Vertical Atmospheric Coupling during the September 2019 Antarctic Sudden Stratospheric Warming

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VERA
VERtical coupling in Earth's Atmosphere at mid and high latitudes

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Introduction/Motivation

Sudden stratospheric warming (SSW)

- Extreme meteorological phenomena
- Mainly in the Northern Hemisphere during winter
- Known to have a significant impact on the low and mid latitude ionosphere
- Rarer and weaker in the Southern Hemisphere

Q: How does the ionosphere respond to Antarctic SSW?

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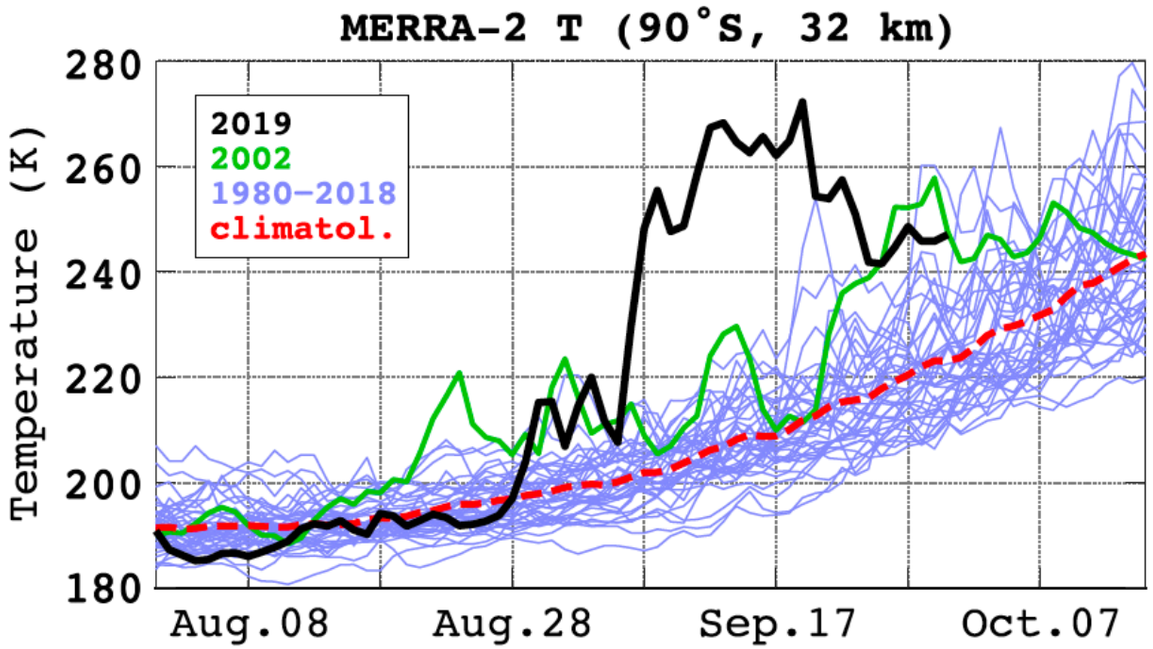
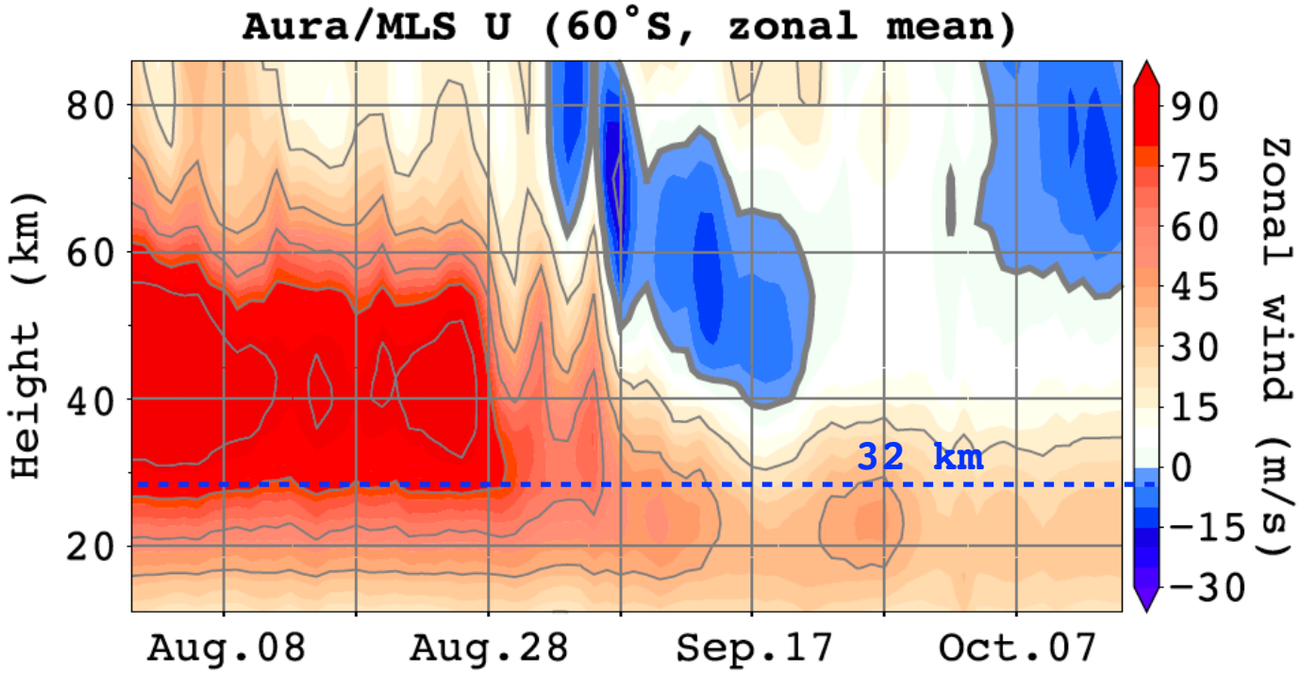
September 2019 SSW Overview



