Sferic-based tomography for D-region electron density modeling

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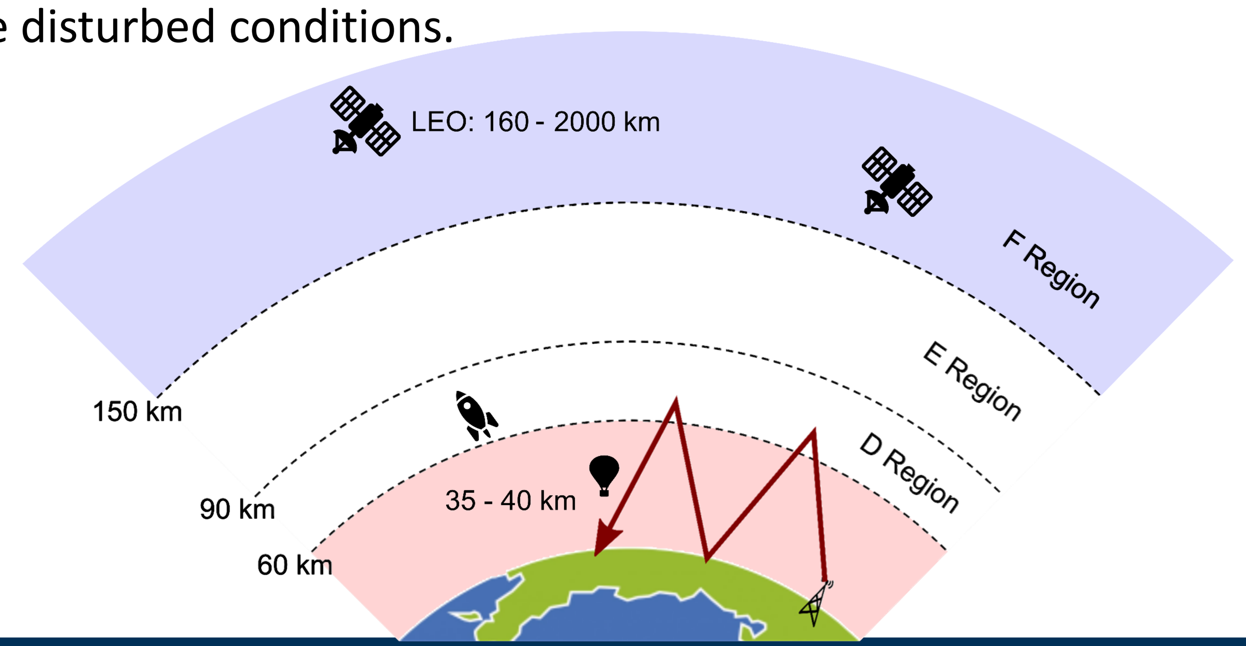
Abstract

