The instantaneous ionosphere peak height shift versus relative changes of the critical frequency

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We witness progress in processing of climatological ionospheric models in data assimilative mode providing capability for instantaneous monitoring the vertical structure and dynamics of the ionosphere. In most of assimilative scenarios the iterative algorithms are used applied to the background ionosphere model such as the International Reference Ionosphere IRI [1]. Advantage of IRI build up is that its electron density profile is fitted to the F2 layer peak density and height thus the IRI code is automatically linked to measured or modelled NmF2 and hmF2. However, ingestion of GPS-derived total electron content TEC through the ionosphere and plasmasphere is based on iterative algorithms [2].

Recent improvements in IRI model extended to the plasmasphere, IRI-Plas, allows an automatic update of the F2 layer peak density NmF2 (related to the critical frequency foF2) and the topside scale height with GPS-TEC input [3,4]. IRI also admits automatic storm-time correction of the F2 layer critical frequency [5]. There are also many other reliable techniques for capturing the foF2 and M3000F2 (related to the peak height hmF2) instantaneous variations [6-8]. Forecast of foF2 and hmF2 changes due to effects of the large-scale internal gravity waves based on the auroral electroject AE index is proposed for the nighttime ionospheric sub-storms [9] but AE index plotted online at http://wdc.kugi.kyoto-u.ac.jp/wdc/ still requires development of its forecasting technique. So more reliable models for the instantaneous nowcasting and forecasting of the F2 layer peak height, hmF2, for variety of the spatial-temporal conditions remains an open problem for ionospheric researchers.

Linkage of the climatological variations of the peak height with the peak electron density has been inferred with the topside sounding electron density profiles measured onboard of ISIS1, ISIS2, Intercosmos-19 and Cosmos-1809 satellites [10-11]. In the present paper we have applied a similar approach to the study of opposite changes of the instantaneous F2 layer peak height hmF2 and peak electron density NmF2 [12] normalized by the quiet reference (median) values Nq and hq inferred from the data of topside and bottomside vertical sounding of the ionosphere.

Figure 1 illustrates relative changes of log(hm/hq) versus log(Nm/Nq) derived with Digisonde DPS-4 observations at Moscow during four equinox months of 2009.

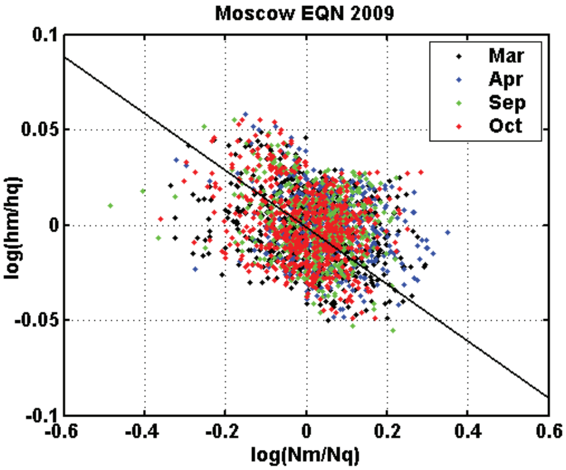

Fig. 1. Anti-correlation of relative changes of the hourly values of the peak density and height at Moscow for equinox at low solar activity

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An analytical model of relative changes of log(hm/hq) versus log(Nm/Nq) is developed in terms of magnetic latitude, season (day-of-year) and solar activity. Figure 2 shows results of dlog_hmF2 model implementation for 3 days of the space weather storm at Grahamstown on 6-8 April 2000 at solar maximum. The middle panel shows the empirical foF2 data (red circles) and forecast (blue triangles) with IRI-STORM model [5] based on the planetary magnetic Ap index integrated for preceding 39 hours shown in lower panel. Relevant dlog_hmF2 model results are shown in the upper panel. Quiet reference IRI-CCIR (ITU-R) predictions of foF2 and hmF2 are shown by green line, and Digtisonde observations are shown with red circles. The plasma density depletion (middle panel) is accompanied by uplift of the peak height which is observed at the main phase of magnetospheric storm.

