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TESTING OF THE UPPER ATMOSPHERE MODEL USING THE EMPIRICAL IONOSPHERIC MODELS

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Abstract. The seasonal variations of the quiet ionospheric F2-layer have been modeled by using different versions of the numerical global Upper Atmosphere of the Earth Model (UAM). The results of f_0F2 and h_mF2 calculations have been compared with data of two empirical models: 1) IRI-2001 and 2) Q-F2 developed by Deminov et al. [2009]. All versions of the model calculations show a better agreement for winter solstice and spring equinox in the northern hemisphere. There are the maximal differences between all model results and experimental data in the night-time sector. It has been shown that these differences are related with the theoretically calculated variations of the thermospheric circulation and neutral gas composition.

Introduction

In order to investigate the ionospheric F2-layer behaviour during disturbed periods the ionospheric parameters (the F2-layer critical frequency (f_0F2), the maximal electron density (N_mF2) and the height of the F2-layer peak (h_mF2)) are estimated relative to quiet background values. The reliability and interpretation of the obtained results depend on a method used for background values calculation.

The empirical model Q-F2 developed by Deminov et al [2009] calculates the diurnal variations of the background values of f_0F2. The model was approved by using the data of the middle-latitudinal ionosonde stations Slough (52.5ºN, 104ºE) and Irkutsk (51.5ºN, 359.4ºE) for the periods of 1958-1992 and 1958-1995 respectively [Deminov et al., 2009]. It was shown that the Q-F2 model reproduced qualitatively and quantitatively the observed regular seasonal and annual variations of the quiet ionospheric F2-layer.

In this work we present the results of testing of the global numerical three-dimensional time-dependent Upper Atmosphere Model (UAM) [Namgaladze et al., 1998] from the point of view of simulating the seasonal variations of the quiet ionospheric F2-layer by this model.

Model calculations

We have tested three versions of the UAM: 1) with the theoretically calculated thermosphere parameters (UAM-TT in abbreviated form); 2) with the empirical thermospheric NRLMSISE-00 model [Picone et al., 2002] (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).

The UAM versions differ from each other in the method of the thermospheric three-dimensional circulation and neutral gas composition calculations. In the UAM-TT version the thermospheric composition and neutral wind velocity are calculated by the numerical integration of the continuity, momentum and heat balance equations for the neutral atmosphere. In the UAM-MSIS version the neutral composition and circulation are calculated by using the MSIS model. In the UAM-MSIS-HWM version the 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 diurnal variations of f_0F2 and h_mF2 over Slough and Irkutsk were calculated by all UAM versions for three selected quiet days representing conditions near the winter and summer solstices and spring equinox under the middle solar activity: December 16, 1992 ($F_{10.7}$=146.0), July 15, 1983 ($F_{10.7}$=124.6), April 16, 1988 ($F_{10.7}$=147,6).

Two top plots of the Figures 1-3 present the calculated f_0F2 and h_mF2 diurnal variations over Slough. The UAM results were compared with the data of the empirical model Q-F2 [Deminov et al., 2009] and the ionospheric model IRI-2001 [Bilitza D., 2001].

The third and fourth plots of the Fig. 1-3 present the corresponding variations of the northward neutral wind V_{nx} and the ratio of the O and N_2 concentrations at the altitude of 300 km. The plots are used to analyze possible reasons of the disagreement between the UAM results and the empirical models data.

The f_0F2 and h_mF2 variations calculated by the UAM, Q-F2 and IRI-2001 show a good agreement for winter solstice and spring equinox at first twenty four hours. The UAM-MSIS version has a better agreement with the data of the empirical models.

The most evident differences between all model calculations of f_0F2 diurnal variations take place for the night-time sector results. The main role in the night-time peak F2-layer behaviour plays the meridional wind.

