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A MODEL STUDY OF THE SEASONAL AND SOLAR ACTIVITY VARIATIONS OF THE ENHANCED ELECTRON DENSITY REGIONS IN THE NIGHT-TIME IONOSPHERIC F2-LAYER AND PLASMASPHERE

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Abstract

Enhanced electron density regions (EEDR) in the night-time ionospheric F2-layer and plasmasphere have been modeled using the global Upper Atmosphere Model (UAM) for eight selected days representing four seasons and two levels of the solar activity. The modeling calculations have been performed in two versions: 1) by using the empirical thermospheric NRLMSISE-00 model for the neutral component calculations and 2) by using the theoretically calculated thermosphere parameters. The results were compared with the empirical model IRI-2001 predictions. All model calculations show the noticeable MLT, UT, seasonal and solar activity effects. The latitudinal and MLT locations of the EEDR are established. These regions are better expressed in equinoxes under low solar activity. The strong UT dependence exists in all model runs with maximum of the effect in the 12-24 UT sector. The EEDR extend to the plasmasphere along the geomagnetic field lines forming the tubes with enhanced electron density. The electromagnetic drift influences on the latitudinal locations of the high-latitude sides of these tubes, moving them to the lower latitudes. The main cause of the occurrence of the night increases of the electron density is the equatorward thermospheric wind driving the F2-layer plasma to the higher altitudes thus decreasing the ion loss rate. Seasonal and solar activity effects of the night-time EEDR are formed by the corresponding variations of the thermospheric wind velocity.

Introduction

The night-time middle-latitude enhanced electron density regions (EEDR) are apparent in the diurnal NmF2 variations. The statistical analysis of these variations for the latitudinal chain of four ionosonde stations in the Eurasian longitudinal sector is presented by Mikhailov et al (2000). The authors found the time of the occurrence, amplitudes and seasonal variations of two night NmF2 peaks: pre-midnight and post-midnight.

These regions extend up along the geomagnetic field lines of the Earth to the plasmasphere altitudes forming the tubes with enhanced electron density, which are presented in the experimental dependence of the ion densities on L-parameter (Gringauz and Bassolo, 1990).

The night-time EEDR manifest in the increase of the total vertical electron content (TEC) at the middle latitudes (Horvath and Essex, 2000).

The thermospheric wind and electromagnetic drift influence on forming of the night electron density increase in the F2-layer of the middle-latitude ionosphere and plasmasphere. The main cause of the occurrence of these night-time increases is the equatorward thermospheric wind driving the F2-layer plasma due to ion-neutral collisions to the higher altitudes thus decreasing the ion loss rate (Knyazeva and Namgaladze, 2005). The electromagnetic drift influences on the latitudinal locations of the high-latitude sides of these tubes, moving them to the lower latitudes proportionally of the drift velocity.

In the present study we investigate the seasonal variations of the EEDR under different solar activity levels by means of the global Upper Atmosphere Model (UAM) (Namgaladze et al., 1998).

This model describes the thermosphere, ionosphere and plasmasphere of the Earth as a single system by the numerical integration of the corresponding time-dependent 3D equations of the continuity, motion and heat balance for the neutral and electron gases and equation for the electric field potential. The thermosphere parameters can be calculated in the UAM by two ways: with using the empirical model NRLMSISE-00 (Picone et al., 2002) and with theoretical model of the thermosphere. Both versions of the calculations are presented below. They differ mainly by the thermospheric winds influencing the EEDR formation.

Model calculations

The model calculations of the electron density have been performed for eight selected quiet days representing four seasons and two levels of solar activity. The results of the calculations have been compared with the empirical ionosphere model IRI-2001 (Bilitza et al., 2004).

The results of the LgNe calculations for the altitude 300 km are presented together with the IRI-2001 data in Figs. 1 and 2 for UT=18:00 at the night longitudinal sector (18:00-06:00 MLT) under low (Fig. 1) and high (Fig. 2)

