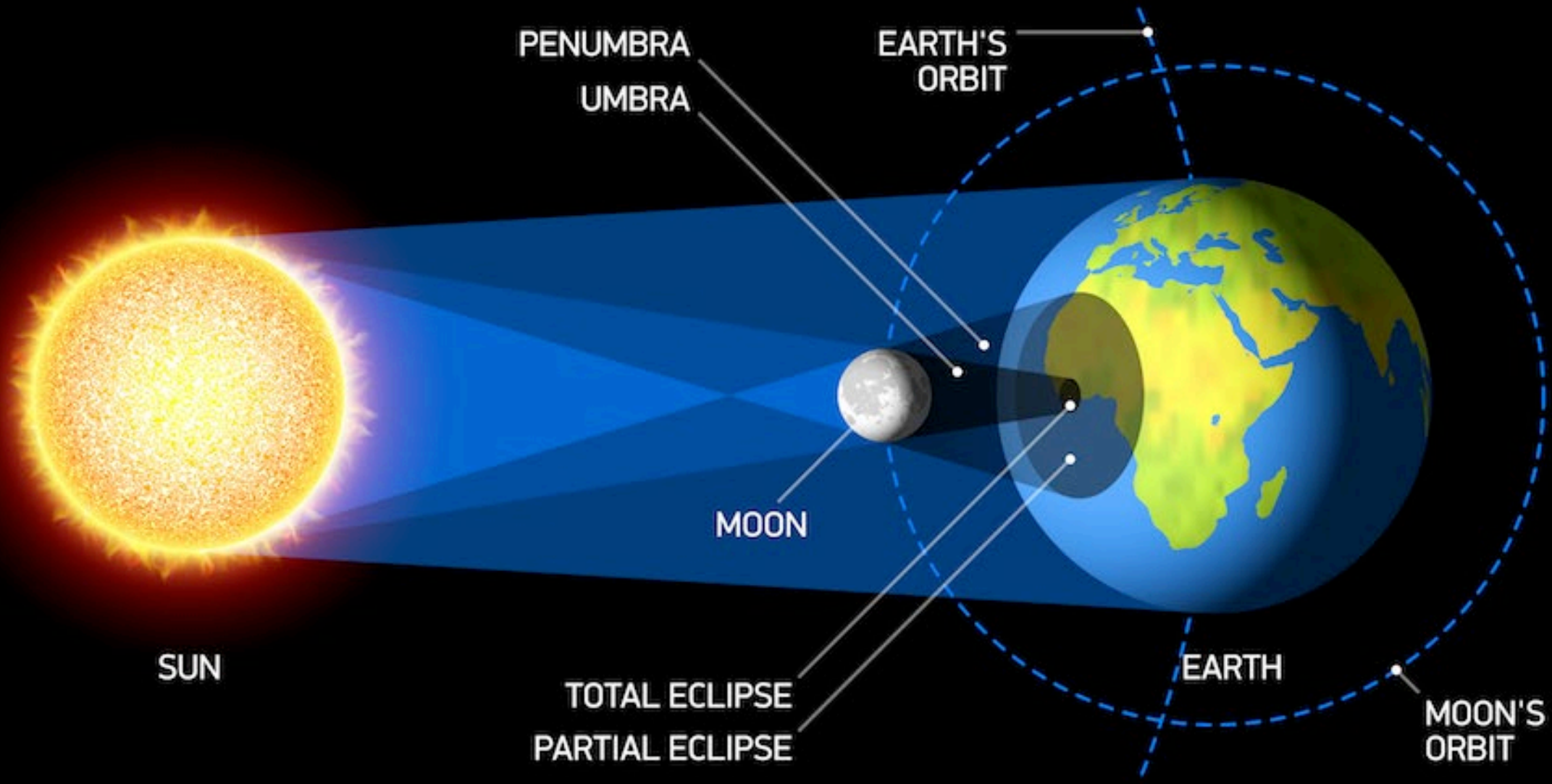
Ionospheric variations during the solar eclipse event by space weather forecasting system

Chia-Hung Chen[1], Chien-Hung Lin[1], Tomoko Matsuo[2]

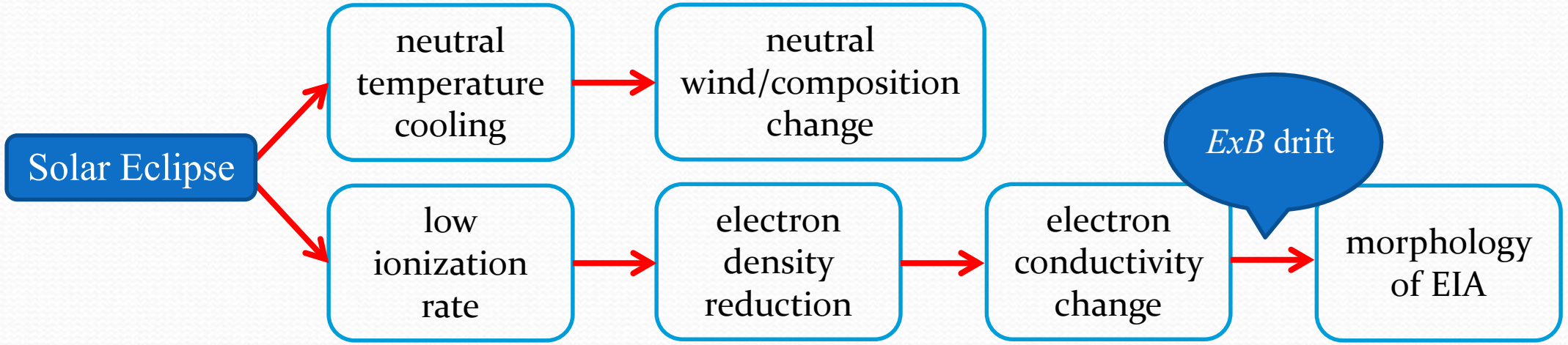
1 Department of Earth Sciences, National Cheng Kung University, Tainan, Taiwan
2 Ann and H. J. Smead Department of Aerospace Engineering Sciences, University of Colorado, Boulder, CO 80309-0429, USA

