



Realistic Ionosphere: real-time ionosonde service for UN International Space Weather Initiative

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Abstract

Realistic Ionosphere (RI) is a part of the International Space Weather Initiative (ISWI), a cooperative program of United Nations Committee on the Peaceful Uses of Outer Space. RI is an ISWI instrument suite dedicated to continuing, accurate, and prompt nowcast of the 3D global plasma density distribution in the subpeak ionosphere of the Earth, based on the real-time data feeds from a global network of ionosondes with installations in 26 countries. The RI suite includes several remote sensing, modeling, and computer science components, including Global Ionosphere Radio Observatory (GIRO) and an online data processing and dissemination center with an open data portal at <http://giro.uml.edu>. The paper summarizes ionospheric weather services provided by the RI project.

1. Introduction

The objective of the United Nations International Space Weather Initiative (ISWI) is to develop scientific insight for the understanding, reconstruction, and forecast of the near-Earth space weather in a global international cooperation of scientists and coordinated instrumentation and data systems. The Realistic Ionosphere (RI) is an ISWI *instrument suite* whose objective is to provide an accurate and prompt nowcast of the 3D global plasma density distribution in the subpeak ionosphere using high-frequency (HF) ionospheric sounding technology. It includes several remote sensing, modeling, and computer science components

2. Components of Realistic Ionosphere

2.1 GIRO: Global Ionosphere Radio Observatory

GIRO is a multi-nation coordinated network of HF ionosondes [1] providing near-real-time (nRT) low-latency measured data of the subpeak ionospheric plasma density, including raw and derived data products with public dissemination via Open Data Portal at <http://giro.uml.edu> (Figure 1):

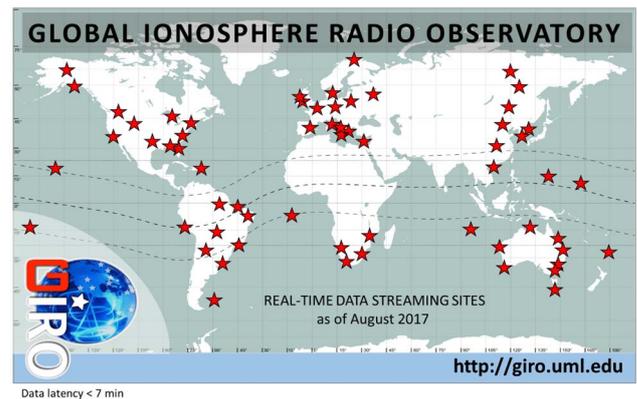


Figure 1. Global Ionosphere Radio Observatory with near real-time data feeds to Realistic Ionosphere

- vertical and oblique ionogram data and displays;
- ionogram-derived autoscaled and manually validated records of electron density profiles, and standard URSI characteristics (foF2, hmF2, etc.);
- Doppler skymaps of signal propagation;
- overhead ionospheric plasma drift velocities;
- local tilts of the ionosphere;
- measurements of Traveling Ionospheric Disturbances (TIDs), and
- ray-tracing computations through the 3D specifications of the Realistic Ionosphere

2.2 IRTAM: IRI-based Real Time Assimilative Model

IRTAM 3D is a global 3D empirical nowcast of the ionospheric plasma density [2] based on a Real-Time IRI technique of smooth transformation of the background International Reference Ionosphere (IRI) climatological model [3] into the optimal match with GIRO measurements. The IRTAM 3D updates are issued every 15 minutes with 7.5 minute latency from the GIRO start of ionogram measurements (Figure 2).

Lowell GIRO Data Center (LGDC) operates a database of retrospective IRTAM computations with access webpage at <http://giro.uml.edu/GAMBIT/>, covering the period from year 2000.

