The Response of Geomagnetic Daily Variation and Ionospheric Currents to the Annular Solar Eclipse on 21 June 2020

Junjie Chen[1,2], Xiaocan Liu[3], Jiuhou Lei[1] and Tong Dang[1]

[1]University of Science and Technology of China

[2]The University of Hong Kong

[3]China Earthquake Administration

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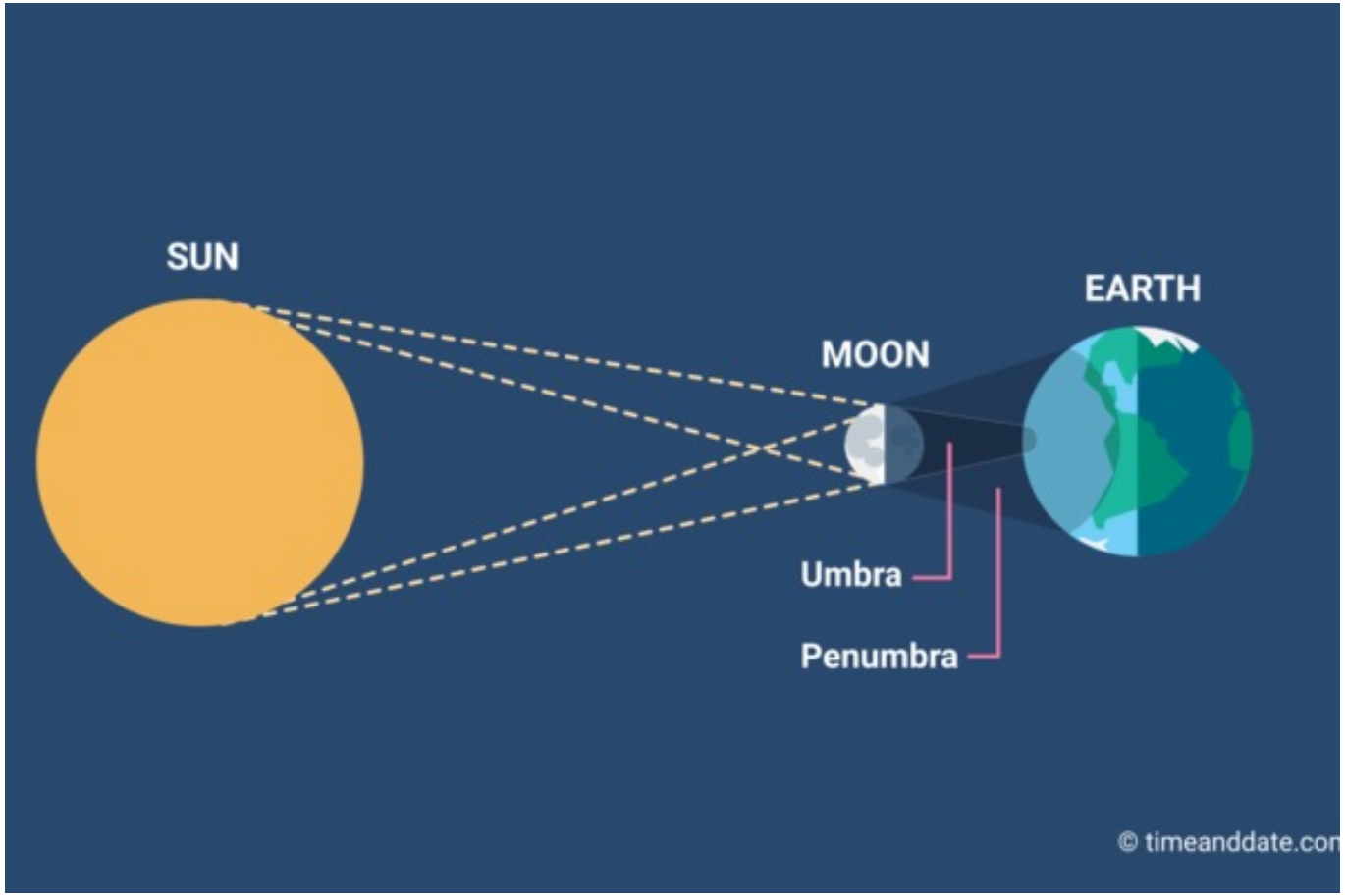
Outline

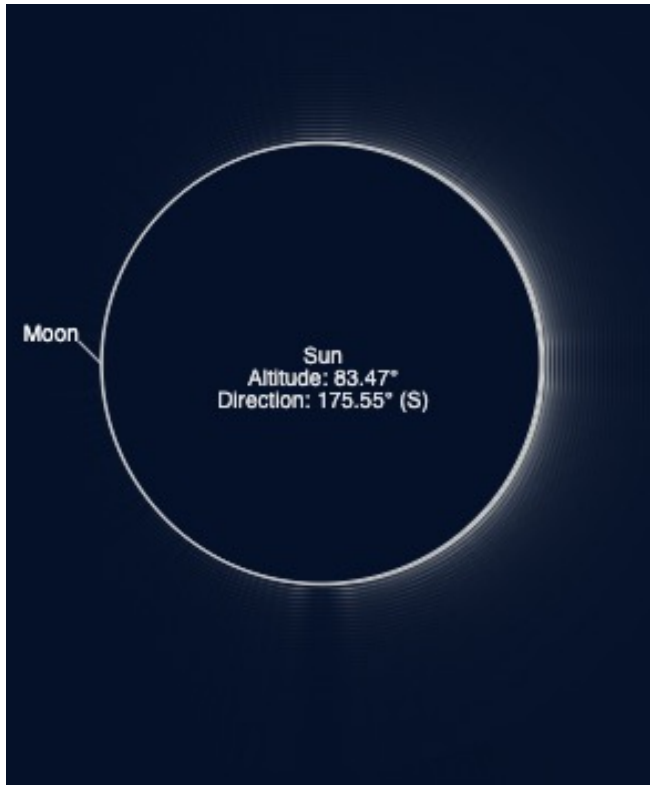
- ❑ Background: Solar Eclipse Effect
- ❑ Data and Model
- ❑ Results: Observations and Simulations
- ❑ Summary

