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GLOBAL IONOSPHERE-PROTONOSPHERE STORM MODELING

A.A.Namgaladze [1,2], R.Yu.Yurik [1,2]
[1] *Murmansk State Technical University, 13 Sportivnaya Str., Murmansk, 183010, e-mail: namgaladze@mstu.edu.ru;*
[2] *Polar Geophysical Institute, 14 Halturina Str., Murmansk, 183010.*

Abstract. The global patterns of the protonospheric and ionospheric effects of the strong magnetic storm of April, 3,1979 have been obtained by the numerical simulation using the global upper atmosphere model. The cross-polar cap electric potential served as the main model input parameter. The results of the numerical simulation show the coupled LT-depending storm dynamics of the ionospheric F2-layer troughs and plasmapause for different MLT sectors. The ion "hot zone" in the outer nightside plasmasphere has been obtained as a result of the heating by the contraction of the plasma during its electromagnetic drift when the plasma moves into the regions where the volume of the tube is smaller.

Introduction

During geomagnetic storms, the enhanced magnetospheric energy transferred into the ionosphere via the electric fields penetration and the energetic electron precipitation causing the changes in the regular distribution of the thermospheric and ionospheric parameters (so-called thermospheric and ionospheric storms). Earlier, we investigated only the thermospheric and ionospheric effects of geomagnetic storms related to the thermospheric gas composition and wind disturbances (*Namgaladze et al.*, 1998) but it is well-known from the observations that the plasmasphere is changed during geomagnetic storms as well (*Gringauz and Bassolo*, 1990). The present investigation concerns mainly the storm-time behaviour of the plasmaspheric electron concentration and ion temperature related to the plasma drift and geomagnetic field tube filling and depletion processes.

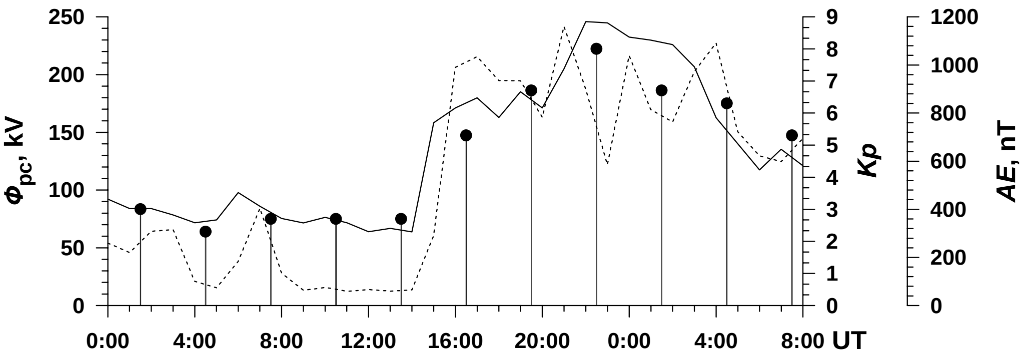

Fig 1. Electric potential drop across the polar cap Φ_{pc} (kV) used as input in the model calculations according to *Boyle et al.*, 1997 (solid curve), *AE* index value (doted curve) and *Kp* index (black circles) for 3-4 April 1979.

Calculations

Our calculations were performed for the intense geomagnetic storm of 3-4 April 1979. The sudden storm beginning took place at 1001 UT. The peak value of the D_{st} was –202 нT at 0300 UT on April,4, 1979. The peak value of the *Kp* was 8 at 21-24 UT on April,3. Solar radio flux F10.7 adjusted at 1AU was 194.2 10^{-22} W/m^2/Hz on April, 3 1979.

