"Physics of Auroral Phenomena", Proc. XXX Annual Seminar, Apatity, pp. 202 - 204, 2007
© Kola Science Centre, Russian Academy of Science, 2007
Polar Geophysical Institute

# A MODEL STUDY OF THE WIND INFLUENCE ON THE IONOSPHERIC F2-LAYER BEHAVIOUR DURING THE APRIL 2002 MAGNETIC STORMS

Yu.V. Zubova[1], A.A. Namgaladze[1], L.P. Goncharenko[2]

[1]*Murmansk State Technical University, Murmansk, Russia; namgaladze@mstu.edu.ru*
[2]*Massachusetts Institute of Technology, Haystack Observatory, Westford, MA, USA*

**Abstract.** The ionospheric F2 layer parameters were calculated by the Upper Atmosphere Model (UAM) for the period of April 15-20, 2002 including the geomagnetically disturbed days. The calculations have been performed in four versions with the same initial conditions: 1) with the NRLMSISE-00 neutral composition and temperature data and the theoretically calculated neutral wind velocities; 2) with the NRLMSISE-00 neutral composition and temperature data and the horizontal neutral wind velocities calculated by the empirical model HWM-93; 3) with the neutral composition, temperature and wind velocities calculated by the UAM fully self-consistently; 4) with the theoretically calculated neutral composition and temperature, but with the horizontal neutral wind velocities calculated by the HWM-93. The modelling results were compared with the observation data obtained by seven incoherent scatter radars located at high, middle and low latitudes of the Northern Hemisphere. The comparisons 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.

## Introduction

We continue to investigate the ionosphere behaviour during the great magnetic storms of April 2002 using the method of mathematical modelling. The disturbed period of April 2002 included several successive magnetic storms. The storms were predicted in advance and that allowed to organize ionospheric parameters observations by seven incoherent scatter radars (ISR) situated at low, middle and high latitudes of the Northern Hemisphere. The radars operated jointly not only during the storm time, but also in the preceding quite days.

We compared the model results obtained by the global numerical Upper Atmosphere Model (UAM) (Namgaladze et.al., 1998) for the April 2002 period with the observation data and the International Reference Ionosphere (Bilitza et.al., 2004) values in the previous papers (Namgaladze et.al., 2003, 2005). It was shown that as a whole the UAM reproduced the ionospheric parameters behaviour more or less satisfactorily for the quiet days and the disturbed conditions. But the model-observation agreement needs to be improved for some time moments, for example, nighttime hours of April 16 and 17, 2002 over Millstone Hill, when the UAM strongly underestimates the ISR electron density.

In this paper we investigate the influence produced by thermospheric wind calculation method on the ionosphere parameters calculated by the UAM for the April, 2002 magnetic storms period.

## Model calculations

The global numerical Upper Atmosphere Model (UAM) was initially developed in the West Department of IZMIRAN (Namgaladze et.al., 1988) and later modified in the Polar Geophysical Institute and the Murmansk State Technical University (Namgaladze et.al., 1998). The model calculates the time-dependent global three-dimensional distributions of the temperatures, vector velocities and densities of neutral components ($O_2$, $N_2$, O), atomic ($O^+$, $H^+$) and molecular ($N_2^+$, $O_2^+$, $NO^+$) ions and electrons and the electric field potential. The UAM has been described in more details in Namgaladze et.al., (1988, 1998). One of the main features of the UAM is the ability to use the empirical models NRLMSISE-00 (Picone J. M. et.al., 2002), HWM-93 (Hedin et.al., 1996) and IRI-2001 for the neutral composition and temperature, thermospheric wind velocity, ionospheric parameters calculation correspondingly in various combinations with theoretical equations solving.

