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THE ROLE OF ELECTRIC FIELDS AND MAGNETOSPHERIC ELECTRON PRECIPITATIONS FOR THE FORMATION OF THE EQUATORIAL TOTAL MASS DENSITY MINIMUM

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Abstract
The global theoretical Upper Atmosphere Model (UAM) shows a minimum of the thermospheric total mass density near the geomagnetic equator similar to that obtained by the accelerometer on board the CHAMP satellite. The empirical thermospheric model NRLMSISE-00 does not show this minimum. We have investigated the role of electric fields and magnetospheric electron precipitations for the formation of this daytime minimum by successive switching off the low and high latitude electric fields and the magnetospheric electron precipitations within the UAM calculations. We conclude that the high latitude magnetospheric heating is the likely reason of the daytime thermospheric density minimum near the equator.

Introduction
The global distribution of the thermospheric total mass density at 400 km altitude derived from the CHAMP satellite accelerometer shows maxima at about 20-25 degrees of geomagnetic latitude on both sides of the magnetic equator and the corresponding minimum at the magnetic equator between 10 and 20 magnetic local time, whereas the empirical thermospheric model MSIS90 does not reveal such dayside behaviour [H. Liu et al., 2005]. The authors assumed the equatorial anomaly as a possible reason of such dayside density structure.
We investigated this phenomena using the global numerical Upper Atmosphere Model of the Earth (UAM) [Namgaladze et al., 1991; Namgaladze et al., 1998] and empirical thermospheric model NRLMSISE-00 (afterward MSISE) [Picone et al., 2002]. UAM describes the thermosphere-ionosphere-plasmasphere system by means of numerical integration of the time-dependent 3D continuity, momentum and heat balance equations for neutral, ion and electron gases and the equation for the electric potential.
UAM was tested for the April 2002 magnetic storm events by comparison with the ionospheric data of seven incoherent scatter radars. The comparisons have shown that the theoretical thermosphere-ionosphere model (UAM) gives a better agreement between the model ionosphere results and ISR data than in the case when the empirical thermosphere model (MSISE) incorporated in the UAM is used for the calculations of the ionospheric parameters [Namgaladze et al., 2006].
We have investigated the influence of the low and high latitude electric fields and magnetospheric electron precipitations on the formation of the equatorial density minimum by successive switching off these factors within the UAM calculations.

Results
The calculation results are presented in Fig. 1, 2 as the global maps of latitude-longitudinal distribution of the total mass density and neutral temperature at the height of 400 km.
Fig. 1 shows the global maps of total neutral mass density for four UT moments in the "magnetic longitude – magnetic latitude" co-ordinates: 06 UT corresponds to the quiet conditions of April, 15, 2002, and the 12, 18 and 24 UT of April, 18, 2002 – to the disturbed ones.
The left column presents the MSISE results. The other three columns show the theoretical UAM results for three versions of calculations. The first one (UAM 1) is our standard calculation. In the second calculation (UAM 2) we switch off the low-latitude electric field (equatorward 30 degrees of magnetic latitude). In the third calculation (UAM 3) we switch off both total electric field and magnetospheric electron precipitations.
The calculation results with MSISE show only one neutral density maximum near the equator in the post-noon sector. An increase of the geomagnetic activity leads to the global increase of the density.
The results of the numerical experiments with the UAM show the dayside minimum of the total mass density near the equator in the UAM 1 and UAM 2 versions of calculations in agreement with global thermospheric total mass density distribution obtained by CHAMP satellite.

