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Evaluation of the TEC prediction performance of NeQuick2 model

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Abstract

This paper examines the performance of the NeQuick2 model, an empirical three-dimensional ionospheric electron density model, in terms of TEC prediction. The investigation was carried out for three months period in 2022 (January-March), which includes geomagnetic active, solar active, and calm days. In order to evaluate the accuracy of the model, NeQuick2-VTEC values were compared with the TEC data from four GPS stations in different regions. The results show that the differences between the VTEC values obtained from the NeQuick2 and IGS are less on calm days and at stations in high latitude regions. However, discrepancies increase on geomagnetic and solar active days.

1. Introduction

The ionosphere is a part of Earth's upper atmosphere that contains free ions and electrons, affecting the transmission of electromagnetic signals. The density of free electrons and ions in the ionosphere is not constant, and changes depending on various factors such as geomagnetic activity, solar activity, and natural disasters. Thus, regularly monitoring the changes in the ionosphere and modeling the layer is of great importance. In order to describe the ionosphere, physical models, mathematical models, and empirical models are generally used (Wang et al 2022). Among them, empirical models are widely used. The main parameter used to examine the changes in the ionosphere is Total Electron Content (TEC) which is defined as the total number of electrons along a ray path of 1 m^2 cross-section. In recent years GNSS is widely used for the study of the ionosphere and verification of the empirical models.

Among the empirical models, the International Reference Ionosphere (IRI) model and the NeQuick model are widely used. Both models are regularly improved and updated. Recent versions of these models are IRI-2020 and NeQuick2. Many studies have been conducted on the analysis of both models from different aspects (Pietrella et al. 2017; Alcay et al. 2017; Atıcı et al. 2021; Guo et al 2021; Alcay 2021; Liu et al. 2022; Iluore et al. 2022; Wang et al. 2022; Poudel et al. 2022).

In this study, TEC prediction performance of NeQuick2 model was evaluated over four IGS stations in different regions.

2. Method

In this study, quarterly GPS-VTEC values of MDVJ, ZECK, GUUG, and CHPI IGS stations were used for validation of the NeQuick2 model. The locations of the stations are given in "Fig. 1".

In order to examine whether there is any activity on the experimental days, the kp, Dst, and F10.7 indices, which indicate the level of geomagnetic storm, geomagnetic activity, and solar activity, respectively, were taken into consideration "Fig. 2". The dashed lines in "Fig. 2" represent threshold values for the presence of activity.

GPS-VTEC values were obtained using ionolabtecv1.35 software (http://www.ionolab.org/index.php?page=index&language=tr). Details of the software are provided in Arikan et al. (2003), (2004), Nayir et al. (2007), and Sezen et al. (2013). NeQuick2 VTEC values were obtained using the web interface of the model available at https://t-ict4d.ictp.it/nequick2/nequick-2-web-model.

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Figure 1. Location of the IGS stations used