The ionospheric parameters behaviour during April 15-18, 2002 was calculated by the UAM in the following four versions: 1) with the NRLMSISE-00 neutral composition and temperature and theoretically calculated neutral wind velocity (marked as MSISE); 2) with the NRLMSISE-00 neutral composition and temperature, but with the HWM-93 neutral wind velocity (marked as MSISE-HWM); 3) with the fully self-consistent theoretical calculation of neutral composition, temperature and wind velocity (marked as TM); 4) with the theoretical calculation of neutral composition and temperature, but with the HWM-93 neutral wind velocity (marked as TM-HWM). All versions started from the same initial parameters – the distributions of thermospheric, ionospheric and electric field parameters for 24 UT April 14, 2002 calculated by the UAM. The input parameters were also the same for all versions: the energetic electron precipitation parameters and the electric potentials drop across the polar cap were taken according the DMSP data (Zubova et.al., 2003). The loss rate of O+

in the reactions with the vibrationally excited molecules N2 was taken from Pavlov (1988).

## Model results

The time variations of the model electron density and northward wind velocity during April 15-18 are shown in Figures 1-3 for Irkutsk, Kharkov and Millstone Hill for the height of ~350 km. The model results obtained by the described four versions of the UAM calculations are comparing with the measurements (ISR data). The horizontal neutral wind velocity obtained in the Millstone Hill observatory was calculated from the radar measured values of the electric field and ion drift velocity.

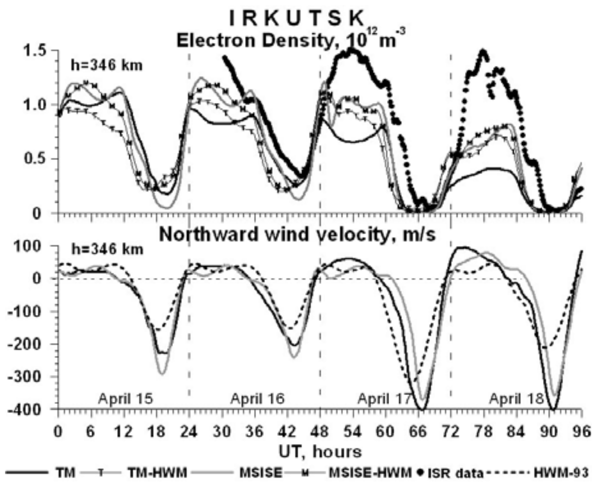


**Figure 1.** Time variation of the electron density and northward wind velocity during April 15-18 at h=346 km calculated by the UAM for Irkutsk and observed by the IS radar

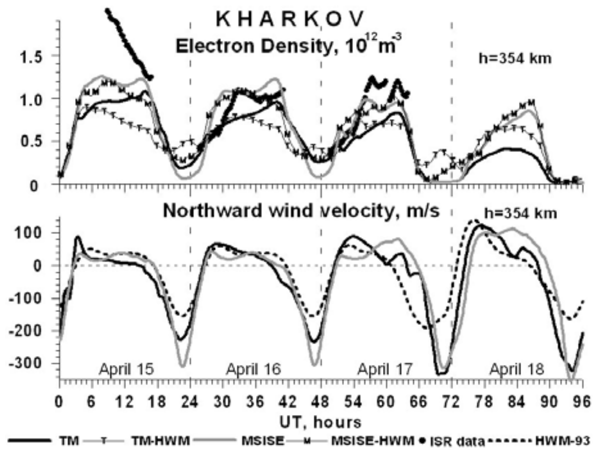


**Figure 2**. Time variation of the electron density and northward wind velocity during April 15-18 at h = 354 km calculated by the UAM for Kharkov and observed by the IS radar