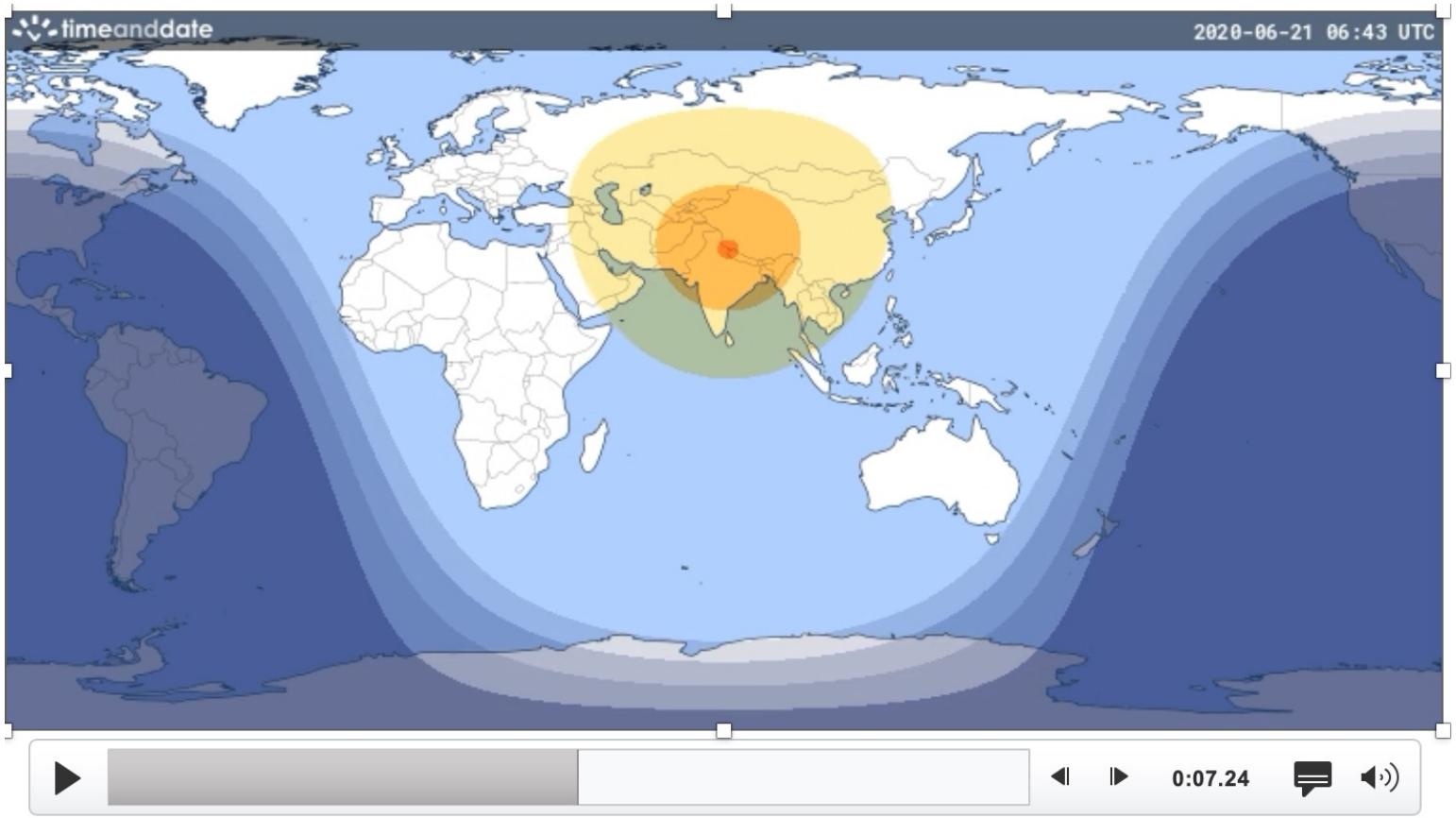
Solar Eclipse Effect



- **Solar eclipse -> EUV radiation -> Ne and conductivity -> Ionospheric current and ground geomagnetic daily variation?**
- **Previous studies used a single magnetometer station or a few ones, which hardly investigates the global responses**