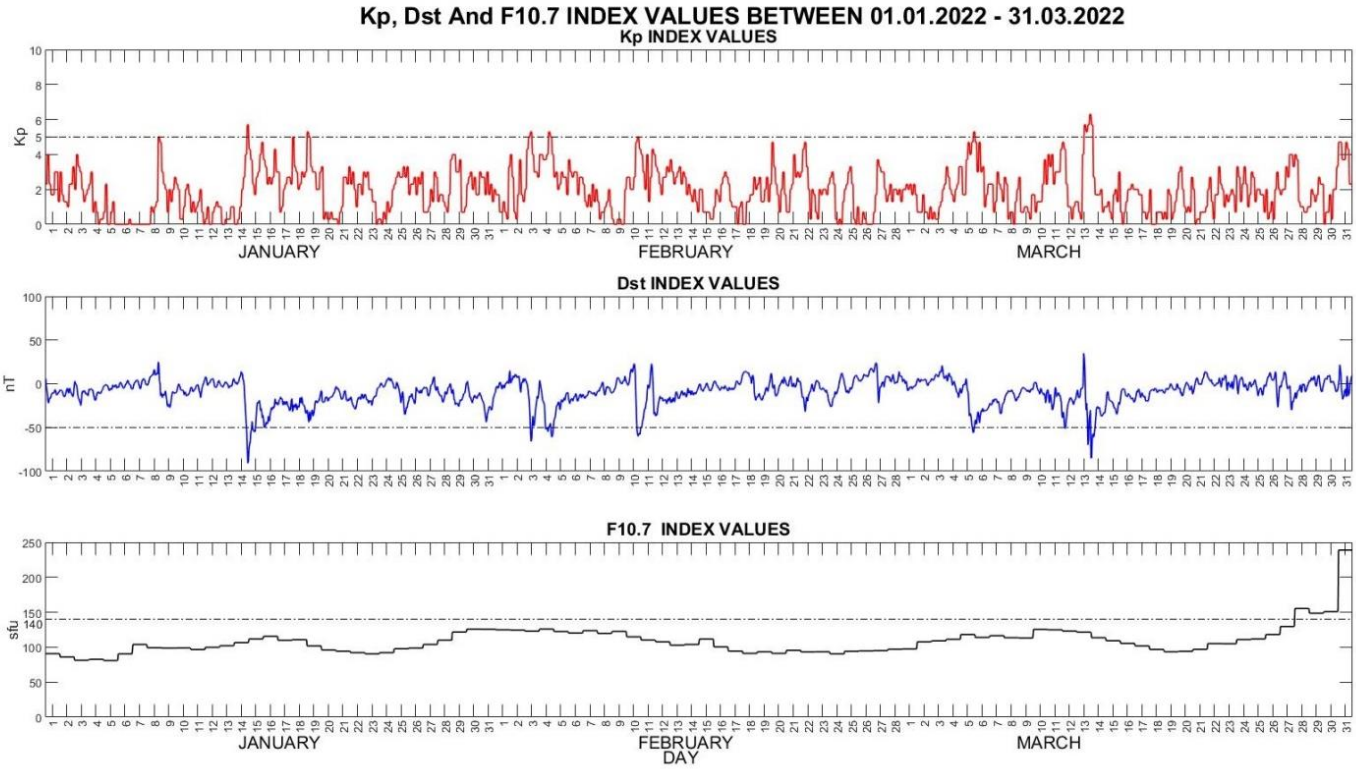

Figure 2. kp, Dst and F10.7 index values

3. Results and Analysis

The differences between obtained hourly GPS-VTEC and NeQuick2 VTEC values between 01.01.2022 and 31.03.2022 are given in “Fig. 3”. “Fig. 3” shows that VTEC differences are larger in February and March compared to January, particularly at GUUG and CHPI stations. The differences in the calm day range between 0.06-23.87 TECU, 2.01-29.24 TECU, 0.02-61.48 TECU, and 3.69-66.61 TECU for MDVJ, ZECK, GUUG, and CHPI stations, respectively. Since the differences are large, the effects of solar and geomagnetic activities are not clearly observed. According to the threshold values, active and calm days were chosen and corresponding mean and RMS values were computed “Table 2”. As given in “Table 2”, the VTEC differences are larger on active days, and the mean and RMS values of the GUUG and CHPI stations located in the equatorial region are relatively large.

