Atmospheric Gravity Waves in the Ionosphere and Thermosphere During the 2017 Solar Eclipse

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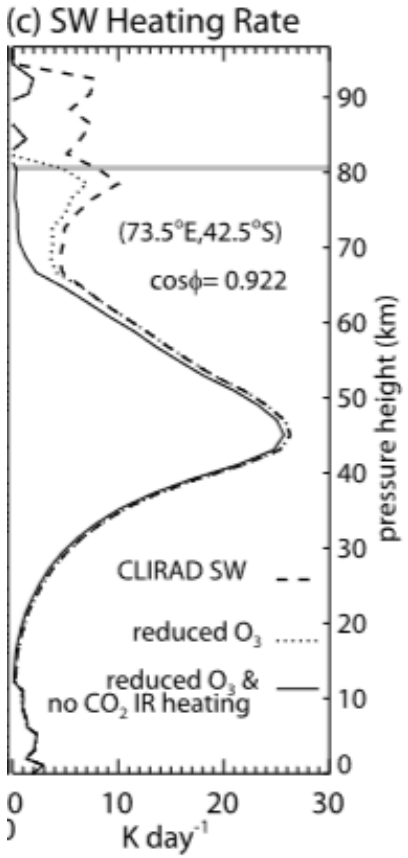
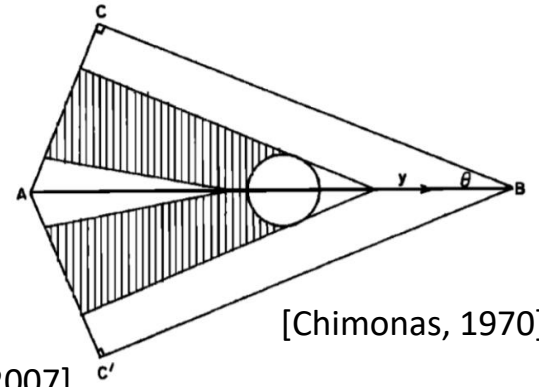
2017 Solar Eclipse

Eclipse-Induced Bow Waves

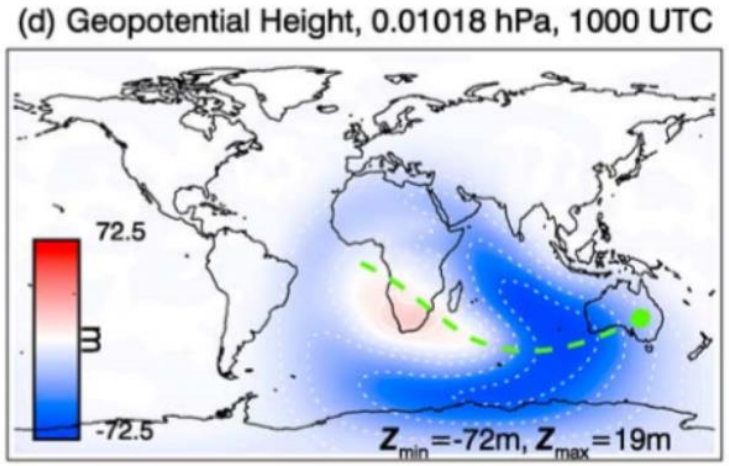
- Absence of heating source becomes a moving perturbation source. When the footprint moves supersonically, a bow-wave front is formed.
- GNSS network observed both bow-wave front and the trailing gravity waves.



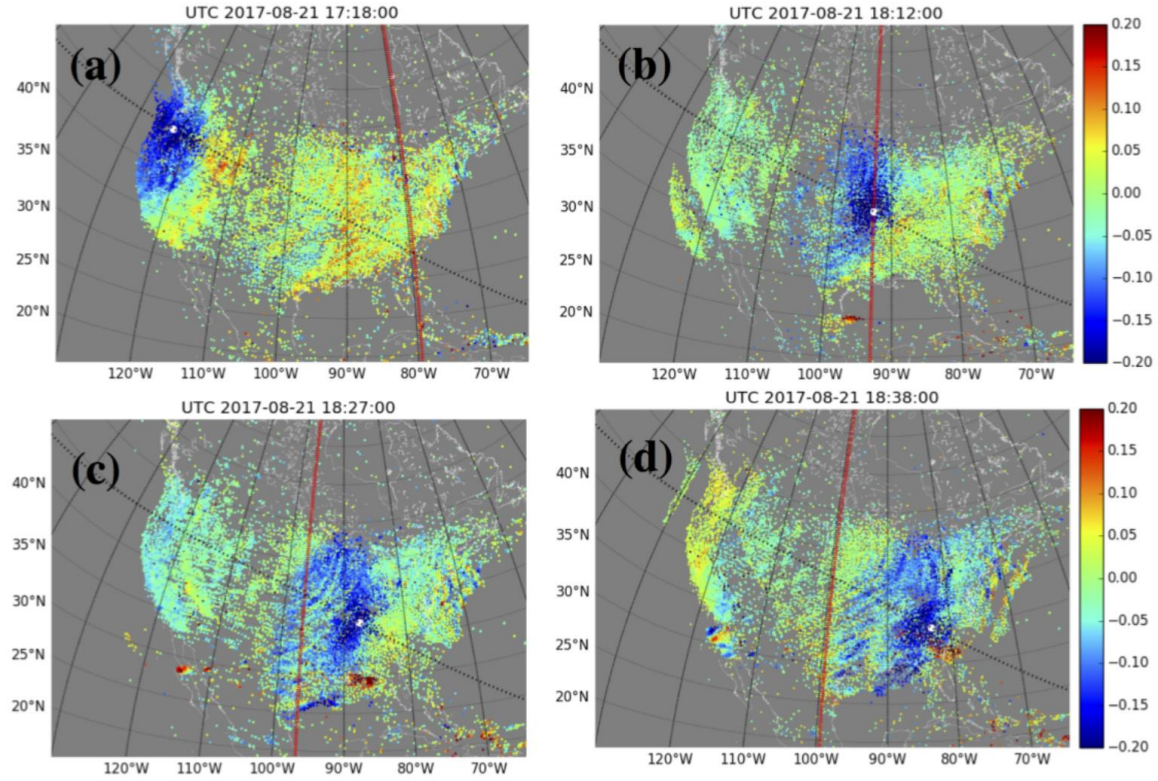
[Eckermann et al., 2007]