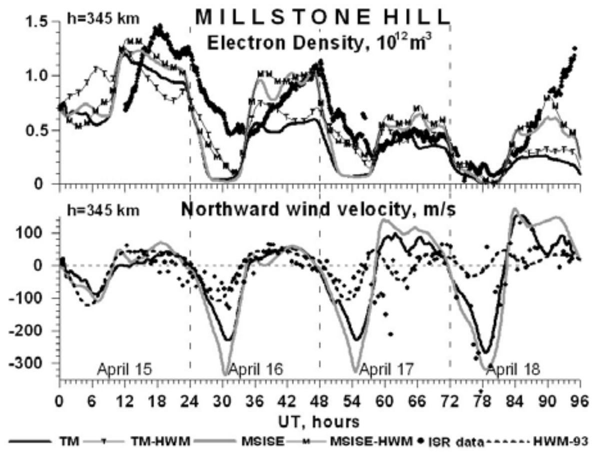


**Figure 3.** Time variation of the electron density and northward wind velocity during April 15-18 at h = 345 km calculated by the UAM for Millstone Hill and observed by the IS radar

As our calculations show, the influence of the wind calculation method on electron density values is the strongest for the middle latitudes. This fact can be explained by the vertical plasma transport by the thermospheric wind. The effect of such transport is the greatest at the middle latitudes where the angle between the geomagnetic lines and the horizontal wind vector is about 45 degrees.

The model results for April 19-20 are not presented in the figures because the electron density behaviour on these days is very similar to the April 18 one.

Figures 1-3 show that the northward wind velocities calculated by different UAM versions and the empirical model HWM-93 for all ISR locations have the same order during the day hours. The velocity values are about 20-100 m/s at that time. During the short night-time intervals (of about 3-4 hours) the difference between wind velocities becomes greater and can reach ~200-250 m/s. The HWM-93 gives the lowest values of the wind velocity (about 100-150 m/s) and the UAM winds can reach 300-400 m/s.

The electron density values of the versions MSISE and MSISE-HWM differ less than those of the versions with the “theoretical thermosphere”. The thermosphere wind influences on the electron density only by ion drag in the calculations with the empirical neutral composition and temperature taken from the NRLMSISE. In the calculations with “theoretical thermosphere” the thermosphere wind influences on the electron density not only directly by momentum transfer via ion-neutral collisions, but also changing neutral composition and temperature.

In Figure 1 we can see that the Ne values calculated for Irkutsk in the versions with the HWM-93 winds differ from each other to a lesser degree than Ne of the versions with theoretically calculated winds. The TM version gives the largest negative storm effect, but the storm effect in the TM-HWM calculation is like the one in the MSISE calculations.

The best agreement with the observations takes place in the versions with the NRLMSISE-00. The electron density of the MSISE-HWM differs from the MSISE version values not significantly excepting the night values of April 15.

The Figure 2 shows that the difference between the Ne values of the versions MSISE and TM does not become less with using the HWM winds except the day hours on April 18. The electron density of the TM-HWM differs from the TM Ne especially significantly on April 15 and 18. Using empirical thermosphere winds with the "theoretical thermosphere" leads to a less negative storm effect in Ne than reproduced by the TM version. As in the case of Irkutsk the versions with empirical neutral composition and temperature have the best agreement with the Ne radar observations.

The Figure 3 shows that the daytime Ne values calculated by the versions with empirical winds for Millstone Hill differ from each other even in a greater degree than the values modeled with theoretical thermospheric winds. But the night-time density values modeled with the HWM-93 are very similar. Using the HWM winds increases the nighttime Ne values calculated for April 16 and 17 and thus improves the agreement of the model results with the observation data especially for April 17. The only MSISE-HWM version gives a small increase in the Ne daytime values on April 18 comparing with April 17. Similar but greater Ne increase was represented in the observations. The versions with the NRLMSISE-00 give a better agreement with the electron density observed in Millstone Hill than the versions with the theoretical neutral composition and temperature. The Figure 3 shows that the HWM-93 gives the thermospheric winds values which are very similar to the calculated in Millstone Hill for April 15-16, i.e. for the quiet period. The UAM reproduces better the large morning values of the northward wind during the storms on April 18.

## Conclusions

The thermosphere wind velocities calculated by the theoretical and empirical models differ dramatically (up to 250 m/s) only during the short night-time intervals when the HWM-93 gives the lowest wind velocity values.

