Effects of mesosphere and lower thermosphere dynamics on ionospheric weather

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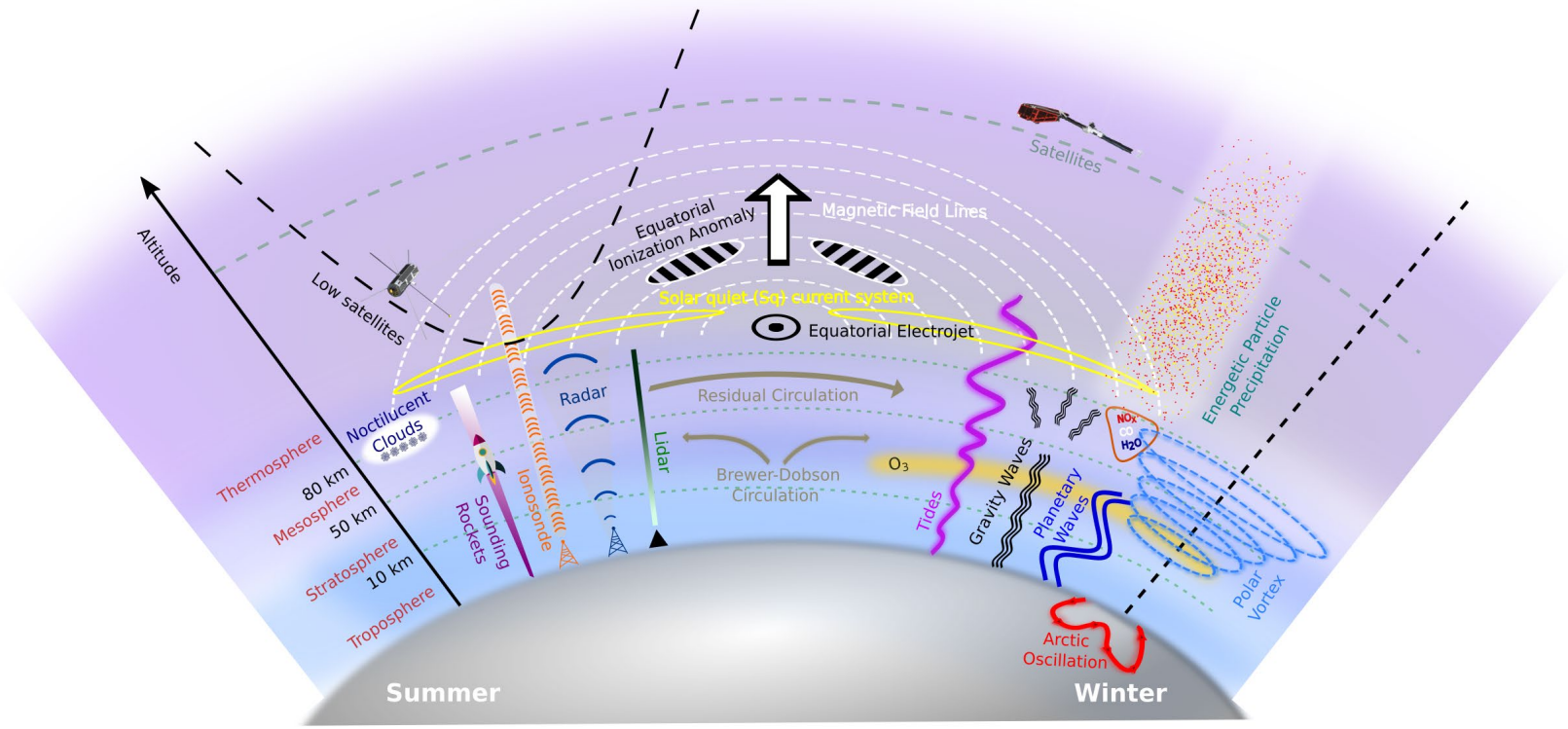
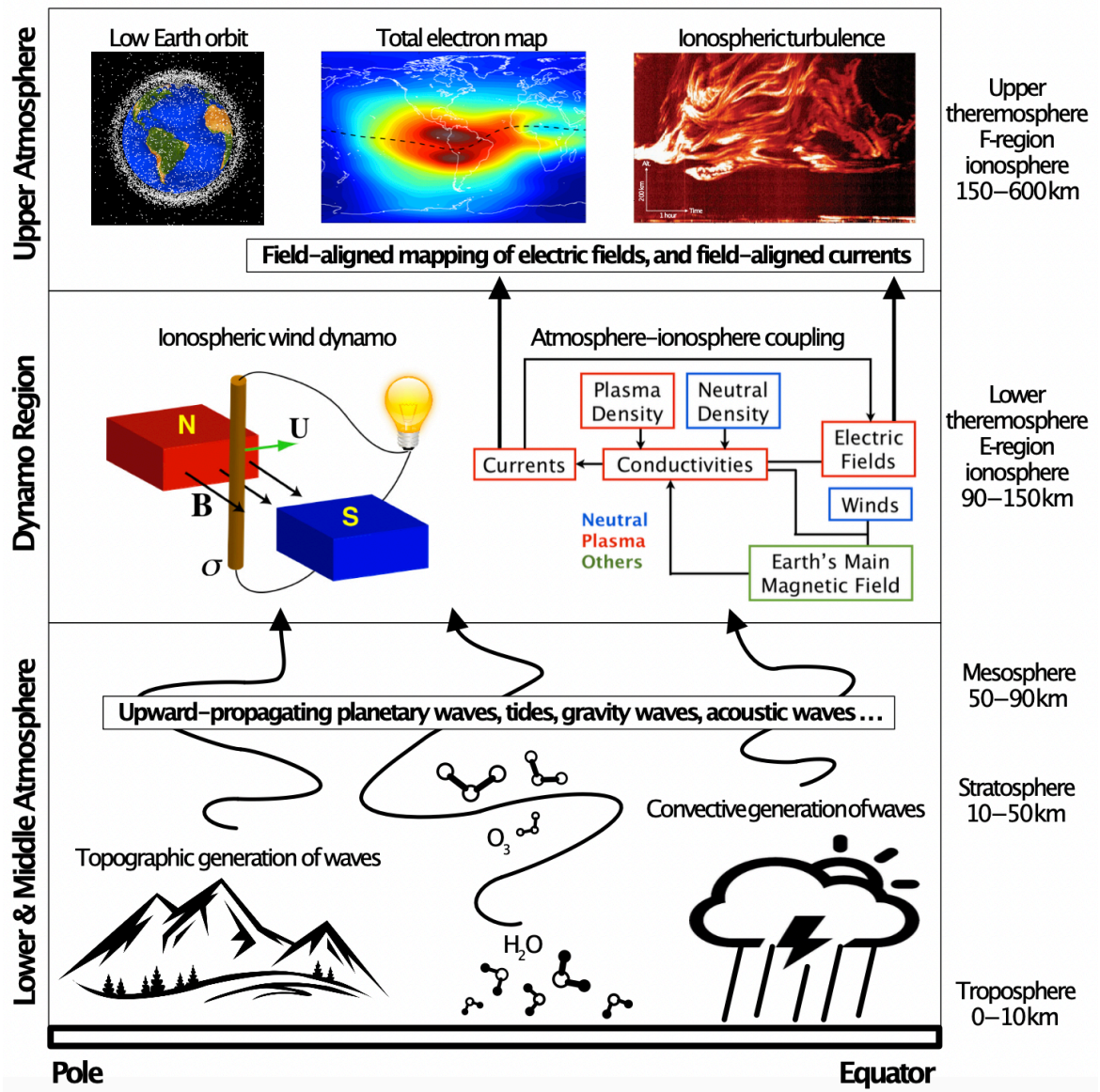
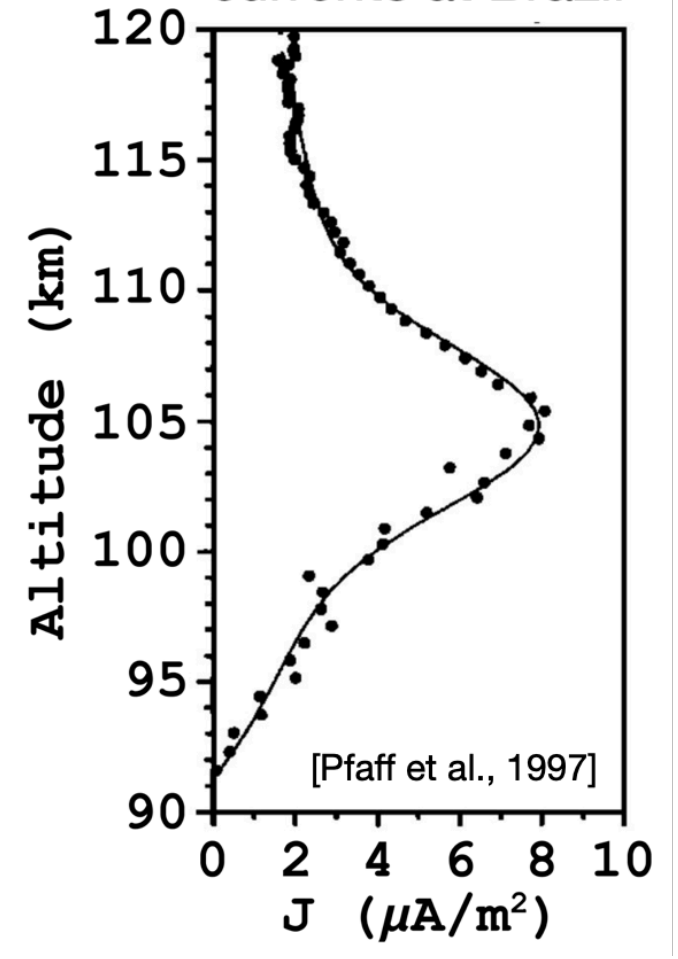


