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Ground-Based GNSS Data for the Ionosphere Model Correction at high-latitudes

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Abstract

The preliminary results of the ionosphere model correcting method using slant TEC data were presented. We compared model results and observation data of the vertical sounding stations in Sodankylä (high-latitudes). We used two models: IRI-Plas and NeQuick. It was shown that the proposed method needs improving, the correcting data should be enlarged and additional tools for more accurate model updating should be added.

1. Introduction

In recent years, attention to investigation and diagnostic of ionosphere significantly increases. Nowadays, global navigation satellite system (GNSS) such as GPS and GLONASS, worldwide ground-based network of satellite signal receivers provide a new possibility of real time ionospheric monitoring [1]. GNSS Signal Processing is used for calculating absolute total electron content (TEC) along radio path between each satellite and ground-based receiver [2]. Absolute TEC can be used for the correction of ionospheric models providing more accurate electron density distribution [3]. Most of the recent papers based on GNSS data in the mid-latitude ionosphere showed a good agreement between the corrected and the experimental ionospheric data [4-6]. However there is no main approach for such problem for all ionospheric regions. The problem of ionospheric model correcting (updating) is a subject of present work. The relevance of the proposed research is due to the following points: (1) It is necessary to improve operational environment models i for applications (directly radar); (2) The updating ionospheric models at high-latitudes has not been studied and developed sufficiently.

2. Formulation of the problem

The receivers in Lovozero will be used by us to correct the ionosphere models to describe the space weather in the considered high-latitude region. Verification of this updating will occur by comparing the model calculations with the data of the vertical sounding station in Sodankylä (Fig. 1).

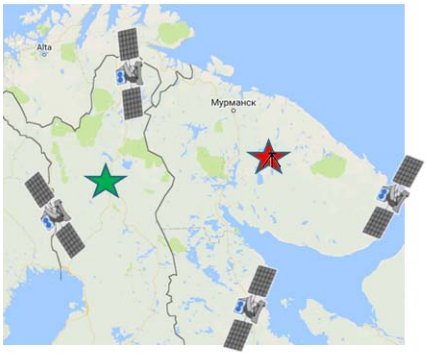

Figure 1. Location of GNSS receiver (red asterisk) and vertical sounding station (green asterisk).

In order to validate the method, the following days have beem chosen: March 22, June 22, September 22 and December 18, which correspond days equinox and solstice with quiet magnetic conditions: Kp index has not exceeded 3, Dst has not fallen less than -10 nT.

3. Description of the correction (updating) procedure

Radio Communication Sector of the International Telecommunications Union (ITU-R) recommends using the International Reference Ionospheric (IRI) [7] model or the NeQuick [8] model for a long-term ionospheric forecast. There is IRI extended to the plasmasphere – IRI-Plas model [9-10]. They use R12 index as the index of the solar activity. R12 is the 12-months moving average (with center at the given month) of the relative sunspots number

In our work, we perform the correction of the IRI-Plas and NeQuick models based on the absolute slant TEC data. An updating procedure is based on the changing some control parameters of models (here it isRz12). The criterion for Rz12 value is the minimum of the standard deviation (SD) between the experimental (GNSS) TEC and model those. The initial Rz12 value is the Rz12 forecast for a specific month [11].

The procedure is divided into two stages. At the first stage, the updating is made based on data from all the azimuths (360°-sector). 45° elevation cut-off was used. Then changing Rz12 we minimized SD. The second stage is similar to the first, except for the selection of satellites in azimuth and elevation. The total area of 360° is divided into 18 subsectors of 20°. In each subsector, we used data from satellites with elevation less than 45 °. The result of updating procedure is an array of Rz12 values for each azimuth sector.