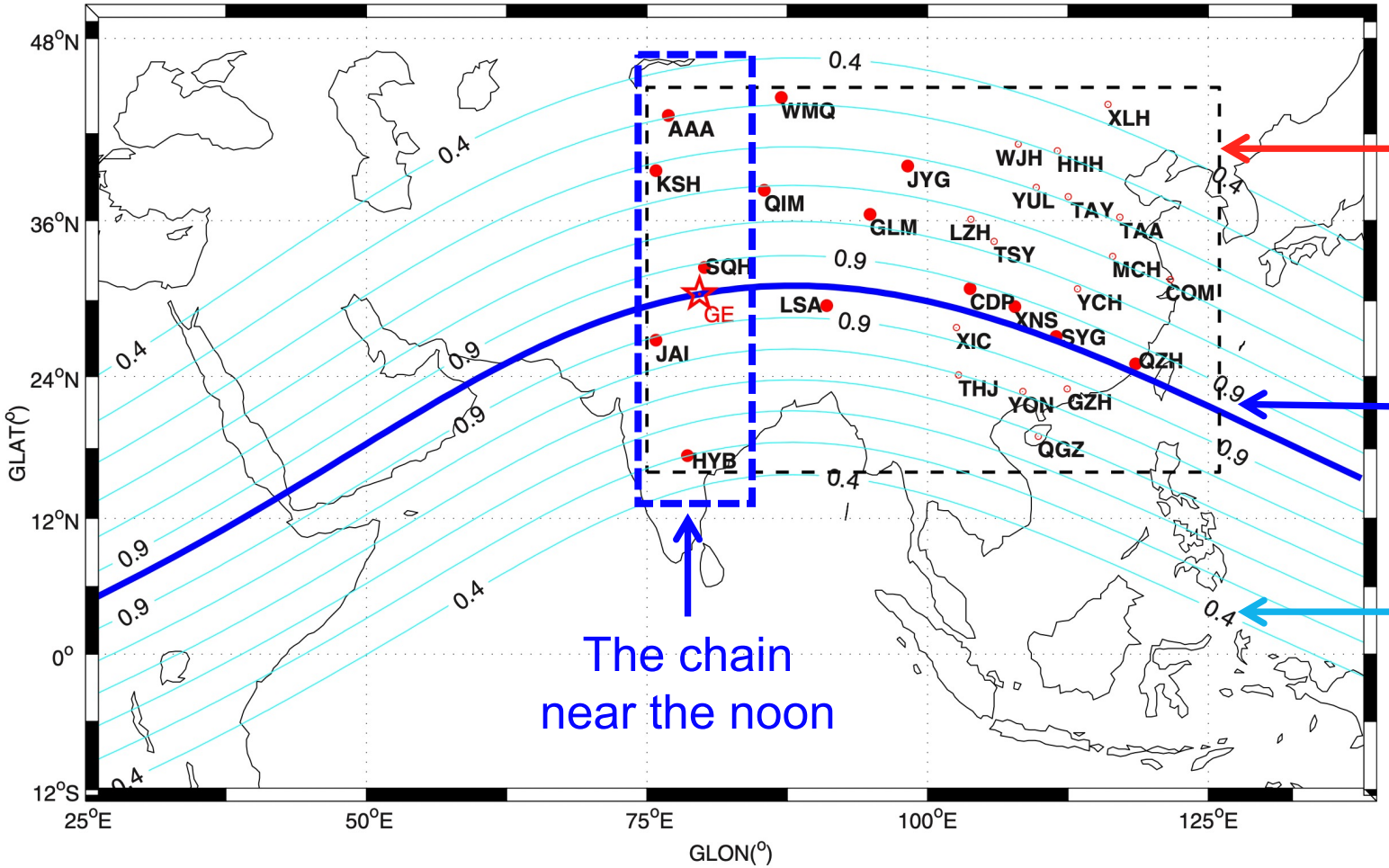
The Annular Solar Eclipse on 21 June 2020





- **On 21 June 2020, an annular solar eclipse swept through the entire South China from west to east**

Magnetometer Observatories



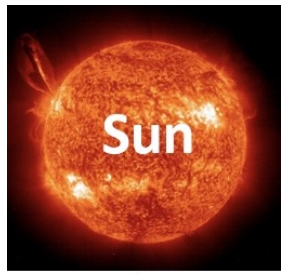
30 observatories,
6 longitudinal chains

The path of the
eclipse totality

The solar eclipse
obscuration rate

- **The dense magnetometer network provides an opportunity to address the LT and latitudinal dependence of geomagnetic responses during solar eclipses**

Model



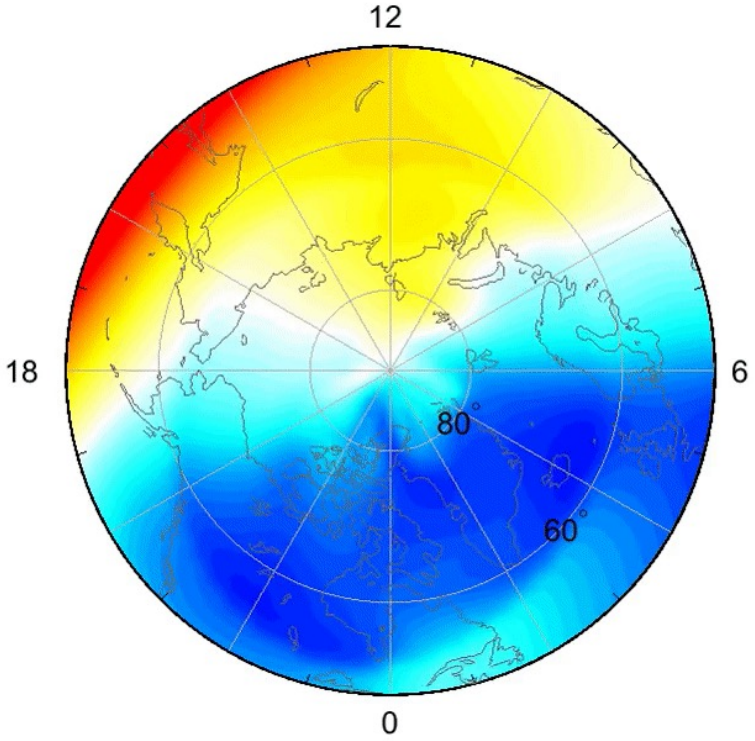
EUV Radiation

Eclipse Factor Function

[Dang et al., 2021]

Empirical Tide Model

TIEGCM:
Physical Model of the Coupled I-T System



Empirical Polar Model

Potentials

Particles

Current

Post-Processing Codes

[Yamazaki & Maute, 2017]