Stratospheric polar temperature

50+ K/week → SSW



Zonal mean zonal wind

No reversal at 32 km

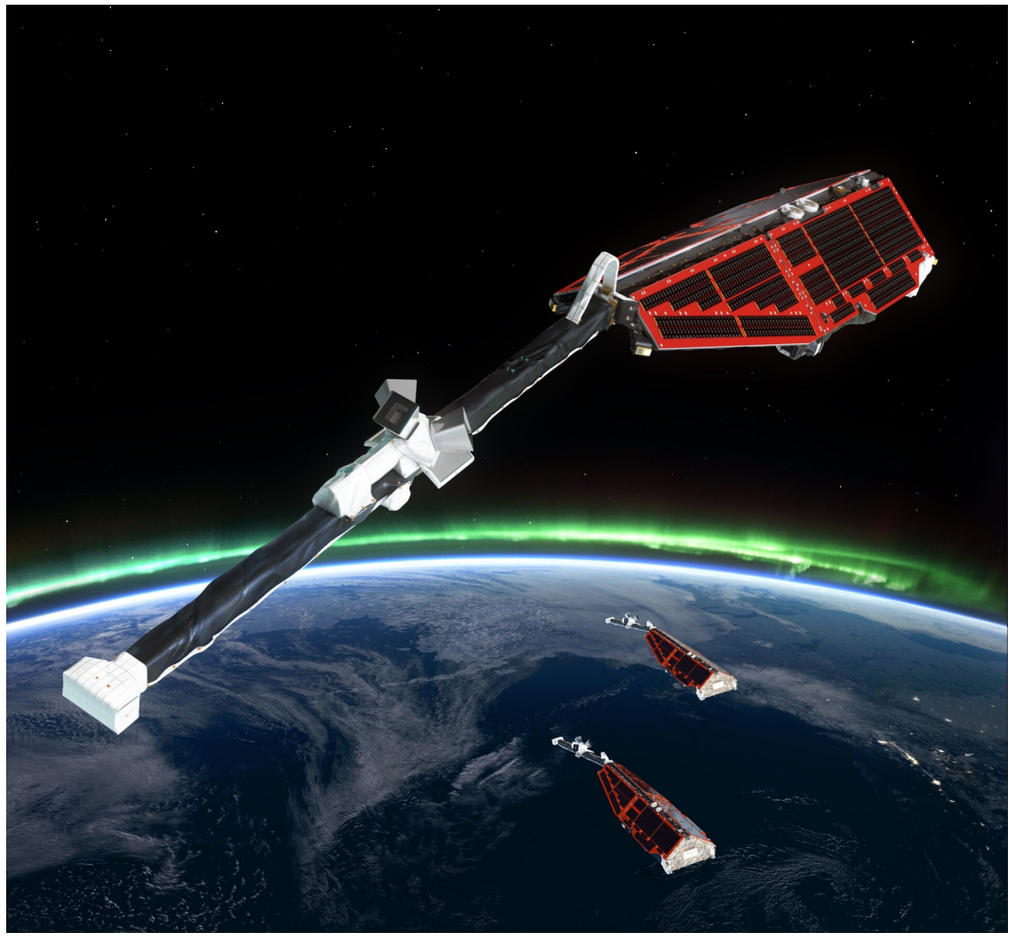
↓

Minor SSW

Date 2019

[*Yamazaki et al.*, 2020]

Swarm Observations



[http://www.esa.int/]