Atmospheric forcing of the ionosphere

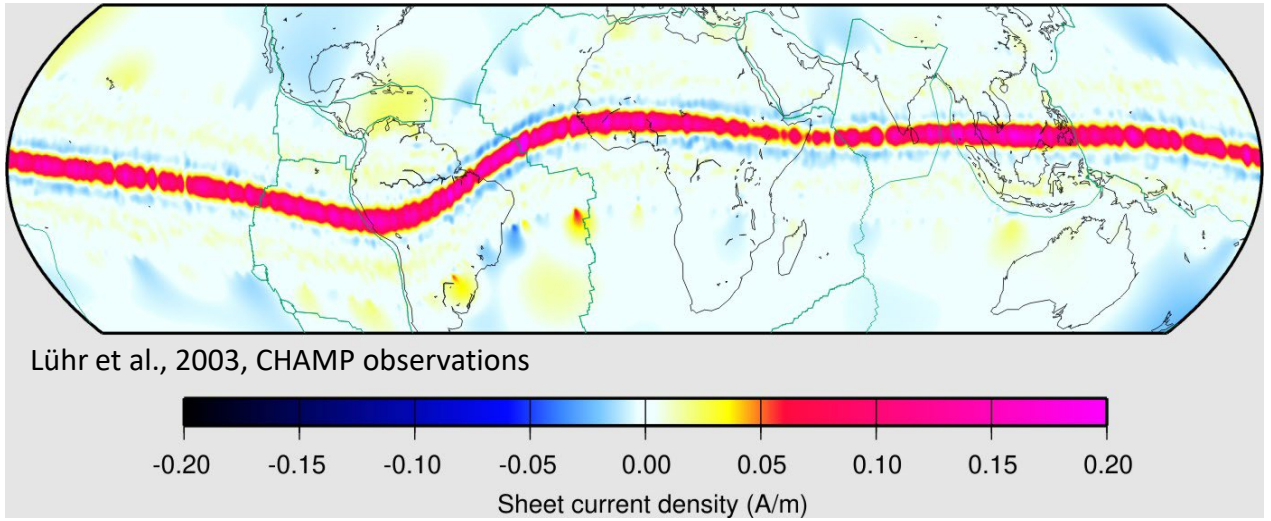


The Equatorial Electrojet (EEJ)

Vertical profile of currents at Brazil



Spatial distribution of the dayside EEJ



Ionospheric Ohm's Law $\mathbf{J} = \sigma\mathbf{E} + \sigma\mathbf{U} \times \mathbf{B}$

