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LONGITUDINAL VARIATIONS OF THE ELECTRON DENSITY ENHANCEMENTS IN THE SUMMER NIGHT-TIME IONOSPHERIC F2-LAYER: NUMERICAL MODELING

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Abstract. The longitudinal variations of the enhanced electron density regions (EEDRs) under the quiet conditions of the December solstice are investigated using the global numerical Upper Atmosphere Model (UAM) and the empirical ionospheric model IRI-2001. It has been proved that the Weddell Sea Anomaly in the southern hemisphere under the summer conditions is reproduced qualitatively by the UAM. The numerical experiments have showed that the phenomenon is caused by the non-coincidence of the geomagnetic and geodetic axes which produces the difference in the vertical ion velocities due to the thermospheric wind action at different longitudinal sectors.

1. Introduction

The numerous papers described the anomalous night-time enhancements of the F2-layer electron density at the geomagnetic middle-latitudes. The morphology and physical mechanism were investigated by the global 3D Upper Atmosphere Model in details [Knyazeva and Namgaladze, 2008a]. In the late 1950s in the Antarctica region the ionosonde measurements detected the anomalous diurnal electron density variations with the night-time values exceeding the day-time ones under summer conditions [Bellchambers and Piggott, 1958; Penndorf, 1965]. The phenomenon was called the Weddell Sea Anomaly although the anomaly covers rather the Bellinshausen Sea [Horvath and Essex, 2003]. Later satellite observations verified the WSA existence and revealed the analogous phenomenon in the Northern Hemisphere also in summer [Thampi et al., 2009]. The electron density enhancements are observed in the region from 40°S to 80° in latitude. The phenomenon covers longitudes of about 255°-315° in the summer Southern Hemisphere and longitudes of about 75°-135° in the summer Northern Hemisphere.

Various hypotheses of physical mechanisms forming the WSA and analogous phenomenon in the Northern Hemisphere were advanced. The most discussed are the effects of solar ionization, neutral winds, geomagnetic field geometry, energetic particles precipitations, electric fields and plasma convection [Karpachev et al., 2010].

Almost all investigations were performed using ionosonde and satellite data. No WSA reconstruction was produced using global theoretical models.

2. Model calculations

We performed the investigation of the EEDRs and in particular Weddell Sea Anomaly using the global numerical Upper Atmosphere Model which was described in details by [Namgaladze et al., 1998].

One of the UAM most important features is the ability to use empirical models alternative to theoretical calculation. So the NRLMSISE-00 model [Picone et al., 2002] can be used for neutral composition and temperature calculation; the HWM-93 [Hedin et al., 1996] can be employed for thermospheric wind velocity calculation. Such combined simulations allow estimating an influence of a single physical mechanism on the upper atmosphere behavior.

We performed numerical experiments using the following UAM configurations:

1) marked as UAM-T – the fully self-consistent UAM version which calculates neutral composition, temperature neutral gas velocity by solving of the continuity, heat balance and momentum equations;

2) marked as UAM-MSIS – the configuration using the NRLMSISE-00 model for neutral composition, temperature and pressure gradients calculations;

3) marked as UAM-MSIS-HWM – the configuration using horizontal neutral gas velocities calculated by the HWM-93 model and neutral composition and temperatures by the NRLMSISE-00 model.

The numerically calculated distributions of the F2-layer critical frequency (foF2), diurnal variations of the F2-layer peak electron density (NmF2) and height (hmF2) were compared with the empirical IRI-2001 model [Bilitza, 2001] results.

3. Simulation results

The foF2 distribution at the 285º geodetic meridian was simulated using the UAM-T, UAM-MSIS and UAM-MSIS-HWM versions for the December solstice (23.12.1985) under lower solar activity. The meridian of the 285º geodetic longitude is crossing the Weddell Sea Anomaly region approximately in the middle. The calculation results are shown in Fig.1 in comparison with the IRI-2001 data.

Fig.1 demonstrates that the IRI-2001 reproduces the WSA (marked by the solid black circles) at 45º-70º of southern geomagnetic latitudes. In this latitude region the night-time foF2 values exceed the daytime ones. The UAM-MSIS version gives the most evident phenomenon at higher latitudes with the difference between daytime and nighttime values up to 30 per cents. The UAM-T and UAM-MSIS-HWM versions produce the less evident WSA than in the UAM-MSIS results.