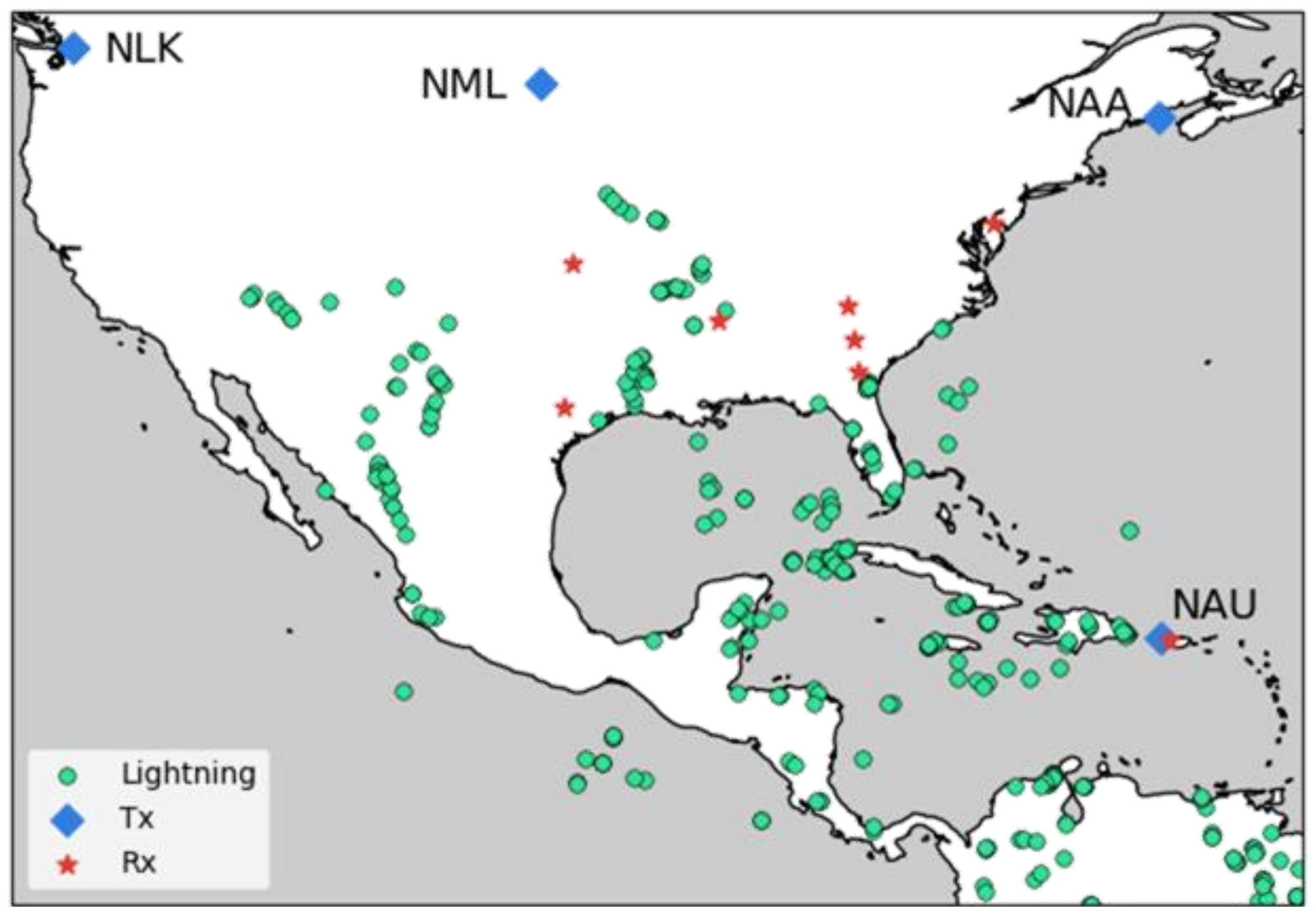
While important for communication, the D-region ionosphere is difficult to measure using conventional means. Instead, researchers have historically relied on very-low-frequency and low-frequency (VLF, LF) radio waves, often from lightning or VLF transmitters, to indirectly infer D-region electron density. These methods have become highly capable of producing path-average electron density profiles; however, they typically do not provide great spatial resolution. In this work, we present tomography as a method for producing 3D electron density maps over the SE United States and Gulf of Mexico using lightning emissions known as sferics. Our method achieves approximately 3–4-degree spatial resolution and can capture both daytime and nighttime conditions as well as the day-night terminator. Additionally, we show strong agreement between electron density and sunlight fraction during the 2017 "Great American Solar Eclipse" indicating our method can capture disturbed conditions.