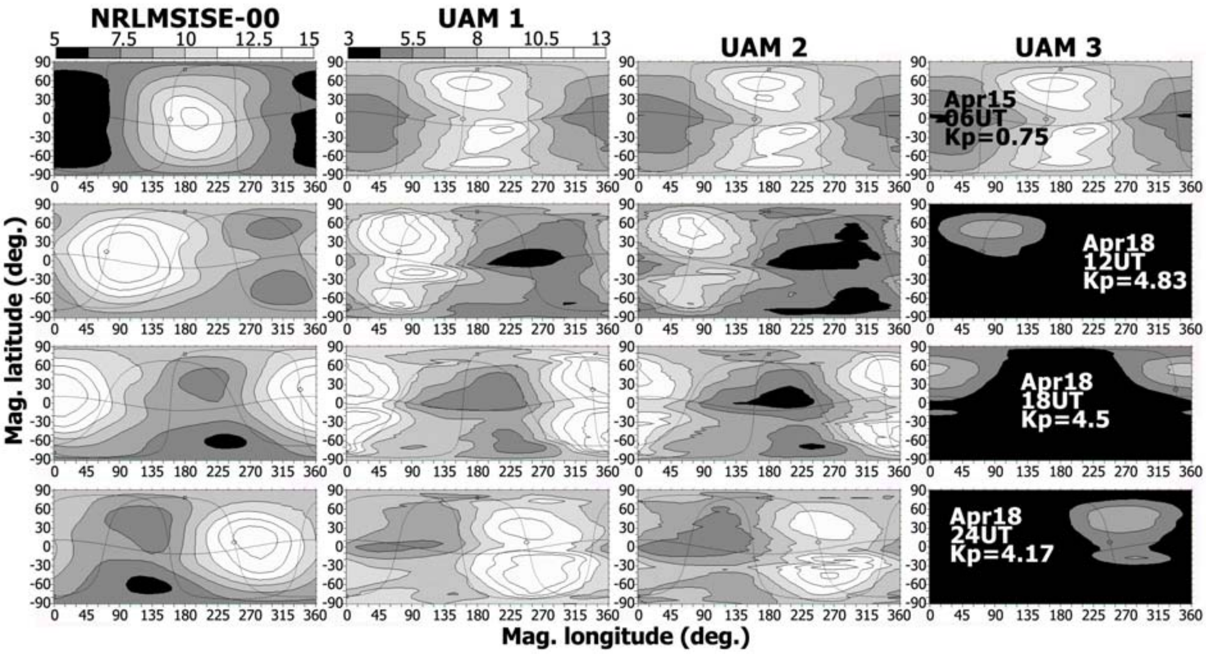

Fig. 1. Global distribution of total mass density (10^{-12}, kg/m^3), h=400 km.
UAM 1 – standard calculation
UAM 2 – calculation without low-latitude electric field
UAM 3 – calculation without total electric field and electron precipitations

In the full version of the UAM calculation (UAM 1) there is an evident density minimum near the geomagnetic equator between two maxima both in quiet and disturbed conditions. The density peaks are located at middle latitudes being larger in the Northern hemisphere under geomagnetically quiet conditions and in the Southern hemisphere under geomagnetically disturbed conditions. In the simulation without low-latitude electric field (UAM 2), neutral density distribution has not changed principally.

Another pattern takes place after switching off the high latitude electric fields and magnetospheric electron precipitations (UAM 3): the equatorial neutral mass density minimum disappeared and only one daytime density maximum persists, being displaced into the Northern hemisphere.

Fig. 2 shows the global distribution of the neutral temperature in the same form as Fig. 1.

The MSISE model shows only one temperature maximum in the post-noon sector in the quiet conditions. In the disturbed condition, the energy source in the polar areas prevails over usual dayside solar heating source. As a result the temperature minimum at the middle latitude of southern hemisphere appears. But there is no such feature in the density distribution where the only equatorial maximum exists.

In the UAM simulation, the temperature increases with the rise of the geomagnetic activity, especially in the northern hemisphere. In opposition to MSISE, in the UAM results the latitudinal variation prevails over the longitudinal both in quiet and storm conditions.

The picture remains still the same when we switch off the low-latitude electric field (UAM 2). In model calculation with full elimination of the electric field and magnetospheric electron precipitations (UAM 3) we see again the only maximum near subsolar point, as in density plots. Some increase of the temperature in the storm time was generated by the increase of the solar UV radiation calculated according to F10.7 index.

