Title: *Observing and Modeling Radio Blackout in the Ionosphere Following Solar Flares*

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Summary: The Earth's ionosphere plays an important role in the coupling of energy between the lower atmosphere, magnetosphere and the solar wind. Improved understanding of the drivers of ionospheric transients is necessary to gain additional scientific insight and increase forecasting accuracy. Continuous, multipoint observations of the ionospheric parameters of the coupled ionosphere-space weather system are a necessary component of any strategy to fully understand such important space weather effects as radio blackout following solar flares. We recommend that networks of ground-based remote sensing instruments, such as SuperDARN radars, riometers, and ionosondes, be developed to address research and operational imperatives, including the development of comprehensive, first-principles models.

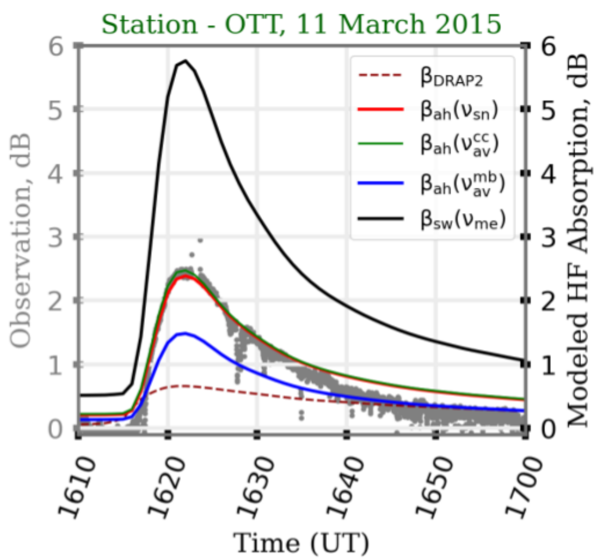

Figure 1: A data-model comparison of HF absorption for an SWF event observed with the Ottawa riometer (gray dots). The predictions of the new ionospheric model using different combinations of dispersion relation and collision frequency are shown as the upper four color traces while the predictions of the D-RAP2 model are shown with the dashed trace.

Motivation: Radio blackouts following solar flares, solar energetic particle (SEP) events, and CME driven geomagnetic storms are one type of extreme space weather phenomena. Forecasting of radio blackouts is currently performed by the NOAA Space Weather Prediction Center (SWPC) using the D-region Absorption Prediction (D-RAP) model which predicts D-region electron density enhancements and radio wave absorption based on solar X-ray flux and SEP flux measurements from satellites. Aside from the D-RAP model outputs, however, very few direct, real-time measurements of HF absorption are available to users. This can be traced to the paucity of instruments that are suitable for monitoring absorption. Direct measurements of real-time HF absorption would provide more detailed and accurate information about the intensity and spatial coverage of ongoing events than what is provided by the model. Several recent studies have demonstrated that the Super Dual Auroral Radar Network (SuperDARN) can be used for real-time monitoring of high frequency (HF) radio absorption in addition to the relative ionospheric opacity meter (Riometer). Riometers distributed across the high and polar latitudes are dedicated to detection of energetic particle precipitation driven HF absorption. However, ionospheric disturbance effects are more widespread than this and better use can be made of both riometers and radars to provide coverage that extends to mid-latitudes. We note that the SuperDARN radars straddle latitudes from the mid-latitude region to the polar cap and provide continuous observations and operate at frequencies similar to those used for trans-ionospheric radio communications, making them well-suited to providing real-time information about ionospheric space weather and its impact on HF communications.

Information from the ground-based system can also be used to develop first-principles models that can be applied to demonstrate understanding and make predictions. Figure 1 shows initial results from the application of a new first-principles based model with varying inputs for one solar flare driven HF absorption event as observed by a riometer. The model with one particular combination of dispersion relation and collision frequency profile predicts the rise and peak in absorption very well. The D-RAP2 model (dashed red line) significantly underestimates the absorption, a result that has also been reported in other comparisons by recent studies. This indicates that significant progress can be made in modeling and forecasting the impact of solar flares on the ionosphere.

Recommendations: The following actions are recommended to work towards the scientific goals described above:

1. Build additional sites for monitoring absorption in the ionosphere over all latitudes, e.g., riometers, HF radars.
2. Develop comprehensive models of the ionosphere suitable for predicting solar flare impacts including radio blackout.