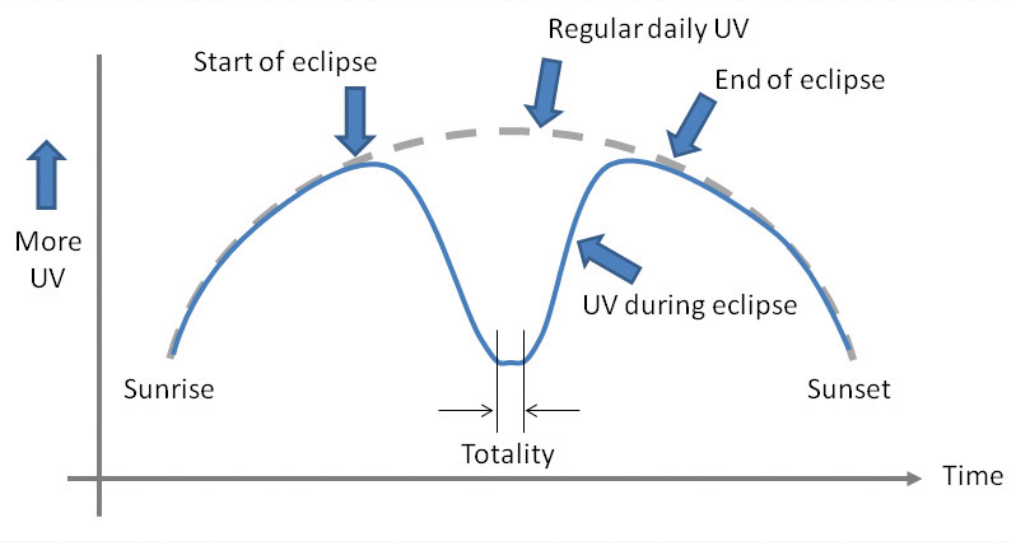
Solar Eclipse



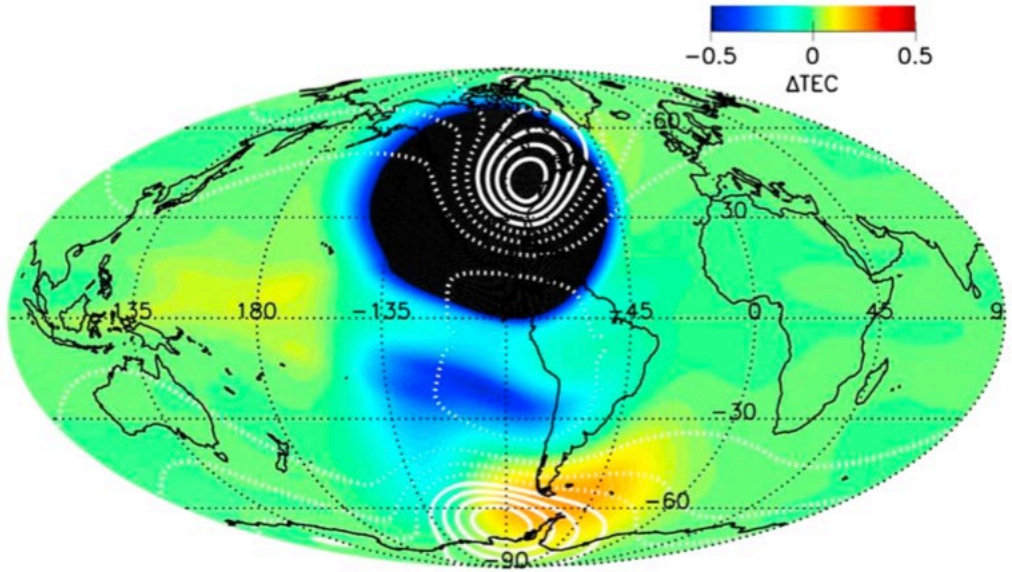
[From: https://jp.mathworks.com/]

Solar eclipse effect in the ionosphere



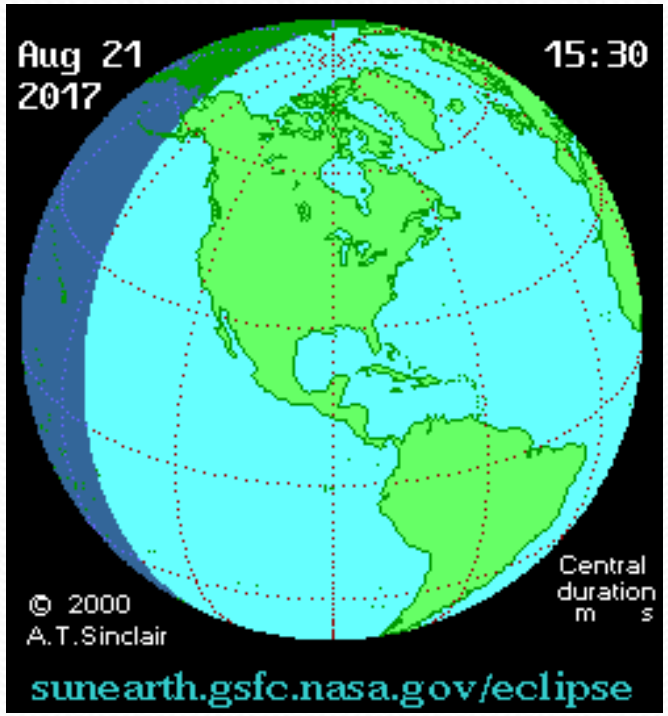


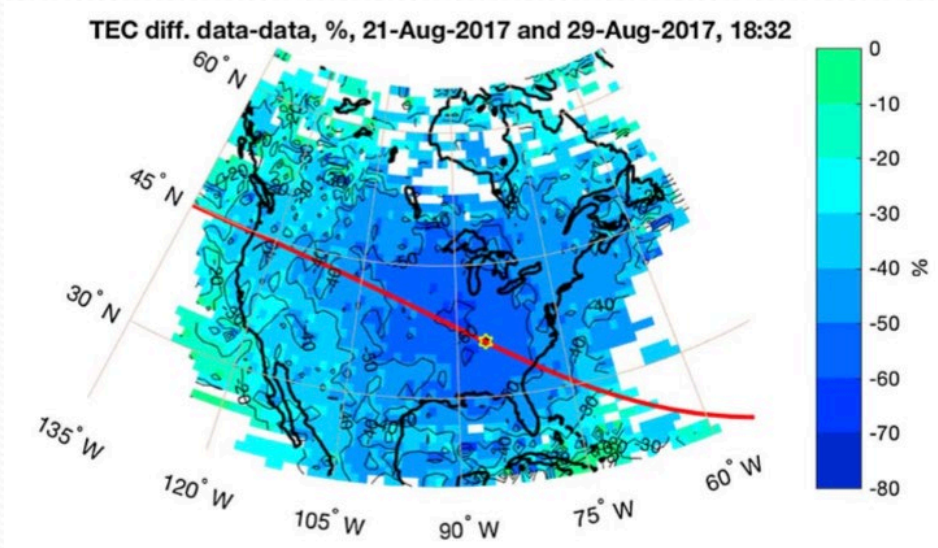
[From: https://www.nutsvolts.com/magazine/article the-solar-eclipse-and-ham-radio]

