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MAGNETOSPHERIC AND THERMOSPHERIC ORIGIN ELECTRIC FIELDS INFLUENCE ON THE ENHANCED ELECTRON DENSITY REGIONS IN THE NIGHT-TIME IONOSPHERIC F2-LAYER

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Abstract. The electric fields influence on the equatorial sides of the enhanced electron density regions (EEDR's) in the night-time middle-latitude ionospheric F2-layer has been investigated by using the global Upper Atmosphere of the Earth Model (UAM) and the empirical model of the ionosphere IRI-2001. It has been shown that the strengthening of the magnetospheric electric field results in the decrease of the steepness of the equatorial sides of the EEDR's. The seasonal and solar activity variations of the latitudinal location of the EEDR's equatorial sides are formed by corresponding variations of the thermospheric dynamo electric field.

Introduction

The middle-latitudinal enhanced electron density regions (EEDR's) appear in the night-time F2-layer of the ionosphere in all seasons under different solar activity levels. These regions have been detected in the observed diurnal and latitudinal variations of the F2-layer critical frequency (f_0F2), maximal electron density (*NmF2*) and total electron content (*TEC*) [Gilliland, 1935; Bertin and Lepine, 1970; Balan et al., 1991; Richards et al., 1994, 2000; Horvath and Essex, 2000; Mikhailov et al., 2000; Farelo et al., 2002; Brunini et al., 2003].

The mechanism of the EEDR's forming is based on the joint action of the plasma flows from the plasmasphere and the wind induced transportation of the ionospheric plasma along the geomagnetic field lines [Knyazeva and Namgaladze, 2005; Knyazeva, 2009].

The electromagnetic drift influences on the latitudinal location of the high-latitude sides of the EEDR's, moving them to lower latitudes due to the equatorward displacement of the main ionospheric trough under the action of the magnetospheric electric fields [Knyazeva and Namgaladze, 2005; Knyazeva, 2009].

In this work we have presented the results of the investigation of the magnetospheric and thermospheric (dynamo) electric fields influence on the equatorial sides of the EEDR's for different helio-geomagnetic conditions including quite conditions, equinox and solstice under the low and high solar activity. The global numerical model of the Upper Atmosphere of the Earth Model (UAM) has been used in this investigation [Namgaladze et al., 1998].

Model calculations

1. Magnetospheric electric field influence on the EEDR's

The global distributions of the electron density have been calculated by using the version of the UAM with the empirical model of the thermosphere NRLMSISE-00 [Picone et al., 2002] (UAM-MSIS in abbreviated form) in which the across polar cap potential $\Delta\varphi$ was constant and equal to 20 kV and 60 kV. The global pattern of the electromagnetic drift velocity has been calculated from the distribution of the electric field intensity $\boldsymbol{E}=-\boldsymbol{grad}\varphi$. The selected day (16.04.2002) represents quiet condition (near equinox) under the high solar activity.

The calculated geomagnetic latitude-altitude distributions of the electron density (n_e) along the night-time geomagnetic meridian 01:30 MLT for the altitude range from 800 to 3000 km (top row) and the corresponding latitude-longitude distributions of the eastward electric field at the altitude 175 km (bottom row) at the night longitudinal sector (18:00-06:00 MLT) are presented in Fig. 1. The results of the model calculations with constant across polar cap potential $\Delta\varphi$=20 kV are presented at the left column and with $\Delta\varphi$=60 kV ones are presented at the right column. The midday-midnight geographic meridian, the terminator line and geographic equator are drawn on the maps. The geomagnetic force field lines are drawn on the meridional cuts.

The increase of $\Delta\varphi$ results in strengthening of the magnetospheric origin electric field. As it was noted before this effect results in compressing of the EEDR's from poles because of main ionospheric trough displacement to lower latitudes.

The model calculation with constant across polar cap potential $\Delta\varphi$=20 kV has shown that at middle and low latitudes the zonal electric field is eastward in pre-midnight hours and it reverses (to westward) near 21:30-22:30 MLT. The increase of $\Delta\varphi$ influences weakly on the magnitude of the middle-latitude electric field. At low latitudes it leads to disappearance of the eastward electric field area, i.e. the zonal electric field is westward in all night-time longitudinal sector. It determines the night-time variations of the low-latitudinal and equatorial ionospheric F2-layer.

