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Process-based diagnostics of the impact of new observing systems: a case study of the Aeolus wind satellite

Robin Pilch Kedzierski [1], Nedjeljka Žagar [1], Giovanna De Chiara [2], Michael Rennie [2], Sean Healy [2]

[1] Universität Hamburg, Meteorological Institute, Hamburg, Germany.

[2] European Centre for Medium-Range Weather Forecasts, Reading, United Kingdom.

10.09.2024

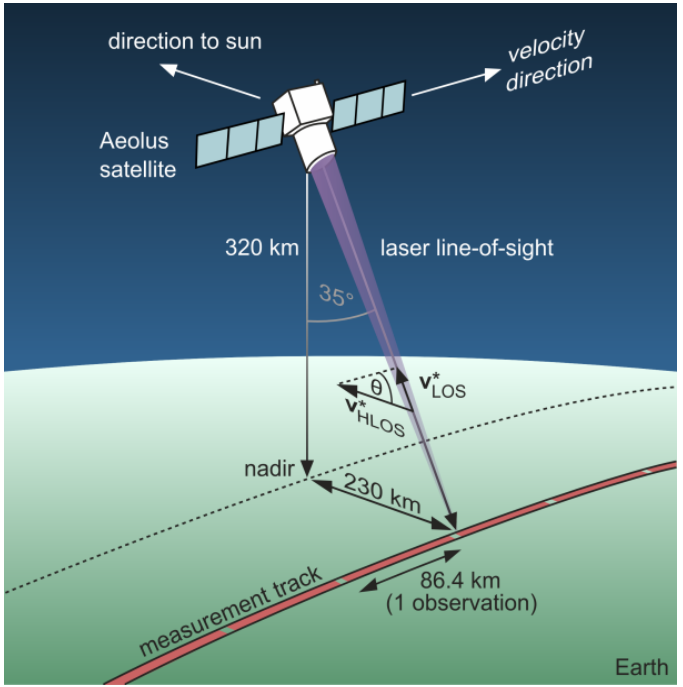
ECMWF

esa

The Aeolus satellite

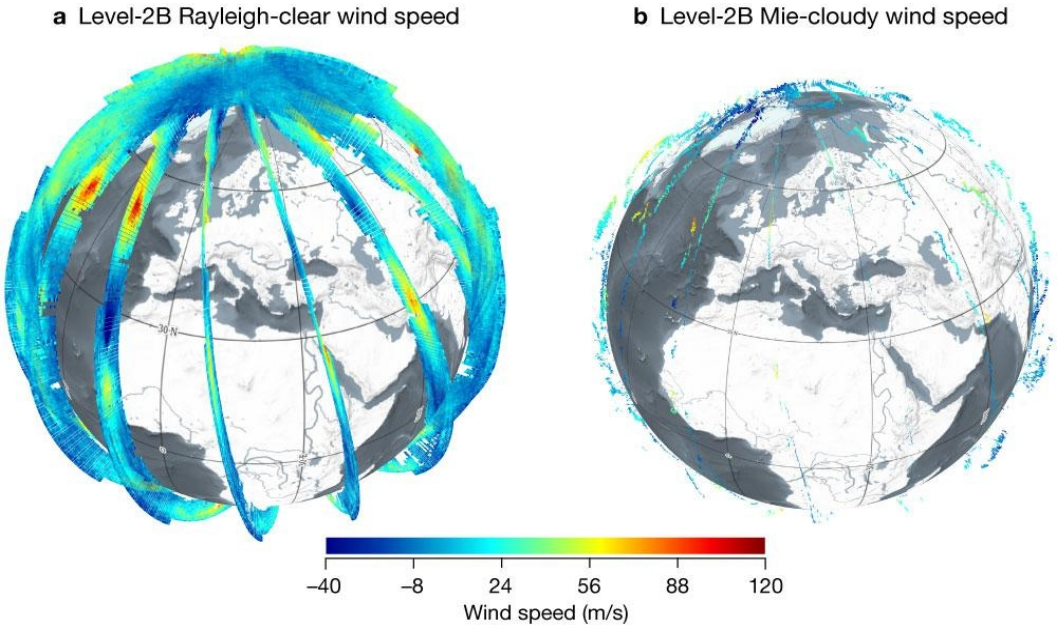
Launched 22 Aug. 2018, 3y expected lifetime
→ Operational until 30 Apr. 2023

