Electron Density Height Profiles Calculated by the Theoretical Upper Atmosphere Model: Comparison with the Empirical IRI Model

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Abstract

We have compared the electron density height profiles calculated by the global numerical Upper Atmosphere Model with the empirical IRI-2007 and IRI-2012 model values. The comparison has been performed for two solar activity levels and different seasons. It is shown that the UAM results agree well at middle latitudes being closer to the IRI-2007 than to the IRI-2012 values.

1. Introduction

The Upper Atmosphere Model is the global, three-dimensional, time-dependent, numerical model simulating the thermosphere, ionosphere and plasmasphere of the Earth as a single system [1]. The UAM allows performing the fully self-consistent numerical calculations as well as alternatively modeling using the empirical models, for example, the model of neutral composition and temperatures NRLMSISE-00 [2]. Testing and verifying of a numerical model is a significant problem for all modelers. We have calculated electron density global distribution for two solar activity levels ($F_{10,7}$~90 and $F_{10,7}$~180) and for different seasons using two UAM versions. The calculation results are presented as electron density height profiles which are compared with the values of two empirical International Reference Ionosphere model versions: IRI-2007 [3] and IRI-2012 [4].

2. Numerical Calculations

Model simulations have been performed using two different UAM versions: 1) with neutral densities and temperature calculated by the empirical NRLMSISE-00 model (marked as UAM-TM) and 2) the fully self-consistent version with theoretically calculated thermospheric parameters (marked as UAM-TT).

Input parameters are set for both versions identically: 1) solar UV and EUV spectra are taken from the model by [5]; 2) the potential drop across the polar cap is calculated by the empirical AE-index relation of [6]; 3) precipitating fluxes are calculated by the empirical model of [7].

Electron density distributions have been calculated for two solar activity levels and different seasons: for the low solar activity ($F_{10,7}$~90) the modeled dates were the December solstice of 2004 and the April equinox of 2005, for the high solar activity ($F_{10,7}$~180) the modeled dates were the December solstice of 2000 and the April equinox of 2002.

Initial conditions were prepared for the each date using the following procedure:
1) firstly, model data was calculated according to the empirical NRLMSISE-00 and IRI-2007 models for the ionosphere and thermosphere respectively; 2) to obtain the stationary state of the ionosphere and thermosphere two consequent runs were performed; 3) then five model days were calculated as usual. The paper presents the results for the 24:00 UT of the fifth model day (00:00 UT, next day).

3. Comparing with the Empirical IRI Values

The simulation results are presented as electron density height profiles for the following coordinates: the geomagnetic latitudes of ±45˚ and the geomagnetic longitudes of 115˚ and 295˚ corresponding to 03:00 MLT and 15:00 MLT. The model electron density profiles are compared with the empirical IRI-2007 and IRI-2012 values. The Figure 1 and Figure 2 show the height variations of the electron density common logarithm calculated by the UAM and the IRI versions for low and high levels of solar activity correspondingly for different seasons. The UAM profiles are presented by circles, the IRI profiles – by the solid (IRI-2012) and dotted (IRI-2007) lines.

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The figures demonstrate electron density height variations calculated by 2 empirical and 2 theoretical models versions for 2 solar activity levels for 2 seasons and for 4 locations, i.e. total 64 electron density profiles. The profiles calculated by the both UAM versions have a similar shape with the maximum near 250 km in the daytime and near 300 km at night under the low solar activity and near 300 km in the daytime and near 350 km at night under the high solar activity. As a whole the UAM-TM gives larger electron density values than the UAM-TT. The maximal difference between the UAM versions amounts to factor 4 but usually it is factor 2.

Let us consider a bottom part (up to 600 km) and a top part (above 600 km) separately. For the altitudes below 600 km the IRI-2007 and IRI-2012 versions give practically the same values of electron density. The bottom parts of profiles indicate that in most cases one or both UAM versions demonstrate a very good agreement with the IRI values. At altitudes below 600 km an excellent agreement between both UAM versions results and IRI values take place during night hours for: 1) low solar activity equinox conditions and 2) high solar activity solstice conditions.

Considering the top profiles parts we can see the difference between the IRI versions which is increasing with the height. The IRI-2007 electron densities values are up to factor 10 larger then IRI-2012 values. For the heights above 600 km in most cases both UAM versions demonstrate a good agreement with the IRI-2007. Both UAM-TT and UAM-TM modelled electron number density profiles are between the IRI-2012 and IRI-2007 values.

