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The 2019/2020 QBO Disruption in Aeolus Wind Lidar Observations

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3rd Aeolus NWP Impact Meeting, Webex, 3 December 2021

Image: ESA

THE EUROPEAN SPACE AGENCY

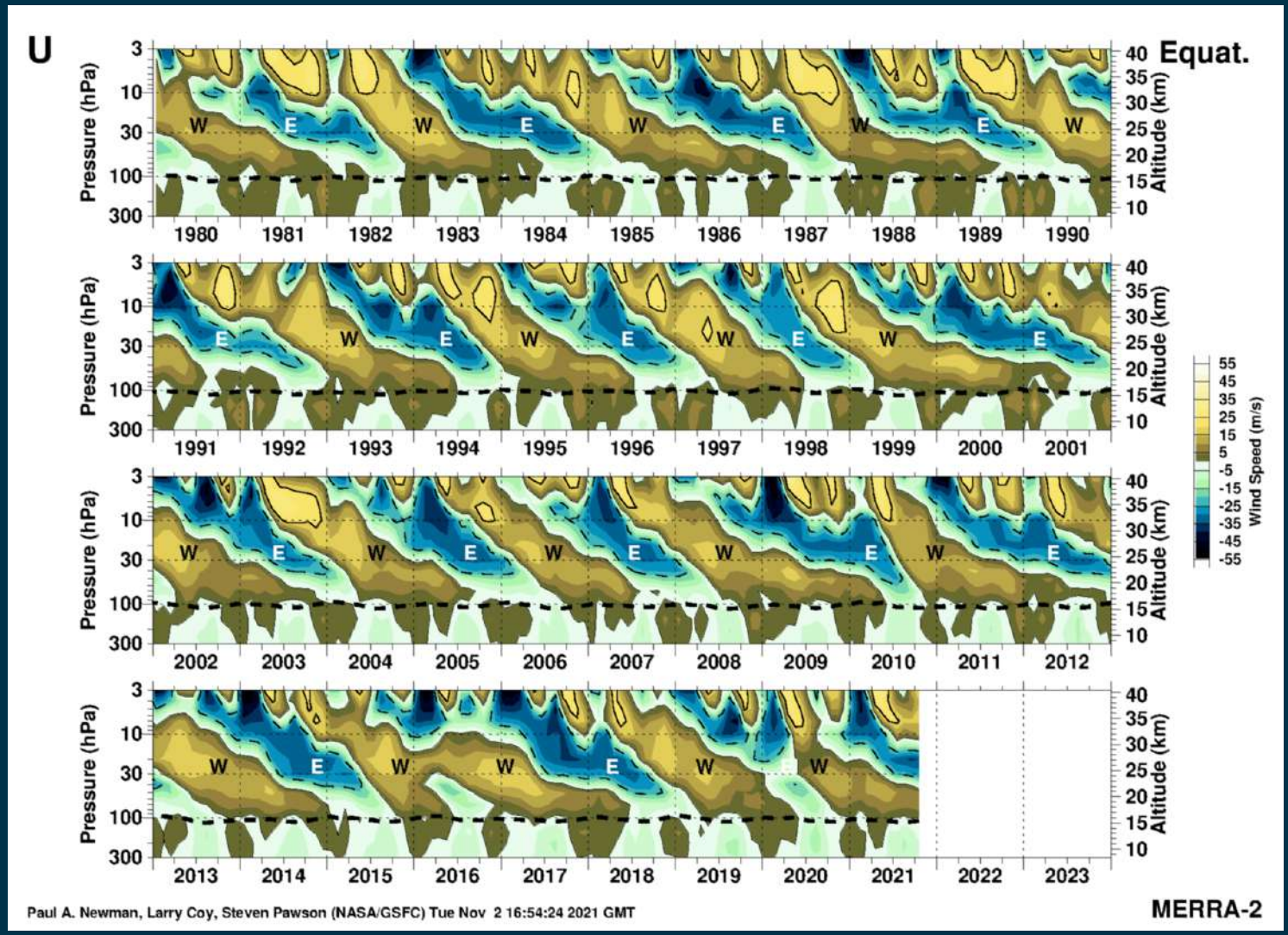
Why the QBO?

- The Quasi-Biennial Oscillation (QBO) is **vital** for long-term forecasts
- It has global impacts:
  - Tropical and Subtropical troposphere – MJO and equatorial wave propagation
  - ITCZ shifts depending on QBO phase
  - Polar vortex strength and NAO response - Holton-Tan effect
- Aeolus is the **only** provider of direct global wind measurements – all others are either derived winds (e.g. from radiances) or local winds (e.g. radiosondes)
- The QBO is a global wind phenomenon – therefore Aeolus could provide the **first** direct measurements of its full global extent

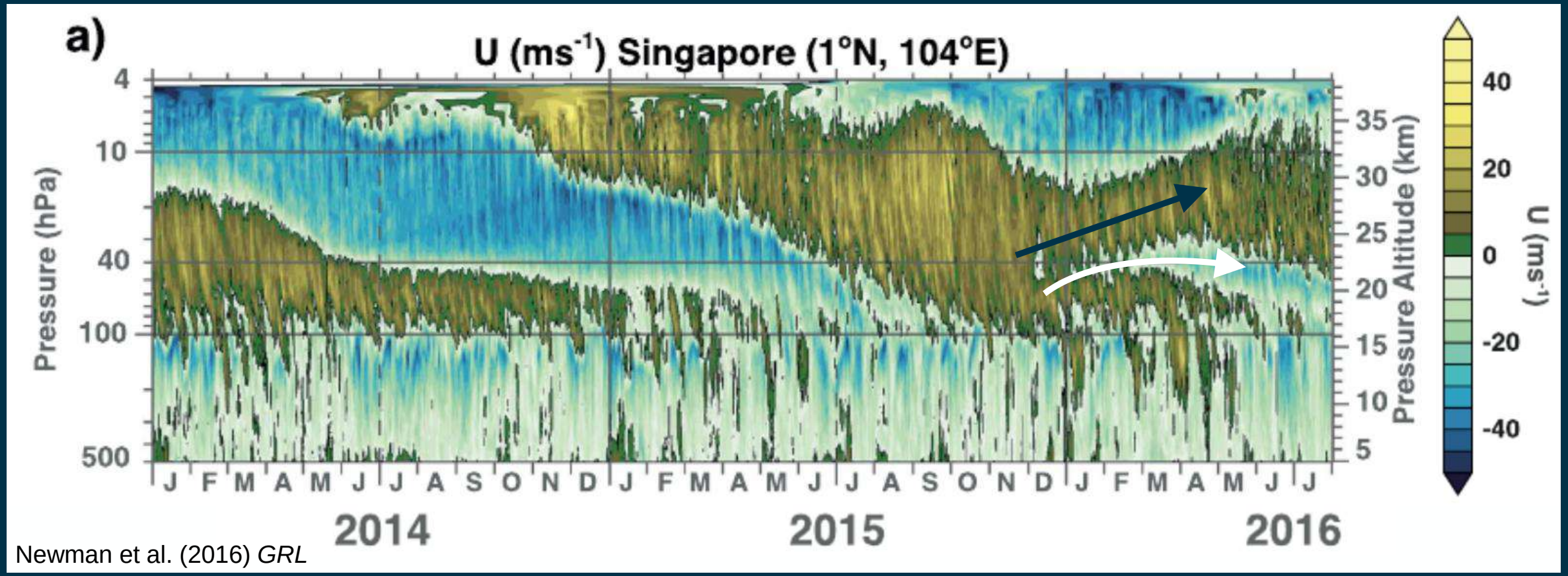
The Quasi-Biennial Oscillation (QBO)

The Quasi-Biennial Oscillation (QBO) is a regular oscillation of the zonal winds in the tropical stratosphere, alternating between westerlies and easterlies, and propagating downward towards the tropopause.

- The QBO is driven by atmospheric waves, including gravity waves
- These waves propagate upwards and ‘break’ in the stratosphere
- The resultant force leads to the alternating wind pattern seen opposite



