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# The D-region response to the 2017 Total Solar Eclipse: Observations and Modeling

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## 1 Extended Abstract

Solar EUV, Lyman-alpha (L$\alpha$) and X-ray fluxes provide the sources of ionization that sustain the D-region ionosphere in the daytime [e.g., Nicolet and Aikin, JGR, 65, 1469, 1960]. After sunset, the solar inputs disappear, and the D-region relaxes to a state of very weak ionization. The D-region ionosphere is particularly difficult to measure due to the very low electron densities. Nonetheless, the D-regionis integrally important in a number of areas in heliophysics, aeronomy, and long-range communications. It couples to the higher regions of the ionosphere and to the neutral atmosphere through atmospheric gravity waves, energetic particle precipitation, and transport. Energetic particle precipitation inputs from the radiation belts deposit energy in the D-region, where ion chemistry then controls the production of odd nitrogen and its descent to lower altitudes.

The 2017 solar eclipse provides a unique opportunity to study the D-region ionosphere and its response to solar inputs. In this work, we present observations and modeling of the D-region ionosphere and its response to the solar eclipse. We measure the D-region response via subionospheric VLF transmitter signals, which propagate in the waveguide formed by the Earth and the D-region ionosphere. From VLF receivers at Bear Lake, Utah; Boulder, Colorado; and Elginfield, Ontario, we record the amplitude and phase of the 25.2 kHz transmitter signal broadcast from Lamoure, North Dakota. As the eclipse track crosses the VLF transmitter-receiver path, we observe a large perturbation to both the amplitude (>10 dB) and phase (>100 deg) at the Utah and Colorado receivers, as expected.

We next conduct modeling of the D-region response and VLF signals to reproduce the observed data. We apply occultation factors – which provide the fraction of solar insolation as a function of latitude, longitude, altitude and time – to the sources in the Whole Atmosphere Community Climate Model with D-region chemistry (WACCM-D) and the Sodankyla Ion and Neutral Chemistry (SIC) model. SIC uses a detailed chemistry model to estimate the D-region electron density due to solar sources; WACCM-D uses a truncated chemistry, but provides a global solution including circulation and horizontal transport. By using these models, we are able to tune particular solar inputs, including hard and soft X-rays, EUV, and L$\alpha$, to compare their relative contributions to the D-region ionization. Next, we take 2D (altitude-range) slices of the electron density response along VLF transmitter paths from North Dakota to our receivers. We then simulate the VLF signal along this propagation path using our Finite-Difference Time-Domain VLF propagation model. Finally, we compare our modeled VLF amplitude and phase, and their variation over the duration of the eclipse, with the observed data at both VLF sites.