"Physics of Auroral Phenomena", Proc. XXVI Annual Seminar, Apatity, pp. 79-82 , 2003

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PLASMASPHERE STATE EFFECT IN THE POSITIVE PHASE OF THE IONOSPHERIC STORM

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Abstract

Mathematical modelling has been performed to study positive ionospheric storm dependence on the initial state of the plasmasphere. The self-consistent global model of the Earth's upper atmosphere was used. The calculation was made for the case of the geomagnetic storm of August 15, 1993. The locations of auroral precipitation and field-aligned current regions were set in agreement with the DMSP satellites data. Energy and intensity of precipitating electron fluxes were taken as functions of geomagnetic activity. A numerical experiment demonstrated that storm-induced neutral wind effect in ionospheric F2 region electron density is strongly dependent on the initial plasmasphere state, namely, on the degree of plasmaspheric tube filling.

1. Introduction

We have examined the influence of the initial plasmasphere state on ionosphere dynamics during geomagnetic storm by means of numerical modelling. The numerical self-consistent global model of the upper atmosphere - UAM (Upper Atmosphere Model, *Namgaladze et al.*, 1988; 1998) was used. We have simulated upper atmosphere effects of a real moderate geomagnetic storm under low solar activity, which took place in August 15-17, 1993. The geomagnetic *AE*-index and electric potential drop across the polar cap $\Delta\Phi_{pc}$, calculated with the use of empirical model by *Weimer et al.* (1990), are shown in Fig. 1. Two quiet days preceded the geomagnetic storm, which started after 1500 UT on August 15, 1993. At magnetic disturbance maximum the D_{st} index was approximately - 75 nT, the value of $\Delta\Phi_{pc}$ ~150 kV, and *AE* index ~1100 nT.

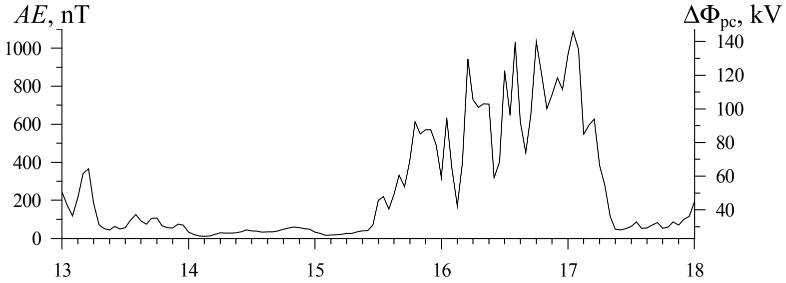

Fig.1 AE-index of geomagnetic activity and electric potential drop across the polar cap $\Delta\Phi_{pc}$ on August 13-17, 1993

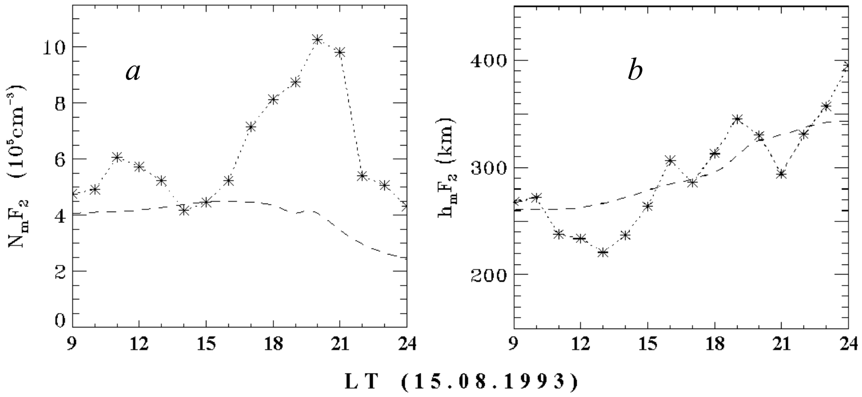

Fig. 2 Parameters of ionospheric F2-layer maximum, according to the ionosonde data at Rome station. The dotted lines with stars correspond to storm period, the dashed lines show median values. This Figure is due to courtesy of M. Förster (private communication).