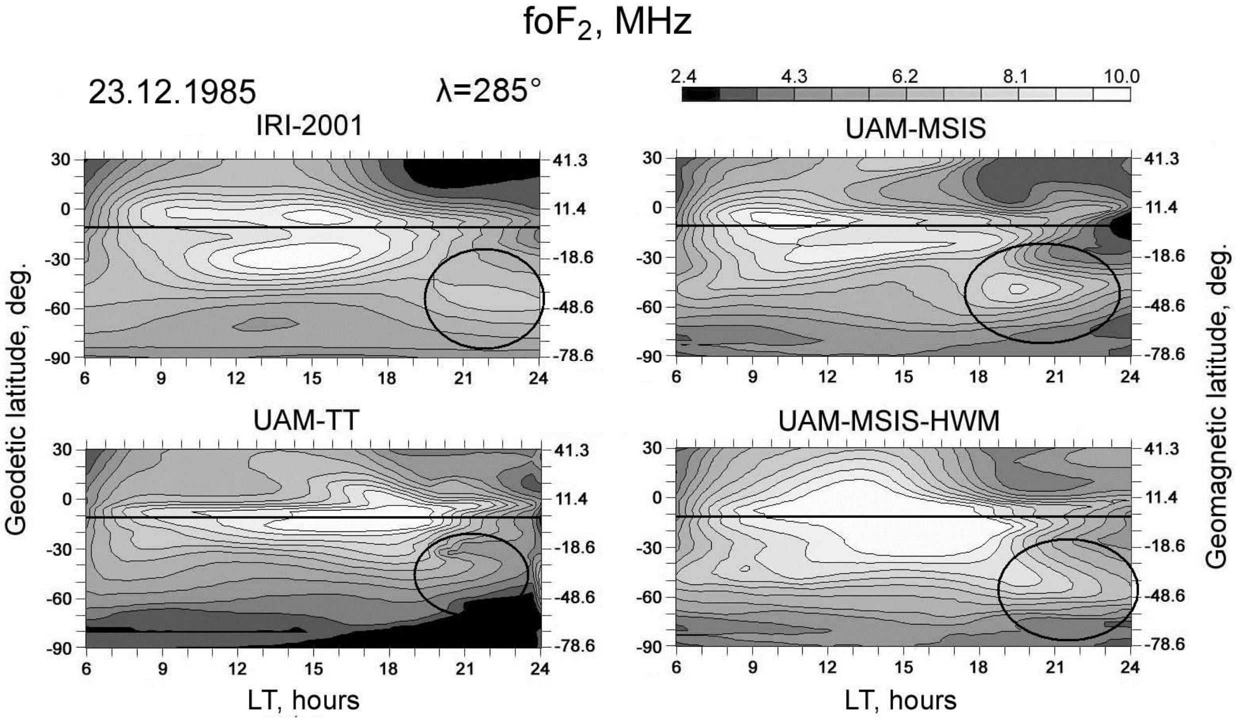

Fig.1. LT-latitudinal distributions of the foF2 values at the geodetic meridian of 285º calculated for December 23, 1985 by three UAM versions in comparison with the IRI-2001 data. The geomagnetic equator is marked by the horizontal solid black line.

As it was shown in [Knyazeva and Namgaladze, 2008b] the main physical mechanism forming the middle-latitudinal enhanced electron density regions under quiet geomagnetic conditions is the ion drag induced by the thermospheric wind. In the night sector the equatorward neutral wind drives the F2-layer plasma to higher altitudes where the rate of ion losses in collisions with neutral molecules is lower. It results in electron density increasing. The vertical ion velocity induced by the meridional wind is proportionate to the cosI·sinI value, where I is the inclination of the magnetic field. When the geomagnetic and geodetic axes are not coincident, the cosI·sinI magnitude at the fixed geodetic latitude depends on the geodetic longitude value. Thus at the geodetic latitude of 45ºN the cosI·sinI value is maximal at the geodetic meridian of about 300º which crosses the Weddell Sea anomaly region.