Experimental Setup

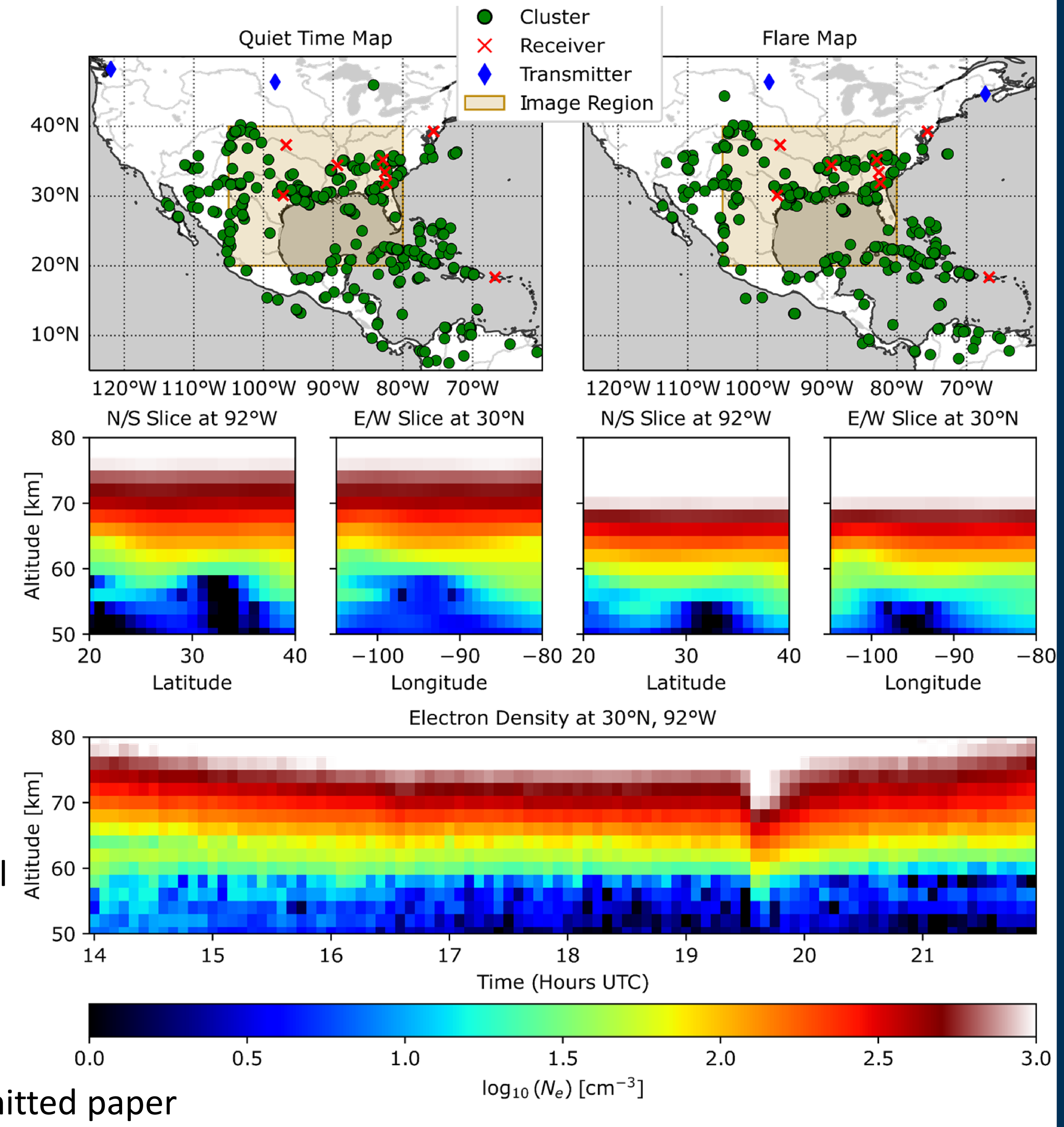
VLF waves can travel long distances via the Earth-ionosphere waveguide. At each reflection from the ionosphere, the wave's amplitude and phase are affected. By analyzing the received signals, it is possible to back out information about the state of the ionosphere along the wave's path.

This works used eight Georgia Tech VLF receivers detecting VLF waves from three Navy transmitters as well as sferic emissions from lightning.