https://de.wikipedia.org/wiki/ADM-Aeolus



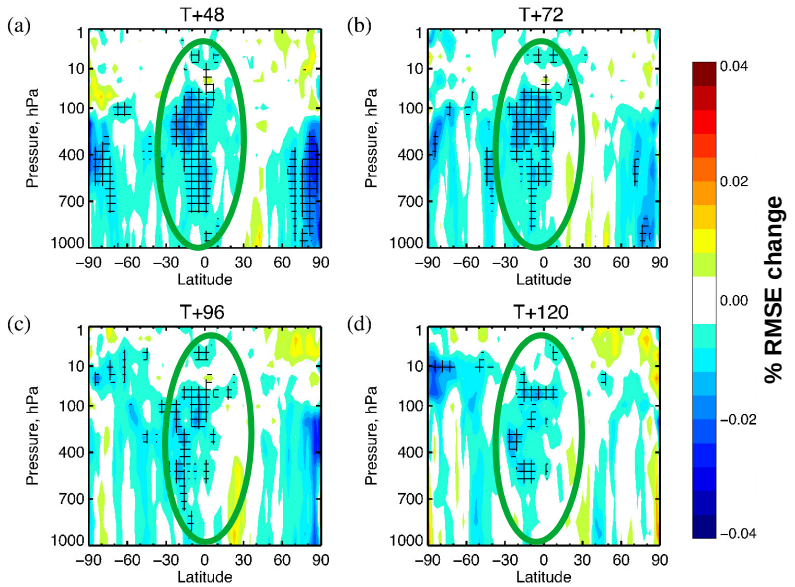
https://www.dlr.de/en/pa/research-transfer/expertise/space/aeolus-and-aeolus-2

Aeolus measurements: 12h period 9 Feb 2020



https://www.ecmwf.int/en/newsletter/173/earth-system-science/aeolus-positive-impact-forecasts-second-reprocessed-dataset

Assimilating Aeolus improves forecasts



(Aug. - Dec. 2019)

Rennie et al. (2021), QJRMS

Aeolus assimilation in ECMWF

Blue → better

Observing system experiments (OSEs),
with vs without Aeolus

→ **no Aeolus OSE**: all other observations,
as assimilated operationally by ECMWF forecast system
→ **Aeolus OSE**: same + Aeolus

Forecast improvements centered at equator,
probably mediated by equatorial waves.

Aeolus+Processes, ESA-funded project

→ **what processes are involved in these improvements?**
→ **how do we explain the above with equatorial wave dynamics?**

Equatorial wave diagnostics

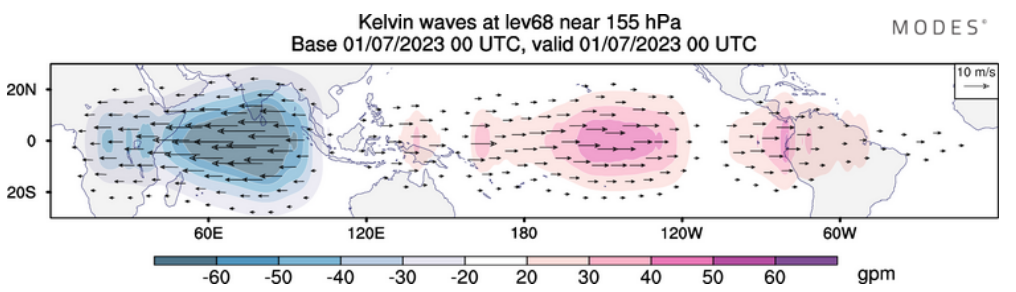
MODES: wavenumber filtering

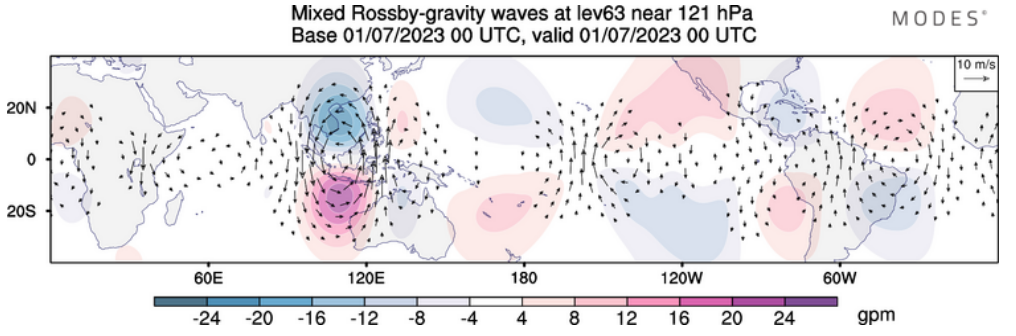
- Decomposes instantaneous 3D global circulation in terms of normal-mode functions (NMFs)