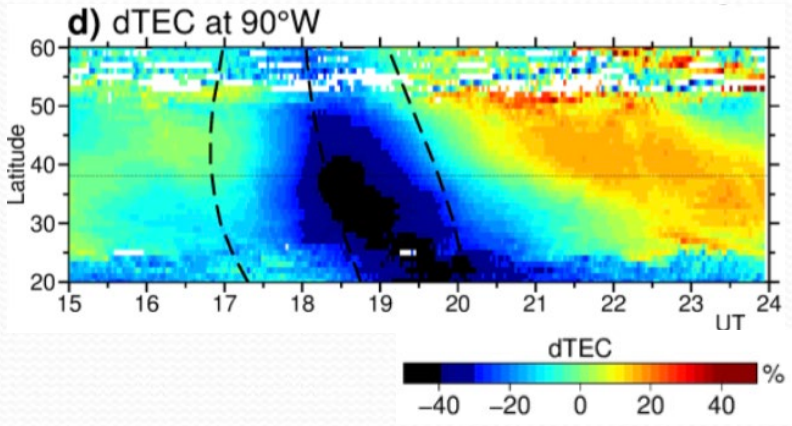


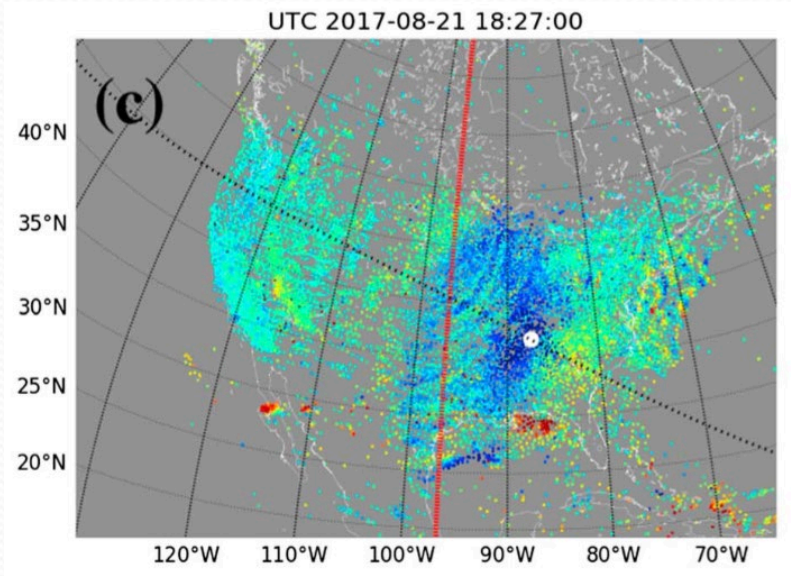
[*Huba and Drob, 2017*]

2017 August solar eclipse event









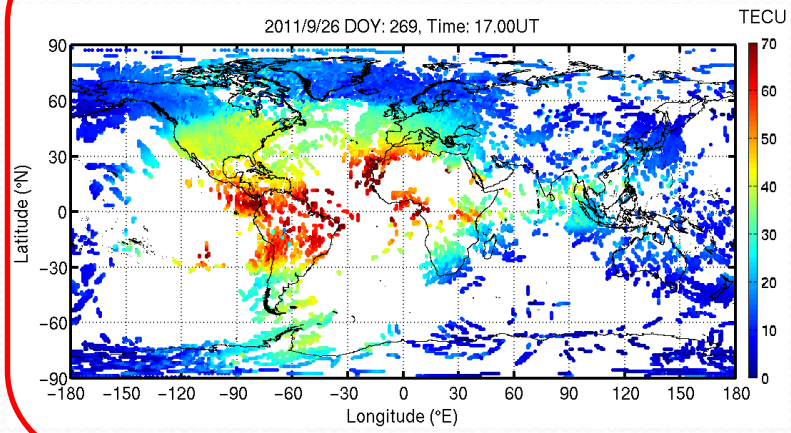
- Using the ionospheric TEC driven from a dense network of GNSS receivers over North America, Coster et al. [2017] showed large TEC depletion during the eclipse.
- Zhang et al. [2017] presented the eclipse-induced ionospheric bow waves and gravity wave-like structures on the electron density.
- Cherniak and Zakharenkova [2018] further showed the large-scale TEC enhancement after eclipse.

Questions

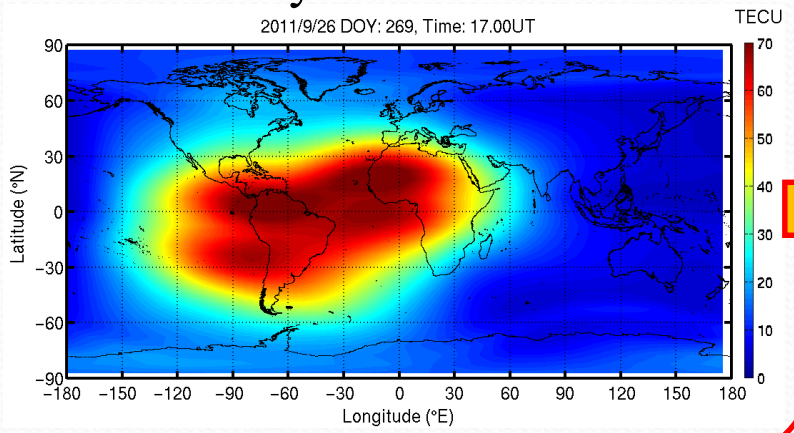
- How are these ionospheric disturbances trigged by the 2017 August solar eclipse?
  - the change of ionospheric electric field system