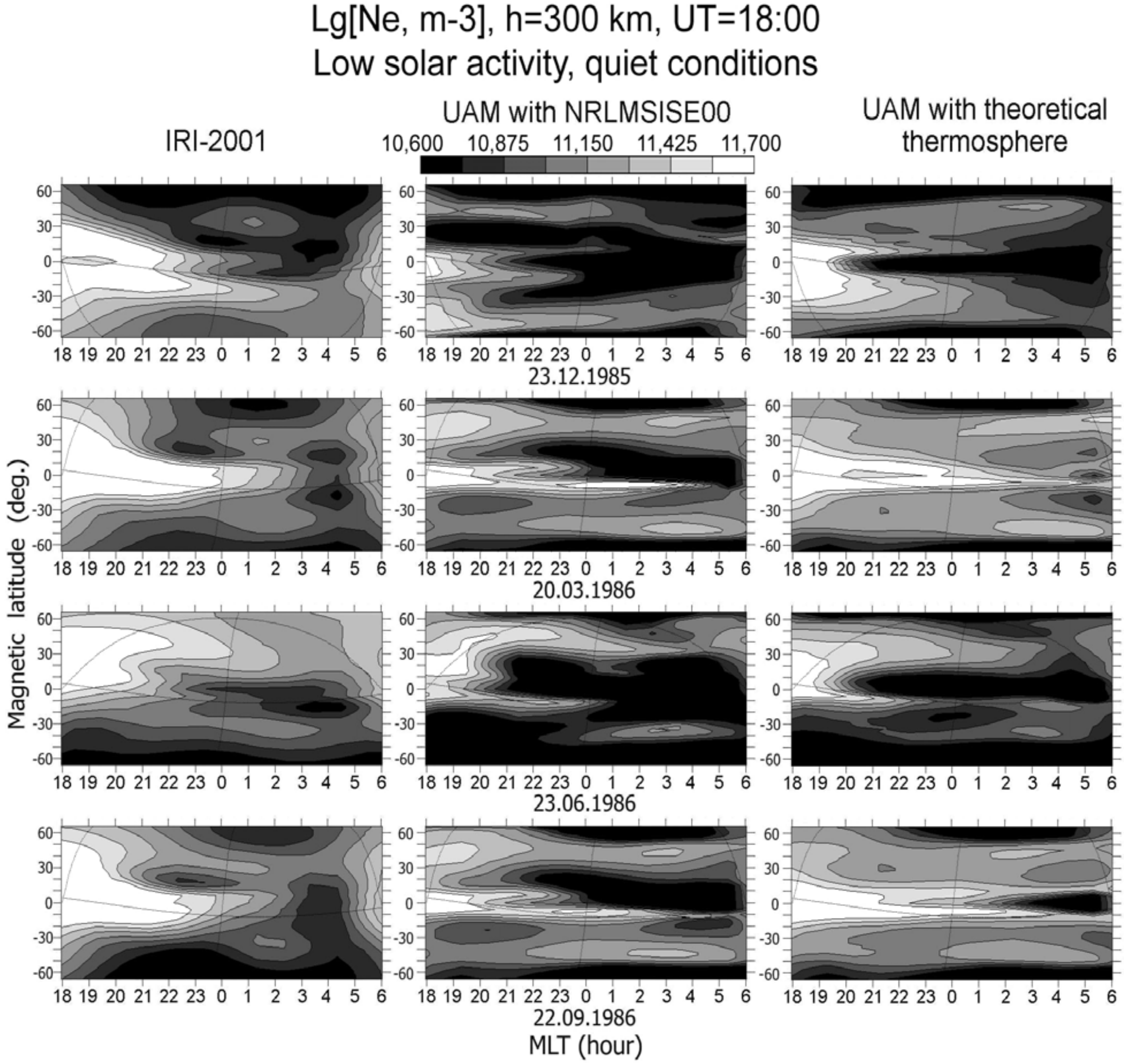

Fig. 1. The geomagnetic latitudinal-longitudinal distributions of LgNe (m^{-3}) for 18:00 UT at 300 km altitude under low solar activity for four seasons.

solar activity. These figures show that the enhanced electron density regions exist in all model calculations (UAM and IRI) for all seasons and solar activity levels. These regions are extended in MLT-direction and located at the 30°-60° geomagnetic latitudes. They are better expressed in equinoxes under low solar activity.

The empirical model of the ionosphere IRI-2001 reproduces these regions better in the northern hemisphere (Fig. 1-2 – left column). Possibly that is associated with a larger number of the stations in the northern hemisphere and with their deficit in the southern one.

The EEDR have clearly visible MLT-variation: they displace from higher to lower latitudes when going from evening to morning hours. This variation is well expressed in all prognoses of the IRI-2001, in the UAM calculations with the empirical model NRLMSISE-00 for the solstice under low solar activity (Fig. 1 – central column) and in both versions of the UAM calculations for all seasons under high solar activity (Fig. 2 – central and right columns).

The values of the electron density in the enhanced electron density regions are larger under high solar activity, than under low activity.

The examination of other UT moments shows that the enhanced electron density regions depend on the universal time in all model calculation versions. These regions are the best visible in the 12:00-24:00 UT sector.

A comparison between the empirical IRI-2001 prognoses and both UAM calculations shows that the best agreement between them is seen for the June date.

