

Remote sensing of the ionospheric impact of the April 2024 total solar eclipse

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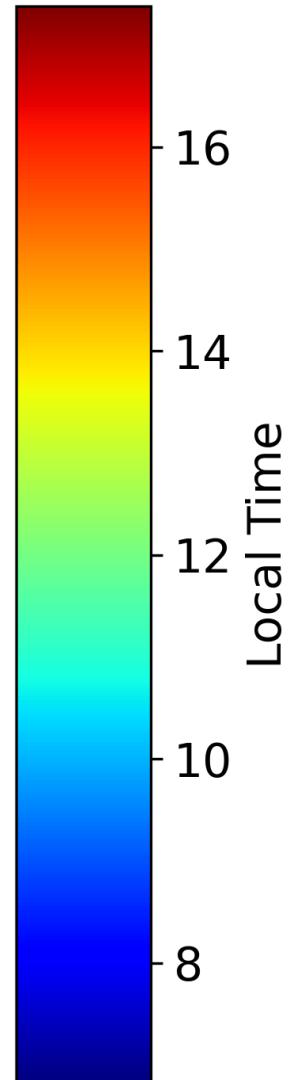
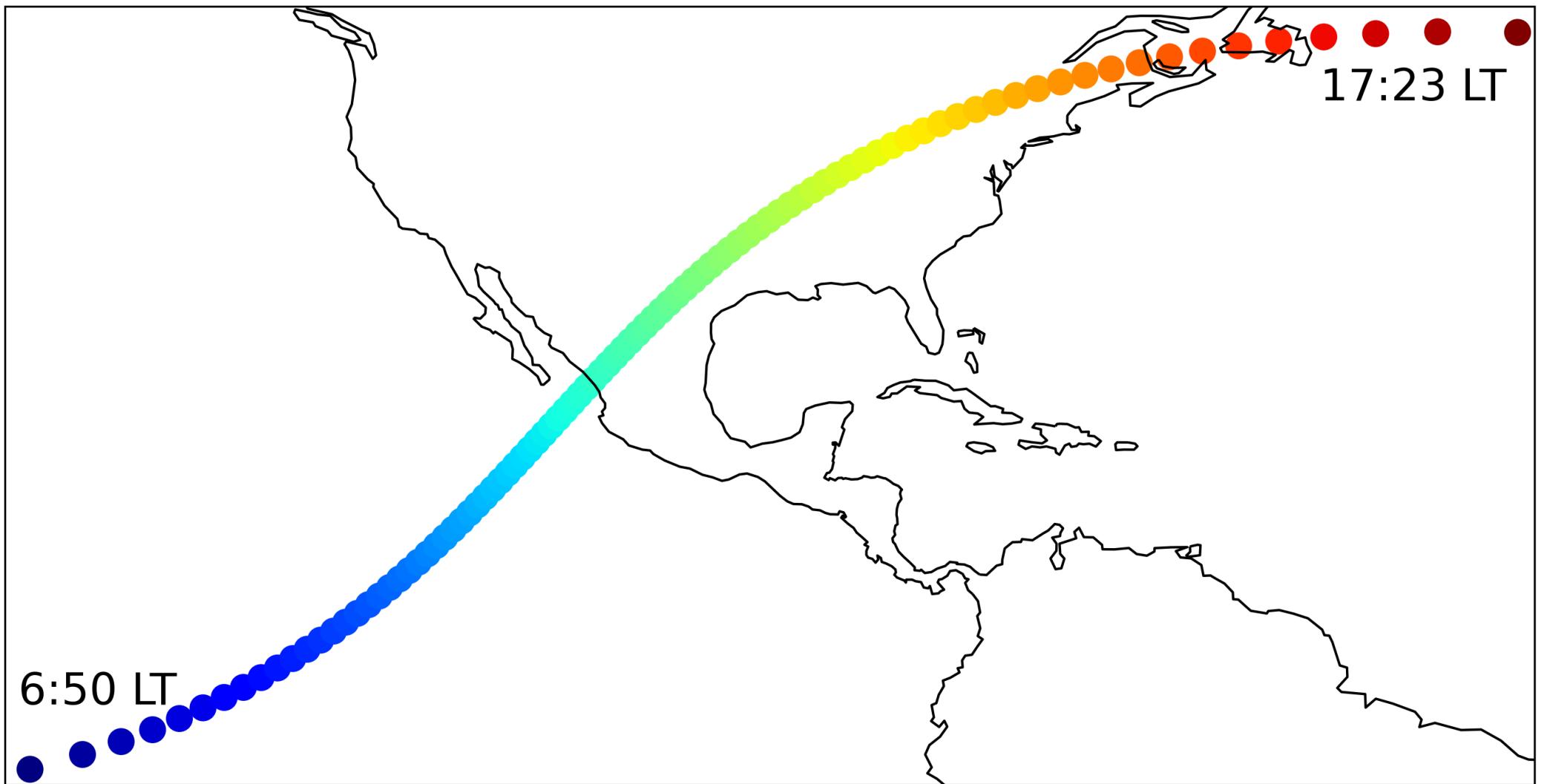
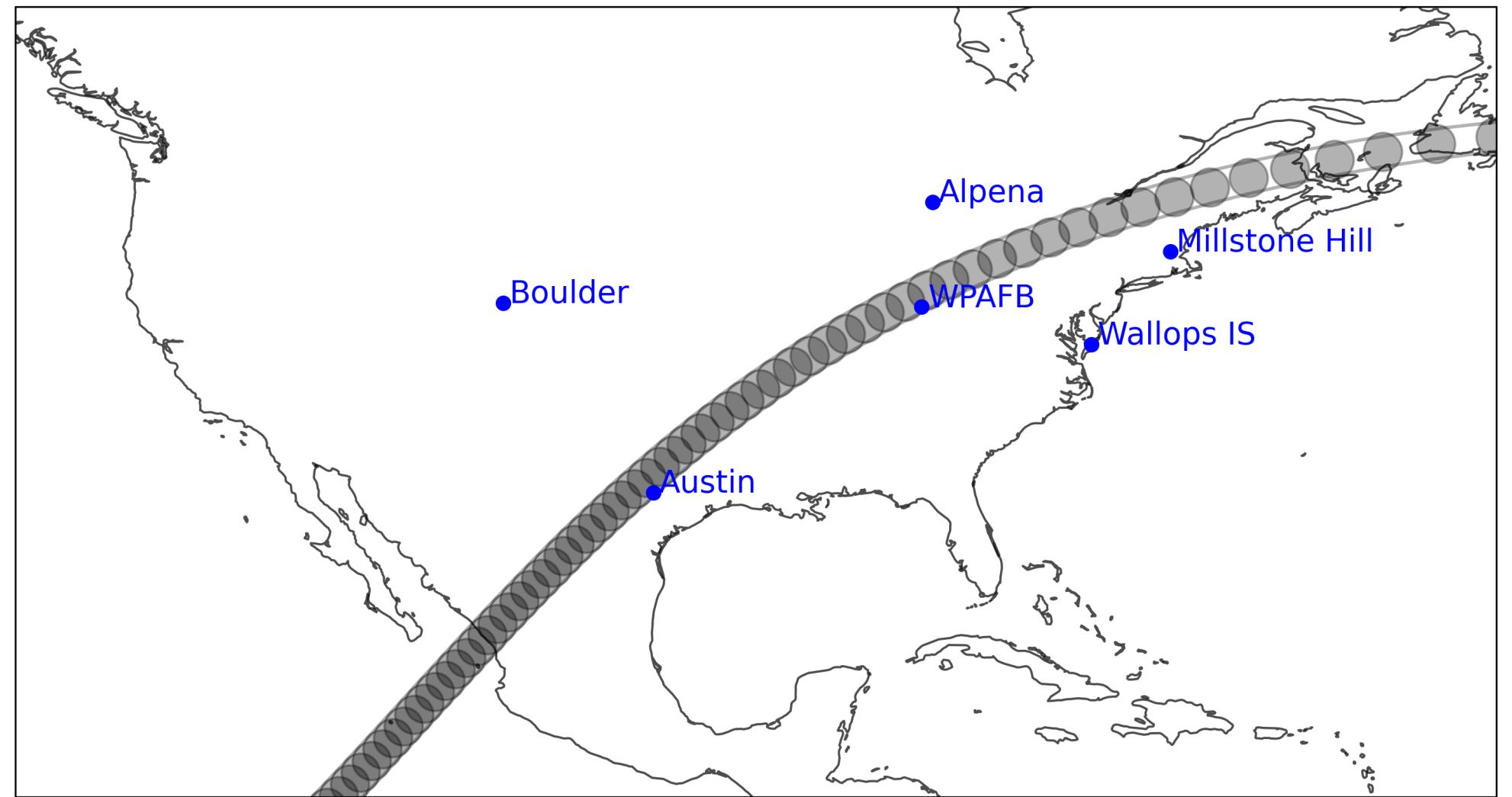
Motivation and Science Questions

- "The April 8, 2024 "Great American Eclipse"—not to be confused with the August 21, 2017 "Great American Eclipse"—was our last chance to see a total solar eclipse over CONUS for a long while..
- **What was the ionospheric response to the total solar eclipse?**
- **How well do our models reproduce the ionosphere's response to an eclipse?**
- **Is there an asymmetry in the ionosphere's onset/recovery response to the eclipse?**

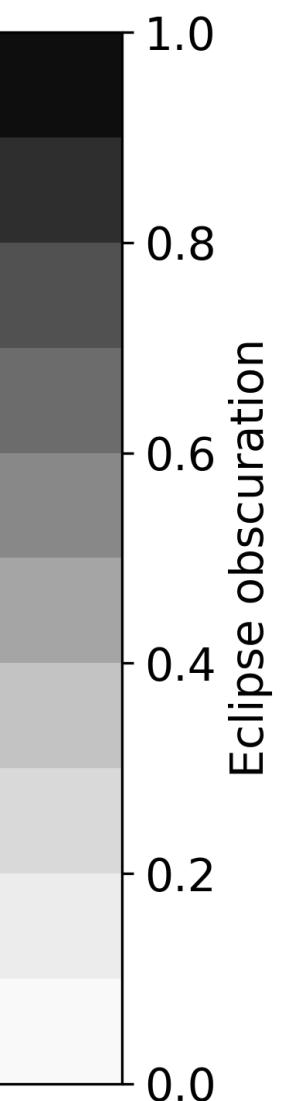
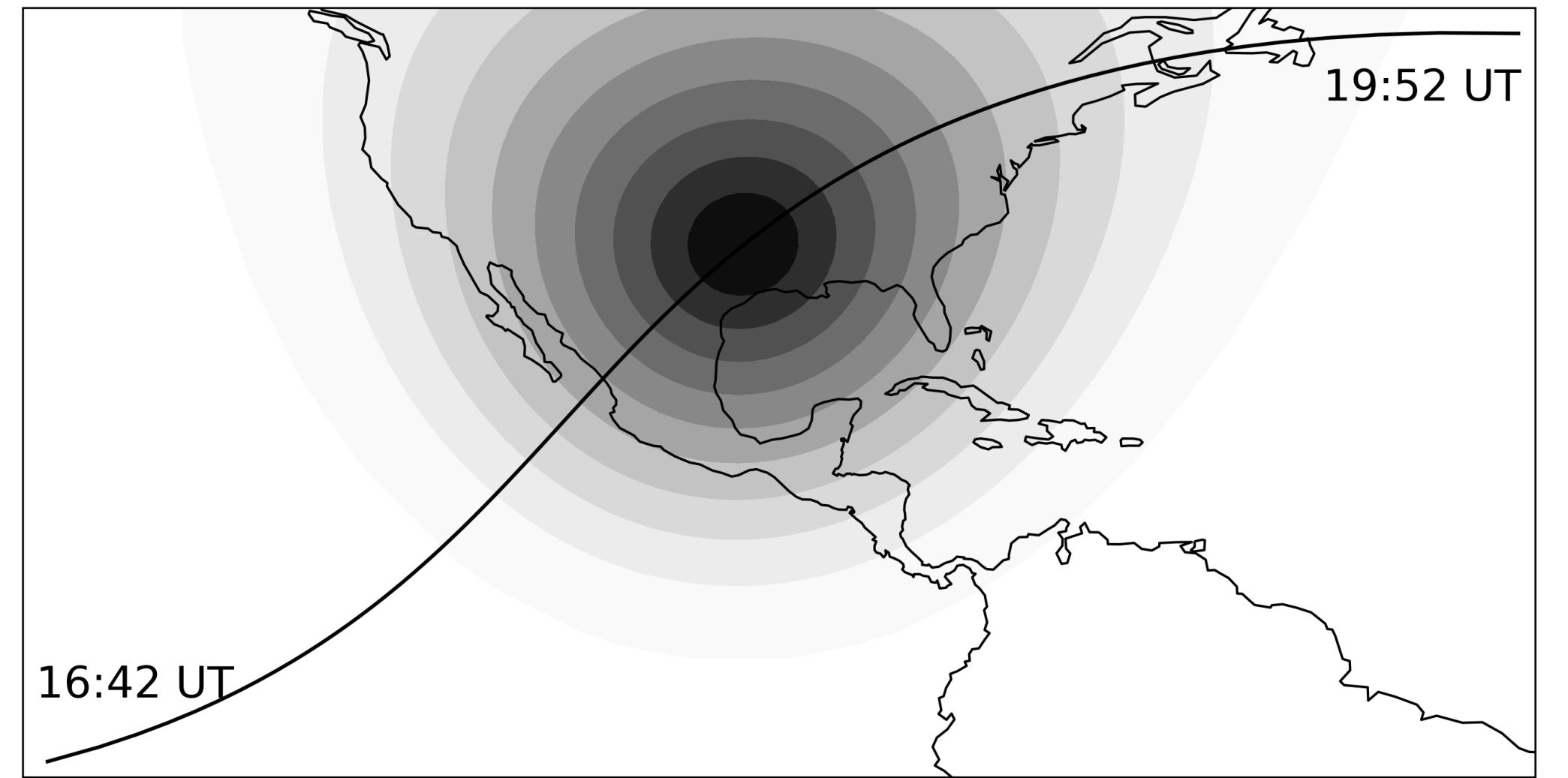
Today we'll look at some:

- Ionosonde observations of the ionosphere's response to the total solar eclipse.
- Amateur ("ham") radio observations of the ionosphere's response to the total solar eclipse.