4. Model calculations results

Figures 2 and 3 show the comparison of model and experimental *foF*2 values. The ionosonde observation data is shown in violet, not updated IRI-Plas and updated NeQuick (forecast) – in blue, updated model results is shown in green (first state) and red (second state). For the second stage of updating procedure, azimuths close to 263 ° (LOZ → SOD) were considered. For March and September, the daily maximum of *foF*2 after model updating better correlate with experimental data than without updating. In June, there is agreement of observation data and model results (after updating) at night, in December - in the evening and in the morning. In December the updating led to the precision deterioration. Not updated model better agree with experimental data.

In the Table 1 we shown the standard deviation of the daily model value *foF*2 from the experimental those for different updating. The minimum values are indicated in bold. As one can see from Table 1, the correction did not give the expected improvements: SD without change in Rz12 is less than after correction (except for March and September). Also we can see that after the second stage of correction, the SD value is less than after the first one.

Table 1. Standard deviation

	22.03.	**22.06.**	**22.09.**	**18.12.**	
Without correction	2,20	***0,38***	0,83	***0,91***	**NeQuick**
Stage 1	1,85	0,47	0,80	1,72	
Stage 2	***1,74***	0,41	***0,70***	1,61	
Without correction	2,05	***0,41***	0,79	***0,95***	**IRI-Plas**
Stage 1	1,53	0,60	0,75	1,33	
Stage 2	***1,44***	0,52	***0,60***	1,30	

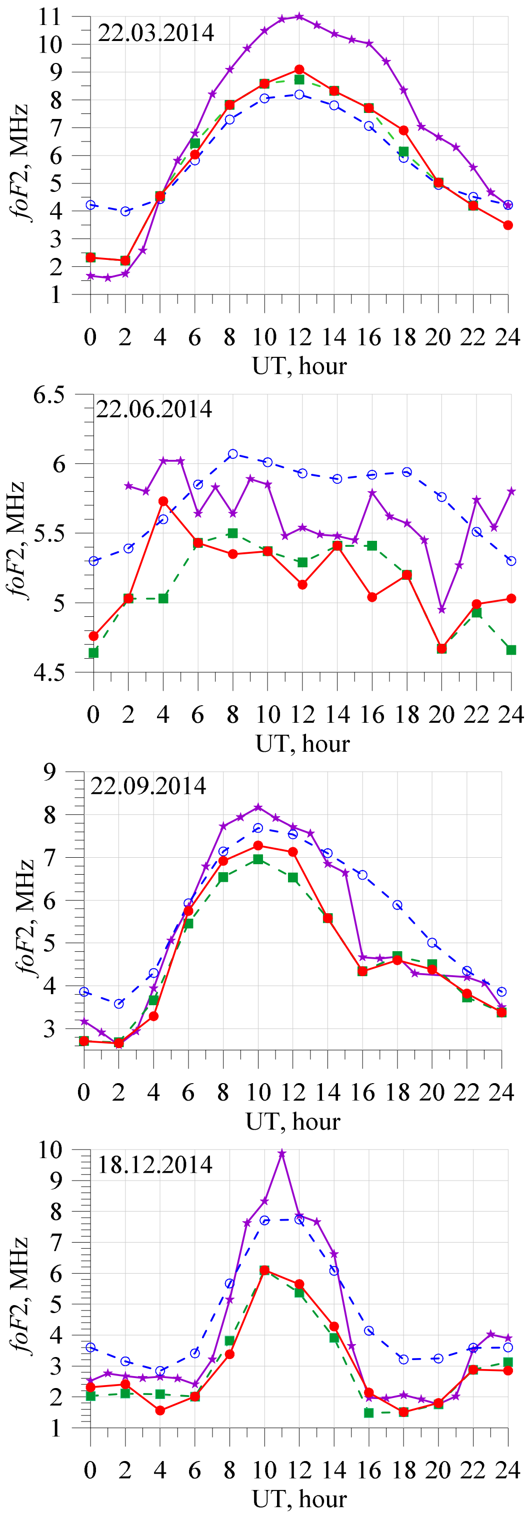

Figure 2. The ionosond observation data (violet stars), forecasted model IRI-Plas results (blue hollow circles), and model results after first (green circles) and second (red circles) correction.