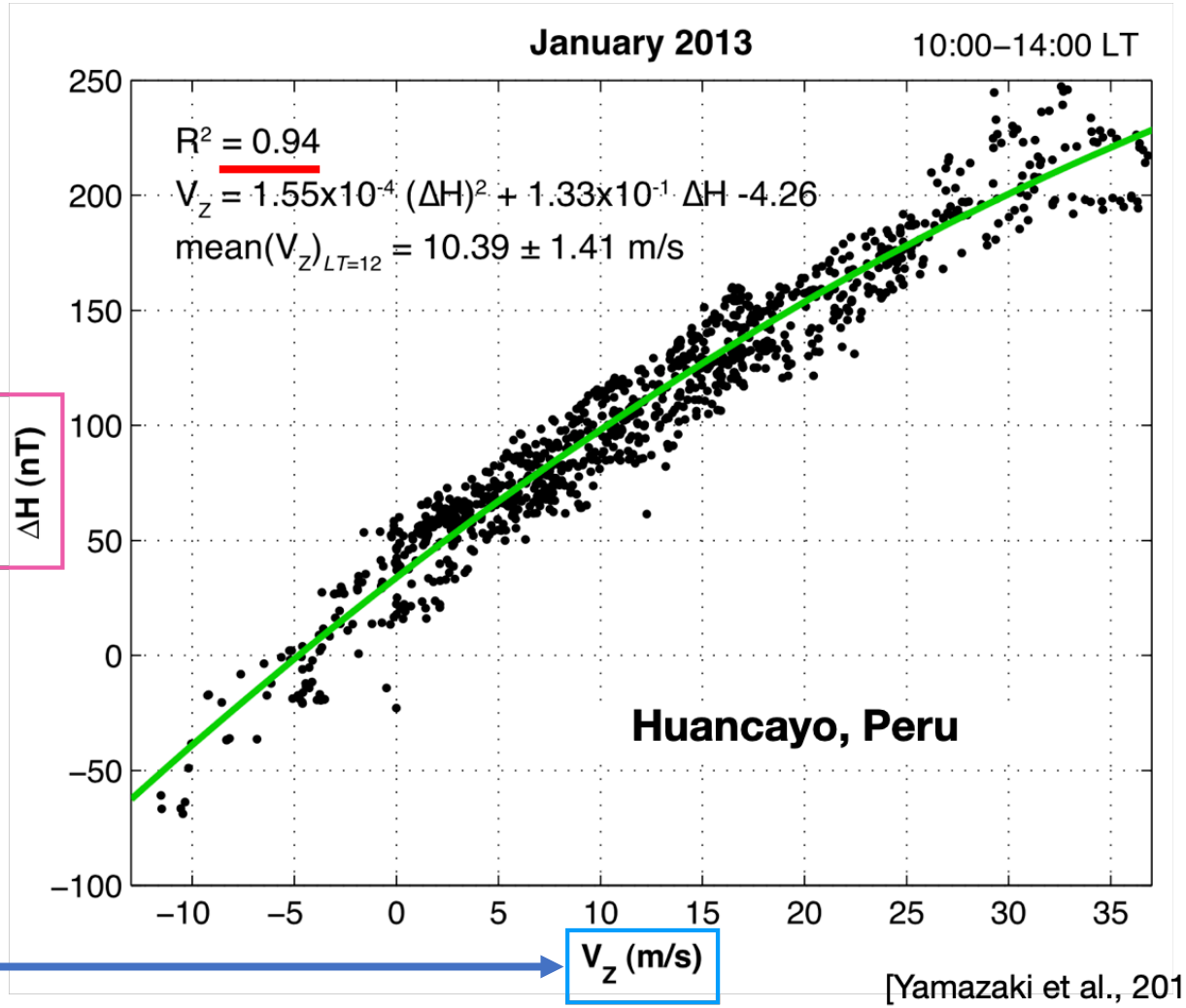
$\mathbf{J}$: *current density* σ : *ionospheric conductivity*

$\mathbf{E}$: *electric field* $\mathbf{U}$: *neutral wind velocity*

$\mathbf{B}$: *magnetic field*

The Equatorial Electrojet (EEJ)

Magnetic field deviations due to the EJJ

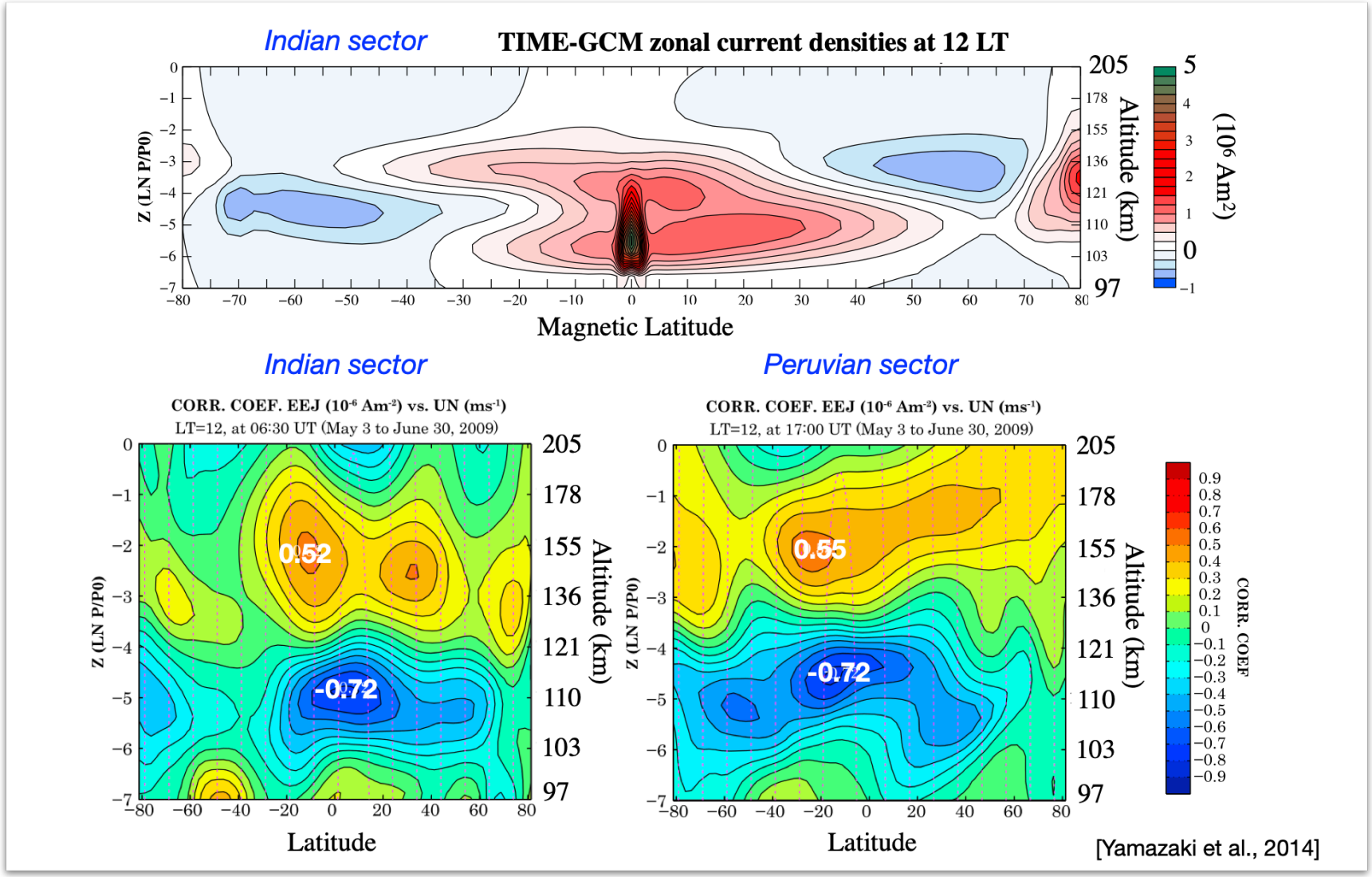


[Yamazaki et al., 2018]