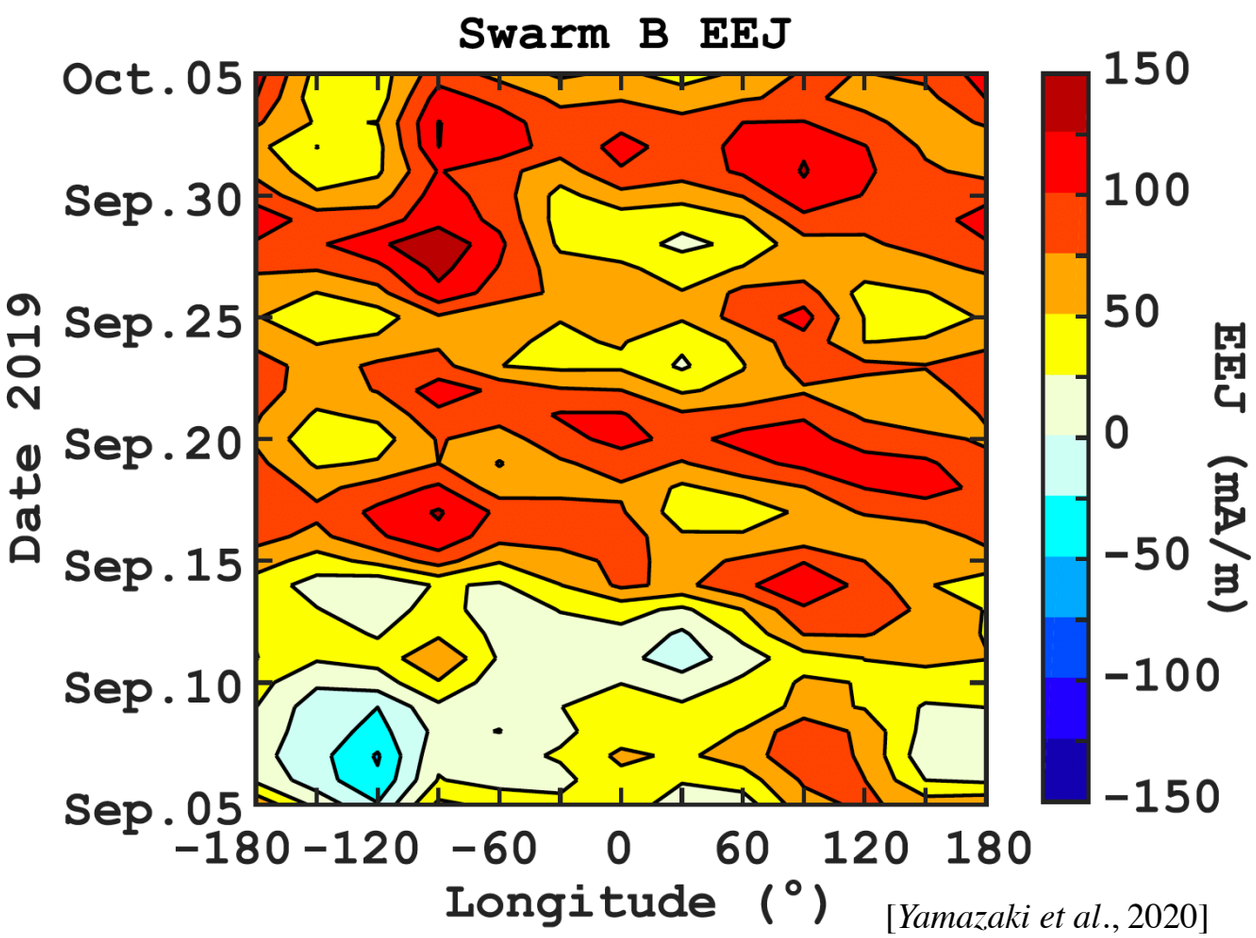
- Satellite constellation: Swarm A, B & C
- Operational since November 2013
- Altitude 450-500 km
- Near sun-synchronous orbit
- Measurements include:

1. **Equatorial electrojet (EEJ)**