[Chimonas, 1970]

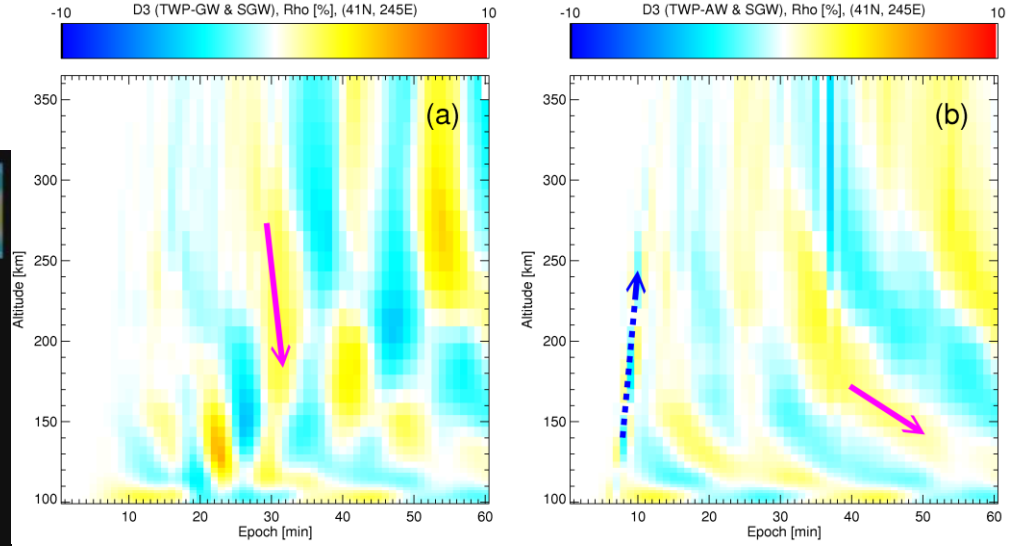


[Zhang et al., 2017]



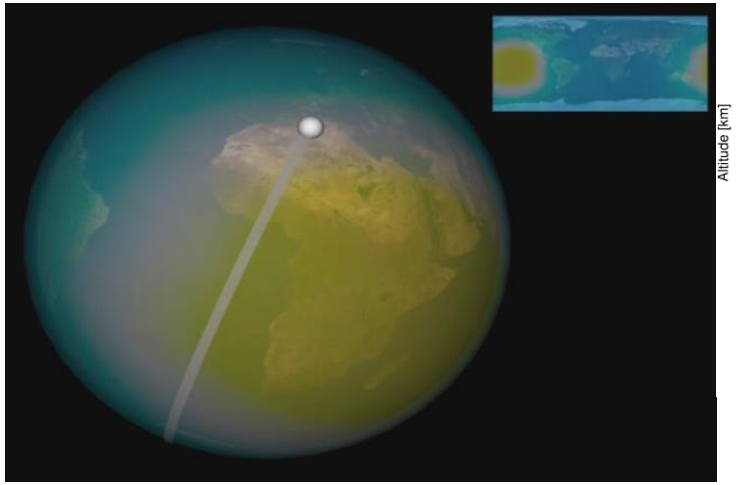
Global Ionosphere-Thermosphere Model (GITM)

[Lin et al., 2017]



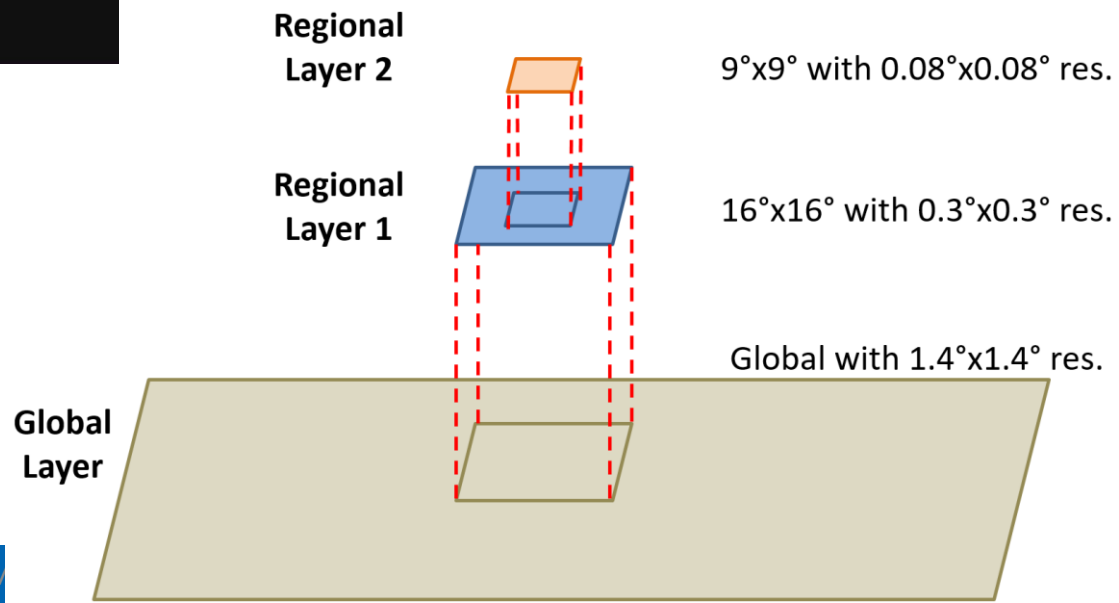
❑Features:

- Self-consistent global circulation model for the upper atmosphere
- **Non-hydrostatic** solutions
- Flexible 3D grids

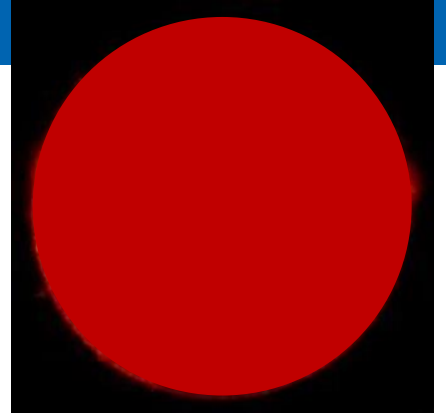


❑Solar Eclipse Simulation:

- **Time:** 13:30–23:30 UT, Aug 21, 2017
- **Global simulation** with resolutions of **2°x0.5°** in geophysical longitude and latitude **0.3 of the scale height** between **100–600 km** altitude.
- Differences between *control* and *eclipse* runs are considered as consequential effects by eclipse.

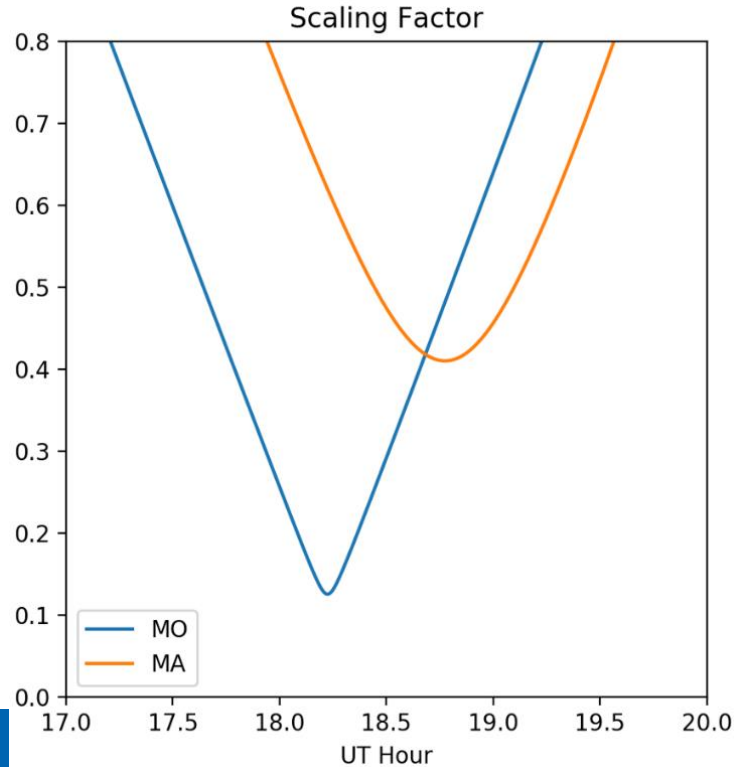


EUV Obscuration Factor

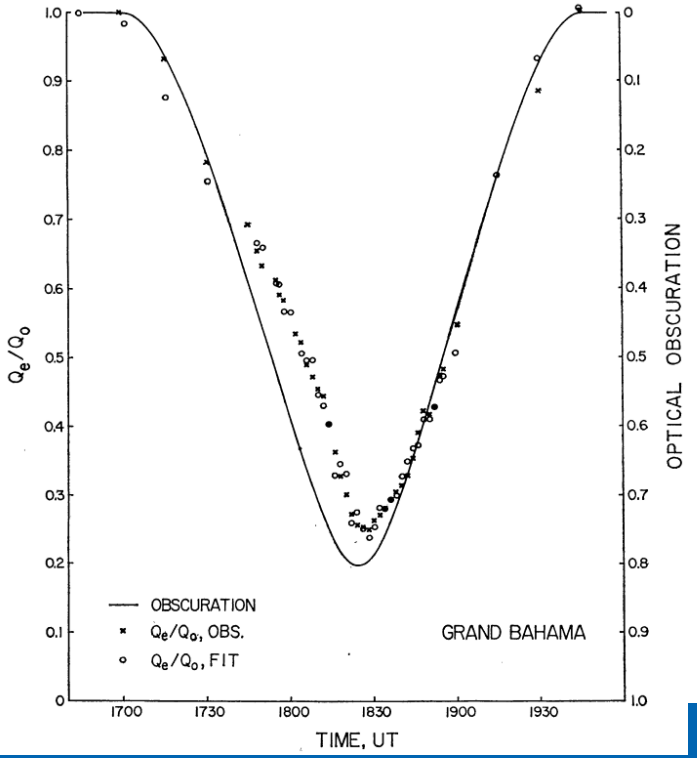


- The obscuration factor is set to be 10% at totality.
- EUV flux is assumed uniform across the solar disk, a simplified setup.
- The ionosphere-thermosphere responses are extracted at **2 ground station locations**: Missouri (**MO**), and Massachusetts (**MA**), at **5-sec** cadence. The former station underwent *totality* and a *partial* eclipse of 60% at the latter station during the peak time.

