The importance of lower thermospheric winds for studies of the low-latitude ionosphere

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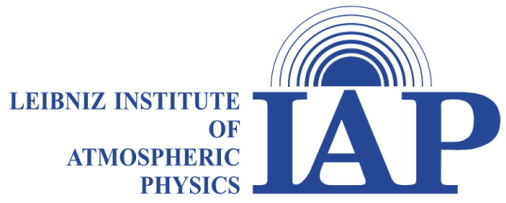
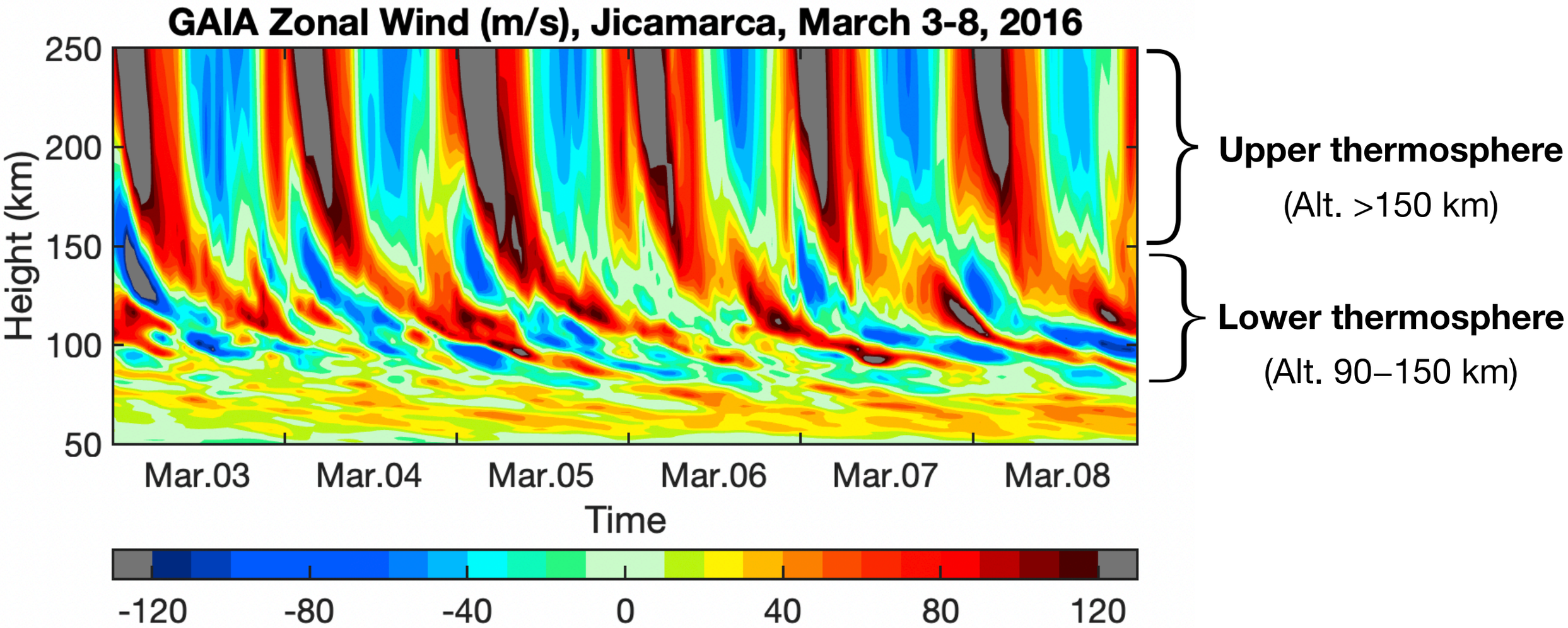


Jicamarca 60th Anniversary Workshop, Lima, Peru, 25 Jul 2022

Neutral Winds in the Lower Thermosphere



Upper thermosphere

→ In-situ generated 24h tide

→ Height-invariant phase

Lower thermosphere

→ Tides and other upward-propagating waves

→ Vertical wind shear

→ Considerable day-to-day variability

→ Wind velocity often exceeding 100 m/s

Why to Care about Lower Thermospheric WInds?

- Electrodynamics (Wind dynamo)
  - → Electric fields & currents (Sq, EEJ)
  - → E×B plasma drift
  - → Equatorial Ionization anomaly
  - → Equatorial plasma bubble
- Wind shear
  - → Metallic ion layers (sporadic E)

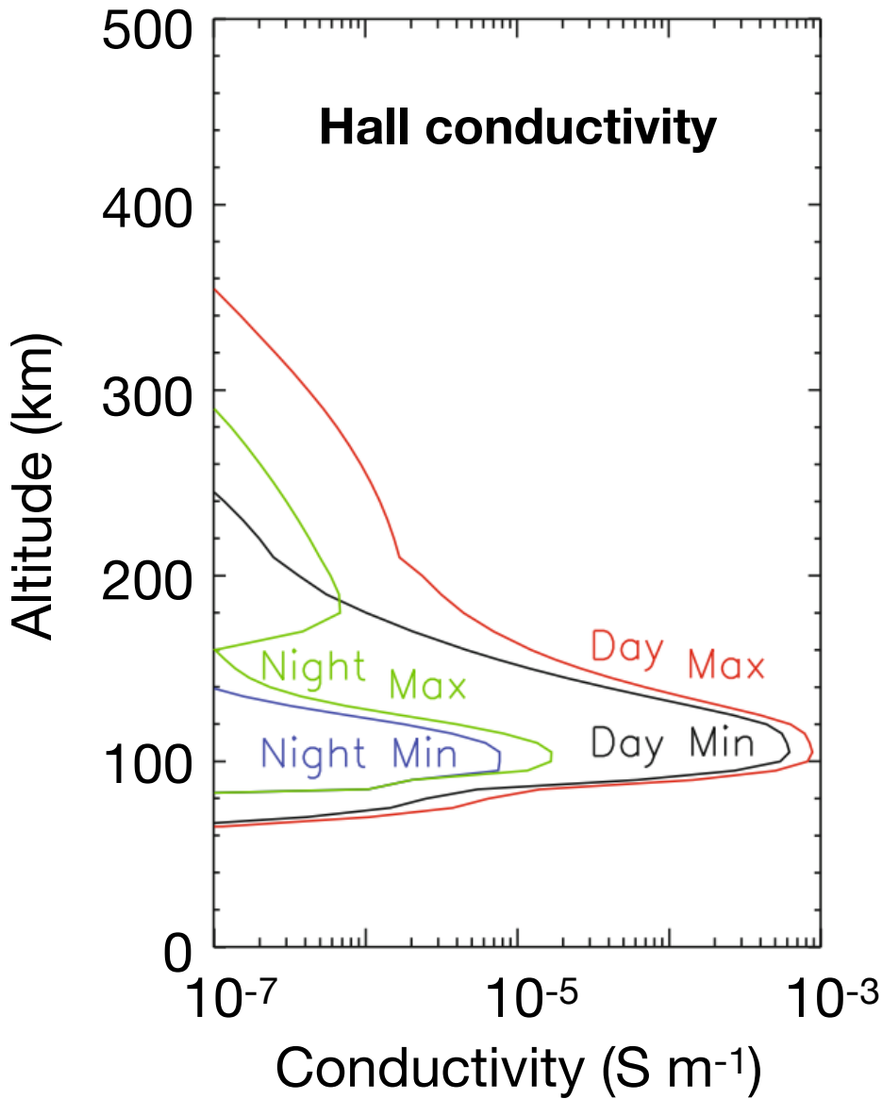
Sq = solar quiet
EEJ = equatorial electrojet

Difficult to observe

→ Limited number of rocket soundings

→ Too high for ground-based radars

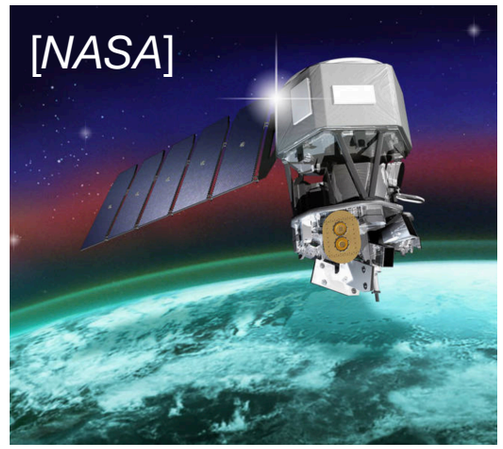
→ Too low for in-situ satellite observations

