Data Assimilation of Ground-based GPS and Radio Occultation Total Electron Content for Global Ionospheric Specification

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We present a practical approach to the global ionospheric specification that is based on the Gauss-Markov Kalman filter designed to assimilate the slant total electron content (TEC) data from ground-based GPS receivers and space-based radio occultation instrumentations, including FORMOSAT-3/COSMIC (F3/C) and FORMOSAT-7/COSMIC-2 (F7/C2), into the International Reference Ionosphere (IRI). Observing System Simulation Experiments (OSSEs) for F3/C and F7/C2 underscores the importance of implementing the forecast step that propagates both the state and covariance properly in the Kalman filter, even without the use of time-dependent dynamics in the forecast step, to extend the impact of slant TEC observations on the ionospheric specification beyond what is possible with an assimilation procedure consisting only of the measurement update. Our approach furthermore makes use of a low-rank non-parametric covariance model derived from principal component analysis of the IRI ensemble, which helps prescribe a priori non-stationary (anisotropic and inhomogeneous) correlation and variance structure of the three-dimensional ionospheric electron density in the Kalman filter measurement update. In comparison to F3/C, the denser F7/C2 occultation observations can improve the analysis accuracy significantly as suggested by a comparative analysis of OSSEs. Results from data assimilation experiments with real F3/C and ground-based GPS observations are validated with independently obtained global ionosphere maps, global ground-based GPS measurements that are not assimilated, and the ionospheric F_2-peak height and density sounded by a handful of ionosondes. Both the OSSEs and validation results confirm a number of improvements over a previously available practical data assimilation approach. With these improvements, the procedure can indeed be used to reconstruct the three-dimensional ionospheric electron density, with a sufficient accuracy, on a routine basis to support the upcoming F7/C2 mission.