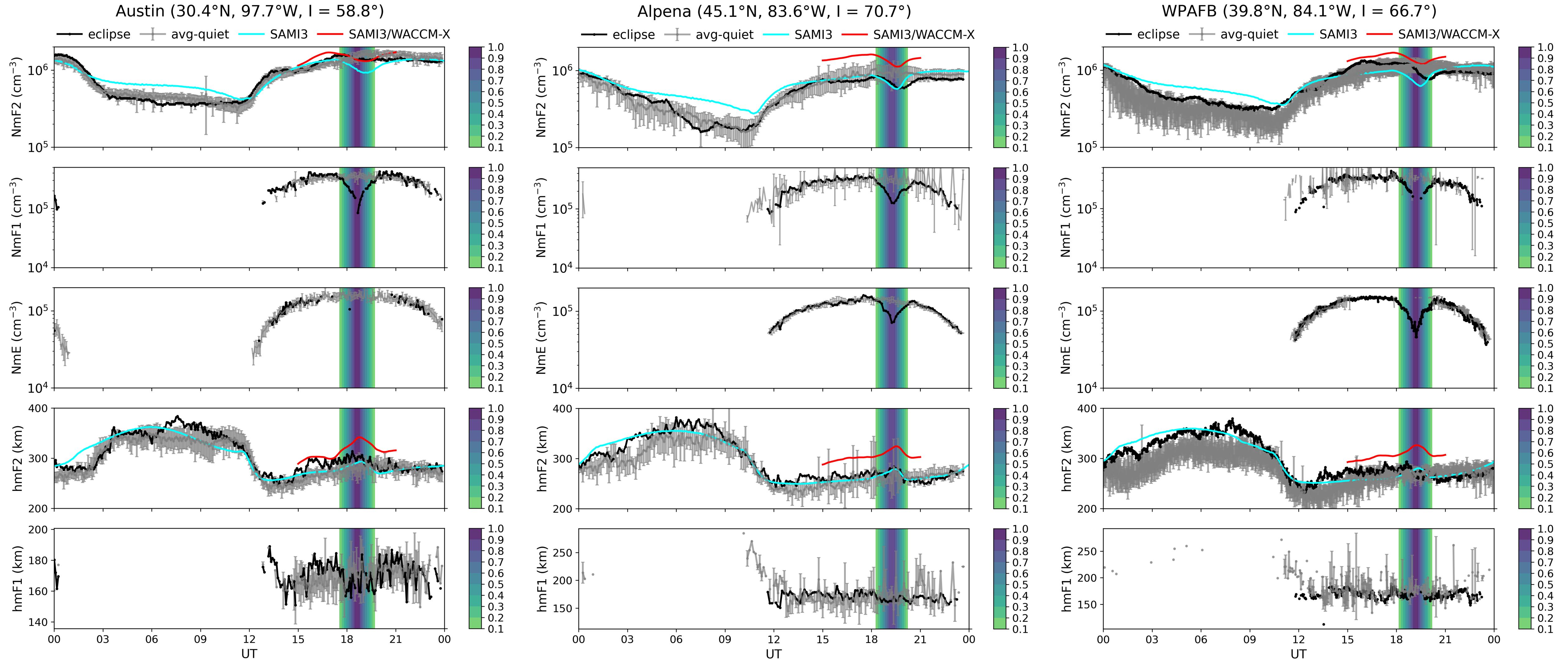
Ionosonde Observations for April 8, 2024



- Two ionosondes were operating under the path of totality.
- Wright-Patterson Air Force Base was installed for eclipse, thanks to collaborators at AFIT and AFRL.
- Observations were compared to SAMI3/SAMI3-WACCM-X.

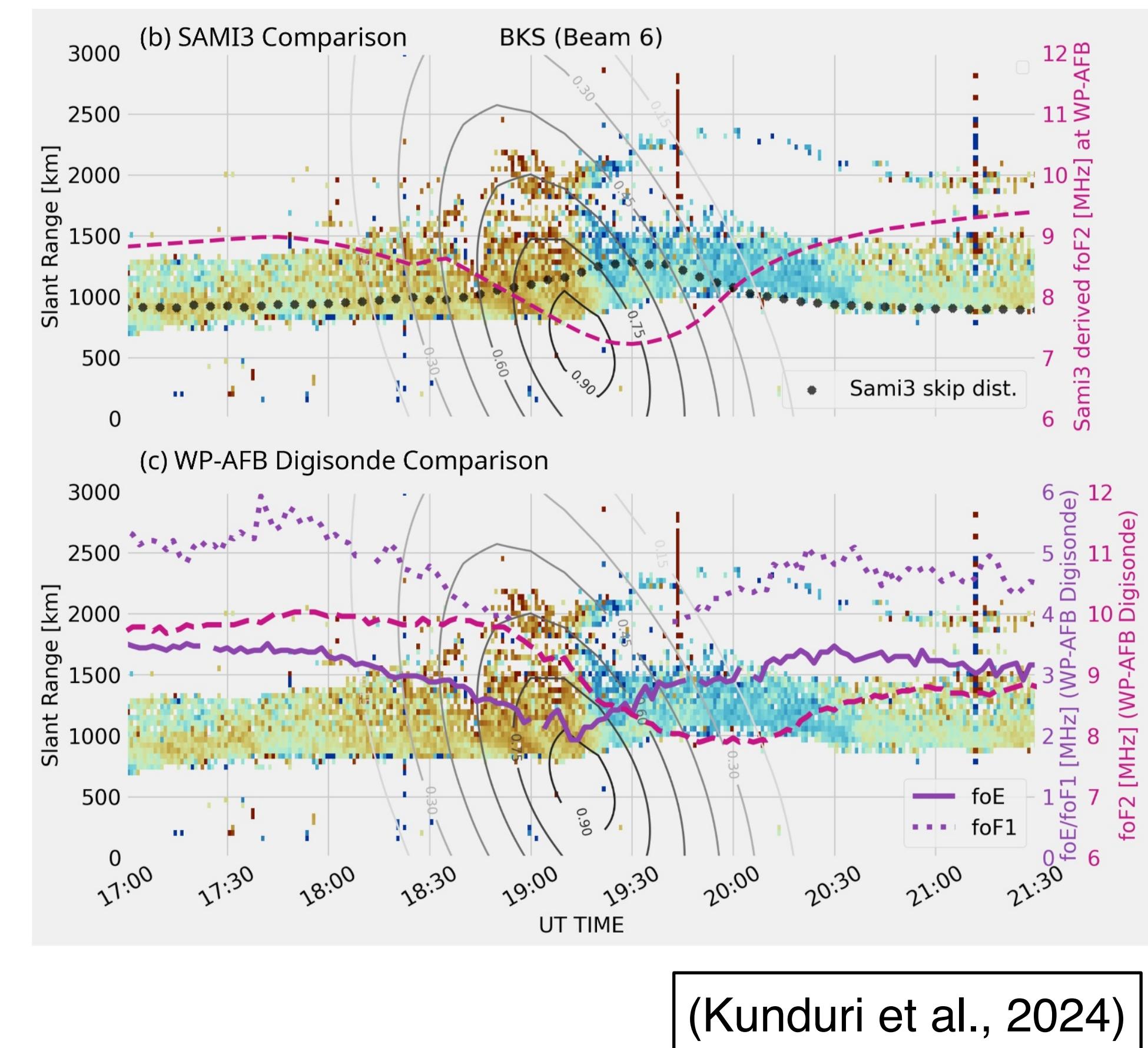
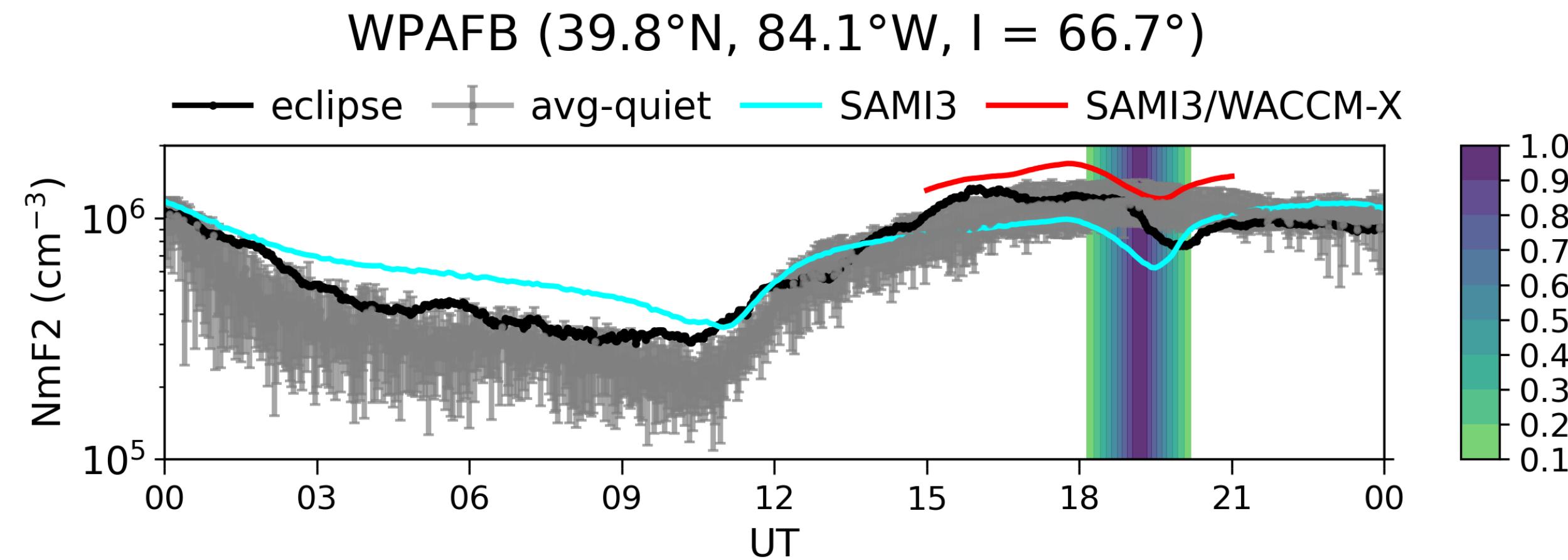