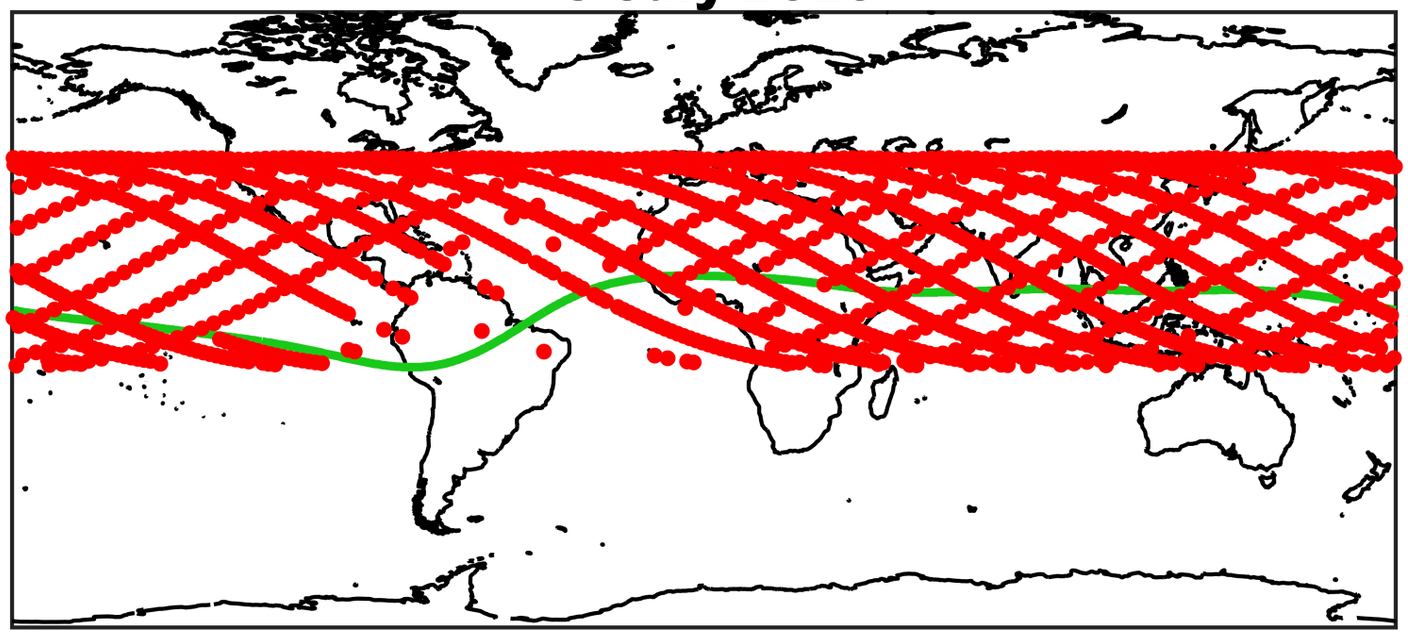


[*Richmond*, 2011]

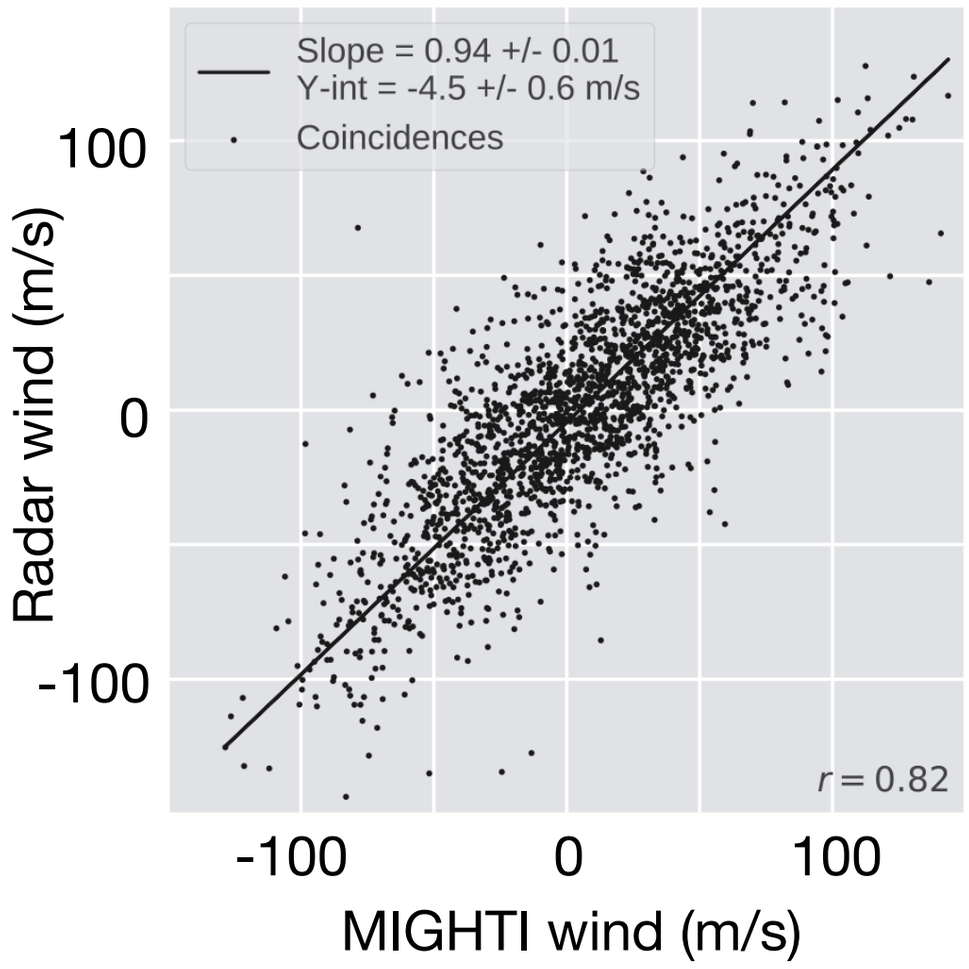
Neutral Winds from ICON/MIGHTI

- NASA Ionospheric Connection Explore (ICON)
  - → Launched in October 2019
  - → 27°-inc. orbit at 575 km
- MIGHTI instrument
  - → Neutral wind velocity profiles
  - → Doppler shifts in *O* airglow emissions
  - → Green line (557.7 nm)
  - → Alt.: 90–180 km, Lat.: 12°S–42°N





Validation of MIGHTI winds

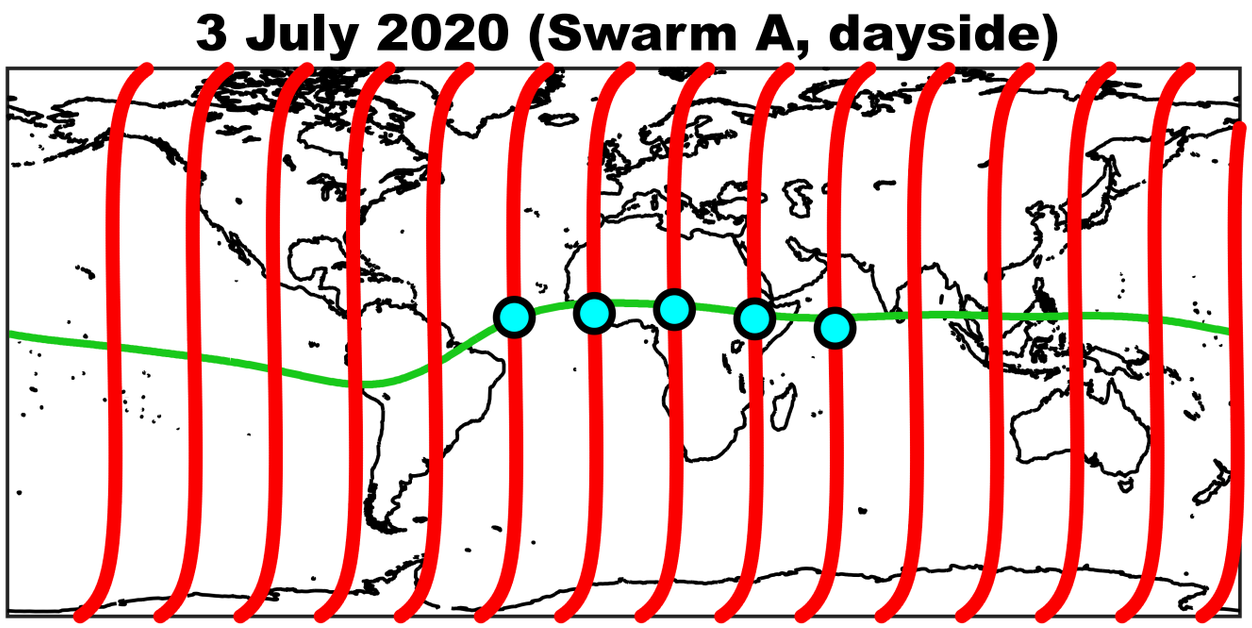


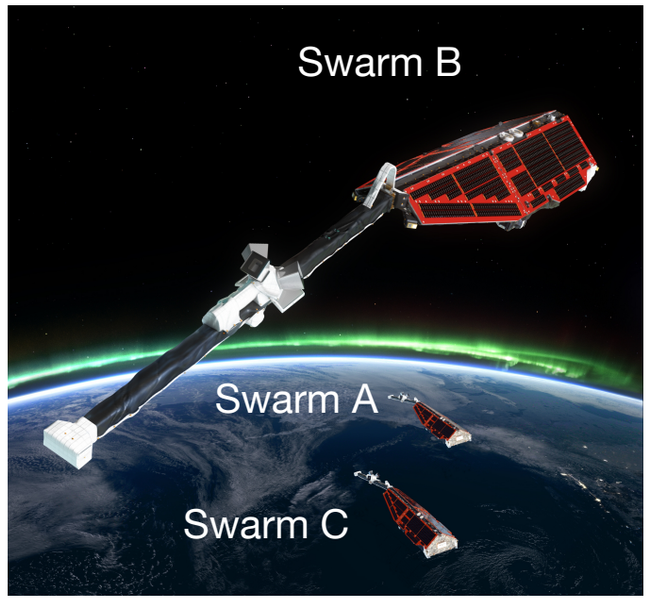
[*Harding et al.*, 2020]