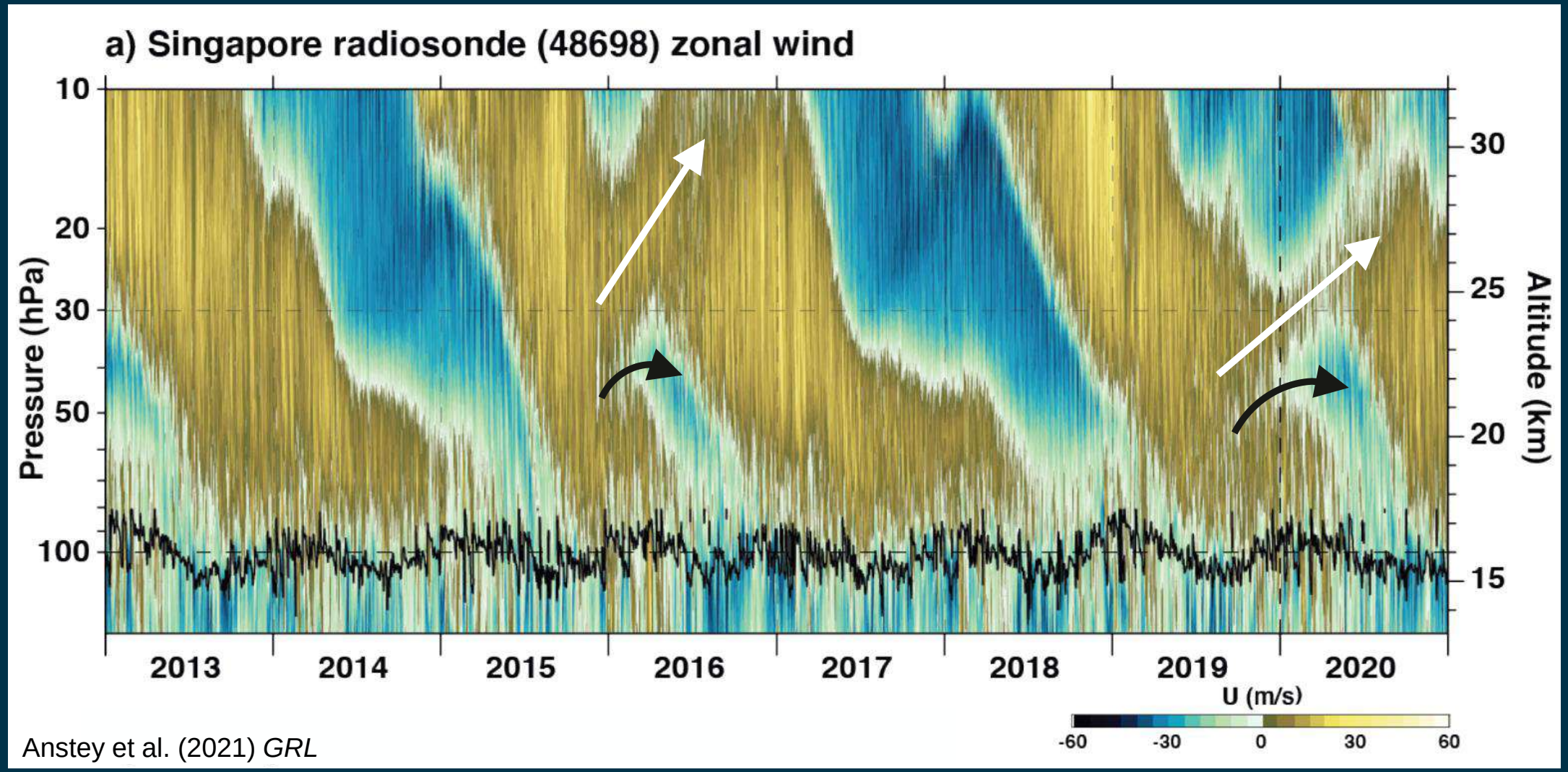
2015-2016 QBO Disruption



Newman et al. (2016) *GRL*

- Steady downward propagation of the QBO's westerly phase is displaced anomalously upwards
- Easterly jet develops at ~ 40 hPa

2019-2020 QBO Disruption



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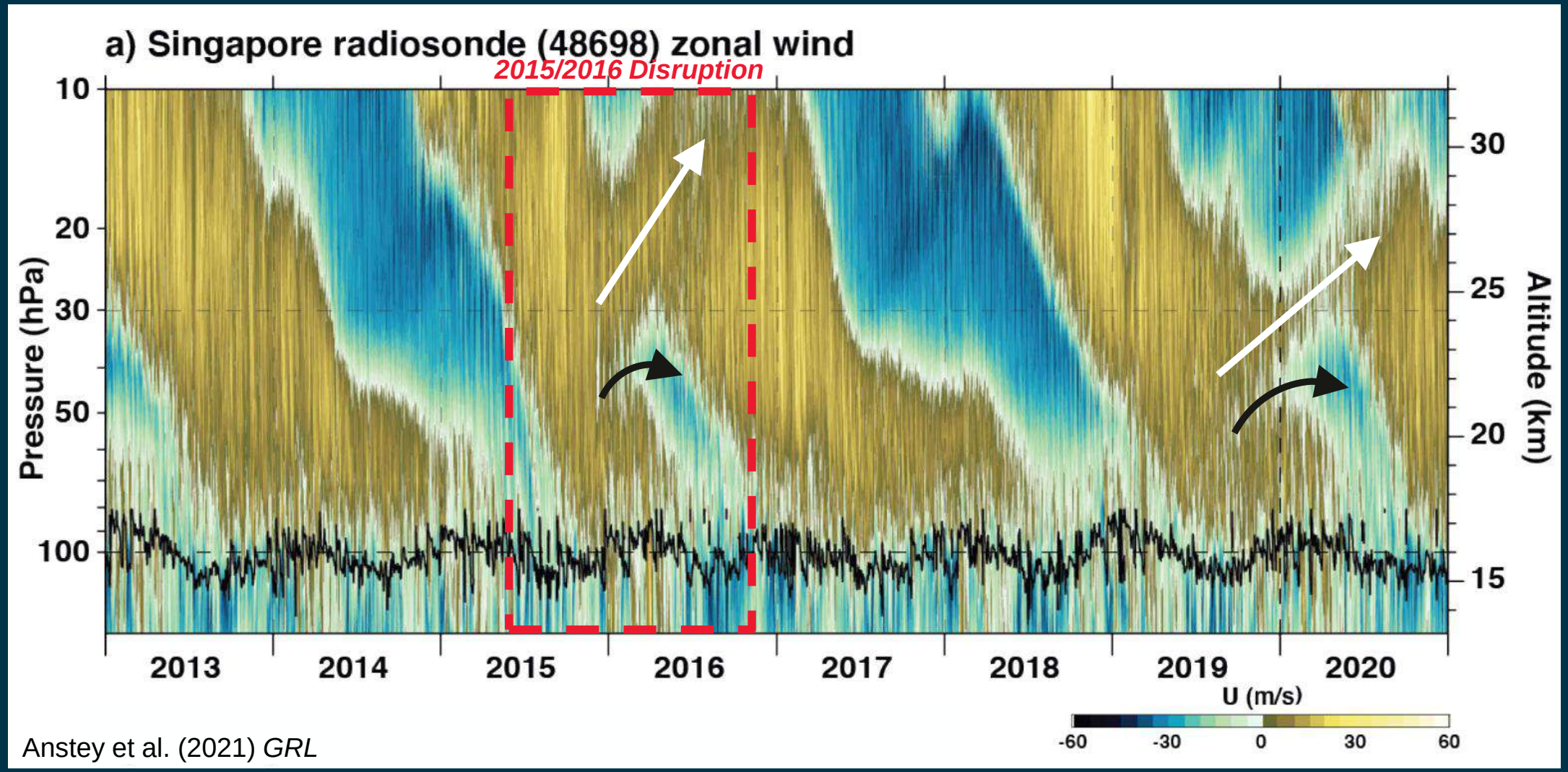

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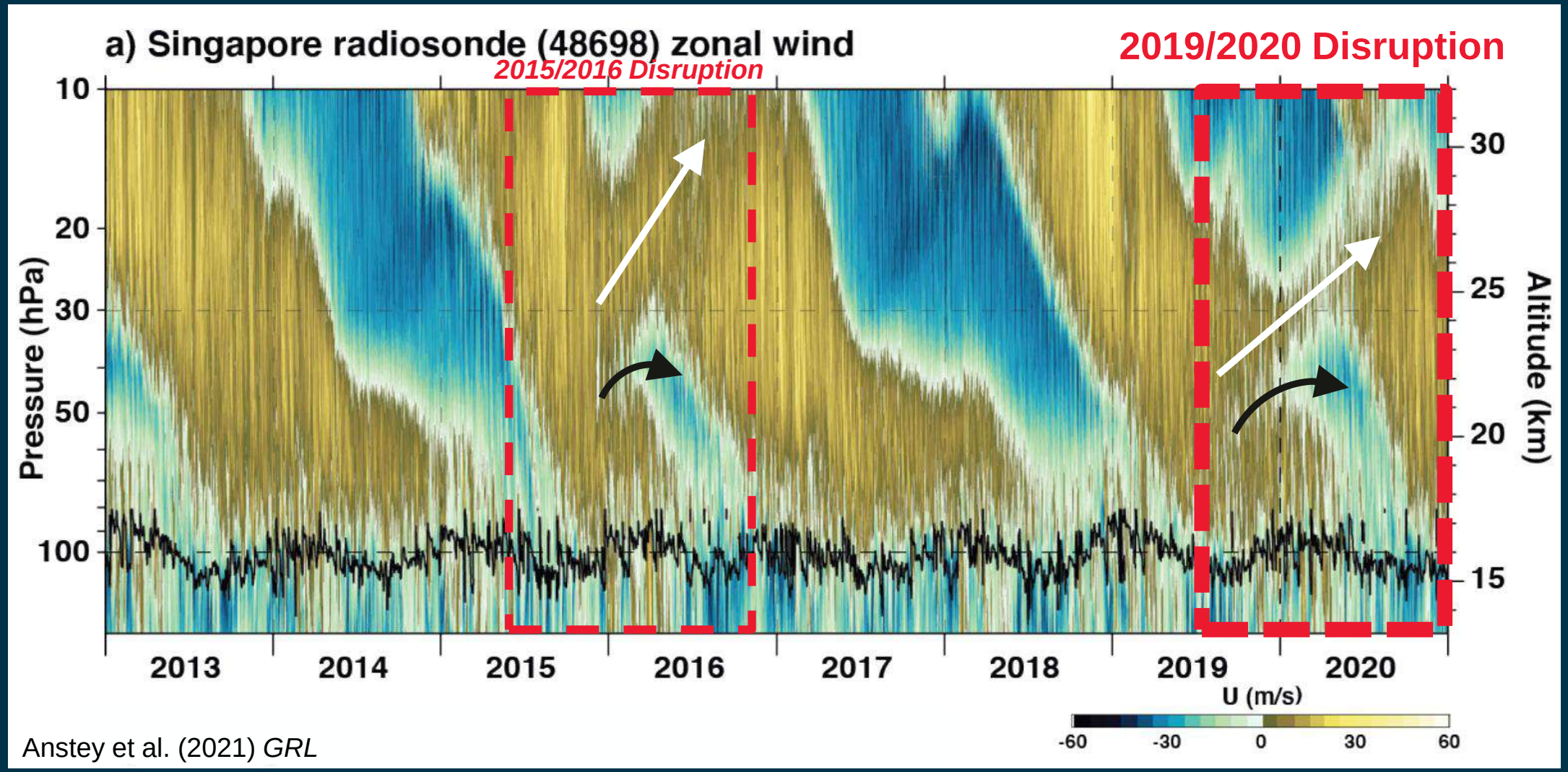