Methodology

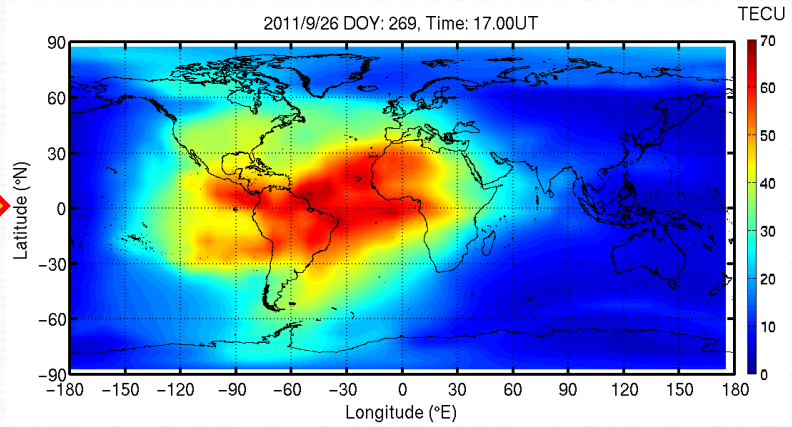
Observations



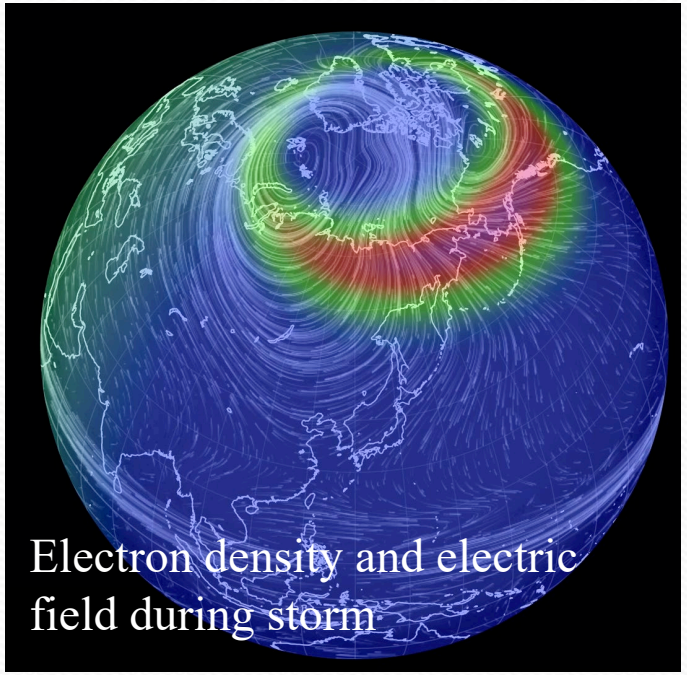
Physical Model



Data assimilation

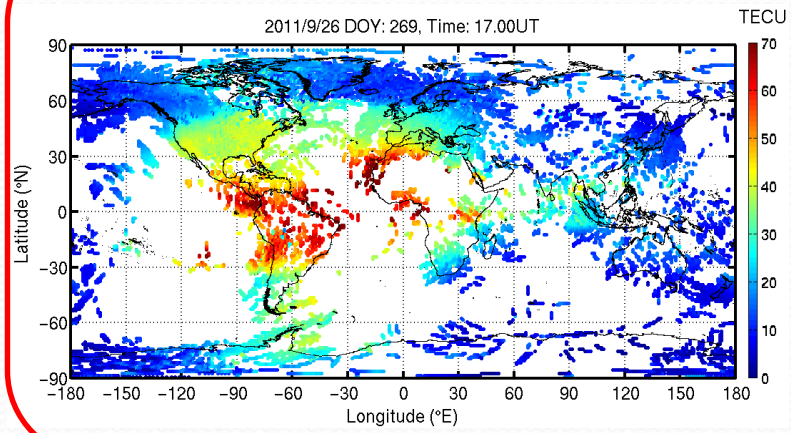


- Observations:
  - near the true state, high quality and resolution data
  - lack of spacial and temple coverage, parameter losing
- Model:
  - global coverage, predictable, all parameters
  - larger error, low resolution, control by initial condition