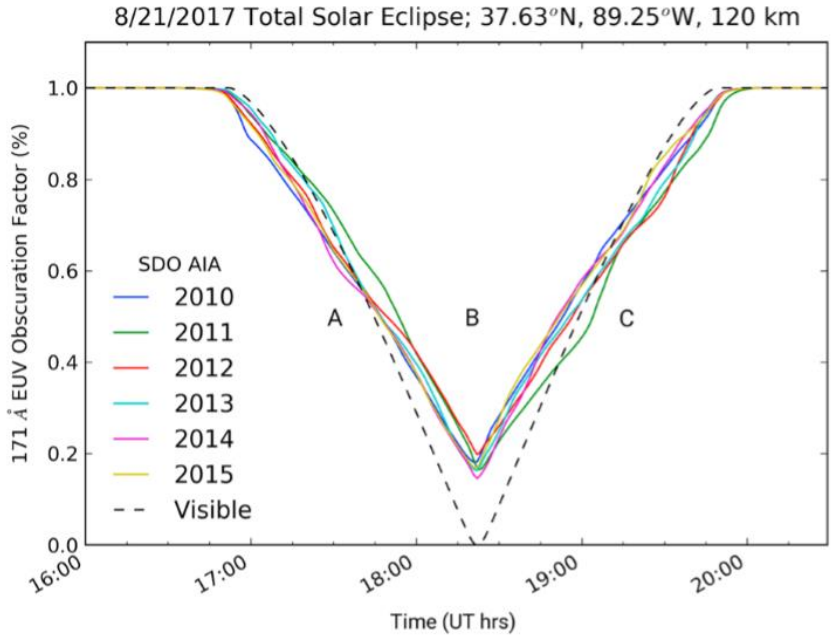
[Lin et al., 2018]



[Marriott et al., 1971]

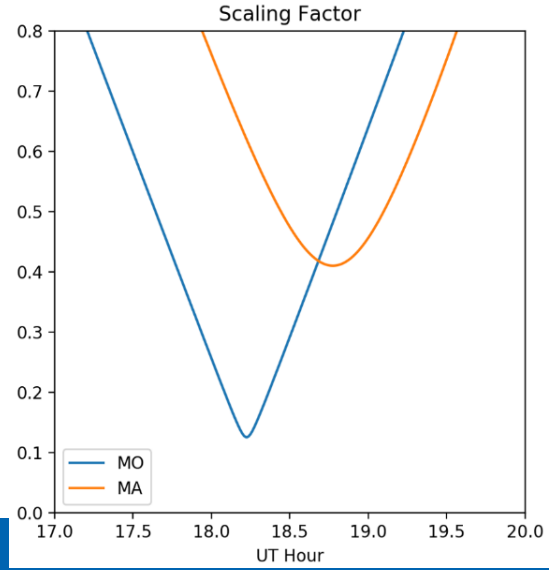


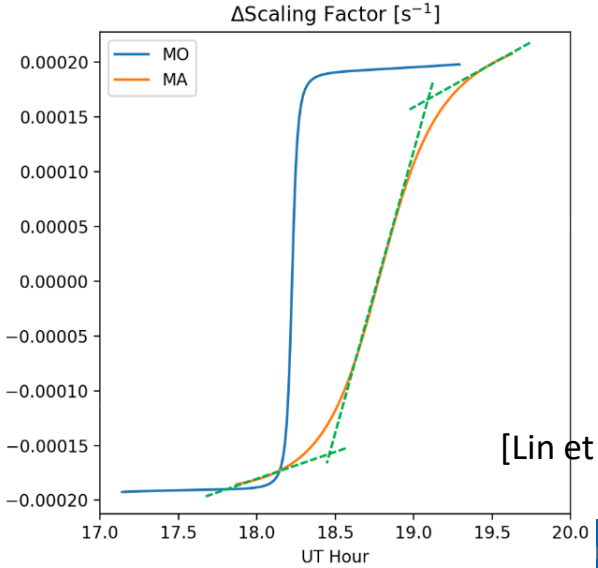
[Huba and Drob, 2017]



Waves in the IT System

- **Electron density (right column)**:
  - < 230 km: decrease peaks at totality
  - > 230 km: ~30 min delay in maximal decrease
- **Neutral density (left column)**: Maximal decrease occurred ~30 min after totality started.
- IT responses at totality location show strong wave features.
- *High-frequency waves* are observable clearly in the neutral density profiles at the totality station because the sharp transition of the change rate of EUV obscuration factor.