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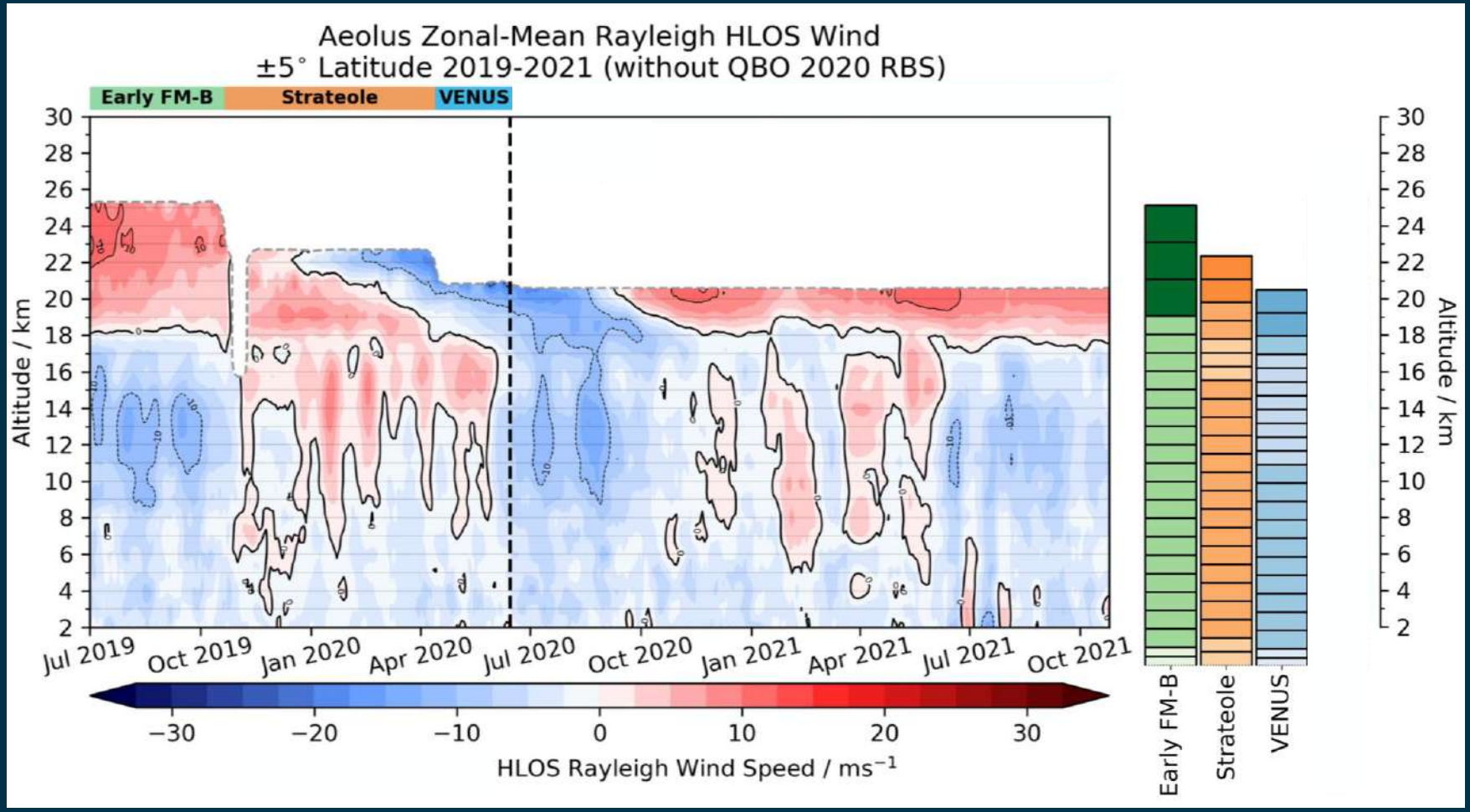
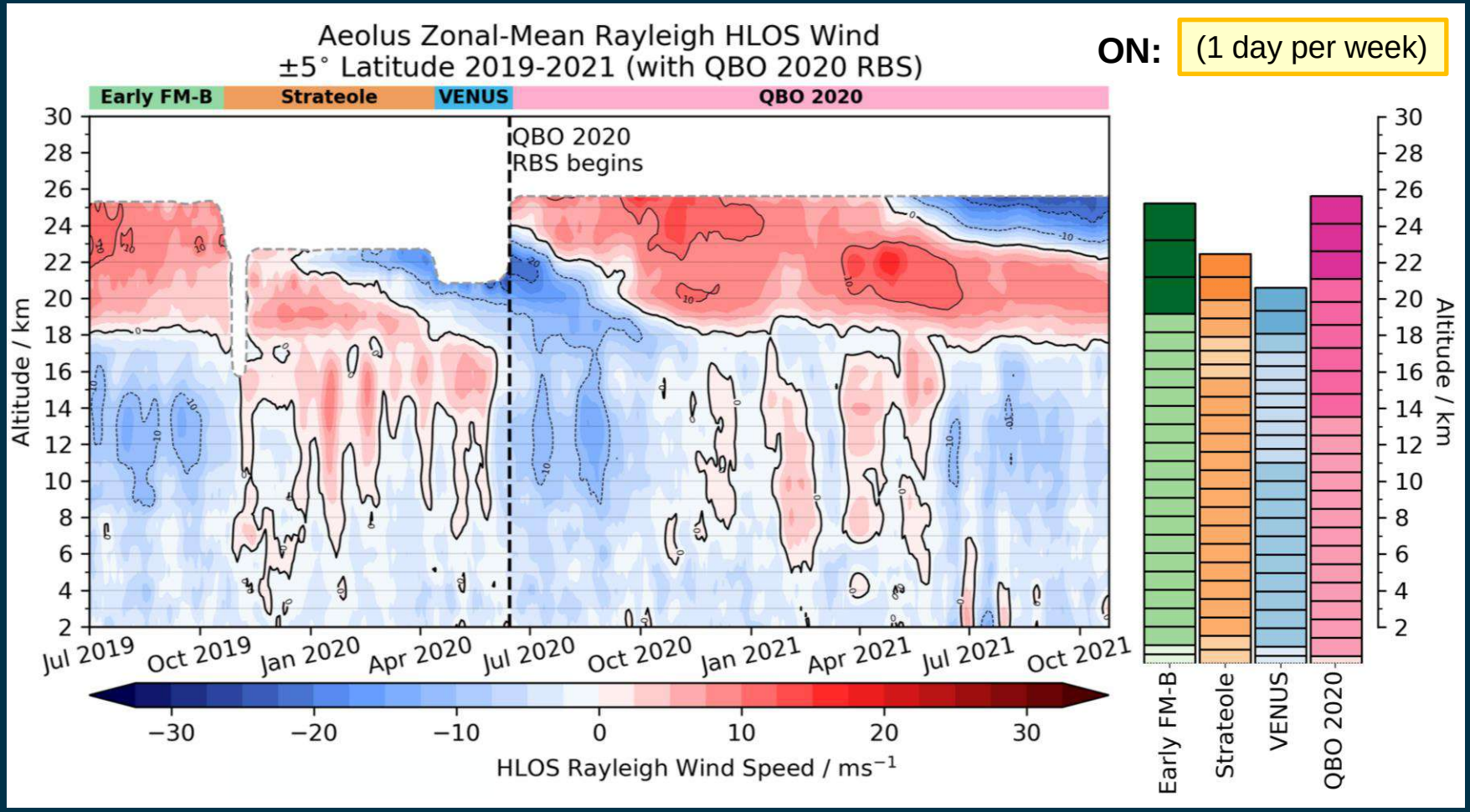
2019-2020 QBO Disruption with Aeolus

- Limited observations of QBO winds without any specific RBS
- Some of the 2019/2020 QBO disruption can be seen by Aeolus



2019-2020 QBO Disruption with Aeolus

- Limited observations of QBO winds without any specific RBS
- Some of the 2019/2020 QBO disruption can be seen by Aeolus
- Special **QBO2020 RBS** introduced in June 2020
- Aeolus can see the lower portion of the QBO
- New easterly QBO has started filtering down into Aeolus' viewing range above 22 km
- Equatorial waves clearly visible in the UTLS



