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Comparison of GPS-derived TEC with IRI-2012 and IRI-2007 TEC predictions at Surat, a location around the EIA crest in the Indian sector, during the ascending phase of solar cycle 24

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Abstract

This paper presents a comparison of GPS-derived TEC with IRI-2012 and IRI-2007 TEC Predictions at Surat (21.16°N Geographic latitude, 72.78°E Geographic longitude, 12.90°N Geomagnetic latitude) a location around the Equatorial Ionisation Anomaly (EIA) crest in the Indian sector, during the Ascending Phase of Solar Cycle 24, for a period of three years (January 2010–December 2012). In this comparison, plasmaspheric electron content (PEC) contribution to the GPS-TEC has been removed. It is observed that percentage PEC contribution to the GPS-TEC varies from about ~15% (at the noon local time) to about ~30% (at the morning local time). From the monthly comparison of GPS-TEC with IRI-TEC, it is observed that, TEC predicted by both the models overestimates in June-2012 and underestimates TEC in November-2011, December-2011 and March-2011. For all other months IRI estimates the TEC well. From the seasonal comparison, it is observed that the peak time appears ~1-h later than the actual peak time in Winter 2010, Summer 2011, and Equinox 2010 and 2012 (the result suggest that it may be due to discrepancies/disagreement of both the versions of the IRI model in estimating the peak density as well as the thickness and shape parameters of the electron density profiles). For the Summer season, the IRI-TEC estimates the TEC well for all the years. Further, the seasonal variation of the GPS-TEC for all the three years matches well with IRI-2012 model compared to IRI-2007 model. Also, the mean annual TEC is predicted well by both the versions of the IRI model.

Keywords: Total electron content; International reference ionosphere (IRI) model; Low latitude ionosphere

1. Introduction

An internationally recognized International Reference Ionosphere (IRI) model is sponsored by (i) Committee on Space Research (COSPAR) and (ii) International Union of Radio Science (URSI), with the goal of establishing an international standard for the specification of ionospheric parameters based on all kinds of available data from universal ground observations as well as from satellites. For a given place, day and time, both versions of the IRI model describes the electron density, electron temperature, ion composition, and ion temperature (Bilitza and Reinisch, 2008; Bilitza et al., 2014). The IRI model is broadly used as an empirical model it is continuously being upgraded and modernized by different working groups (Rawer et al., 1975, 1978a,b; Bilitza, 1986, 1990, 2001; Bilitza and Reinisch, 2008; Bilitza et al., 2014).

The default option of the topside electron density, for both versions of the IRI model (IRI-2007 and IRI-2012) is NeQuick topside model developed by (Radicella and Leitinger, 2001; Coïsson et al., 2006) based on ionosonde

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and topside sounder data. The NeQuick topside model uses an Epstein-layer function with a height-dependent thickness parameter and this technique produces a smooth transition from an atomic oxygen ionosphere near the F-peak to a light ion ionosphere higher up. The model parameters were determined based on fitting this function to the International Satellites for Ionospheric Studies (ISIS) 1, 2 and Intercosmos 19 topside sounder profiles.

The latest available version of the IRI model, IRI-2012 includes three options for bottom-side thickness B0, ABT and B1, where as IRI-2007 used two options for bottom-side thickness namely B0 and B1. The default bottom-side thickness in IRI-2012 is ABT option. ABT-2009 option is established by (Altadill et al., 2008, 2009) by using data from 27 globally distributed ionosonde stations (DGS or DPS methods) for the years 1998–2006. The bottom-side thickness parameter is important in determining the TEC (total electron content), it would be interesting to check the performance of the both versions of the IRI model in predicting TEC at a given station. There is a difference in bottom-side-thickness parameter for both the versions of the IRI model. It is expected that this difference may have an effect on TEC estimation by IRI model.

TEC is a quantity of the total amount of free electrons in a unit area encountered along the exacting line-of-sight of GPS (Global Positioning System) signal from space satellite to a ground receiver (Bhuyan and Borah, 2007). The GPS-TEC is considered a robust parameter to represent the ionosphere over a given receiver position. The TEC in the upper atmosphere plays a crucial role in the determination of the range delays by the electromagnetic signals while traversing through the ionosphere (Rama Rao et al., 2013).