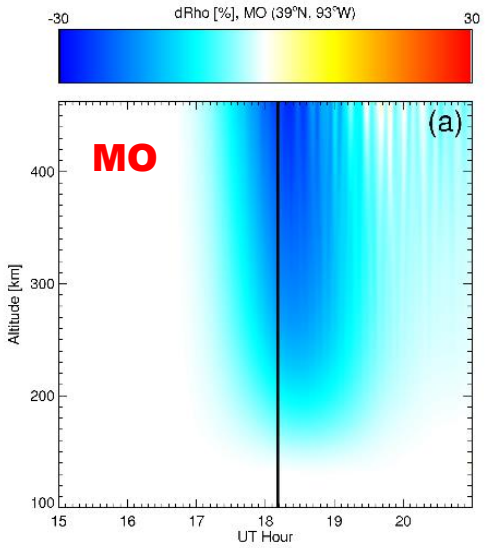


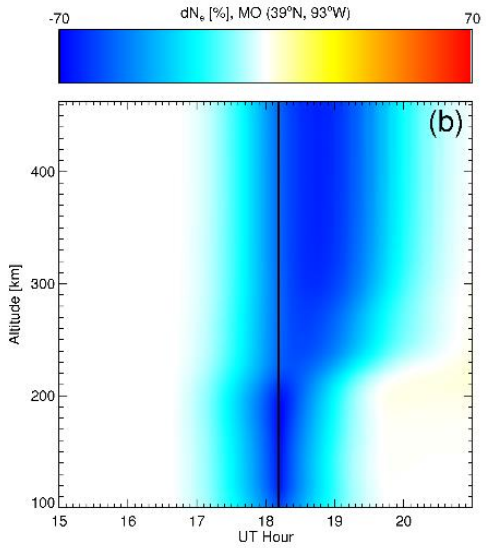


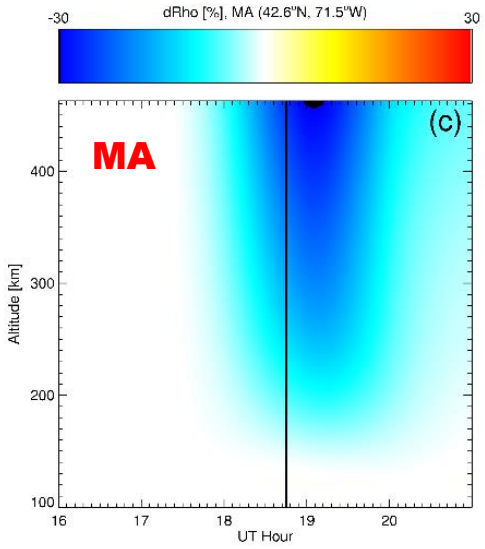
[Lin et al., 2018]