Ionospheric Equivalent Sq Current/
Ground Geomagnetic Daily Variation

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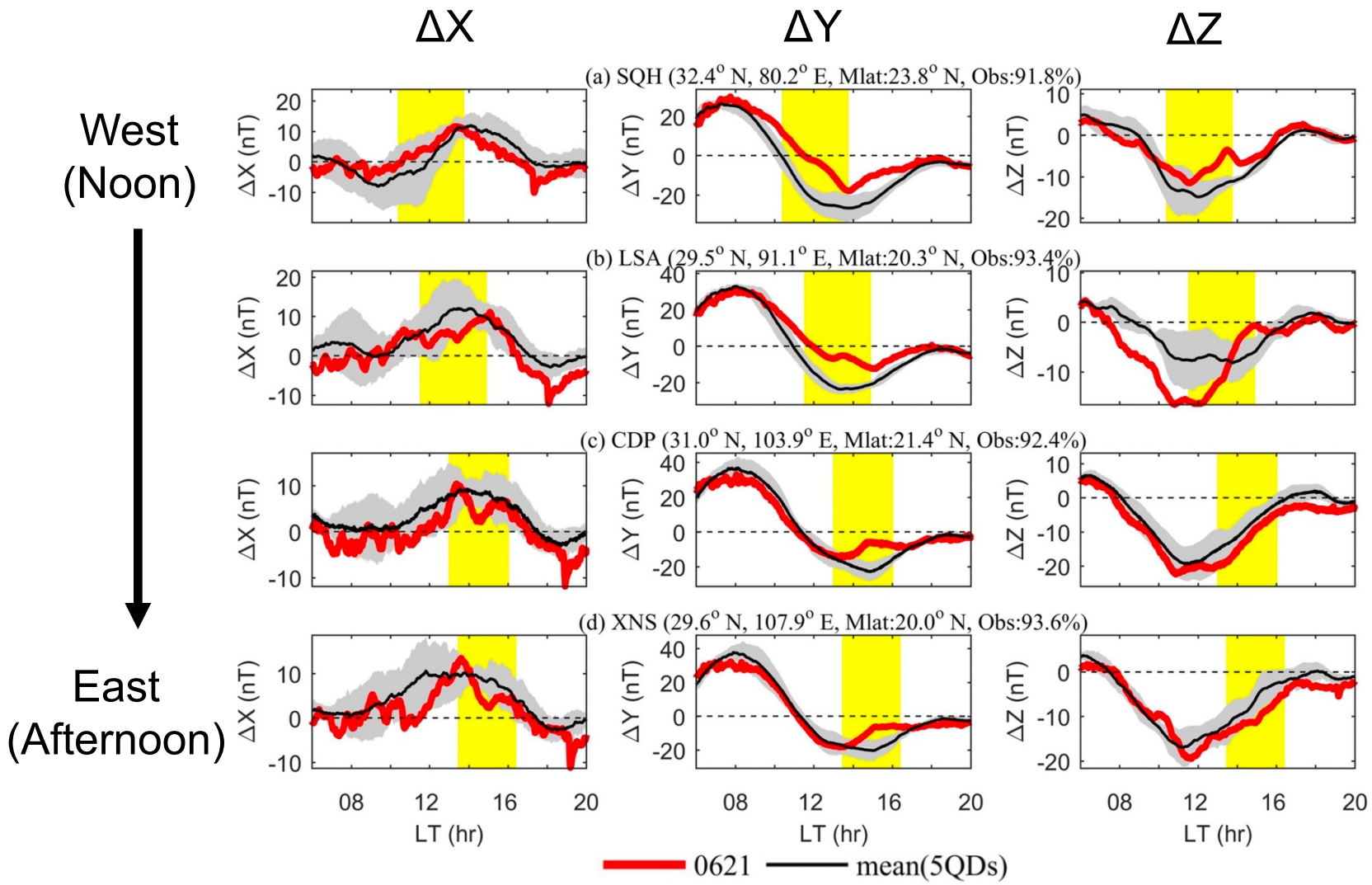
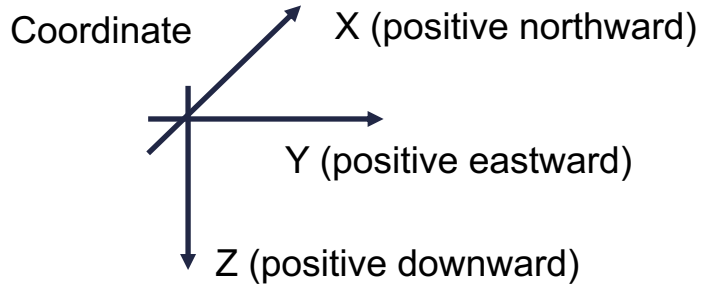
Observatories Along the Totality Path (Low Latitude)



