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Predictive Properties of Real-Time Assimilative IRI

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The International Reference Ionosphere (IRI) [1] includes a 3D empirical quiet-time climatology model of the ionospheric F2 peak electron density NmF2 based on 24 sets of the diurnal 2D maps of the plasma frequency foF2 [2]. With other key characteristics foF2 defines the profile shape at any given location and individually for each of 12 months and the minimum and maximum levels of solar activity. The recently introduced concept of a real-time assimilative IRI model [3] uses prompt ionosphere specification data to modify the IRI definitions into a better match with the measurements, thus offering an ionospheric weather nowcast capability to applications that employ ionospherically propagating radio signals. The paper discusses one implementation of the concept, the IRI-based Real-Time Ionosphere Model (IRTAM) [4], which uses low-latency inputs from the Global Ionosphere Radio Observatory (GIRO) [5] to periodically compute updated coefficients of the diurnal 2D maps of the four major characteristics: O-wave critical frequency foF2, peak height hmF2, and two IRI profile shape parameters, B0 and B1. These four IRTAM map specifications can be used to obtain global 3D bottomside Ne density weather nowcast with 15-minute cadence and 8-minute latency from the GIRO observations.

The cornerstone of the IRTAM model is a novel method for assimilation of fragmentary sensor data, "Non-linear Error Compensation Technique with Associative Restoration" (NECTAR). NECTAR restores missing information by iteratively transforming ("morphing") an underlying IRI model of into agreement with currently available sensor data. The morphing procedure benefits from analysis of the multi-scale inherent diurnal periodicity of the ionospheric dynamics by processing 24-hour time histories of the differences between GIRO measurements and the underlying IRI climatology. Thus collected deviation time series over the 24 hours prior to nowcast are used to compute, and then globally interpolate the diurnal deviation harmonics. Thus, NECTAR views the geosystem in terms of its internal, periodic planetary-scale "eigen" basis (diurnal, half-diurnal, 8-hour, etc.), so that it can associate observed fragments of the activity at observatory sites with the unveiling grand-scale weather processes of the matching variability scales, as the sensors co-rotate with the Earth.

Viewing the geosystems in terms of their internal periodic constituents strengthens the restorative capability of the assimilation update step, specifically when only a limited number of observatories is available for the weather nowcast. Early tests of the NECTAR morphing reveal its enhanced capability to predict system dynamics over no-data regions (spatial interpolation) and time (short-term forecast). The paper discusses such baseline predictability of the ionospheric dynamics based solely on the recent history of its conditions without involving the knowledge of the planetary-scale processes affecting the Sun-Earth environment.

References

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