Plasma drift due to zonal electric field

Observations prove that the equatorial zonal electric field is important

The Equatorial Electrojet (EEJ)



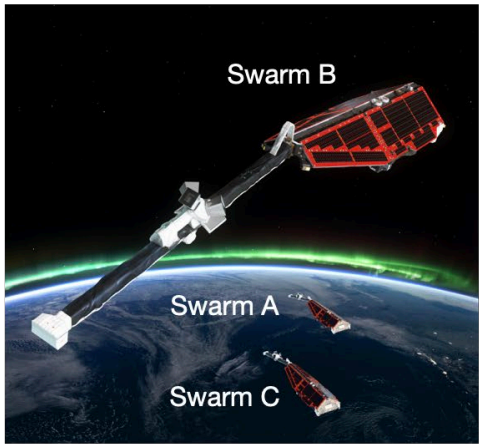
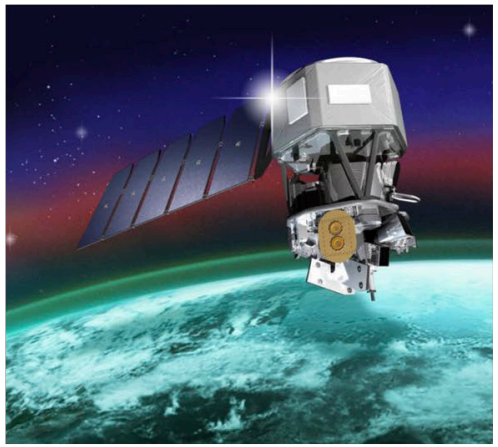
Model predicts that the equatorial zonal wind is important

The Equatorial Electrojet (EEJ)

Data selection:

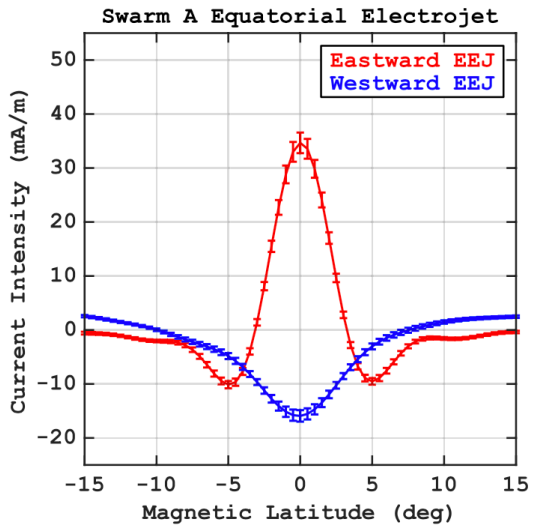
- **Dec 2019–Jan 2021 (solar minimum)**
- **Low geomagnetic activity**
- **Time separation: <15 min**
- **Latitude separation: <5°**
- **Longitude separation: <15°**

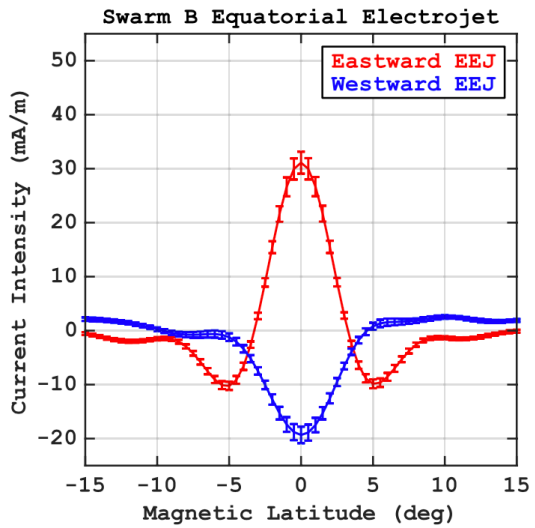
Swarm A–ICON: 246 conjunctions
Swarm B–ICON: 226 conjunctions
Swarm C–ICON: 252 conjunctions

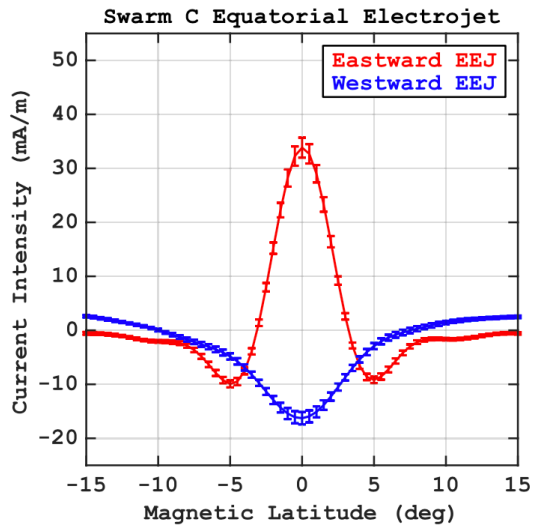
	EEJ	Neutral wind
		
Mission	**Swarm (ESA)**	**ICON (NASA)**
Orbit	**Inclination: 87°**	**Inclination: 27°**
Instrument	**Magnetometer**	**MIGHTI (Green line)**
Parameter	**Current intensity (mA/m)**	**Wind velocities (m/s)**
Product	**L2 EEJ by Dr. P. Alken**	**L2.2 Cardinal wind v4**
Height	**~110 km**	**95–180 km**

