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VLF Imaging of EPP-Perturbed Ionospheres

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Long radio waves from the extremely low frequency (ELF) through low frequency (LF) radio bands propagate efficiently over great distances between Earth's surface and the *D*-region ionosphere in a phenomenon known as the "Earth-ionosphere waveguide." The vertical electron density profile along a propagation path affects the electromagnetic fields measured by a fixed receiver in the waveguide. Besides naturally-occurring lightning emissions, navies across the globe operate high power very low frequency (VLF) communications transmitters which have been used as fixed narrowband VLF sources for scientific studies of the *D*-region. The amplitude and phase of a transmitted signal can be used to infer the average electron density profile of the lower ionosphere between a transmitter and receiver [1, 2]. Recently, an ensemble Kalman filter approach has been suggested to invert the measurements made by an array of VLF transmitters and receivers to produce a spatially varying map of profiles over a large geographic area [3].

One of the phenomena that is believed to influence the typically low electron densities in the *D*-region is energetic particle precipitation (EPP) from Earth's radiation belts [4]. The influx of energetic electrons significantly increases the electron density down to altitudes below 60 km [5]. Therefore, a geographic region with precipitating particles would present a perturbed electron density profile to a VLF wave propagating through the Earth-ionosphere waveguide. We present progress on a technique to invert observations of VLF signals from an array of receivers to characterize precipitation patches in anticipation of real observations from such an array in the next couple of years. The technique is expected to retrieve when energetic particle precipitation is occurring and the spatial extent of the precipitation patch. We also investigate the propagation of VLF waves through modeled EPP-perturbed electron density profiles to explore the possibility of differentiating the effects of precipitation flux and energy. These observations and retrievals will help answer questions about the relative importance of different radiation belt loss mechanisms.

References

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