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Calibration of IRI–ITU-R peak density and height over the oceans with topside sounding data

Tamara L. Gulyaeva *

IZMIRAN, 142190 Troitsk, Moscow Region, Russia
Space Research Center, PAS, Warsaw, Poland

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Abstract

Accuracy of IRI electron density profile depends on the F2 layer peak density and height converted by empirical formulae from the critical frequency and *M3000F2* factor provided by the ITU-R (former CCIR). The CCIR/ITU-R maps generated from ground-based ionosonde measurements suffer from model assumptions, in particular, over the oceans where relatively few measurements are available due to a scarcity of ground-based ionosondes. In the present study a grid-point calibration of IRI/ITU-R maps for the *foF2* and *hmF2* over the oceans is proposed using modeling results based on the topside true-height profiles provided by ISIS1, ISIS2, IK-19 and Cosmos-1809 satellites for the period of 1969–1987. Topside soundings results are compared with IRI and the Russian standard model of ionosphere, SMI, and grouped to provide an empirical calibration coefficient to the peak density and height generated from ITU-R maps. The grid-point calibration coefficients maps are produced in terms of the solar activity, geodetic latitude and longitude, universal time and season allowing update of IRI–ITU-R predictions of the F2 layer peak parameters.

Keywords: Ionosphere; IRI; ITU-R; Topside sounding; Critical frequency; Peak height

1. Introduction

The F2 layer peak parameters are highly affected by diffusive processes which provide linkage of the F region with the plasmasphere. The structure of the F2 region at any geographical location and time depends on the amount of solar radiation from the sun and the electron density arising from processes of photoionisation and recombination. Knowledge of the ionosphere is required by the space engineering community for spacecraft design, mission planning, navigational satellite systems operation, and other applications. For the communication purposes the peak electron density is the most important parameter which determines upper limit of usage of the ionosphere as a reflector of HF radio waves. Theoretical models which account for the chemical processes, diffusion in the complex geomagnetic field configuration, currents, winds and other processes are normally used to examine details of time dependent processes (Cnossen and Richmond, 2008) but are often difficult to implement in practical applications. The empirical models and maps provide a reasonable alternative yielding typically average climatologic values widely used in practice.

Mapping of the F2 layer critical frequency, *foF2*, and *M3000F2* factor, and their derivable peak height *hmF2* are based on the worldwide ionosonde data (Bilitza et al., 1979; Chasovitin et al., 1987; Bradley, 1990; Zolesi and Cander, 2000; Liu et al., 2008). The long-term global maps of *foF2* and *M3000F2* have been produced for the international radio circuit planning by the Radio Communication Sector of the International Telecommunication Union, ITU-R (CCIR, 1990). The limitations of these maps and models are due to the poor geographical coverage afforded by the measurements, with most of the ground-based

* Address: IZMIRAN, 142190 Troitsk, Moscow Region, Russia. Tel.: +7 496 7510284; fax: +7 496 7510124.
E-mail address: gulyaeva@izmiran.ru

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ionosondes located unevenly in industrial areas on the land and large ocean areas not sampled.

A plot of the global topographic map is presented in Fig. 1. Based on it an estimate of percentage of land and sea surface versus latitude has been made (Fig. 2). The dominant part of the ionosphere over 63% of the Earth's surface covered by the oceans poses a problem for mapping and modeling with ground–based data sources sparsely located on the sea shore or islands. The ionospheric modeling community would agree that the topside sounding database is reliable source of relevant data for the sea area.

That is why for the present purpose the topside electron density profiles for the period 1969–1987 have been used for empirical modeling of the peak electron density *NmF2_top* (related to the critical frequency *foF2_top*) and the peak height *hmF2_top* (Gulyaeva et al., 2008; Gulyaeva, 2009). The topside ionospheric peak parameters are represented by analytical functions in terms of the solar activity, season, local time, modified dip latitude and geodetic longitude.

In the present study the main regularities of the topside based peak parameters are compared with the IRI/ITU-R (Bilitza, 2001) and Russian standard model, SMI (Chasovitin et al., 1987). Similar to IRI, the SMI peak height is based on ITU-R *M(3000)F2* map but the peak electron density of SMI includes high latitude model and original polar cap model so that we could see their consistency with the topside sounding results.