B11 Update in progress…

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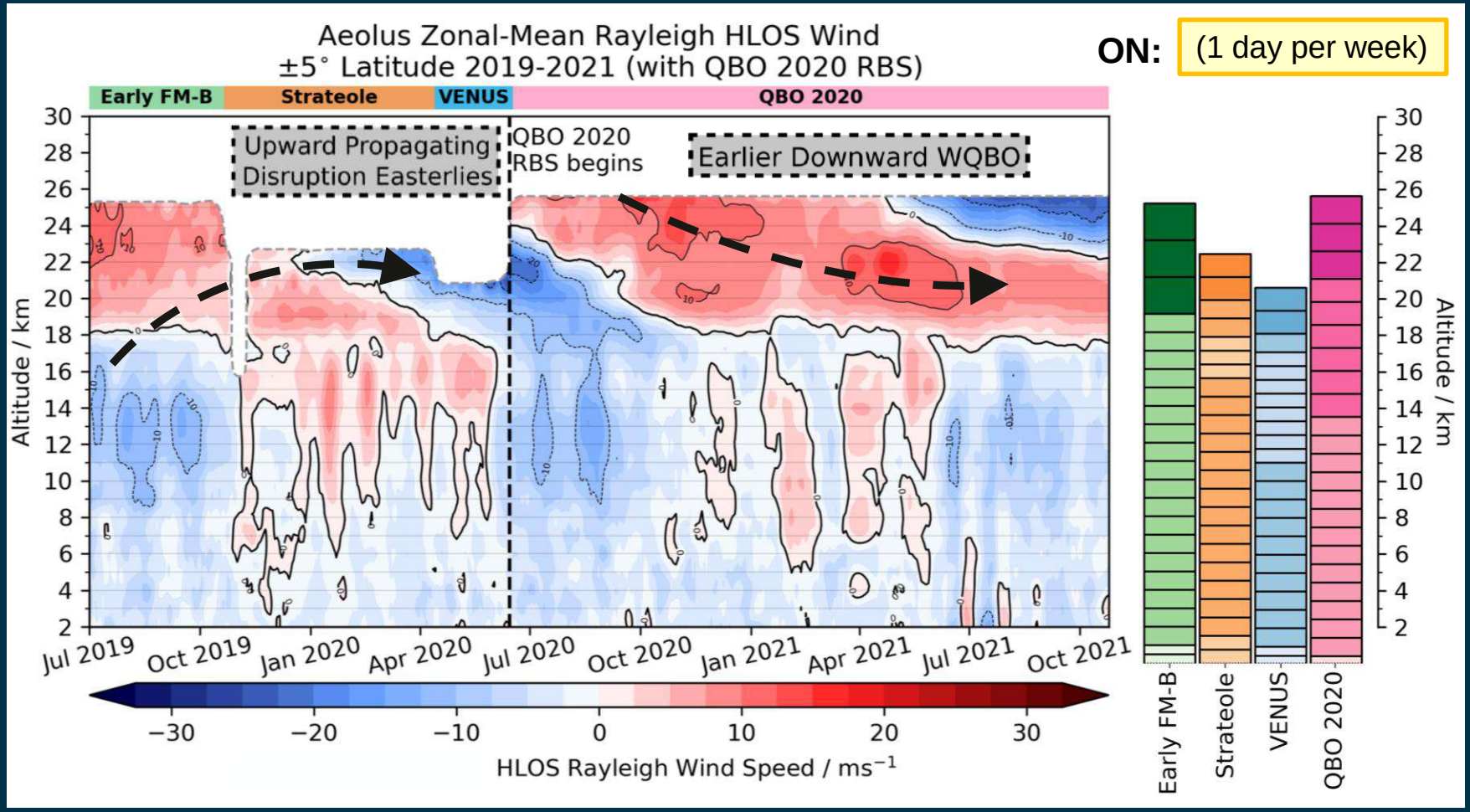
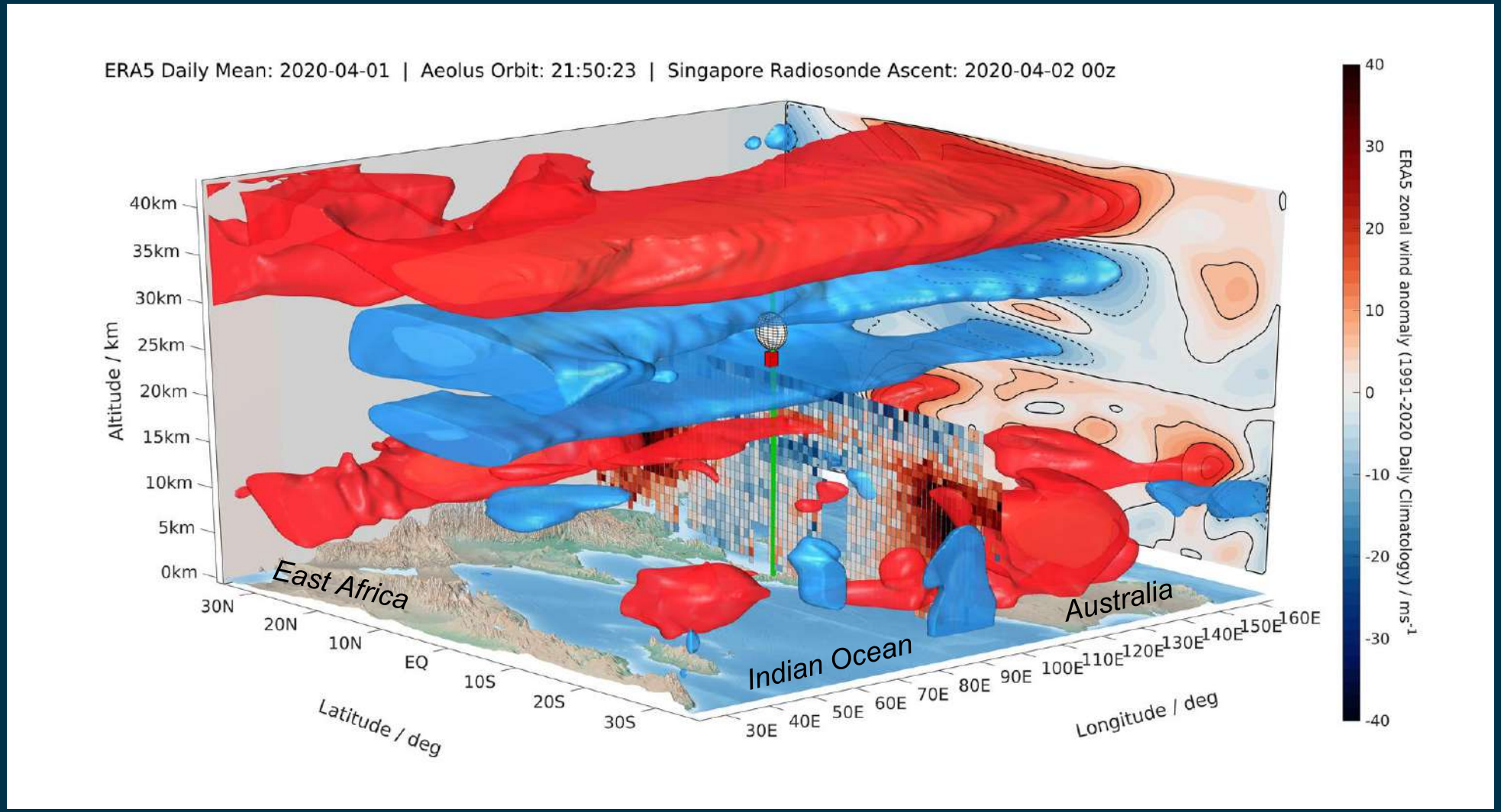


B11 Update in progress…

Observations and Reanalysis



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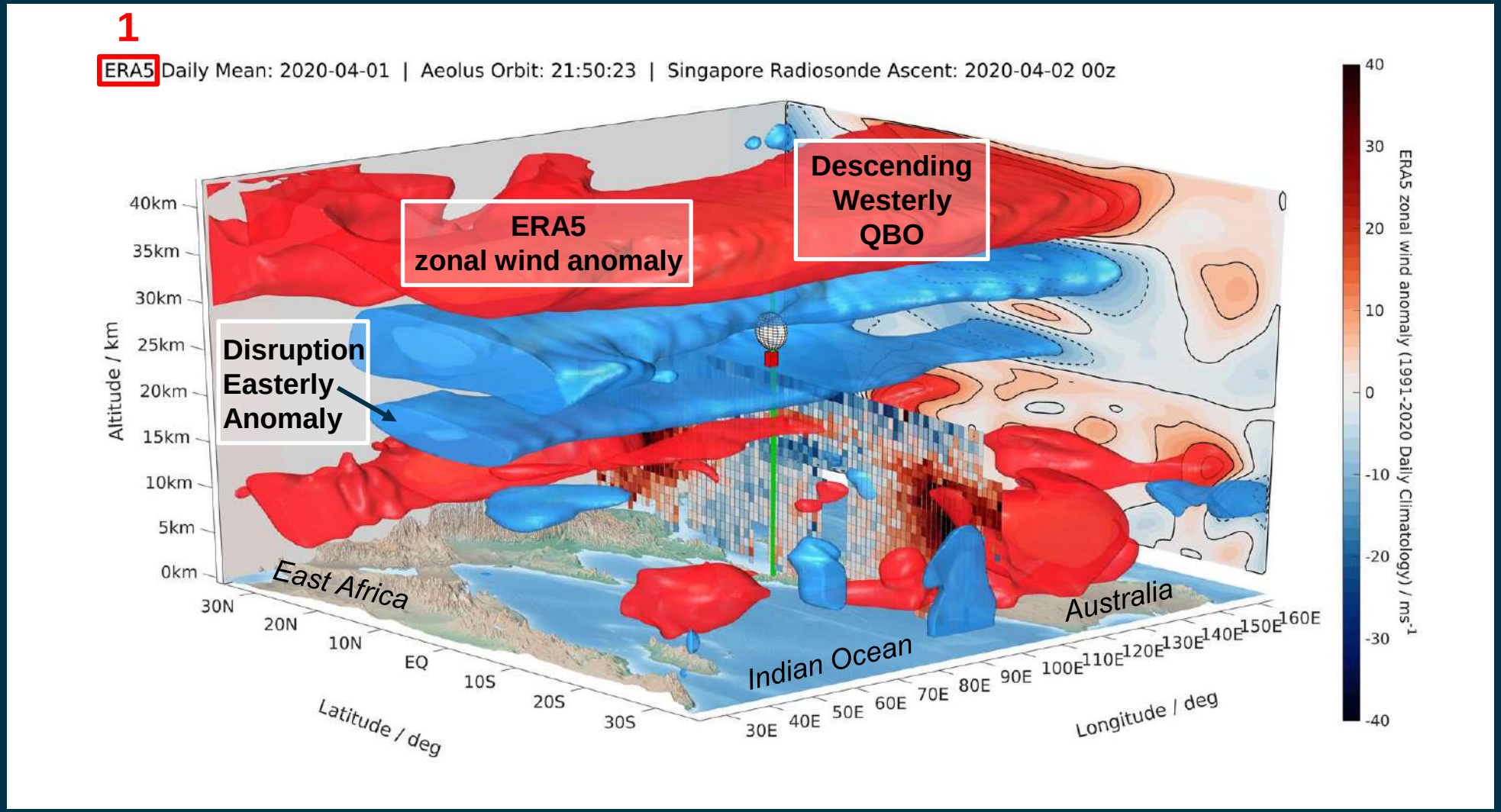