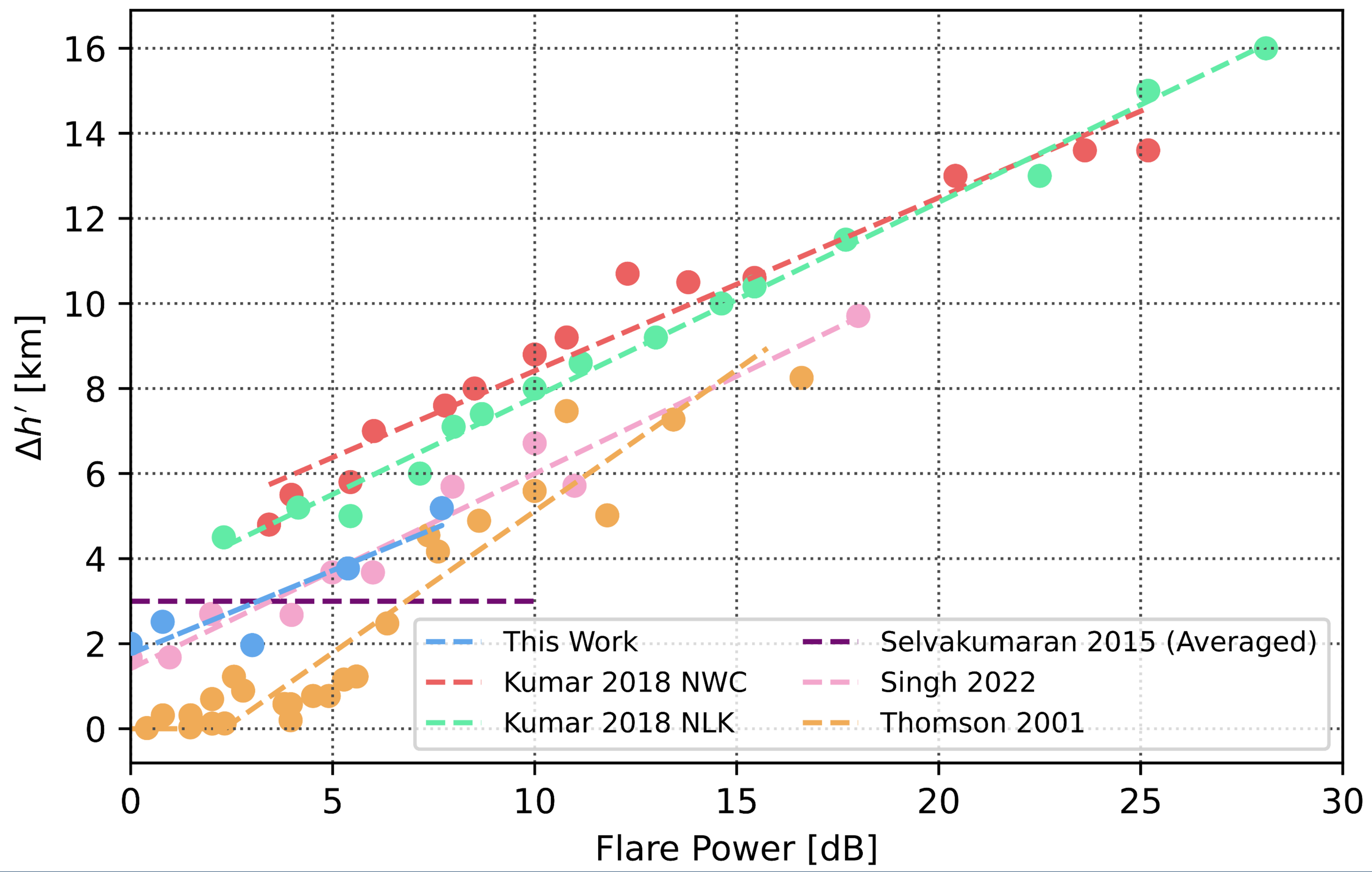
VLF-Transmitter and Sferic Modeling

In addition to the sferic-only approach described in the initial abstract, significant progress has been made on combining measurements of sferics and VLF transmitters in a single model. To highlight this, we model a C5.9 solar flare which occurred on July 15, 2017. A clear decrease in ionosphere height is observed at the flare time (19:36 UT) followed by a gradual recovery over the following 15-30 minutes. These results are included in a soon-to-be submitted paper



