IONOSPHERIC MODEL DEVELOPMENTS FOR SATELLITE NAVIGATION AND COMMUNICATION APPLICATIONS

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ABSTRACT

This paper describes the ionospheric modeling efforts carried out at the Aeronomy and Radiopropagation Laboratory of the Abdus Salam ICTP in Trieste, Italy and at the Institute for Geophysics, Astrophysics and Meteorology of the University of Graz, Austria, essentially for application purposes related to satellite navigation and communications. A family of three electron concentration models which differ in complexity and which have different but related application areas have been developed based on the concept proposed originally by Di Giovanni and Radicella in 1990. A brief description of the models and their use will be given.

INTRODUCTION

Models of the electron concentration profiles have been developed in the framework of the European Commission COST actions 238 and 251. They are based on the original "profiler" proposed by Di Giovanni and Radicella (DGR) [1] to calculate the electron concentration distribution up to the F2 peak and are able to give its distribution on both the bottomside and topside of the ionosphere and the ionospheric total electron content (TEC). A first model was adopted by the European COST 238 action as the basis for its regional model of the ionosphere[2]. With the same concepts but with an improved treatment for the topside ionosphere a family of three electron concentration models which differ in complexity and have different but related application areas have been developed by the Aeronomy and Radiopropagation Laboratory of the Abdus Salam ICTP in Trieste, Italy and at the Institute for Geophysics, Astrophysics and Meteorology of the University of Graz, Austria [3][4]. These are: NeQuick, a quick-run model particularly tailored for transionospheric propagation applications; COSTprof, a more complex model for ionospheric and plasmaspheric satellite to ground applications; NeUoG-plas, a model to be used particularly in assessment studies involving satellite to satellite propagation of radio waves. COSTprof model was adopted by the European COST 251 action. The NeQuick model has been used by the ESA EGNOS program and adopted by Recommendation P.531-6 of the International Telecommunication Union-Radiocommunication sector (ITU-R) as a suitable method for TEC modelling.

CHARACTERISTICS OF THE MODELS

Figure 1 shows the main profile structure characteristics of the models based on the Epstein layer (EP) formulation. Nequick and COSTprof consist of two height regimes: (1) The bottomside model for the height region below the peak of the F2-layer.; (2) The topside model for the height region above the F2-layer peak. NeUoG-plas has an additional geomagnetic field aligned third part for the "plasmasphere".

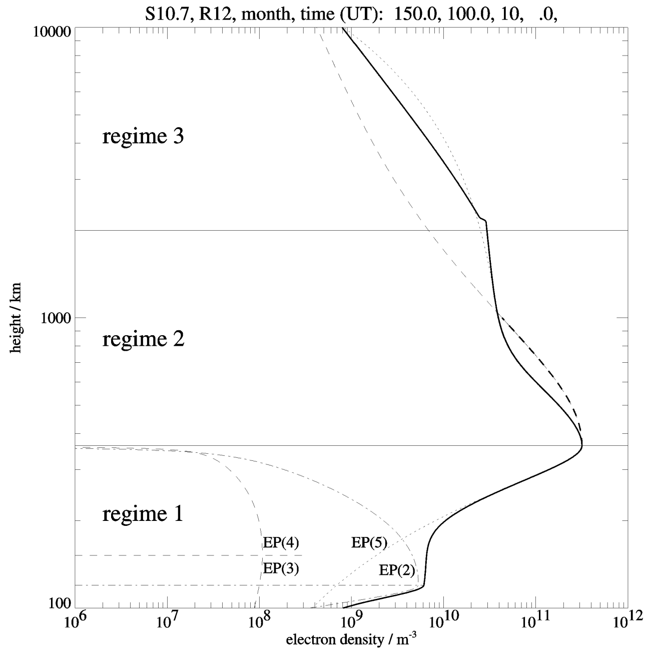


Figure 1: The height regimes in the family of electron concentration models. NeQuick model profile is indicated with dashed lines. COSTprof with dotted lines and NeUoG-plas with solid line.

Height regime 1: Above 100 km and up to the F2 layer peak all three models are identical, they use a modified DGR profile formulation which includes 5 semi-Epstein layers with modelled thickness parameters and is based on foE, foF1, foF2 and M(3000)F2 values. Different sources for these ionosonde parameters can be considered depending on the purpose. The height of the E-layer peak is fixed with 120 km, the F1-layer peak height is modelled, hmF2 is derived from M3000(F2) and the ratio foF2/foE.

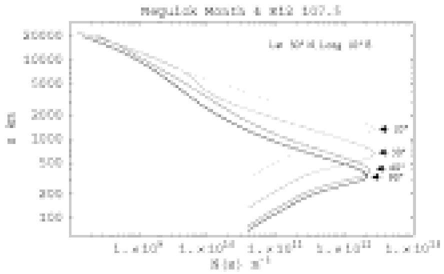
The input parameters of this family of models can be different: ITU-R (former CCIR) coefficients for foF2 and M(3000)F2 and R12 and /or monthly mean F 10.7 or measured values of foE, foF1, foF2 and M(3000)F2 or F2 peak concentration and peak height, or regional maps of foF2 and M(3000)F2 based on grid values constructed from data obtained at given locations. In addition “disturbances” (storm effects, TIDs, trough, etc.) in the form of regional changes of model parameters or electron concentration values can be introduced in the models by multiplying the large-scale model with a small scale one. In the case of the trough the model that considers magnetic field aligned electron concentration has to be used.