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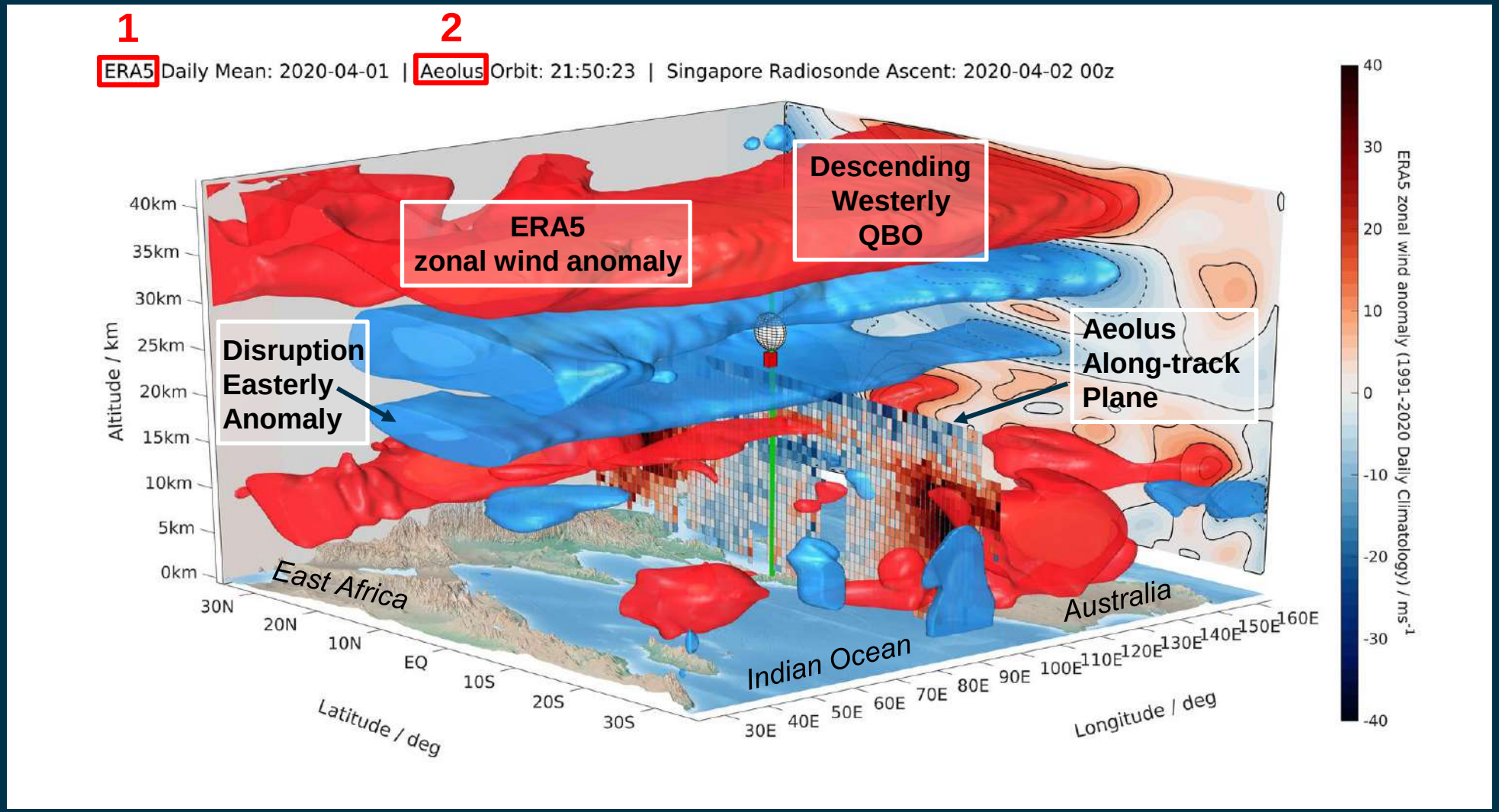

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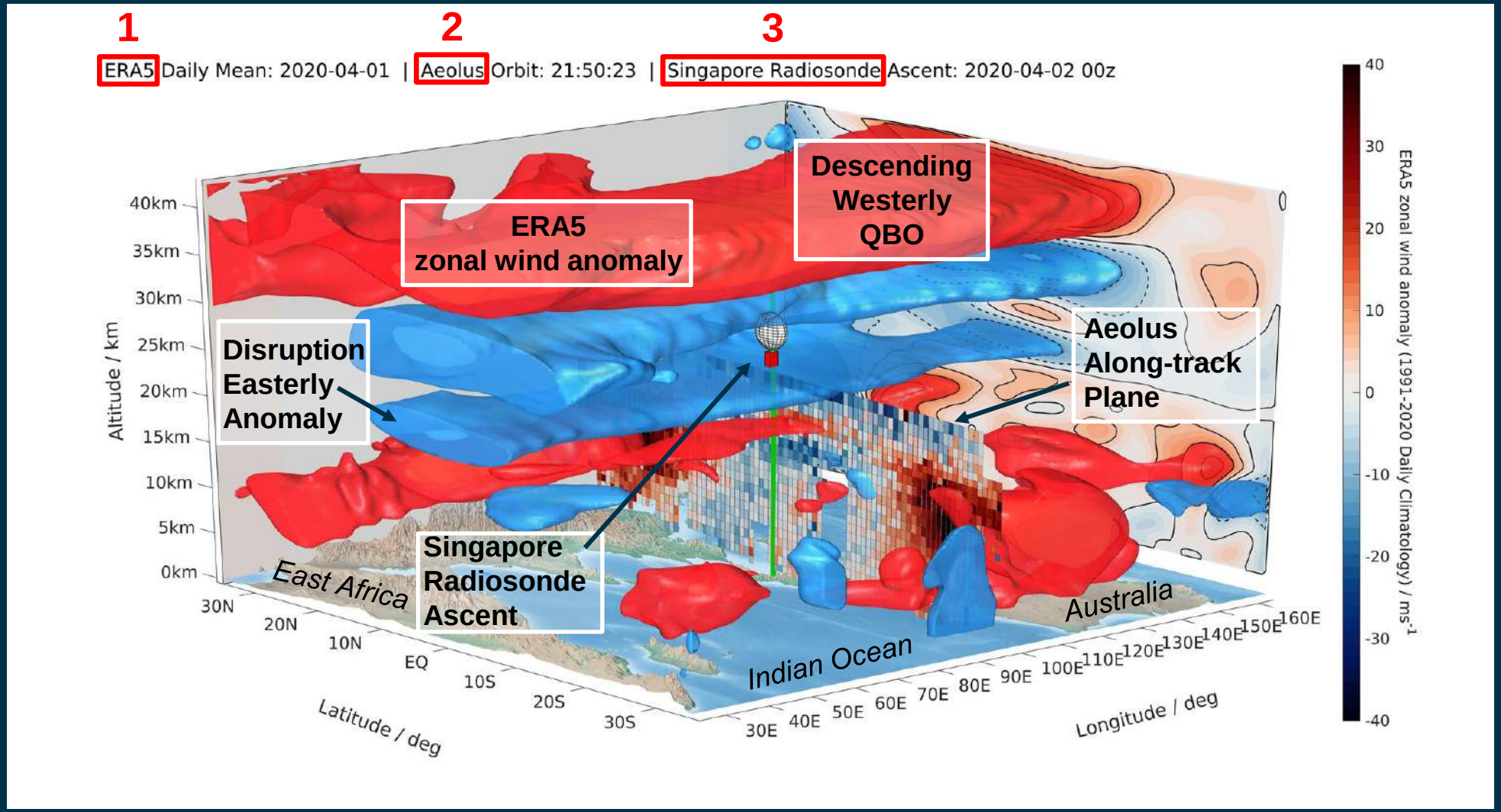


Comparison between datasets

- Comparing between Aeolus and Singapore Radiosonde observations, and ERA5 reanalysis
- All data projected into Aeolus' Horizontal Line-of-sight (HLOS) direction

Aeolus data

- Descending orbit ~21:50 each Wednesday
- All data within 200 km of radiosonde launch site
- Rayleigh Clear only; <8 m/s estimated error
- These results do not contain reprocessed B11 data – update in progress

Radiosonde data

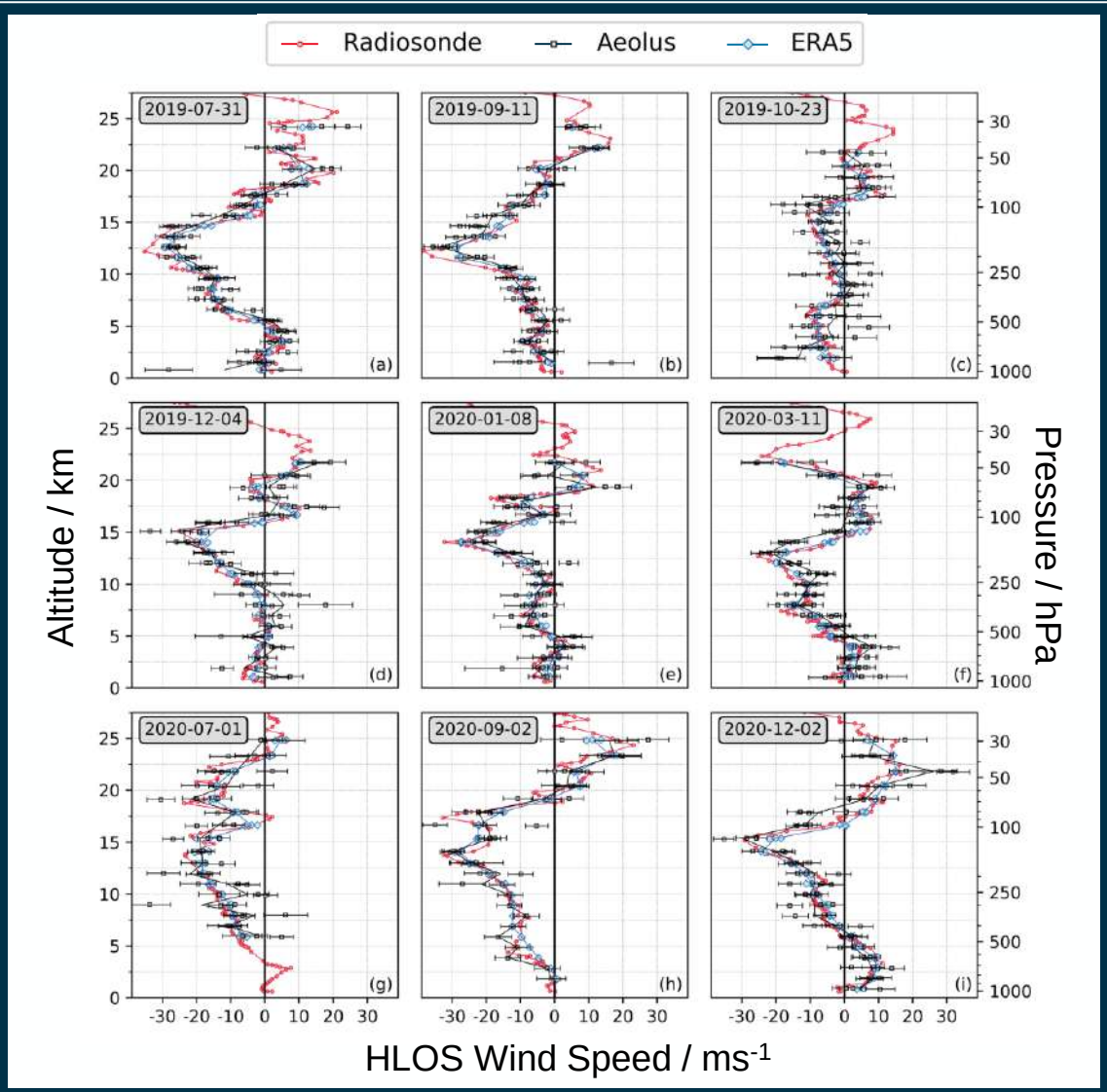
- 00z launch each Thursday morning
- Averages ~70 km distance from Aeolus points
- Assimilated into ERA5; (Aeolus is fully independent)

