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Online International Reference Ionosphere Extended to Plasmasphere (IRI-Plas) Model

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Abstract

International Reference Ionosphere (IRI) is the most commonly used climatic model of ionosphere. Recently developed IRI Extended to Plasmasphere (IRI-Plas) model extended the interest region of IRI to the GPS orbital height of 20,000 km. IRI-Plas can not only input F2 layer critical frequency, foF2, and maximum ionization height, hmF2, similar to IRI but also it can update and scale foF2 with the input of Total Electron Content (TEC). The topside electron density profile is scaled using input TEC value up to 20,000 km to include the variability in plasmaspheric region. IRI-Plas is presented in ftp://ftp.izmiran.rssi.ru/pub/izmiran/SPIM/ as a FORTRAN code. IONOLAB group (www.ionolab.org) offers an user-friendly online version of IRI-Plas as a space weather service. Online IRI-Plas can run for multiple tasks with different inputs and an automatic GPS-TEC input option is offered to the user. The comparison of Online IRI-Plas with ionosonde profiles indicate that TEC input is highly useful in update of electron density profile to the current ionospheric state especially for geomagnetically disturbed days.

1 Introduction

Ionosphere is the most important atmospheric layer for space based navigation and positioning systems and it is the main propagation channel for High Frequency (HF) communication and direction finding systems. The inhomogeneous, anisotropic, dispersive and spatio-temporally variable structure of ionosphere makes it very difficult to model the electron density. The variability of ionosphere can be classified into a trend behavior and secondary disturbances.

International Reference Ionosphere (IRI) is a joint task group of COSPAR and URSI, which is dedicated to provide a reliable and accurate climatic model for structural parameters of ionosphere [1, 2]. IRI is an empirical and deterministic model that uses hourly monthly medians of F2 layer critical frequency, foF2 [3, 4]. It is originally developed in FORTRAN language and currently, it is available at http://irimodel.org/ with an online version. The IRI model can provide electron density profile, layer parameters and ion and electron temperatures in the general range of 80 to 2,000 km [5]. Users can specify the location, date, time and the height profile boundaries for a single run. Optional input parameters include but not limited to solar and geomagnetic indices, critical layer frequencies and thicknesses and alternative profile models. The outputs can be obtained in the text format or the profiles or distributions can be drawn according to user specifications. IRI is accepted as the international standard model of ionosphere in [6].

In the IRI model, the topside and bottomside electron density descriptions use a ‘relative layer shape’ formula depending on vertical coordinate adapting the absolute values to those at the peak. The reference peak electron density and height in the IRI system are provided by the ITU-R (former CCIR) or URSI maps. Since plasma interchange in the F-region is field aligned, it is not possible to describe adequately the spatial structures occurring at low latitudes when admitting that they depend exclusively on the vertical coordinate as is supposed in IRI. The temporal and spatial sparsity of data can be compensated for either by assimilation of new ionosonde results, or by upgrading the IRI model to include situations like space weather storms.

IRI Extended to Plasmasphere (IRI-Plas) is a recently developed version of IRI model by Dr. Tamara L. Gulyaeva of IRI task group [7]. In IRI-Plas, the region of interest can include the plasmasphere up to the GPS satellite orbital height of 20,200 km. IRI-Plas provides structural model of ionosphere up to plasmasphere in regions where ionosonde data are not available [8]. Guided by the knowledge gained from previous data analysis, the IRI-Plas algorithm is complemented with a feedback loop in order to update two model parameters: an instantaneous peak electron density that is proportional to the square of the F2 layer critical frequency, and the electron density scale height at the lower topside. IRI-Plas is available as a FORTRAN code at ftp://ftp.izmiran.rssi.ru/pub/izmiran/SPIM/.

IONOLAB Group has been using IRI-Plas as a basis of various research products provided in www.ionolab.org as space weather services. In IRI-Plas-MAP [9], IRI-Plas model parameters of foF2 and hmF2 can be mapped with or without the input of GIM-TEC according to the user defined region, date and time. In IRI-Plas-STEC [10, 11] service, Slant Total Electron Content (STEC) that is computed using IRI-Plas can be drawn for any desired elevation, and azimuth angles for the user defined coordinates, date and time. GPS satellite tracks can also be chosen for the IRI-Plas-STEC computation. IRI-Plas is also the fundamental model in IONOLAB-CIT, novel computerized ionospheric tomography method of IONOLAB Group [12]. In [13], IRI-Plas has been used with GPS-TEC to fuse model and TEC values to approximate the electron density profiles reconstructed from an ionosonde through an outside optimization loop.

In order to facilitate the usage of IRI-Plas for other possible users, IONOLAB group has implemented the online version at www.ionolab.org. The input page and the output of the program is similar to the internet access page of IRI-2016. The advantages of online IRI-Plas with respect to FORTRAN version or to online IRI are discussed in Section 2. In Section 3, some results that are obtained by using online IRI-Plas are presented.