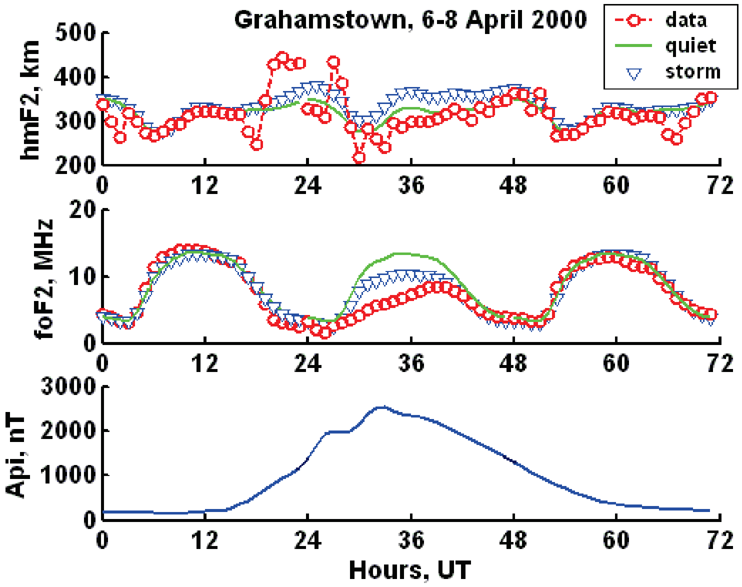

Fig. 2. Observations and modeling of the electron peak density and height during the storm on 6-8 April 2000 in Grahamstown.

Example of model forecast of hmF2 (peak height of the F2 layer of ionosphere, upper panel) obtained from Digisonde observations of foF2 critical frequency and foF2 forecast with technique [6] (middle panel) for Moscow is given in Figure 3. Relevant changes of the ionospheric weather W index is shown in the lower panel.

The ionospheric weather W index indicates logarithmic departure of instantaneous foF2 from the median [13] varying from quiet state to intense storm according to the following designation:

- W=±1 for the quiet state
- W=±2 for moderate disturbance
- W=±3 for moderate ionospheric storm
- W=±4 for intense ionospheric storm