Ionosonde Observations for April 8, 2024

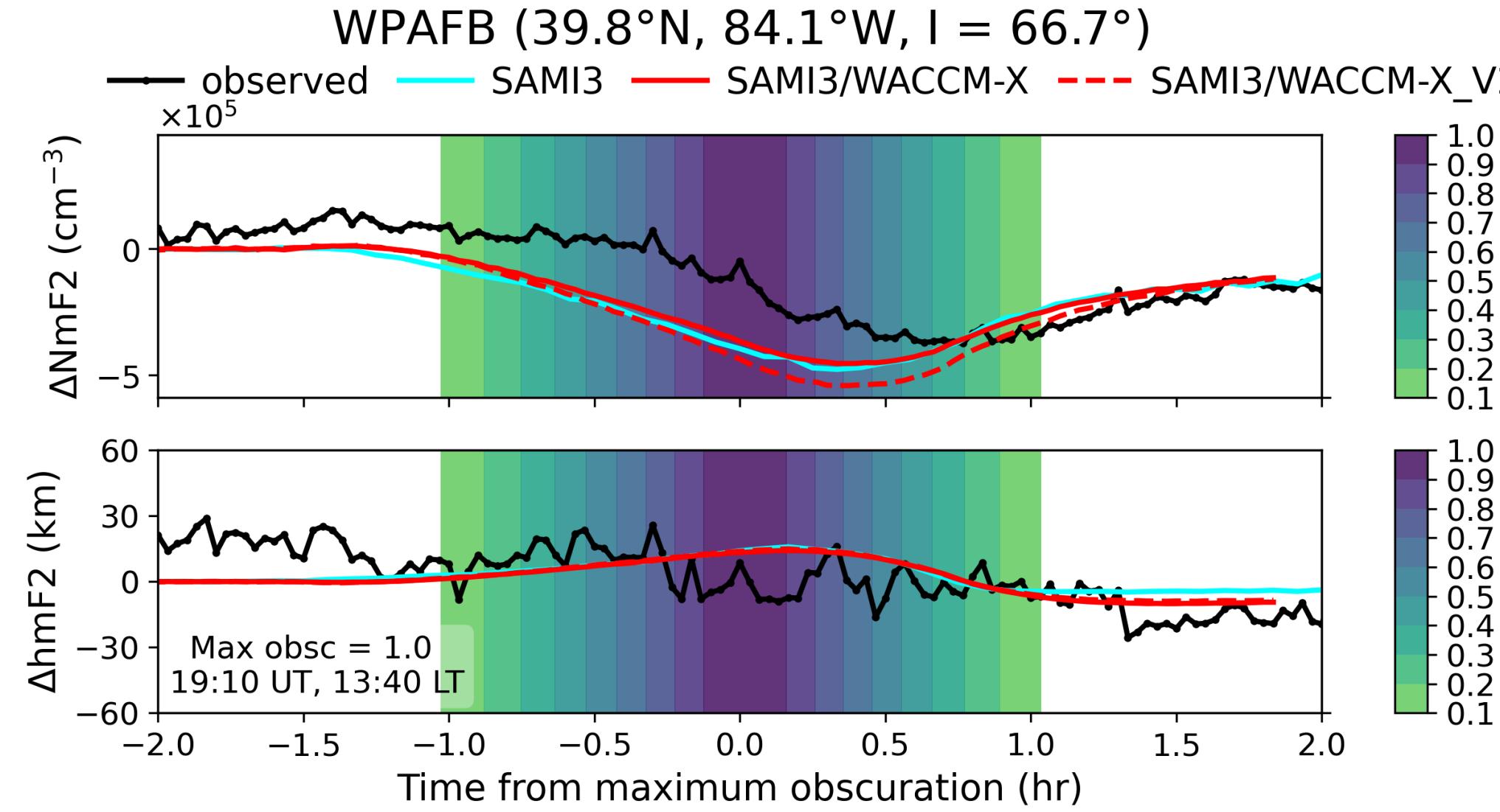
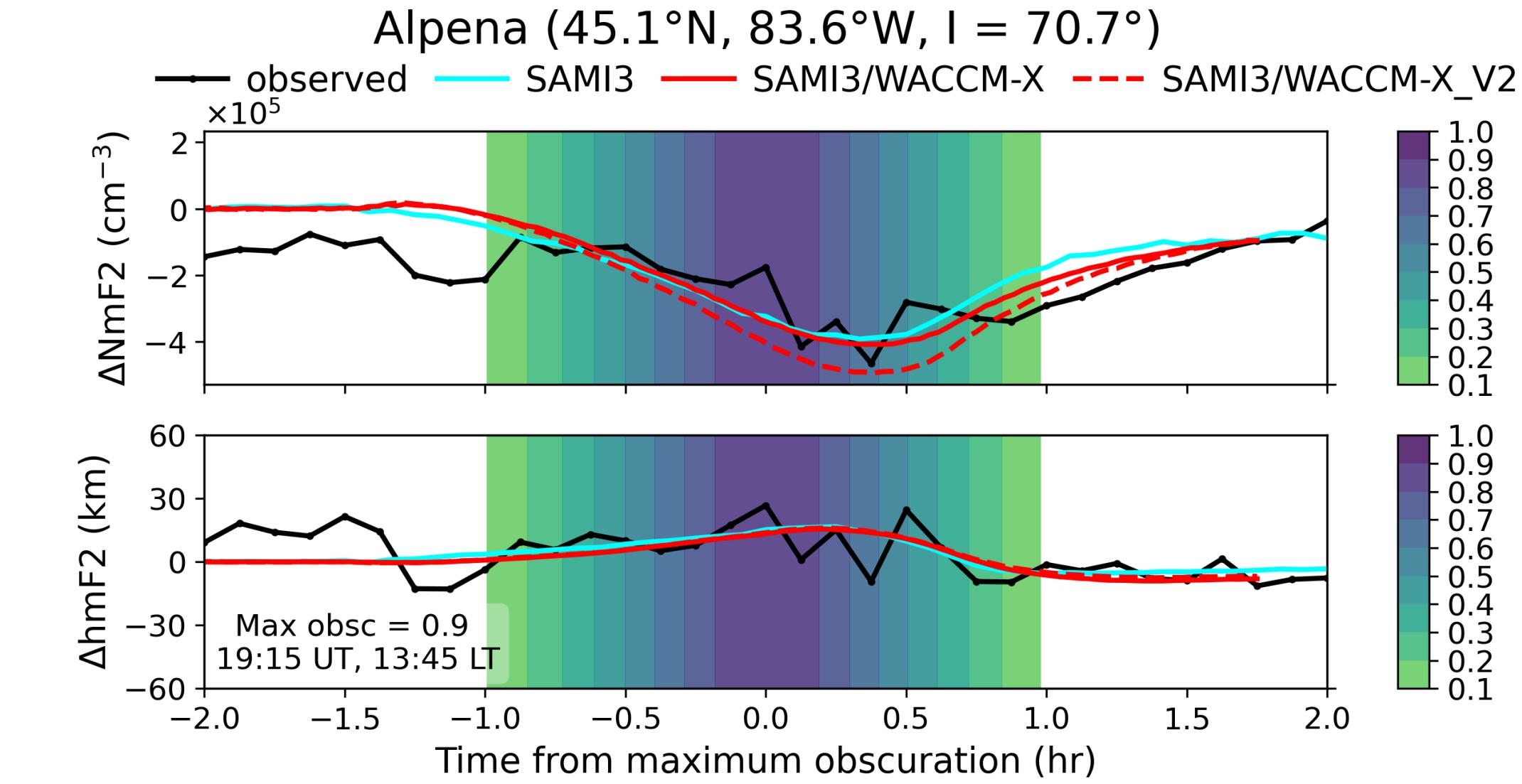
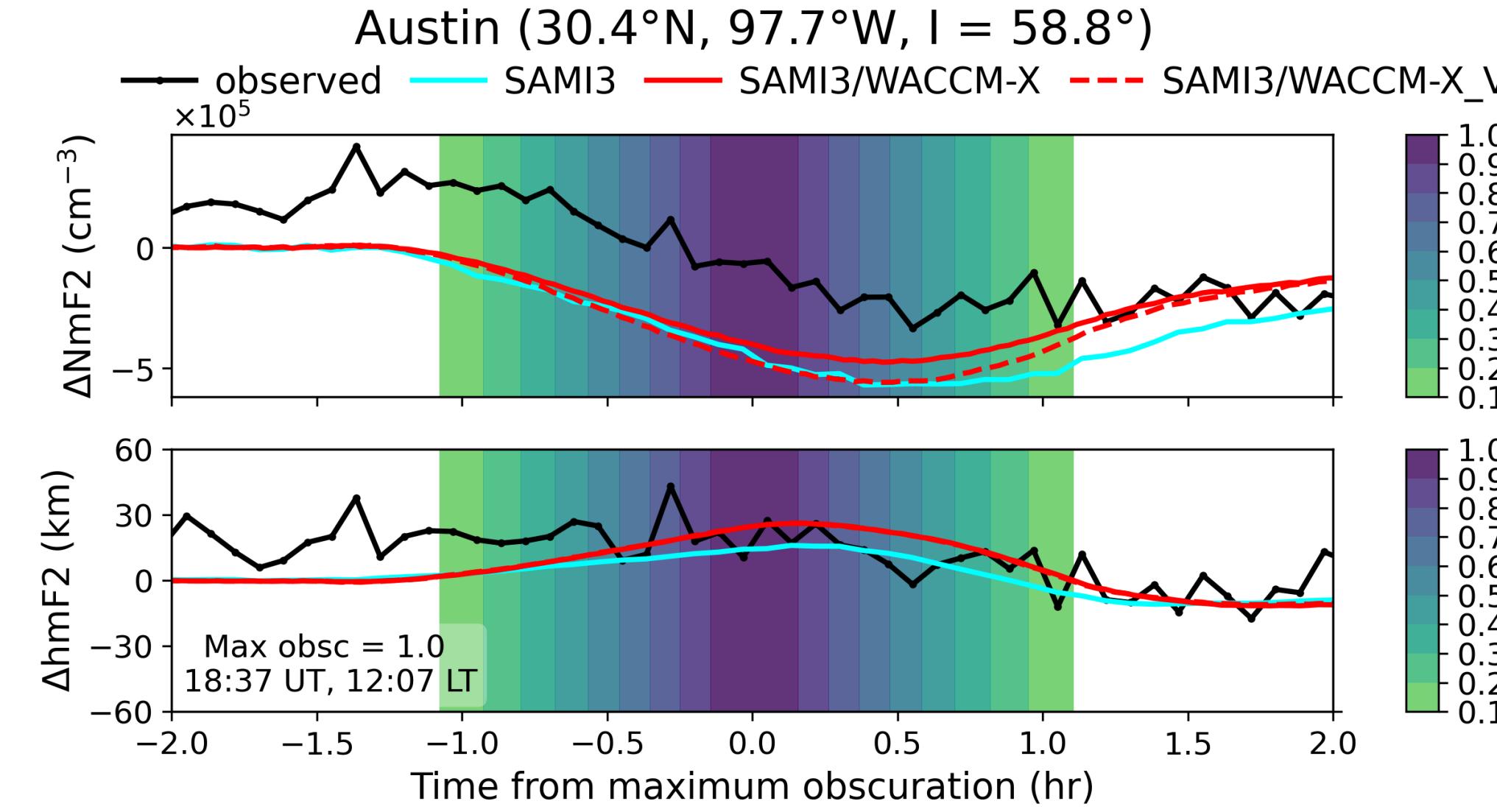


Ionosonde Observations for April 8, 2024

- SAMI3 performs reasonably well at several of the ionosonde sites.
- An interesting discrepancy is the notable lag between the predicted eclipse induced NmF2 depletion predicted by SAMI3 and observed by the ionosonde.
 - This was first reported by Kunduri et al. (2024).



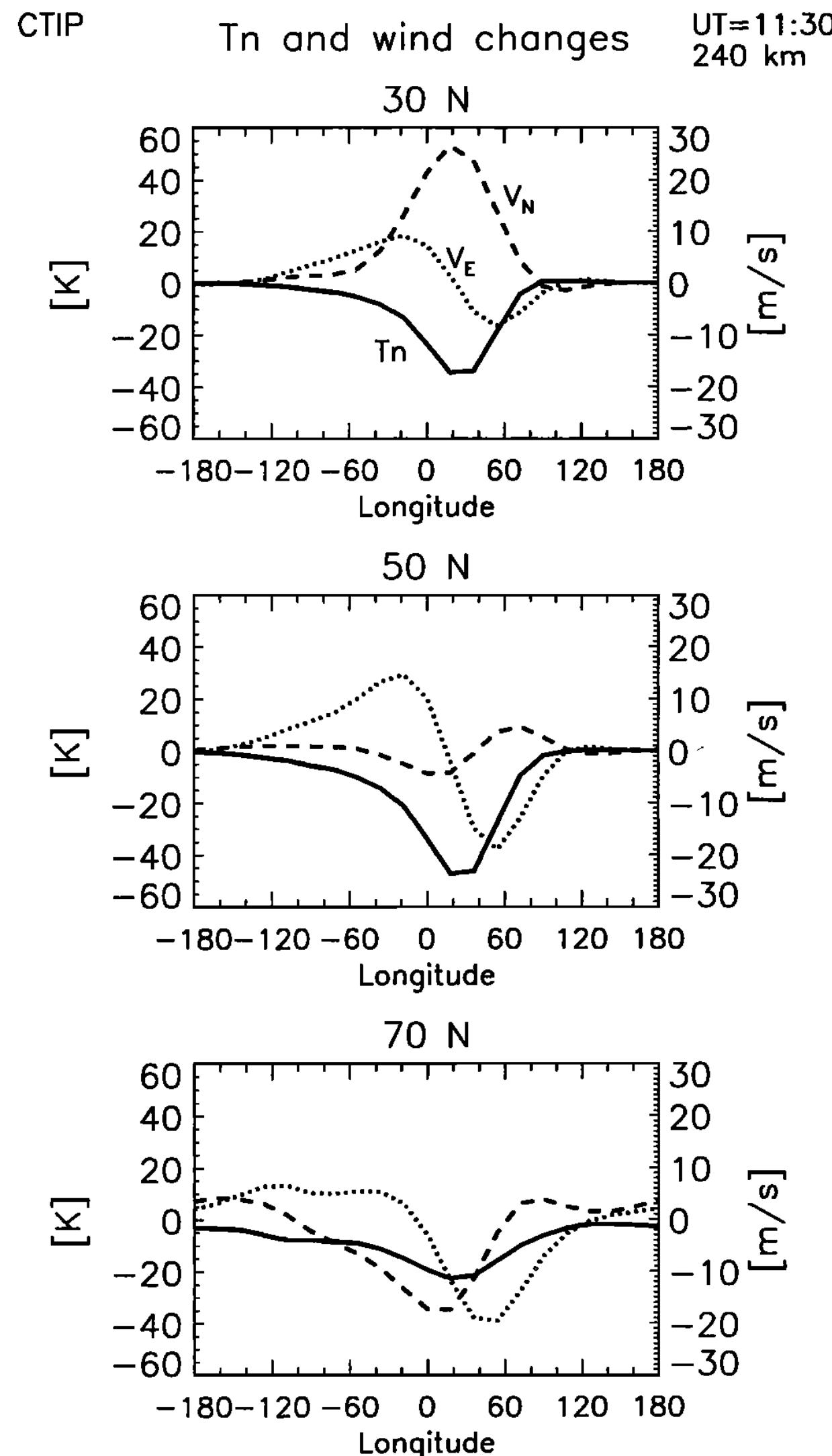
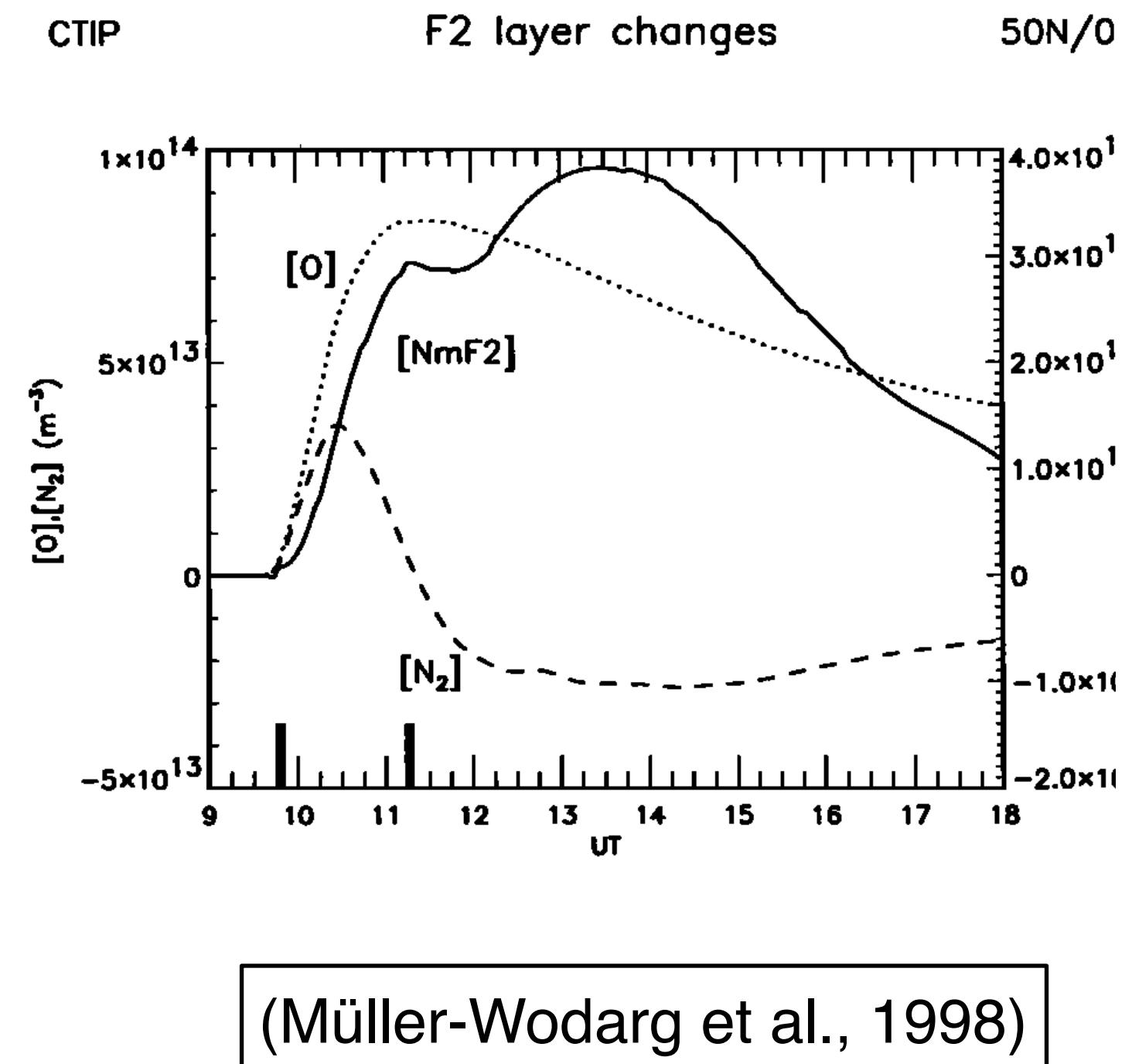
Ionosonde Observations for April 8, 2024