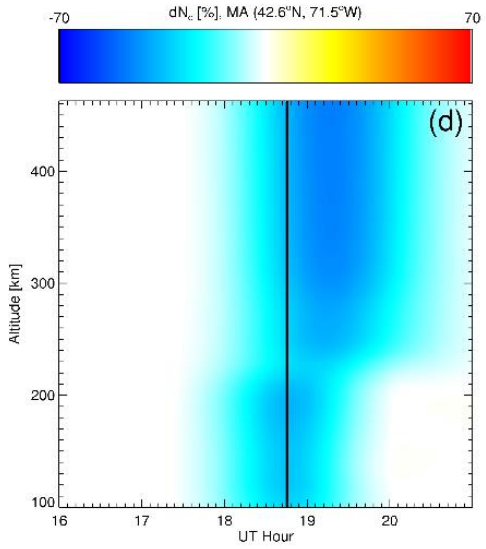
Neutral Density

Electron Density









Periodicity: Short-Period Waves

Strong waves < 20 min: resulting from the sharp gradient of the obscuration

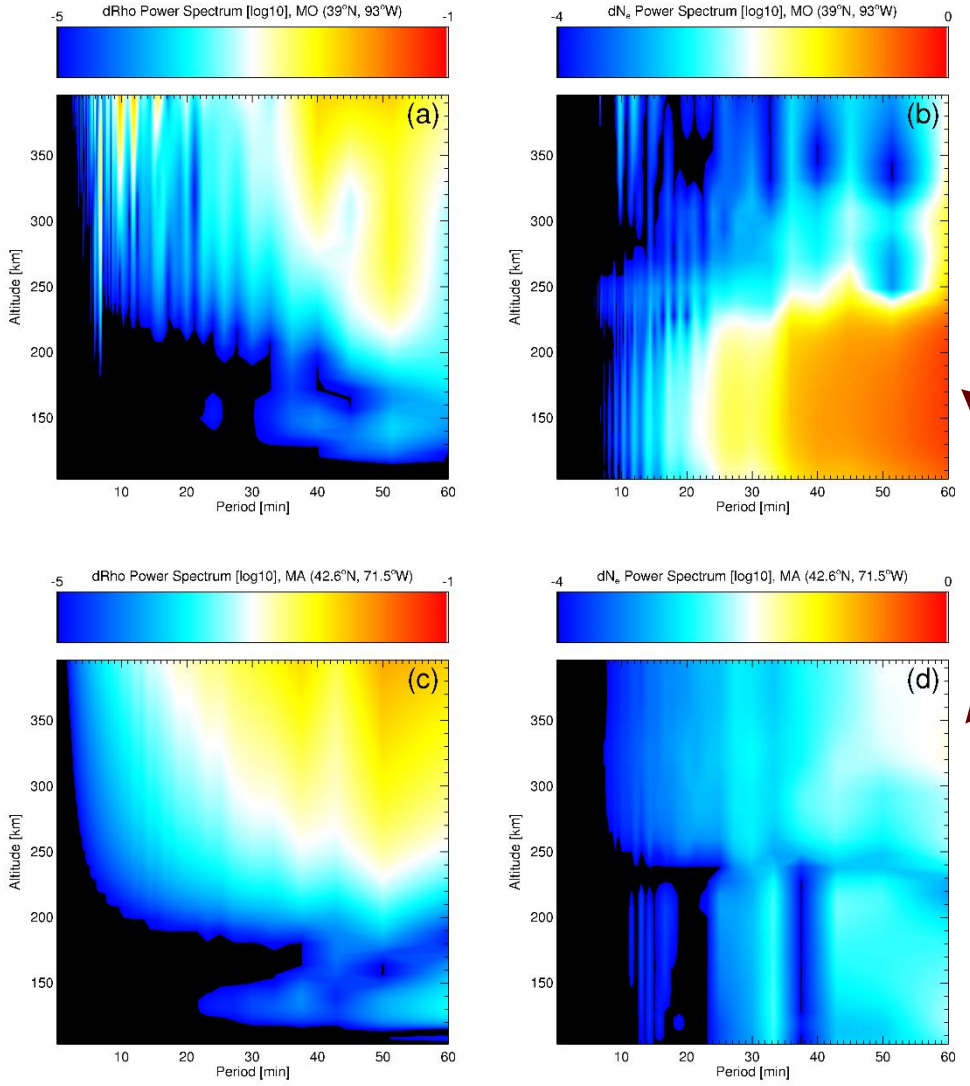
Neutral Density

Electron Density

MO

MA

Altitude [km]

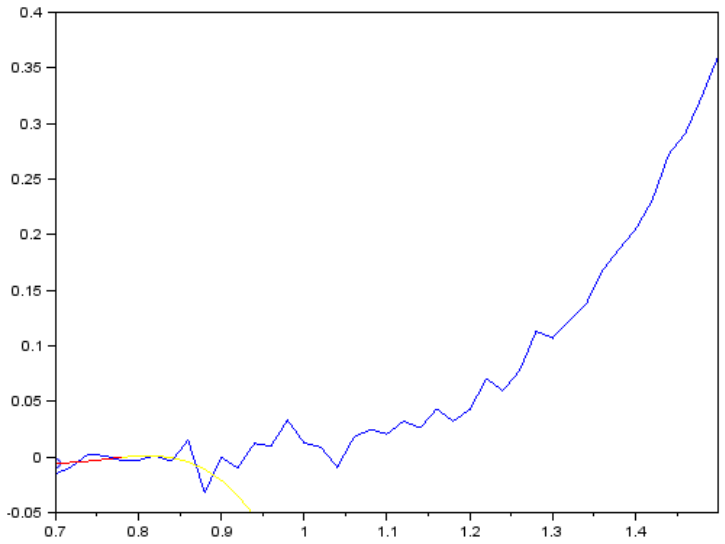


>1 hr: Capturing the large-scale 'cavity' during the eclipse

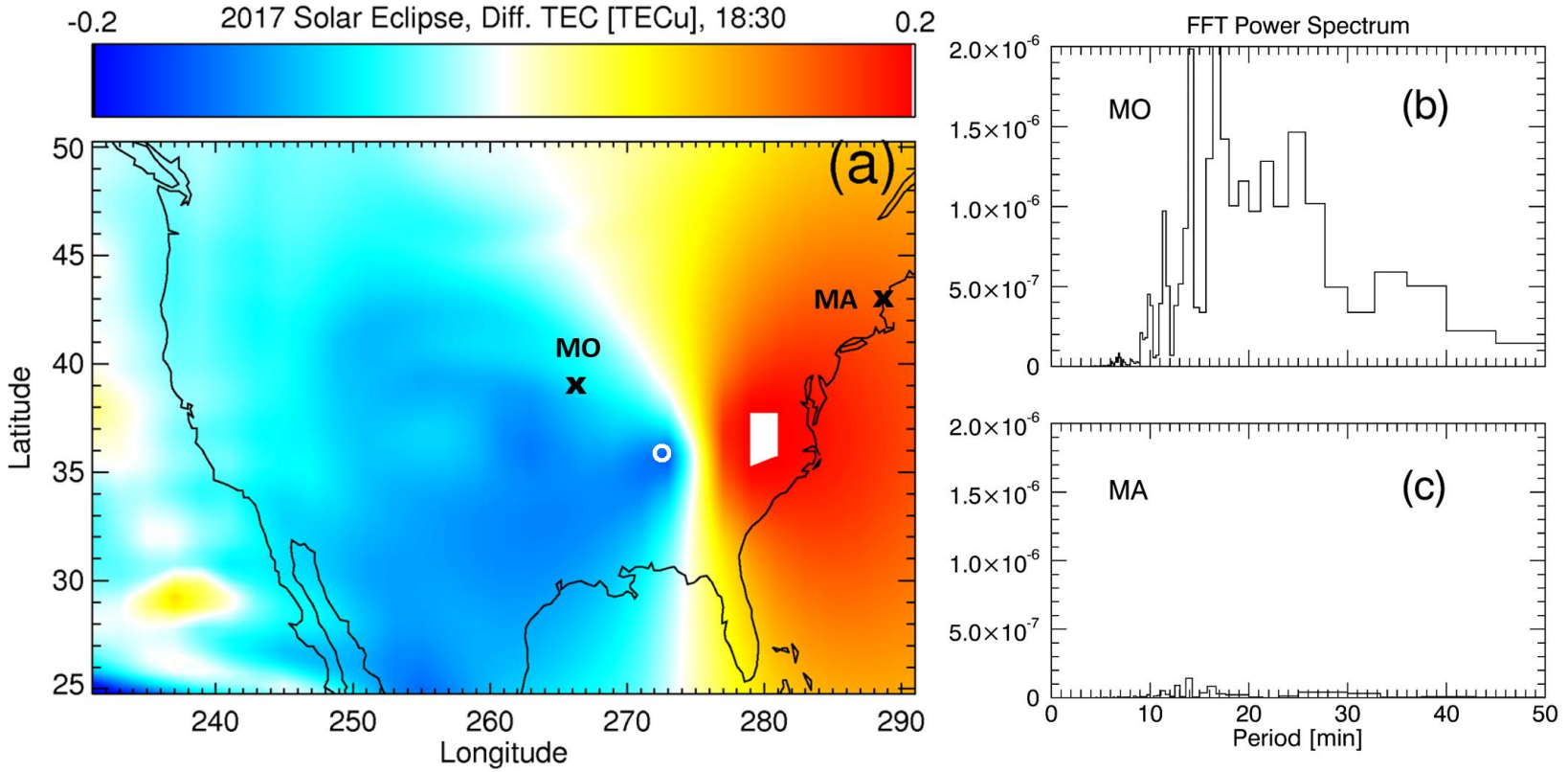
[Lin et al., 2018]

