MODEL INTERPRETATION OF THE UNUSUAL F-REGION NIGHT-TIME ELECTRON DENSITY BEHAVIOUR OBSERVED BY THE MILLSTONE HILL INCOHERENT SCATTER RADAR ON APRIL 16-17, 2002

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Abstract. The numerical experiments with the global numerical Upper Atmosphere Model (UAM) have showed that the mechanism of the unusual night-time F-layer electron density enhancement over Millstone Hill was related to the zonal plasma drift caused by the convection electric field. The electric field values observed during the night hours of April 16 and 17, 2002 in Millstone Hill corresponded to the “anomalous” convection pattern with the converging zonal plasma flow, which succeeded to increase the night-time F2 electron density. Such convection pattern could occur when the FAC2 had intensified and extended to the middle latitudes. The UAM has produced the “classical” convection pattern with diverging zonal plasma flow, which decreased the electron density over Millstone Hill during that period. This explains the fact that the model F2-layer electron density strongly underestimated the measurements performed by the Millstone Hill radar during the night hours of April 16-17.

Introduction

We have investigated the F2-layer behaviour during the April 2002 magnetic storms using the global numerical Upper Atmosphere Model [Namgaladze et al., 1998]. The behaviour of electron density (Ne), ion temperature (Ti), electron temperature (Te) during April 15-20, 2002 has been modeled by two versions of the UAM. The version UAM(TM) solved the continuity and heat balance equations in order to obtain neutral composition and temperature, the version UAM(MSISE) calculated the thermospheric composition and temperature using the empirical model NRLMSISE-00 [Picone et al., 2002]. The calculated ionospheric parameters have been compared with the data of seven incoherent scatter radars (ISR) [Goncharenko et al., 2005] and the IRI-2001 [Bilitza et al., 2004] results. The worst agreement between the UAM results and the observation data took place for the night hours on April 16 and 17, 2002 over Millstone Hill when the numerical model strongly underestimated the ISR electron density (see Figure 1). The empirical model IRI also underestimated the night-time F2-layer electron density, so the F2-layer behaviour observed over Millstone Hill during that period can be described as “unusual”.

![Figure 1](image-url)

Figure 1. Time variations of the electron density over Millstone Hill calculated by the UAM(TM) and UAM(MSISE) for April 15-17, 2002 in comparison with the observation data.
The Millstone Hill observatory (43°N) is situated in the middle geographic latitudes. The mid-latitude ionosphere behaviour depends mainly on the neutral composition (n(O)/n(N2)) and the thermospheric winds. However, the magnetic latitude of the station is subauroral (54.4° mag.lat.). So the electric field variations and hence the ion drift velocities play also a great role in the ionospheric behaviour over the observatory.

**Recent results**

The reason of the poor agreement of the model results with the measurements during the night and morning hours of April 16 and 17, 2002 in Millstone Hill was not related to the neutral composition calculation in the UAM [Namgaladze et al., 2005]. Zubova et al., 2007 described the results of the model experiments, in which the neutral wind velocities were calculated using the empirical model HWM-93 [Hedin et al., 1996]. The comparisons with the observation data obtained by seven incoherent scatter radars showed that using of the HWM-93 winds did not improve the agreement between the model results and measurements, only several details of the F2-layer behaviour may be attributed to the influence of the winds calculated in the UAM. The Figure 2 shows that using the HWM thermospheric winds improved the agreement of the UAM results with the Ne values observed in Millstone Hill, but only partially.

![Figure 2. Time variations of the electron density over Millstone Hill calculated by the UAM(TM) and UAM(TM-HWM) for April 15-17, 2002 in comparison with the observation data.](image)

**Model calculations**

The UAM calculates the electric field as the electric potential gradient. The electric potential is calculated in the UAM by solving the Poisson equation. The potential drop across the polar cap describing voltage supplied from the solar wind is used as a boundary condition of the equation. In the version UAM(TM) the potential drop is set according to the DMSP satellite data approximations.