Topics for This Presentation

1. Neutral wind effects on the EEJ

EEJ = equatorial electrojet





Swarm magnetic data

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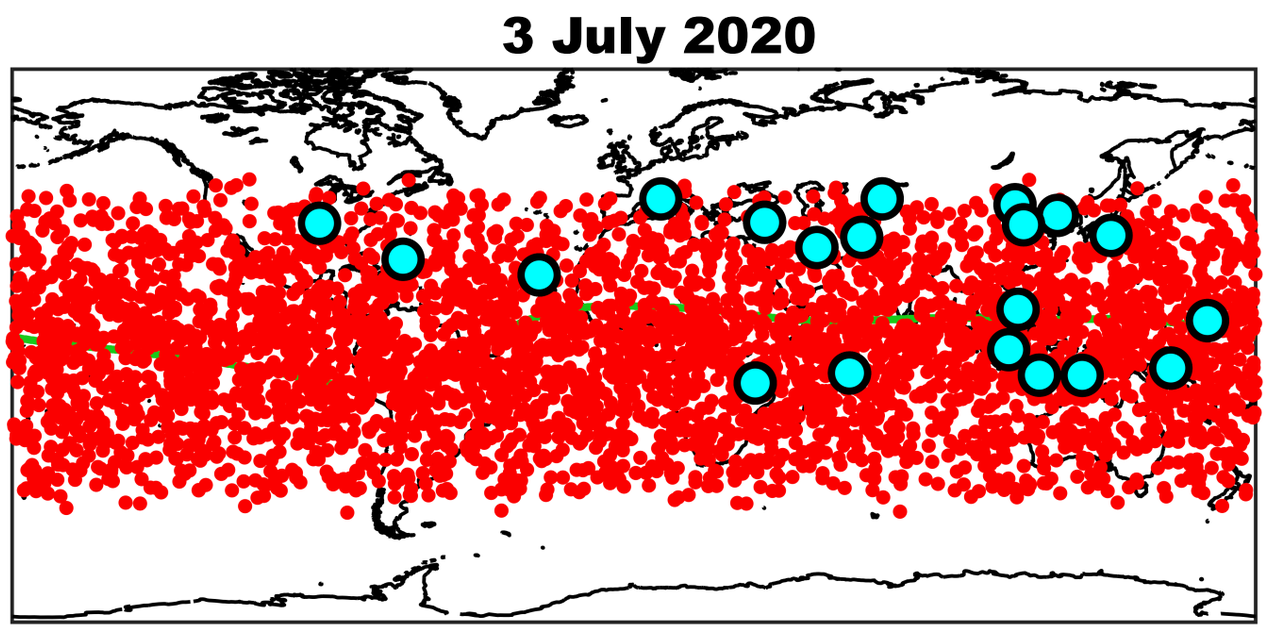
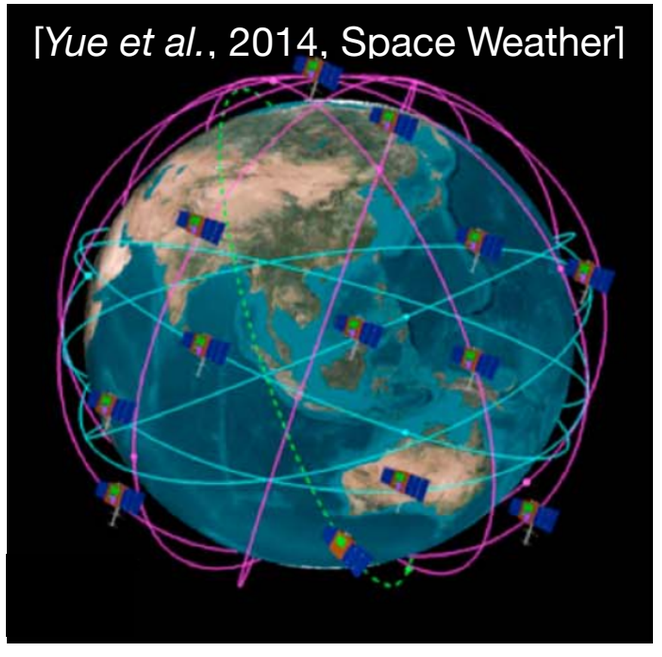
EEJ intensity [*Alken.*, 2020]

2. Neutral wind effects on sporadic E





COSMIC-2 radio occultation

↓

Sporadic E [*Arras & Wickert,* 2018]

Neutral-wind effects on the EEJ

EEJ = equatorial electrojet

Neutral Winds vs EEJ in Model

EEJ = equatorial electrojet

Early modeling work

[e.g., *Richmond*, 1973; *Raghavarao & Anadarao*, 1987]

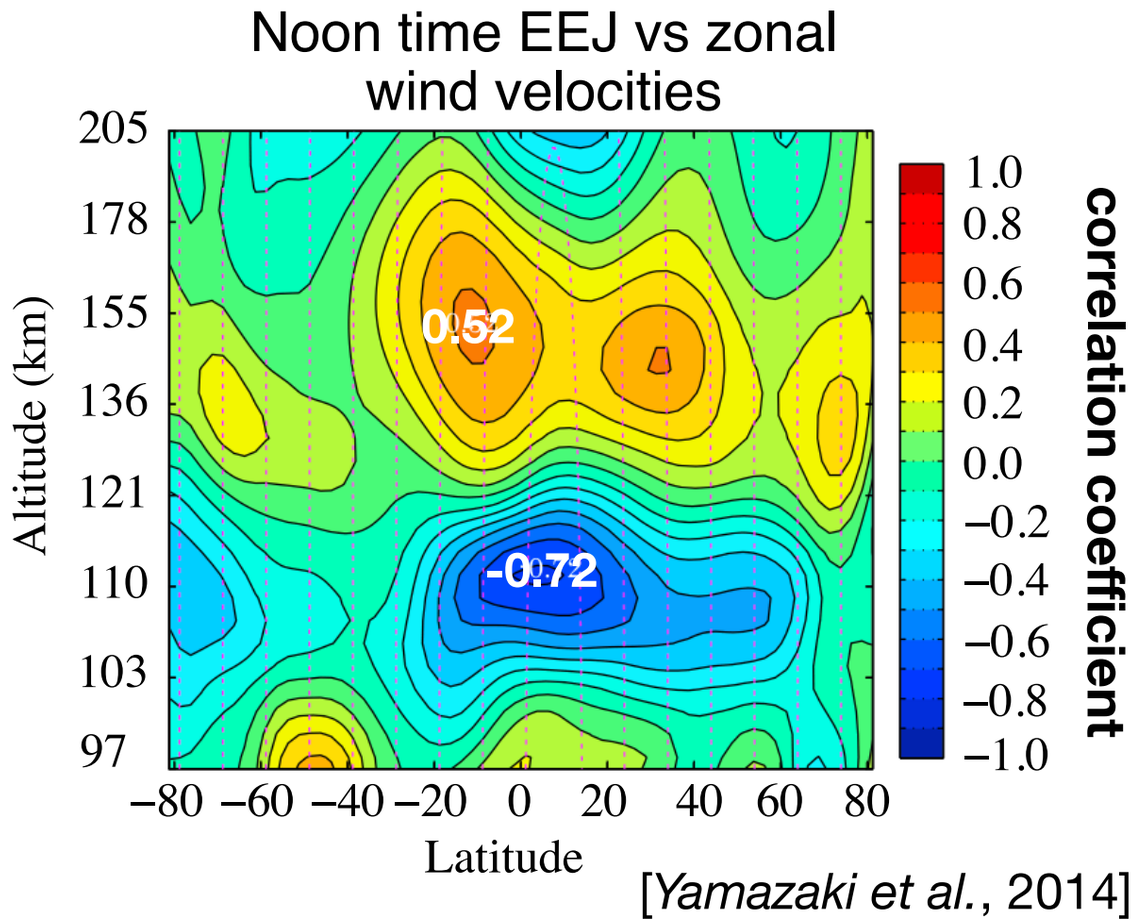
→ Compute EEJ for a specified $\mathbf{E}$ field