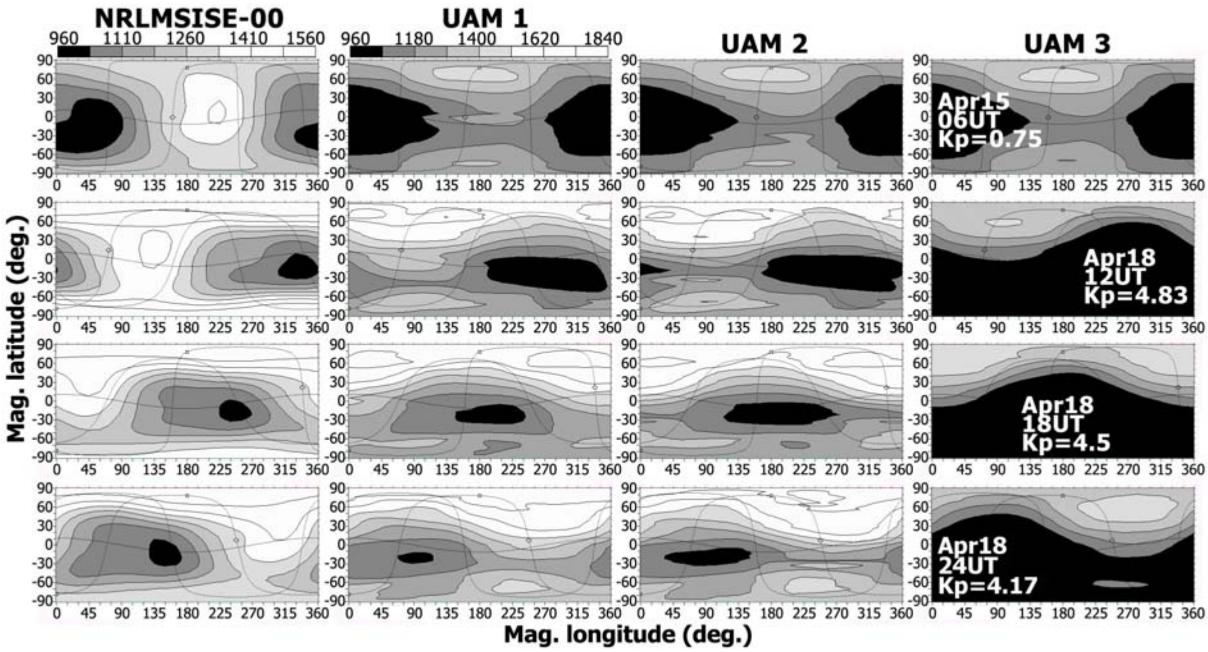

Fig. 2. Global distribution of neutral temperature (K), h=400 km.
UAM 1 – standard calculation
UAM 2 – calculation without low-latitude electric field
UAM 3 – calculation without total electric field and electron precipitations

Conclusions

The UAM results reproduce the daytime neutral density minimum near the magnetic equator in agreement with the CHAMP satellite results.

The daytime density peaks calculated by the UAM are located at middle latitudes. They are larger in the Northern hemisphere under quiet magnetic conditions and in the Southern hemisphere under disturbed conditions.

The neutral density distribution does not change principally after switching off the electric fields at magnetic latitudes below 30 degrees whereas the equatorial anomaly of the electron density disappears. Therefore, the equatorial neutral density minimum is apparently not related to the equatorial anomaly.

After switching off the total electric fields and magnetospheric electron precipitations the equatorial neutral mass density minimum disappears and only one daytime density maximum persists, being displaced into the Northern hemisphere.

We conclude that the high latitude magnetospheric heating is the likely reason of the daytime thermospheric density minimum near the equator. We assume that it is a result of the interference of the large scale atmospheric waves generated by the high latitude sources.

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