ERA5 data

- Interpolated onto each Aeolus data point in space and time

2019-2020 QBO Disruption with Aeolus

- Panels (a) – (i) show a selection of co-located profiles during the QBO disruption.
- Both Singapore Radiosonde and ERA5 measurements have been projected along HLOS.
- Shows profiles from both before and after the QBO2020 RBS are introduced.
- Aeolus profiles validate generally well against Singapore radiosondes and ERA5.



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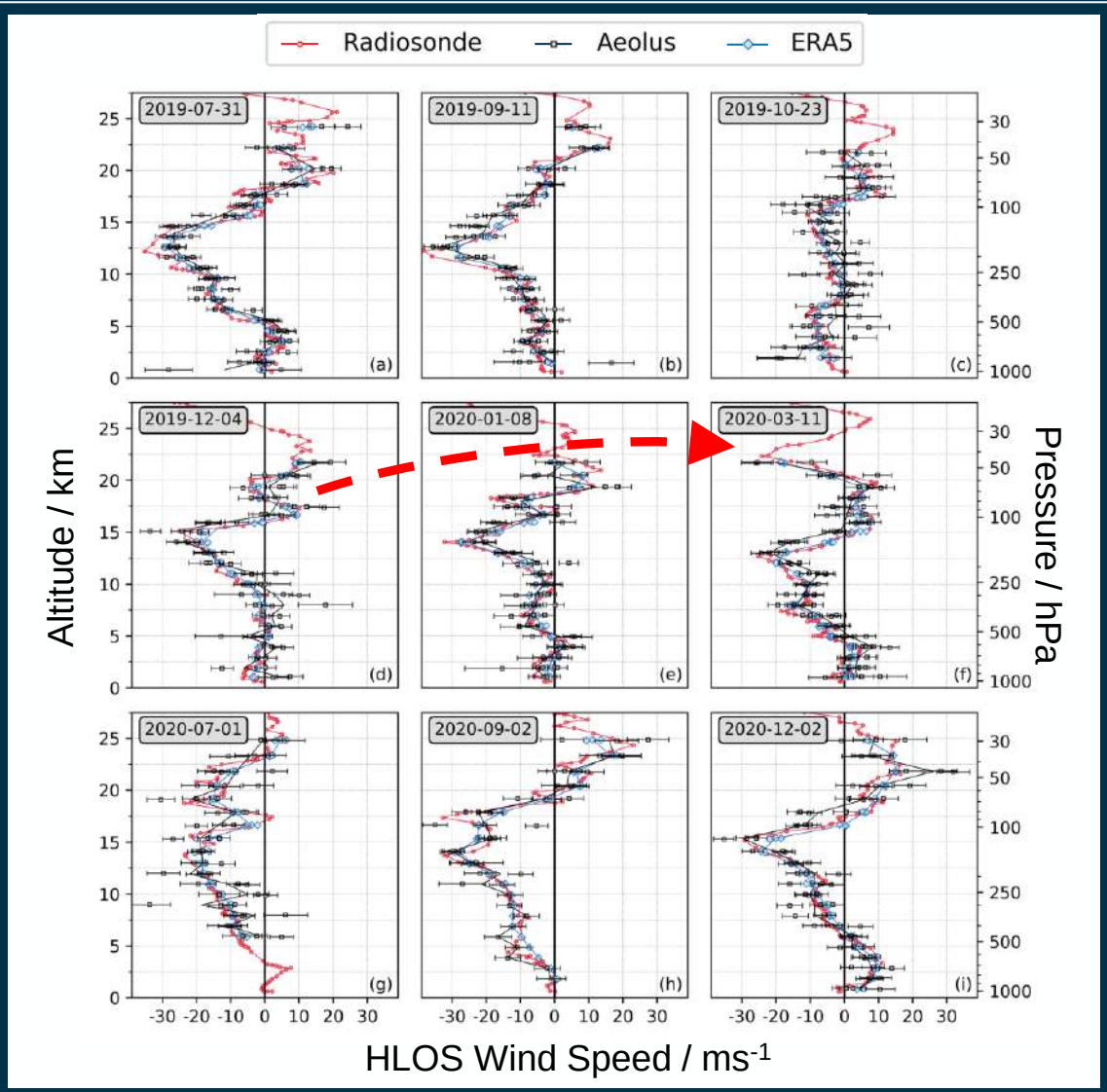

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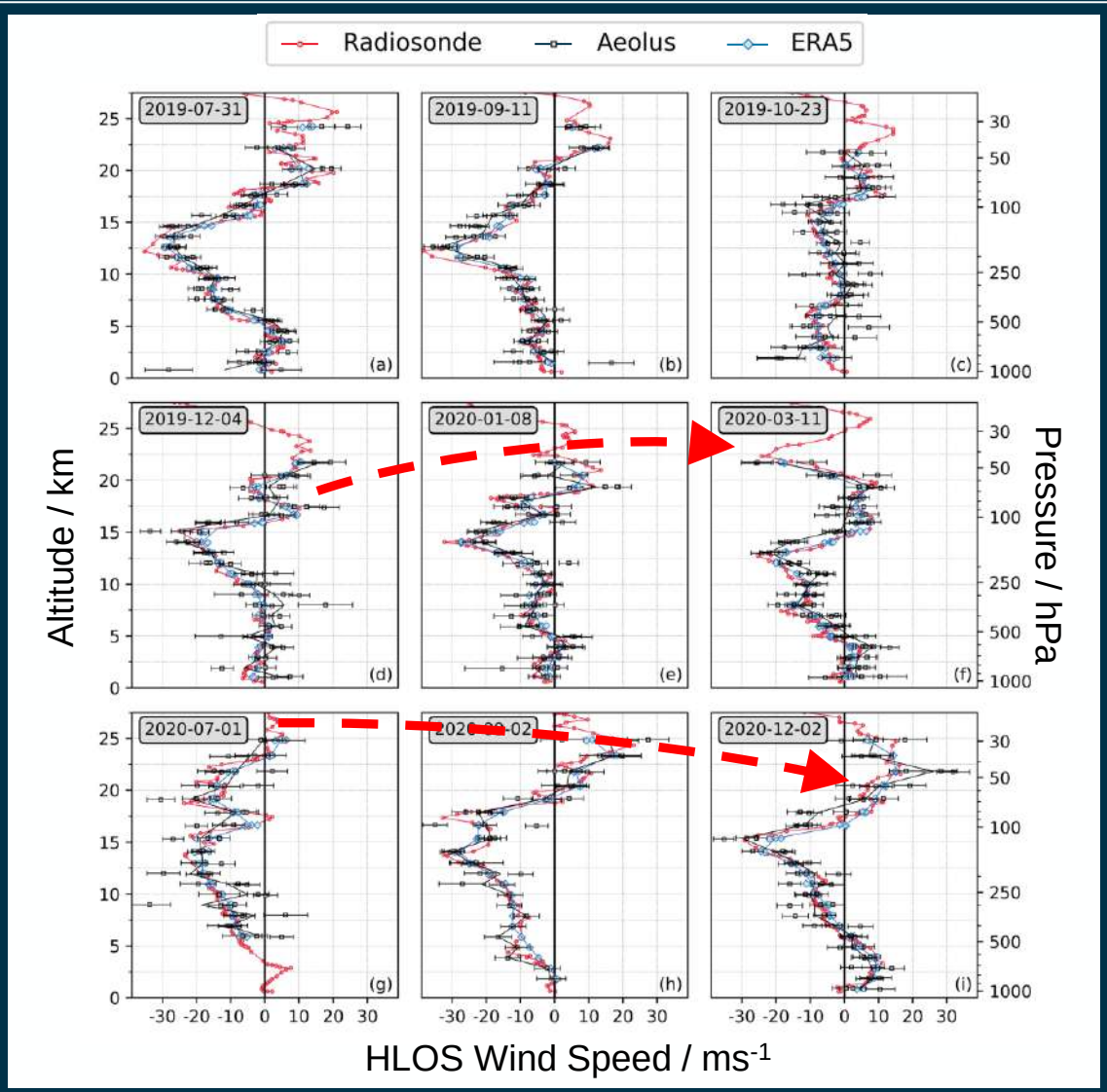