→ Local winds have little effect on the EEJ

Re-visit by TIME-GCM [*Yamazaki et al.*, 2014]

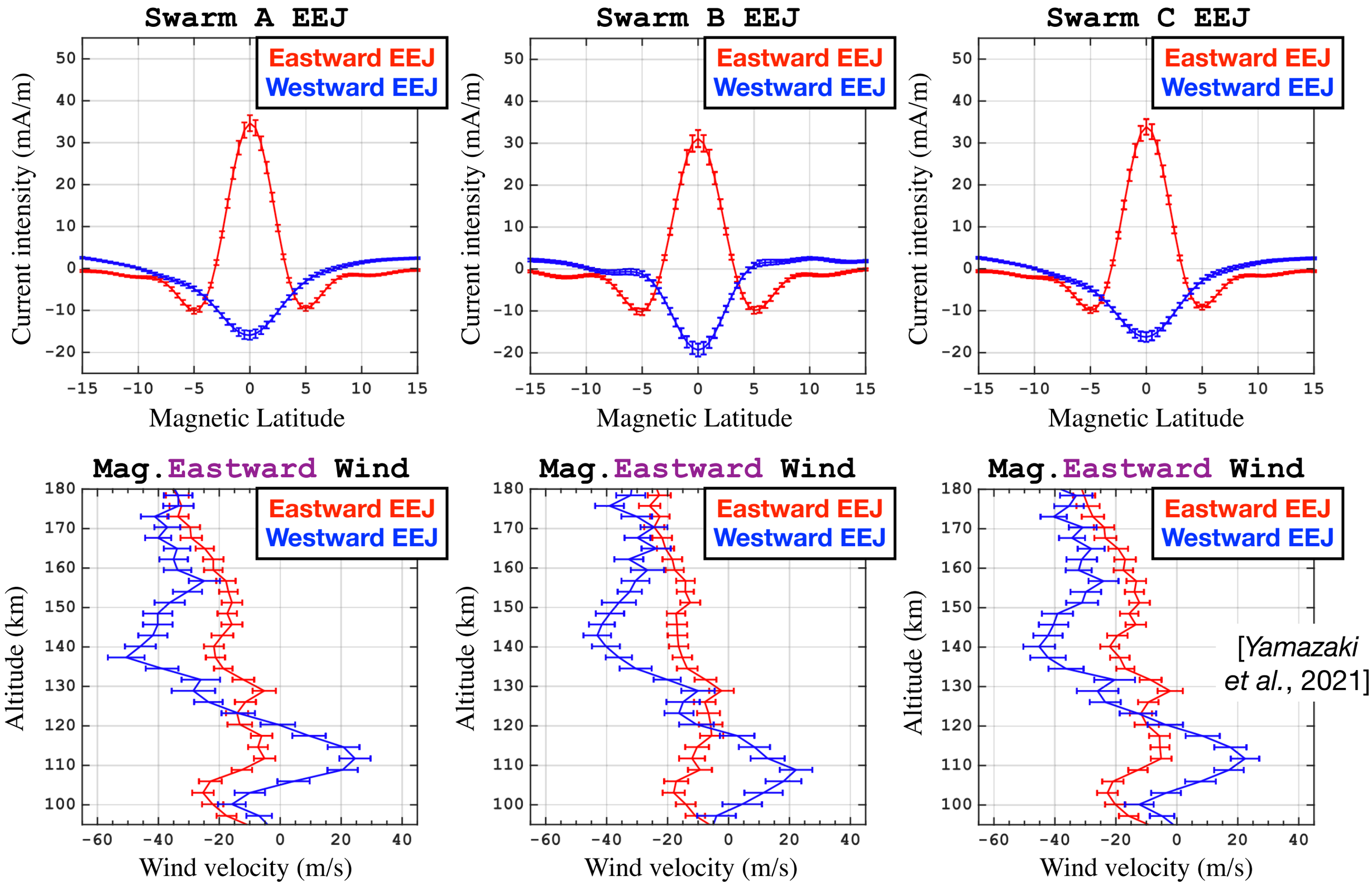
→ Equatorial zonal wind modulates EEJ

→ The $\mathbf{E}$ field response to the zonal wind



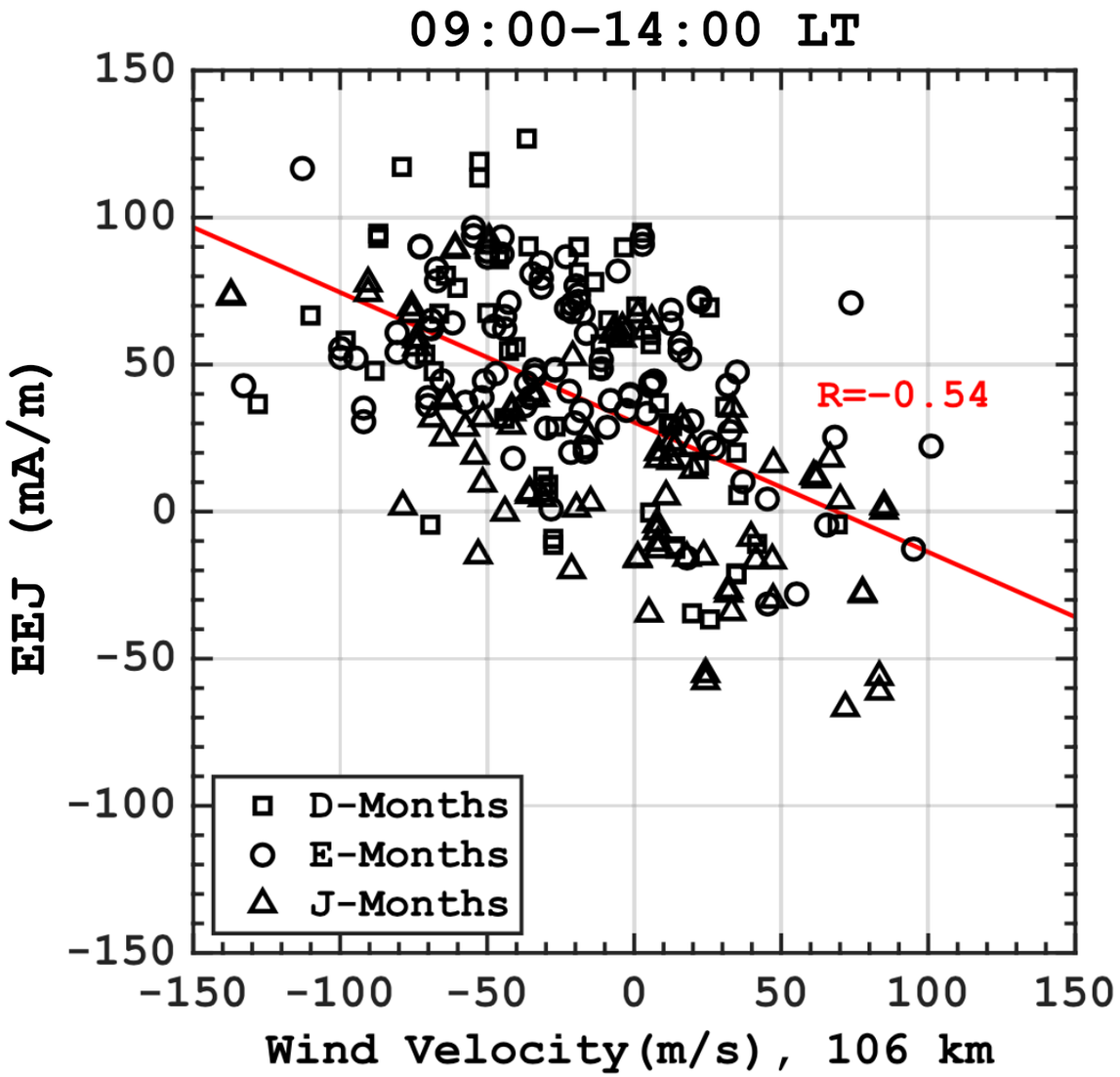
[*Yamazaki et al.*, 2014]