Dual frequency GPS-receivers are mainly used for scientific purposes such as to derive TEC and S4 etc. GPS satellites are located at the altitude of 20,200 km above the earth's surface and the altitude upper limit for IRI model is up to 2000 km above the earth's surface. For this reason, the amount of free electrons along the GPS ray path is composed mainly due to ionospheric electron content (IEC) and partly of the plasmaspheric electron content (PEC) (Balan et al., 2002) so in order to have a fair comparison between GPS-TEC and IRI-TEC, it is important to extract PEC contribution to GPS (Cherniak et al., 2012; Karia et al., 2015; Akala et al., 2015).

In the last few decades number of studies have been conducted in order to validate the IRI-2007 model for TEC predictions (Chauhan and Singh, 2010; Galav et al., 2010; Kenpankho et al., 2011; Aggarwal, 2011; Venkatesh et al., 2011; Sethi et al., 2011; Prasad et al., 2012; Kumar et al., 2012; Adewale et al., 2012; Olwendo et al., 2012; D'ujanga et al., 2012; Okho et al., 2012; Sur and Paul, 2013; Akala et al., 2013; Rabiu et al., 2014; Kumar et al., 2014a; Karia and Pathak, 2015) and for the IRI-2012 model TEC predictions (Bhuyan and Hazarika, 2013; Hazarika and Bhuyan, 2014; Kumar et al., 2014b; Asmare et al., 2014; Venkatesh et al., 2014a,b; Chowdhary et al., 2015a; Grynyshyna-Poliuga et al., 2015; Rathore et al., 2015). However, in the previous study the PEC contribution to GPS-TEC is not excluded.

From the comparison of GPS-TEC variation over an equatorial and anomaly crest in Indian region, Kumar et al. (2015) concluded that performance of the IRI-2012 model is poorer than the IRI-2007 model. Also, for comparison of GPS-TEC measurements with two versions of the IRI-model at a low-latitude station over Thailand, Arunpold et al. (2014) and Chowdhary et al. (2015b) reported that the IRI-2007 model shows better agreement than the IRI-2012 model in predicting GPS-TEC. Therefore, in this study to check the performance of both versions of the IRI-model in determining TEC at Surat station situated under the crest of equatorial anomaly in Indian region we compare the GPS derived TEC with that predicted by both versions of the IRI-model. Further, in our study to have a fair comparison, the percentage contribution of PEC to TEC was retrieved using IRI-Plas and subtracted from observed TEC.

The solar cycle 24 is associated with certain unique features like the deep and longer solar minimum than it has been expected between the solar cycles 23 and 24. The intensity of the current solar maximum cycle 24 is much lower which is the smallest in the past hundred years. Thus, it has become a more special interest in the ionospheric research community to understand the variability of the ionosphere and performance of the IRI models during this solar cycle 24. In the present study, we therefore used data corresponding to the ascending phase of solar cycle 24.

2. Data analysis

2.1. GPS TEC data

The NovAtel GPS receiver GSV4004B is in the operation at the department of applied physics, S. V. National Institute of Technology, at Surat station (21.16°N, 72.78° E) in India since 2008.

The GSV4004B GPS ionospheric scintillation and TEC monitor (GISTM) receiver tracks up to 11 GPS satellites at the L1 (1575.42 MHz) and L2 (1227.60 MHz) frequency at a time which are at different elevation angles (Van Dierendonck et al., 1996). The computed values of TEC from GSV4004B receiver are slant TEC (STEC), defined as the integral of the electron density along the satellite to the receiver line of sight. These are then converted into vertical TEC (VTEC) using suitable mapping function at different IPP (Ionospheric Pierce Point) positions which are determined by the established formulae (Mannucci et al., 1993; Langley et al., 2002). The present paper focuses on a comparison on IRI (IRI-2007 and IRI-2012) modeled TEC with measured TEC, so it is important to mention about the bias error correction associated with the TEC retrieval from GPS signal as it affects the final outcome. There is a bias error correction, which is different for different satellite–receiver pairs. Sardon et al. (1994),