The model calculation with $\Delta\varphi$=60 kV has shown that the process of the equatorial anomaly disappearance by shifting the anomaly crests toward the geomagnetic equator starts at more earlier hours.

As a result the equatorial trough is filled. The equatorial sides of the EEDR's are moved to lower latitudes and their steepness is decreased.

The analogous model calculations without taking into account the thermospheric wind induced field-aligned ion transport have shown (Fig. 2) that the EEDR's have disappeared (top row of the cuts) as well as the eastward electric field areas (bottom row of the maps) at middle and low latitudes. This confirms the role of the thermospheric wind in the forming of the EEDR's and proves the dynamo origin of these eastward electric field areas.

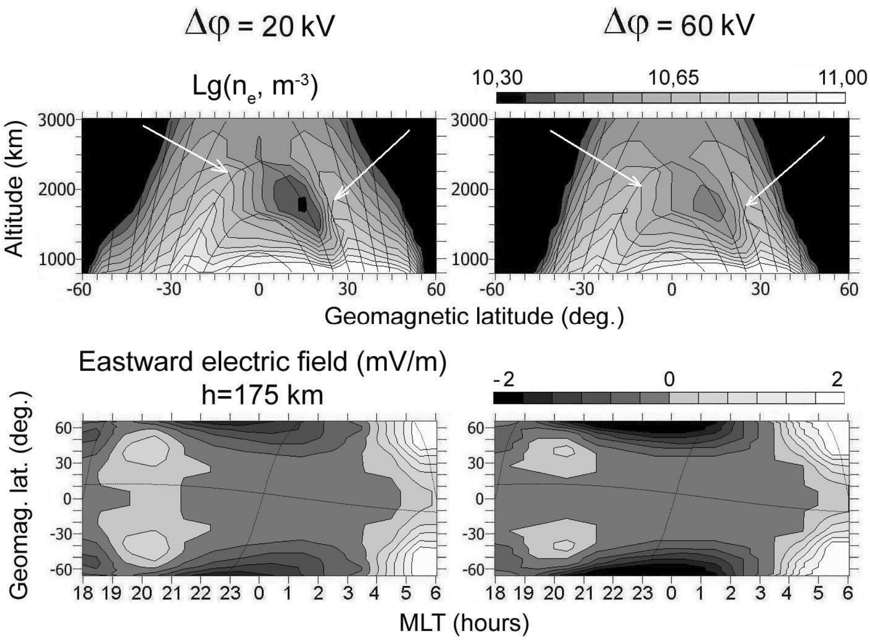

Figure 1. At the *top row* – the calculated by the UAM-MSIS with taking into account the thermospheric wind induced field-aligned ion transport the geomagnetic altitude-latitude distributions of *Lg(n$_e$)* along the night-time geomagnetic meridian 01:30 MLT for the altitude range from 800 to 3000 km, at the *bottom row* – the corresponding geomagnetic latitude-longitude distributions of the eastward electric field at the altitude 175 km for 24:00 UT 16.04.2002. At the *left column* – the meridional cut and map corresponding to the model calculation with $\Delta\varphi$=20 kV, at the *right column* – with $\Delta\varphi$=60кВ. The pointers indicate to EEDR's.