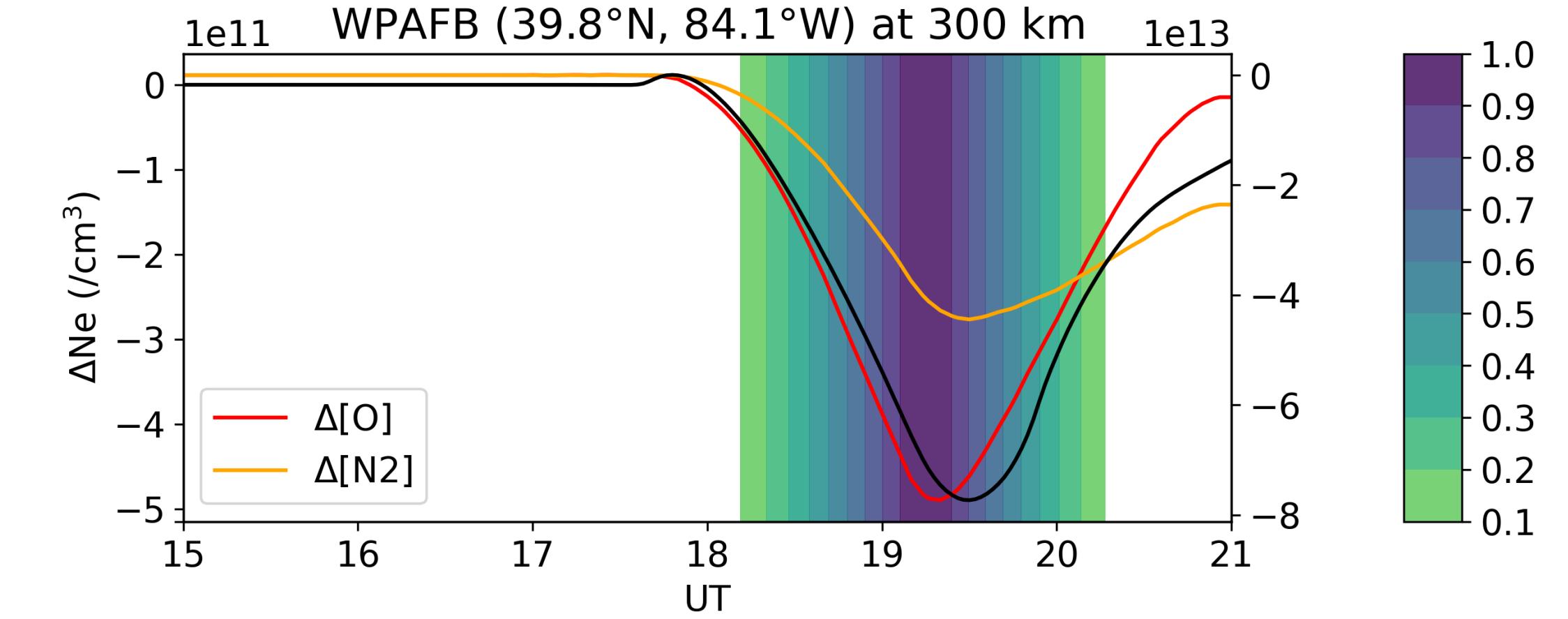
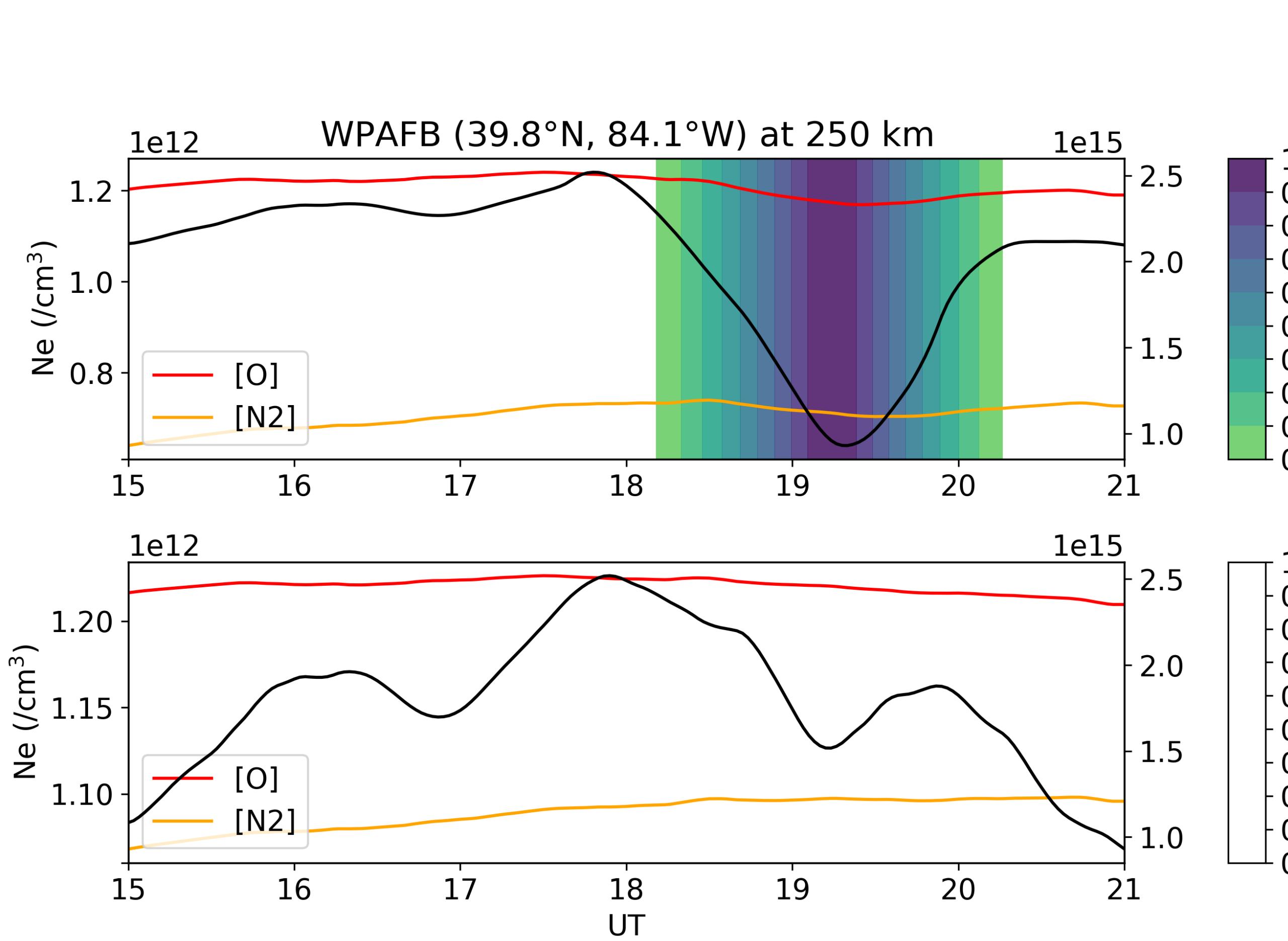
- Alternative SAMI3 runs were conducted and analyzed to try to reproduce the “lagged” depletion feature.
- SAMI3 with WACCM-X
- SAMI3 with WACCM-X and reduced photo electron heating.

How important is vertical transport of the neutrals?

- Vertical neutral transport can have a significant influence on NmF2 (Müller-Wodarg et al., 1998).
- Downwelling of O and N₂ can increase O/N₂ ratio at a given pressure level, leading to an increased NmF2.
 - This may also add to compression of natural at the same pressure level due to cooling effects.



Does the modeling show vertical transport of the neutrals?



- SAMI3/WACCM-X shows eclipse natural temperature and winds that is consistent with previous modeling, but *not* for neutral concentrations.
- Photo electron heating has also been reduced.

HamSCI and the “Great American Eclipse”