   by high-precision magnetometer
2. **Electron density (Ne)**
   by Langmuir probe
3. **Total electron content (TEC)**
   by GPS observations

EEJ during September 2019 SSW

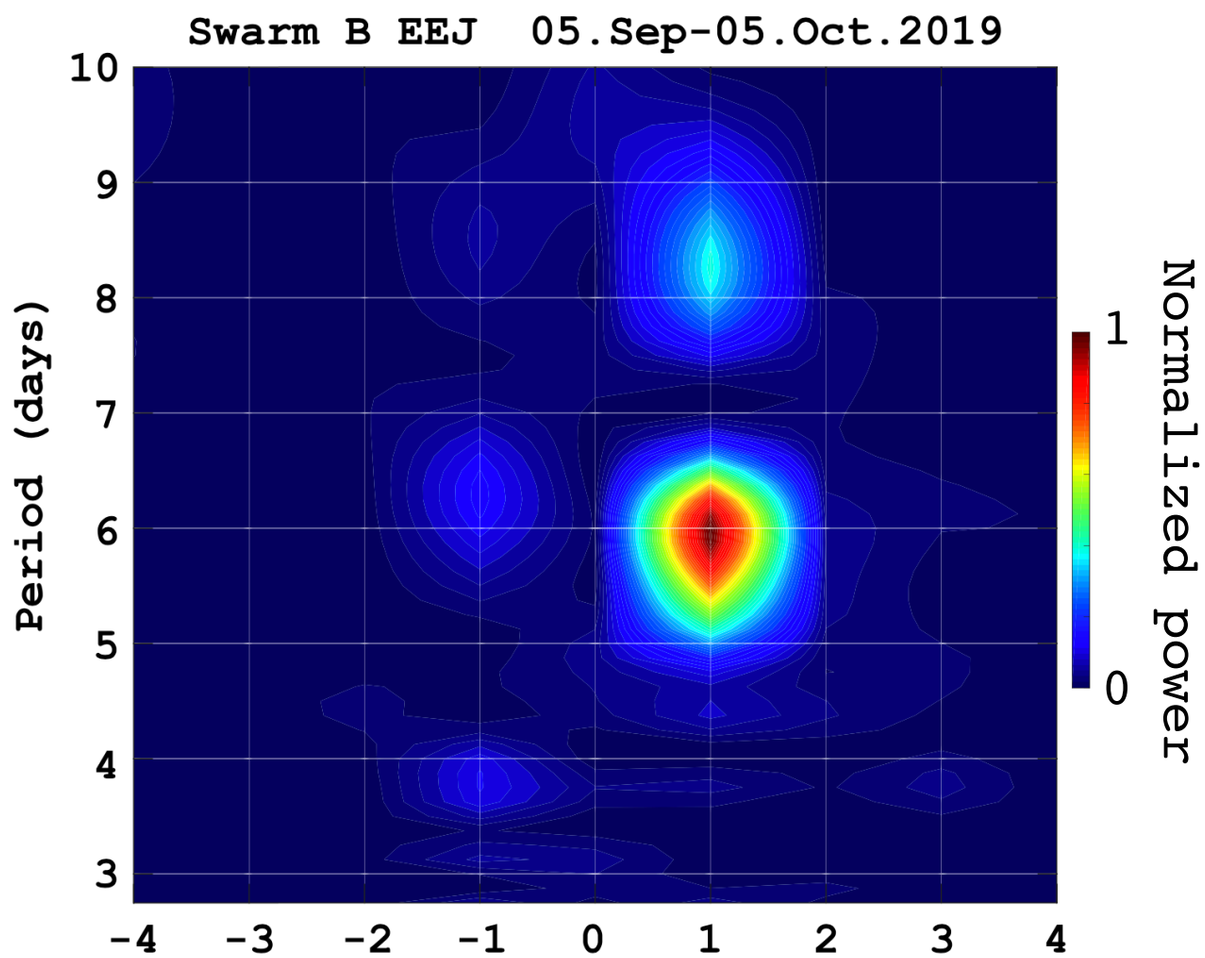
(=equatorial electrojet)