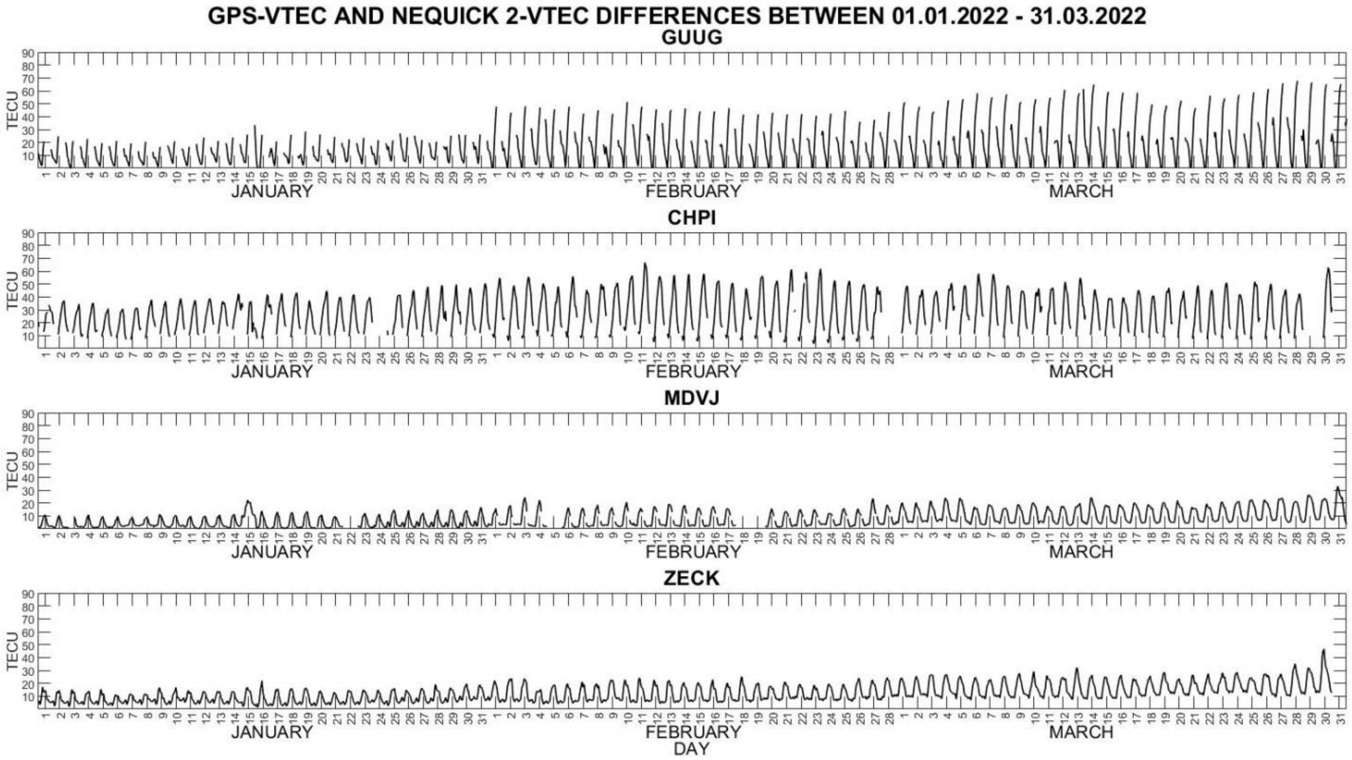

Figure 3. Differences between GPS-VTEC and NeQuick2 VTEC values

Table 1. Mean and RMS of differences corresponding to stations

Differences between GPS-VTEC and NeQuick2-VTEC		Mean	RMS
Active Days	GUUG	20.52	27.12
	CHPI	30.01	32.67
	MDVJ	9.87	12.46
	ZECK	13.88	16.23
Calm Days	GUUG	17.46	22.22
	CHPI	28.32	31.43
	MDVJ	7.68	9.54
	ZECK	11.88	13.30

4. Conclusion

In this study, the TEC prediction performance of the NeQuick2 model was evaluated with a comparative approach with GPS TEC values. For this purpose, hourly data of 4 IGS stations between January 1, 2022 and March 31, 2022 were taken into account. According to the results, the differences are higher on geomagnetic and solar active days. In addition, the differences of the two stations located in the equatorial region are higher than the other stations.

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