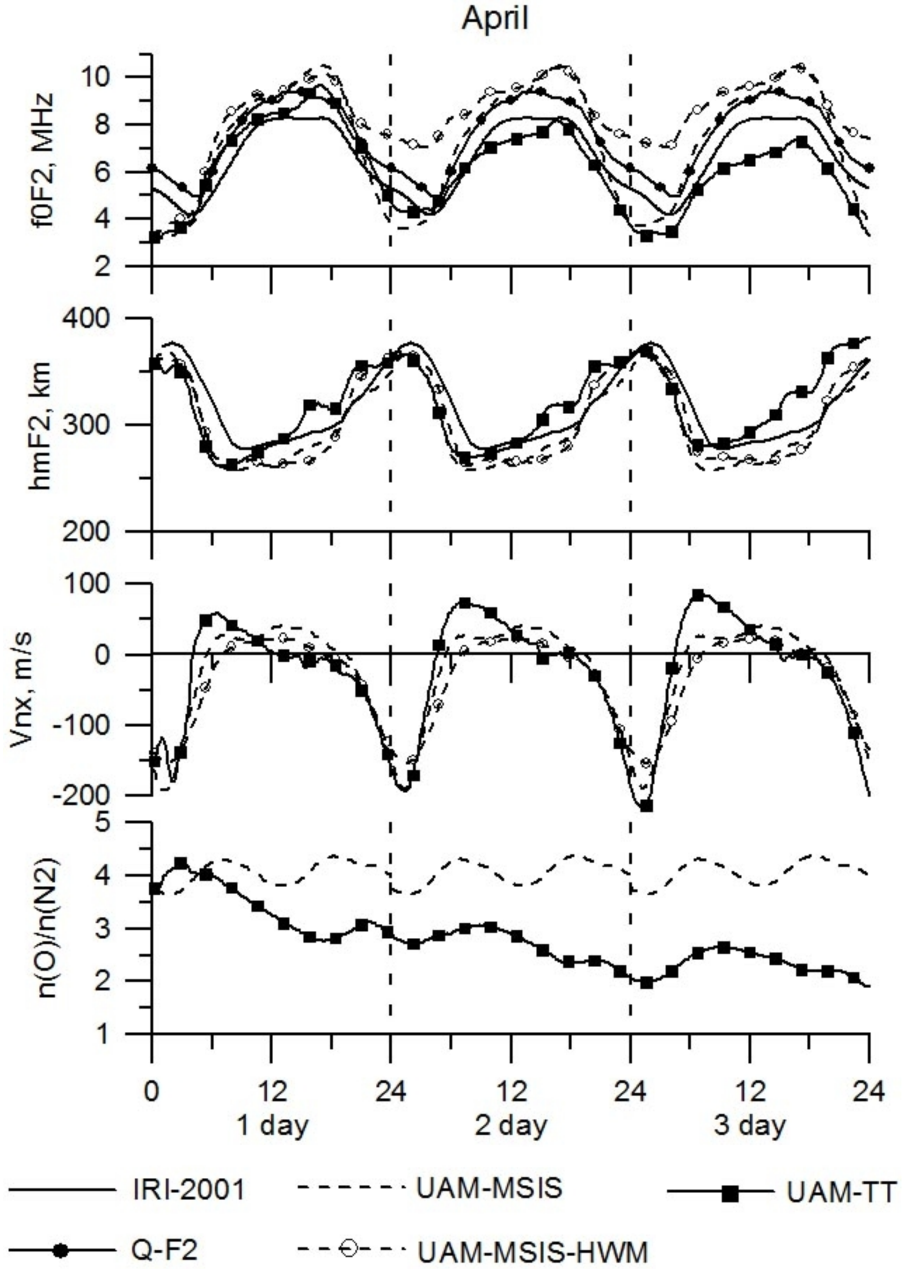

Figure 1. The calculated F2-layer critical frequency (f_0F2), height of the F2-layer peak (h_mF2), northward neutral wind velocity at the altitude of 300 km (V_{nx}) and ratio of the *O* and N_2 concentrations at the altitude of 300 km ($n(O)/n(N_2)$) diurnal variations over Slough (*top-down*) for April 16, 1988.
The IRI-2001 data are pictured by *solid line*, the Q-F2 data – by *solid line with black bubbles*, the UAM-MSIS values – by *dotted line*, the UAM-MSIS-HWM values – by *dotted line with circles*, the UAM-TT values - by *solid line with squares*.

The ionospheric plasma transfers along the geomagnetic field lines by the equatorward neutral wind to the higher altitudes thus decreasing the ion loss rate. As a result the h_mF2 and f_0F2 increase.
The meridional wind velocity calculated by all UAM versions is equatorward in summer solstice and spring equinox. The UAM-MSIS version gives larger V_{nx} values than the UAM-TT. It explains the differences between h_mF2 and f_0F2 values calculated by these UAM versions.
The UAM-TT version underestimates the day-time f_0F2 values at the end of the third twenty-four hours integration period in all seasons. The day-time $n(O)/n(N_2)$ values do not change practically in winter and summer conditions, but in spring equinox the ratio values decrease. The poleward wind velocity increases and that causes decreasing of the h_mF2 and f_0F2 in winter and summer solstices. In spring condition the V_{nx} values calculated by the UAM-TT version do not change.