Longitude vs time plot (~12 LST)



[*Yamazaki et al.*, 2020]

Zonal wavenumber spectrum



Eastward

Westward

[*Yamazaki et al.*, 2020]

Shows westward-propagating ~6d variations (wavenumber = 1)

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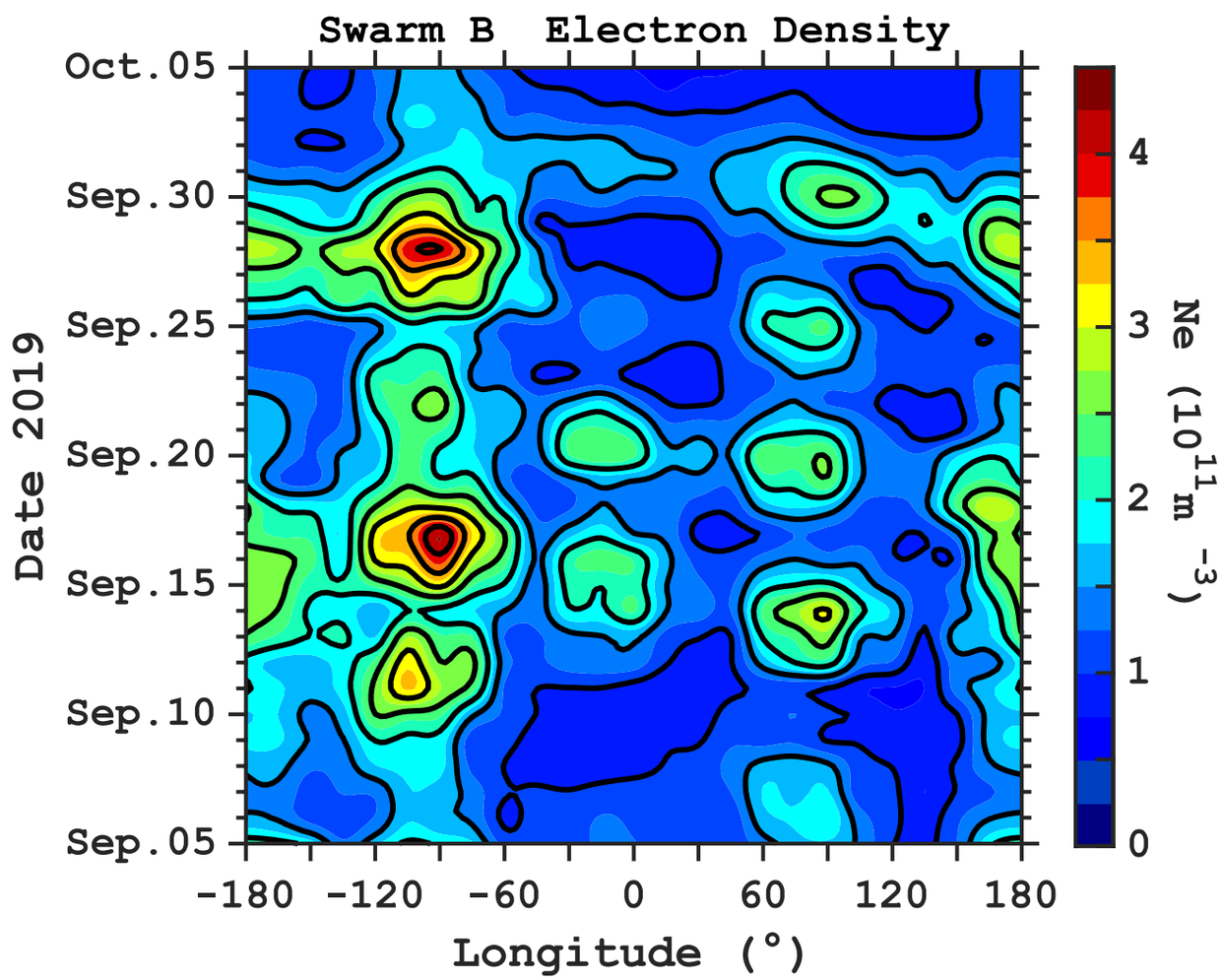
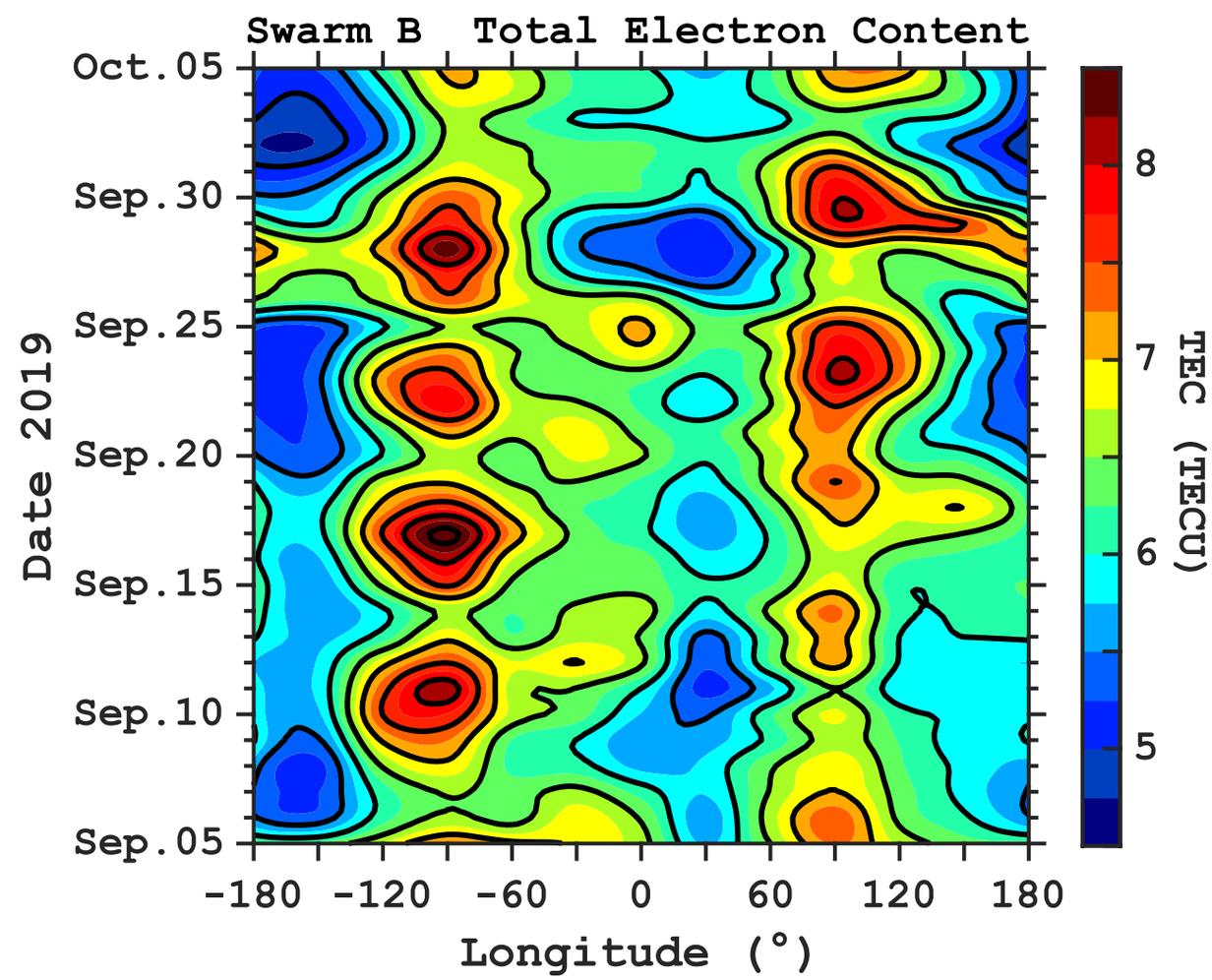
Ne & TEC during the SSW

Longitude vs time plot (Mag Lat. 20°)