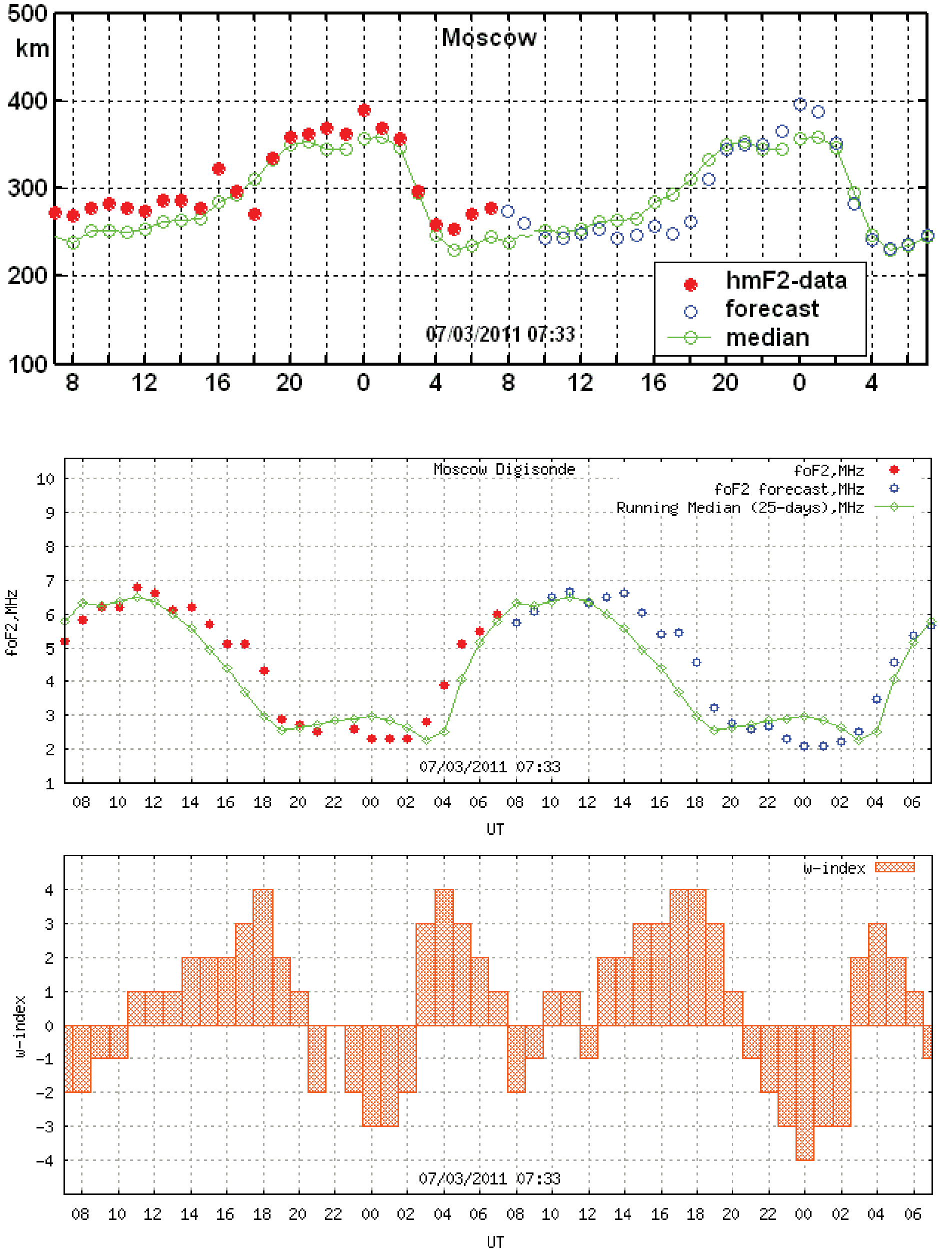

Fig.3. DPS-4 observations of foF2 (middle panel, red circles) and forecast foF2 (blue circles) used for modeling/forecast of hmF2 (top panel) and derivation of the ionosphere weather W index (bottom panel). Median foF2 and hmF2 are also given (green line).

Using available data and forecast of NmF2 and quiet background median NqF2 and hqF2, the instantaneous hmF2 is calculated online at (http://www.izmiran.ru/services/iweather) for missed ionosonde observations at selected ionosonde sites and their counterparts at magnetic conjugate hemisphere.

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References

1. Bilitza D. “International Reference Ionosphere 2000”, *Radio Science*, 36 (2), 261-276, 2001.
2. Bust, G.S., and Mitchell, C.N. “History, current state, and future directions of ionospheric imaging”. *Rev. Geophys.* 46, RG1003, doi:10.1029/2006RG000212, 2008.
3. Gulyaeva T.L. “Storm time behavior of topside scale height inferred from the ionosphere-plasmasphere model driven by the F2 layer peak and GPS-TEC observations”. *Adv. Space Res.*, 47, 913-920, doi:10.1016/j.asr.2010.10.025, 2011.
4. Gulyaeva, T.L., Arikan, F., and Stanislawska, I. “Inter-hemispheric imaging of the ionosphere with upgraded IRI-Plas model during the space weather storms”. *Earth, Planets and Space*, 2011 (accepted).
5. Araujo-Pradere, E.A., T.J. Fuller-Rowell and M.V. Codrescu, “STORM: An empirical storm-time ionospheric correction model, 1. Model description”, *Radio Science*, 37, 10.1029/2001RS002447, 2002.
6. Belehaki, A., I. Stanislawska, J. Lilensten, “An Overview of Ionosphere-Thermosphere Models Available for Space Weather Purposes”, *Space Science Rev.*, doi:10.1007/s11214-009-9510-0, 2009.
7. McKinnell, L.A., Oyeyemi, E.O. “Progress towards a new global foF2 model for the International Reference Ionosphere (IRI)”. *Adv. Space Res.*, 43(11), 1770-1775, doi:10.1016/j.asr.2008.09.035, 2009.
8. Oyeyemi, E.O., McKinnell, L.A., Poole, A.W.V. “Neural network-based prediction techniques for global modeling of M(3000)F2 ionospheric parameter”. *Adv. Space Res.*, 39(5), 643-650, doi:10.1016/j.asr.2006.09.038, 2007.
9. Deminova, G.F., Shashunkina, V.M., Goncharova, E.E. “A global empirical model for effects of large-scale internal gravity waves in the night-time ionosphere”, *J. Atmos. Solar-Terr. Phys.*, 60(2), 227-245, 1998.
10. Gulyaeva, T.L., Bradley, P.A., Stanislwska, I., and Juchnikowski, G. “Towards a new reference model of hmF2 for IRI”. *Adv. Space Res.*, 42(4), 666-672, doi;10.1016/j.asr.2008.02.021, 2008.
11. Gulyaeva, T.L. “Linkage of the ionospheric peak electron density and height deduced from the topside sounding data”. *Adv. Space Res.* 43(#11), 1794-1799, doi:10.1016/j.asr.2008.08.015, 2009.
12. Gulyaeva, T.L. “Storm-time model of the ionospheric peak height associated with changes of peak electron density”. *Adv. Space Res.*, 2011 (submitted).
12. Gulyaeva, T.L., Stanislawska, I., Tomasik, M. “Ionospheric weather: Cloning missed foF2 observations for derivation of variability index”, *Ann. Geophys.*, 26(2), 315-321, 2008.