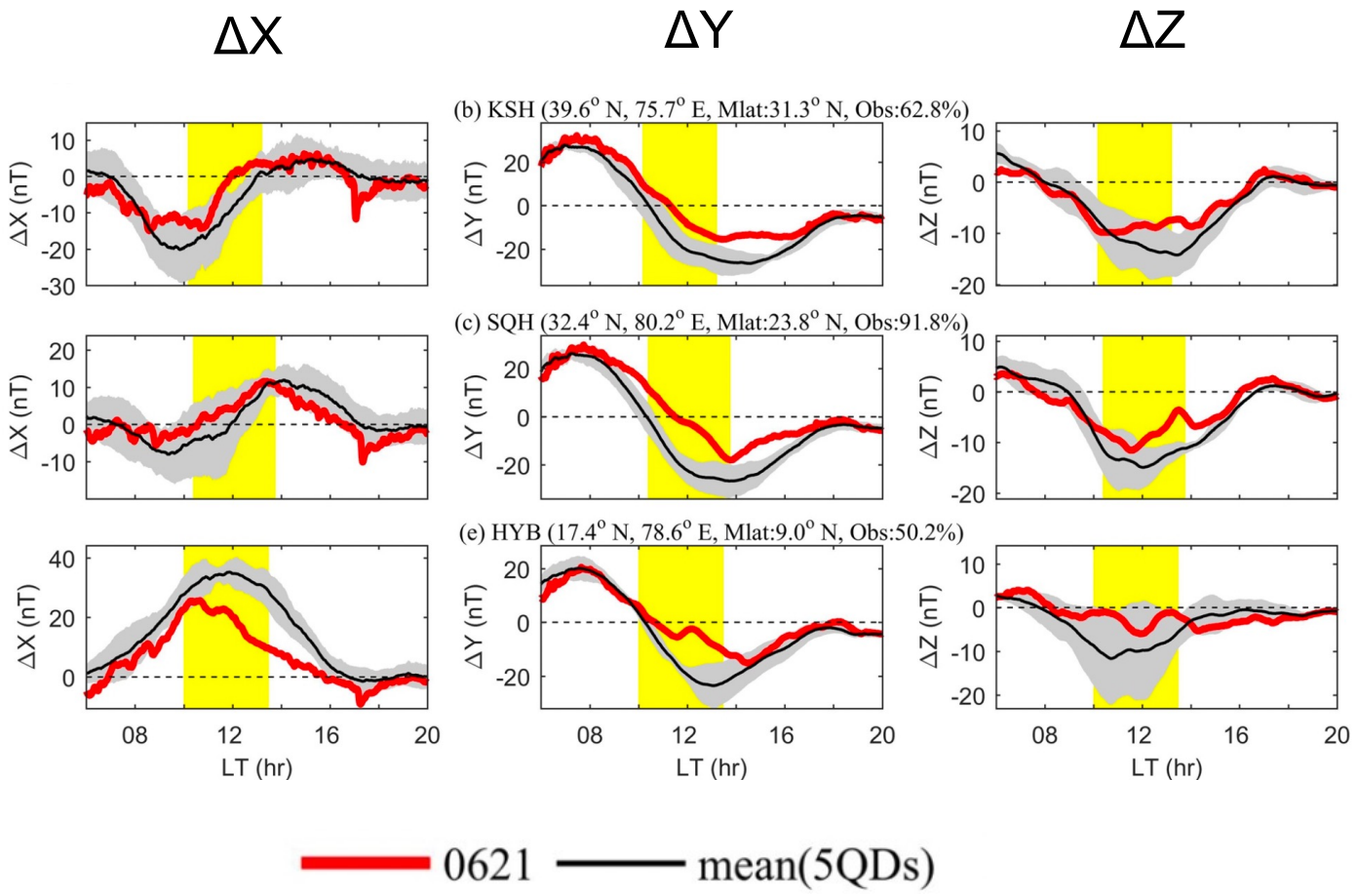


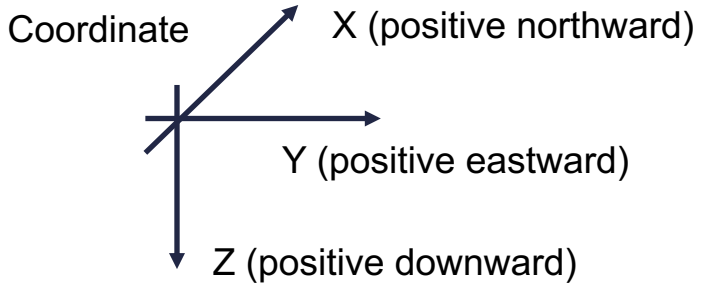
- local time dependence
- decreases ΔX and ΔY at most stations
- affect ΔZ around the early afternoon