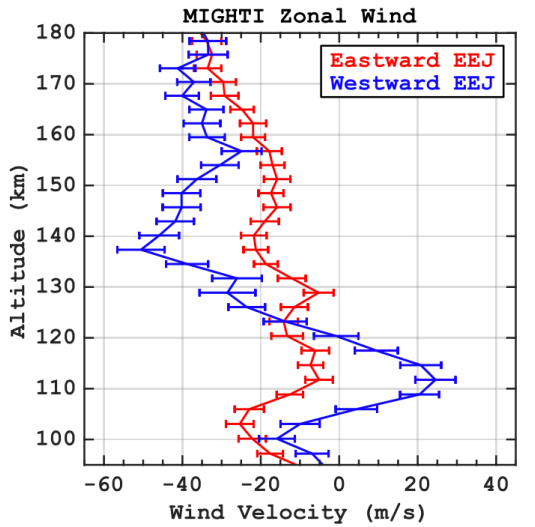
Yamazaki et al., 2021

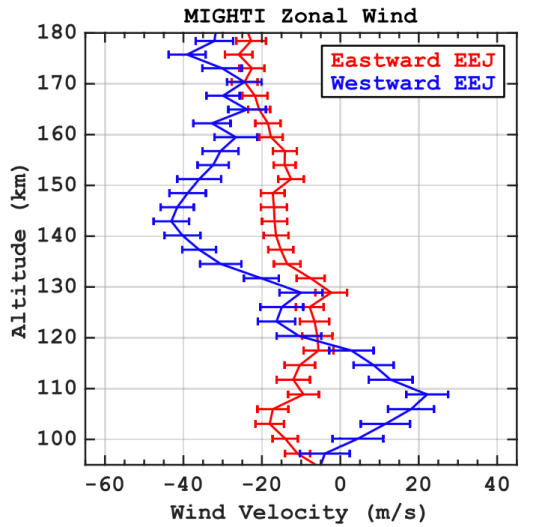
Observational evidence of thermospheric wind forcing