4. Conclusion

The results of UAM simulations have been compared with the electron density profiles calculated by the IRI-2007 and IRI-2012 models. For the altitudes below 600 km the UAM results demonstrate a good agreement with the IRI-2007 and IRI-2012 values which are close to each other. For the altitudes above 600 km the electron density values calculated by the UAM versions are between the IRI-2007 and IRI-2012 values being closer to the IRI-2007.

5. References

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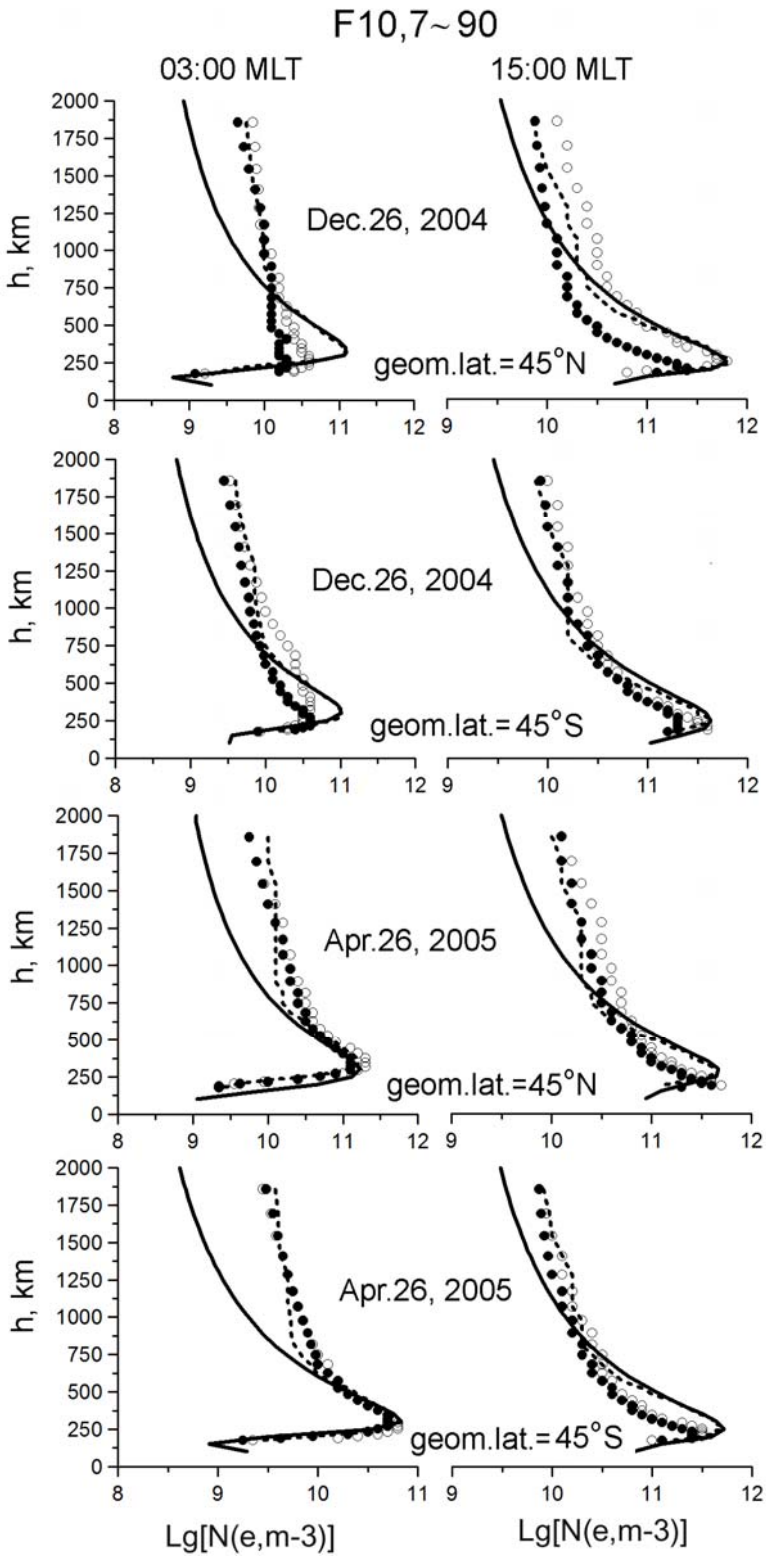

Fig.1 Height variations of electron density common logarithm calculated by the UAM-TM(white circles), the UAM-TT(black circles), the IRI-2007(dotted lines), the IRI-2012(solid lines) for the solstice of December 26, 2004 and the equinox of April 26, 2005 (low solar activity).