To check the leading role of the non-coincidence of the geodetic and geomagnetic axes we calculated the foF2 distribution by the UAM-T version with the coincided geodetic and geomagnetic axes. The results are shown in Fig.2 in comparison with the results of the UAM-T taking into account the non-coincidence of the axes. It is visible that the WSA disappears when the axes are coincided.

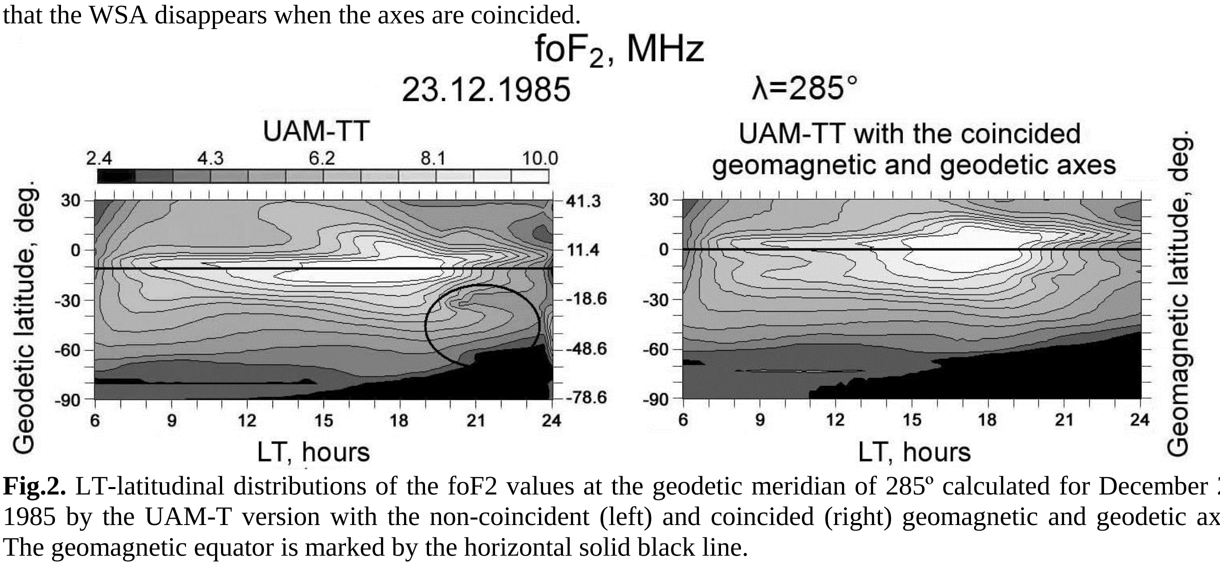

Fig.2. LT-latitudinal distributions of the foF2 values at the geodetic meridian of 285º calculated for December 23, 1985 by the UAM-T version with the non-coincident (left) and coincided (right) geomagnetic and geodetic axes. The geomagnetic equator is marked by the horizontal solid black line.

Fig.3 demonstrates the F2-layer peak electron density and height calculated by the UAM-T and UAM-MSISE-HWM versions for the geodetic meridian of 285º in comparison with the IRI-2001 data. In Fig.3 the NmF2 diurnal variations calculated by the IRI-2001 for the geomagnetic latitudes of -50º and -55º have the maximum values at 22-24 LT. The hmF2 diurnal maximum of about 350 km is produced by the IRI-2001 for the same hours. The UAM versions give the NmF2 maximum at 19-21 LT. The UAM-MSISE-HWM results agree better with the IRI-2001 for both NmF2 and hmF2 values.