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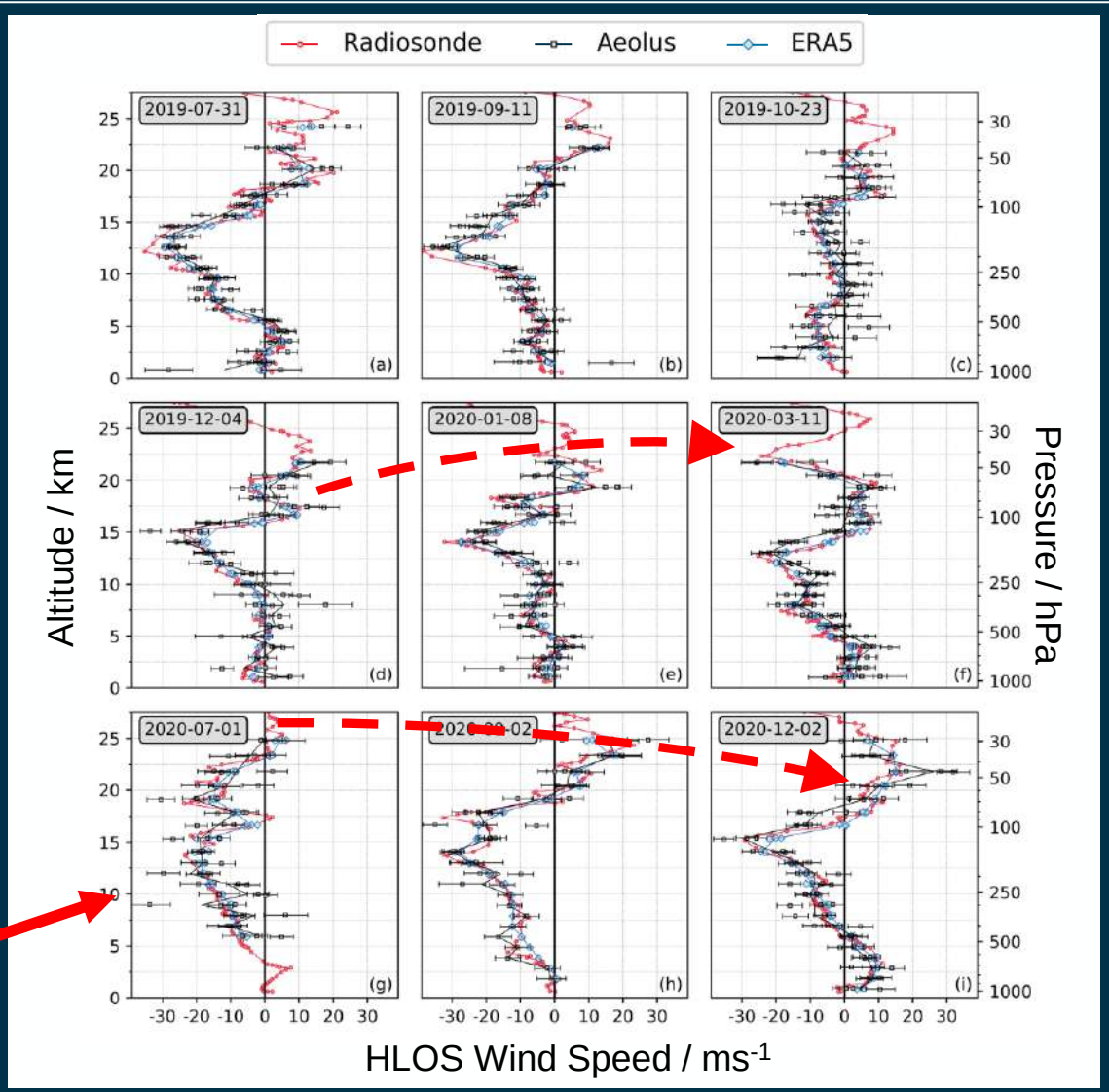
- Easterly disruption can be seen in panels (d) – (f), followed by descending westerlies in panels (g) – (i).
- Could the increase in random error in panel (g) be due to upper-level cirrus attenuating the signal?



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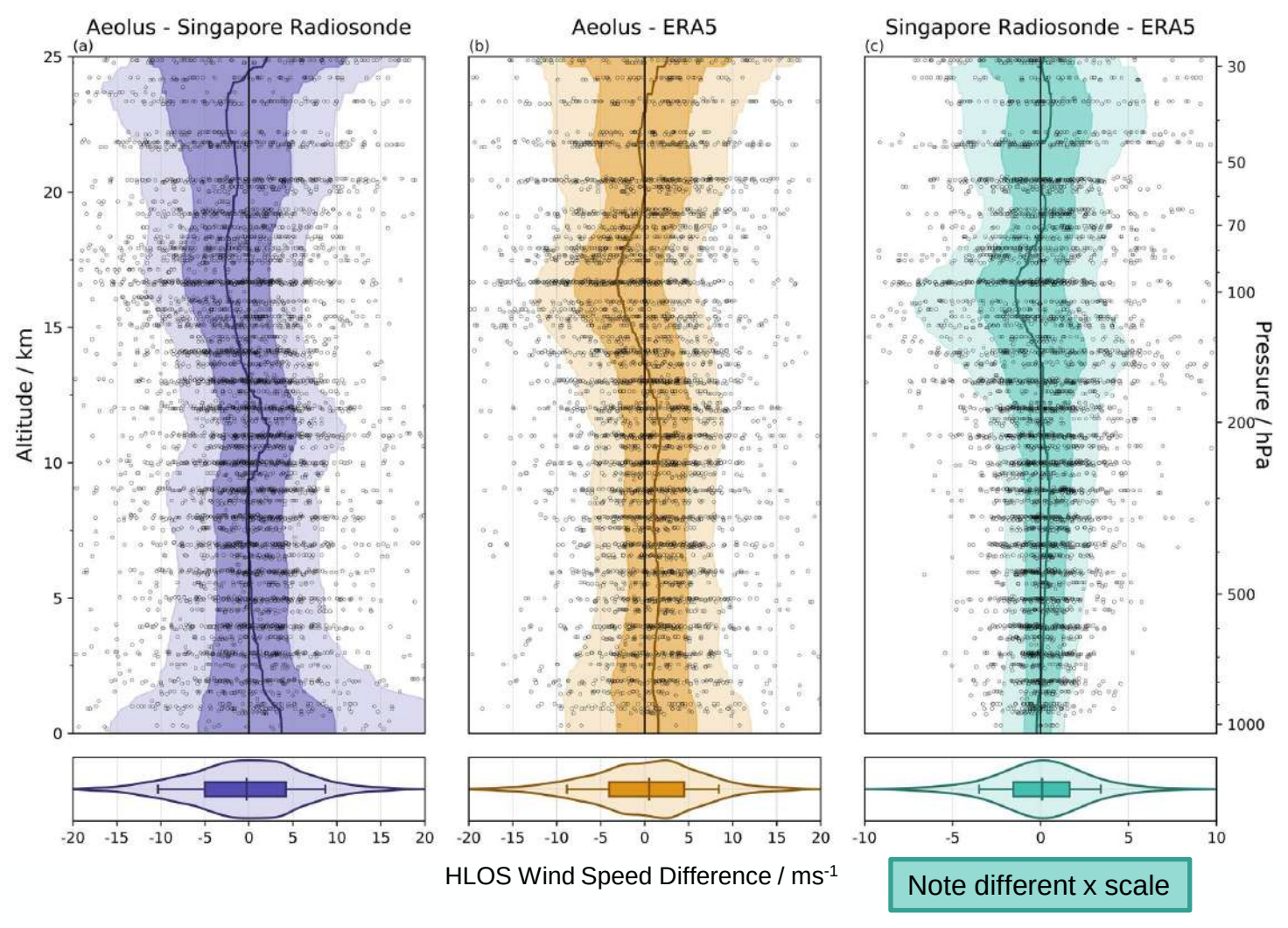
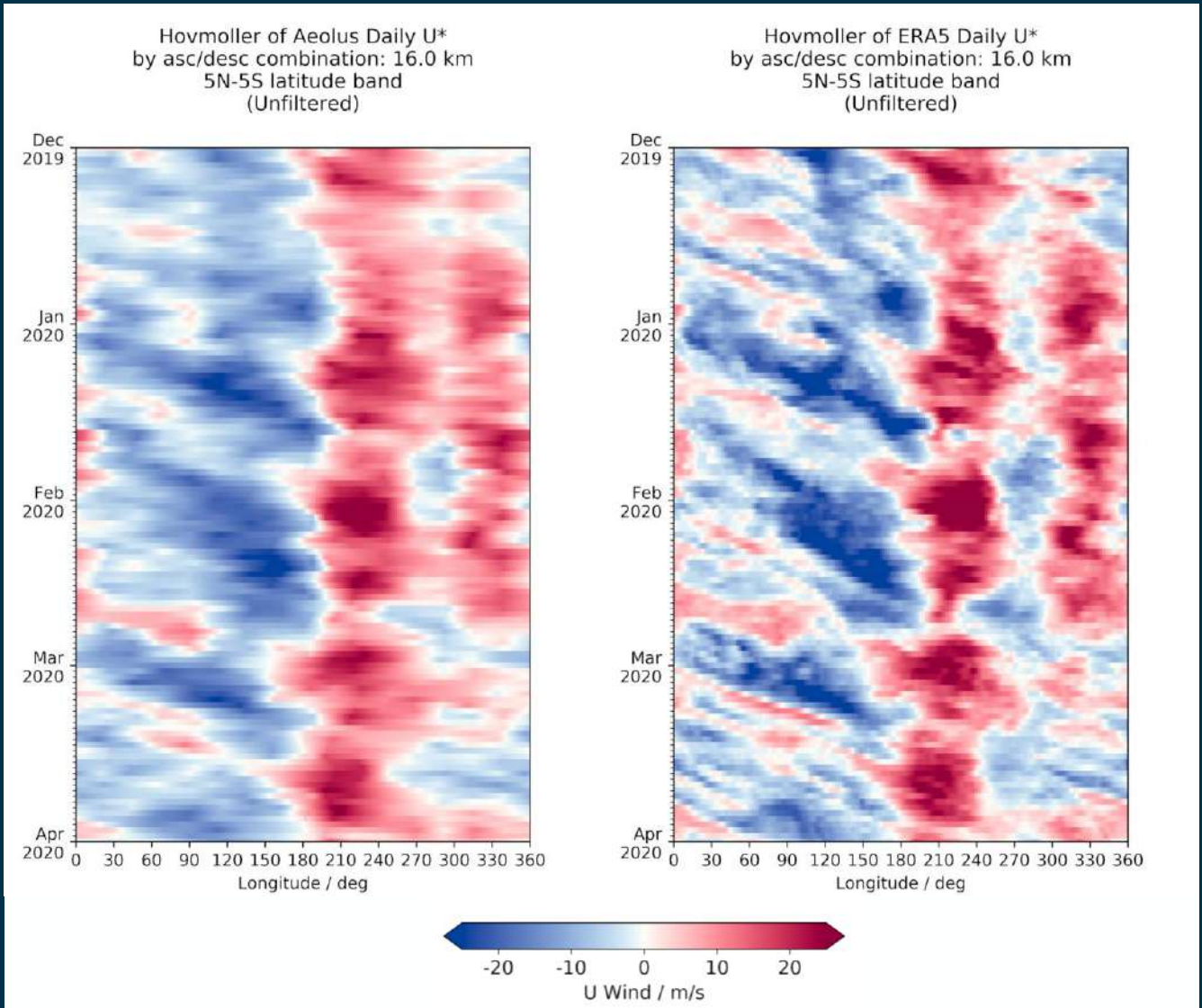