Observatories on the Chain Around the Noon

Mid Latitude

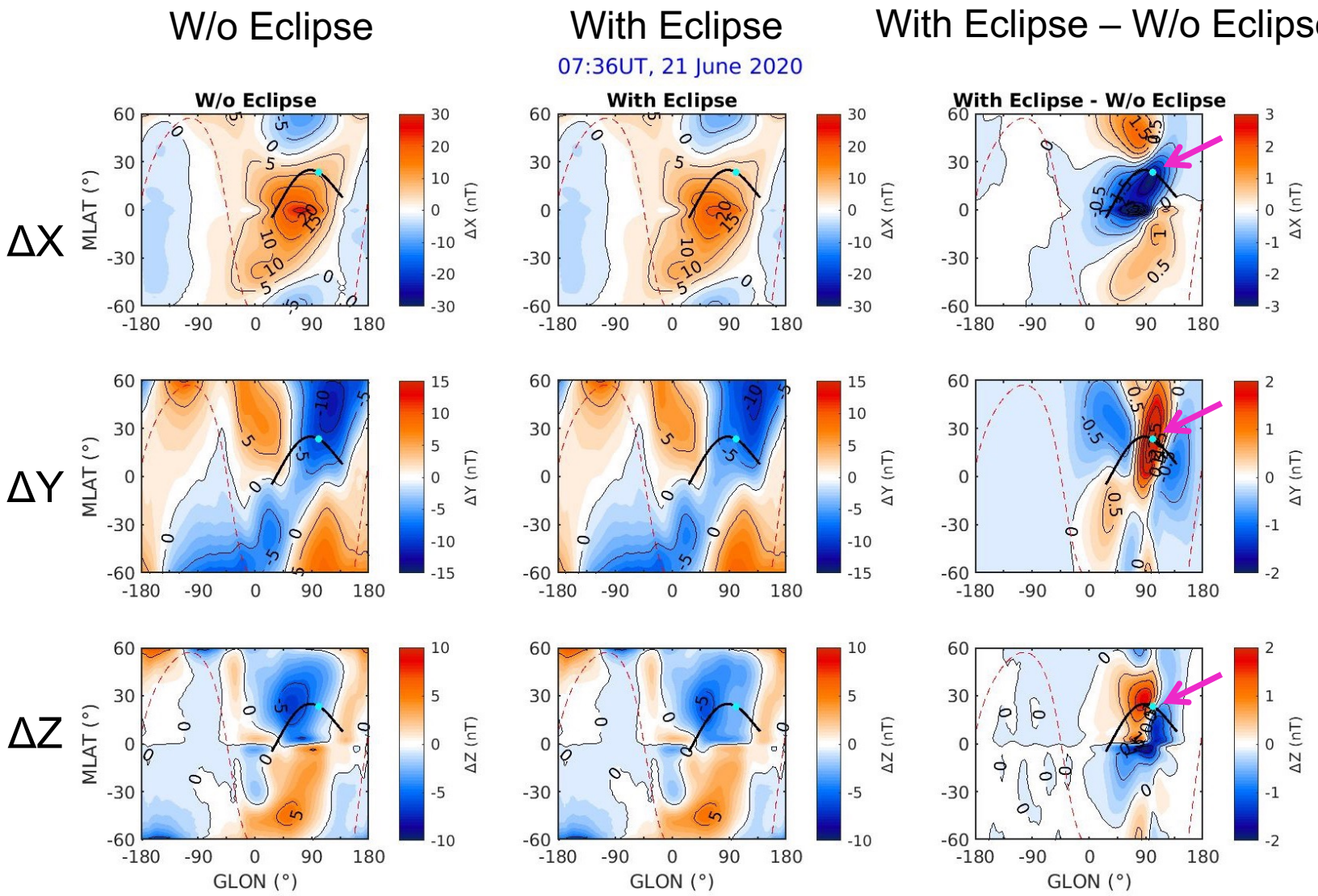
Low Latitude





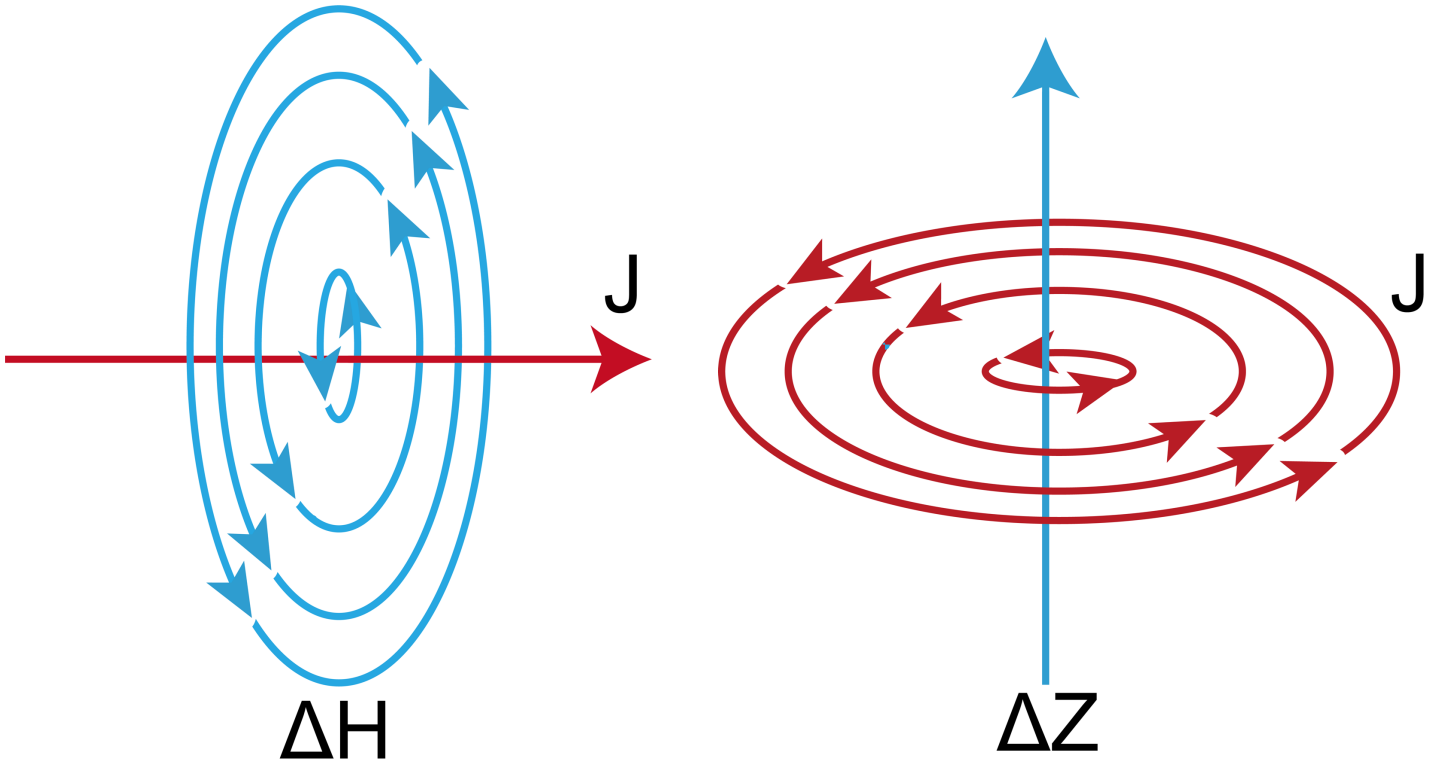
- latitudinal dependence
- decreases ΔX, ΔY, and ΔZ around early afternoon

Simulated Geomagnetic Daily Variation



- There is a global response
- The ΔX and ΔY decrease is the strongest near the eclipse totality
- The ΔZ response is the largest aside the eclipse totality
- Consistent with the observations