Neutral Winds during East- & Westward EEJ

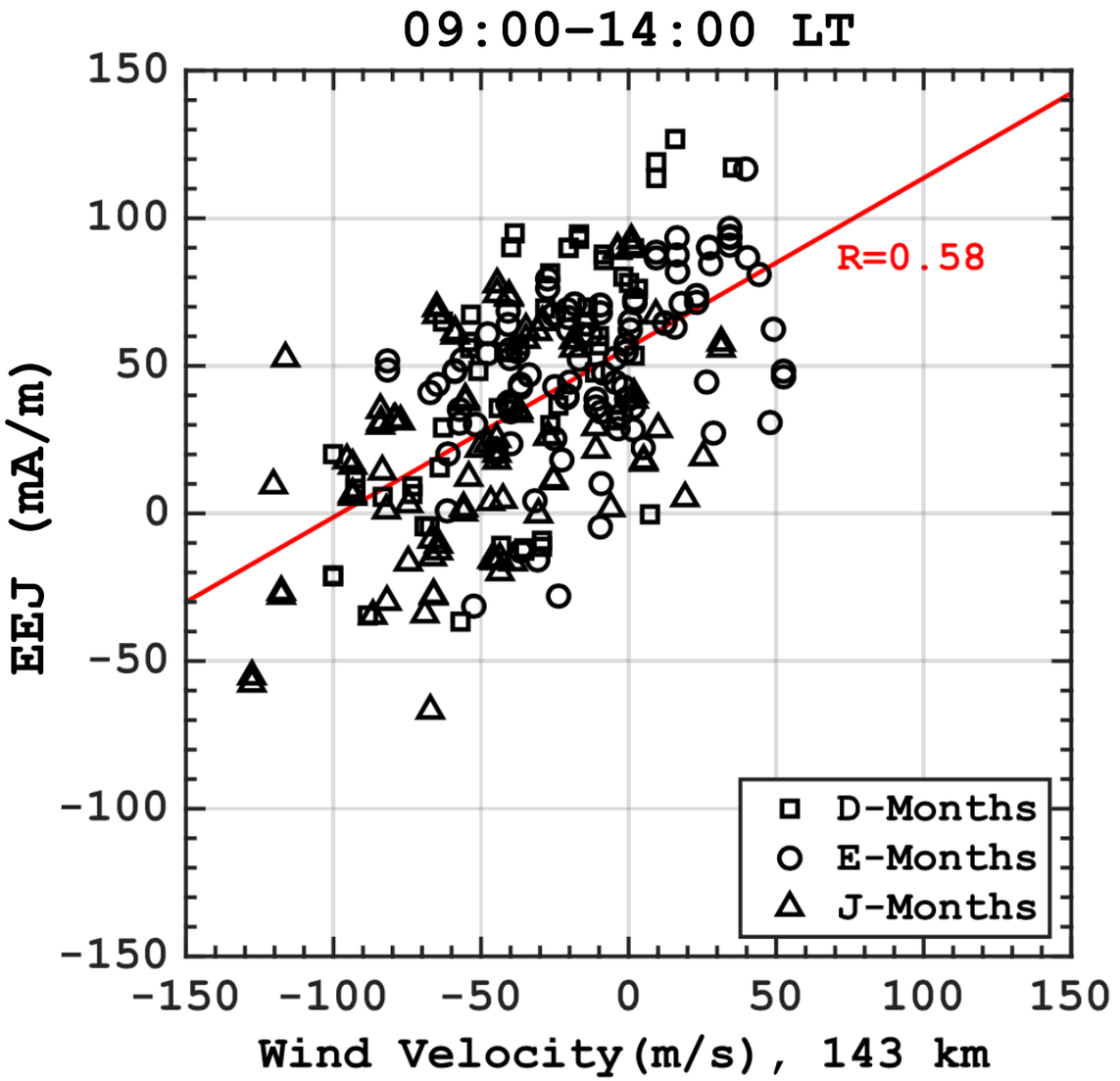


Correlation between

106 km



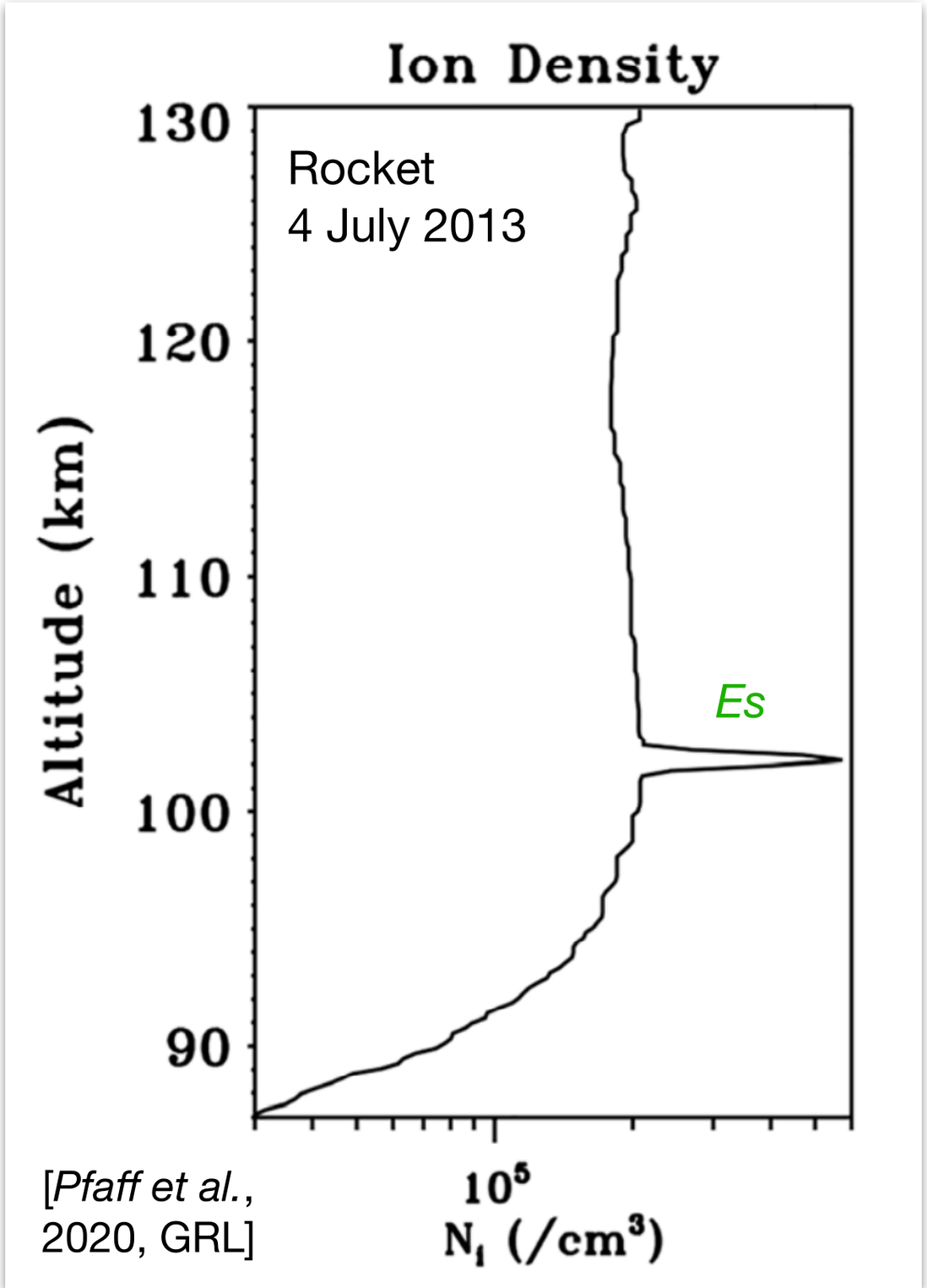
143 km



- EEJ correlates negatively with zonal wind at 106 km
- EEJ correlates positively with zonal wind at 143 km
- Results are consistent with the TIME-GCM prediction

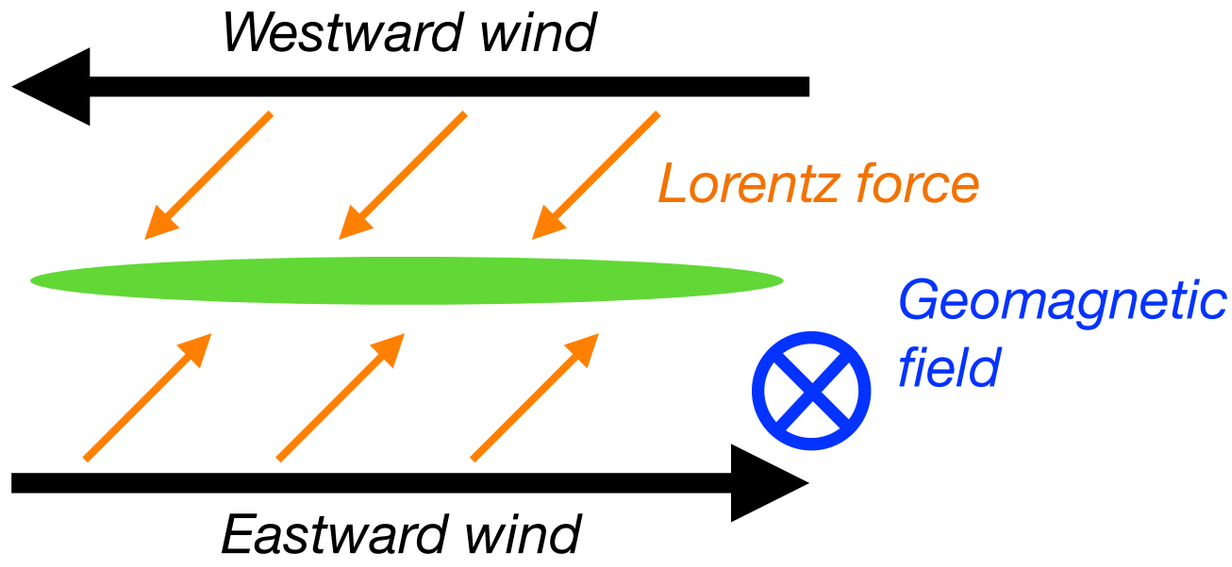
Neutral-wind effects on sporadic E

Wind Shear Theory



[*Pfaff et al.*, 2020, GRL]

