmatrix} D_1 & D_2 & 0 \\ -D_2 & D_1 & 0 \\ 0 & 0 & D_0 \end{bmatrix} \qquad (4)$$

Where (for steady-state case; ω=0), $D_0 = \dfrac{k_b T}{m\nu}$, $D_1 = \dfrac{\nu^2}{\nu^2 + \omega_c^2} D_0$ and $D_2 = \dfrac{\nu\ \omega_c}{\nu^2 + \omega_c^2} D_0$

3. Results and Discussion

The general system of transport equations is applied to the low-latitude for ionospheric F2 region. The restriction to this region of the ionosphere enables us to make several simplifying assumptions that significantly reduce the general system of transport equations. It is fully ionized plasma composed of two major ions, electrons, and a number of minors.

The classical diffusion coefficients (D_0, D_1 and D_2 for both steady case) at the equatorial F2-region of ionosphere plasma is seasonally both solstice (June 21 and December 21) investigated by taking ($\mathbf{B}=B_0\mathbf{z}$) the geometry of Earth's magnetic field for) 12.00 LT and 24.00 LT. Examining was made in the height (280,300,340,390 and 410 km) where the observed predominantly to the equatorial anomaly. The results are obtained I (dip angle)=55.6°, d(Declination)=3°, R=159 for 1990 year by using Eqs. (1)-(4). The ionospheric parameters used for calculations are obtained using the IRI (International Reference Ionosphere) model.

The coefficients of the classical diffusion tensor have complex structure as mathematical. We calculated the magnitude of tensor elements in the accepted conditions and investigated at both solstice days.

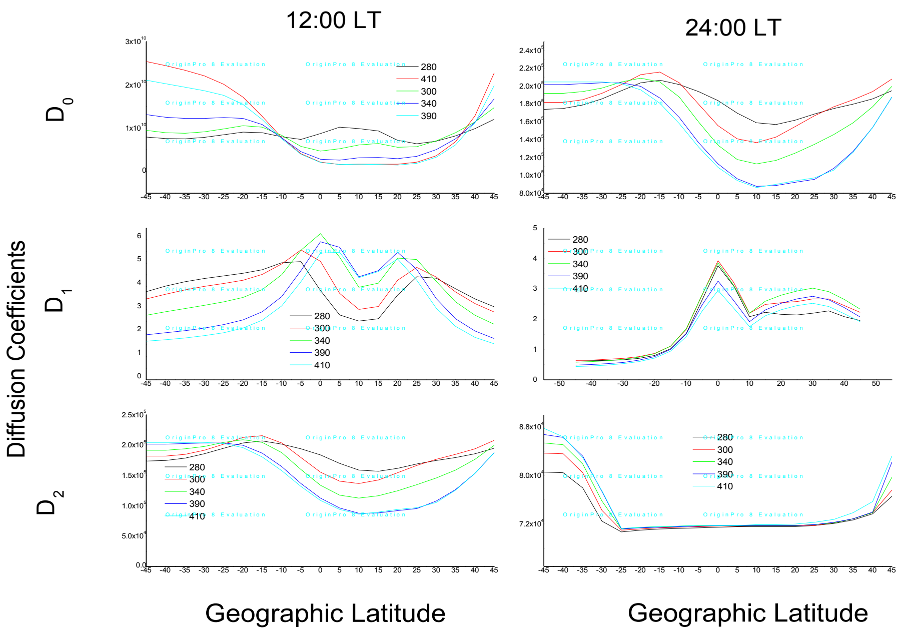

Fig.1. Change with latitude of classical diffusion coefficients for June-21day

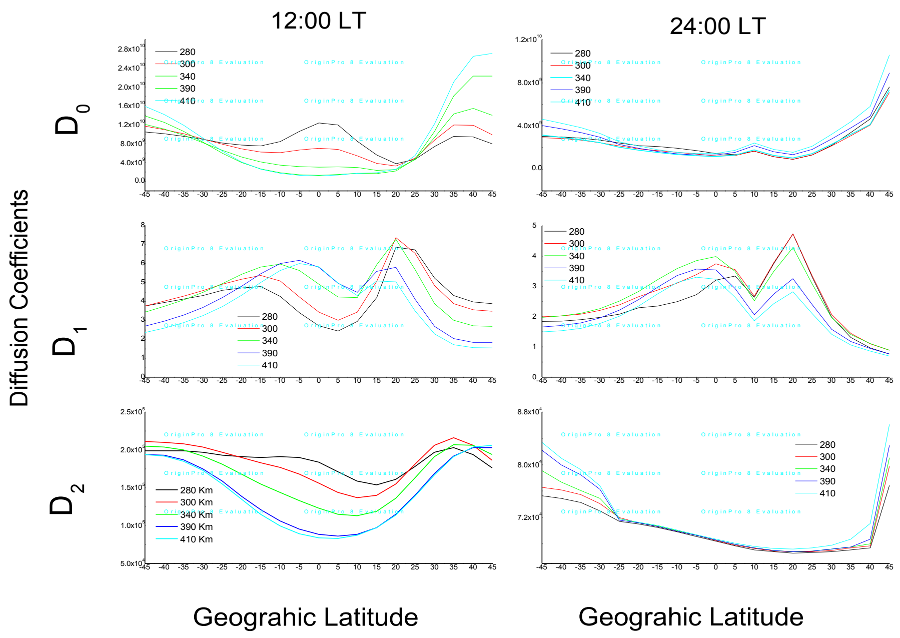

Fig.2. Change with latitude of classical diffusion coefficients for December 21 day

4. Conclusion

This article has reviewed the coefficients of classical diffusion tensor for electrons in the low-latitude ionospheric plasma and investigated whether any relationship between the diffusion and equatorial anomaly exists

The findings indicate that the magnitudes of D_0, D_1 and D_2 is bigger value calculated at 24.00 LT than 12.00 LT for both solstice days. The values of D_0, $D_1$and D_2 value calculated at both 12.00 and 24.00 LT is order 10^{10} (m^2/sn),10^0(m^2/sn), 10^{4} -10^{6} (m^2/sn) for all of season (June21, and December 21) respectively. Finally, The magnitudes of the coefficients of classical diffusion tensor for electrons are D_0>D_1 >D_2 at Equatorial F-region for both solstice days at both 12.00LT and 24.00LT. However, D_1 and D_2 are bigger night time than daytime and show a behavior unlike the change with latitude of electron density in the magnetic equator. It is possible to say that the behavior of these abnormal result from electromagnetic drift, diffusion and dynamo effect. The coefficients of classical diffusion tensor depends only on the temperature of electron and collisions frequency of electron D_0 (longitudinal diffusion) in eq.(4). However, the other coefficients classical diffusion, such as Pedersen and Hall are affected Earth's magnetic field as well as electron temperature and electron collisions.

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