The night-time meridian cuts of LgNe (Fig. 3) for 18:00 UT and 01:00 MLT of 23.06.1986 are shown in the Fig.3 for two overlapping altitude ranges: from 200 to 1000 km and from 800 to 3000 km. In these plots the geomagnetic field lines are drawn as well. The enhanced electron density regions exist in the form of the

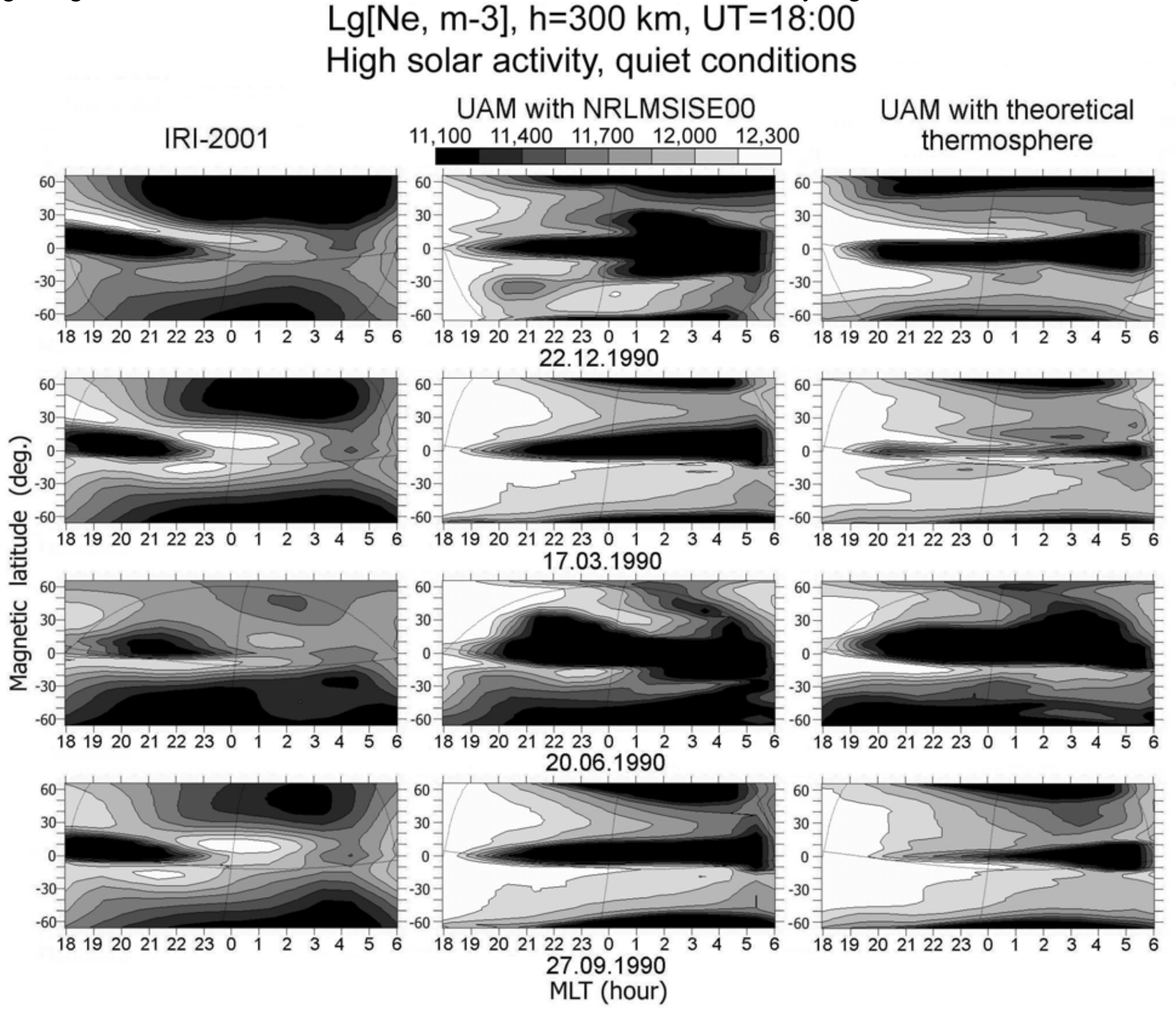

Fig. 2. The geomagnetic latitudinal-longitudinal distributions of LgNe (m^{-3}) for 18:00 UT at 300 km altitude under high solar activity for four seasons.

prominences of the LgNe isolines near the geomagnetic latitudes 40° in both hemispheres. These regions are extended to the plasmasphere up to altitudes order 8000 km. The form of the prominences is controlled of the geomagnetic field lines geometry.

Conclusions

Thus, our investigation shows that the enhanced electron density regions exist in all model UAM and IRI-2001 calculations for all seasons and solar activity levels.

There is the best agreement between the empirical model of the ionosphere IRI-2001 data and both versions of the UAM calculations for the June date. The IRI-2001 reproduces these regions better in the northern hemisphere.

The EEDR have clearly visible UT- and MLT-variations in all model calculations.

The enhanced electron density regions are extended to the plasmasphere along geomagnetic force lines up to altitudes of the order of 8000 km. Their form is controlled by geometry of the geomagnetic field lines.