At the same period, according to ionosonde observations carried out in Rome, a pronounced positive phase of the ionospheric storm began in the local evening. Fig. 2 demonstrates variations of electron concentration at F2-layer maximum N_mF2 (Fig. 2, left panel) and the height of maximum H_mF2 (Fig. 2, right panel), recorded for 09-24

LT on August 15, 1993 at ionosonde station in Rome (geomagnetic latitude 42.3° and longitude 93.2°). The time variation of N_mF2 in Fig.2 indicates a large positive ionospheric disturbance observed at 2000 LT. The variation of H_mF2 does not display any noticeable long-lasting changes around the median values but from 12 through 20 LT the values of H_mF2 are increased by more than 100 km.

2. Model inputs for numerical calculations

We have performed our investigation in the framework of numerical global self-consistent model of the Earth's upper atmosphere (*Namgaladze et al.*, 1988; 1998) with some modifications of model inputs.

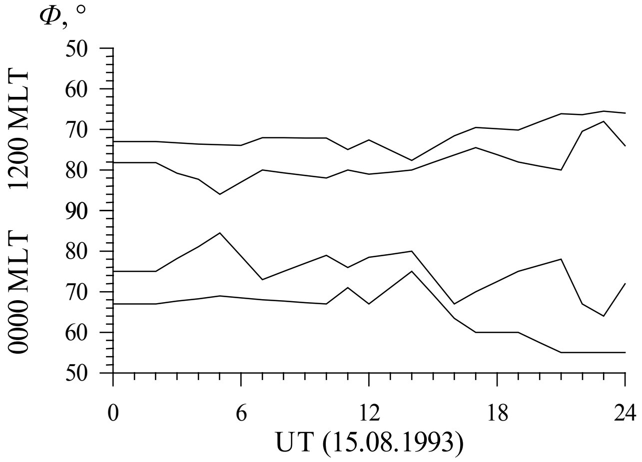

Fig. 3 Geomagnetic latitudes of auroral oval boundaries at midday (upper curves) and midnight (lower curves) magnetic meridian, according to DMSP observations.

The principle input parameters that mostly control storm development are electric potential drop across the polar cap $\Delta\Phi_{pc}$ that we have taken from the empirical model by *Weimer et al.,* (1990, see Fig. 1), and fluxes of precipitating electrons. The locations of polar cap boundary and auroral oval equatorial boundary, which in our calculations are coincident with the field-aligned currents, were set in agreement with those observed by the DMSP satellites. Grid spatial resolution was variable in latitude (2° in the vicinity of the auroral oval, and 5° and 10° near the equator for ionospheric and thermospheric parameters, respectively).

The relation between region 1/ region 2 field-aligned currents (FACs) was set in such way, that the density of region 2 FACs amounted to ~70 % of the density of region 1 FACs (*Maltsev,* 1995). The intensities of precipitating electron fluxes were set via four spectral lines according to the model of *Hardy et al.* (1985). Three of them were specified in the auroral oval, and one - inside the polar cap (so-called ‘polar rain’).

3. Plasmasphere states

We have tried to examine the effect of initial plasmasphere state in positive ionospheric storm development. It is well known that charged particle concentration in the plasmasphere grows under quiet conditions due to plasma tube filling and drops during geomagnetic disturbances in result of plasma tube depletion associated with neutral composition changes.

In Fig. 4 logarithm of electron concentration is shown in the height range from 300 to 60000 km and latitudes from northern pole (90°) to southern pole (-90°) along the Rome magnetic meridian, for 0000 UT, 1600 UT, and 2400 UT (Fig. 4 from top to bottom). The runs were performed for different initial plasmaspheric states, namely, for ‘depleted’ state (left panel) and ‘filled’ state (right panel). The version with filled magnetic tubes has been obtained from that with depleted magnetic tubes as an extension of the calculations for one day under quiet conditions (Kp = 1, $\Delta\Phi_{pc}$ =32 kV).

From Fig. 4 one can see that electron concentration in magnetic tubes at mid-latitudes is larger under ‘filled’ conditions than under ‘depleted’ conditions. Both initial plasmasphere states were used as initial conditions in geomagnetic storm modelling.