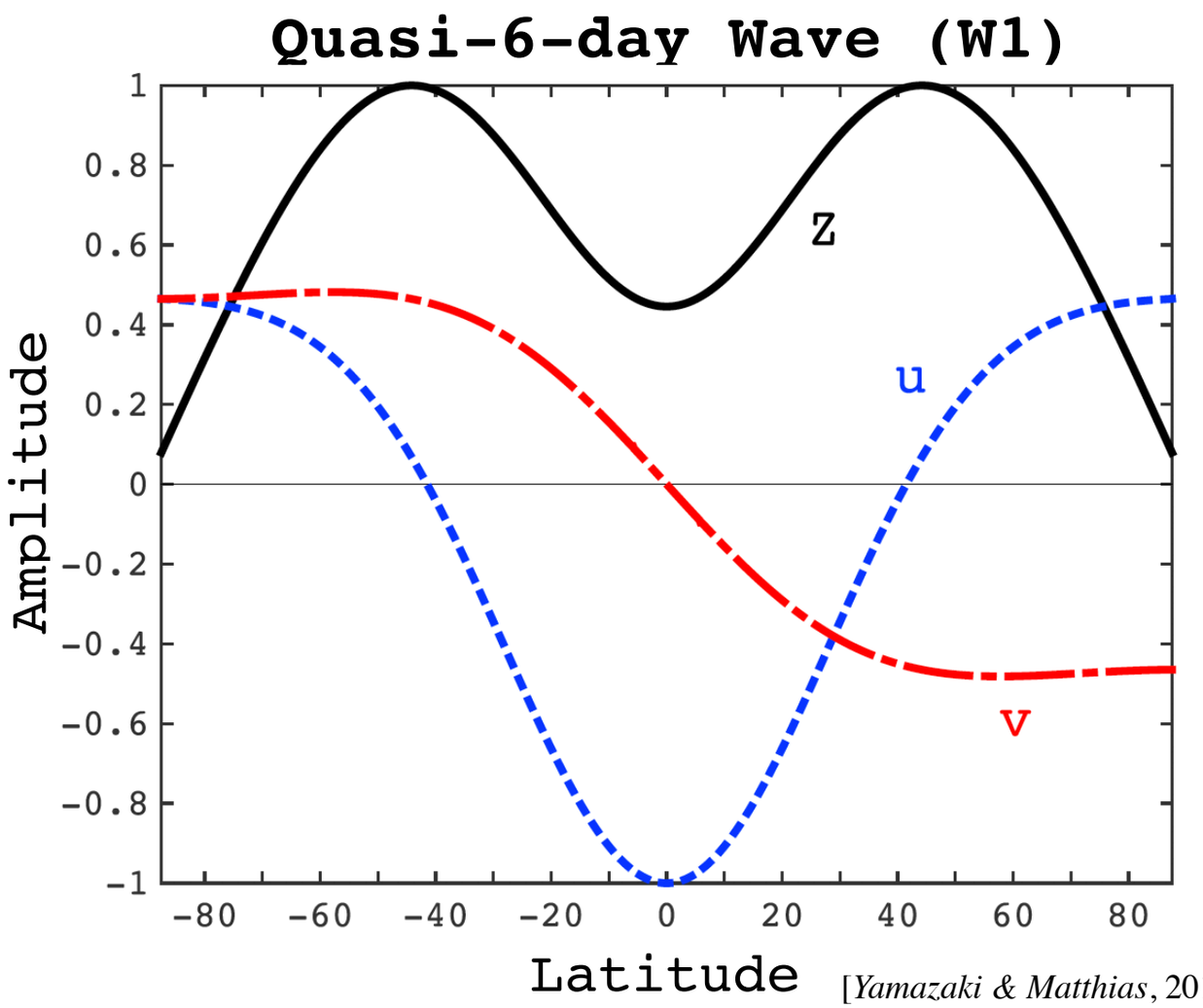
Longitude vs time plot (Mag Lat. 20°)



Also show ~6 day variations (longitudinally dependent)

→ Response to forcing by "quasi-6-day wave"??

What is a Quasi-6-day Wave?



[*Yamazaki & Matthias*, 2019]