Wave Activities in Vertical Total Electron Content (VTEC)

- Savitzky-Golay (3-degree, 0-order) low-pass filter to separate the large-scale and small-scale structures.
- Longer-period waves (gravity waves) sustain hours after eclipse ended.
- Compared with measurements:
  - Bow-wave front
  - Trailing waves within the bow
  - Negative zone spans ~20˚x 20˚



[Lin et al., 2018]



Summary & Conclusions

- Lack of **thermospheric heating** is sufficient to induce bow waves.

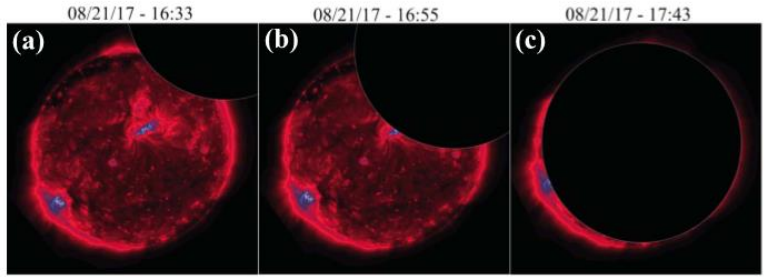
- Strong **high-frequency wave components (T < 30 min)** are observable in both I&T at the totality stations but absent from the partial-eclipse station.

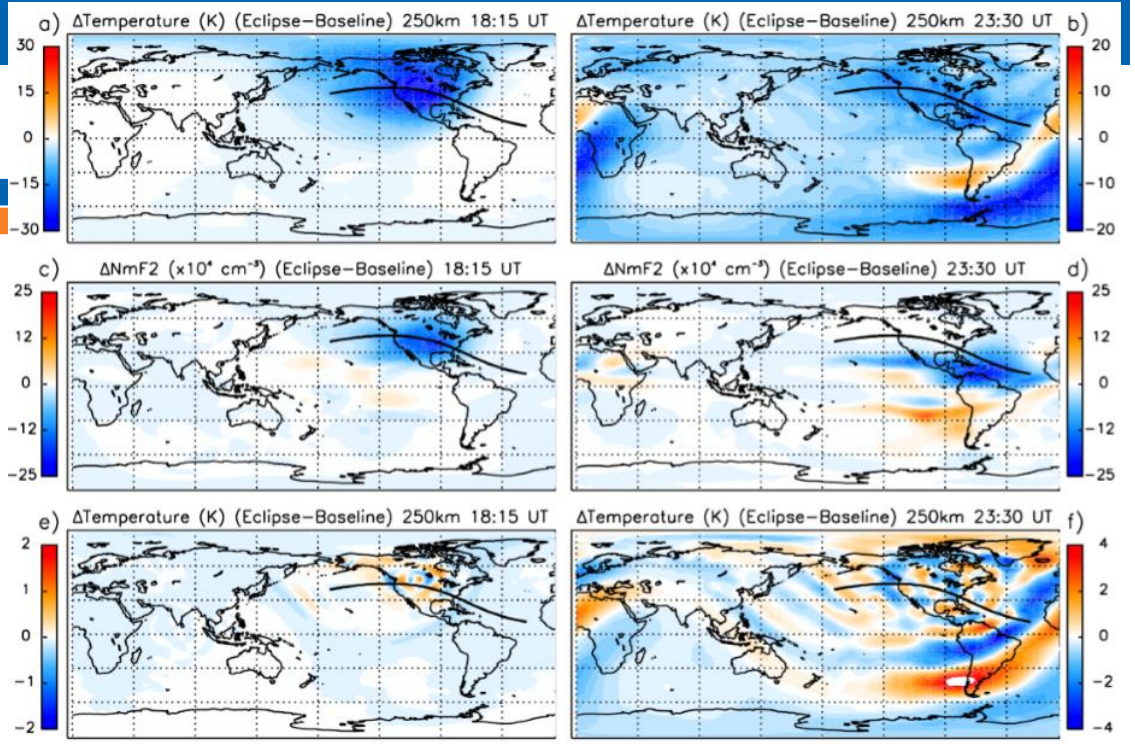
- The supersonic moving shadow results in a **bow-wave front** and trailing **gravity waves** seen in VTEC. Large-scale variability has an elongated tail and small-scale variability reveal wave structures within a negative zone spanning ~20˚x 20˚.