Ampère's Circuital Law



Northward ΔX ← Eastward Current

Eastward ΔY ← Southward Current

Upward ΔZ ← Counterclockwise Current

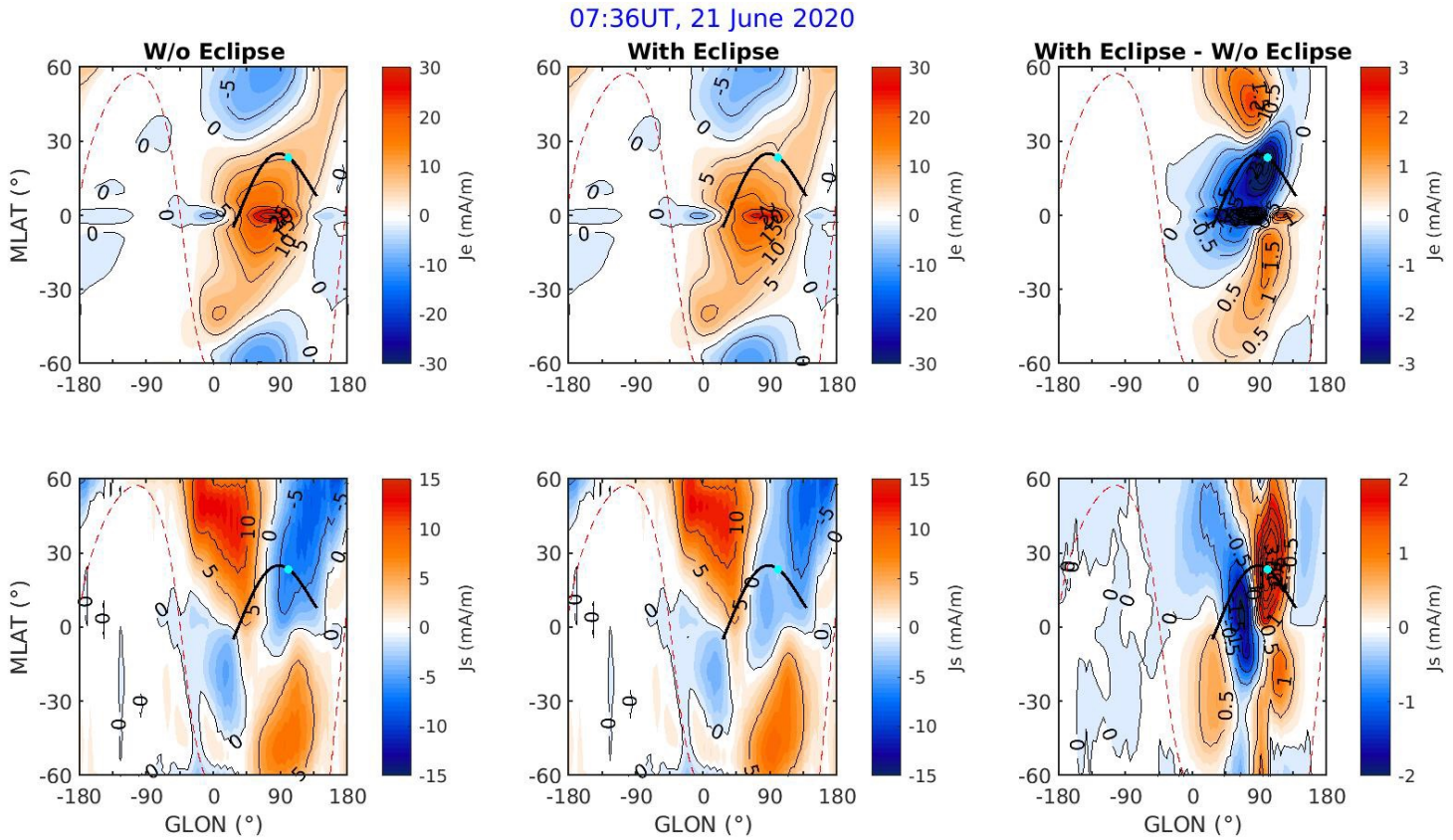
➢**The ground geomagnetic daily variation is induced by ionospheric currents**

Global Ionospheric Current

W/o Eclipse | With Eclipse | With Eclipse – W/o Eclipse

Zonal Current
(Positive Eastward)

Meridional Current
(Positive Southward)



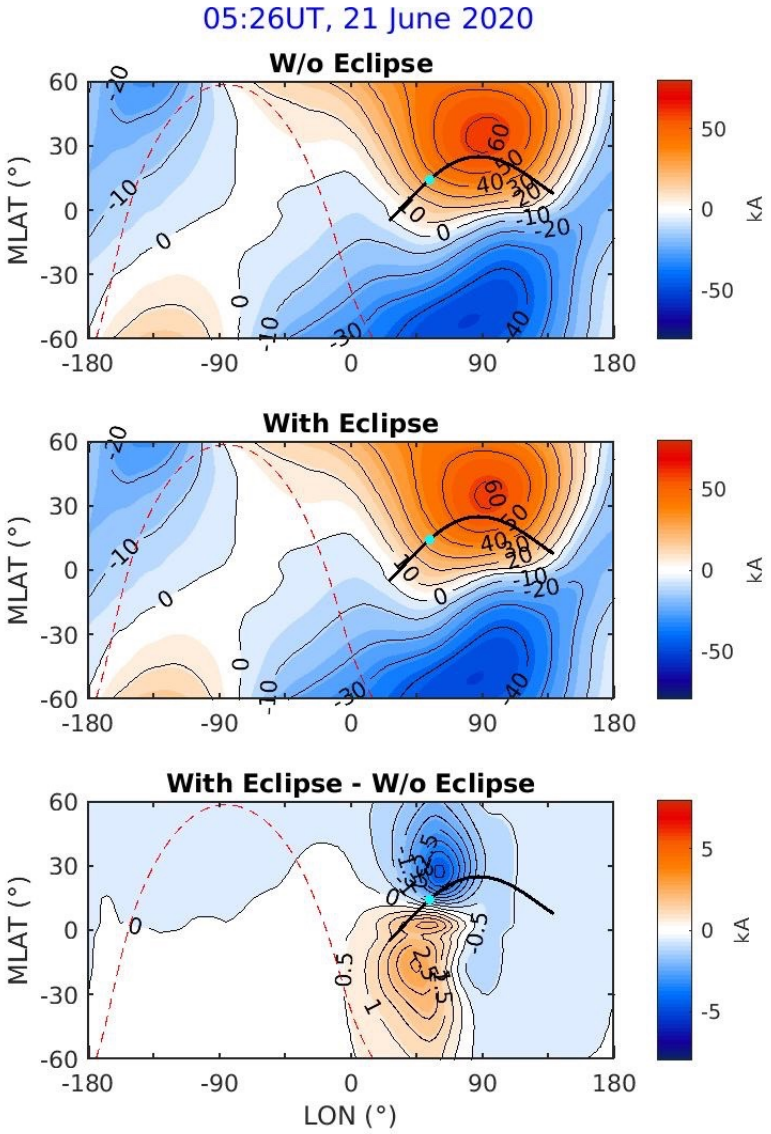
- Ionospheric currents are corresponding to ground ΔX and ΔY
- The eclipse decreases the global ionospheric currents