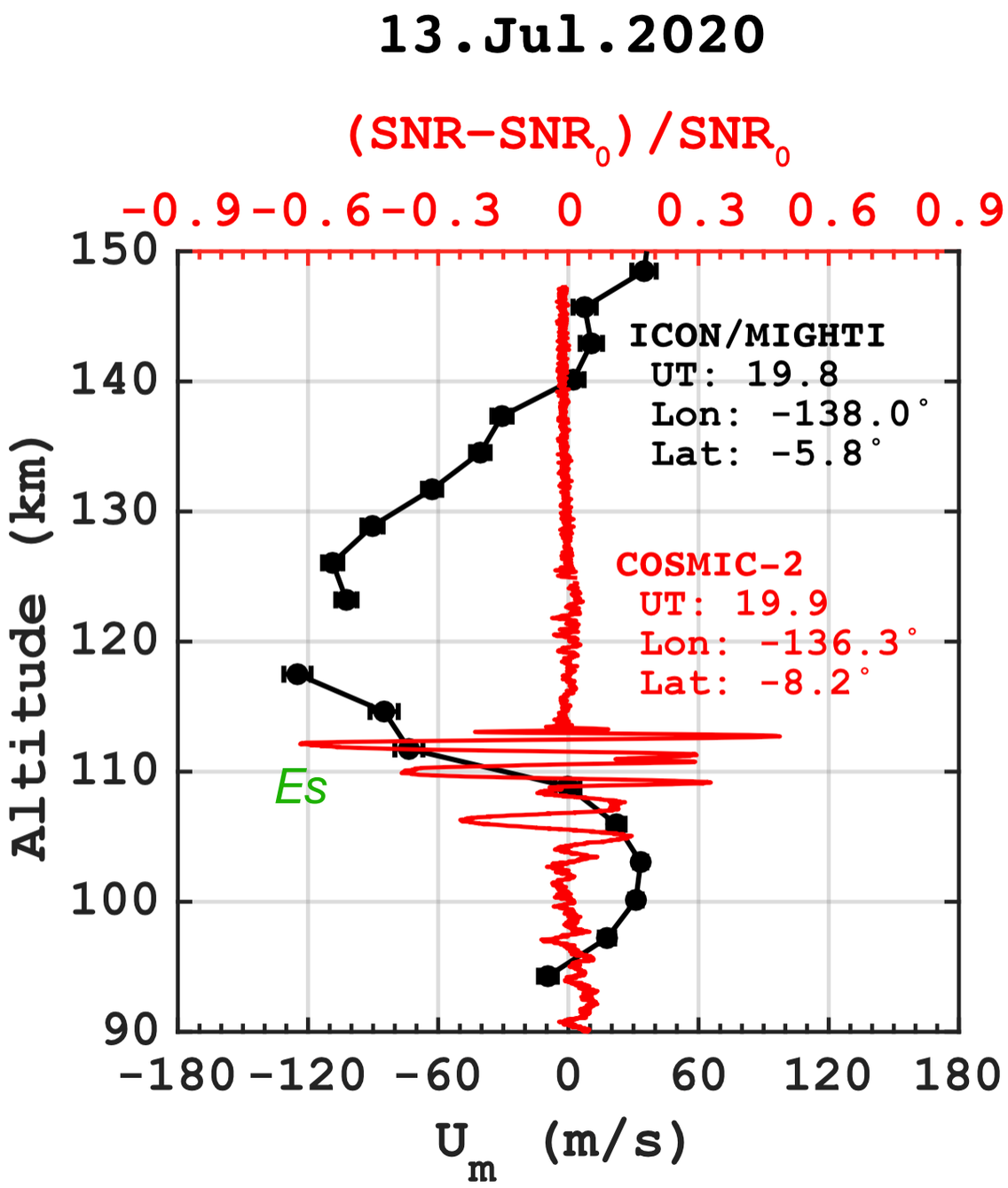
- Sporadic E (Es): layer of enhanced plasma density at E-region heights
- Consists of metallic ions (e.g., Fe^+, Mg^+)
- Theory: wind shear mechanism



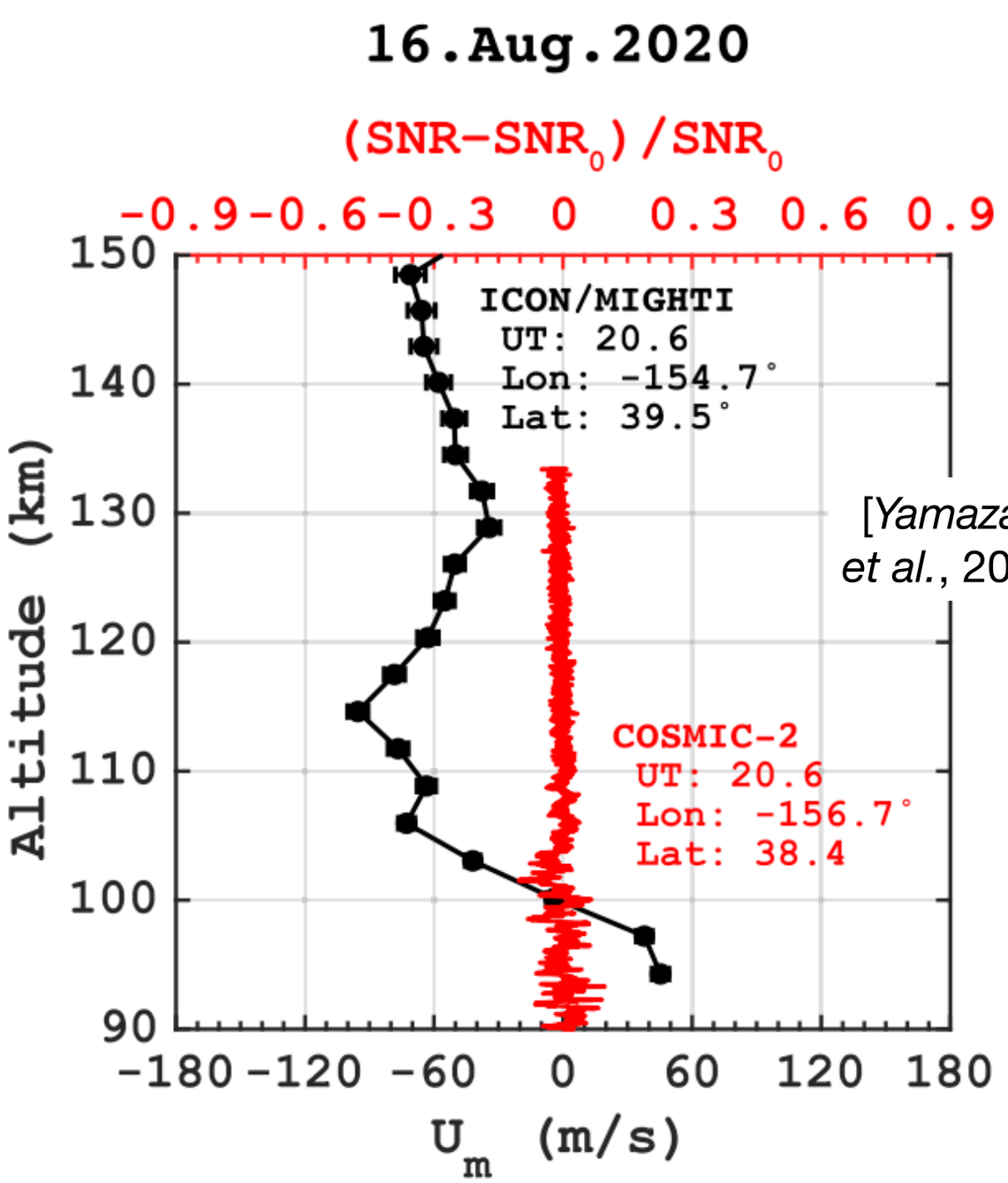
[after *Mathews*, 1998]