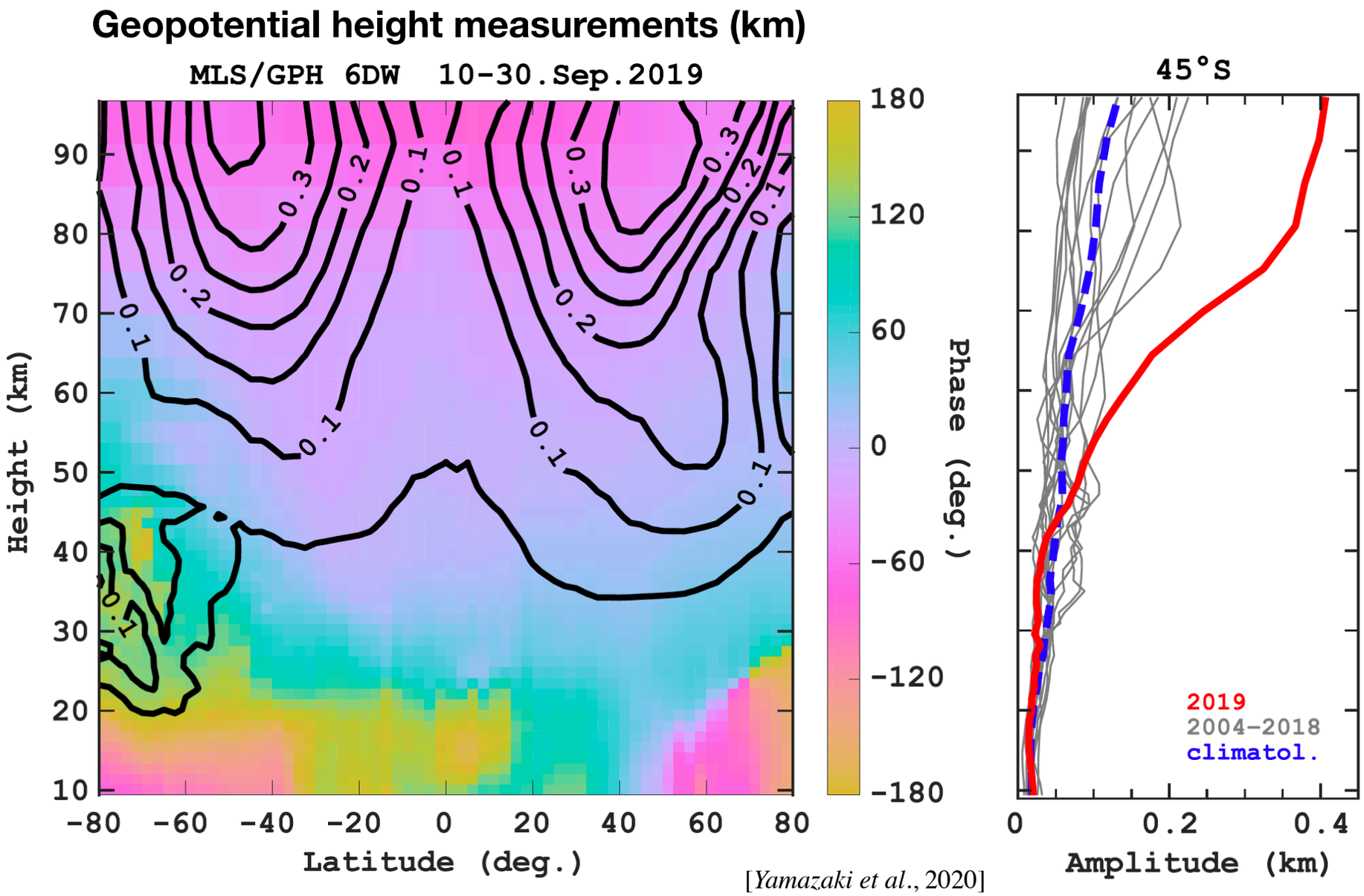
- **One of atmospheric "normal modes"**
- **Predicted by classical wave theory**
- **Zonal wavenumber = 1**
- **Westward-propagating**
- **Period: ~6 days**

z: geopotential height
u: zonal wind
v: meridional wind

Q: Was the Q6DW strong during the September 2019 SSW?
(=quasi-6-day wave)

Aura/MLS Observations of Q6DW

(=quasi-6-day wave)