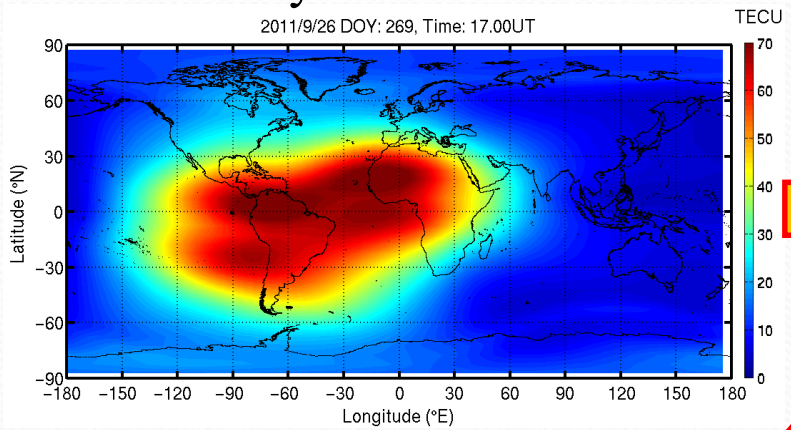


Methodology

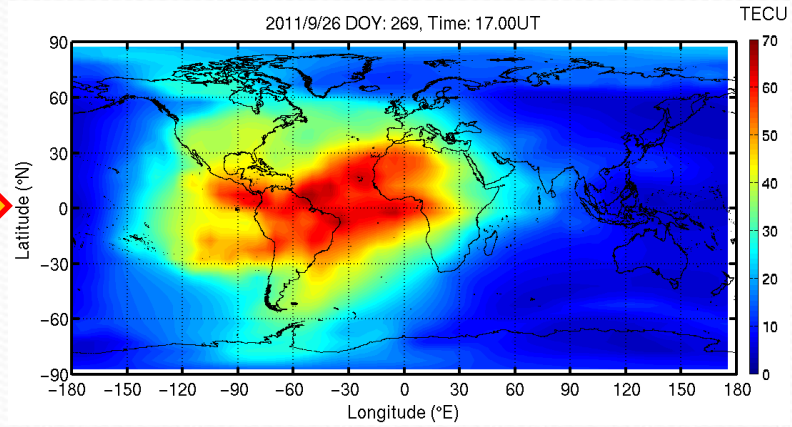
Observations



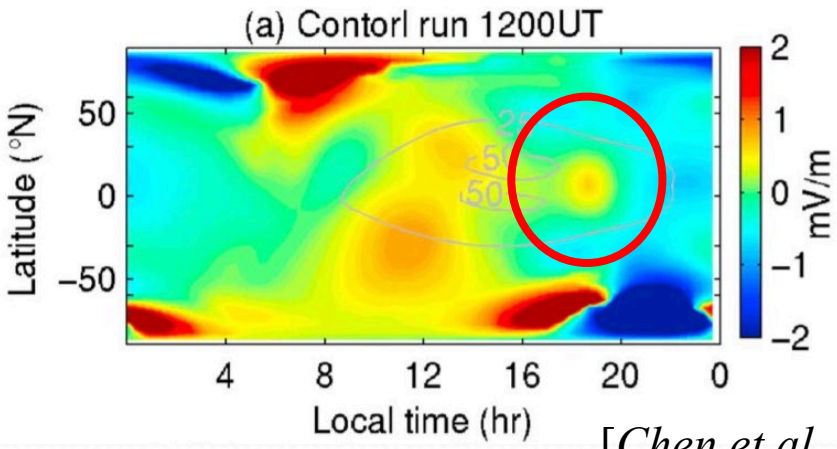
Physical Model



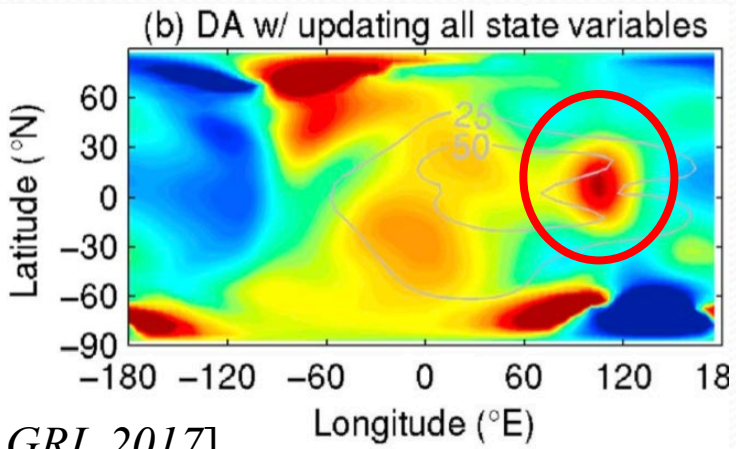
Data assimilation



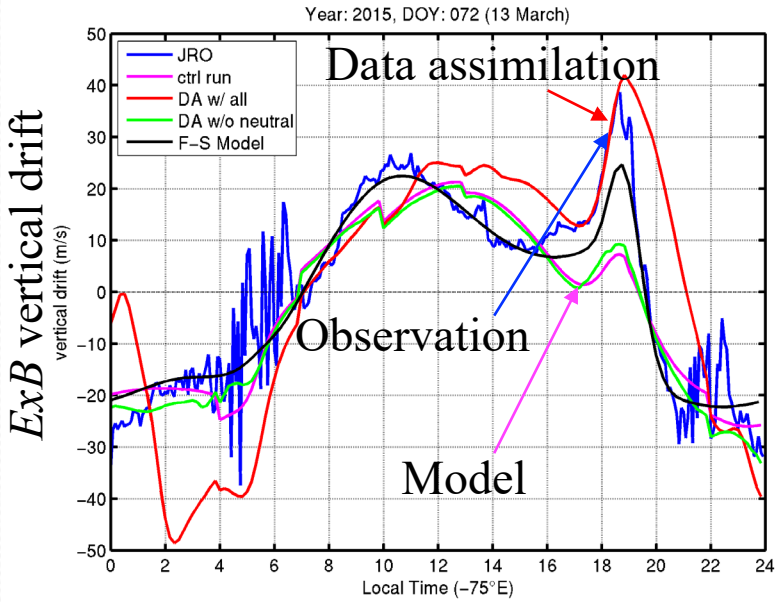
Electric field by Physical Model



Electric field by DA



[*Chen et al., GRL 2017*]