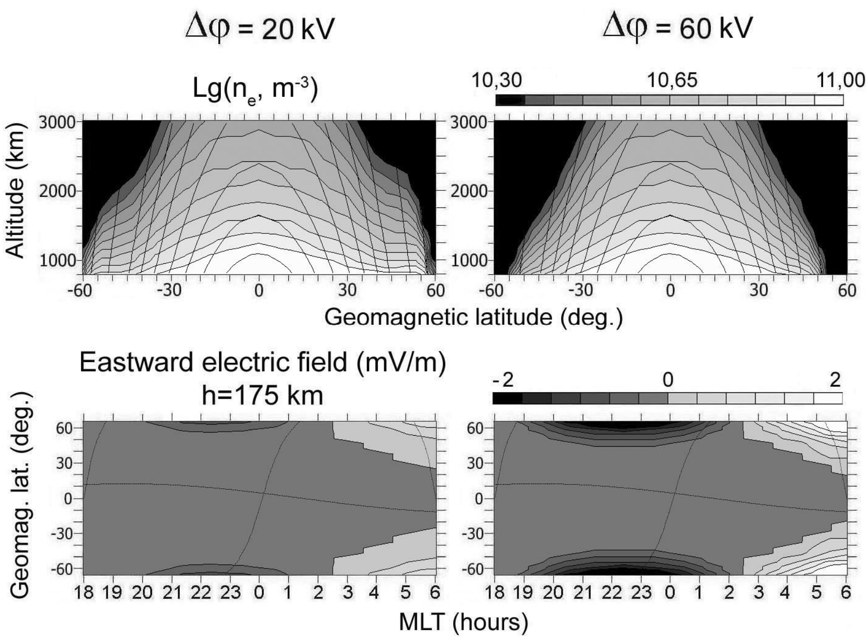

Figure 2. The same as in Fig. 1, but without taking into account the thermospheric wind induced field-aligned ion transport.

2. Thermospheric (dynamo) electric field influence on the EEDR's

To investigate the thermospheric (dynamo origin) electric field influence on the equatorial sides of the EEDR's under different seasons and solar activity levels, the global distributions of n_e have been calculated by using the following versions of the UAM: 1) with the theoretically calculated thermosphere parameters (UAM-TT); 2) with the empirical thermospheric NRLMSISE-00 model (UAM-MSIS); 3) with the NRLMSISE-00 and the empirical model of the horizontal neutral wind HWM-93 [Hedin et al., 1996] (UAM-MSIS-HWM).
These versions of the UAM differ by the method of the thermosphere wind velocity and neutral gas

