Modeling and Analysis of the D-region Response to the 2017 Total Solar Eclipse

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It is well known that the daytime D-region ionosphere is created by solar Lyman-alpha (La) and X-ray flux [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. Despite the difficulty in measuring the D-region, this layer is 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 provided a unique opportunity to study the D-region ionosphere and its response to solar inputs. In this work, we present a full 3D model of the D-region in terms of the electron density response to the solar eclipse; we then compare the expected signatures of VLF subionospheric transmitter signals to those observed in data. Our modeling begins by incorporating 2D, time-varying occultation factors for the eclipse into the Whole Atmosphere Community Climate Model with D-region chemistry (WACCM-D), to estimate the 3D electron densities over the globe and their time variation during the eclipse. By using WACCM-D, we are able to tune particular solar inputs, including hard and soft X-rays, EUV, and La, 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 Boulder, CO and to Bear Lake, UT, where our VLF receivers collect amplitude and phase data. 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.