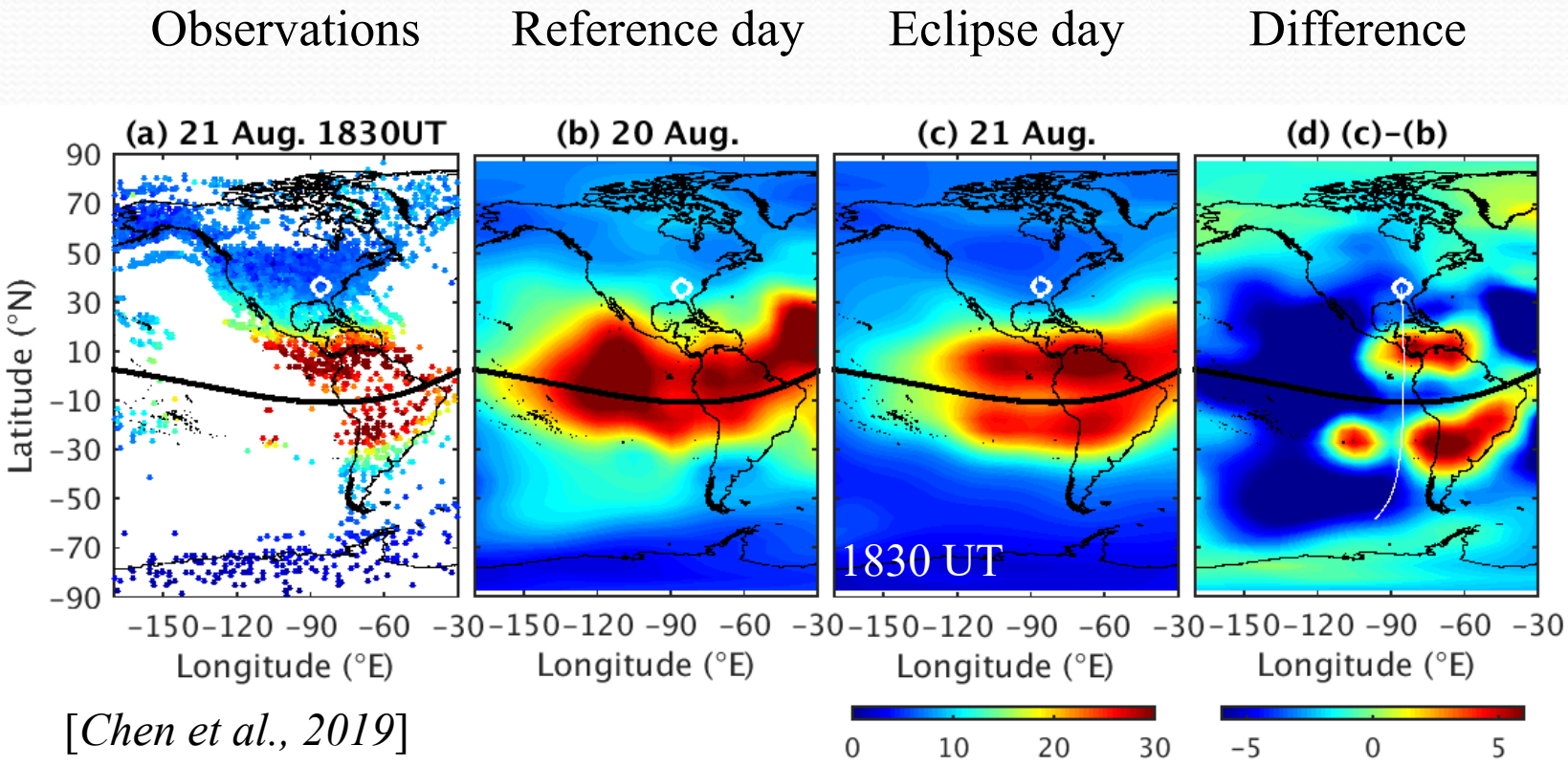
Experiment design

Assimilation of ionospheric observations → Update model neutral winds → Calculate the modeled electric field

1. 21 August 2017 (solar eclipse day) Electron density − 20 August 2017 (reference day) Electron density = Eclipse-triggered electron density change

2. Compare with the time variations of electron density and the electric field.

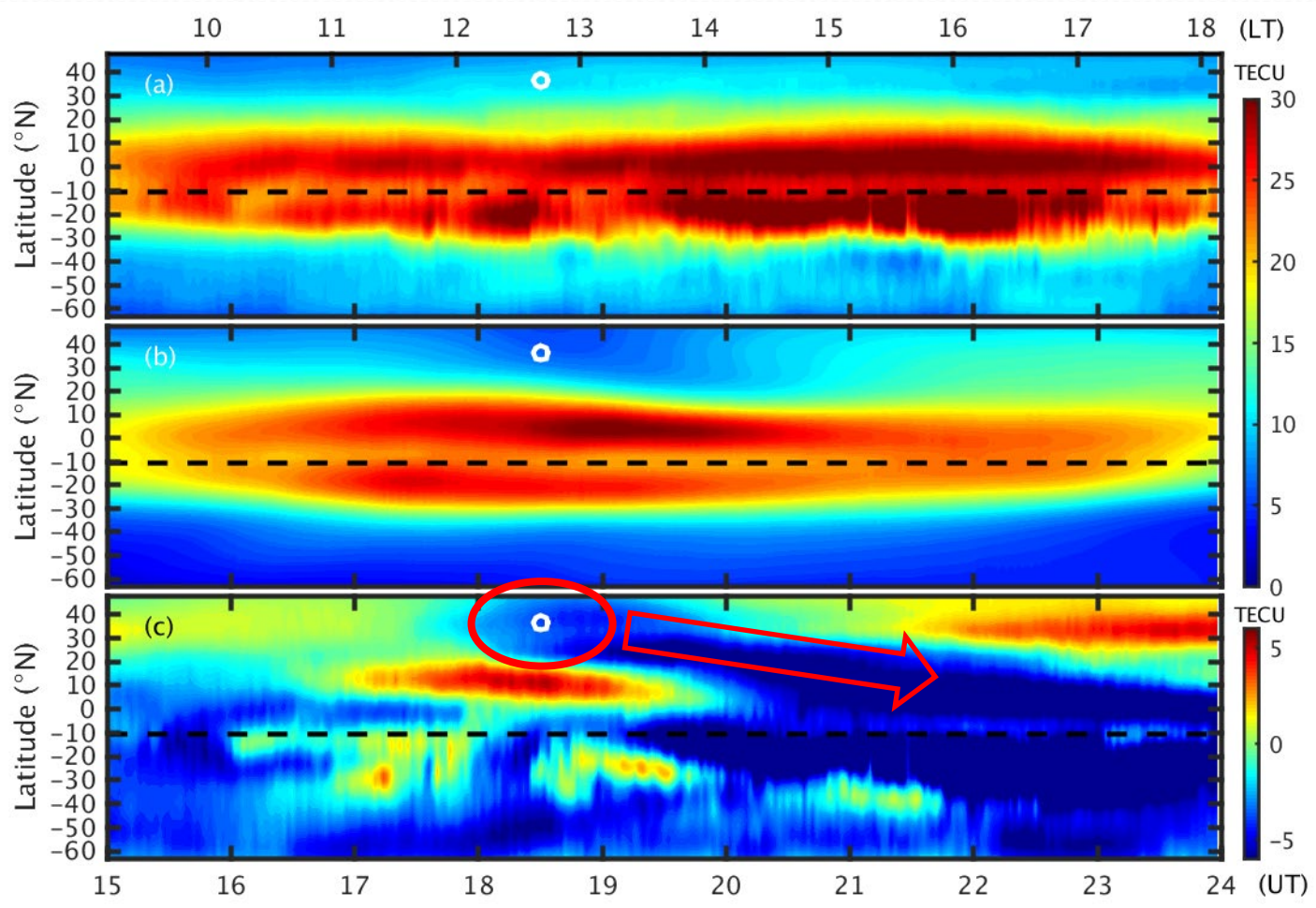
Assimilation results in latitude-longitude plane



[*Chen et al., 2019*]

- The assimilation results (c) are closer to the observations and showed two clear equatorial ionization anomaly (EIA) crests.
- The TEC differences (d) shows two clear TEC enhancements around EIA regions, but TEC reductions around the obscuration region with around -4 TECU (40%).
- Results further showed that the TEC depletions were also clearly seen at the relative conjugate hemisphere.