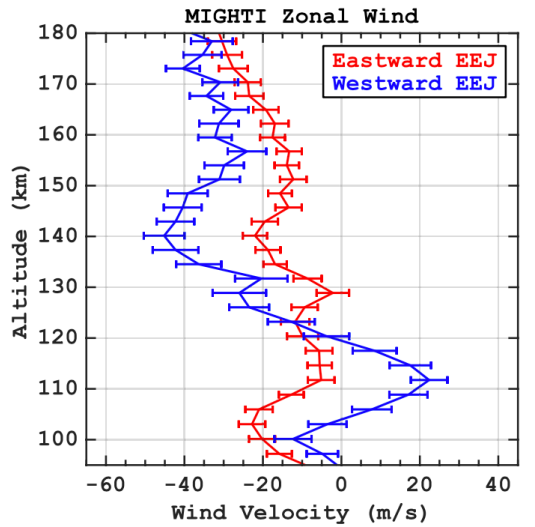


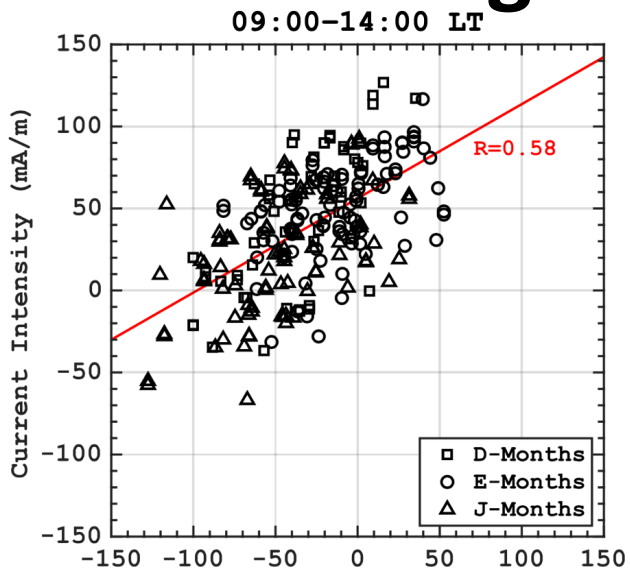


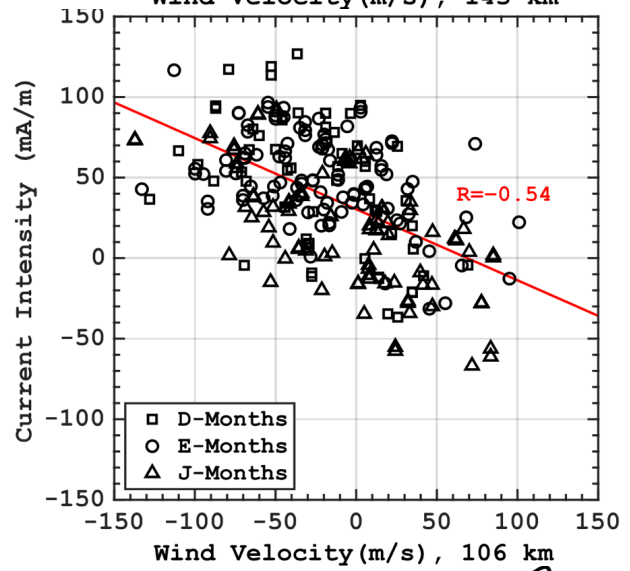










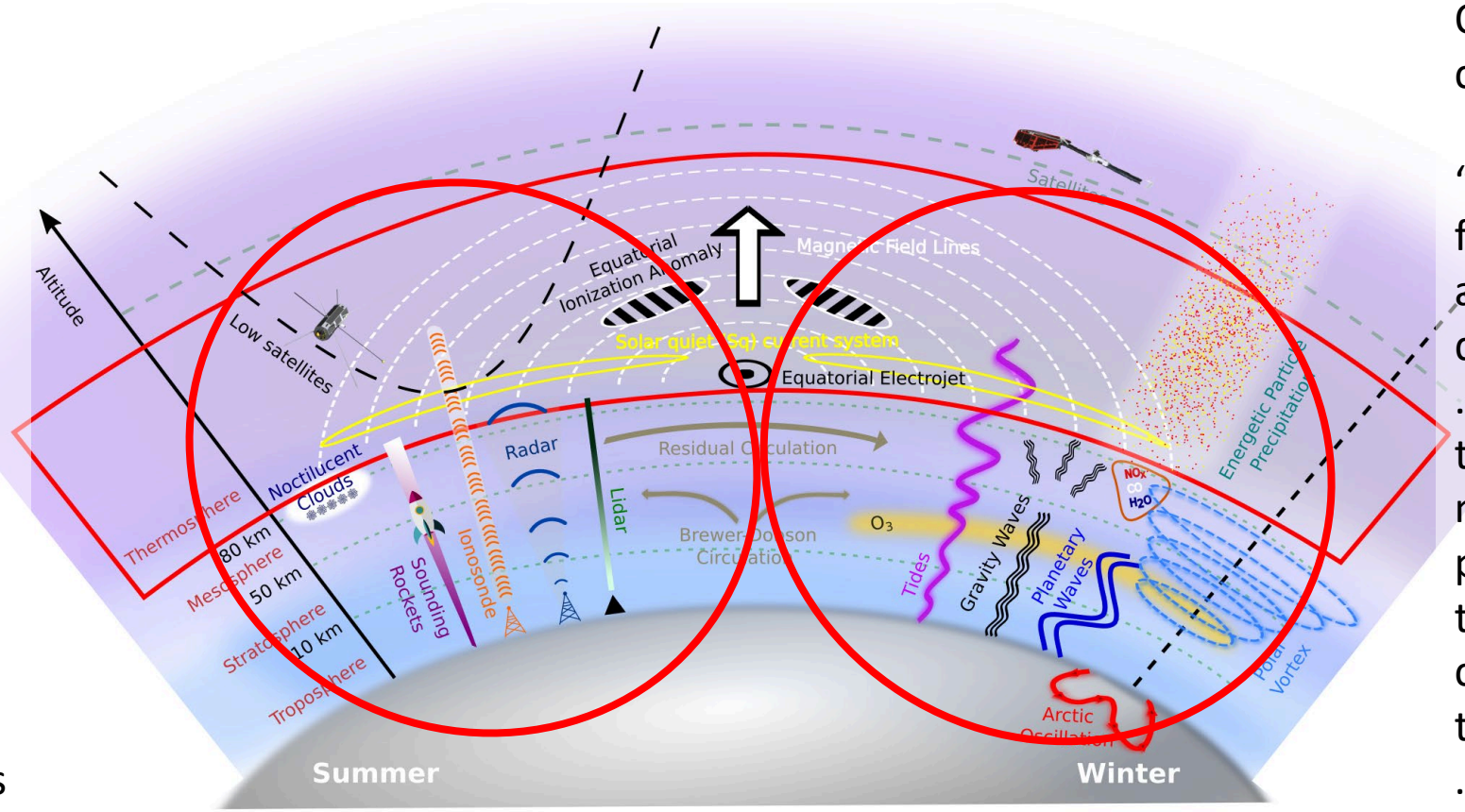


Yamazaki et al., 2021

The lower thermosphere is influenced by and connects to the whole atmosphere / ionosphere

Connected through, e.g.,

- Transport and deposition of energy through atmospheric wave propagation and breaking
- Mapping of E-fields along magnetic field lines and by FACs



Observational challenge

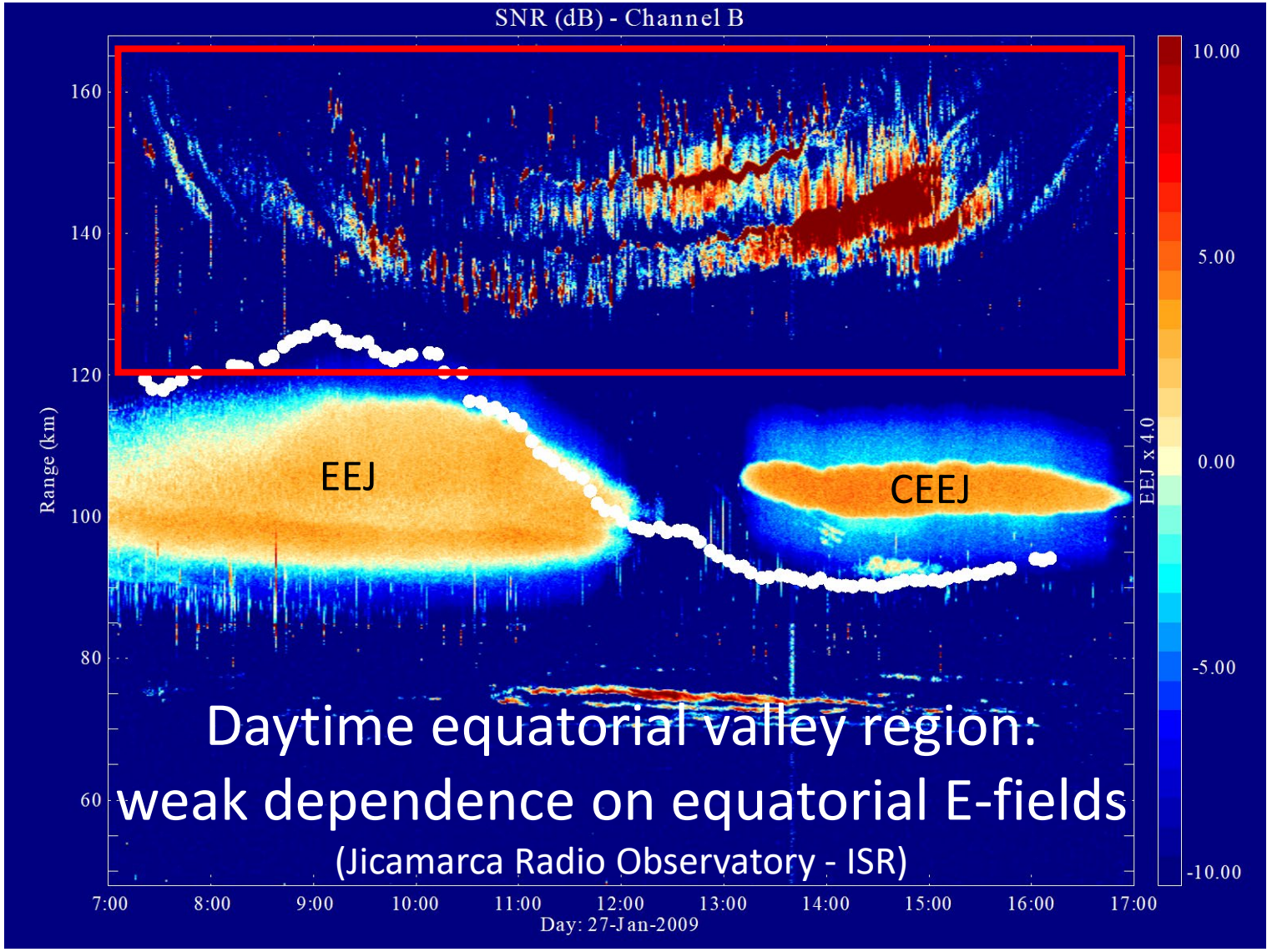
"… the **critical transition** from a fully mixed atmosphere to a diffusively separated one. … Observations needed to constrain lower and middle thermospheric physics are **scarce**, and the 100–200 km region can perhaps be termed the new "**ignorosphere**" …"

Emmert et al., 2021

150-km radar echoes: local and non-local forcing

Origin:

