Validation of a Global Ionospheric Data Assimilation Model

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As the number of ground and space-based receivers tracking the global positioning system (GPS) steadily increases, and the quantity of other ionospheric remote sensing data such as measurements of airglow also increases, it is becoming possible to monitor changes in the ionosphere continuously and on a global scale with unprecedented accuracy and reliability. However, in order to make effective use of such a large volume of data for both ionospheric specification and forecast, it is important to develop a data- driven ionospheric model that is consistent with the underlying physical principles governing ionosphere dynamics.

A fully 3-dimensional Global Assimilative Ionosphere Model (GAIM) is currently being developed by a joint University of Southern California and Jet Propulsion Laboratory team. GAIM uses a first-principles ionospheric physics model ("forward" model) and Kalman filtering and 4DVAR techniques to not only solve for densities on a 3D grid but also estimate key driving forces which are inputs to the theoretical model, such as the ExB drift, neutral wind, and production terms. The driving forces are estimated using an "adjoint equation" to compute the required partial derivatives, thereby greatly reducing the computational demands compared to other techniques. For estimation of the grid densities, GAIM uses an approximate Kalman filter implementation in which the portions of the covariance matrix that are retained (the off-diagonal elements) are determined by assumed but physical correlation lengths in the ionosphere. By selecting how sparse or full the covariance matrix is over repeated Kalman filter runs, one can fully investigate the tradeoff between estimation accuracy and computational speed.

Although GAIM will ultimately use multiple datatypes and many data sources, we have performed a first study of quantitative accuracy by ingesting GPS-derived TEC observations from ground and space-based receivers and nighttime UV radiance data from the LORAAS limb scanner on ARGOS, and then comparing the retrieved density field to independent ionospheric observations. A series of such GAIM retrievals will be presented and validated by comparisons to: vertical TEC data from the TOPEX altimeter, slant TEC data from ground GPS sites that were not included in the assimilation runs, and global ionosonde data (F0F2, HMF2, and bottom-side profiles where available). By presenting animated movies of the GAIM densities and vertical TEC maps, and their errors computed as differences from the independent observations, we will demonstrate the reasonableness and physicality of the climatology derived from the GAIM forward model, examine the consistency of the GPS and UV datatypes, and characterize the quantitative accuracy of the ionospheric "weather" specification provided by the assimilation retrievals.