We have performed the numerical experiments in order to estimate the electric field influence on the F2-layer behaviour in Millstone Hill.

We calculated the ionospheric parameters (Ne, Ti and Te) and the electric field values for April 15-17, 2002 using two versions of the UAM with the theoretical neutral composition and temperature:

- with the potential drop across the polar cap taken from the DMSP satellite data (used in the previous calculations) – marked as UAM(DMSP);
- with the constant potential drop equal to 10 kV - marked as UAM(10 kV).

We have compared the model results with the measurement data (see Figure 3 and Figure 4).
Another numerical experiment was related to changing the field-aligned currents (FAC) position. The ionospheric parameters and the electric field were calculated using two versions of the UAM with the theoretical neutral composition and temperature:

- with the FAC1 at 75° mag.lat., the FAC2 at 70° mag.lat.;
- with the FAC1 at 80° mag.lat., the FAC2 at 75° mag.lat.

In the base version UAM(TM) the FAC1 were set at the polar boundary and the FAC2 - at the equatorial boundary of the auroral oval. The boundaries of the auroral oval were taken from the DMSP satellite data approximations and amounted on average 73° (the polar boundary) and 66° (the equatorial boundary) for the modeled period.

The results of the calculations are presented in Figure 5 and Figure 6.
Figure 6. Time variations of the electron density over Millstone Hill calculated by the UAM with various FAC positions for April 16-17, 2002 in comparison with the observation data.

Discussion

In Figure 3 we can see that the UAM(TM) northward electric field was opposite to the observed values during the most part of the modeled period. The Millstone Hill measurements demonstrate the northward electric field component increasing from April 15 to 16 and during the night hours of April 17 while this component is decreasing to negative values in the UAM results. It means that during the first hours of April 16 and 17, 2002 the real electric field over Millstone Hill caused the ion drift to change its direction from eastward to westward. But the northward electric field calculated by the UAM(TM) changed the ion drift direction from westward to eastward (see Figure 7). The UAM version with $\Delta\phi = 10$ kV gives lower ion drift velocities and hence produces a slower plasma flow. Figure 3 shows that the UAM version with $\Delta\phi = 10$ kV has a better agreement with the ISR data because of a less Ne decrease during the night hours of April 16 and 17, 2002.

Figure 7. Time variation of the plasma drift velocity at the magnetic latitudes 50°-60° at 05 UT (left) and 06 UT (right) of April 16, 2002 calculated by the UAM(TM)

So, at night on April 16 and 17 over Millstone Hill the real electric field corresponded to the “anomalous” convection pattern with the converging zonal plasma flow, which succeeded to support the night-time F2 electron density. The UAM produced the “classical” convection pattern with diverging zonal plasma flow, which decreased the electron density over Millstone Hill during this period. The “anomalous” convection pattern could be caused by the FAC2 moving to higher latitudes.

As we can see in Figure 5, the northward electric field values calculated with setting the FAC1 at 80° mag.lat., the FAC2 at 75° mag.lat. had the time variations very similar to the observed variations. The Figure 6 shows that setting the FACs at higher magnetic latitudes than in the base version UAM(TM) improved the agreement between the model results and the electron density observed during the night hours of April 16 and 17, 2002. The best agreement with the ISR electron density belongs to the version with the FACs at magnetic latitudes 80°-75°.
Conclusion
The numerical experiments have showed that the reason of the poor model-measurement agreement was the difference in the electric field variations over Millstone Hill calculated by the UAM and observed by ISR and thus the difference of the plasma drift velocities. At the night hours of April 16 and 17, 2002 the field-aligned currents of the second zone moved to higher latitudes and acted so that the real electric field over Millstone Hill caused the converging zonal plasma flow. The electric field calculated by the UAM for the same time period agreed with the classic convection pattern with diverging zonal plasma flow decreasing electron density.

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References