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Low and equatorial latitudes topside in NeQuick

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Abstract

The NeQuick electron density model of the ionosphere is designed for trans-ionospheric propagation applications. The model topside has been revised on the basis of ISIS 2 topside sounder profiles, producing a new formulation of its empirical shape parameter. Comparisons between experimental slant TEC data and values modelled using both versions of NeQuick topside showed that in general we have obtained a distinct improvement. However, during some months of the year and at low latitudes, the new topside formulation does not produce improvements on the slant TEC estimates. We discuss the likely reasons for this behaviour including assessment of merits and shortcomings of the ISIS 2 data in low latitudes. The topside sounder on Intercosmos 19 satellite extensively sounded the equatorial region during a period of high solar activity, which was less covered by ISIS 2. This paper presents comparisons of NeQuick and topside sounders profiles at low latitudes using Intercosmos 19 satellite data.

Keywords: Ionospheric modeling; Topside region; Equatorial ionosphere

1. Introduction

For trans-ionospheric propagation applications it is very important to have a good three-dimensional model of the ionospheric electron density, in which the topside is one of the most critical elements. Operational models have to be very simple and fast to allow real time applications, therefore empirical models are the most suitable for practical applications. Simple empirical relations are used to describe the electron density profile at any location for any time. Only few satellites had been equipped in the past with topside sounders instruments and only a small number of the recorded profiles had been analysed and converted into electron density profile, therefore empirical models are based on a limited set of experimental data. Recently the NeQuick model topside has been revised using the database of ISIS 2 topside sounder, providing a simpler empirical relation to represent globally and for any time the thickness parameter of this layer of the ionosphere. Tests done using both original and new formulation of the topside to compute electron density profiles pointed out that at low latitudes for some months of a high solar activity year there is an increased tendency to underestimate the slant total electron

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content (TEC) using the new formulation of the topside. It has to be noted that while ISIS 2 satellite was measuring data during a complete solar cycle, only few telemetry stations were in operation during high solar activity. Therefore, for that period, only a limited number of ISIS 2 topside profiles is available at low latitudes. In this paper we use an independent source of topside sounders data to assess the behaviour of the new topside in that region.

2. NeQuick model characteristics

NeQuick is an ionospheric electron density model, based on the original DGR "profiler" (Di Giovanni and Radicella, 1990). It is a quick-run model for trans-ionospheric applications that enables calculation of both vertical or slant electron density profiles and TEC for any specified ground to satellite ray-path (Radicella and Leitinger, 2001; Leitinger et al., 2002). Original NeQuick software code is available on International Telecommunications Union—Radio-communications (ITU-R) website ⟨http://www.itu.int/ITU-R/index.asp?category = documents&link = rsg3⟩. Bottomside ionosphere is represented by five semi-Epstein layers with modelled thickness parameters and anchor points defined by foE, $foF1$, $foF2$ and M(3000)$F2$ values. The topside is a semi-Epstein layer with a height dependent thickness parameter empirically determined. NeQuick topside formulation has been included in 2007 version of IRI.

3. Topside representation

The NeQuick topside electron density is formulated as a modified Epstein layer, with a height dependent thickness parameter:

$$N(h) = 4NmF2\exp(z)/[1+\exp(z)]^2, \quad (1)$$

where

$$z = \Delta h/\{H_0[1 + 12.5\Delta h/(100H_0 + 0.125\Delta h)]\}, \quad (2)$$

$$\Delta h = h - hmF2, \quad (3)$$

where h is the height [km], $NmF2$ [m^{-3}] and $hmF2$ [km] are the electron density and height of the $F2$ maximum and H_0 [km] is the thickness parameter for the layer:

$$H_0 = kB2_{\text{bot}}/v, \quad (4)$$

$$v = (0.041163x - 0.183981)x + 1.424472, \quad (5)$$

$$x = (kB2_{\text{bot}} - 150)/100, \quad (6)$$

where $B2_{\text{bot}}$ [km] is the thickness of the $F2$ bottomside and k is an empirical parameter:

$$k = 6.705 - 0.014R12 - 0.008hmF2 \quad \text{April to September}, \quad (7)$$

$$k = -7.77 + 0.97(hmF2/B2_{\text{bot}})^2 + 0.153NmF2 \quad \text{October to March}, \quad (8)$$

where $R12$ is the smoothed sunspot number and $hmF2$ [km], $NmF2$ [10^{11}m^{-3}] are the $F2$ layer peak parameters. The values of k are kept in the interval of $2 \leqslant k \leqslant 8$. k formulation has been originally

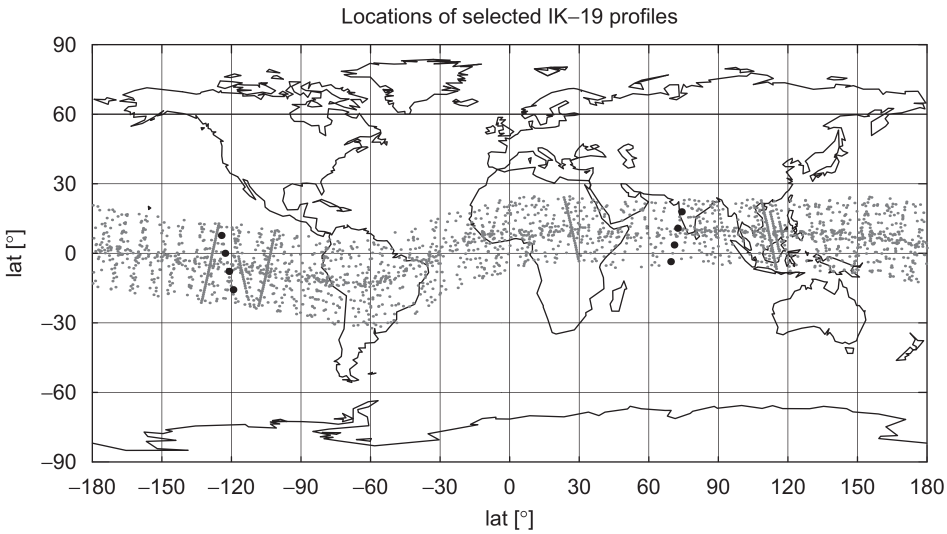

Fig. 1. Sub-satellite positions of the selected profiles recorded during 1979 and 1980. Black points indicate the locations of the profiles shown in Figs. 2 and 3.