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Empirical Long-Term Forecasting In a Parametric Data Assimilative Model

Alan R. Hoskinson [(1)], Dima Paznukhov [(1)], and Keith M. Groves* [(1)]
(1) Boston College – Institute for Scientific Research, Chestnut Hill, MA, 02467, e-mail: alan.hoskinson@bc.edu

We present the design and validation of a long-term (up to 3 days) forecasting algorithm applied at individual ionosonde locations. The forecasting algorithm operates on ratios of measured ionospheric profile parameters to climatological predictions, and is based on the empirical observation that such normalized deviations have a significant diurnal component that can persist for several days. The forecasted values are then used in the Regional Ionospheric Profile Estimator (RIPE) model [1]. We demonstrate that the approach improves ionospheric specification substantially for forecast durations of up to 3 hours, and modestly out to 3 days.

The forecasting is performed using an unscented Kalman filter [2] with a periodic measurement model. The filter is run on a recent time series of normalized deviations from climatology at each ionosonde, then used to forecast forward to the time of interest. We make climatological predictions using the IRI [3] collection of profile parameter models: specifically the URSI model for foF2, the Shubin model for hmF2 [4], and the Altadill, Torta, and Blanch model for B_0 and B_1 [5]. The application of a periodic time series model is, in effect, a localized data-driven adjustment of the time dependence embedded in the climatological models, similar to the adjustment in the spatial domain applied by the RIPE model. We present our approach to designing the forecasting algorithm, including selecting the filter models, estimation of measurement and process noise, and time scales for data ingestion and decay of the forecast towards climatology.

The forecasting approach is primarily useful in the context of a data-assimilative model that can use the forecasts to predict the local ionospheric state. We ingest forecasted data into the RIPE model and use it to predict ionospheric profile parameters are non-ingested locations. In validation studies over North America and Europe, use of forecasted data improved the accuracy of all four examined profile parameters improved at most or all tested locations when compared to direct use of climatological models. Compared to climatology models, typical root-mean-squared errors (RMSE) for foF2 are ~0.5 MHz lower for nowcasts and ~0.1 MHz lower for 2-day forecasts. RMSE values for both hmF2 and B_0 are lower than climatology by ~5-10 km for nowcasts and ~1-2 km for 2-day forecasts. The precise amount of improvement depends largely on how much deviation from climatological predictions occurs at the validation times and locations.

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