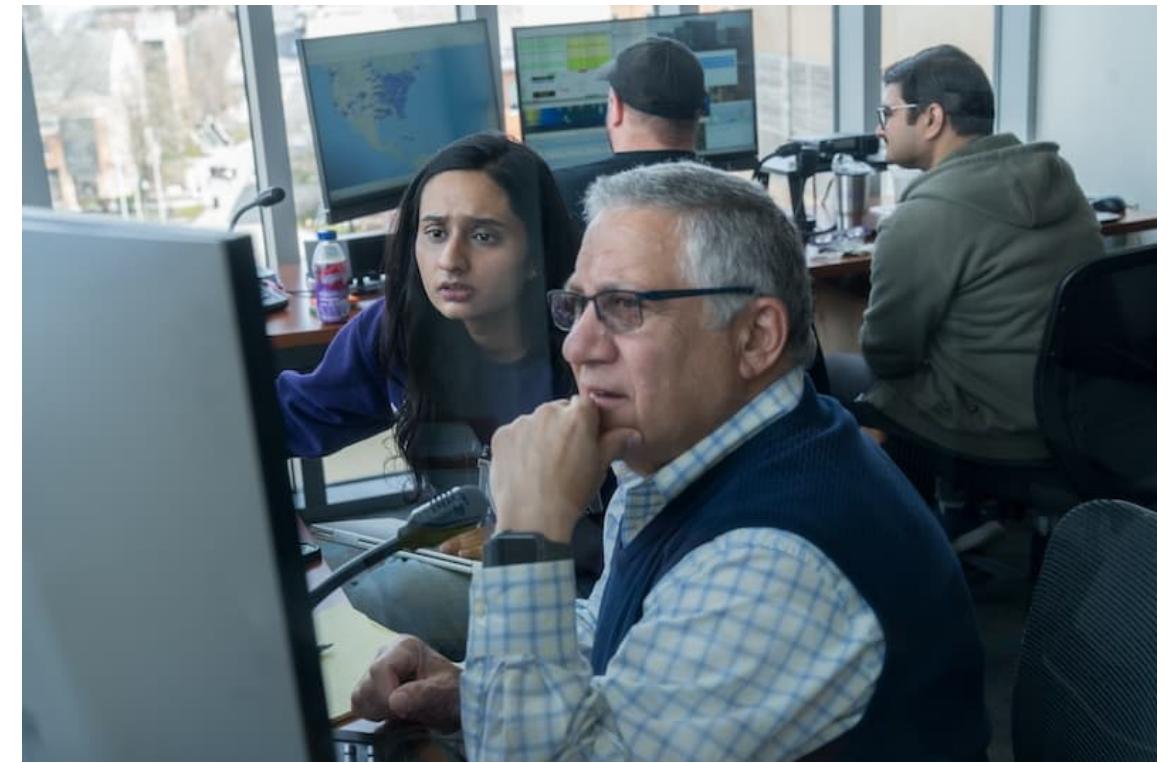


WP3R



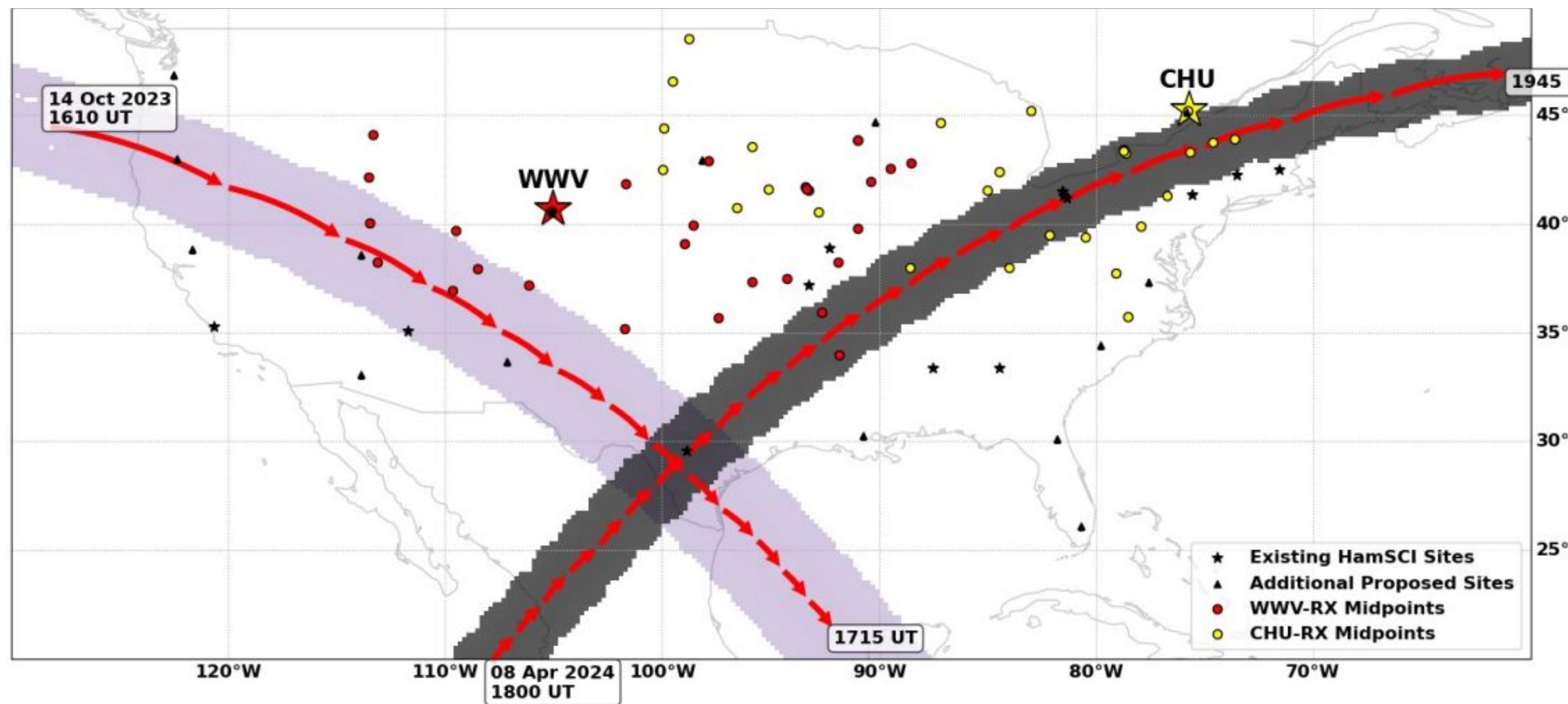
KO4GQT

- Get as many hams “on the air” to transmit and communicate with each other during eclipse period.
- Analyze ham radio community receiving networks.
 - These receivers provide time, frequency, point of origin, point of reception information for individual communications.
- Observe eclipse effects with HF receiver.

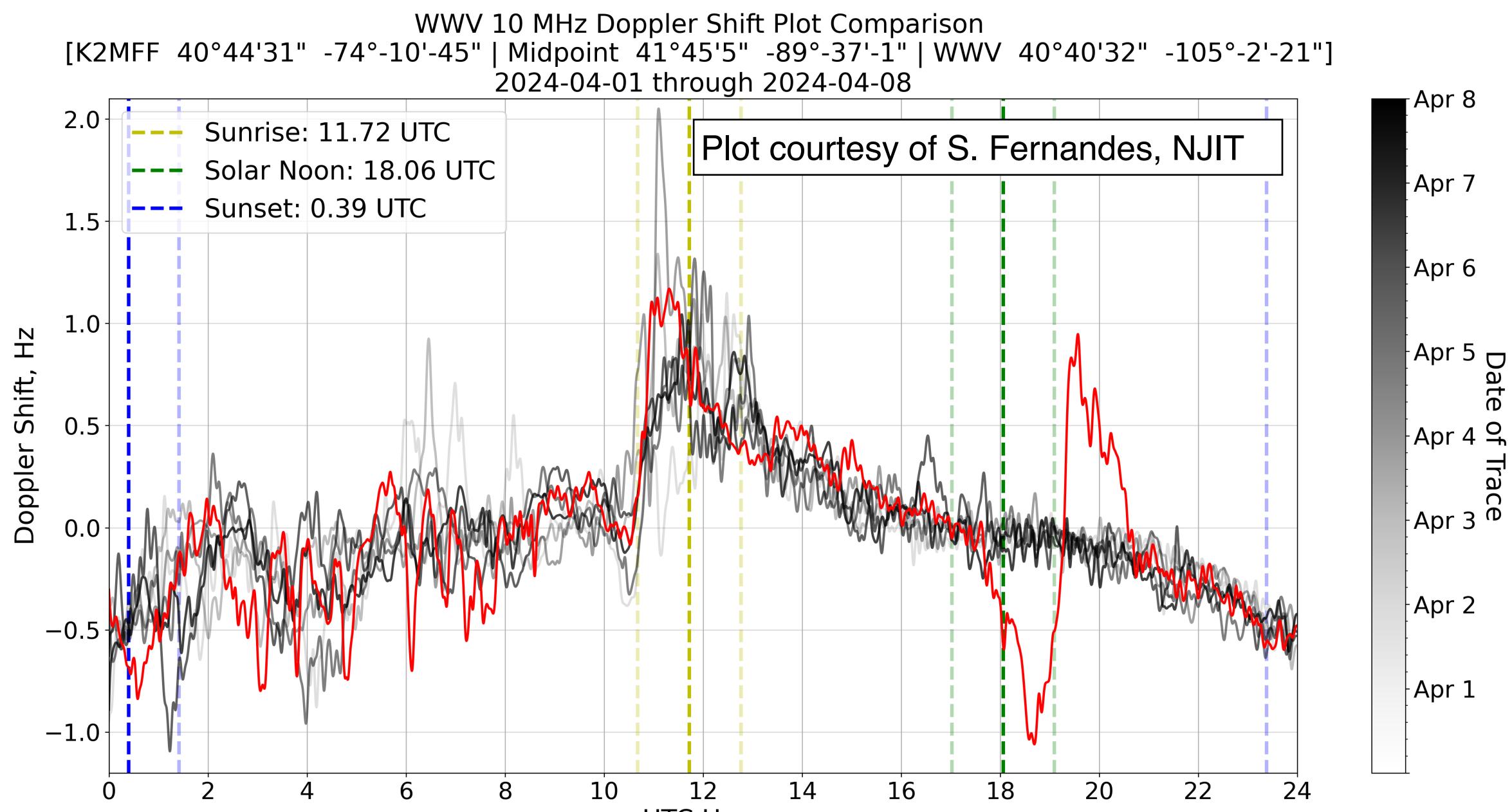


Credit: U. Scranton

HamSCI and the “Great American Eclipse”



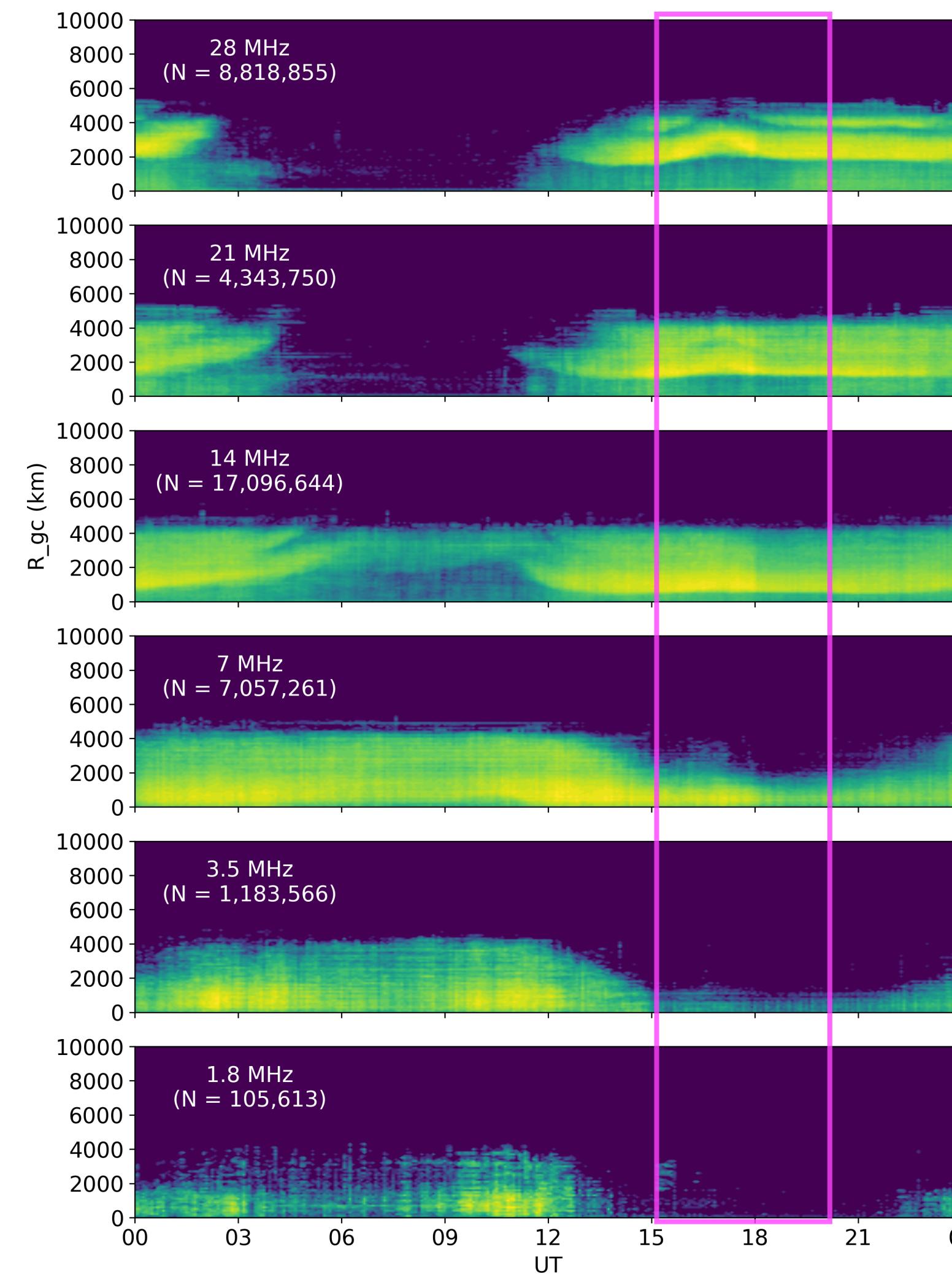
Deployment of HamSCI infrastructure for 2023 and 2024 solar eclipses