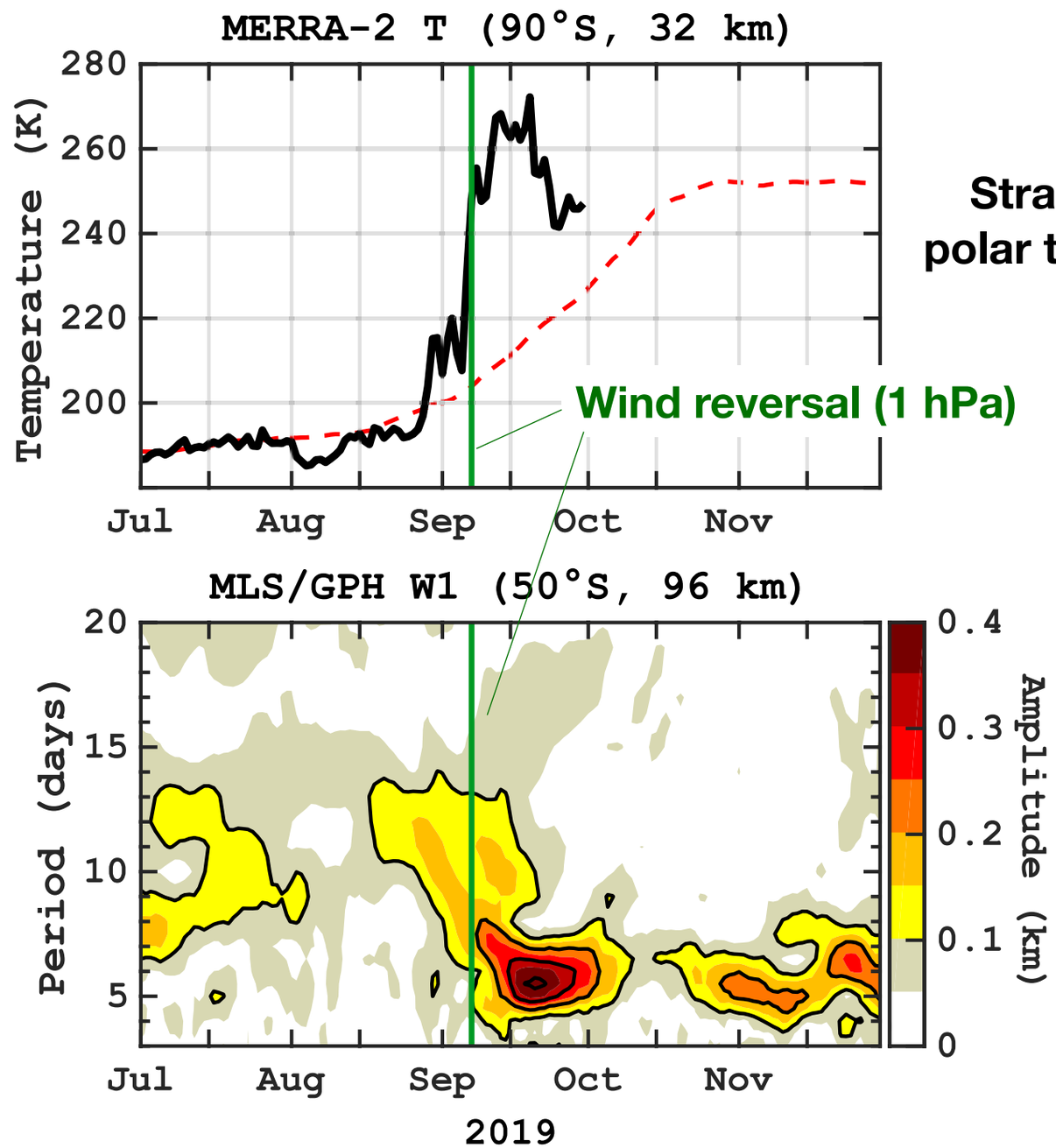


[*Yamazaki et al.*, 2020]

- **Symmetric about the equator; consistent with theory**
- **Amplitude is ~4 times greater than climatology during SSW**

Aura/MLS Observations of Q6DW

(=quasi-6-day wave)



Stratospheric polar temperature

Time vs period plot (Westward propagating wave with WN=1)

Q6DW enhancement follows the polar vortex weakening

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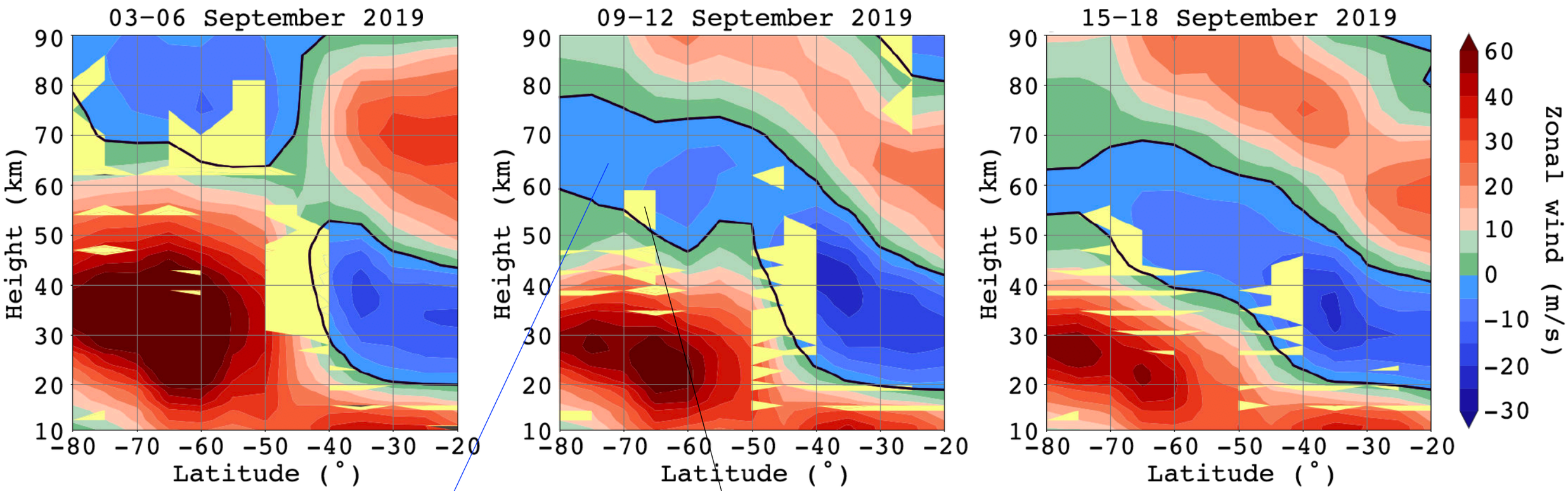
Possible Source of Q6DW

(=quasi-6-day wave)



Westward winds associated with SSW

Instability due to vertical wind shear

- **Instability driven in the stratosphere?**
- **Or driven by convective processes in the troposphere?**

→ More studies required to identify the source

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Conclusions

- A rare SSW event in the S.H. occurred in September 2019
- Involved polar temperature increase of 50+K/week; largest ever recorded
- Swarm observations reveal prominent ~6-day ionospheric variability
- Aura/MLS data show unusually strong quasi-6-day wave activity
- Highlighting the importance of wave coupling during S.H. SSW
- More information of this study can be found in:

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September 2019 Antarctic Sudden Stratospheric Warming: Quasi-6-Day Wave Burst and Ionospheric Effects

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