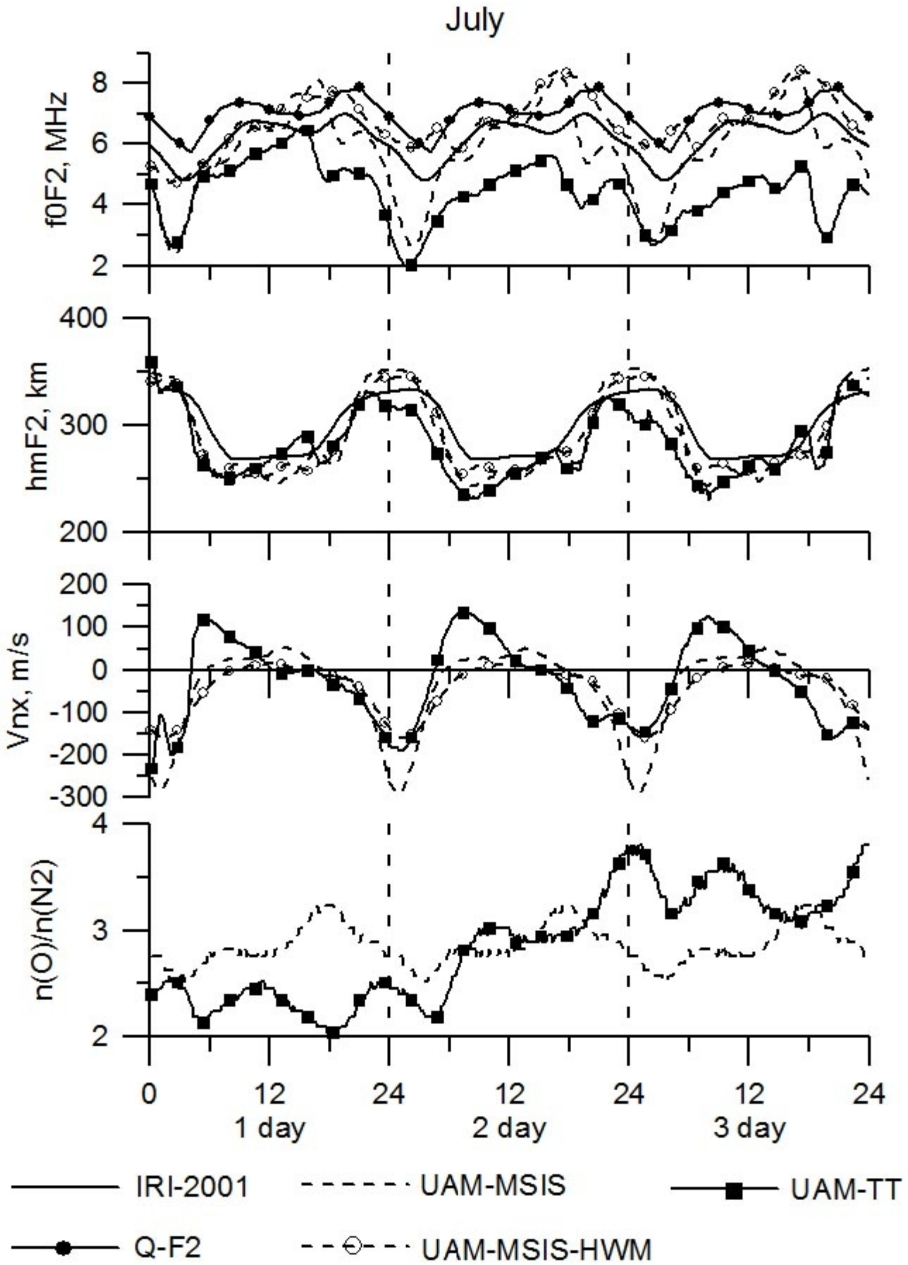

Figure 2. The same as in Fig. 1, but for July 15, 1983.

Conclusions

All versions of the model calculations show a better agreement for winter solstice and spring equinox. The UAM version with the NRLMSISE-00 gives the best agreement with the F2-layer parameters calculated by the Q-F2 and IRI-2001 empirical models.