The global upper atmosphere model (UAM) were used in our numerical calculations. This model is the theoretical self-consistent three-dimensional time-dependent model (*Namgaladze et al.*, 1988,1998) which considers the thermosphere, ionosphere and protonosphere of the Earth as a single system. It covers the height range from 60 km up to 15 Earth radii of geocentric distance and takes into account the offset between the geomagnetic and geographic axes of the Earth. The model solves numerically the full system of the hydrodynamical equations (continuity, momentum and heat balance equations) as well as the electric field potential equation by the finite difference methods. It calculates the temperature, mass density, gas composition and winds for the neutral atmosphere and electron and ion temperatures, molecular and atomic ion densities and velocities for the ionosphere and plasmasphere. Furthermore, it calculates electric field potential both of magnetospheric and thermospheric (dynamo) origin assuming that the geomagnetic field lines are equipotential at the heights above 175 km.

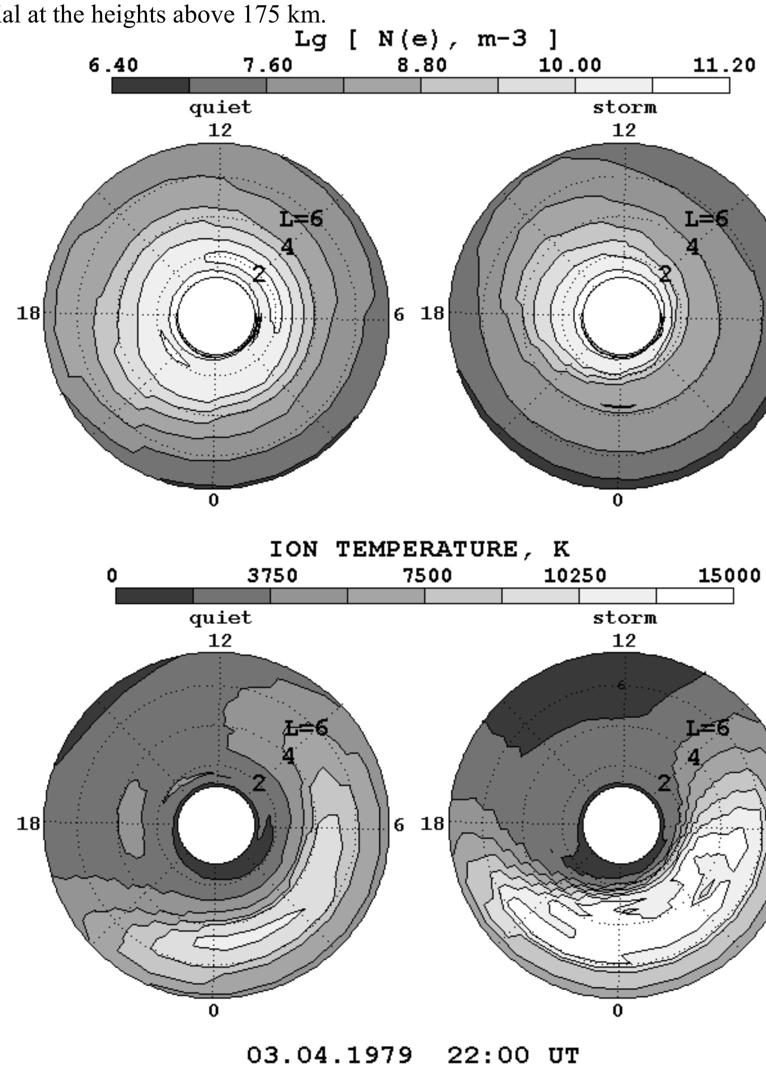

Fig 2. Electron number density and ion temperature distribution patterns at the equatorial plane as functions of the geocentric distance measured with the Earth radii and MLT for the quiet (left panels) and storm (right panels) conditions.

For the presented model calculations, the cross polar cap potential drop or corresponding zone I field-aligned current (FAC) density serve as a main model input parameter. The magnitude of zone II field-aligned current varied with the model input and was proportional to the zone I FAC as 2/5. Figure 1 shows the time variation of the potential drop cross the polar cap (Φ_{pc}) during April,3, 1979 calculated by the use of the empirical models by *Boyle et al*. (1997). For the quiet conditions (Kp=1),Φ_{pc} has been assumed constant and equal to 35 kV. Other model input parameters are the electron precipitation fluxes, values of which varied according to *Kp* similar to the precipitation patterns by *Hardy et al.* (1985).