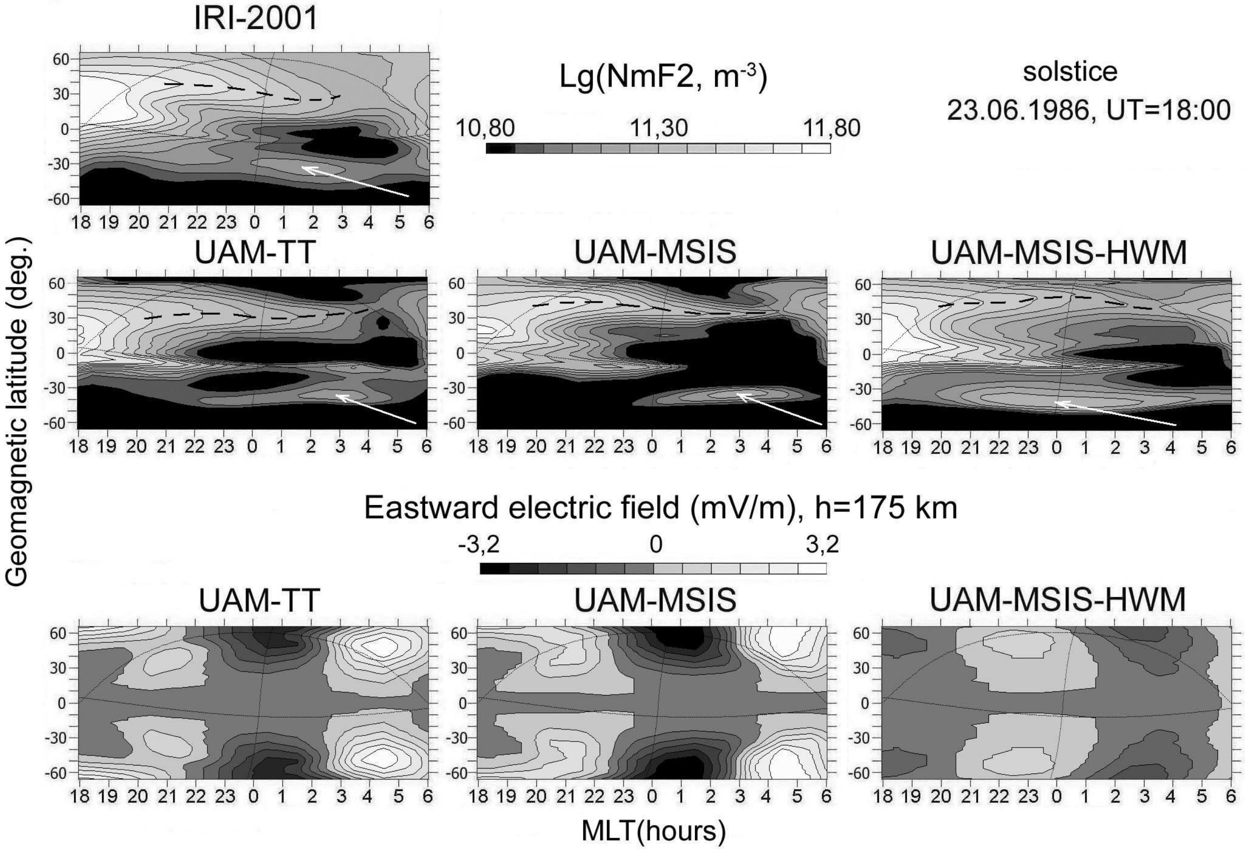

Figure 3. At *first* and *second rows* – the calculated by the IRI-2001 and all UAM versions distributions of *Lg(NmF2)* maps, at *third row* – the corresponding geomagnetic latitude-longitude distributions of the eastward electric field at the altitude 175 km for 18:00 UT 23.06.1986. The black broken curves indicate the summer type of the EEDR's. The pointers indicate the winter type of the EEDR's.

composition calculations. In the UAM-TT version the thermospheric composition and circulation are calculated by the numerical integration of the continuity, momentum and heat balance equations for the neutral atmosphere. In the UAM-MSIS version composition and three-dimensional circulation of the neutral gas are calculated by using the MSIS model. In the UAM-MSIS-HAM version neutral atmospheric composition is calculated by using the MSIS model and the horizontal neutral wind velocities are calculated by using the HWM. The vertical component of the thermospheric wind velocity is calculated by numerical solution of the continuity equation for the neutral mass density.
The model calculations were carried out for eight selected quiet days representing four seasons under the low and high solar activity. The results of the *NmF2* calculations were compared with data of the empirical ionospheric model IRI-2001 [Bilitza D., 2001].
The calculated geomagnetic latitude-longitude distributions of *NmF2* in the night longitudinal sector (18:00-06:00 MLT) corresponding to solstice (23.06.1986) under the low solar activity are presented in Fig. 3 (first and second rows of the maps). The format of the map presentation is such as preceding ones.
Earlier, we showed that two types of the EEDR's exist in the latitude-longitude distribution of the *NmF2*: 1) the summer type, when the electron density isolines have the form of a "ridge with decreasing altitude" (by the "altitude" we understand the values of *NmF2*) and 2) the winter type, when the closed isolines have the form of a "hill" [Knyazeva, 2009].
Both types of the EEDR's are clearly visible at all maps in Fig. 2 (the summer conditions –in the northern

hemisphere, the winter ones – in the southern hemisphere, respectively). Their formation is caused by corresponding longitudinal variation of the meridional neutral wind at the altitudes of the ionospheric F2-layer and geomagnetic field line geometry [Knyazeva, 2009].

The equatorial sides of the EEDR's abut on the equatorial anomaly remains in the night-time MLT sector. In the winter hemisphere the anomaly remains are clearly visible in the results of the IRI-2001 and all UAM calculations. The equatorial anomaly and EEDR's are separated by the through. In the summer hemisphere the equatorial "sides" of the EEDR's lie on the equatorial anomaly remains. As result these regions and equatorial anomaly are not separated. This effect takes place in summer solstice conditions under the high solar activity also.

The seasonal variations of the equatorial anomaly and EEDR's spatial structure at low latitudes are related to the corresponding variations of the dynamo origin zonal electric field (in Fig. 3, third row of the maps). The anomaly crests are clearly visible in winter (in all UAM versions) and summer conditions (by the UAM-MSIS and UAM-MSIS-HWM) in that hours by MLT, when the zonal electric field is eastward at low latitudes. The ionospheric plasma drifts under the action of this field to higher altitudes thus decreasing the ion loss rate. Accumulated plasma flows downward along the geomagnetic force lines and forms the equatorial anomaly crests.

Conclusions

Thus our investigation shows that the magnetospheric and thermospheric (dynamo) origin electric fields influence on the latitudinal location and form of the EEDR's equatorial sides abutting on the equatorial anomaly remains in the night-time MLT sector.

The strengthening of the magnetospheric electric field results to decrease of the steepness of the equatorial sides.

The seasonal and solar activity variations of the latitudinal location of the EEDR's equatorial sides and equatorial anomaly are formed by corresponding variations of the neutral winds due to the dynamo action generated electric fields.

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