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A MODEL STUDY OF THE FAC2 INFLUENCE ON THE NIGHT-TIME NE VARIATIONS OVER THE MILLSTONE OBSERVATORY DURING THE APRIL 2002 MAGNETIC STORMS

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Abstract. We continue the investigation of the F2-layer behaviour during the April 2002 magnetic storms using the Upper Atmosphere Model. The model ionospheric parameters were compared with the data of seven incoherent scatter radars and the IRI-2001 values. The worst agreement between the numerical results and the observation data took place in the night hours on April 16 and 17 when the UAM strongly underestimated the IRI and ISR electron density. The numerical experiments showed that the reason of this underestimate was connected with the difference in the electric field variations over Millstone Hill calculated by the UAM and observed by ISR and thus with the difference of the plasma drift velocities. At night on April 16 over Millstone Hill the ISR electric field caused the converging zonal plasma flow whereas the UAM field agreed with the classic convection pattern with diverging zonal plasma flow and decreasing increasing electron density.

Introduction

In our previous papers (*Namgaladze et.al.*, 2005, *Zubova et.al.*, 2007) we compared the ionospheric F2 region parameters calculated for the April, 2002 magnetic storms period using the global numerical Upper Atmosphere Model (*Namgaladze et.al.*, 1998) with the IRI-2001 (*Bilitza et.al.*, 2004) and the observation data obtained by seven incoherent scatter radars (*Goncharenko et.al.*, 2005) situated in low, middle and high latitudes of the Northern hemisphere. As a whole the UAM reproduced the ionospheric parameters behaviour more or less satisfactorily for both quiet and disturbed conditions. But the model-observation agreement needs to be improved for some time moments. For example, for night-time hours of April 16 and 17, 2002 the UAM strongly underestimates the ISR electron density over Millstone Hill.

The Millstone Hill observatory (43°N) is situated at middle geographic latitudes. The mid-latitude ionosphere is controlled mainly by the neutral composition (n(O)/n(N2)) and the thermospheric winds. The magnetic latitude of the station is subauroral (54.4°). During magnetic disturbances the auroral zone can reach Millstone Hill. Therefore the electric field variations play also a great role in the ionospheric behaviour over the observatory.

The numerical experiments showed that the reason of the pointed model-observations disagreement is not related to a possible inaccuracy of the neutral composition and temperature calculation by the UAM (*Namgaladze et.al.*, 2005).

The paper of Zubova et.al., 2007 described the numerical experiments with the incorporation of the empirical model of horizontal neutral winds HWM-93 (*Hedin et.al.*, 1996) in the UAM. The numerical calculations showed that using empirical neutral winds partly improved the agreement of the theoretically calculated Ne values with the Millstone Hill radar observations during night and morning hours of April 16, 2002.

Another possible reason of the discussed model-measurements disagreement is the discrepancy between the electric field values observed by the Millstone Hill radar and calculated by the UAM and thus between the plasma $\vec{E} \times \vec{B}$ drift velocities.

Model experiments

The electric potential distribution is calculated in the UAM by solving the equation for the electric potential. This equation has the input parameter – the potential drop across the polar cap describing voltage supplied from the solar wind. The model chooses the field-aligned currents of the zone 1 (FAC1) at the polar boundary of the auroral oval to match the input potential drop. This input drop is a result of the DMSP satellite data approximations. The FAC2 are set at the equatorial boundary of the auroral oval on the assumption that the FAC2 amplitude amounts 0.7 of the FAC1 amplitude. This assumption nearly corresponds to the results described by the work of *Maltsev and Ostapenko,* 2004. We should notice that the auroral oval boundaries are also the model input parameters and they are set by the DMSP data approximations.

We have performed the numerical experiment in order to investigate how plasma drift velocity variations influence the theoretically calculated electron density over Millstone Hill. We calculated ionospheric parameters by the UAM with the constant electric potential drop across the polar cap (Δφ) equal to 10 kV instead of variable potential drop according to the DMSP data.

Figure 1 shows time variations of the electron density at 345 km and variations of meridional (positive to the North) and zonal (positive to the East) electric field during April 15-16, 2002 over Millstone Hill calculated by the UAM with two variants of potential drop across polar cap setting (as variable according to the DMSP data and constant value equal to 10 kV) in comparison with the incoherent scatter radar data.