The differences between all UAM results and the empirical models data for the night-time sector are explained by the variations of the thermospheric winds.

The day-time values of the critical frequency of the F2-layer calculated by the fully theoretical UAM version are seen too low at the third day of calculation in all seasons. Such f_0F2 behaviour is related with increasing of the neutral poleward wind velocity at winter and summer solstices and decreasing of the ratio of the concentrations O and N_2 at spring equinox.

The analysis of the model results for Irkutsk has given the same conclusions as for Slough.

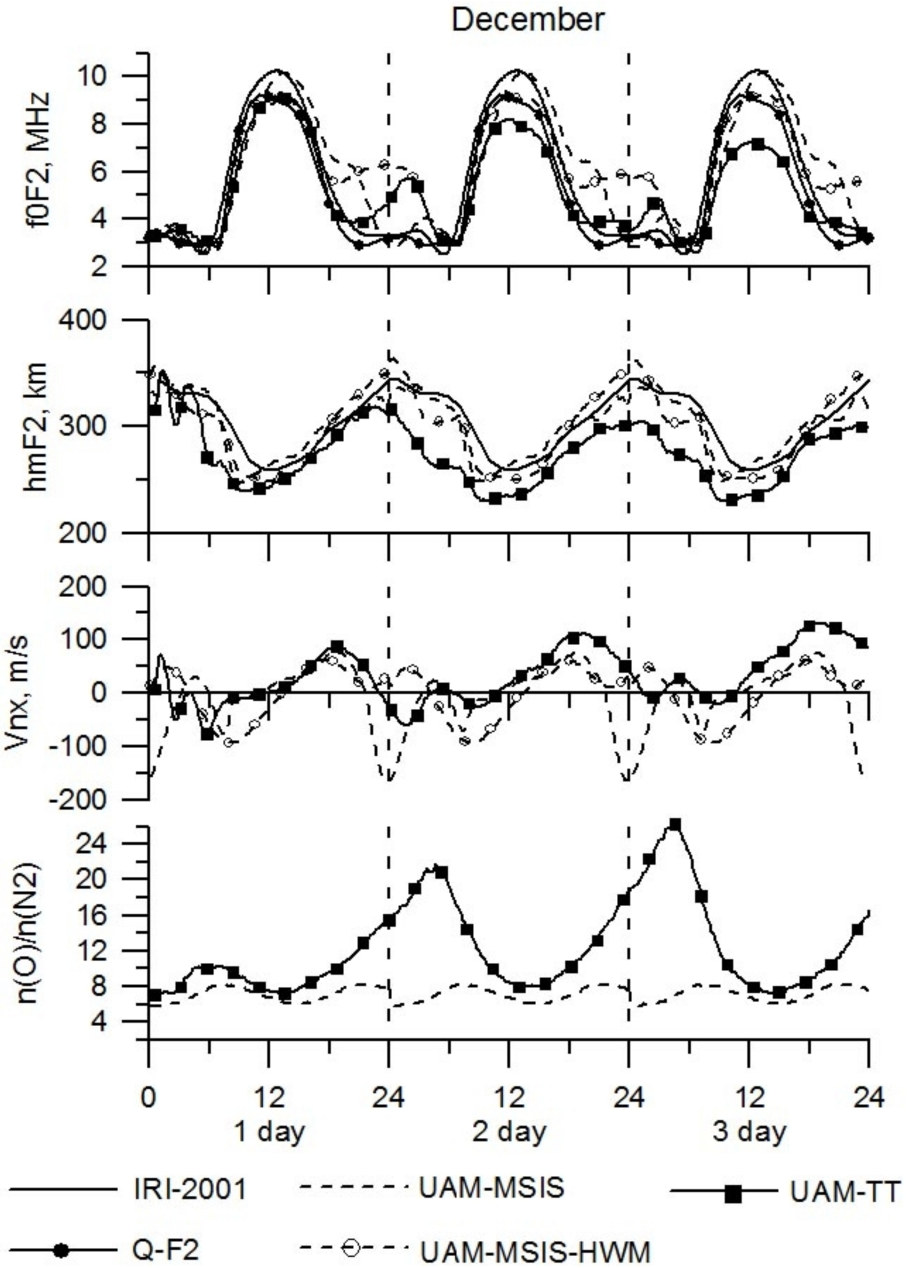

Figure 3. The same as in Fig. 1, but for December 16, 1992.

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