Using a single GSP/GLONASS receiver for estimating the level of ionospheric disturbance

Berngardt O.I.[1], Voeykov S.V.[1], Ratovsky K.G.[1]*

[1]Institute of Solar-Terrestrial Physics of Sibirean Branch of Russian Academy of Sciences,
664033, 126a, Lermontova str., Irkutsk, Russia, POBox 291, e-mail:berng@iszf.irk.ru

Abstract

In this paper we present an index of quasi-vertical TEC variations (W_{tec}) obtained from GPS/GLONASS receiver data. Procedure for the calculation of the index is based on the original algorithm for the detrending of TEC data using a model of spherically stratified ionosphere. We carried out a comparison between 27-day medians of the W_{tec} index from the GPS/GLONASS IRKJ station and peak electron density from Irkutsk Digisonde DPS-4. We revealed the positive correlation between the W_{tec} index and |dNmF2/dt|, considerably exceeding the noise level.

1. Introduction

Over the past 15 years, the use of GPS/GLONASS total electron content (TEC) data in ionospheric studies has become common practice. Network of receivers provides the data for monitoring the Earth ionosphere. However, the relationship between the TEC variations obtained by single GPS/GLONASS receiver and variations of ionospheric parameters obtained by ionosonde remains an open issue. The basic limitation for the comparative analysis is the short duration of GPS/GLONASS TEC measurements, limited by observation time of single satellite (about 2-6 hours).

We present a technique which allows investigation of the continuous changes of TEC variations by using measurements on a dual-frequency GPS/GLONASS receiver. The comparison of the GPS/GLONASS receiver IRKJ and Irkutsk Digisonde DPS-4 data was carried out.

2. Method

Procedure of TEC processing is based on the original algorithm for the detrending TEC data using a model of the spherically stratified ionosphere. The trend is calculated by minimization of the difference between the experimental TEC series I(t) and a function (1).

$$I_{mod}(t) = B_0 + \sum A_n \sin^{-2n-1}\left(\theta_s(t)\right) \tag{1}$$

where $\theta_s(t)$ is elevation of GPS/GLONASS satellite; B_0, A_n are constants associated with the parameters of the spherically stratified ionosphere model. In this paper we used two terms of power series with n = 0 and n = 1. In order to obtain vertical TEC variations $\Delta I(t)$ we multiply the TEC variations (obtained after detrending) by the correction factor $\sin\left(\theta_s(t)\right)$:

$$\Delta I(t) = \left(I(t) - I_{mod}(t)\right)\sin\left(\theta_s(t)\right) \tag{2}$$

We used an original technique of weighted summation of different satellite contributions to obtain the average values of the TEC variations. This allows us to get continuous series of values with 30 seconds resolution. The average value of the TEC variations is further named as index of quasi-vertical TEC variations W_{tec}:

$$W_{tec}(t) = \sqrt{\frac{\sum \Delta I_i(t)^2 \times S_i(t)}{\sum S_i(t)}} \tag{3}$$

where $\Delta I_i(t), S_i(t)$ are series of vertical TEC variations for the i-th satellite and the weight function, respectively. As a weighting function we used cosine window which decreases from the series center to the periphery. The weighting function is required only for smoothing the series due to small number of satellites.

978-1-4673-5225-3/14/$31.00 ©2014 IEEE

The described method can be used only for relatively high elevations ($\theta_s(t) > 30^0$), where the terms of the power series (1) with n > 1 may be neglected. At elevations less than 30^0 , the following terms of power series in both trend (1) and the corrective factor (2) should be considered.

3. Results

The analysis of the IRKJ station data showed that average number of satellites used by the proposed method is 7-8 for GPS and 1-2 for GLONASS. Due to small number of GLONASS satellites one can apply the method to GPS data only or to both GPS and GLONASS data. In the paper we used both GPS and GLONASS data. Figure 1 shows a series of the W_{tec} index of the IRKJ station for 2012.

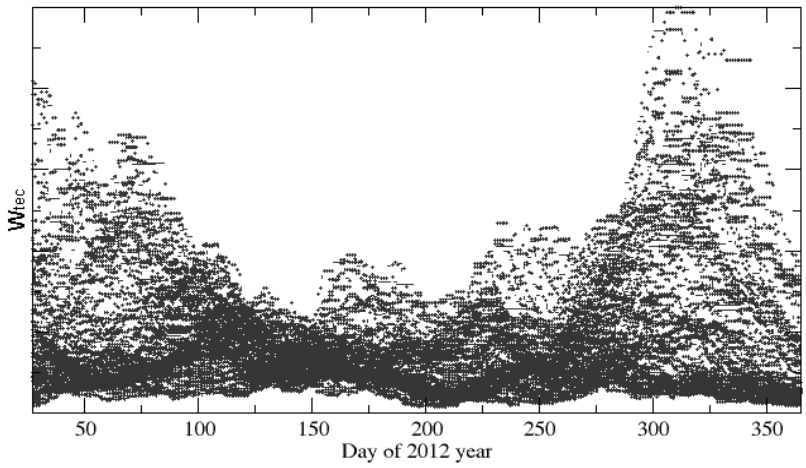

Figure 1. The W_{tec} index of quasi-vertical TEC variations of the IRKJ station for 2012.