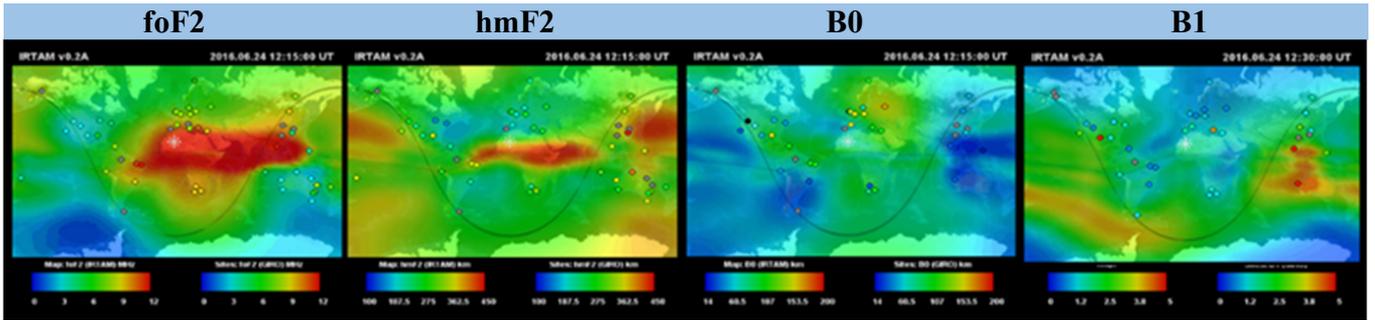


Figure 2. Global ionospheric weather maps computed by IRTAM at 15 min cadence.

2.3 TID Explorer

Traveling Ionospheric Disturbance (TID) Explorer [4,5] is a TID detection and evaluation system based on Doppler-Frequency-Angular Sounding (FAS) sensing method [6] between two Digisonde DPS4D instruments. TID Explorer provides nowcast and forecast of traveling ionospheric disturbances: natural or artificial phenomena associated with the wave-like perturbation of plasma density in response to propagation of the acoustic gravity waves in the neutral atmosphere. The FAS method allows full specification of the TID ensemble, including its amplitude, period, and the \mathbf{K} vector of propagation. The

TID characteristics are derived from observed variations of the signal properties (group path ρ , Doppler frequency f_D and angle of arrival expressed as elevation ϵ and azimuth β). Figure 3 presents an example detection of a 44% TID on a 517 km radiolink between DPS4D instruments in Puhonice, Czech Republic, and Juliusruh, Germany, during high activity period on May 7, 2017 between 00 and 05 UT. Intelligent systems are used for signal clustering [4] and tracking [7] in the multi-path propagation conditions in the D2D radiolink. A pilot TID warning system based on TID Explorer computations is operational at <http://tid.space.noa.gr> based on the network of DPS4D observatories in Europe.

