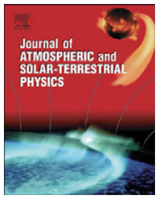
Journal of Atmospheric and Solar-Terrestrial Physics 70 (2008) 1911–1918

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

journal homepage: www.elsevier.com/locate/jastp



NeQuick bottomside analysis at low latitudes

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ARTICLE INFO

Article history:
Accepted 10 August 2008
Available online 23 August 2008

Keywords:
Ionospheric modeling
Ionospheric structure
F region
Equatorial ionosphere

ABSTRACT

NeQuick ionospheric electron density model produces the full electron density profile in the ionosphere using the F2 layer peak values (*foF2* and *hmF2*) as anchor points. Each part of the profile is modeled using Epstein layer formalism. Simple empirical relations are used to compute the thicknesses of each semi-Epstein layer. It has been observed that when NeQuick model is used to estimate total electron content at low latitudes the modeled values tend to underestimate the observed ones. Beside the F2 peak values, the most important profile parameter is the thickness of the F2 layer bottomside. The present study focuses on NeQuick model behavior at low latitudes comparing modeled profiles parameters with the ones extracted from experimental data mostly from African and Indian sector at different levels of solar activity and different time of the day. Possible model improvements are discussed.

1. Introduction

The NeQuick model (Radicella and Leitinger, 2001) has been developed on the basis of the analytical model Di Giovanni–Radicella (DGR) (Di Giovanni and Radicella, 1990), later improved by Radicella and Zhang (1995). It gives an analytical representation of the vertical electron density profile, continuous with continuous first and second derivatives. It is called more properly a "profiler" because its mathematical formulation of the electron density profile is characterized by anchor points mainly linked to the peaks of the different ionospheric layers. It belongs to the International Centre for Theoretical Physics (ICTP)-University of Graz family of models (Hochegger et al., 2000). It is designed for use in transionospheric propagation and includes routines to compute slant total electron content (TEC) values by means of numerical integration along the ray-path. The NeQuick model has been deeply studied to validate its formulation and to obtain improvements, especially for the topside region (Coïsson et al., 2006b) and the F1 layer (Leitinger et al., 2005). These studies led to the development of the version 2 of NeQuick (Nava et al., 2008).

Since NeQuick is an empirical model it is necessary to validate it against all possible data sources. It has been observed that during high solar activity the model has a tendency to underestimate the TEC at low latitudes (Coïsson et al., 2004) and in a recent study (Coïsson et al., 2007) it has been found that in the topside region at low latitudes during high solar activity the model could underestimate thick electron density profiles. Since the NeQuick mathematical formulation for the topside includes the thickness parameter of the bottomside, any of its features can impact on the topside and on the TEC. Therefore, it is important to study the behavior of the

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doi:10.1016/j.jastp.2008.08.004

empirical relations used in NeQuick bottomside. Mosert de Gonzales and Radicella (1990) used data from Argentinean ionosondes to derive a simple relation between the base point of the F2 layer and $foF2$ and $M(3000)F2$. This relation was included into NeQuick model to compute the thickness parameter of the bottomside F2 layer, $B2_{bot}$ (details are given in Section 2). In the IRI model (Bilitza, 1990) the F2 bottomside parameter, analogous to NeQuick $B2_{bot}$, is B0 and many studies on comparison of experimental B0 with IRI model prediction have been carried out at low latitudes (Adeniyi and Radicella, 1998a, b; Sethi and Pandey, 2001; Sethi and Mahajan, 2002; Obrou et al., 2003, 2005; Zhang et al., 2004; Lee and Reinisch, 2006). This paper constitutes a further validation of NeQuick model bottomside in that region. Ionosonde profiles from two low latitude stations located in Nigeria and India are used to compare with NeQuick model profiles. It appears from our limited database that during the daytime at high solar activity the NeQuick tends to underestimate $B2_{bot}$.