The output of the models are: electron concentration vertical profile to a given height (including the GPS satellite altitude), electron concentration along arbitrary ground to satellite or satellite to satellite ray paths vertical Total Electron Content (vTEC) up to any given height, slant Total Electron Content between a location on earth and any location in space (examples given in Figure 2 a and b).

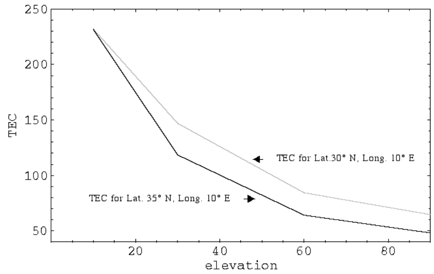
From the ITU-R coefficients maps of vertical TEC can be created with the three models. An example obtained with the NeQuick model is shown in Figure 3.

Regional maps using experimental data grids and two dimensional third order interpolation for geographic locations can be obtained from the models replacing the ITU-R coefficients with regional maps created from grid maps of foF2 and M(3000)F2. [5]

An example of the use of NeUoG-plas model multiplied with a trough model is given in Figure 4. [6]



(a)



(b)

Figure 2: (a)Nequick electron concentration along arbitrary ground to satellite ray paths for a satellite at 20000 km altitude. Ground location: Lat: 30° N and Long. 10° E and elevation angles 10°, 30°, 60° and 90°. At 90° s corresponds to vertical height. (b) NeQuick total electron content (TEC) from ground to satellite at 20000 km altitude at different elevation angles (in degrees). TEC at 90° corresponds to vertical TEC. Conditions are for April, 16 UT and R12=107.5.

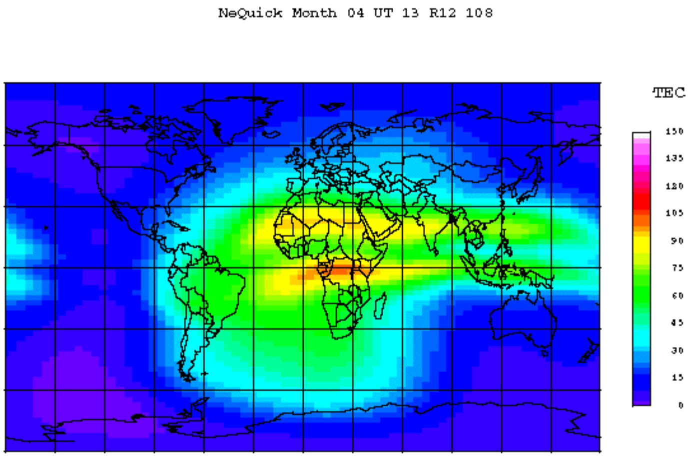


Figure 3: NeQuick vertical TEC (in TEC units) map using ITU-R coefficients for April, 13 UT and R12 =108.

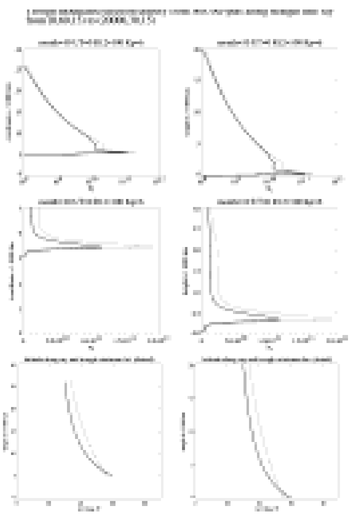


Figure 4: Example of electron density along slant rays calculated with NeUoG-plas modulated by a trough model. Ray from ground (60°N, 15°E) to a satellite at 20000 km (30°N, 15°E) for October, 0 UT and R12=0 and R12=100 respectively.

The ability of the models to reproduce experimental data have been tested with different type of data. As an example Table 1 gives absolute differences between hourly experimental and NeQuick model values (in TEC units) averaged for each day of observation for all the available locations on the globe (mostly from Europe) for low solar activity conditions (1995) (experimental data courtesy of N. Jakowski).

Table 1

SLANT TEC GPS MEASUREMENTS, |TEC exp -TEC mod|

MONTH	**DAY**	**|D| [TECUNIT]**		**DAY**	**|D| [TECUNIT]**
Mar.	**19**	**5.63**	**Jun.**	**21**	**1.96**
	20	**5.61**		**21**	**1.84**
	21	**5.73**		**23**	**2.09**
	Aver.	**5.66**		**Aver.**	**1.96**
Sep.	**20**	**2.81**	**Dec.**	**19**	**2.46**
	21	**3.26**		**20**	**3.55**
	22	**3.48**		**21**	**3.36**
	Aver.	**3.18**		**Aver.**	**3.22**

USE OF THE MODELS

The electron density 3D time dependent models described are particularly suitable for assessment studies in connection with advanced satellite navigation and positioning systems. They can be used to assess various radiopropagation effects observed in received satellite signals. They can simulate space and time regional ionospheric variations produced by geomagnetic storms, TIDs or trough, and their effects on transionospheric propagation.

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