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TITLE: Extended lateral heating of the nighttime D region by very low frequency transmitters: Subionospheric observations & modeling

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ABSTRACT BODY: Very low frequency (VLF, 3–30 kHz) signals propagating in the Earth-ionosphere waveguide are used to probe the heated nighttime D region over three keyed U.S. Navy VLF transmitters. The keyed VLF transmitters are turned on-off in periodic formats for thirty to sixty minutes each day over the course of several months each, providing sensitive measurements of their heating effect on the surrounding ionosphere. On several occasions, the heating effect is observed on probe signal pathways at distances greater than 1500 km from the keyed transmitter. It is proposed that the heating effect of VLF transmitters extends over very large distances through the subionospheric propagation of its radiated signal. General statistics are presented on the observed extent of the heating region over the course of the experiments, and a combination of propagation, heating, and scattering models are used to analyze the results. A series of two-dimensional finite difference frequency domain VLF propagation simulations estimates the keyed transmitter's radiated fields over a region extending 5000 km radially from the transmitter in all directions. The heated electron temperature is obtained as a secondary effect via the temperature balance equation which accounts for Ohmic heating and collisional cooling. Electron collision frequency changes exceeding 0.1% are estimated to occur at distances over 1000 km from the keyed transmitter. Further modeling suggests this amount of heating can produce observable perturbations on a second VLF signal used to probe the ionosphere at those distances, in agreement with our experimental observations.

KEYWORDS: [2403] IONOSPHERE / Active experiments, [6934] RADIO SCIENCE / Ionospheric propagation, [2487] IONOSPHERE / Wave propagation.

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Additional Details

Previously Presented Material: Approximately 10% of the material (mostly introductory) was published in JGR:

"Transmitter-induced modulation of subionospheric VLF signals: Ionospheric heating rather than electron precipitation" [Graf et al., 2011]

Approximately 40% of the material was present in our AGU poster for 2011. We have developed the modeling and data analysis portions of the material, but the initial results were present last year.

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