2. NeQuick F2 bottomside

The bottomside of the F2 layer is described analytically by a semi-Epstein layer (Rawer, 1982) and its thickness $B2_{bot}$ is defined by the inflection point of the electron density profile:

$$B2_{bot} = 0.385\frac{NmF2}{(dN/dh)_{max}} \quad (1)$$

where $NmF2$ is the maximum electron density of F2 layer ($10^9\,m^{-3}$) and the maximum value of the electron density height derivative $(dN/dh)_{max}$ is computed using the empirical relation (Mosert de Gonzales and Radicella, 1990):

$$\ln\left(\left(\frac{dN}{dh}\right)_{max}\right) = -3.467 + 1.714\ln(foF2) + 2.02\ln(M(3000)F2) \quad (2)$$

where dN/dh is in ($10^9\,m^{-3}\,km^{-1}$) and $foF2$ in (MHz). This relation was derived using data from Tucumán, San Juan, Buenos Aires and Ushuaia stations, using mostly noon time profiles for various periods at high and medium solar activity. Only San Juan data were available on a bi-hourly basis and constituted the widest database for establishing this relation. These stations cover a region from the equatorial anomaly peak (Tucumán) to mid-latitudes (Ushuaia).

3. Data used

This study focuses on low latitudes and two stations located near the geomagnetic equator have been used. Ilorin (Nigeria) and Trivandrum (India) ionosondes have been chosen (Fig. 1). At Ilorin (8.53°N, 4.57°E) an Ionospheric Prediction Service (IPS) 42 ionosonde was in operation since 2002 but not in regular basis (Adeniyi et al., 2007). Available and reliable ionograms for January 2002 and January 2006 representing high and low solar activity, respectively, were used. At Trivandrum (8.47°N, 76.9°E) a KEL ionosonde is in operation. Ionospheric soundings are available every 15 min. Data used for this station correspond to January 2002 and March 2006. Ionograms from these two stations were scaled manually. Electron density profiles were obtained using POLAN inversion program by Titheridge (1985).

4. Results

Using the F2 layer peak values ($foF2$ and $hmF2$) as basic input to the model, $B2_{bot}$ was calculated with formulae (1) and (2) and the corresponding profiles in the bottomside region were computed. The thickness parameter $B2_{best}$ that reproduces the semi-Epstein layer closest to each experimental profile was found. This has been done minimizing the electron density difference between the experimental profile and the semi-Epstein layer having the same NmF2 and hmF2. Examples of profiles at Ilorin station during high solar activity are shown in Figs. 2–5. They indicate typical diurnal behaviours of the electron

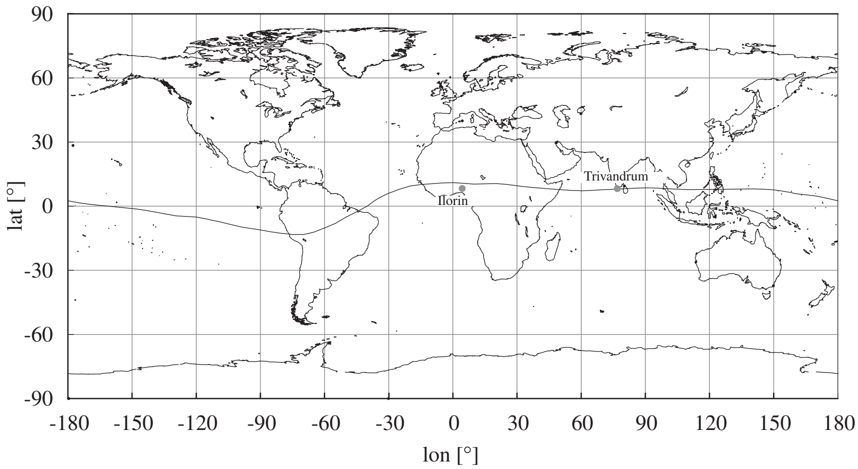

Fig. 1. Locations of the ionosondes used in this study. The geomagnetic Dip equator has been indicated by a solid line.