The main cause of the occurrence of the EEDR is the equatorward thermospheric wind. Therefore the season and solar activity variations of the enhanced electron density regions are formed by the corresponding variations of the thermospheric wind velocity.

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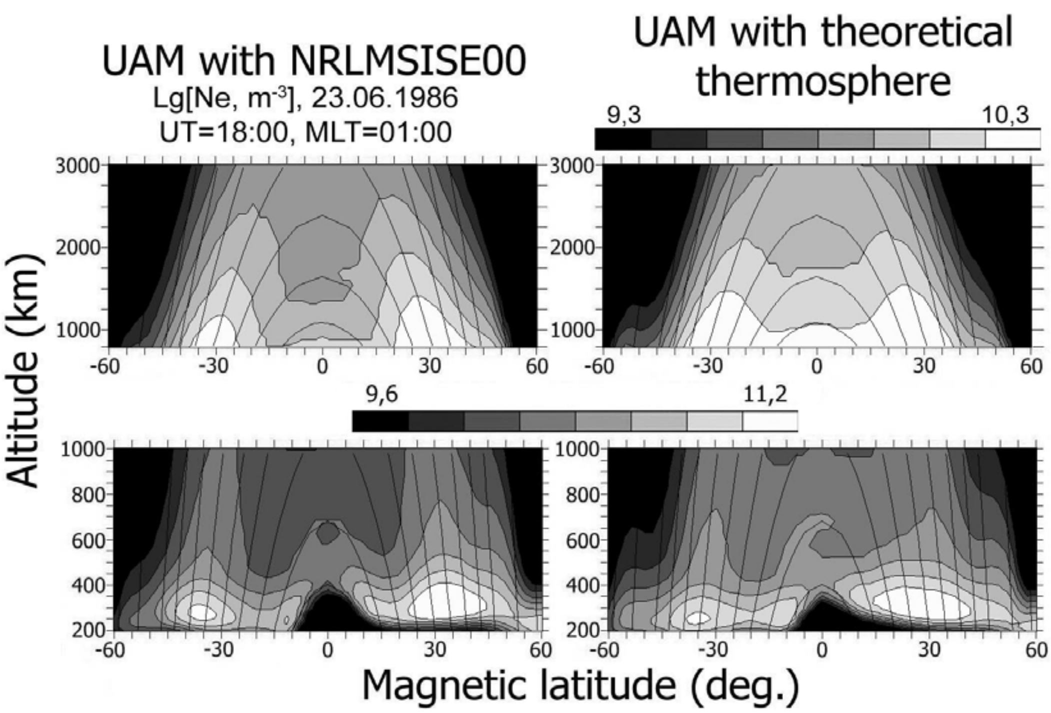

Fig. 3. The altitudinal-latitudinal distributions of LgNe (m^{-3}) along geomagnetic meridian MLT 01:00 for 18:00 UT for the ranges of the altitudes h=200÷1000 km (top panels) and h=800÷3000 km (bottom panels) under low solar activity.

References

Mikhailov A.V., Leschinskaya T.Yu., Förster M. Morphology of NmF2 nighttime increases in the Eurasian sector. *Annales Geophysicae*, v.18, p.618, 2000.

Gringauz K.I., Bassolo V.S. The structure and properties of the Earth's plasmasphere. The experimental data and problems of their interpretation. Review. *Geomagnetism and Aeronomy* (in Russian), v.30, № 1, pp.1-17, 1990.

Horvath I., Essex E.A. Using observations from the GPS and TOPEX satellites to investigate night-time TEC enhancements at mid-latitudes in the Southern Hemisphere during a low sunspot number period. *Journal of Atmospheric and Solar-Terrestrial Physics*, v.62, p.371, 2000.

Knyazeva M.A., Namgaladze A.A. The mathematical modeling of the forming of the night-time electron density increases in the F2-layer of the quiet middle-latitude ionosphere and in the Earth's plasmasphere. *Proceedings of the MSTU* (in Russian), v.8, №1, pp.144-155, 2005.

Namgaladze A.A., Martynenko O.V., Volkov M.A., Namgaladze A.N., Yurik R.Yu. High-latitude version of the global numerical model of the Earth's upper atmosphere. *Proceedings of the MSTU*, v.1, N 2, p.23-84, 1998.

Picone J.M., Hedin A.E., Drob D.P., Aikin A.C., NRLMSISE-00 empirical model of the atmosphere: Statistical comparisons and scientific issues, *J. Geophys. Res.*, 107 (A12), doi: 10.1029/2002JA009430, 2002

Bilitza, D., K. Rawer, B. Reinisch (eds.), Path Toward Improved Ionosphere Specification and Forecast Models, Advances in Space Research, V. 33, Number 6, 2004.