Q: **Is there always a negative vertical wind shear at Es layer?**

Sporadic E and Neutral Wind Profile



Sporadic E with negative wind shear

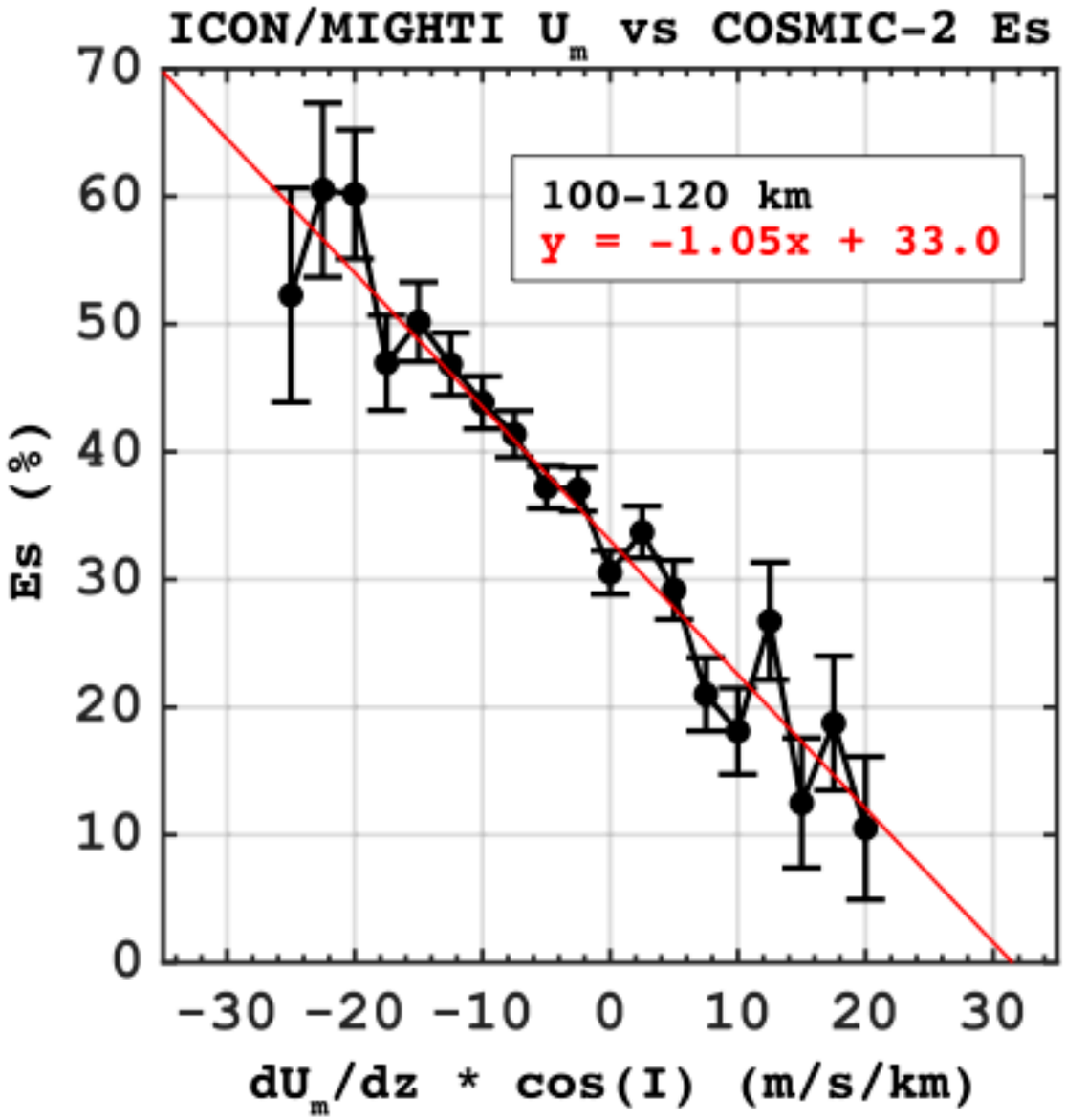


No sporadic E with negative wind shear

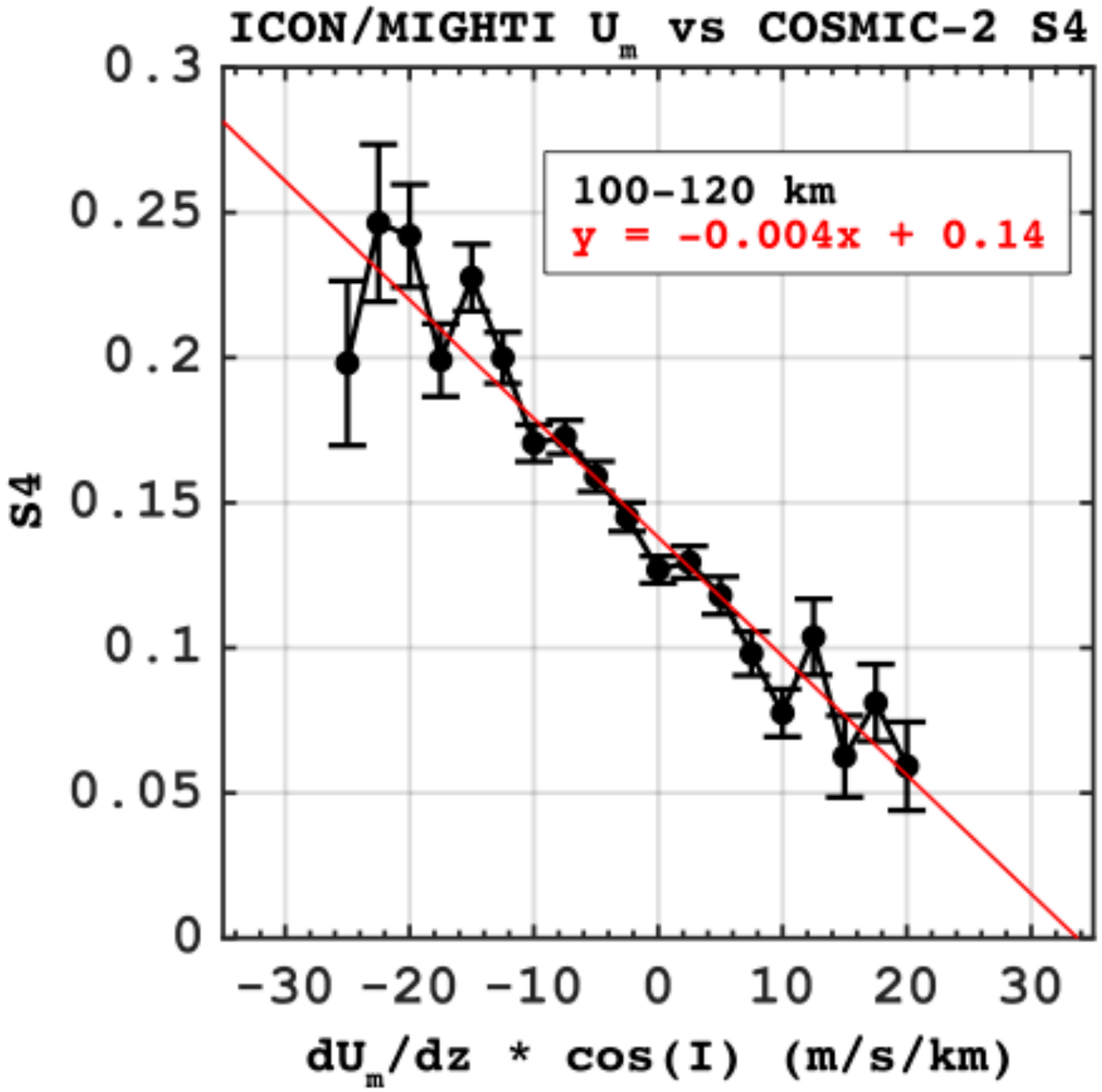
[*Yamazaki et al.*, 2022]

Vertical Wind Shear vs Sporadic E

10,751 conjunction measurements during June 2020–May 2021



Es occurrence rate *increases with negative wind shear.*



*S4 (**Es intensity**) increases with negative wind shear.*

Summary

- Lower thermospheric winds play a very important role for the low-latitude ionosphere, but observational data have been limited.
- NASA's recent satellite mission ICON carries the MIGHTI instrument that provides lower thermospheric wind measurements.
- The data are useful for, e.g., testing existing theories. Two such cases are presented here.
- Comparison of ICON/MIGHTI winds with Swarm EEJ showed that the EEJ intensity changes in response to the equatorial zonal wind, observationally and statistically supporting the TIME-GCM prediction by Yamazaki et al. [2014].
- Comparison of ICON/MIGHTI winds with sporadic E detected by COSMIC-2 radio occultation measurements showed that both occurrence rate and intensity of sporadic E increase with the magnitude of negative wind shear, observationally and statistically supporting the wind shear theory.