Using HWM-93 thermospheric winds makes the model electron density results calculated for Irkutsk by the versions with the NRLMSISE-00 and "theoretical thermosphere" closer to each other. For Kharkov and Millstone Hill this statement is true for only night hours. As a whole using the empirical winds does not improve the agreement of the model Ne values with the observations over the stations excepting Millstone Hill at some time moments.

***Acknowledgments.*** This study was supported by Grant No. 05-05-97511 of Russian Foundation for Basic Research. Millstone Hill radar observations and analysis are supported by a NSF cooperative agreement with the Massachusetts Institute of Technology and NASA grant NAG5-13602. The Kharkov incoherent scatter radar is supported by the Ministry of Education of Ukraine. The Irkutsk incoherent scatter radar is supported by the state grant (NSh-272.2003.5) for Leading Scientific Schools of the Russian Federation and Russian Foundation for Basic Research (grant 03-05-64627). The empirical model HWM-93 was incorporated in the UAM by Martynenko O.V. and Knyazeva M.A.

## References

Bilitza, D., K. Rawer, B. Reinisch. Path Toward Improved Ionosphere Specification and Forecast Models, *Advances in Space Research, V. 33*, Number 6, 2004.

Hedin A.E., E.L. Fleming, A.H. Manson, F.J. Scmidlin, S.K. Avery, R.R. Clark, S.J. Franke, G.J. Fraser, T. Tsunda, F. Vial and R.A. Vincent, Emperical Wind Model for the Upper, Middle, and Lower Atmosphere, *J. Atmos. Terr. Phys.*, *58*, 1421-1447, 1996.

Namgaladze A.A., Yu.N.Korenkov, V.V.Klimenko, I.V.Karpov, F.S.Bessarab, V.A.Surotkin, T.A.Glushchenko, and N.M.Naumova, Global model of the thermosphere-ionosphere- protonosphere system, *Pure and Applied Geophysics*, *No.2/3*, 127, 219-254, 1988.

Namgaladze A.A., O.V.Martynenko, M.A.Volkov, A.N.Namgaladze, R.Yu.Yurik, High-latitude version of the global numerical model of the Earth's upper atmosphere, *Proceedings of the MSTU*, *V.1*, No.2, p.23-84, 1998.

Namgaladze A.A., A.N. Namgaladze, O.V.Martynenko, E.N.Doronina, M.A.Knyazeva, Yu.V.Zubova, Numerical modeling of the thermosphere, ionosphere and plasmasphere behaviour during the April 2002 magnetic storms, *Proceedings of the XXVI Annual Apatity Seminar "Physics of Auroral Phenomena"*, Preprint PGI.- 2003.- P.74-78.

Namgaladze A.A., Yu.V. Zubova, A.N. Namgaladze, O.V. Martynenko, E.N. Doronina, L.P.Goncharenko et.al., Modelling of the ionosphere/thermosphere behaviour during the April 2002 magnetic storms: A comparison of the UAM results with the ISR and NRLMSISE-00 data, *Advances in Space Research*: doi:10.1016/j.asr. 2005.04.013, 2005.

Pavlov A.V. The role of the vibrationally excited nitrogen in the ionosphere, *Pure Appl. Geophys., 127 (2/3)*, 529-544, 1988.

Picone, J. M., A. E. Hedin, D. P. Drob, and A. C. Aikin. NRLMSISE-00 empirical model of the atmosphere: Statistical comparisons and scientific issues, *J. Geophys. Res., 107,* 1468, doi:10.1029/2002JA009430, 2002.

Zubova Yu.V., K.A. Stakhov, O.V. Martynenko, A.A. Namgaladze, The precipitating electron fluxes as input parameters for the April 15-25, 2002 magnetic storms modeling, *Proceedings of the XXVI Annual Apatity Seminar "Physics of Auroral Phenomena"*, Preprint PGI.- 2003. - P.98-101.