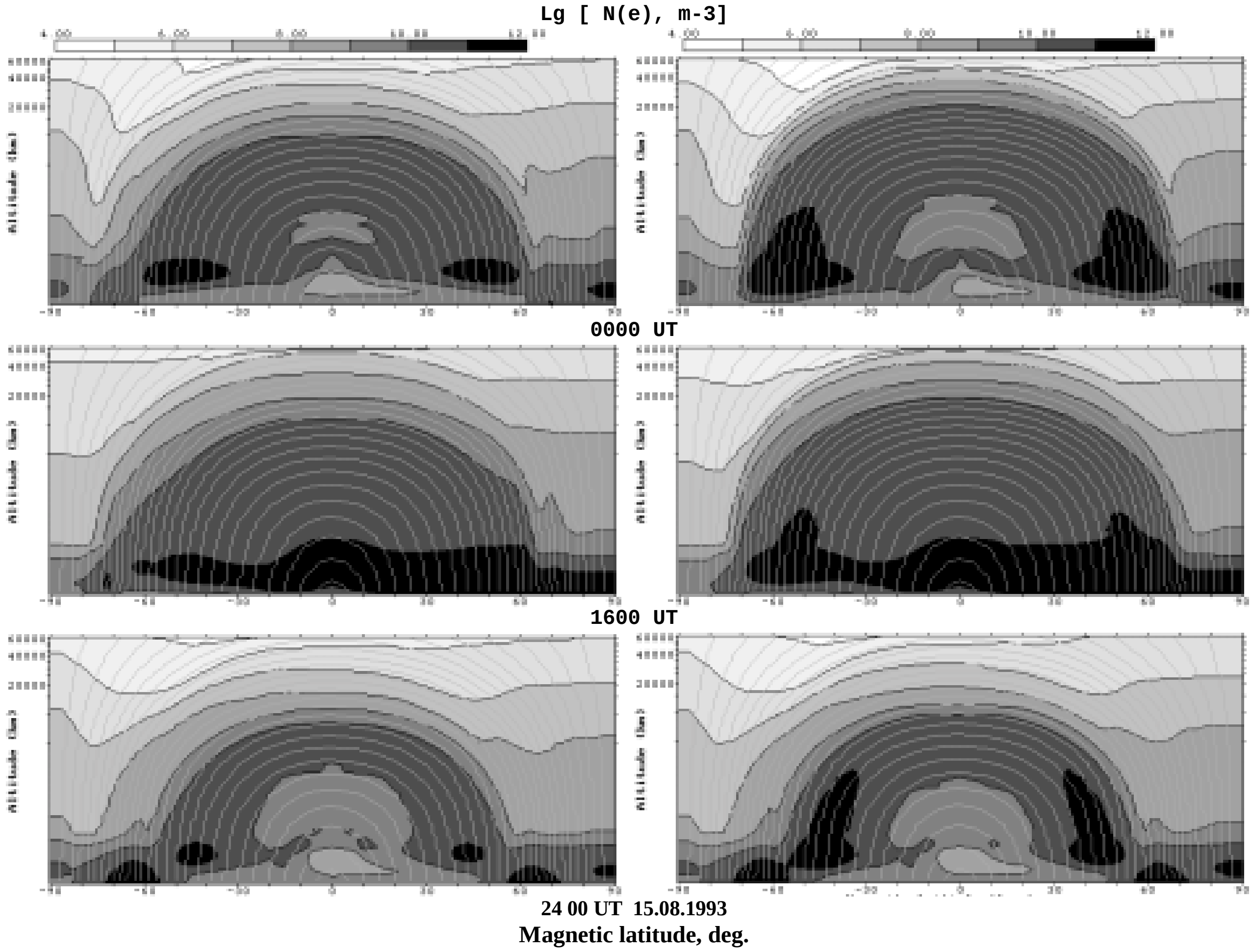

Fig. 4 Electron concentration in magnetic meridional section of the plasmasphere for three UT with initially depleted (left) and filled (right) magnetic tubes.

4. Model results on ionosphere and wind behaviour

Our previous modelling of ionosphere storm-time behaviour had shown that neutral wind plays a dominant role in formation of positive phase of ionospheric perturbation associated with geomagnetic storm (*Namgaladze et al.,* 1998). These winds blow toward the equator from high latitudes and move ionospheric plasma along geomagnetic field lines to higher altitudes, where ion losses are lower.

Figure 4 represents disturbances of the critical frequency ($\Delta foF2$) and thermospheric wind northward component (ΔV_x) in the Rome geomagnetic meridian plane for UT from 0900 to 2400 and geomagnetic latitudes from 0° to 70°. The top panel shows the results obtained in the model calculations with initially ‘depleted’ plasmasphere, and the bottom panel – with initially ‘filled’ one.

