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Variations of the ionospheric parameters and vertical electron density distribution at the northern edge of the EIA from 2010 to 2015 along 95°E and comparison with the IRI-2012

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Abstract

The vertical electron density profiles over Dibrugarh (27.5°N, 95°E, 43° dip) a low mid latitude station normally located at the northern edge of the EIA for the period of July 2010 till October 2015 are constructed from the measured bottom side profiles and ionosonde-GPS TEC assisted Topside Sounder Model (TSM) topside profiles. The bottom side density profiles are obtained by using POLAN on the manually scaled ionograms. The topside is constructed by the modified ionosonde assisted TSM model (TaP-TSM assisted by POLAN) which is integrated with POLAN for the first time. The reconstructed vertical profile is compared with the IRI predicted density profile and the electron density profile obtained from the COSMIC/FORMOSAT radio occultation measurements over Dibrugarh. The bottom side density profiles are fitted to the IRI bottom side function to obtain best-fit bottom side thickness parameter B0 and shape parameter B1. The temporal and solar activity variation of the B-parameters over Dibrugarh are investigated and compared to those predicted by IRI-2012 model with ABT-2009 option. The bottom side thickness parameter B0 predicted by the IRI model is found to be similar to the B0 measured over Dibrugarh in the night time and the forenoon hours. Differences are observed in the early morning and the afternoon period. The IRI doesn't reproduce the morning collapse of B0 and overestimates the B0 over Dibrugarh in the afternoon period, particularly in summer and equinox. The IRI model predictions are closest to the measured B0 in the winter of low solar activity. The B0 over Dibrugarh is found to increase by about 15% with solar activity during the period of study encompassing almost the first half of solar cycle 24 but solar activity effect was not observed in the B1 parameter. The topside profile obtained from TaP profiler is thicker than the IRI topside in equinox from afternoon to sunrise period but is similar to the IRI in summer daytime. The differences in the bottom side may be attributed to the non-inclusion of ground measurements from 90°E to 100°E longitude in the ABT-2009 model while differences in the topside could be due the non-uniform longitudinal distribution of topside sounder profiles data and the stronger fountain effect in this longitude.

Keywords: IRI; B0; B1; Density profile; TSM; POLAN

1. Introduction

The electron density profile of the ionosphere affects the radio transmission systems and the knowledge of the temporal, spatial and solar cycle variation of the profile is critical for reliable functioning of the communication and navigation systems employing radio transmission. The global experimental data on the ionosphere comes from diverse sources and measurement techniques which requires reliability check and standardization. The empirical model International Reference Ionosphere (IRI), a joint project of International Union of Radio Science (URSI) and Committee on Space Research (COSPAR) is the

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international standard for ionospheric parameters. The International Reference Ionosphere (IRI) project was initiated by COSPAR and URSI in the late sixties with the goal of establishing an international standard for the specification of ionospheric parameters based on all worldwide available data from ground-based as well as satellite observations (Bilitza and Reinisch, 2008). The first version of IRI was released in 1978 when IRI provided a set of tables for typical conditions. The model has been continuously upgraded with the addition of new available experimental data and modeling approach and resulted in many improved version (Bilitza, 1990, 2001a; Bilitza and Reinisch, 2008; Bilitza et al., 2014). Currently, the IRI provides monthly mean values of ionospheric parameters as well as total vertical electron density profile at any location for specified solar and magnetic activity. The total vertical density profile is generally divided into two parts – the region up to the maximum density of the F2 layer is called the bottom side and the region beyond the height of maximum is called the top side. The division is mainly because of the different physical mechanisms effective in these two regions. In the IRI, the altitudinal variation of the bottom side electron density of the ionosphere –$N(h)$, particularly from the maximum density of the F2 layer to the F1 layer is described by the following function (Ramakrishnan and Rawer, 1972):

$$N(h) = \frac{\mathrm{NmF2}\exp(-x^{\mathrm{B1}})}{\mathrm{Cosh}(x)}, \qquad x = \frac{\mathrm{hmF2} - h}{\mathrm{B0}} \tag{1}$$