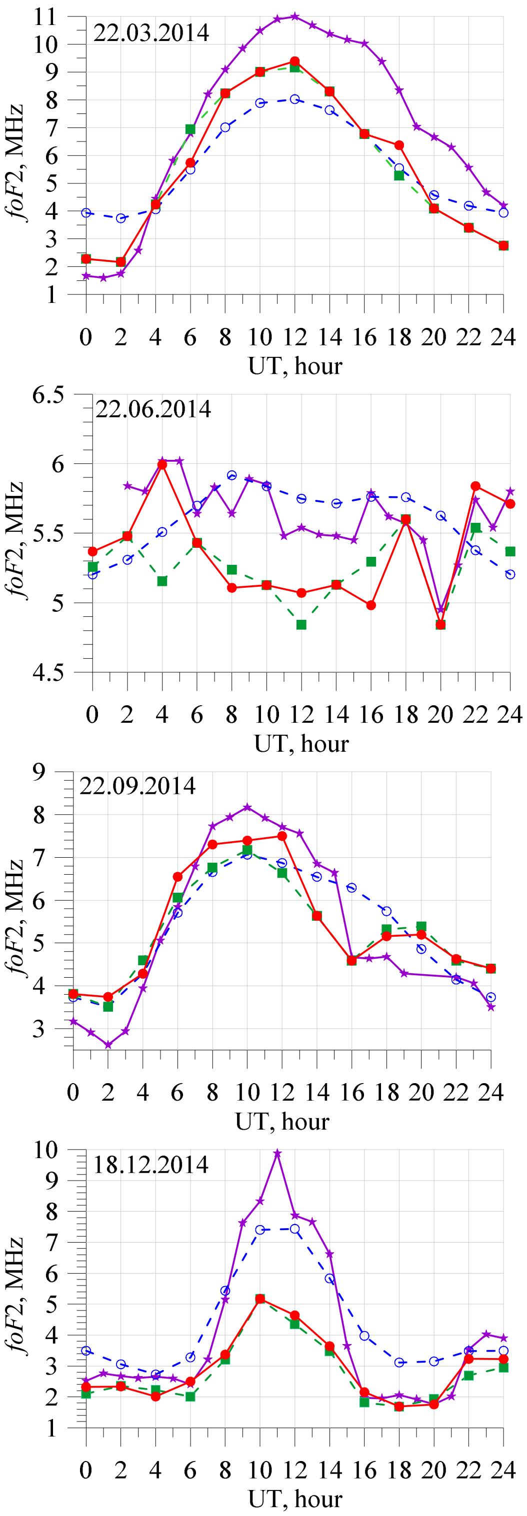

Figure 3. The same as in Fig. 2 but for NeQuick model.

In general, standard deviations for updated IRI-Plas is less than these for NeQuick.

5. Conclusion

For considered periods, the updating procedure with the NeQuick model works worse than those with the IRI-Plas model. It is still a question "Why correction procedure has not led to a significant improvement of model results?" Klimenko et al. [12] shown, that the contribution of the plasmasphere to the TEC can be compared with the ionospheric contribution. Therefore, it is important to describe the electron concentration profile used by the ionospheric model above the peak of the *F*2 layer correctly. It can be assumed that the deterioration of the results of the updating procedure is due to the errors in the description of the electron concentration profile in the plasmosphere by the NeQuick model. The *foF*2 deviation of the IRI-Plas model is less due to the contribution of the plasmasphere is taking into account.