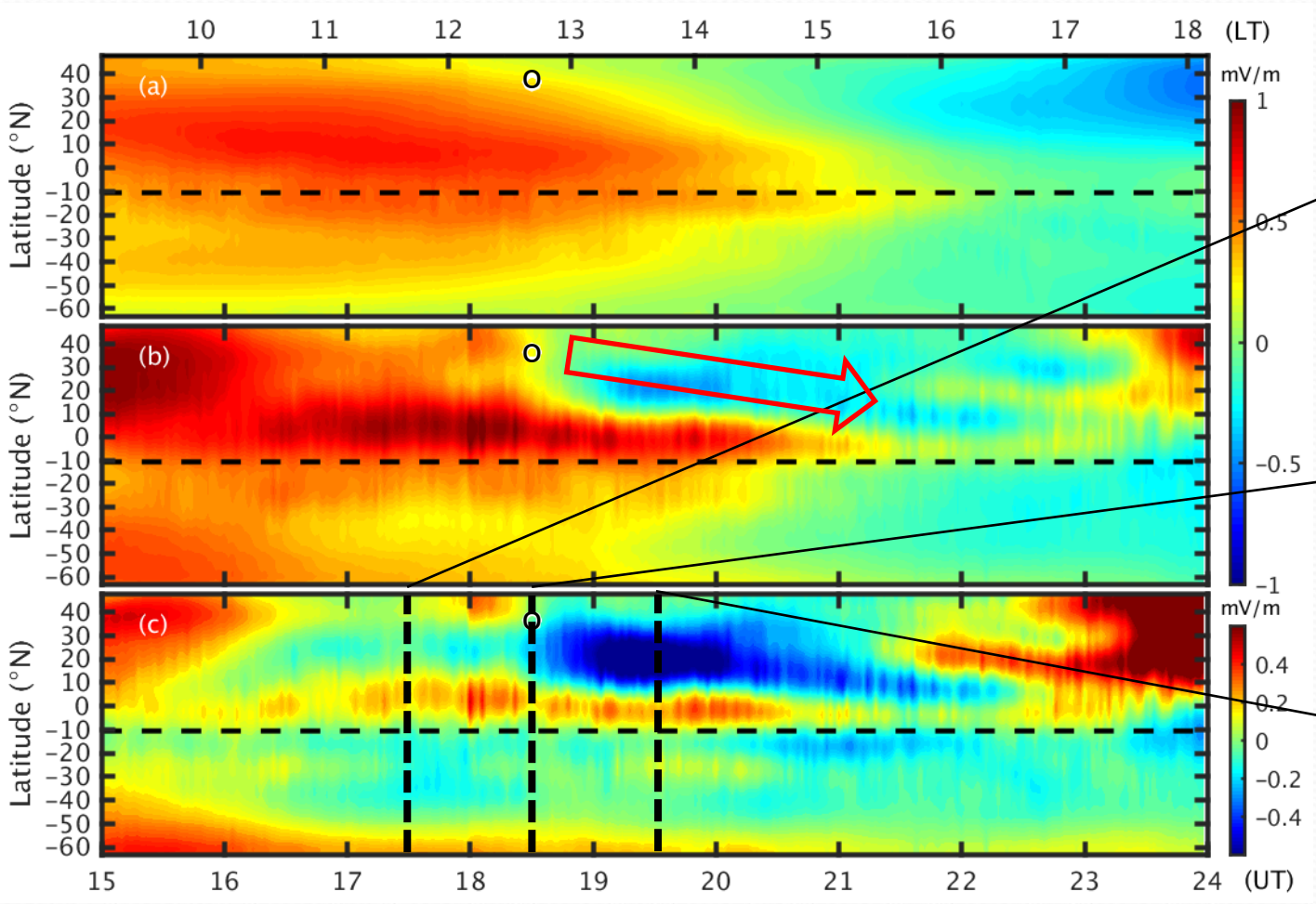
Assimilation results in latitude-time plane



[*Chen et al., 2019*]

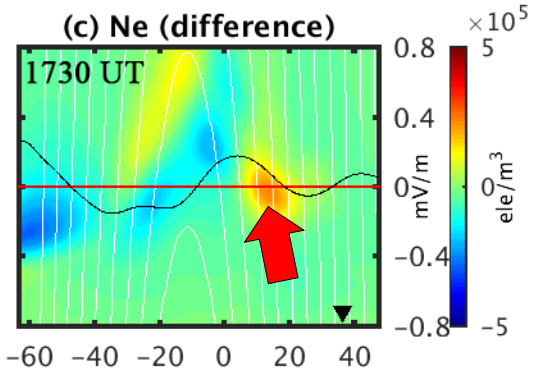
- It shows a clear TEC reduction around the occurrence time (1830 UT) and the latitude (36°N) of the solar eclipse region and then moved to the lower latitude regions and became stronger over time.
- Before the arrival of the solar eclipse, there are TEC enhancements around 1730 UT (~ 1130 LT) at the EIA regions at the northern hemispheres, which formed the EIAs earlier than the day before the eclipse.

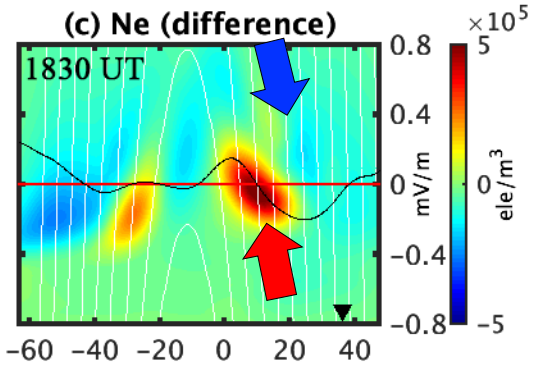
Electric field in latitude-time plane

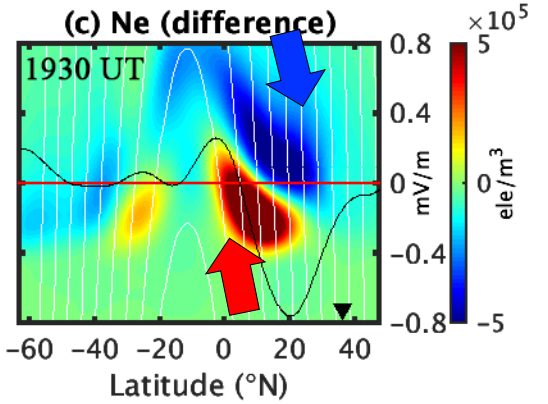


[*Chen et al., 2019*]