Furthermore, in the present paper separation of grid-point global maps of *foF2_top* and *hmF2_top* over the land and oceans is made for the first time. Comparison with CCIR/ITU-R mapping results has allowed devise a procedure to retain existing CCIR/ITU-R maps updated with the calibration coefficients based on the topside ionospheric peak parameters.

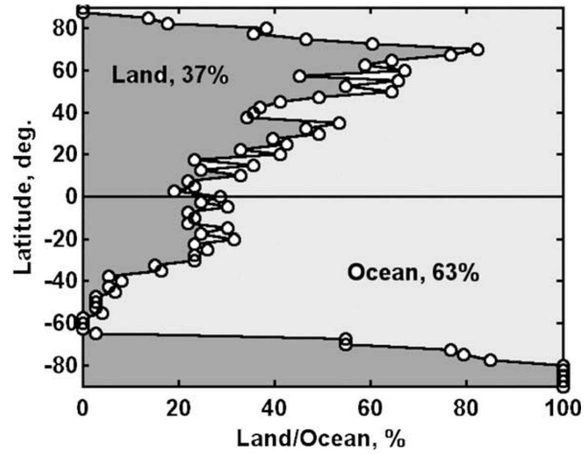

Fig. 2. Percentage ocean/land surface at geodetic latitudes.

2. Binning of the topside sounding database for the land and oceans

More than 100,000 electron density profiles deduced from the topside sounding data onboard the International Satellites for Ionospheric Studies, ISIS1, ISIS2, Intercosmos-19 and COSMOS-1809 satellites for the period of 1969–1987 have been used as the database. These profiles are evaluated successively along the satellite track up to the highest frequency that the ionosphere reflects at vertical incidence (Bilitza et al., 2003). The *foF2* and *hmF2* are obtained from the topside electron density profile by exponential extrapolating of its 1st derivative to zero (Gulyaeva, 2009). Examination of the space weather conditions for the period of observation indicated that near 30% of observables were obtained under disturbed geomagnetic conditions. However, one cannot distinguish the ionospheric disturbance along the satellite track due to the lack of a quiet reference at each particular point of the orbit. Hence,

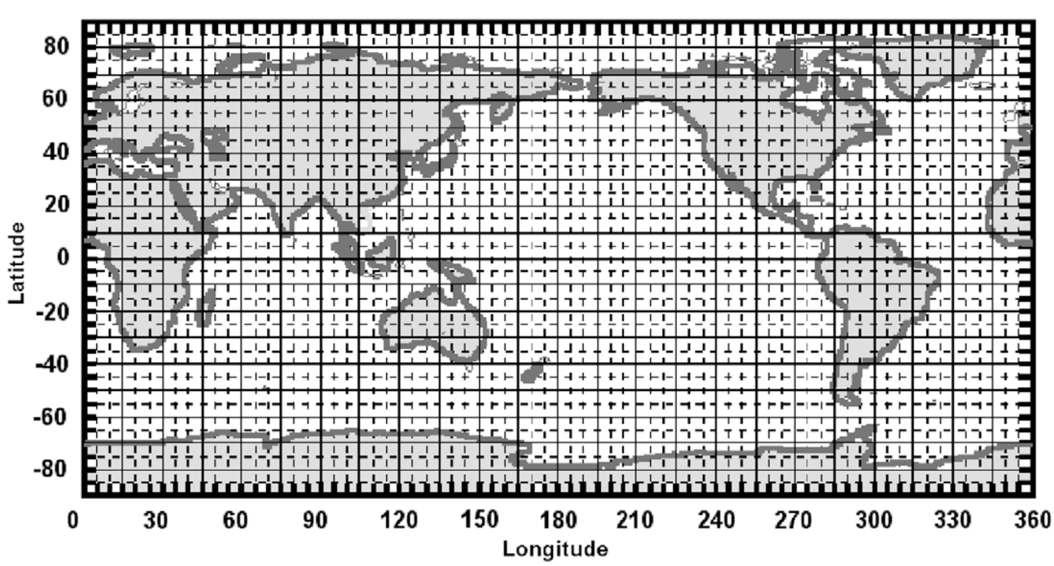

Fig. 1. Global topographic map specifies the land and oceans on the Earth.