Ionospheric Equivalent Sq Current

W/o Eclipse

With Eclipse

With Eclipse – W/o Eclipse



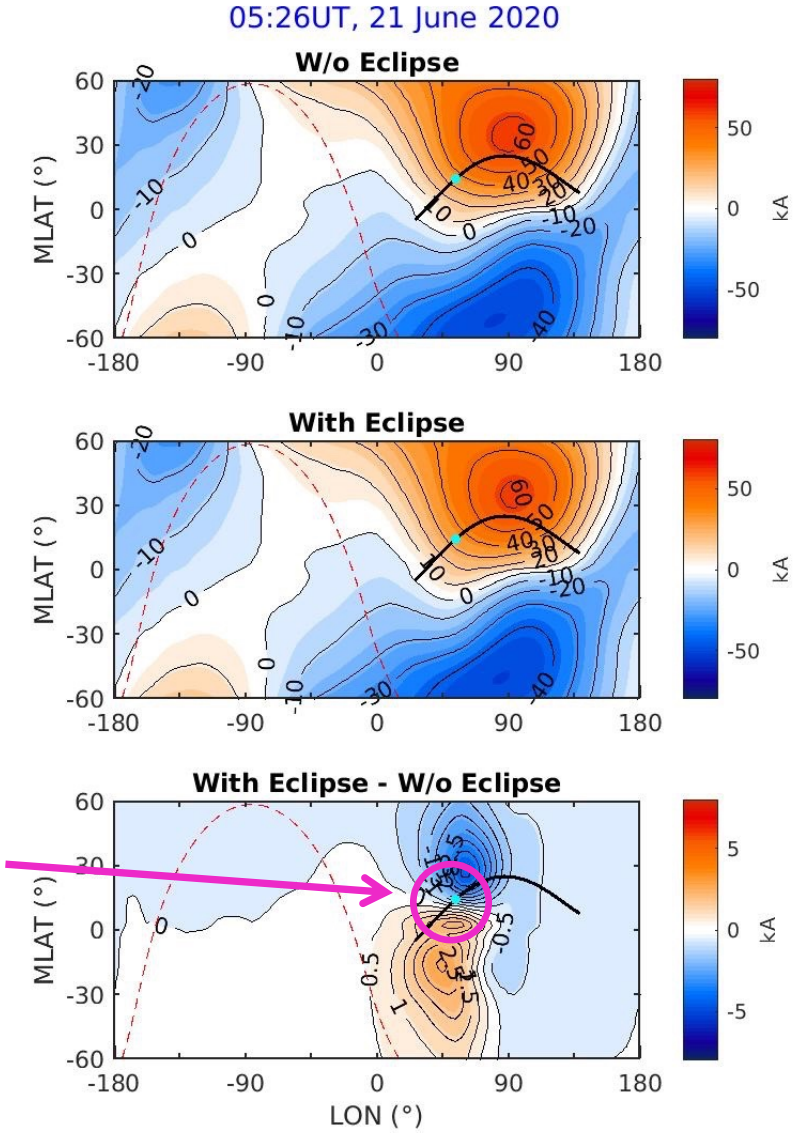
Equivalent Current Function
(Positive Counterclockwise)

$$\nabla \times F_{EC} = J_{iono}$$

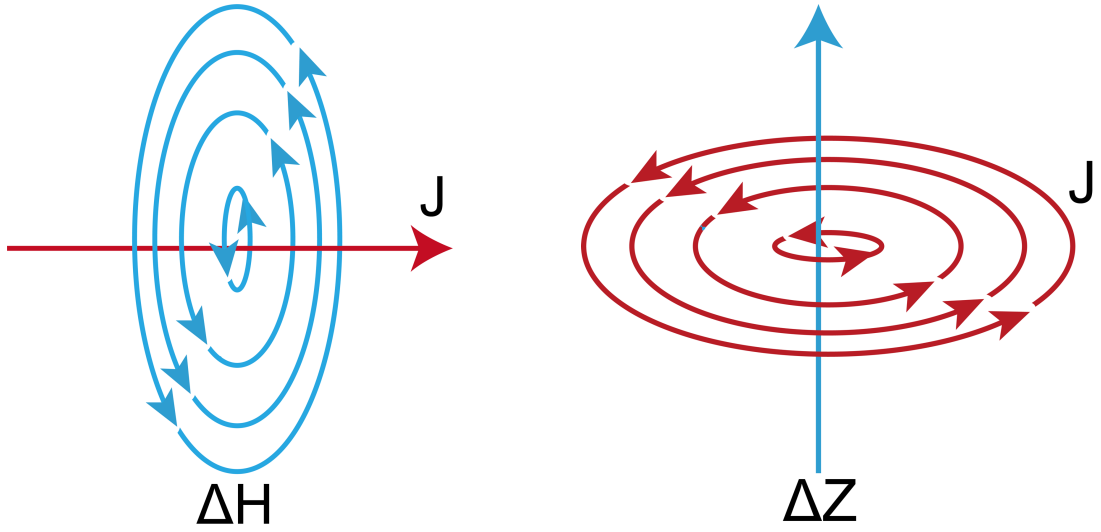
$$\nabla \cdot J_{iono} = 0$$

- The ionospheric current system caused by the solar eclipse has a counter-Sq pattern

Physical Mechanism



Conductivity Reduction



Solar eclipse
-> reduce local conductivity and current
-> electric fields and currents in non-eclipse region to satisfy the current continuity
-> ionospheric counter-Sq current
-> ground geomagnetic daily variation

Summary

Extensive geomagnetic data and a global physical model shows that:

- The response of geomagnetic daily variation and ionospheric currents to the solar eclipse shows local time and latitudinal dependence.
- The eclipse mainly reduces ΔX and ΔY near the eclipse totality and ΔZ around the early afternoon aside the totality.
- There is also a response of ionospheric currents in the non-eclipse shaded regions in both northern and southern hemispheres.

Overall, the ionospheric current system caused by the solar eclipse has a counter-Sq pattern.

Liu, X., Chen, J., Han, P., Lei, J., Dang, T., Huang, F., et al. (2022). The response of geomagnetic daily variation and ionospheric currents to the annular solar eclipse on 21 June 2020. *Journal of Geophysical Research: Space Physics*, 127, e2022JA030494. https://doi.org/10.1029/2022JA030494

Thanks!