VLF Remote Sensing of Lightning Induced Ionospheric Perturbations using Overlapping Paths of VLF Signal Propagation

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VLF remote sensing of the lower ionosphere has a rich history as it is one of the few techniques applicable for assessing electron density changes in the ionospheric D region (60- 95 km altitudes). The typical scenario of such sensing is that the signal of a powerful VLF band transmitter is observed at a distant receiver after propagation through the Earth-ionosphere waveguide channel. Despite many years of efforts, unambiguous quantification of D region changes to lightning induced disturbances is rare. Two challenges are the multimode nature of VLF propagation leading to nonlinear scattering and the unknown ambient state that exists before any perturbation.

We perform VLF remote sensing on a unique overlapping propagation path geometry in which the signals from two VLF transmitters (at different frequencies) are observed at a single receiver after propagation through the same channel in the Earth-ionosphere waveguide. This measurement diversity allows for greater certainty in quantification of D region perturbations. Changes in amplitude and phase are modeled with the Long Wave Propagation Capability (LWPC) software package Since the ambient nighttime D region profile prior to the perturbation is found to strongly affect the resulting quantification, and is highly variable and generally unknown at nighttime, an error minimization method for identifying the most likely ionospheric disturbance independent of the ambient profile is used. Analysis of 12 large lightning perturbations resulting from discharges with peak currents greater than 160 kA shows that the ionospheric reference height can change by up to 10 km.