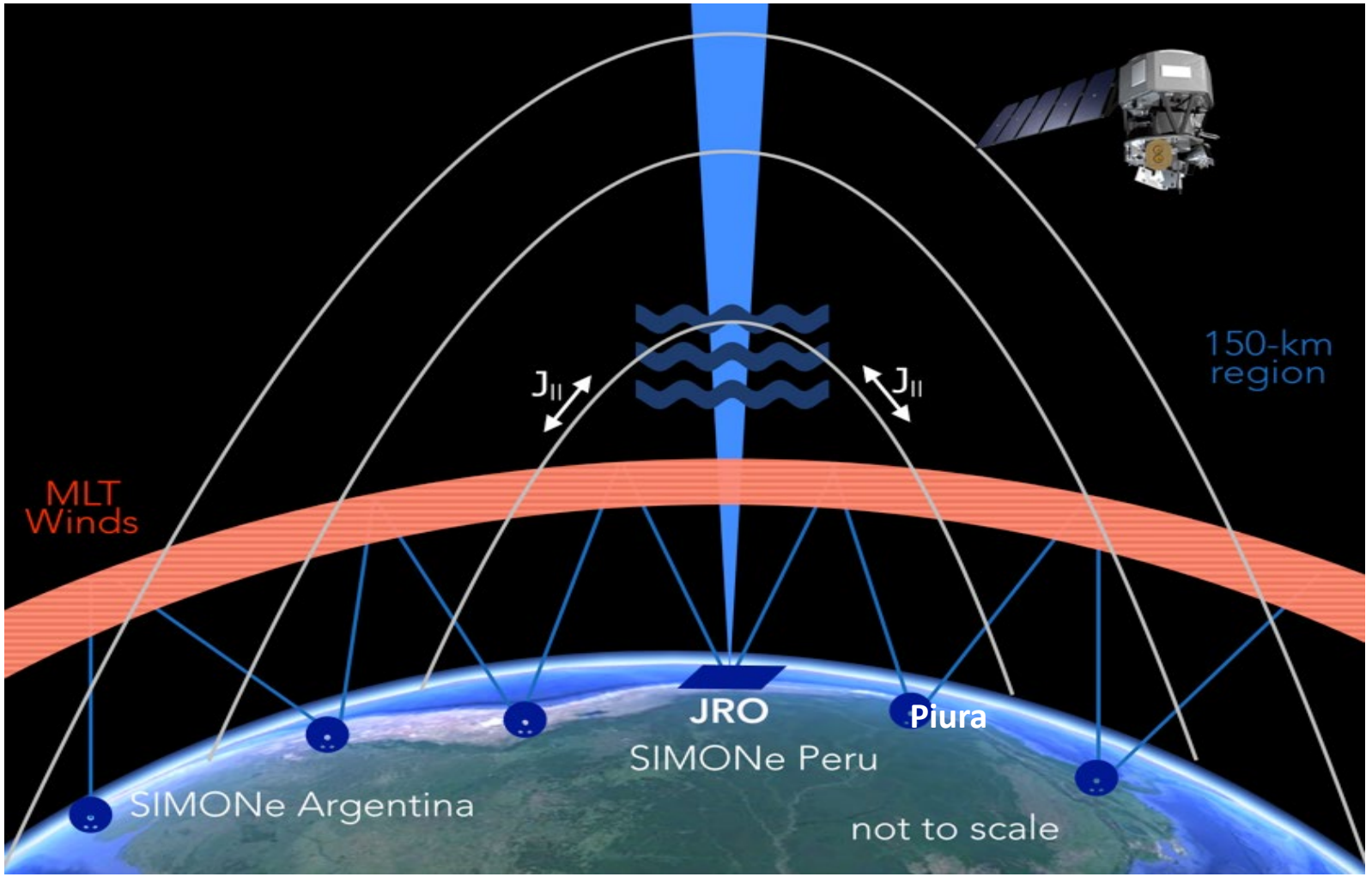
Photo-electron stream generating a "bump-on-tail" of the particle velocity distribution in the plasma exciting coherent plasma waves
(Longley et al., 2020)

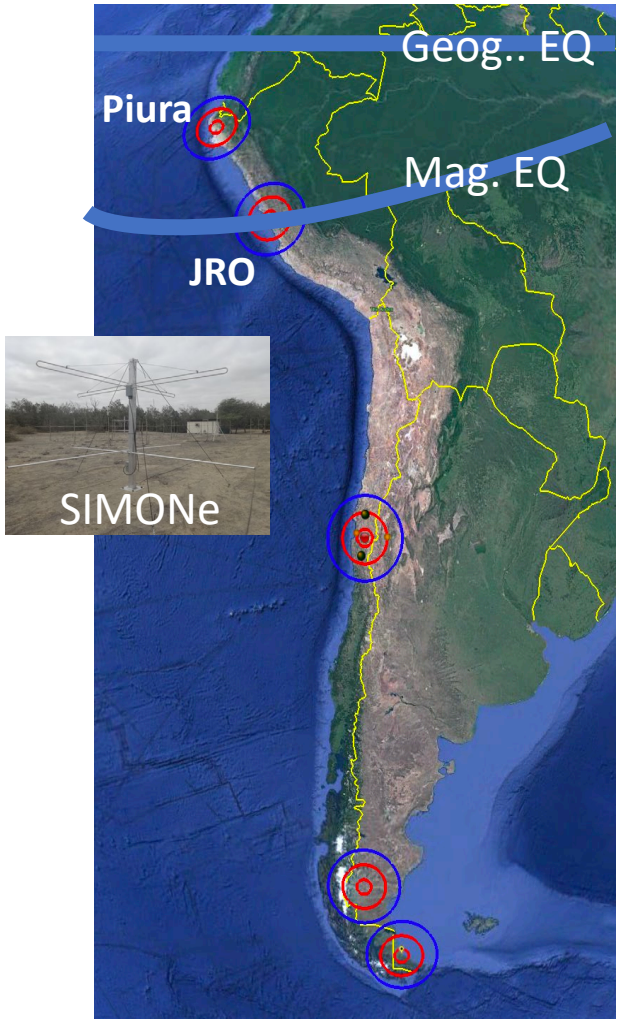


Small-scale variability:

