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Imaging Ionosphere with Assimilative IRI

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Remote sensing of the near space plasma environments of the Earth using radio waves has become the realm of research and applications; however, rarely we see it described in the *imaging* terms. Even if a visual presentation of the sensor data is an image (for example, a *plasmagram* recorded by NASA radio plasma imager (RPI) for IMAGE mission), association of the visible signatures in such "images" with the physical phenomena that they represent is not an intuitive undertaking.

One important step towards true radiowave imaging of the plasmas is presentation of the measurements in a more familiar language outside the experts' box. The paper presents one successful attempt to abstract from the wave data peculiarities and synthesize a clear global picture of the Earth's ionosphere dynamics by assimilating sensor-provided data into a 3D timeline of the ionospheric plasma dynamics. In turn, the 3D density specification admits significantly more intuitive presentations such as 2D global maps in Figure 1.

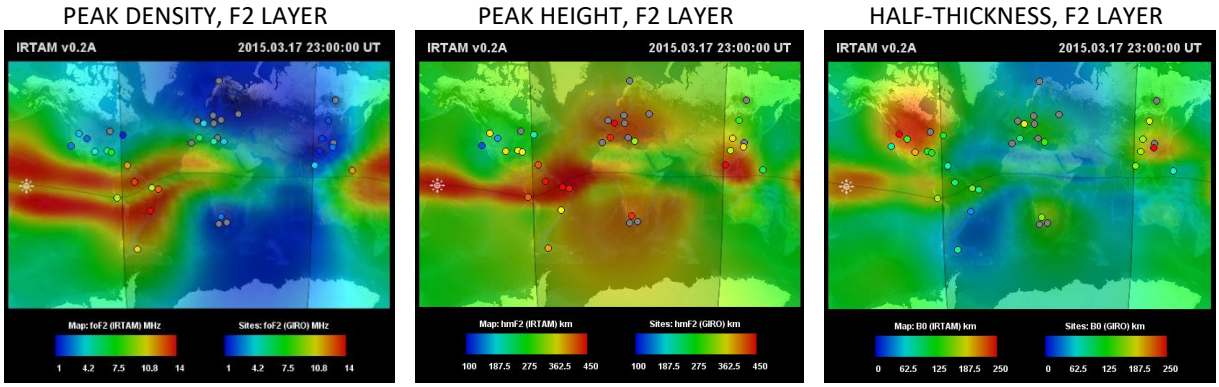

Figure 1: Imaging the ionospheric F2 layer during the Halloween storm, 2015.03.17 23:00 UT, using IRTAM global weather nowcast (color surface) driven by GIRO ionosonde measurements (dots).

In Figure 1, color surfaces correspond to the 2D maps of the key F2 layer parameters computed by IRI-based Real-Time Assimilative Model (IRTAM) [1] that smoothly transforms ("morphs") the underlying International Reference Ionosphere (IRI) climatology into agreement with the low-latency measurements from ionosondes of the Global Ionosphere Radio Observatory (GIRO) [2], for a rapid look at the ionospheric weather timeline.

Under the hood of IRTAM, the Non-linear Error Compensation Technique with Associate Restoration (NECTAR) [3] analyses the ionospheric dynamics over the 24-hour period preceding the computation in order to sense the diurnal harmonics of plasma variability. The NECTAR view of the ionosphere in terms of its internal, periodic planetary-scale "eigen" basis allows it to associate the activity fragments at the sparse GIRO sites with ongoing grand-scale weather processes of the matching temporal scales, as the observatories co-rotate with the Earth. The IRTAM team actively pursues two new collaborative projects to enhance its ionosphere imaging capability: (a) multi-site GNSS VTEC data service to retrieve the slab thickness of the ionosphere and to distinguish ionosphere/plasmasphere contributions to the weather variability and (b) COSMIC-derived radio occultation profiles for improved peak height representation and extended IRTAM coverage to the topside ionosphere.

References:

[1] Galkin, I. A., B. W. Reinisch, and D. Bilitza (2018), Realistic Ionosphere: real-time ionosonde service for ISWI, *Sun and Geosphere*, 13, No.2, doi: 10.31401/SunGeo.2018.02.09.
[2] Reinisch, B.W. and I.A. Galkin (2011), Global Ionospheric Radio Observatory (GIRO), *Earth Planets Space*, vol. 63 no. 4 pp. 377-381, doi:10.5047/eps.2011.03.001.
[3] Galkin, I. A., B. W. Reinisch, et al., (2020), Assimilation of Sparse Continuous Near-Earth Weather Measurements by NECTAR Model Morphing, (submitted to *Space Weather*, 2020SW002463).