Mapping the *D*-region Ionosphere by VLF Propagation Model Inversion

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1 Extended Abstract

The *D*-region of the ionosphere forms a natural waveguide with Earth's surface, allowing for efficient propagation of very low frequency (VLF) radio waves over long distances. High power VLF transmitters support global communication and navigation systems, but these signals can also be used to remotely sense the lower ionosphere. The amplitude and phase of a VLF wave measured by a receiver is related to the vertical electron density profile which varies along the propagation path from the transmitter to the receiver. Improved knowledge of the state of the *D*-region aids in the study of this region of the atmosphere and can increase the accuracy of VLF navigation systems.

Previous work has used VLF signals to estimate the average vertical electron density profile as parameterized by a height h' and sharpness β along the propagation path [1, 2]. To produce spatial estimates of the *D*-region ionosphere on a grid across a large geographic region, we demonstrate the use of a network of VLF transmitters and receivers with criss-crossing propagation paths. Each individual receiver measurement provides information about the integrated ionosphere along the great circle path from a transmitter, but correlations with neighboring grid cells and intersecting propagation paths from other transmitters and receivers constrains the estimated ionosphere. We begin with a best-guess estimate of the *D*-region based on an empirical model in solar zenith angle and latitude [3]. The U.S. Navy's Long Wavelength Propagation Capability (LWPC) [4] is then used to predict the amplitude and phase that would be expected at each VLF receiver through the *estimated* ionosphere and is compared to corresponding receiver measurements through the *true* ionosphere to produce a better estimate. As more measurements are assimilated, the estimated ionosphere should converge to the truth. A candidate true ionosphere has been identified when the *measured* amplitude and phase at each receiver matches the LWPC-*predicted* amplitude and phase to within the modeled receiver noise. We demonstrate the use of such an ensemble Kalman filter technique to estimate possible *D*-region ionospheres over a large geographic area with simulated receiver measurements that occur over a short period of time.

References

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