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Session 3A Paper 1

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The use of an HF data assimilative optimization of a physics based model of TIDS to predict time-delay versus frequency from an oblique ionospheric sounder

This paper focuses on improving our understanding of the physics of traveling ionospheric disturbances (TIDs) on the bottom side of the F region. In particular, we want to study how well a physics-based model of a single TID is able to accurately reproduce HF sounder observations of time delay versus frequency through the entire range of frequencies allowed by the bottom side ionosphere.

To study this question, a method for high-resolution ionosphere data assimilation has been developed that uses ionospheric models combined with HF observations from three known transmitters. The method uses an ensemble run of a physics-based model of ionospheric TIDs and optimizes to the best fit to the HF observations. The result consists of a 3D time evolving map of the electron density. The method is referred to as DA_3HF where DA stands for data assimilation and the 3HF indicates the use of three known reference points transmitting HF signals.

The HF observations used for data assimilation were collected during two days of a dedicated campaign of ionospheric measurements at White Sands Missile Range (WSMR) in New Mexico in January 2014. The three known HF reference points transmitted at 5.3 MHz. The signals were collected by a receive array capable of accurately measuring the received elevations and azimuths, or angles of arrival (AoAs) from the known transmitters. The transmitters were located North of the receive array at distances of 100-140 km, and with a spread of azimuths of ~15 degrees. The typical reflection altitude from the 5.3 MHz transmissions was 160-180 km.

An additional transmitter (OSC) was run in “sounder” mode. OSC was located at 113 km from the receive array, at an azimuth of ~ 10 degrees. Every two minutes, OSC transmitted a linear chirp over a frequency range of 3.0 to 11.0 MHz. A crossed-dipole array (CDA) located at the receive array collected time delay versus frequency sweeping through 81 frequencies every 2 minute sampling window. Both ordinary and extraordinary propagation modes were collected. The OSC sounder ran from 17 to 20 UT on January 19th and 20 to 24 UT on January 26th.

Ionospheric waves were observed in the AoA's throughout the observation periods for both January 19th and January 26th for reference transmitters. For January 19th, the elevation variability was 4-6 degrees, with excursions as high as 9 degrees over a 15-30 minute period. Azimuth variations were 5-10 degrees, with excursions as large as 30 degrees. For January 26th the observed wave variability was much larger with elevation variations of 8 degrees, with excursions up to 12 degrees, and azimuth variations of 20-40 degrees, with excursions of up to 90 degrees.

The DA_3HF optimization method was use to estimate the optimal physics-based TID for each wave period over both days. The optimal TID physics models were then used to predict the observed time delays from OSC for a number of separate frequencies spanning the range from 3 to 11 MHz. For frequencies less than 5.3 MHz, we are able to study how well the DA_3HF optimized TID model predicts time delays at lower altitudes, while for frequencies larger than 5.3 MHz we can study the ability to accurately predict time delays at higher altitudes. By studying the entire range of frequencies and time delays measured from Oscura we are able to investigate what range of altitudes a single physics-based model of an ionospheric TID is able to accurately predict oblique HF propagation observations.

This paper presents results of the optimized wave predictions of time delay for both January 19th and 26th 2014. In addition, results are presented of the time delay versus frequency using the International Reference Ionosphere (IRI) empirical ionospheric model, and the classical single site location (SSL) method using nearby ionosondes. For the SSL method, we used an ionosonde located near the center of the experimental array, and an ionosonde located ~150 km north of the array. Comparisons are made of the accuracy of the predictions across the range of observed time delay versus frequencies between the DA_3HF method, IRI, and the two SSL methods.

The results of this study will provide improved understanding of the primary question addressed by this study: Given an optimal estimation of a single physics based TID over a wave period, using three reference transmitters with a single frequency (5.3 MHz), over what range of altitudes and frequencies can the results of the optimization be accurately applied. A secondary question that will be addressed is to what extent does the DA_3HF method more accurately predict the observations than IRI and the SSL methods?