The B1 and B0 are the shape and thickness parameters of the profile which together with the maximum F2 layer density NmF2 and the height of the maximum density hmF2 completely specify the bottom side density profile in the IRI model. Unlike the topside of the ionosphere, where density profile measurements are scarce, the bottom side of the ionosphere is constantly monitored by global network of ionosondes. The ionograms recorded by ionosondes can be inverted by profile inversion techniques and software (POLAN, NHPC) to obtain the altitudinal variation of electron density with real height up to the maximum of the F2 layer. Based on these measurements and modeling approach, the current version of IRI 2012 provides three options for B1 and B0 values- Gul-1987 (Gulyaeva, 1987), Bil-2000 (Bilitza et al., 2000) and ABT-2009 (Altadill et al., 2009). Using these values the bottom side electron density at any location can be estimated from function 1. The large number of studies carried out so far to test and validate the B1 and B0 models have shown the short comings of the IRI model options Gul-1987 and Bil-2000, particularly in the equatorial and low latitude region (Chen et al., 2006; Blanch et al., 2007; Zhang et al., 2008;Sethi et al., 2009). The ABT-2009, option based on the work of Altadill et al. (2009) is yet to be investigated widely. The model is based on data from 27 ionosonde stations distributed worldwide from high to low latitudes in both the hemispheres covering most of the longitudes. The time series consists of almost the entire solar cycle 23 from 1998 to 2006. The only data gap in this model is in the Indian zone as no station to the west of 109°E longitude (in the northern hemisphere) is included. Another weakness of the model is the "zero order approximation" which may hide the longitudinal effect on the variation of the B0/B1 parameters (Altadill et al., 2009).

The widely reported longitudinal variation of the equatorial ionization anomaly (Sagawa et al., 2005; Immel et al., 2006; Luhr et al., 2008; Scherliess et al., 2008) and other ionospheric parameters like vertical E × B drift (Kil et al., 2007), EEJ (England et al., 2006), neutral composition (Oberheide and Forbes, 2008; He et al., 2010) and temperature (Shepherd et al., 2012) etc predicts the strongest crest of the WN4 structure to be along the 90–100°E longitude. Liu et al. (2010) have investigated the longitudinal variation of B0 and B1 parameters using density profiles from COSMIC radio occultation measurements and reported a stable peak in the 100°E longitude in all seasons. The B0 estimation is affected by the NmF2 and hmF2 values both of which show longitudinal structure. Bilitza et al. (2012) have found that the IRI underestimates the hmF2 in the low latitude region during the deep solar minimum of 2007–2008 and that more hmF2 data from low latitudes are required to model hmF2 in the IRI. The IRI topside provides three options IRI2001, IRI01-Corr and NeQuick. The NeQuick topside model was developed by S. Radicella and his collaborators (Radicella and Leitinger, 2001; Coisson et al., 2005; Coïsson et al., 2006) and is the default option. The model uses an Epstein-layer function with a height-dependent thickness parameter which provides a smooth transition from an atomic oxygen dominated ionosphere just above the F2 layer to a lighter ion dominated ionosphere far above it. The model parameters were determined based on fitting the layer function to ISIS 1, 2 and Intercosmos 19 topside sounder profiles (Bilitza and Reinisch, 2008). The longitudinal distribution of these topside sounder profile data is highly non-uniform (Bilitza, 2001b; Kutiev et al., 2006) and the coverage of some longitude sectors like the Indian zone along 90–100°E is quite inadequate. In the absence of regular topside sounder data and scarce topside profiles, efforts have been made to mathematically model the topside using Chapman, parabolic, Epstein and vary-Chapman functions. The basic approach is to model the parameters-scale height (fixed and variable) and transition height which provide the shape of the electron density profile in terms of the gradient of electron density and the transition height from atomic oxygen dominated region to lighter ion dominated upper topside region respectively. The work of Reinisch et al. (2004), Stankov and Jakowski (2006), Kutiev et al. (2006), Kutiev and Marinov (2007), Reinisch et al. (2007), Kutiev et al. (2009), Gulyaeva (2011), Nsumei et al. (2012) and many others have significantly improved our understanding of the topside density profile. Recently the electron density profiles estimated by the radio occultation (RO) measurements onboard low earth orbiting satellites

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