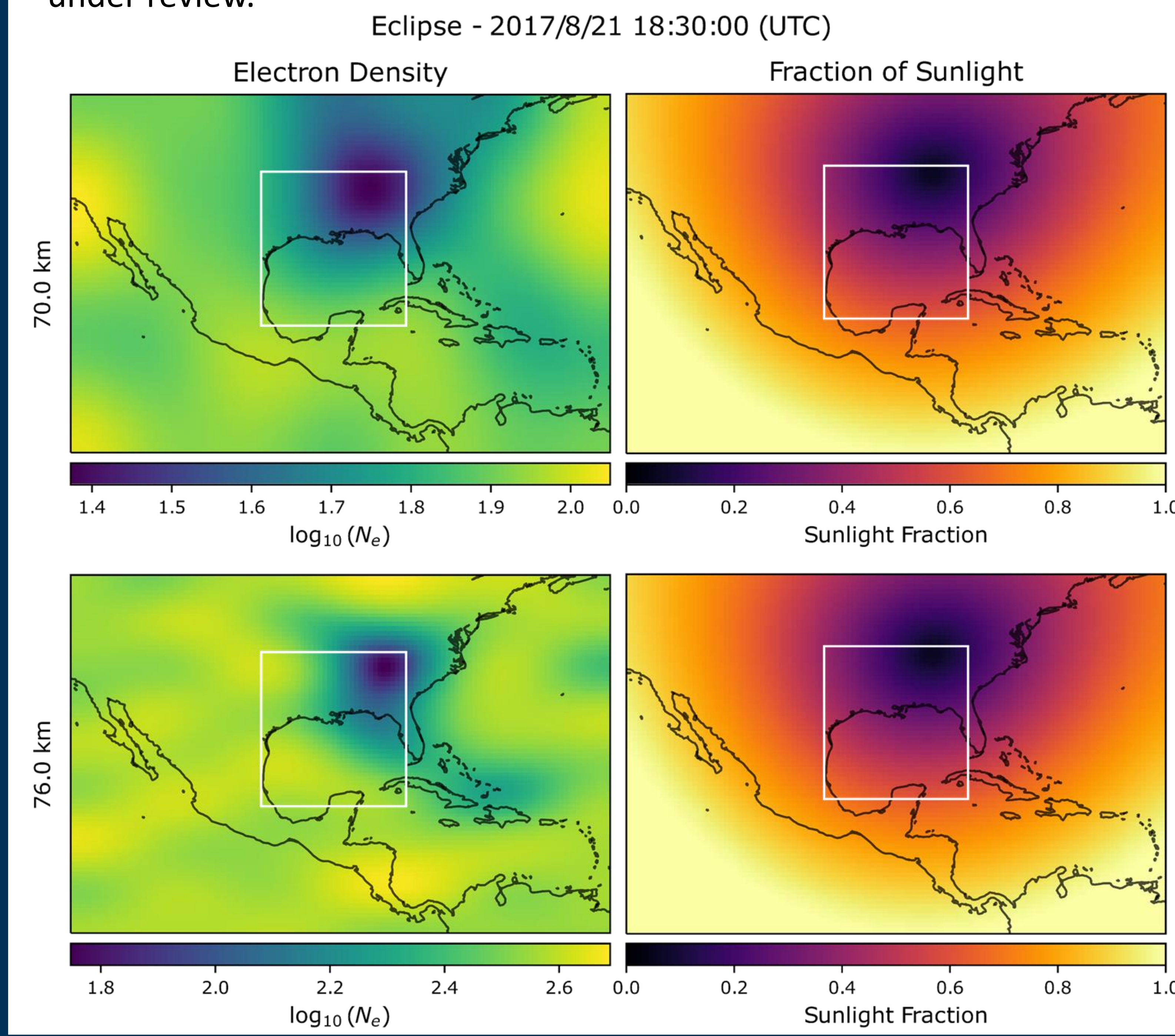
Solar Flare Model vs Prior Work

In addition to the solar flare highlighted above, our modeling efforts covered 4 more flares. By fitting an h', β profile to our predicted electron densities, it is possible to compute a Δh' and compare with other studies. Our results are directly in-line with other studies of C-class solar flares.



Eclipse Modeling Efforts

Here, we show good agreement between the totality spot of the 2017 "Great American Solar Eclipse" and our model's electron density. In this case, the sferic-only model is used as there is limited VLF transmitter data availability on this day. These results are part of a paper currently under review.



Summary

- It is now possible to generate 3D maps of electron density using measurements of sferics and VLF transmitters
- Modeled outputs agree well with the 2017 "Great American Solar Eclipse"
- The model can capture solar flares, such as the C5.9 solar flare which occurred on July 15, 2017.
    - Modeled results agree well with prior studies and show a similar linear relationship between Δh' and flare power.

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