The plasmaspheric O+ and H+ ion number densities as well as ion and electron temperatures and ion velocities have been calculated for the height range from 175 km to the radial distance of $15R_E$. The numerical integration of the equations has been done along the dipole geomagnetic field lines.

The boundary conditions have been given near the bases of the field lines in the northern and southern hemispheres at the height of 175 km. The atomic ion concentrations at this boundary have been obtained from the photochemical equilibrium conditions. The values of the ion and electron temperatures at this boundary have been calculated from the thermal equilibrium conditions. The geomagnetic field lines with $L \geq 15R_E$ (L parameter of McIlwain) have been considered as open and ion concentrations and heat fluxes are set equal to zero at $r = 15R_E$.

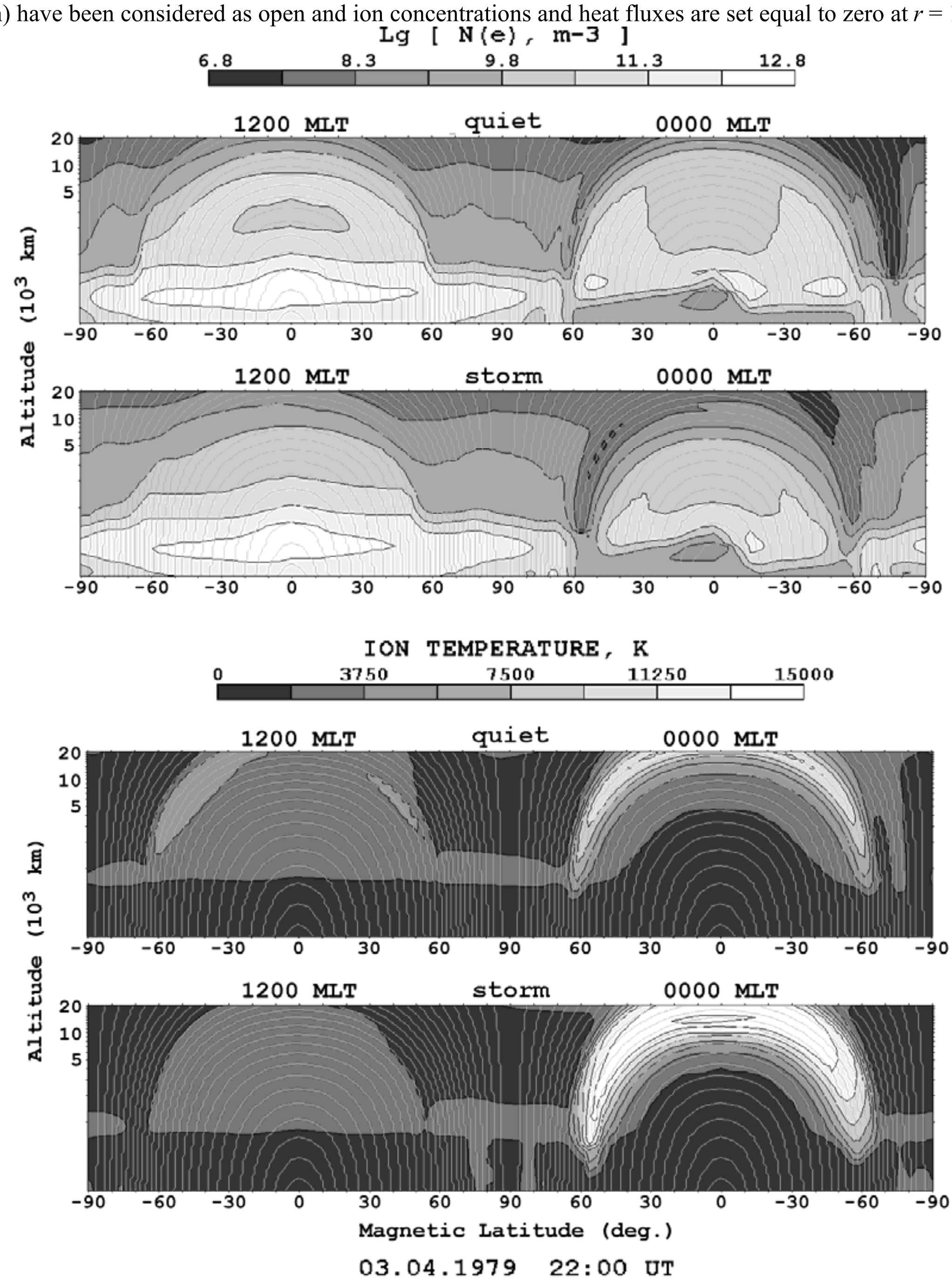

Fig 3. The electron number density and ion temperature distribution patterns at the meridian section as functions of the magnetic latitude and height for the quiet and storm conditions. The Southern pole is at the outer edges of the panels and the Northern pole is at the center of the panels. The light lines denote the geomagnetic field lines.

Results

The model simulation results are shown in Figs.2-3. Figure 2 shows the plasmasphere electron concentration and ion temperature at the geomagnetic equatorial plane for the quiet (left panels) and stormy (right panels) conditions. The plasmaspheric parameters are shown at the polar MLT – *L*-shell co-ordinate frame with *L* as a geocentric radial distance to the top of the geomagnetic field line. Sun position is at the top of the figure (1200 MLT), morning is at the right and evening is at the left side of the plots.

It can be seen that plasmasphere has the MLT asymmetry both under quiet and stormy conditions: electron concentration has greater values at the day-evening side of the plasmasphere than at the morning-night side whereas ion temperature is much higher at the night side in comparison with the day side. The plasmapause determined as the region of the sharp electron density gradient is the most remarkable at the night side (the night side gradient of the electron density is greater than the one of the day side). All these MLT features of the plasmasphere are in full agreement with the observations (*Gringauz and Bassolo*, 1990).