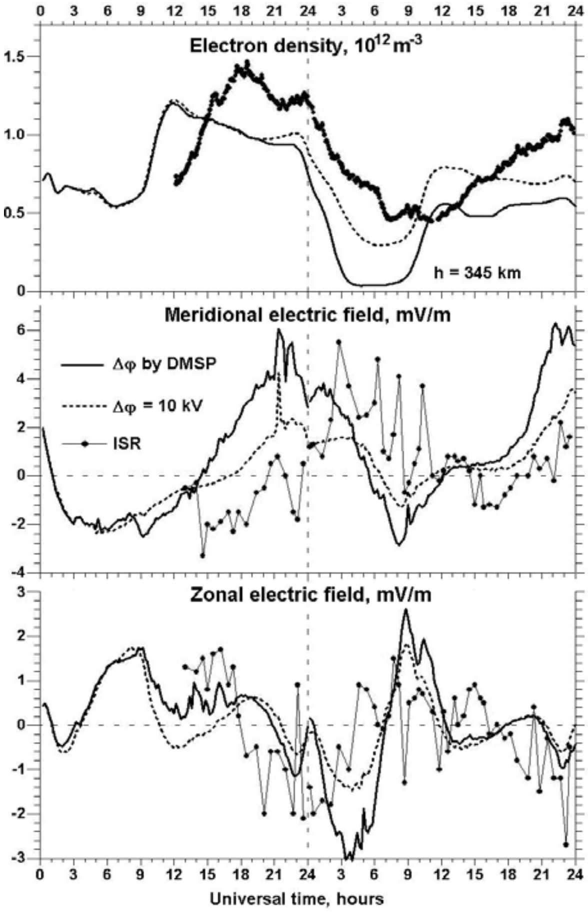

Figure 1. Time variations of the electron density at the height of 345 km (the top panel), the meridional (the middle panel) and zonal (the bottom panel) electric field over Millstone Hill calculated by the UAM with the DMSP potential drop across polar cap and the constant potential drop for April 15-16, 2002 in comparison with the observation data (marked as ISR).

Discussion

The Figure 1 demonstrates that for almost whole period of observations the UAM meridional electric field is the opposite the measured values whereas the UAM zonal electric field has the same sign as the measurements have. The most important fact is the following: at the night hours from April 15 to April 16, 2002 the measurements showed growing of the meridional electric field from negative to positive values, but the UAM gave falling of that field component to negative values for the same time period. The meridional electric field causes the zonal plasma drift: the western plasma drift corresponds to the northern electric field.

The calculation with the constant potential drop gave the meridional electric field mostly of the same sign, but of about two times lower magnitude than modeling with the variable potential drop by the DMSP data.

Besides, the Figure 1 shows that setting Δφ equal to 10 kV gave about two times lesser falling of the night values of electron density over Millstone Hill at April 16, 2002. Thus, the version with Δφ = 10 kV had the better agreement with the observation data. This fact has demonstrated that during the investigated period the electron density behaviour over Millstone Hill was determined mostly by the electric field variations.

If we imagine the convection pattern, the UAM modeled the following situation. Millstone Hill passed the western plasma drift region, got over the divergence point and reached the eastern plasma drift region. Such pattern corresponds to the usual (classical) plasma convection.

The observations are evidence of Millstone Hill passing from the eastern drift region through the convergence point to the western drift region. This situation corresponds to the “anomalous” convection pattern. Such “anomalous” convection pattern can be caused by the FAC2 forcing and its expansion to higher latitudes.

The Figure 2 shows the plasma drift velocities at the geomagnetic latitudes 50°-60° North at 05 and 06 UT of April 16, 2002 calculated by the UAM with the DMSP potential drop.

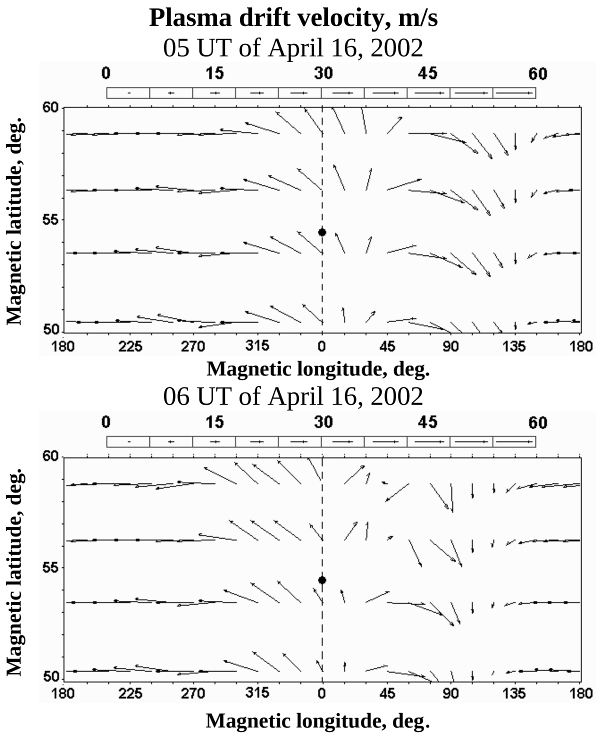

Figure 2. Time variation of the plasma drift velocity at the magnetic latitudes 50°-60° at 05 UT (top) and 06 UT (bottom) of April 16, 2002 calculated by the UAM with the DMSP potential drop

As we can see in the Figure 2, the calculation with the DMSP potential drop gave Millstone Hill passing the divergence zone between 05 and 06 UT. This corresponds to the model meridional electric field values which changed the sign from plus to minus at about 5:30 UT and with the electron density variation which had the minimum at about 6 UT of April 16. The calculation with the constant potential drop demonstrated the divergence zone over Millstone Hill at about 06 UT but gave lesser drift velocities than modeled by the version with the DMSP drop.

Conclusion

The electric field observations over Millstone Hill are evidence that during the night and morning hours of April 16, 2002 the field-aligned currents of the zone 2 caused a transformation of the convection pattern. The originated "anomalous" convection pattern managed plasma to gather around Millstone Hill due to the electromagnetic drift and to keep high the night F2 region.

The UAM gave the classical convection pattern for the night and morning hours of April 16, 2002. Such convection pattern caused passing of Millstone Hill through the region of plasma diverging which leaded to sharp decreasing of the F2 region electron density values after sunset.

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