For the method verification, we compare the 27-day medians of W_{tec} index from the GPS/GLONASS IRKJ station with Irkutsk Digisonde DPS-4 data. As a Digisonde parameter, we used the peak electron density NmF2. The series of the 27-day medians of W_{tec} and NmF2 are shown in Figure 2.

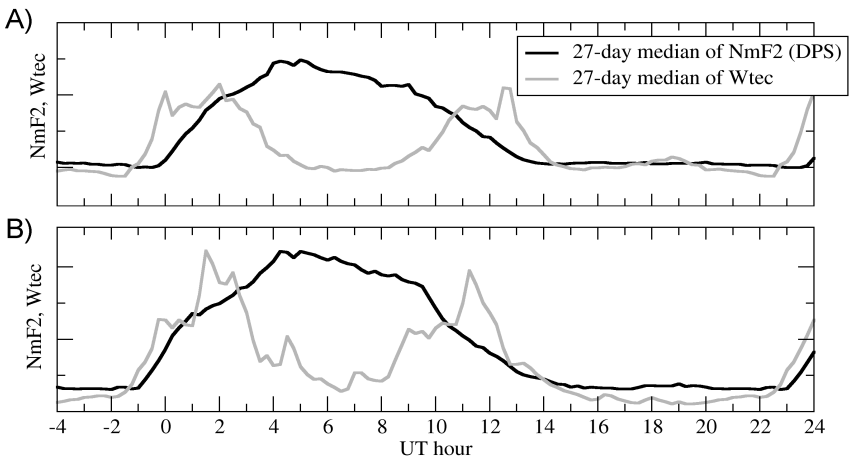

Figure 2. The 27-day medians of the W_{tec} index (gray line) and the peak electron density NmF2 (black line). A) – for March 1, 2012 B) – for November 1, 2012

Figure 2 shows that the maximal W_{tec} index values correspond to the periods of largest changes in NmF2. For more detailed comparison, the correlation coefficients R between 27-day medians of the W_{tec} index and |dNmF2/dt| were calculated with prior removal of the average values. To check the validity of the method, an additional analysis using a random values of W_{tec} (random noise) was performed. The results are shown in Figure 3. The GPS/GLONASS data was previously averaged over 15 minutes to obtain the Digisonde temporal resolution.

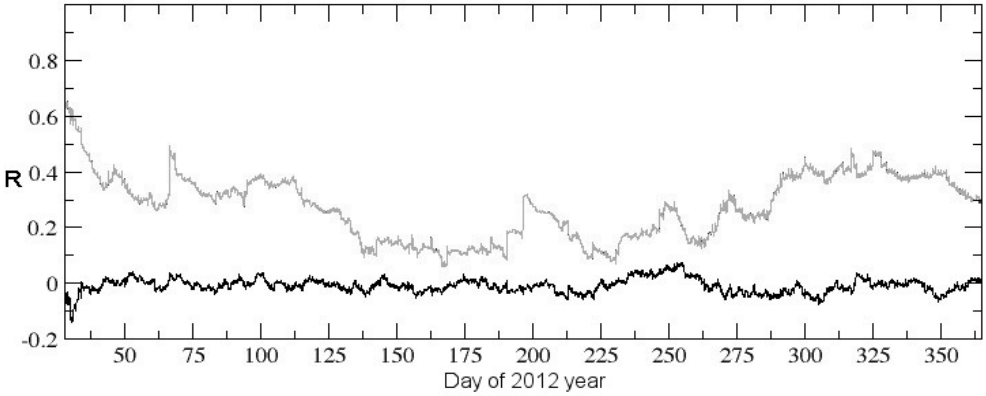

Figure 3. Seasonal dynamics of the correlation coefficient between 27-day medians of |dNmF2/dt| and the W_{tec} index for 2012 (gray line). The black line presents the same for random values of W_{tec}.

Figure 3 shows a positive correlation between the data, considerably exceeding the similar result for the random noise. It is obvious that the correlation is higher in winter than in summer.

4. Conclusions

In this paper we introduced a continuous index of quasi-vertical TEC variations (W_{tec}) from the single dual-frequency GPS/GLONASS receiver data. We presented the algorithm for calculation of the index. For the method verification, we compared the 27-day medians of W_{tec} index from the GPS/GLONASS IRKJ station with Irkutsk Digisonde DPS-4 data. We revealed the positive correlation between the W_{tec} index and |dNmF2/dt|, considerably exceeding the noise level. The correlation was higher in winter than in summer. The nature of the relationship requires further research.

5. Acknowledgments

This work was supported by the OFN RAS Project IV.12.2, the RFBR Project 14-05-00259, SB RAS Integration project No 106. and SB RAS interdisciplinary collaboration project No. 11. We acknowledge the Scripps Orbit and Permanent Array Center (SOPAC) for providing GPS/GLONASS data used in this study.