2 Online IRI-Plas

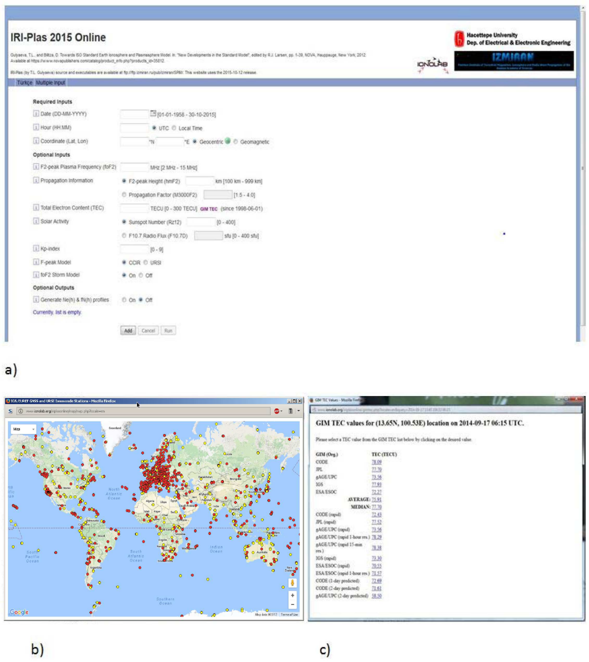

Figure 1. IRI-Plas Online screenshots: a) main input screen, b) pop-up map of GNSS/Ionosonde stations, and c) GIM-TEC values pop-up window.

Online IRI-Plas is developed by the IONOLAB group and presented at the IONOLAB website (www.ionolab.org) as 'IRI-Plas 2015 Online' service. In order to use this service, users should login with their IONOLAB username and password which they determined during online registration. The site is in both English and Turkish. The user-friendly graphical interface of IRI-Plas can be run with no extra input; with desired geomagnetic indices similar to online IRI; with ionosonde foF2 and hmF2 inputs, as shown in Figure 1(a). One of the most important features of Online IRI-Plas is the option of choosing an IGS-GNSS (formerly IGS-GPS) station or an ionosonde station from a pop-up map as shown in Figure 1(b). The coordinates of the chosen station is automatically selected and shown on the IRI-Plas Online main screen for computation.

The most critical advantage is the scaling of the model parameters with Total Electron Content (TEC) input. This input can be provided by the user for the chosen location or it can be automatically provided by the IONOLAB group. When the TEC input option is clicked, a pop-up window containing the Global Ionospheric Map (GIM)-TEC values of IGS analysis centers (CODE, JPL, gAGE/UPC, ESA/ESOC or IGS) appears as shown Figure 1(c). The GIM-TEC is provided by IGS in a $2.5° \times 5°$ resolution in latitude and longitude, respectively. The temporal resolution of GIM-TEC is one or two hours. When the GIM-TEC icon is clicked on, GIM-TEC values—obtained from GIM-TEC maps by interpolation according to the given location, date and time—are shown in the pop-up window automatically. The mean and median values are also presented along with rapid, 1-day predicted and 2-day predicted TEC map values, where available. Once a TEC value is clicked, it will be selected and shown on the IRI-Plas Online main screen. It is also possible to calculate more accurate GPS-TEC [14, 15, 16] values for a GNSS station location using the 'IONOLAB-TEC Online' service [17] or downloadable 'IONOLAB-TEC Software' available on the IONOLAB website, and enter these GPS-TEC values on the IRI-Plas Online page.

Unlike online IRI, and FORTRAN coded IRI and IRI-Plas, online IRI-Plas can be run for multiple inputs in one batch. Output is displayed beneath the input screen and also provided as a downloadable text file.

3 Results

In order to show some results of the IRI-Plas Online, we have selected a ionospherically disturbed day of 25 October 2011, and the two ionosonde (DPS-4D) locations of Jeju (33.43°N, 126.3°E) and Jicamarca (-12°N, 283.2°E) in South Korea and Peru, respectively. URSI codes for the Jeju and Jicamarca ionosonde stations are JJ433 and JI91J, respectively. Their ionosonde dataset is obtained from ftp://ftp.ngdc.noaa.gov/ionosonde/data/. Due to limited space, we are going to only present electron density (Ne) profiles and foF2 values obtained on 25 October 2011, a geomagnetically disturbed day with a significant storm peak.

