Assimilation of Sparse Continuous Ionosonde Data into Real-Time IRI

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ABSTRACT

The International Reference Ionosphere (IRI) is a monthly median empirical model that captures the climatologic essence of observational data collected at a large number of observatories around the world. This limits the use of IRI for applications that require real-time information on the status of the ionosphere. Over the years, a variety of concepts for building a nowcasting version of the IRI were introduced, all leveraging available geospace observations to modify the IRI climatology on its local or global scales [1]. In the current technological state of space weather instrumentation the availability of near-real-time (nRT) sensor coverage (below a few minutes) is however very limited in comparison to the large data base that contributed to the original IRI electron density definitions. Computational schemes that use sparsely available observations to modify the IRI climatological predictions are prone to the numerical artifacts of extrapolating corrections to fill the data gaps between regions of good sensor coverage.

In 2010, a new approach was introduced with the IRI-based Real Time Assimilating Model "IRTAM" [2] for the F2-peak parameters foF2 and hmF2 based on the nRT capability of the growing Global Ionosphere Radio Observatory "GIRO" [3]. Every 15 minutes, the IRTAM software at the Lowell GIRO Data Center updates the global ionospheric plasma distribution using the GIRO inputs. Because the nRT data coverage of GIRO is still limited in comparison to the original datasets used for building the IRI global ionospheric maps, special techniques for smooth transformation of the IRI were designed. The new class of algorithms elastically and iteratively *morphs* the climatological IRI model into agreement with the GIRO measurements, so that the updated model representation of the ionosphere closely follow its "weather" variability as reported by the GIRO sensors. Rapid insight into ongoing weather processes is gained by mapping the differences between the updated (weather) and climate ionospheric specifications as

illustrated in Figure 1. It shows the deviations of the ionospheric weather values for foF2 and hmF2 from its climate values.

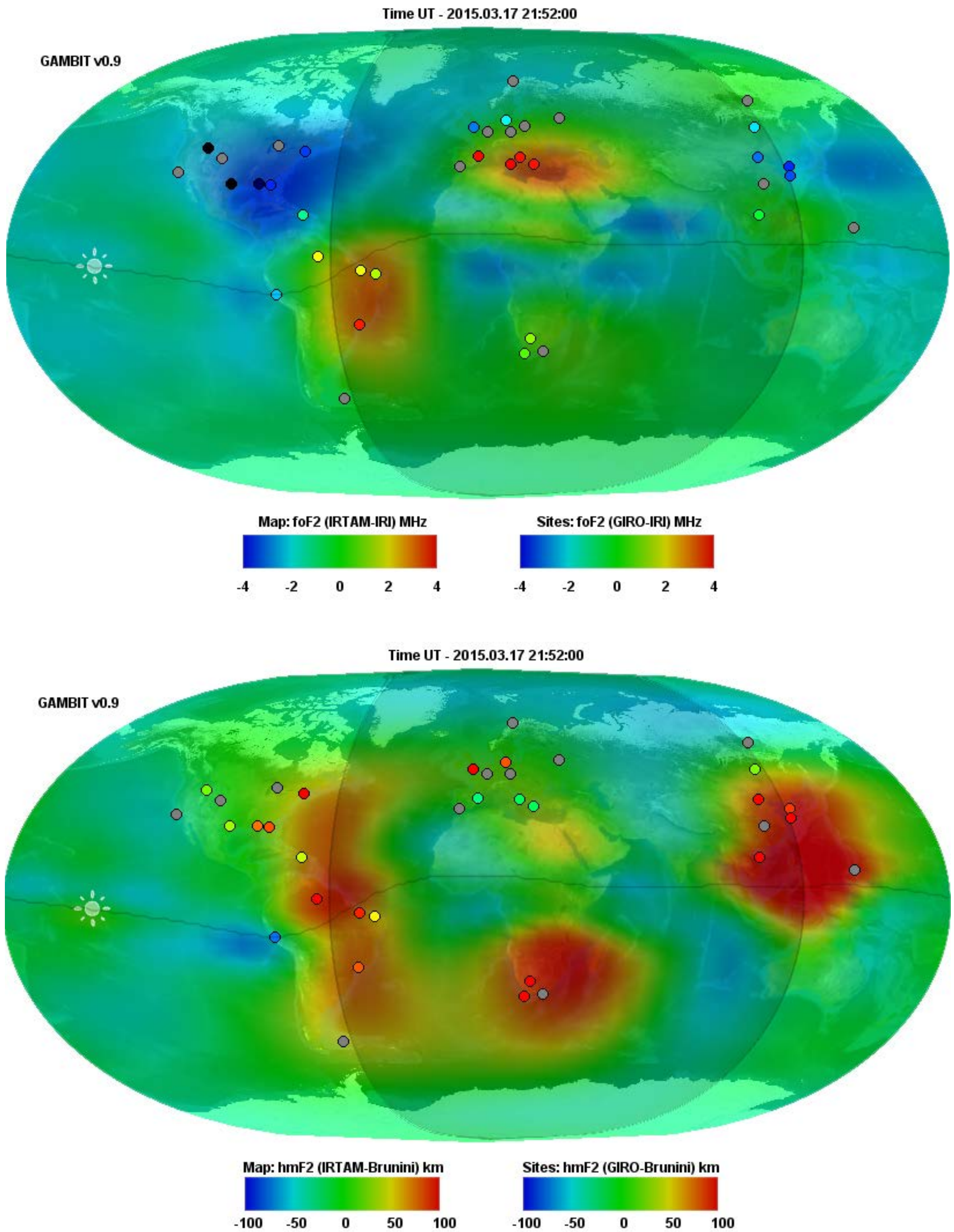

Figure 1. Saint Patrick storm event on March 17, 2015. Deviations at 21:52 UT of the ionospheric weather (IRTAM) from its quiet-time (IRI) behavior for ΔfoF2 (upper panel) and ΔhmF2 (lower panel)

In Figure 1, the green colors indicate small deviations from the climate, while blue and red shades of color denote observations below and above the quiet-time prediction, respectively (Note: the STORM model is turned off when calculating the IRI quiet-time perdiction). The color dots in Figure 1 denote the locations of the GIRO Digisondes that contributed foF2 and hmF2 measurements in real-time. Individual data values that are flagged as "low confidence" by the Digisonde's automatic ionogram scaling software [4,5] are shown as gray dots for the 21:52 UT maps; low confidence values are not included in the 24-hour diurnal harmonic expansion.

The latest operational IRTAM version uses the Non-linear Error Compensation Technique for Associative Restoration (NECTAR) to assimilate fragmentary sensor data into the global IRI model. The NECTAR software identifies diurnal harmonics of the ionospheric variability at sensor sites to spatially interpolate or extrapolate their deviations from the climate to the global scale. In such significantly 4D Data Assimilation (4DDA) approach, the 24-hour history of observations is used to sense ongoing large-scale (up to planetary) weather processes in the ionosphere to compute one time frame of IRTAM. Early results of the NECTAR model morphing applied to the assimilation of GIRO observations into IRI reveal its intriguing capability to predict system dynamics over no-data areas (spatial interpolation) and in time (short-term forecast). A few examples of comparisons with data acquired by the recently launched SWARM satellites and during the ESWW-12 Pan-European Low-Sun validation study will also be presented.

Key words: space weather, real-time IRI, assimilative ionospheric modeling, global ionosphere radio observatory

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