It is seen that the positive phase of ionospheric storm is very weak or absent under ‘depleted’ conditions (Fig 4, left panel), while large positive ionospheric disturbance (i.e. increase in electron density) occurs equatorward of the negative phase under ‘filled’ conditions. The meridional components of neutral wind disturbances (Fig 4, right panel) are similar under both ‘depleted’ and ‘filled’ conditions and their direction favours formation of ionospheric storm positive phase. Nonetheless, their positive ionospheric effect is much smaller in the ‘depleted’ version, in spite of larger wind magnitudes at mid-latitudes in this case.

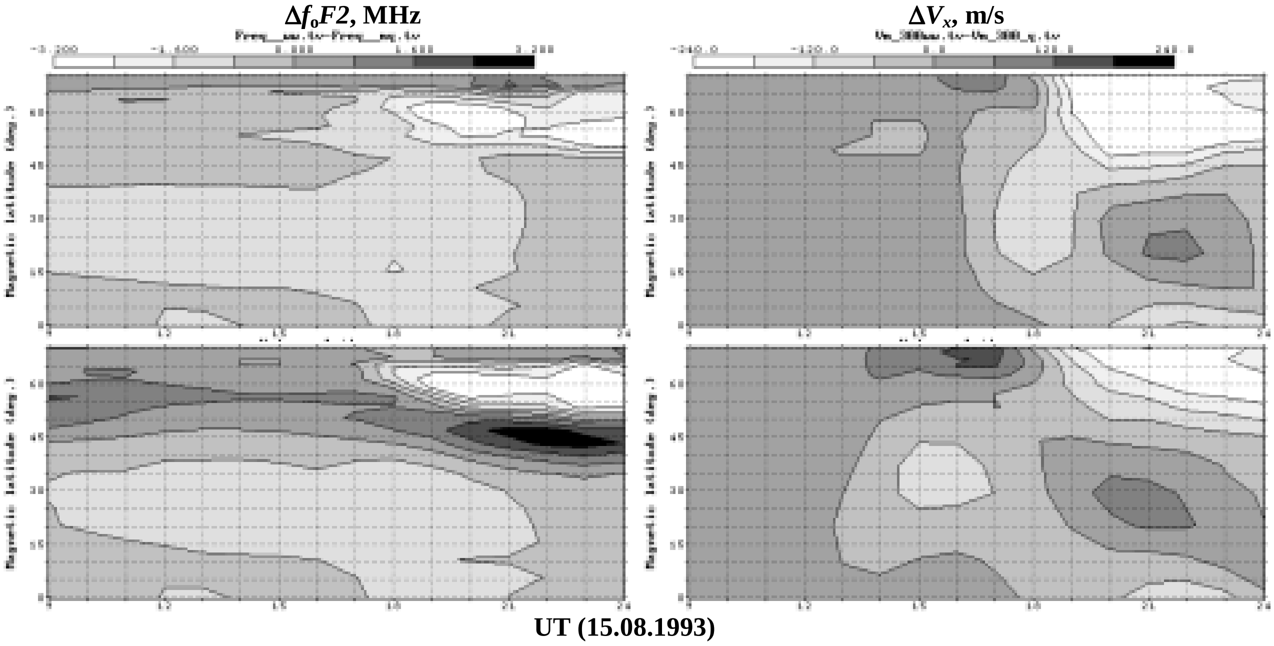

Fig. 5. Disturbances of critical frequency ($\Delta foF2$, left panel) and northward component of neutral wind velocity at 300 km altitude (ΔV_x, right panel) under ‘depleted’ (top) and ‘filled’ plasmasphere conditions.

5. Conclusion

The performed investigation demonstrates that storm-induced neutral wind effect responsible for positive ionospheric disturbance strongly depends on initial plasmasphere state, namely, on extent of plasmaspheric tube filling. The ionospheric perturbation is much stronger in case of filled plasmaspheric tubes, which then can supply charged particles to the ionosphere in the night hours due to downward plasma fluxes.

Acknowledgements. Authors thank Mattias Förster for the initiation of this investigation and for the delivered ionosonde data. This work was supported by the Grant No.02-05-64141 of Russian Foundation for Basic Research

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