Figures 2(a), 2(b), 2(c) and 2(d) present electron density (Ne) profiles of Jeju obtained from the JJ433 ionosonde, IRI-Plas without any input, IRI-Plas with JPL GIM-TEC input, and IRI-Plas with CODE GIM-TEC input, respectively. As the ionosonde profile is plotted for the available time and heights, there are some blank times and heights. In the figures, DPS-4D electron density profile is significantly different from the electron density profile of the IRI-Plas model when there is no input provided. When the coarse GIM-TEC inputs (both JPL and CODE) are provided, elec-

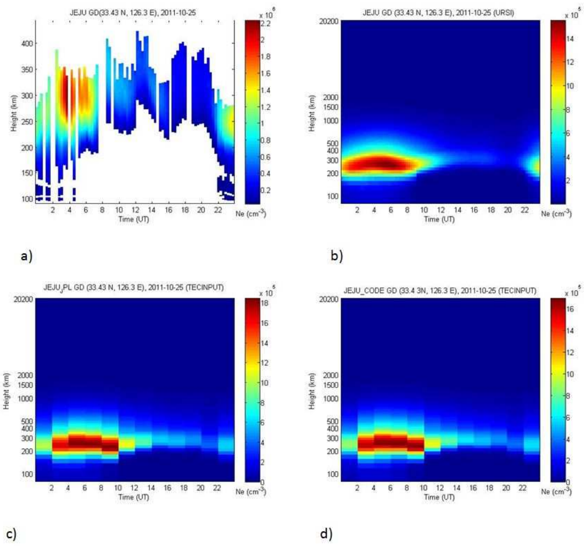

Figure 2. Ne profiles on 25 October 2011 for Jeju: a) ionosonde profile, b) IRI-Plas profile (no input), c) IRI-Plas profile (with JPL GIM-TEC), and d) IRI-Plas profile (with CODE GIM-TEC).

tron density profiles change slightly towards the ionosonde electron density profile. We provided the cases with GIM-TEC inputs specifically, as this is the main difference between IRI-Plas Online and IRI online.

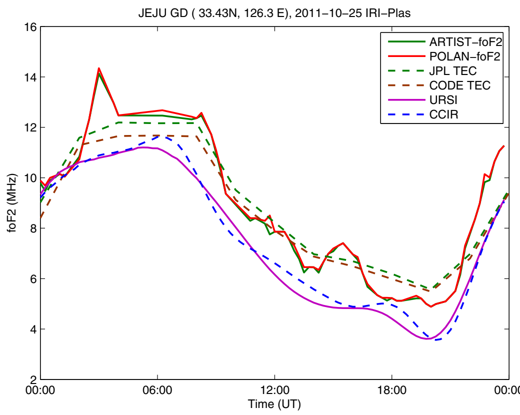

Figure 3. Comparison of foF2 values obtained from the ionosonde and IRI-Plas model on 25 October 2011 for Jeju.

Figures 3 and 4 present foF2 values obtained at Jeju and Jicamarca, respectively. In both figures, ARTIST and POLAN outputs of the ionosonde are shown with solid green and solid red lines, respectively. IRI-Plas model output with JPL and CODE GIM-TEC inputs are shown with dashed green and dashed brown lines, respectively. Similarly, IRI-Plas model output with no input for URSI and CCIR foF2 profiles are shown with solid magenta and dashed blue lines, respectively. At Jeju, both ARTIST and POLAN outputs of the ionosonde match together, and IRI-Plas outputs with GIM-TEC inputs (both JPL and CODE) fit better with the ionosonde output compared to the outputs without any input. At Jicamarca, ARTIST output of the ionosonde is smoother compared to its POLAN output, IRI-Plas outputs with GIM-TEC inputs (both JPL and CODE) fit better (except at 02:00 UTC) with the ARTIST output compared to the outputs without any input. There are also noticable negative and/or positive jumps in foF2 values between 01:00 UTC and 04:00 UTC for both Jeju and Jicamarca locations.

URSI and CCIR are different foF2 profile models and their foF2 output values are obtained from the IRI-Plas model, when no IRI-Plas input is provided and the corresponding foF2 profile is selected. It can be observed that the model foF2 output values do not represent the agility in ionosphere and they behave significantly different compared to ionosonde outputs.

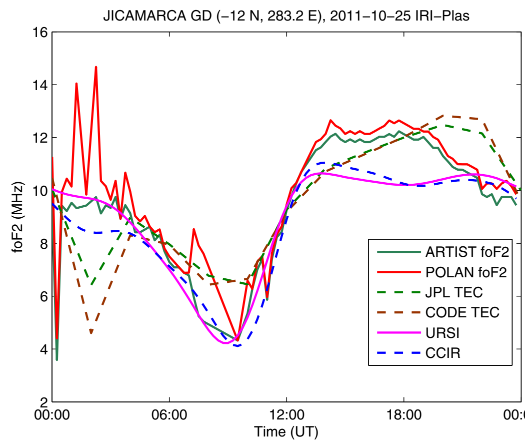

Figure 4. Comparison of foF2 values obtained from the ionosonde and IRI-Plas model on 25 October 2011 for Jicamarca.

4 Conclusion

Online IRI-Plas at www.ionolab.org provides an important opportunity to observe the most developed climatic ionospheric model extended to plasmasphere height in a user-friendly environment. The automatic choice of GPS stations and automatic input of GIM-TEC help the user to visualize the impact of space weather calibration of IRI model. IONOLAB group offers IRI-Plas-MAP and IRI-Plas-STEC (Slant TEC) services for further studies. Any other desired option can be implemented by IONOLAB group in the future.

5 Acknowledgements

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