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Session 2A Paper 6

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A Regional Optimum Assimilative Model for Improved HF Geolocation Accuracy

We introduce a new ionospheric data assimilation system called the Regional Optimum Assimilative Model (ROAM) being developed under the IARPA HFGeo program for geolocating HF emitters. Unlike general-purpose ionospheric assimilation systems, ROAM is designed to provide accurate specifications of the ionospheric bottomside which dictates the propagation path of HF skywave signals. The ionospheric model consists of a parameterized background with a superimposed local plasma frequency gradient (ionospheric tilt) to represent the effects of traveling ionospheric disturbances (TIDs). All or a subset of the model parameters are estimated via nonlinear least-squares optimization using “in-the-loop” 3D magnetoionic ray tracing. Ray trace software developed by the Australian Defence Science and Technology Organisation (DSTO) called PHaRLAP (Cervera and Harris, JGR, 2014) is used for this purpose. ROAM can assimilate electron density profiles or profile parameters from sounders, angle-of-arrival (AoA) measurements from sounders (see companion paper by Paznukhov, et al.) or known HF emitters (check targets), and TID velocity measurements from a sounder or triad of GNSS receivers (see companion paper by Groves, et al.).

For each data type to be assimilated, cost functions are evaluated in terms of the difference between ray-traced predictions and measured quantities. Minimizing the sum of weighted cost functions provides optimum parameter estimates (the ionospheric specification). TID dynamics are accounted for during the assimilation and prediction stages in the following manner. Local gradients due to TIDs are “propagated” from the reflection point of the assimilated sounder or HF link to the presumed reflection point of the emitter of interest by time-shifting the ionospheric state. The time shift is equal to the distance between the assimilation and reflection points projected onto the direction of TID motion and divided by the TID speed. Accounting for TIDs and their motion can enhance the fidelity of HF propagation modeling and improve geolocation accuracy if the aforementioned distance is less than distance over which the TID structure is coherent. While ROAM includes basic geolocation functionally for diagnostic purposes, it was developed to operate in conjunction with a dedicated geolocation system developed by between Systems & Technology Research, LLC (STR) located in Woburn, MA (see companion paper by Rago, et al.).

In this paper, we use ROAM to demonstrate the effectiveness of assimilating Digisonde skymap (AoA) and GNSS data to estimate ionospheric tilt and TID velocity, and accounting for TID dynamics while geolocating an HF emitter. Using HF AoA data collected by the IARPA HFGeo Program Government team at White Sands Missile Range, we compare the accuracy of AoA prediction and geolocation as a function of distance between the reflection points of the assimilated and geolocated emitters, as each source of data is withheld from the assimilation. Considerations regarding the frequency separation between assimilated and geolocated HF emitters are also discussed. We find that ROAM is a relatively simple but very flexible paradigm for modeling HF propagation and its dynamic response to TIDs for the purpose of improving geolocation accuracy.