- Aeolus profiles validate well against Singapore radiosondes and ERA5.
- Descending node only, 1 orbit per week → source of bias
- Singapore Radiosonde data assimilated into ERA5 so smaller differences as expected
- Both observing instruments have a negative bias around the tropopause
- WQBO → EQBO during observation period, could bias results

Bias: **-0.28 m/s** Std.Dev: **9.44 m/s** Bias: **0.49 m/s** Std.Dev: **7.88 m/s** Bias: **0.08 m/s** Std.Dev: **3.11 m/s**

Equatorial Waves during the QBO Disruption



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- Eastward propagating Kelvin waves can be seen even without filtering
- Good agreement between Aeolus and ERA5

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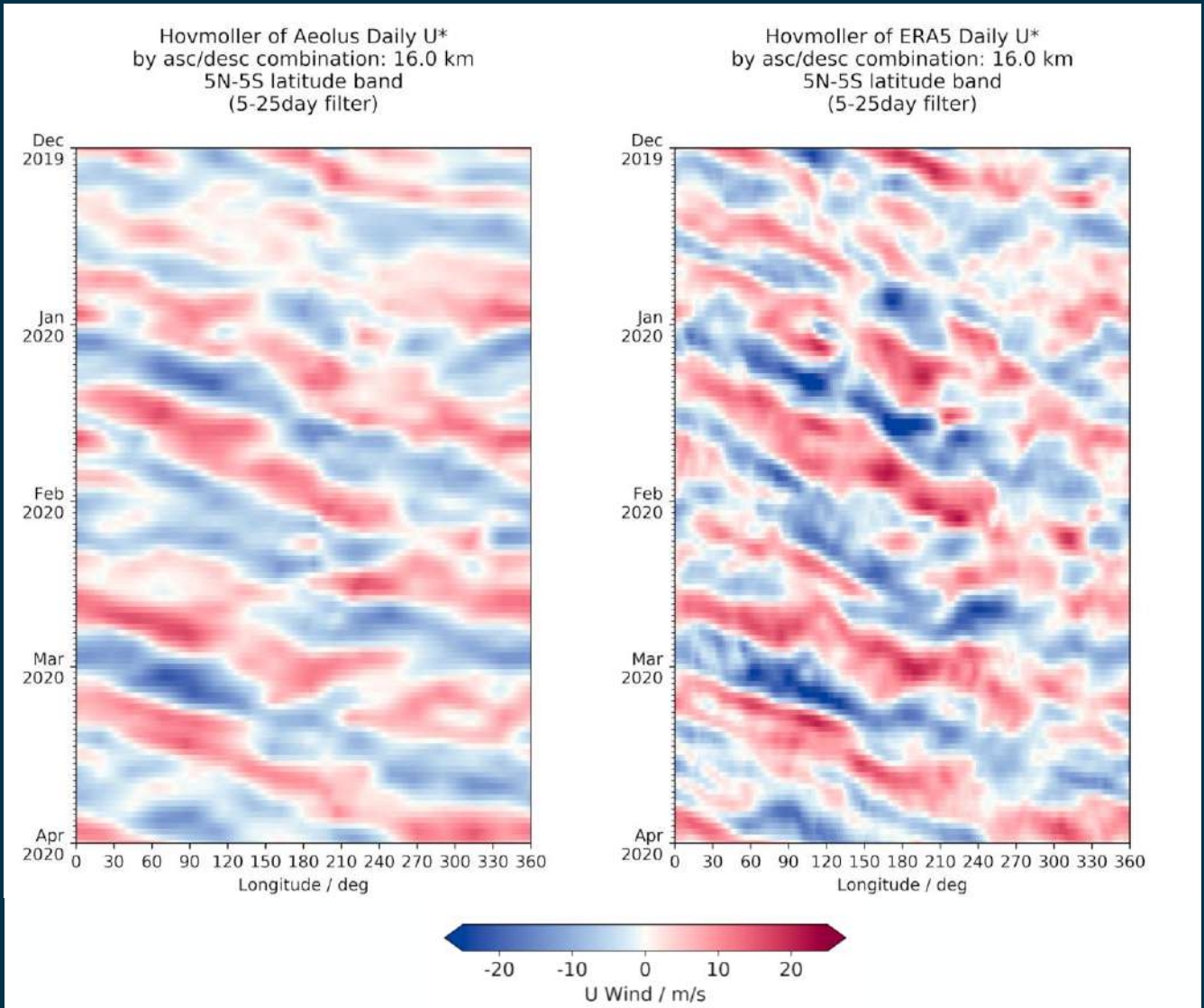

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- Eastward propagating Kelvin waves can be seen even without filtering
- Good agreement between Aeolus and ERA5
- Applying a 2 - 25 day filter reveals the strong Kelvin wave activity during the disruption
- Proposed theory that a lack of Kelvin wave forcing contributed to the disruption can be tested using Aeolus
- Aeolus could improve reanalysis models where radiosonde observations are sparse

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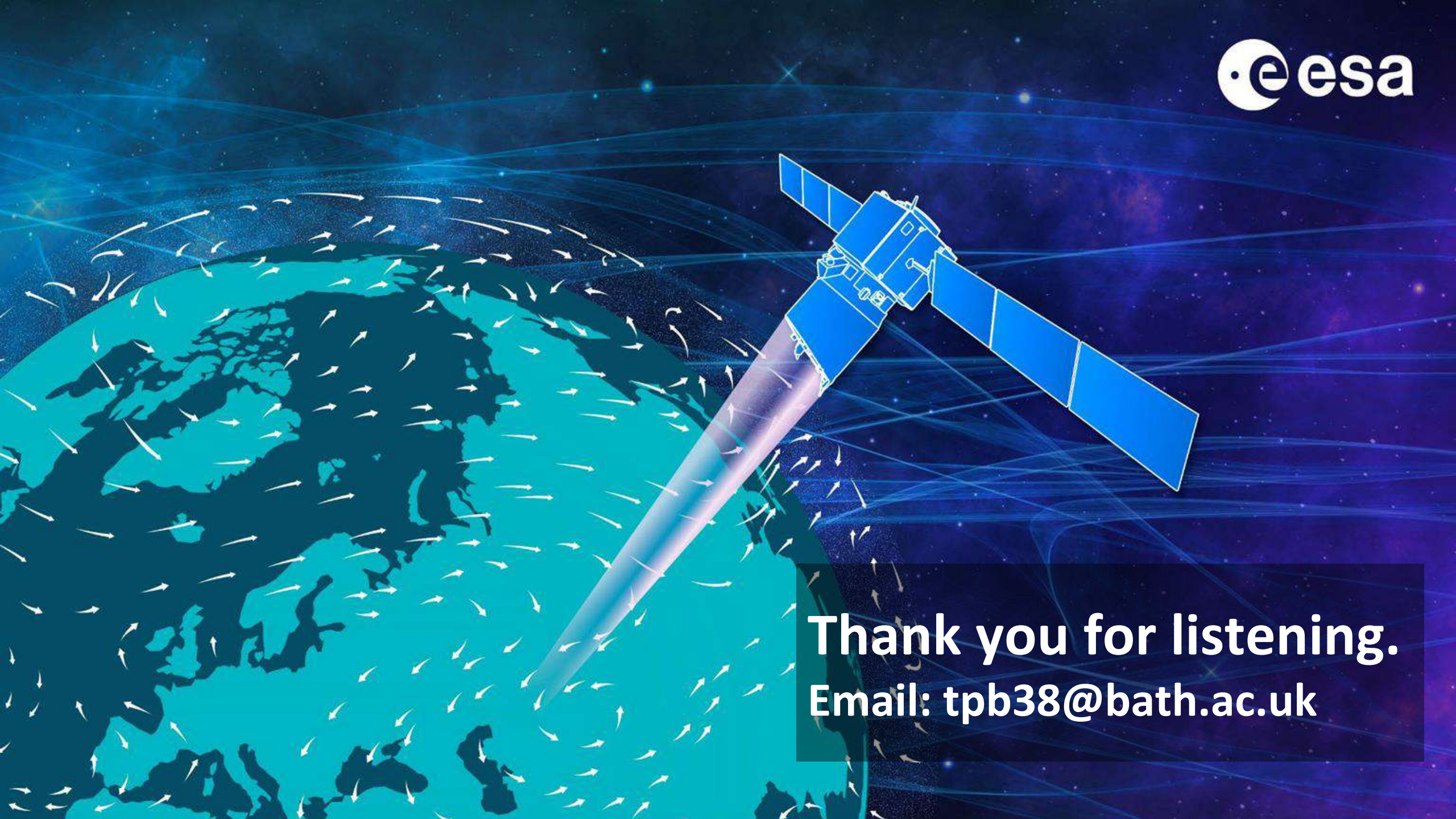
Summary

- Aeolus can be used to observe the lower part of the QBO
- 2019/2020 QBO disruption seen by Aeolus, QBO 2020 RBS implemented
  - These RBS have added a significant amount of new information!

- Good agreement seen between Aeolus, Singapore Radiosonde and ERA5
- Both Aeolus and ERA5 observe strong Kelvin waves traveling eastwards during the disruption

- Future wind lidars that extend higher into the stratosphere could solve many questions about the QBO, tropical equatorial waves and their teleconnections



Thank you for listening.

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