TOWARDS COOPERATIVE GLOBAL MAPPING OF
THE IONOSPHERE. FUSION FEASIBILITY FOR IGS
AND IRI WITH GLOBAL CLIMATE VTEC MAPS

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Since 1998, the IGS Ionosphere Working Group has been continuously releasing global VTEC maps in rapid, final, and predicted schedules.

The IGS Ionosphere Combination and Validation Center at University of Warmia and Mazury is responsible for an ensemble analysis of the global VTEC maps synthesized independently by several ISG Associate Analysis Centers by applying the observation uncertainty weights determined by validating the VTEC data against the original slant TEC measurements.

Products:

- **Final GIM:** resolution 2 hours x 5 deg. x 2.5 deg (UTxLon.xLat.); latency of 11 days
- **Rapid GIM:** resolution 2 hours x 5 deg. x 2.5 deg; latency of less than 24 hours
- **Real Time GIM** provided independently by several IAACs
- **Predicted GIM** for 1 and 2 days ahead (pilot product) - resolution 2 hours x 5 deg. x 2.5 deg; availability 24 and 48 hours in advance
The International Reference Ionosphere (IRI) is an international project sponsored by the Committee on Space Research (COSPAR) and the International Union of Radio Science (URSI).

For given location, time and date, IRI provides monthly averages of the electron density, electron temperature, ion temperature, and ion composition in the altitude range from 50 km to 2000 km. Additional parameters given by IRI include the Total Electron Content, the occurrence probability for Spread-F and the F1-region, and the equatorial vertical ion drift.

The major data sources are the worldwide network of ionosondes, the powerful incoherent scatter radars (Jicamarca, Arecibo, Millstone Hill, Malvern, St. Santin), the ISIS and Alouette topside sounders, and in situ instruments on several satellites and rockets. For further information please refer to: https://iri.gsfc.nasa.gov/
GIRO – Global Ionosphere Radio Observatory

The Lowell GIRO Data Center (LGDC) implements a suite of technologies for post-processing, modeling, analysis, and dissemination of the acquired and derived data products:

- **IRTAM** – IRI-based Real-time Assimilative Model – that builds and publishes every 15-minutes an updated “global weather” map of the peak density and height in the ionosphere, as well as a map of deviations from the classic IRI climate.

- **GAMBIT** – Global Assimilative Model of Bottomside Ionosphere Timelines Database and Explorer holding 15 years worth of IRTAM computed maps at 15 minute cadence.

- **17+ million ionograms and matching ionogram-derived records of URSI-standard ionospheric characteristics and vertical profiles of electron density**

- **Data and software for Traveling Ionospheric Disturbance (TID) diagnostics**
OBJECTIVES

- Introduction of 30-day average empirical (climate) TEC maps into GAMBIT Explorer software in order to build deviation maps for ionosonde-derived global maps of the bottomside ionospheric plasma – fulfilled (presented at EGU General Assembly in Vienna in April 2018) – full data availability since 2010 until now

- Ionospheric weather nowcast based on near real-time data products from IGS and GIRO sensor networks – fulfilled (presented at AT-RASC at Gran Canaria in June 2018)

- System development for enhanced latency, stability, and reliability – advanced works in progress

- Real-time GIM incorporation into GAMBIT – advanced works in progress

- Full assimilation of empirical VTEC data into IRI – future works
GAMBIT EXPLORER

GAMBIT Explorer is a Java application based on NASA WorldWind graphics library, released for academic research use at http://giro.uml.edu/GAMBIT, which allows for rapid and interactive visualisation of different ionospheric properties, such as F0F2, NmF2, HmF2, B0 or B1 in various routines (interpolated climate and weather or observations at GIRO sites). But most importantly it integrates different data sources and allows for their combination in a goal of delivering a detailed insight in the ionosphere. Detailed description of the GAMBIT database and Explorer, as well as underlying formalism and algorithms can be found in. Incorporation of the climate global VTEC maps (described further) led us to extend the capabilities of GAMBIT Database in the climate aspect and opened the path for planned inclusion of weather VTEC.

For further details concerning GAMBIT Explorer features please refer to: http://giro.uml.edu/GAMBIT/GAMBIT-X_UserGuide-v01C.pdf
RESULTS

![Map 1](image1.png)

![Map 2](image2.png)
RESULTS
Towards Cooperative Global Mapping of the Ionosphere: Fusion Feasibility for IGS and IRI with Global Climate VTMC Maps

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Abstract: Recommendations of the International Reference Ionosphere (IRI) 2017 in Taoyuan City, Taiwan and International GNSS Service (IGS) Workshop 2018 in Wuhan, China, included establishment of an ionosphere mapping service that would base measurements from two independent sensor networks: IGS permanent GNSS receivers providing the vertical total electron content (VTEC) measurements and ionosondes of the Global Ionosphere Radio Observatory (GIRO) that compare the horizontal vertical profiles of the ionospheric plasma density. Using available GIRO software at IGS, we introduced new VTEC products to its data center, previously published 550 reads

Global Monitoring of Ionospheric Weather by GIRO and GNSS Data Fusion

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Near-Real-Time and Rapid global weather VTEC maps for GAMBIT in cooperation between IGS and IRI

Adam Frid 4, Ioan Galik 6, Andréj Krzynowko 5, Eirtey Bilta 7, Manuel Hernández-Pajares 5, Bodo Reimold 8, Karag Rasul 5, Irina Zakharenkova 5, Iuri Chernikov 5, David Romo Dallase 9, Nguyen Wang 1, Pavel Hlubik 2 and Albright Garcia-Rizo 10

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Keywords: ionospheric, ionosphere, weather, GIRO, GNSS

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