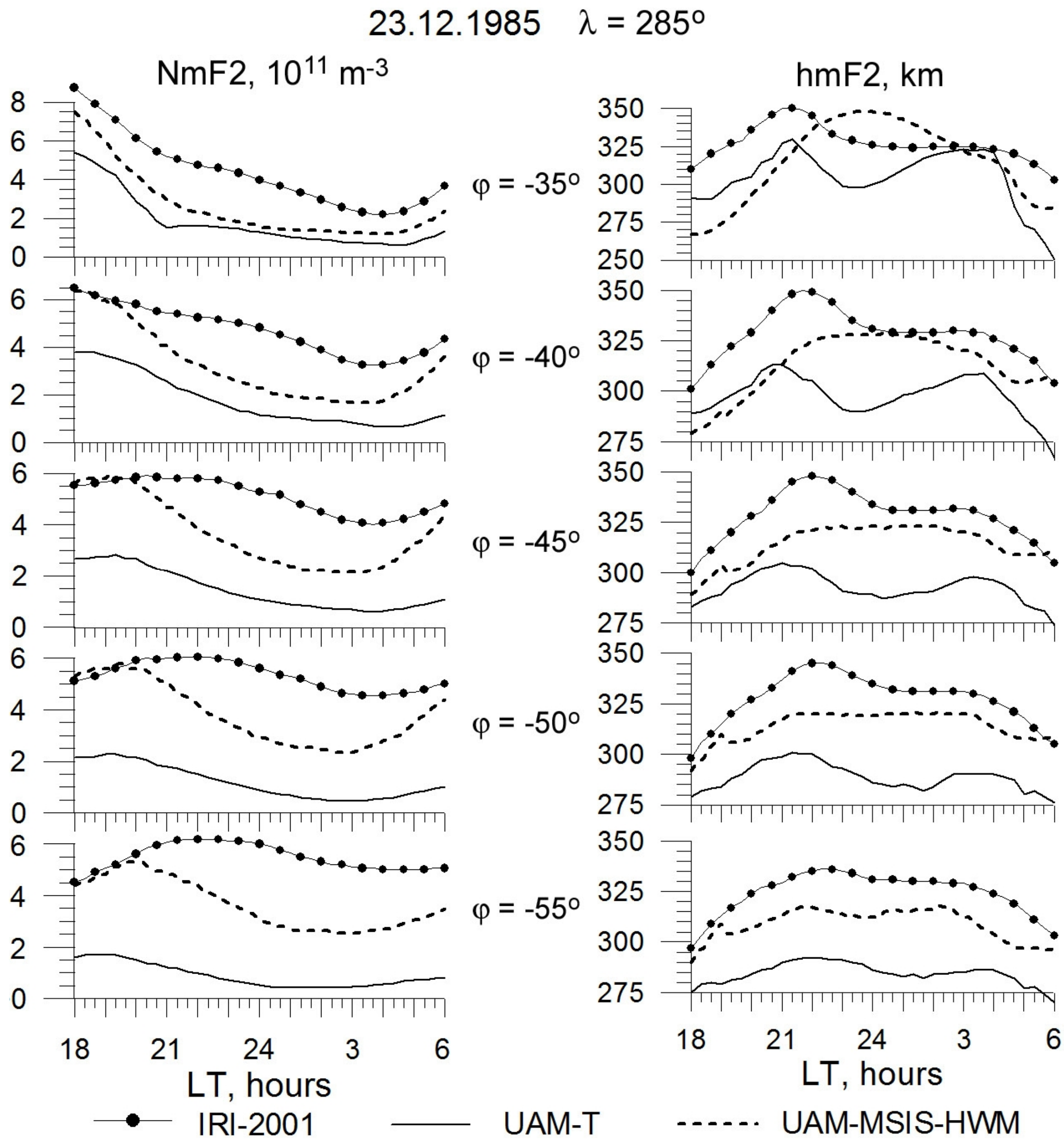

Fig.3. LT variations of NmF2 and hmF2 at geodetic longitude of 285º at several geomagnetic latitudes calculated by the UAM versions for December 23, 1985 in comparison with the IRI-2001 data.

4. Conclusions

We have reproduced the Weddell Sea Anomaly by the global theoretical 3D Upper Atmosphere Model. The UAM gives similar WSA patterns in the versions taking into account the non-coincidence of the geodetic and geomagnetic axes. These patterns reproduce the corresponding IRI-2001 foF2 distribution qualitatively. The phenomenon is caused by the non-coincidence of the geomagnetic and geodetic axes which produces the difference in vertical velocities of the ion transfer by the thermospheric wind action at different longitudinal sectors.

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