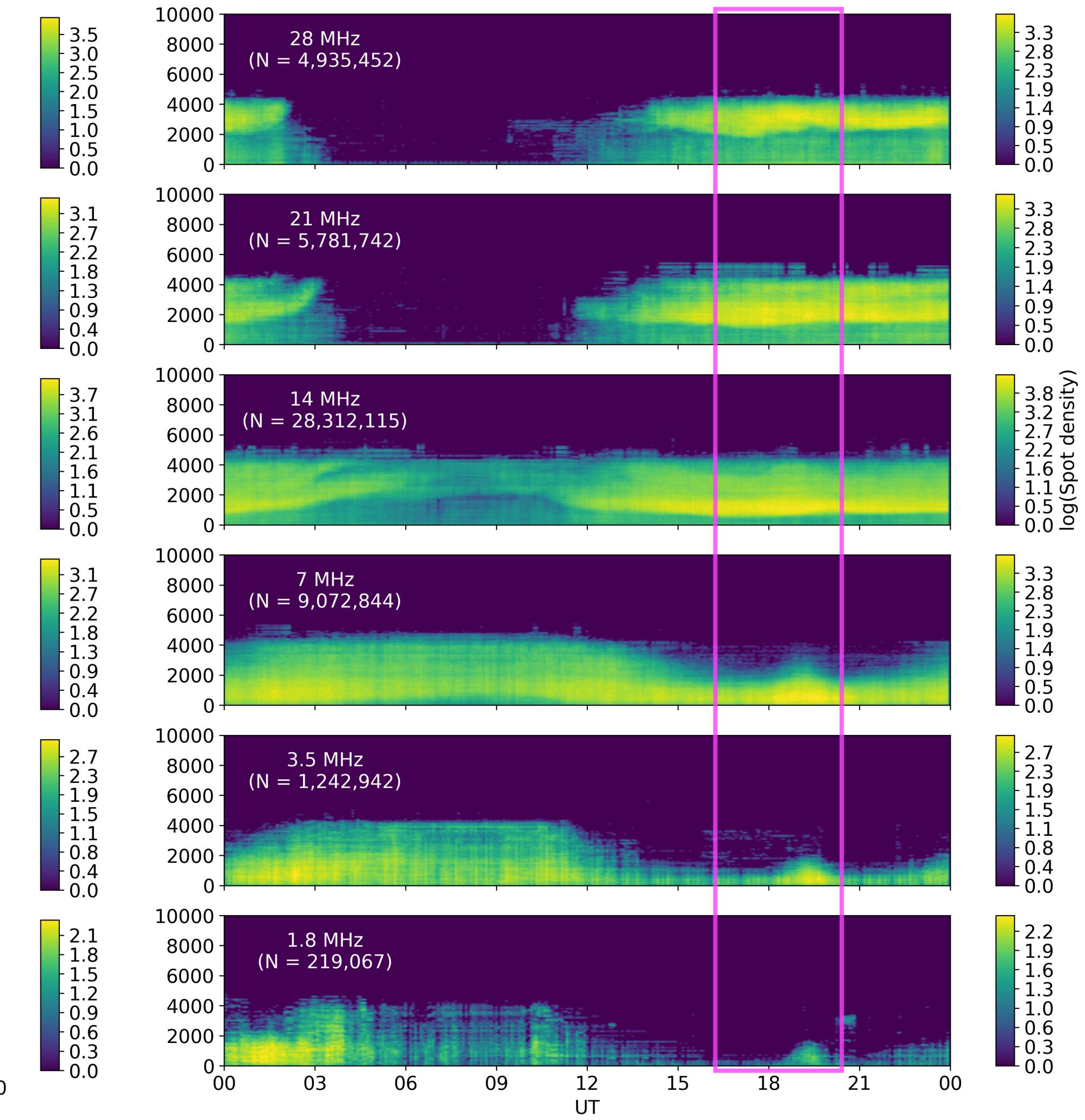
2024 total eclipse Grape data from K2MFF at NJIT in Newark, NJ

HamSCI eclipse observations

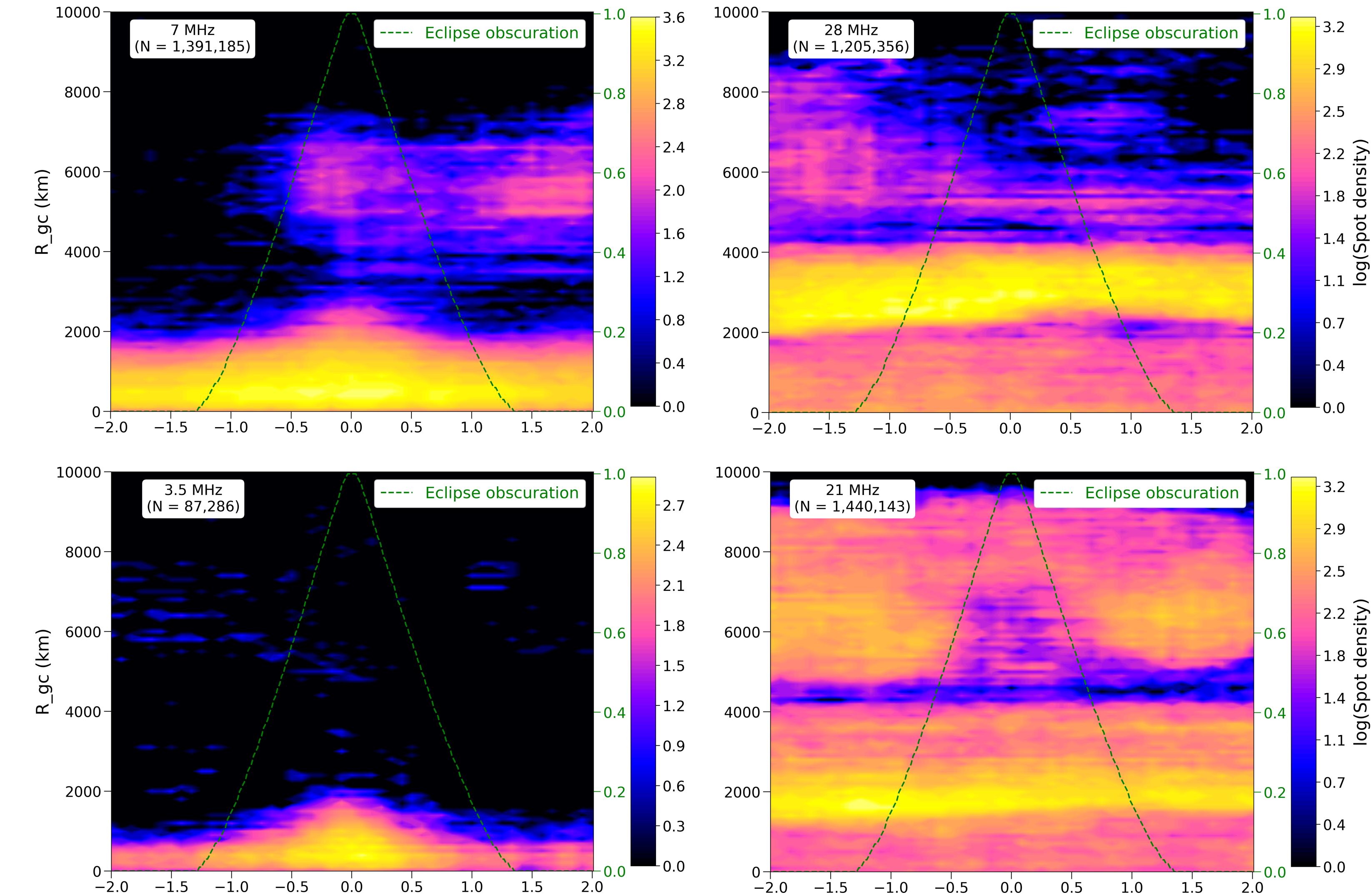
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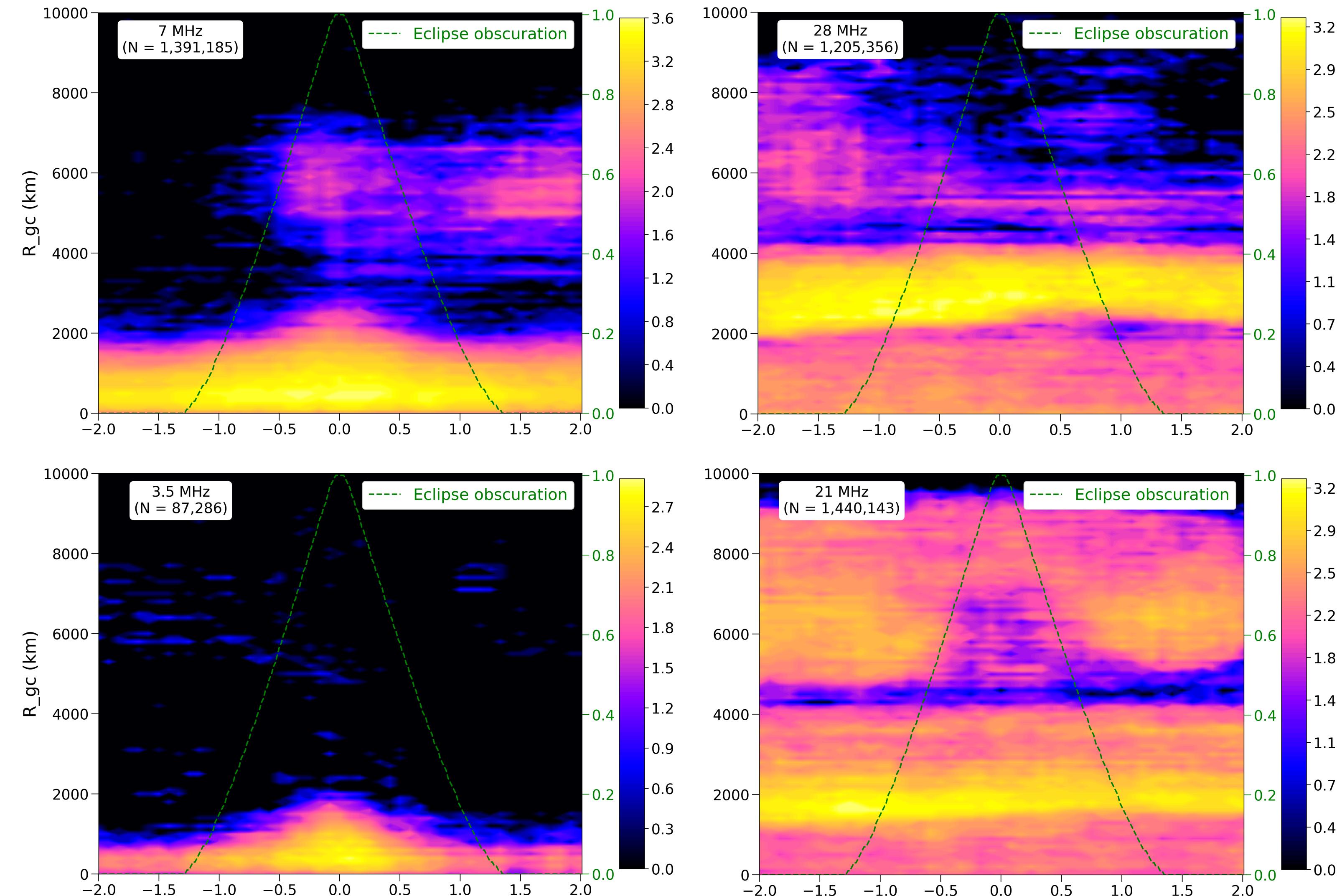
Apr 8, 2024



Epoch analysis of *global* eclipse observations

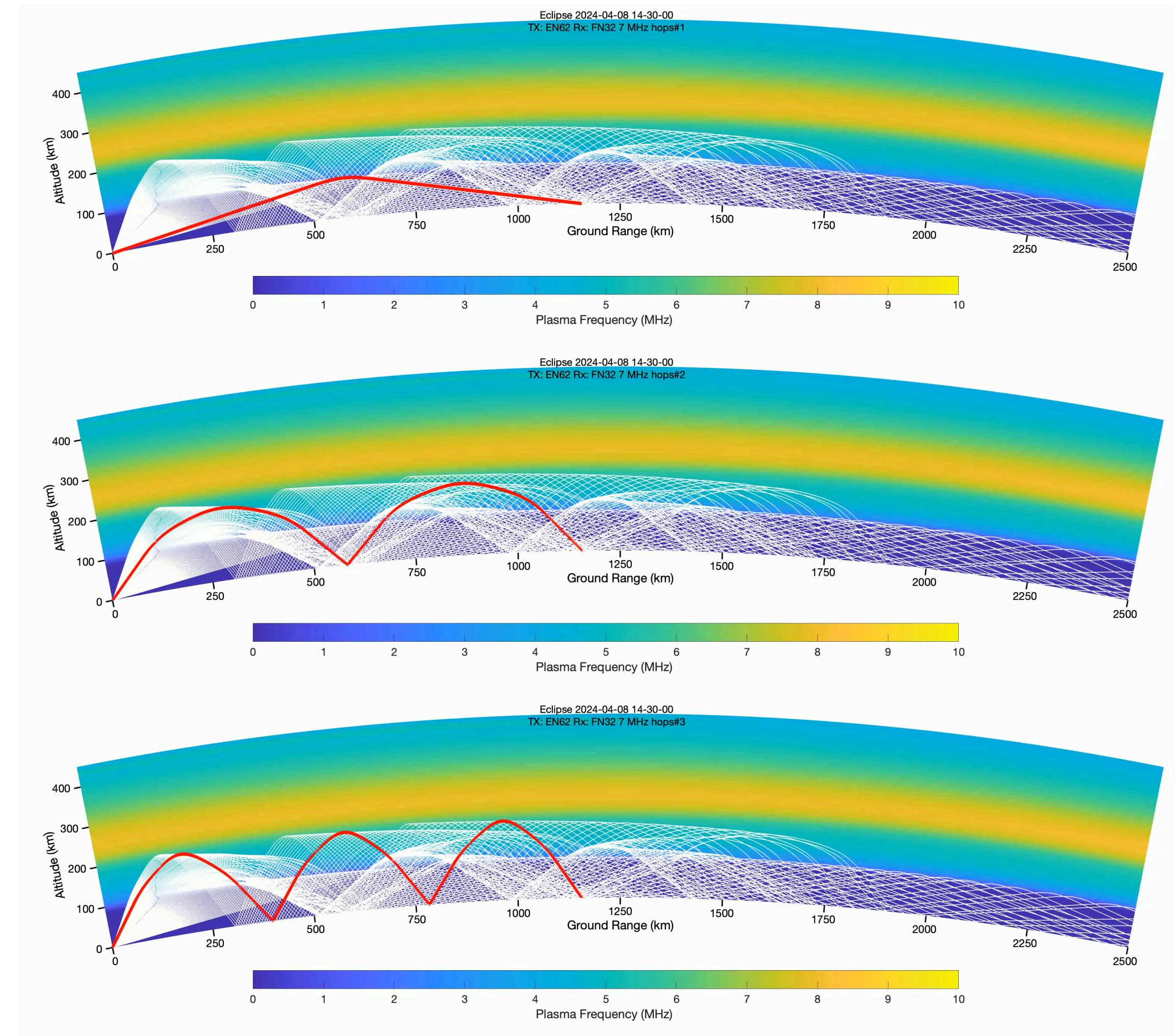
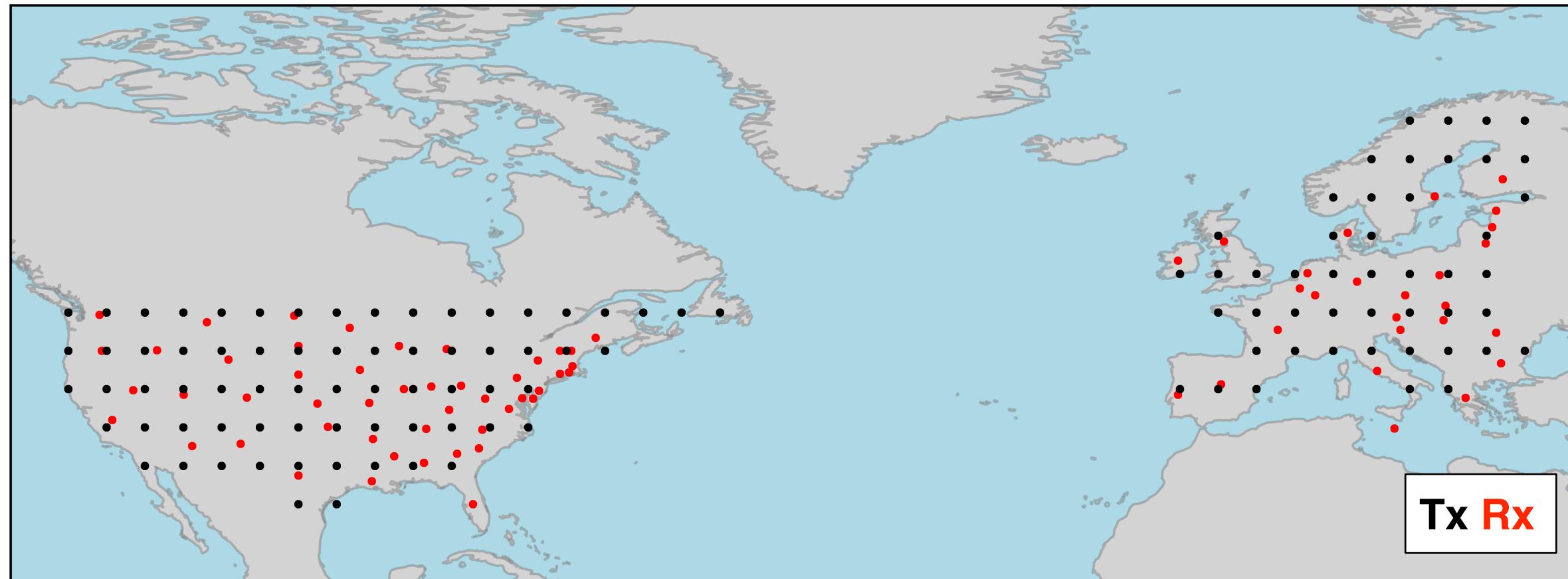