It is clearly seen that under the storm conditions the plasmapause moves towards the Earth as well as the boundary between cold and warm plasma (the ion temperature of which increases significantly) which is also a well-known feature of the plasmasphere (*Gringauz and Bassolo*, 1990).

Figure 3 demonstrates the plasmasphere parameters at the height-latitude section along the midday-midnight meridian. The left and right edges of the plots correspond to the Southern pole and the central part (90° magnetic latitude) corresponds to the Northern pole. The light lines denote the geomagnetic field lines. The midday meridian is at the left side of the plots and midnight is at the right side of the plots.

All above mentioned features of the plasmasphere (day-night and quiet-storm differences) are seen in this figure as well but besides that the ionospheric F2-layer troughs, light ion troughs together with the plasmapause and their storm dynamics are very well seen in the upper two panels of this figure corresponding to the quiet and stormy conditions whereas the bottom two panels demonstrate the storm dynamics of the hot ion zone (the region of the high ion temperature).

The physical mechanisms responsible for all these plasmaspheric features are the plasma drift and geomagnetic field tube filling and depletion processes. The ion "hot zone" in the outer nightside plasmasphere has been obtained as a result of the heating by the contraction of the plasma during its electromagnetic drift when the plasma moves into the regions where the volume of the tube is smaller.

Conclusions

From the obtained numerical results we can conclude that model demonstrates all well known observed plasmasphere features (*Gringauz and Bassolo*, 1990), such as 1) the MLT asymmetry of the plasmasphere; 2) the midday-midnight differences of the electron density gradients and ion temperatures; 3) the storm-time dynamics of the plasmapause and the boundary between cold and warm plasma moving Earthward during the storm. All these plasmaspheric features were reproduced in the model calculations as results of the plasma drift and geomagnetic field tube filling and depletion processes taken into account.

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