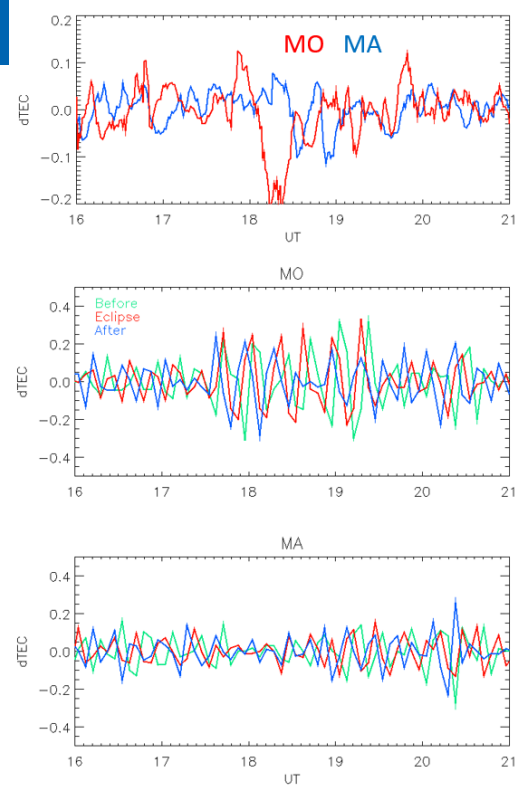
- Gravity waves sustain hours after eclipse ended.

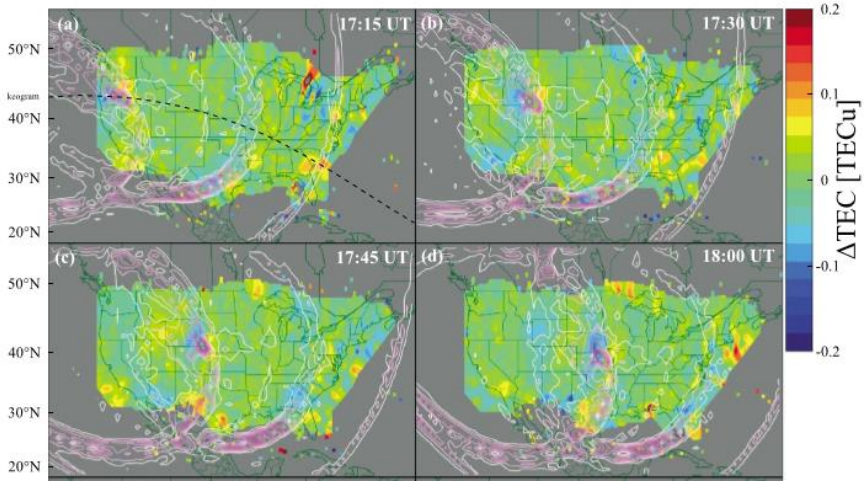
Onward

[Mrak et al., 2018]

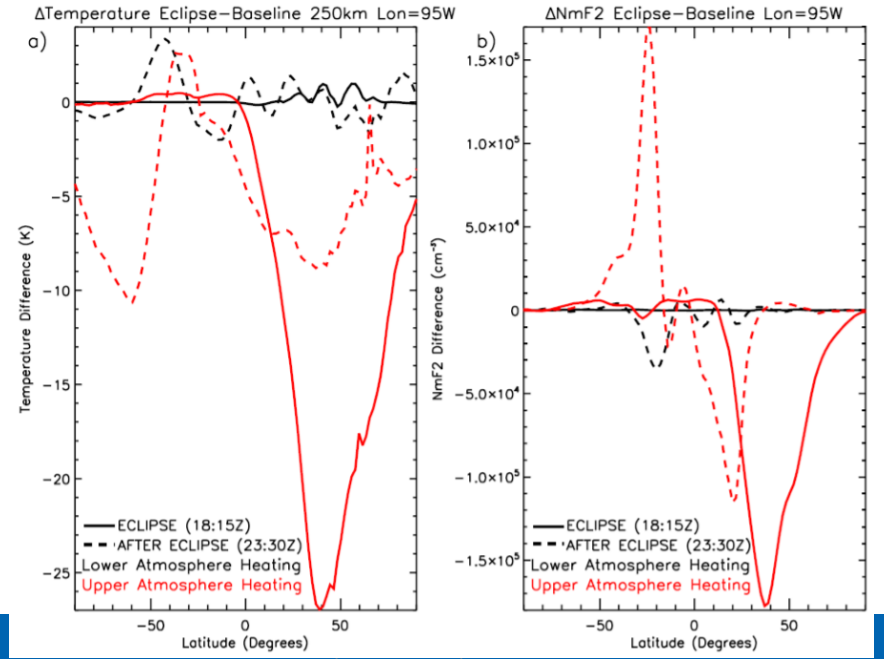


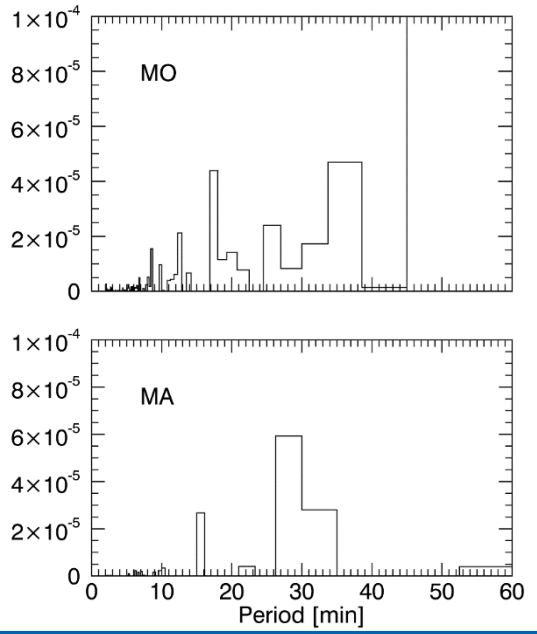






[McInerney et al., 2018]



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