cannot (yet) be explained by local excitation

150-km radar echoes: local and non-local forcing





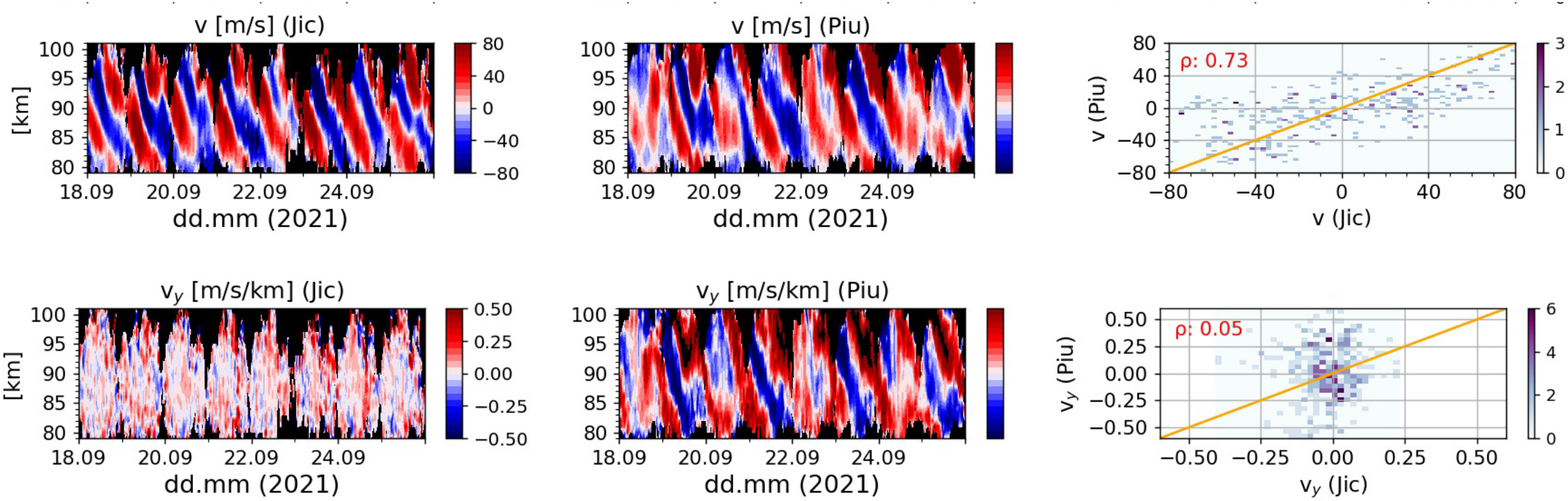
150-km radar echoes: local and non-local forcing

Correlation of 1-h values of horizontal winds and wind gradients between Jicamarca and Piura, September 2021

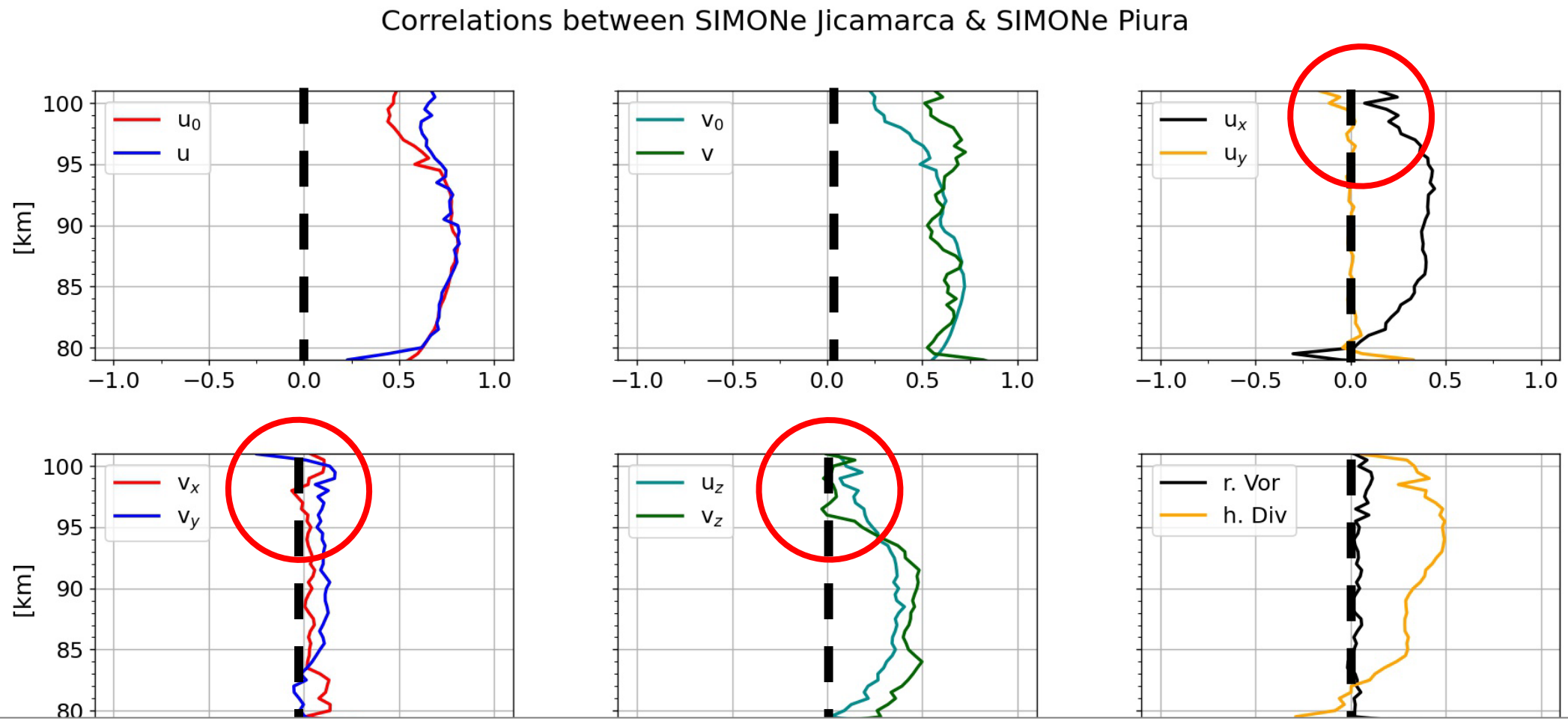
Jicamarca
12°S, 0°mlat

Piura
5°S, 6°N mlat

Jicamarca vs. Piura



150-km radar echoes: local and non-local forcing



Significant variability at foot-points of magnetic field lines at each hemisphere induce electric potential differences and small-scale FACs structuring the ionosphere?

Effects of mesosphere and lower thermosphere dynamics on ionospheric weather

- The lower thermosphere is the transition region between the atmosphere and the ionosphere
- It is challenging to be observed
- Equatorial thermospheric winds play an important role for the variability of the EEJ
- The low latitude lower thermosphere/ionosphere is expected to be ruled by local processes and non-local processes in the mesosphere transmitted via magnetic field lines
- **Combined analyses of satellite and ground observations resolves for better spatial-temporal coverage and local/non-local processes**