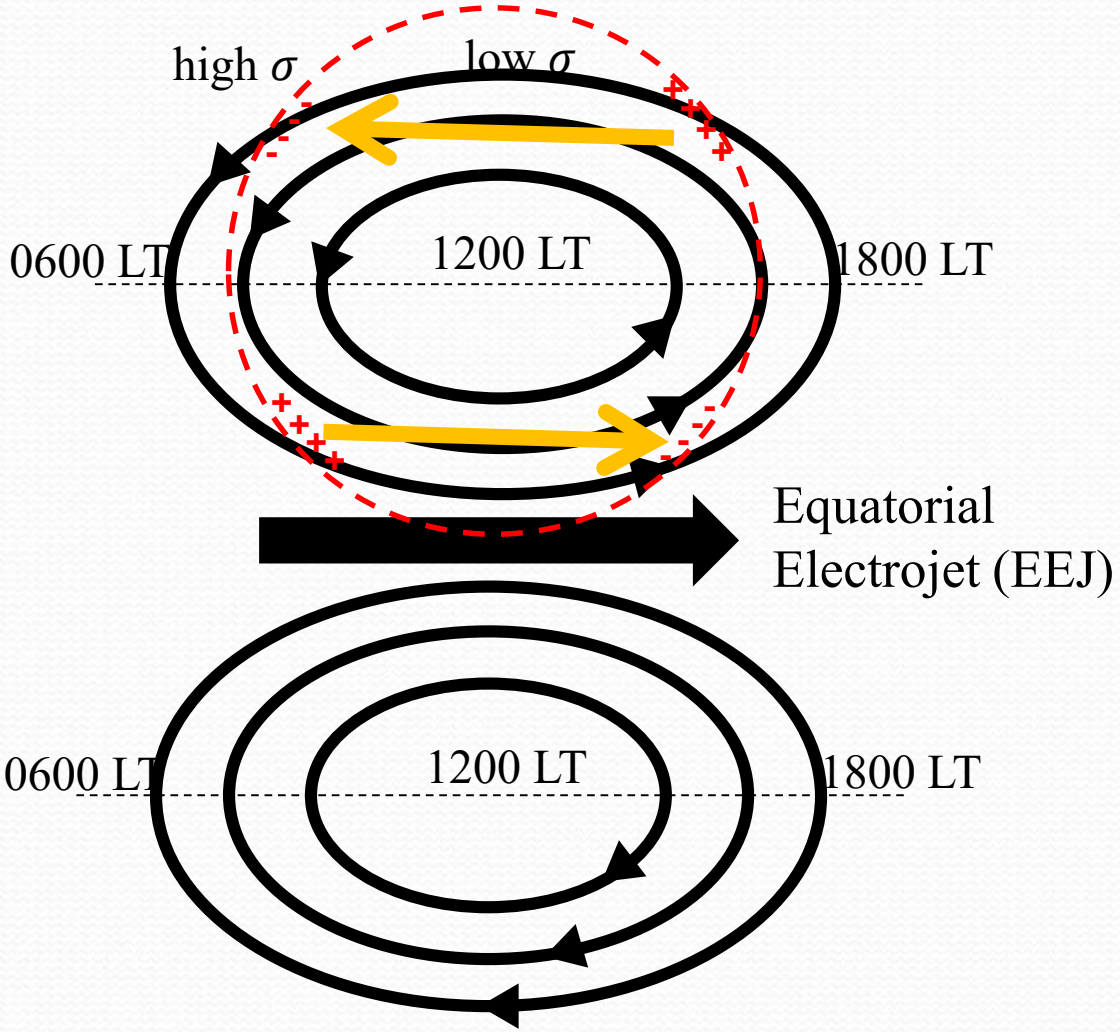
- It shows … fields appeared … 's and then rev … r the evening …
- The east … d to the westwar … maximu … ipse and then … de region o …
- The assi … ipse day further s … eastward … maximu … mid- and … ern



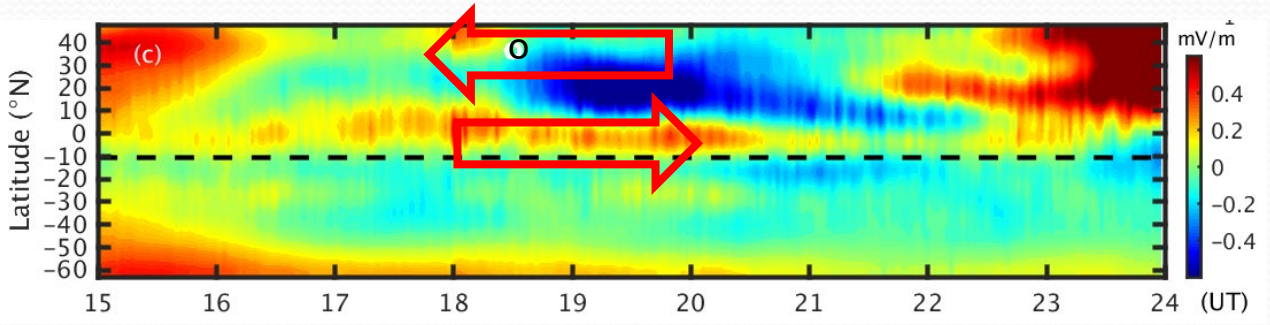




Possible mechanism



- Because the conductivity becomes lower in the obscuration range of solar eclipse, the charge particles accumulate at the boundary of high and low conductivity.
- Due to the direction of electric fields, the positive (negative) charge particles accumulate at the western (eastern) boundary, which induces the eastward electric field at lower latitudes to further enhance the original background eastward electric fields.



Summary

- Compared with the the assimilation results one day before the solar eclipse, the electron density decreased up to 4 TECU (~40% of the background TEC) around the solar eclipse region at 1830 UT.
- The latitudinal variations of electric fields further show significant enhancements and reductions at the equator-side and the polar-side of EIA crests, respectively.
- These electrodynamic processes make the TEC increase at the low-latitude region and the TEC decrease at the mid-latitude region.
- The assimilated EIA crests in both hemispheres were formed earlier comparing to the reference day, which is due to the electrodynamic processes in the wake of the eclipse.

Thank you for your attention!!