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Preliminary results for the assimilation of forward oblique ionosonde data into the Electron Density Assimilative Model

A strong understanding of the spatial and temporal variation of the Earth's ionosphere is paramount for the effective operation of radio systems for communication and navigation. Information about the ionospheric electron density can be determined using a range of measurement techniques. Incoherent scatter radar, total electron content (TEC) derived from global navigation satellite systems (GNSS) data and vertical electron density profiles from ionosondes are all established methods of measuring and inferring ionospheric electron density. These data can be assimilated into a background ionospheric model, such as the empirical International Reference Ionosphere (IRI-2007), to produce three-dimensional nowcasts of the ionospheric electron density. One such assimilative model, EDAM (the Electron Density Assimilative Model), is capable of producing full three-dimensional global nowcasts through assimilation of empirical data via the Gauss-Markov Kalman filter approach (a method which utilises a form of minimum variance optimal estimation). It can be used to provide real time estimations of HF propagation conditions. The performance of such models is, however, limited by the accuracy of the bottomside electron density profile.

Whilst the assimilation of ionospheric measurements into background models to produce three-dimensional global nowcasts of the ionospheric electron density is well established, these conventional measurement techniques are prohibitively expensive and difficult to implement in areas such as oceans and are therefore sparse over vast expanses of the Earth. Information about these under-observed regions can instead be found by assimilating data from forward oblique ionosondes (FOIs) into EDAM. FOIs consist of a receiver and transmitter pair with a known separation distance and can therefore be used to enable measurements over these under-observed regions. They measure the group delay of the radio signal at a range of frequencies to infer the TEC along the ray path. For comparison, a ray is also synthesised through an initial prediction of the ionosphere, forecast from a background ionospheric model and the known previous state of the ionosphere. The group delay along the synthesized ray path is compared to the measured group delay and used to update the total electron content along the ray path. This new value of total electron content is then assimilated into the background electron density grid using minimum variance optimal estimation, thus allowing for the prediction of the ionosphere to be updated.

Here we present preliminary results for the first successful assimilation of forward oblique ionosonde data into EDAM. We compare simulated electron density grids with those created by assimilating FOI data synthesised from the simulated electron density grid into a background grid. Through these comparisons we are able to demonstrate that the FOI assimilation technique is capable of producing electron density grids that show good agreement with the original simulated ionosphere. We also establish that the FOI assimilation technique produces results that are comparable to those output by EDAM when it is assimilating other data sources.

The successful assimilation of FOIs into EDAM has the capability to significantly improve the three-dimensional electron density grid over oceans and other areas where a dearth of ionospheric observation stations impacts the model. This will enable space track radars and navigation systems to be operated with increasing accuracy, as well as improving radio communications by enhancing estimations of HF propagation conditions.