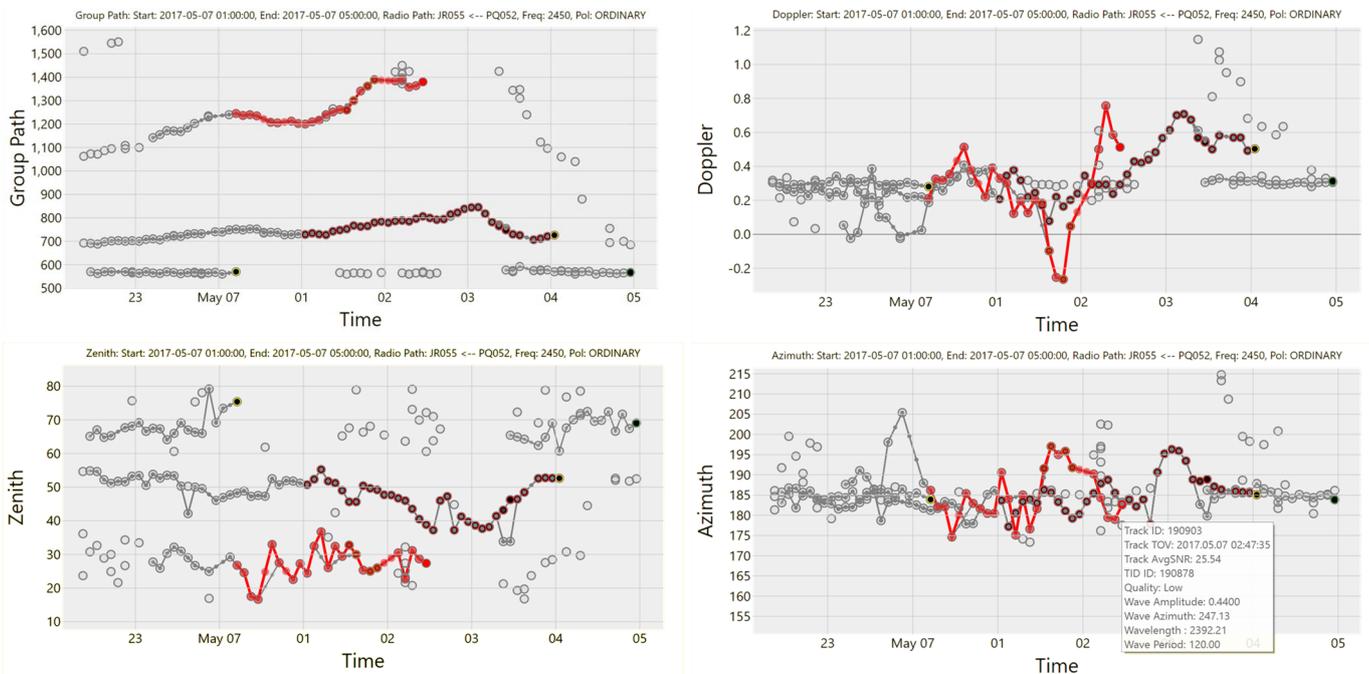


Figure 3. Example TID signature in records of signal variation between DPS4D sounders at Puhonice and Juliusruh, May 7, 2017: detection and evaluation of a large-scale 120-minute 44% TID traveling SSW. Tracks of signal variations (red lines) are extracted automatically using a human vision model ANNAE [7].

2.4 Sky-LITE: Skymapping for Local Ionosphere Tilt Evaluation

Single-site measurements of the reflected signal properties (time of travel, Doppler frequency, and angle of arrival) are called, for historic reasons, vertical-incidence Doppler skymaps, or simply vertical skymaps. The “Skymap” (Figure 4)) is simply a common visual presentation of the acquired directional measurements in polar coordinates of the zenith and azimuth angles of arrival; such presentation resembles images from all-sky cameras [8]. In Figure 4, the Doppler frequency of each echo signal is indicated by color. Signals in the vertical skymaps rarely arrive exactly from zenith because of plasma irregularities responsible for a variety of off-vertical reflections of the HF waves in the ionosphere.

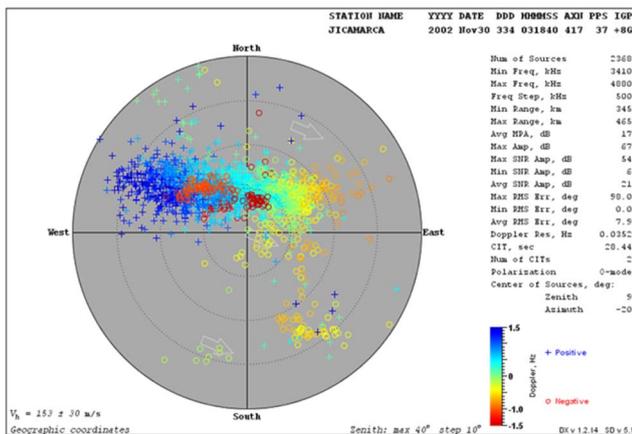


Figure 4: Skymap presentation of reflected signal properties: angle of arrival in polar coordinates, and Doppler frequency (color)

2.5 RayTRIX: Ray-Tracing through Realistic Ionosphere

RayTRIX performs numerical HF signal raytracing through the ionospheric channel specified by IRTAM, Sky-LITE and TID Explorer [9].

2.6 LGDC: Lowell GIRO Data Center

LGDC maintains a collection of computer software, database engines, and computer infrastructure for computations associated with RI nowcast and warning services, and open international data access for academia, students, radio enthusiasts, and space weather applications. Over 600 million records of sounding data are available over the GIRO Web Portal, <http://giro.uml.edu>. LGDCC offers online interactive data explorer software tools for each of its database with capability to submit user-derived and annotation value-added information to LGDC.

3. References

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