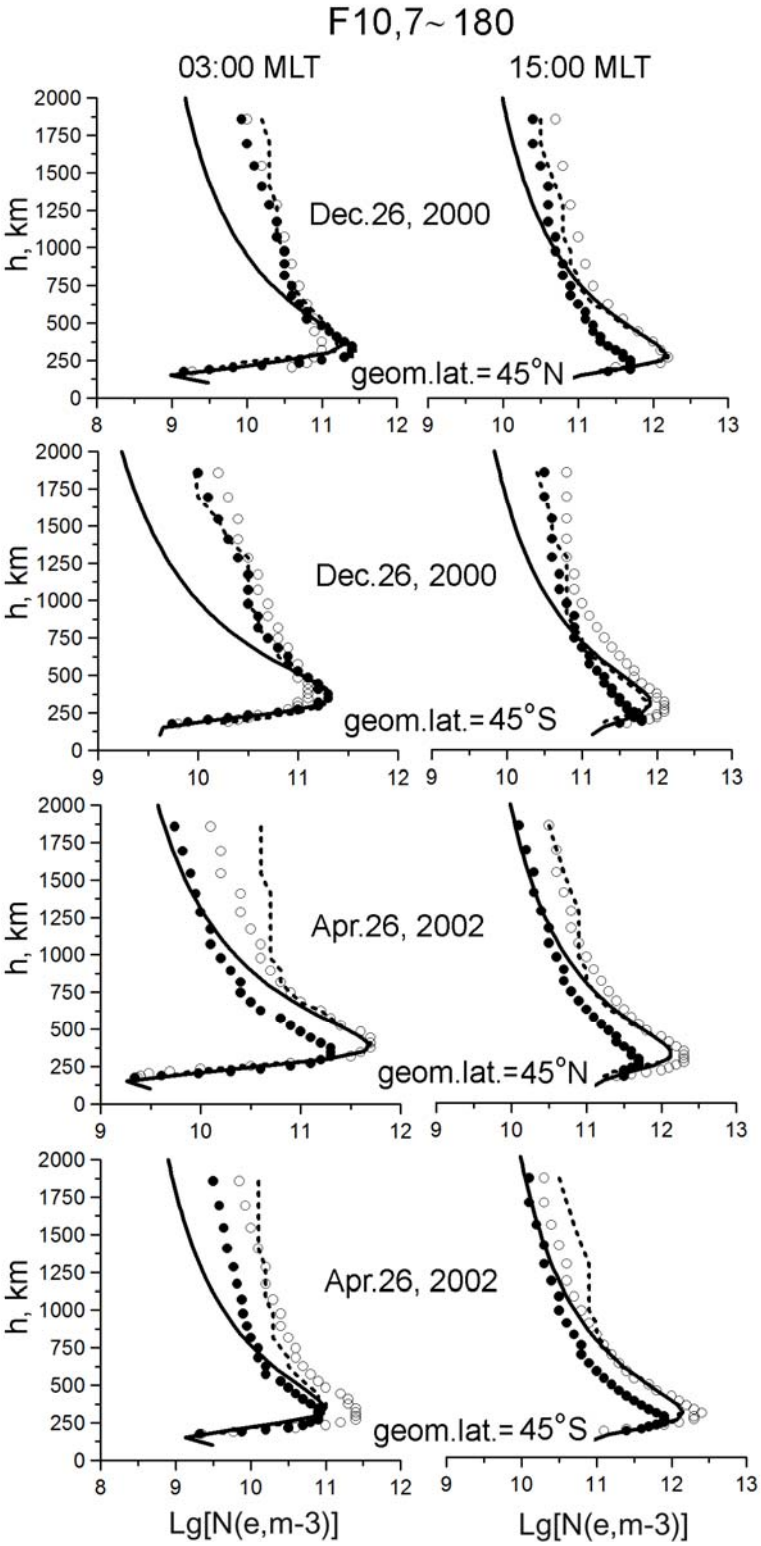

Fig.2 Height variations of electron density common logarithm calculated by the UAM-TM(white circles), the UAM-TT(black circles), the IRI-2007(dotted lines), the IRI-2012(solid lines) for the solstice of December 26, 2000 and the equinox of April 26, 2002 (high solar activity).