Data Availability/References

- Comparison of ICON/MIGHTI winds and Swarm EEJ:

  Yamazaki, Y., Harding, B. J., Stolle, C., & Matzka, J. (2021). **Neutral wind profiles during periods of eastward and westward equatorial electrojet.** *Geophysical Research Letters*, 48(11), e2021GL093567.

- Comparison of ICON/MIGHTI winds with COSMIC-2 sporadic E:

  Yamazaki, Y., Arras, C., Andoh, S., Miyoshi, Y., Shinagawa, H., Harding, B. J., Englert, C.R., Immel, T.J., Sobhkhiz-Miandehi, S. & Stolle, C. (2022). **Examining the wind shear theory of sporadic E with ICON/MIGHTI winds and COSMIC-2 radio occultation data**. *Geophysical Research Letters*, 49(1), e2021GL096202.

- ICON/MIGHTI data are publicly available:

  https://icon.ssl.berkeley.edu/

- Swarm EEJ data are publicly available:

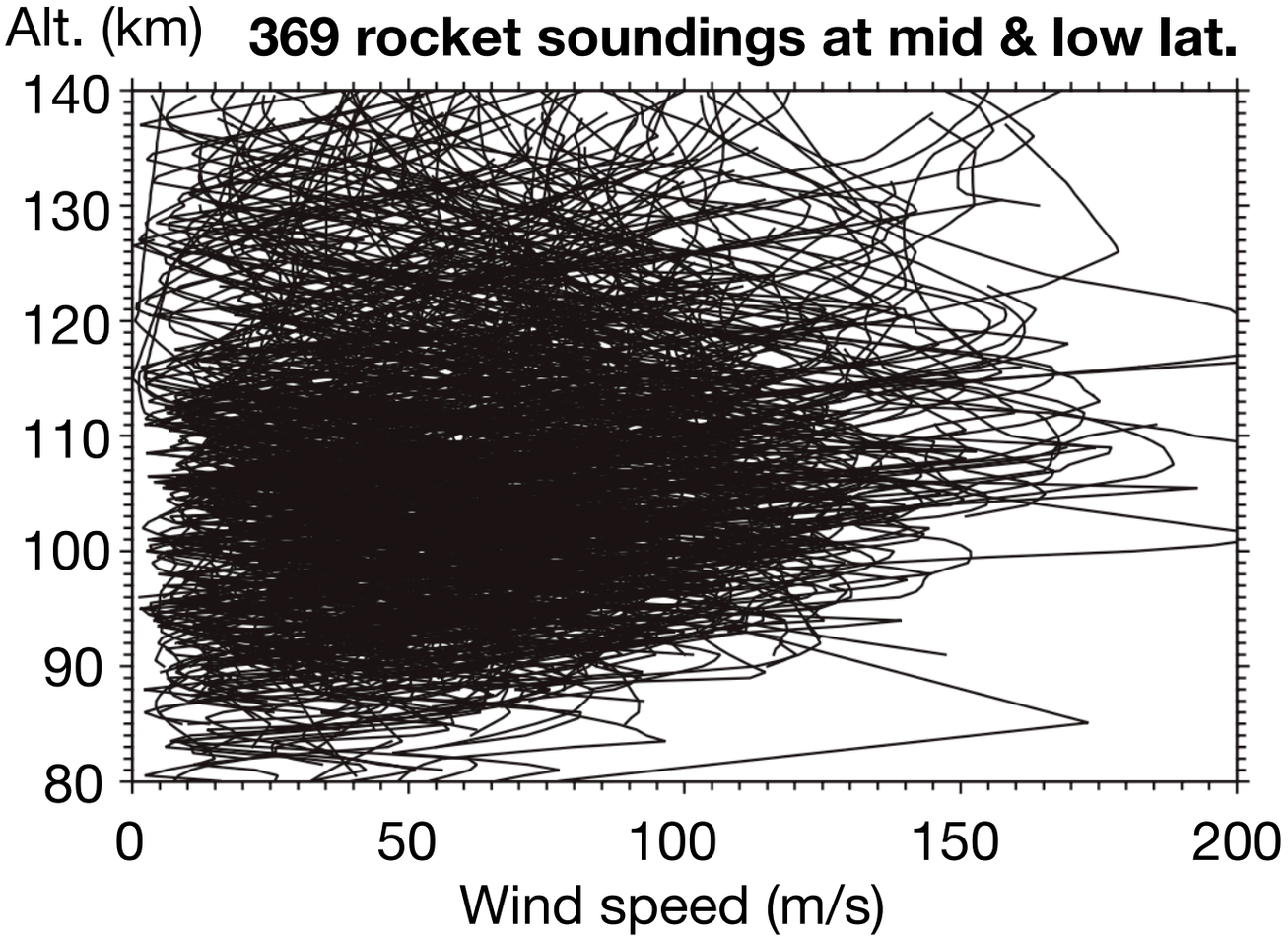
  https://earth.esa.int/eogateway/missions/swarm/data

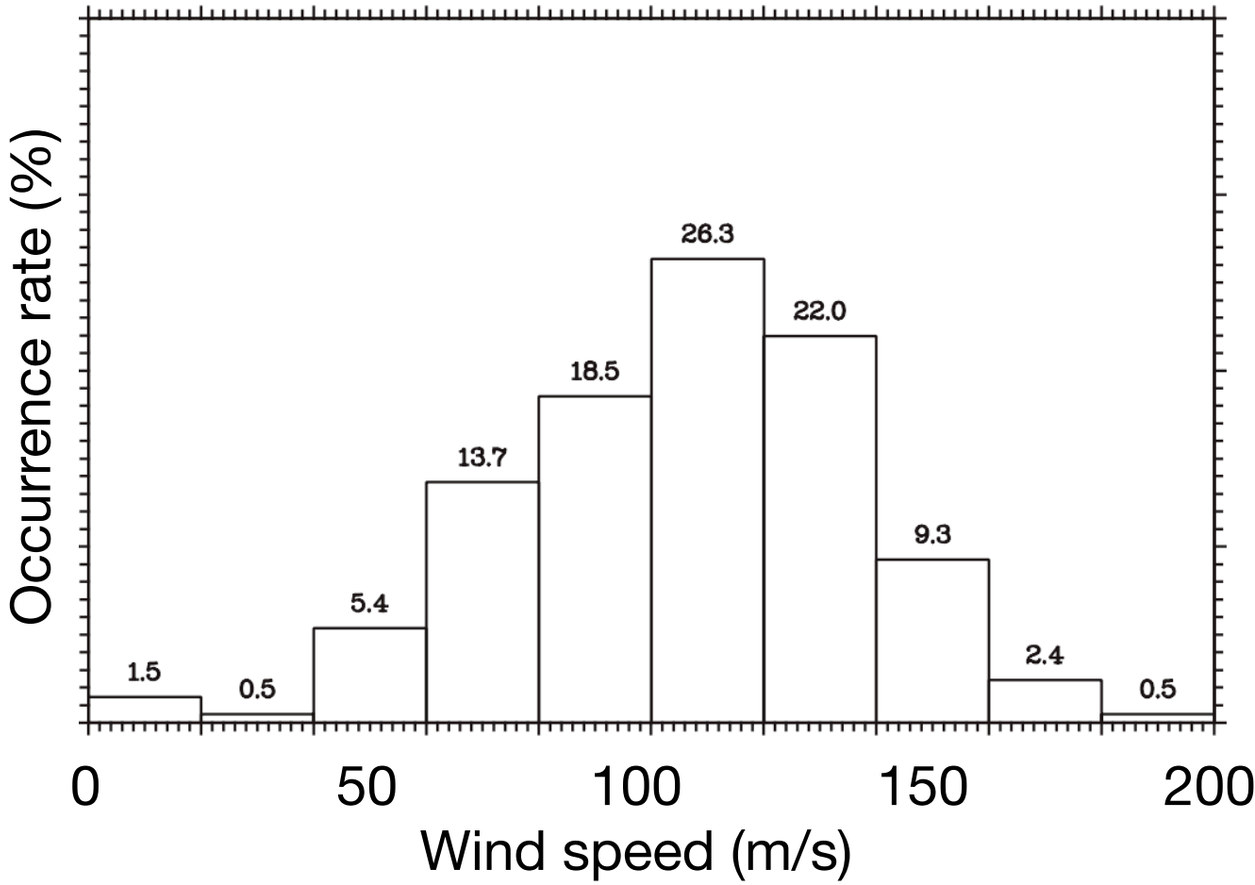
- COSMIC-2 radio occultation data:

  https://www.cosmic.ucar.edu/what-we-do/cosmic-2/data/

Backups

Rocket Observations





[*Larsen*, 2002, JGR]

Chemical trace technique

→ Accurate measurements of neutral wind

→ Limited spatial temporal coverage