Epoch analysis of global eclipse observations



- Evidence of asymmetric (7 and 28 MHz) and symmetric (3.5 and 21 MHz) ionospheric response to the eclipse.

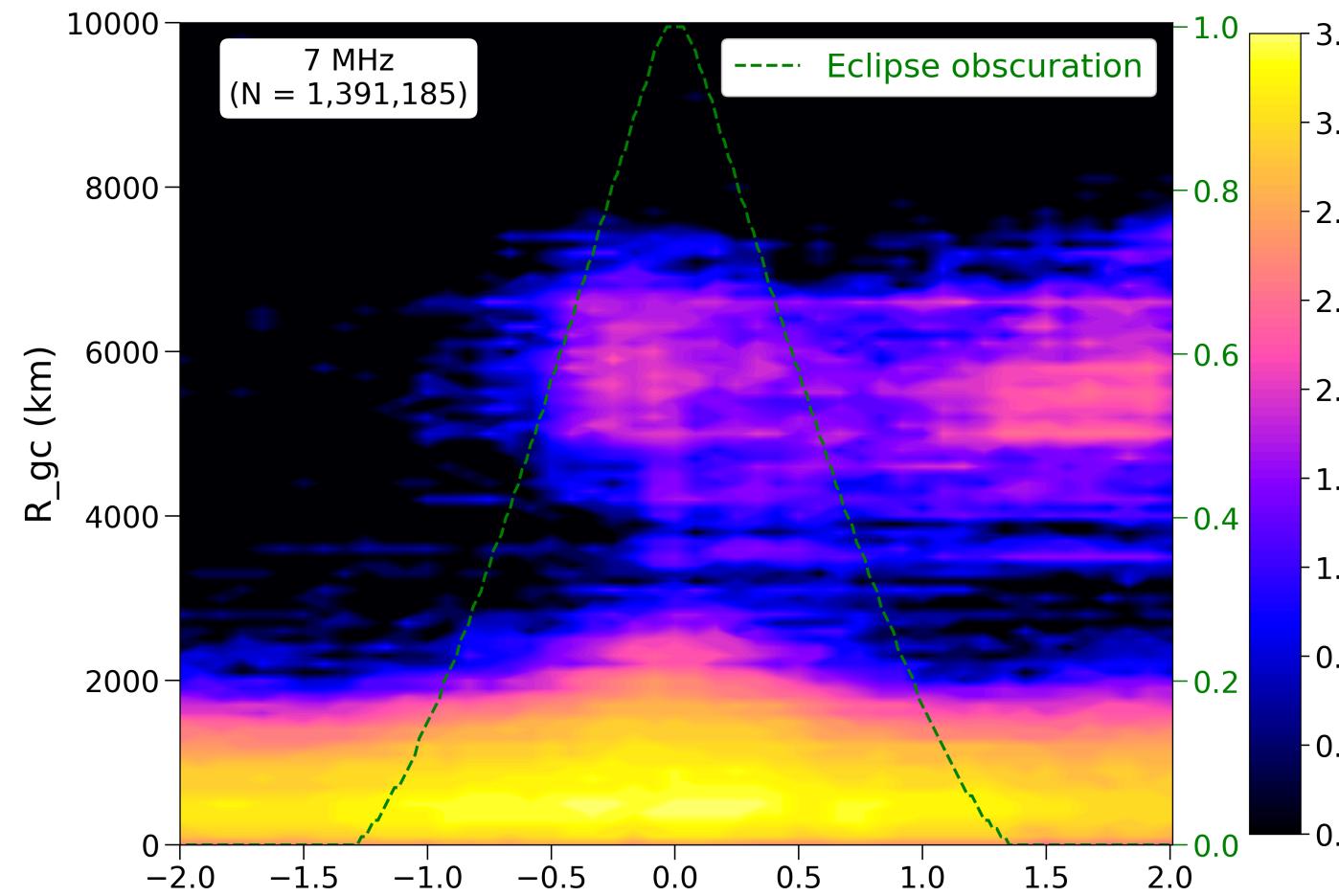
Comparing HamSCI results to ray trace modeling



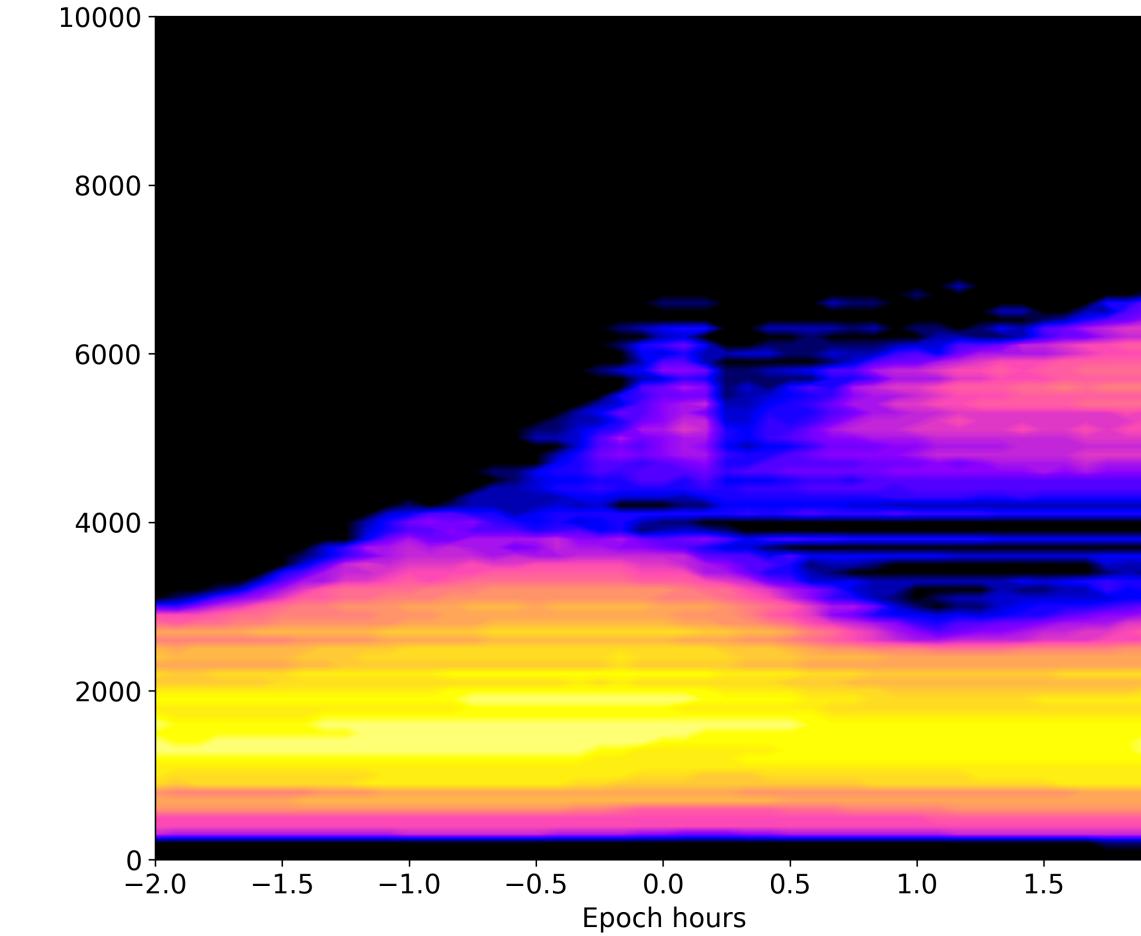
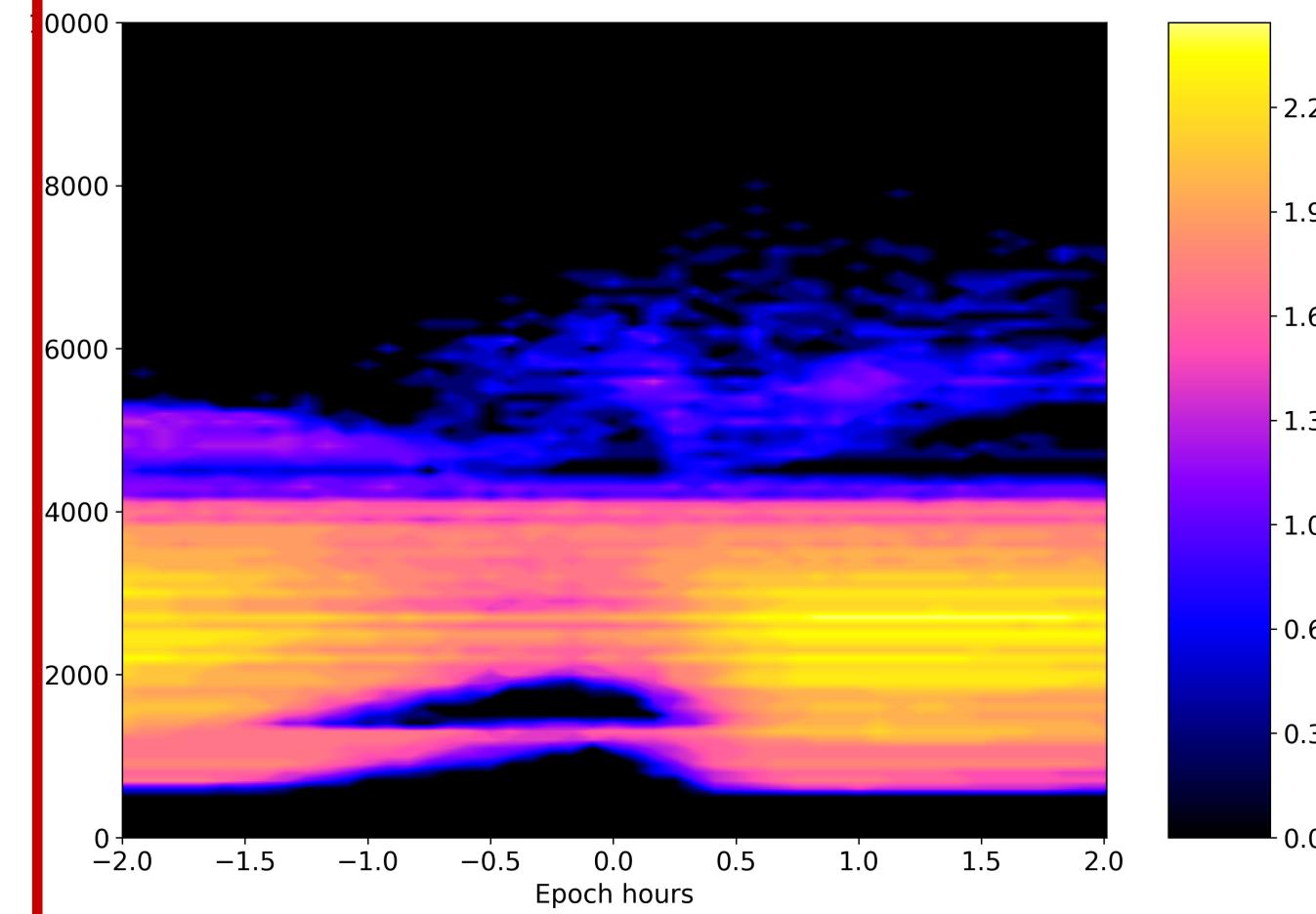
- The PHARLAP numerical ray tracer is used to simulate ham transmissions through SAMI3 and SAMI3-WACCM-X eclipse ionosphere.