6. Acknowledgements

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7. References

1. E. L. Afraimovich, E. I. Astafyeva, V. V. Demyanov, I. K. Edemskiy, N. S. Gavrilyuk, A. B. Ishin, E. A. Kosogorov, L. A. Leonovich, O. S. Lesyuta, K. S. Palamartchouk, N. P. Perevalova, A. S. Polyakova, G. Y. Smolkov, S. V. Voeykov, Yu. V. Yasyukevich and I. V. Zhivetiev, "Review of GPS/GLONASS studies of the ionospheric response to natural and anthropogenic processes and phenomena," *Journal of Space Weather and Space Climate,* **3**, A27, August 2013, doi:10.1051/swsc/2013049.

2. Y. V. Yasyukevich, A. A. Mylnikova, V. E. Kunitsyn, and A. M. Padokhin, "Influence of GPS/GLONASS differential code biases on the determination accuracy of the absolute total electron content in the ionosphere," *Geomagnetism and Aeronomy*, **55**, 6, November 2015, pp. 763-769, doi: 10.1134/S001679321506016X.

3. Yu. V. Yasyukevich, V. B. Ovodenko, A. A. Mylnikova, I. V. Zhivetiev, A. M. Vesnin, I. K. Edemskiy and D. S. Kotova, "GPS/GLONASS total electron content based methods for ionospheric error compensation for the radio communication systems," *Vestnik of the Povolzhsk State Technological University. Series: Radio Engineering and Infocommunication Systems*, **2**, 34, June 2017, pp. 19-31, doi:10.15350/2306-2819.2017.2.19.

4. O. Maltseva, N. Mozhaeva, O. Poltavsky and G. Zhbanko, "Use of TEC global maps and the IRI model to study ionospheric response to geomagnetic disturbances,"

Advances in Space Research, **49**, 6, March 2012, pp.1076–1087, doi:10.1016/j.asr.2012.01.005.

5. Y. Migoya-Orué, B. Nava, S. Radicella and K. Alazo-Cuartas, “GNSS derived TEC data ingestion into IRI 2012,” *Advances in Space Research,* **55**, 8, April 2015, pp. 29-41, doi:10.1016/j.asr.2014.12.033.

6. V. B. Ovodenko, V. V. Trekin, N. A. Korenkova and M. V. Klimenko, “Investigating range error compensation in UHF radar through IRI-2007 real-time updating: Preliminary results,” *Advances in Space Research,* **56**, 5, September 2015, pp. 900-906, doi:10.1016/j.asr.2015.05.017.

7. D. Bilitza and B. Reinisch, “International Reference Ionosphere 2007: Improvements and new parameters,” // *Advances in Space Research*, **42**, 4, August 2008, pp. 599-609, doi:10.1016/j.asr.2007.07.048.

8. B. Nava, P. Coisson and S. M. Radicella, “A new version of the NeQuick ionosphere electron density model,” *Journal of Atmospheric and Solar-Terrestrial Physics*, **70**, 15, December 2008, pp. 1856-1862. doi:10.1016/j.jastp.2008.01.015.

9. T. L. Gulyaeva and D. Bilitza, “Towards ISO Standard Earth Ionosphere and Plasmasphere Model. New Developments in the Standard Model”, *Chapter 1 in New Developments in the Standard Model,* Nova Science Publishers Inc., 2012, pp. 1–39. Available: https://www.novapublishers.com/catalog/product_info.php?products_id=35812.

10. T. L. Gulyaeva, “Modification of solar activity indices In the international reference ionosphere IRI and IRI-Plas models due to recent revision of sunspot number time series”, *Solar-Terrestrial Physics*, **2**, 3, October 2016, pp. 87–98, doi: 10.12737/22287.

11. International Reference Ionosphere [Online]. Available: http://irimodel.org/indices/ig_rz.dat

12. M. V. Klimenko, V. V. Klimenko, I. E. Zakharenkova, Iu. V. Cherniak, “The global morphology of the plasmaspheric electron content during Northern winter 2009 based on GPS/COSMIC observation and GSM TIP model results,” *Advances in Space Research*, **55**, 8, April 2015, pp. 2077-2085, doi:10.1016/j.asr.2014.06.027.