Comparison of HamSCI results to ray trace modeling - 7 MHz

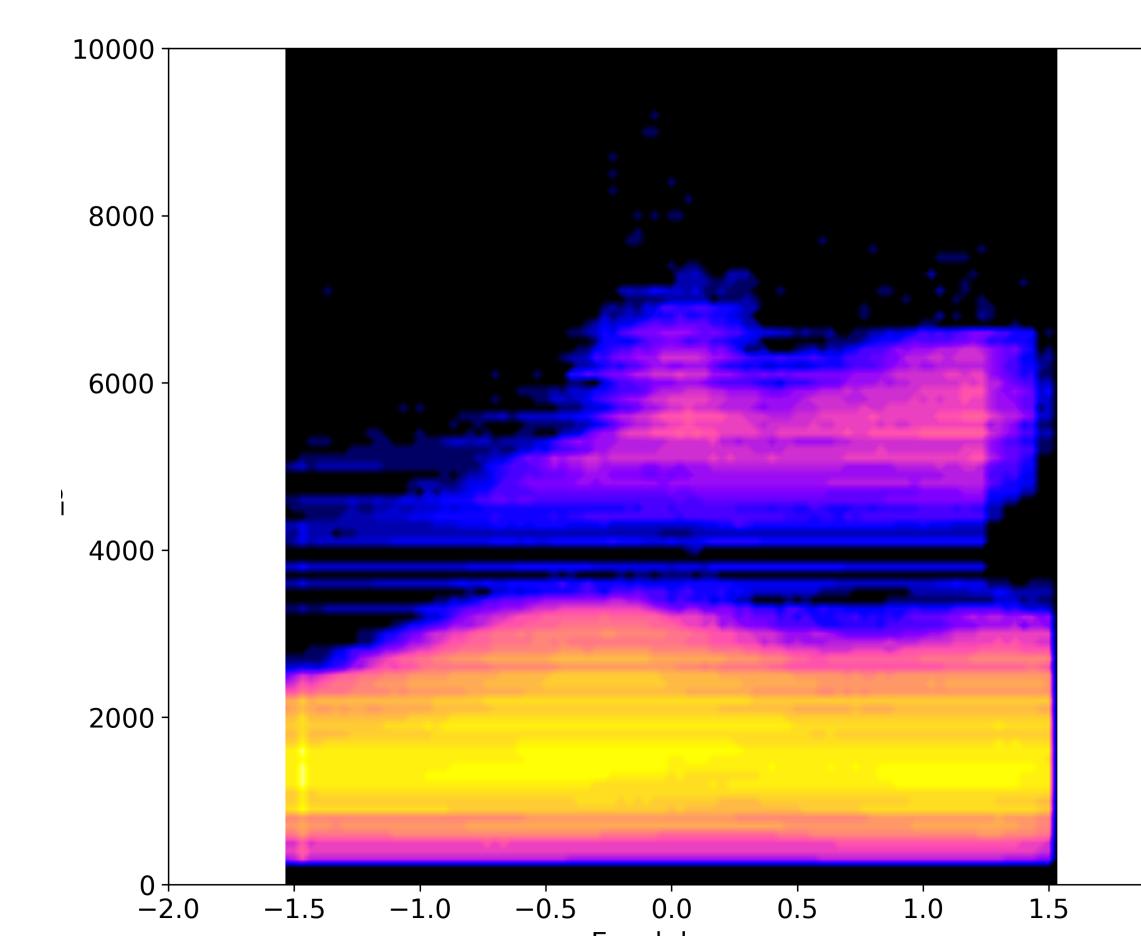
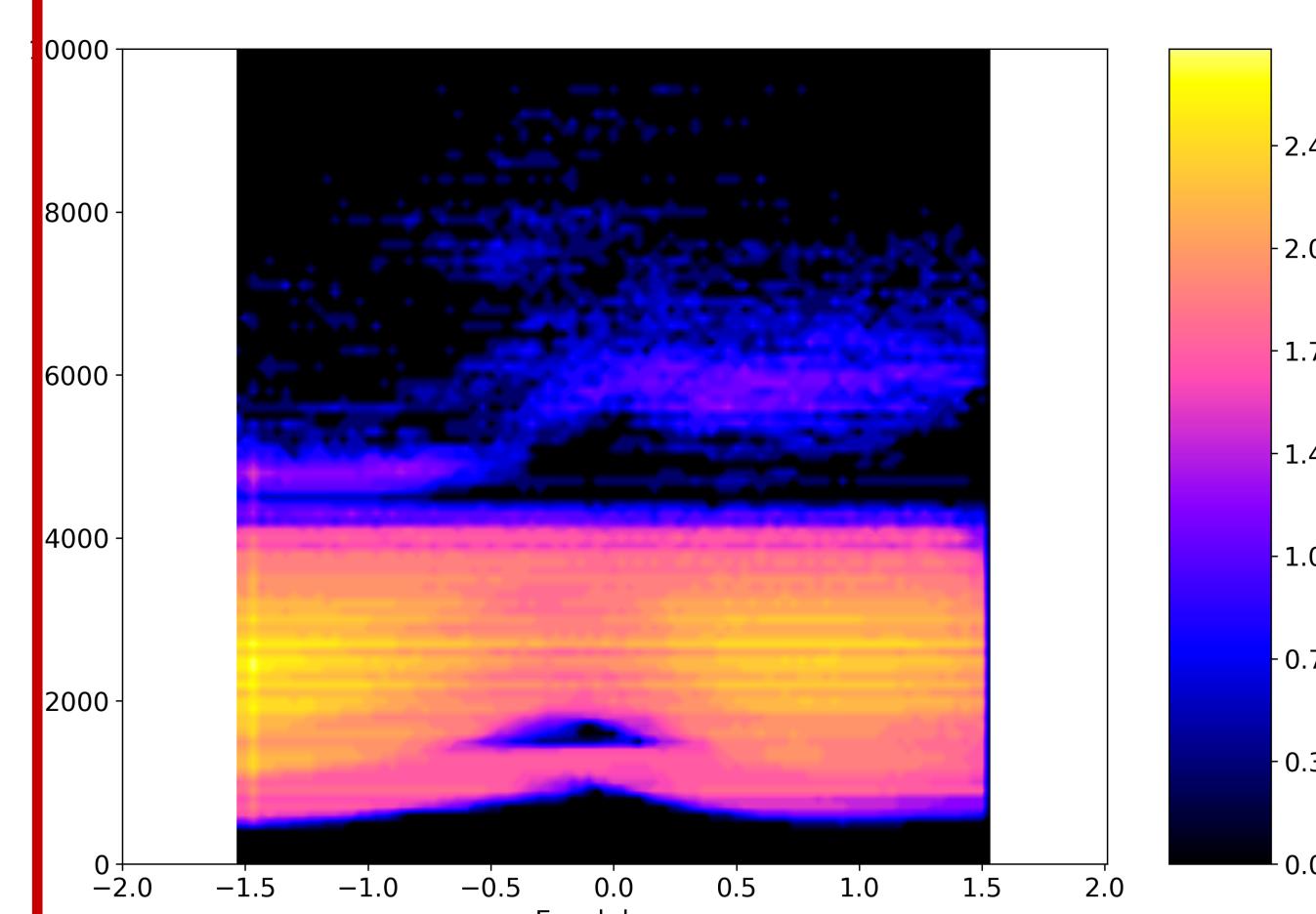
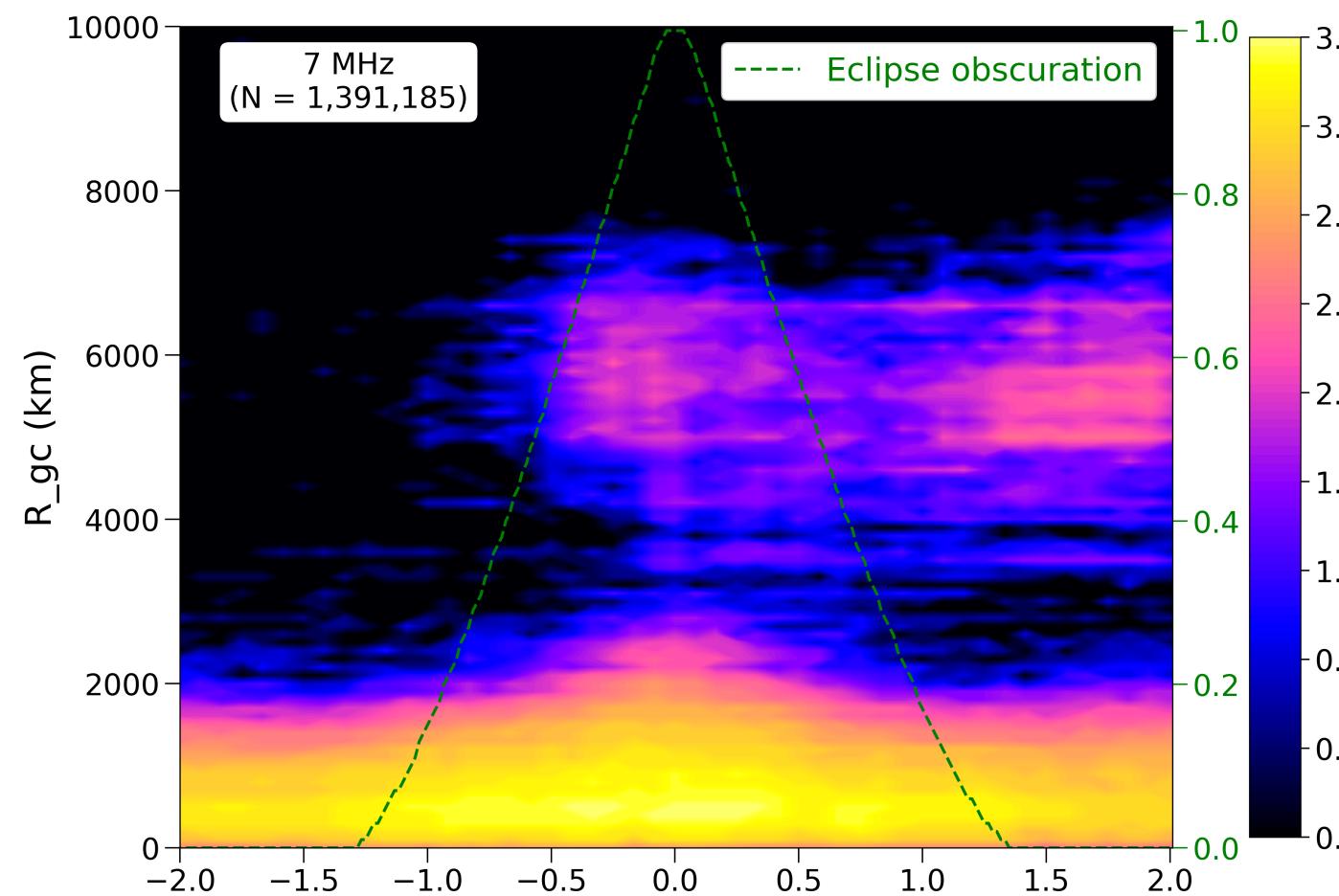
Observed



Simulated



SAMI3



SAMI3-WACCM-X

Summary

- Several ionosondes measured of the ionospheric response during the April 8, 2024 total solar eclipse.
 - Salient features of the response are reproduced by SAMI3 and SAMI3-WACCM-X simulations.
 - The models *do not* reproduce observed “lag” the NmF2 depletion with respect to totality.
 - Models will be refined with an aim of explaining the lag.
- HamSCI analysis show clear effects of the April 8, 2024 eclipse on ham communications.
 - Asymmetric and symmetric ionospheric responses are observed depending on the operating frequency.
 - Numerical ray trace simulations are able to reproduce evolution of ham radio linkages observed during the eclipse.

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Atmospheric responses to total and annular solar eclipses

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The main goal of this SI is to collate papers related to the aforementioned total and annular solar eclipses and to foster an understanding of the morphology, dynamics, structures, and irregularities that were produced in the atmosphere during and after the passage of the Moon's shadow over the continents and oceans.

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- Bibtex
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02 Dec 2024

The Magnetic Vortex during a Solar Eclipse

Atef Zoughlami

Ann. Geophys. Discuss., <https://doi.org/10.5194/angeo-2024-19>, 2024

Preprint under review for ANGEO (discussion: open, 0 comments)

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Müller-Wodarg, I. C. F., Aylward, A. D., & Lockwood, M. (1998). Effects of a mid-latitude solar eclipse on the thermosphere and ionosphere—A modelling study. *Geophysical Research Letters*, 25(20), 3787-3790. doi:10.1029/1998GL900045.