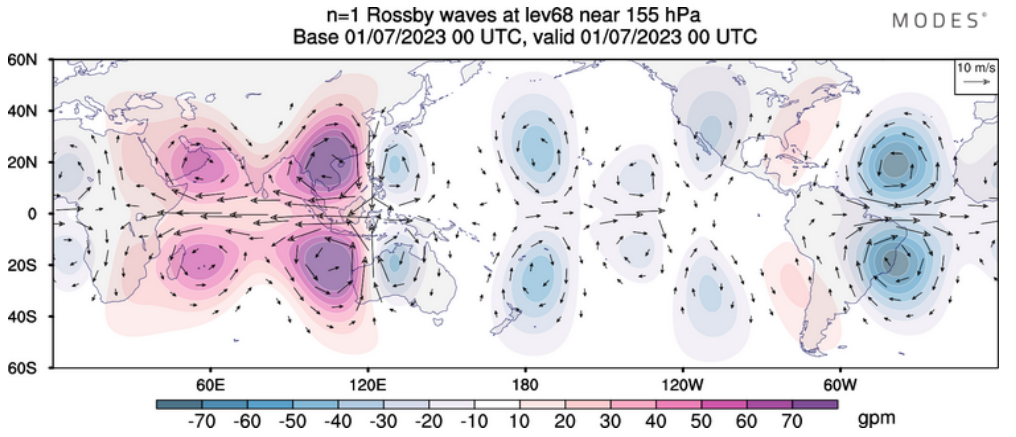
- No time filtering

https://modes.cen.uni-hamburg.de/

2-year long OSEs decomposed and compared
2019-07 – 2021-06







Equatorial wave diagnostics

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2-year long OSEs decomposed and compared
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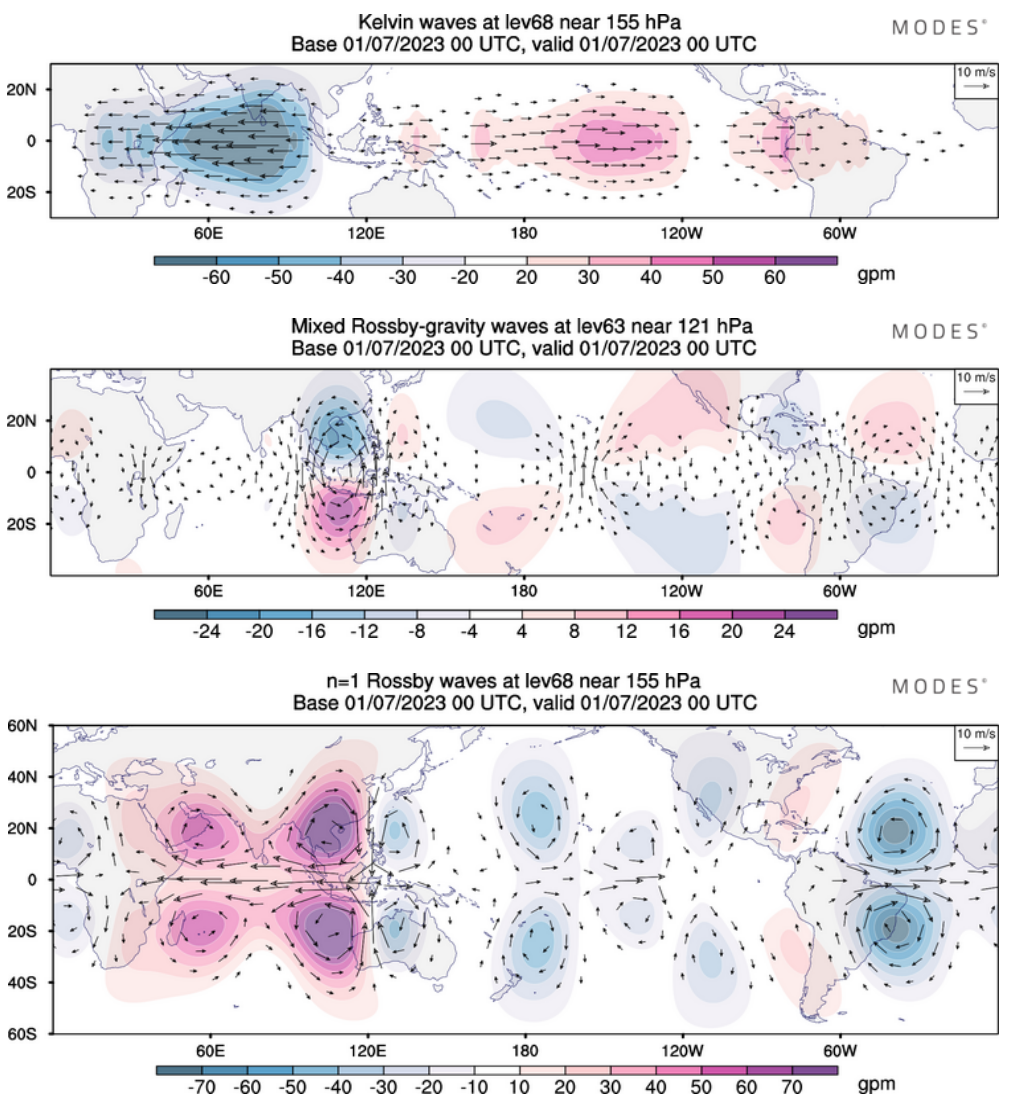
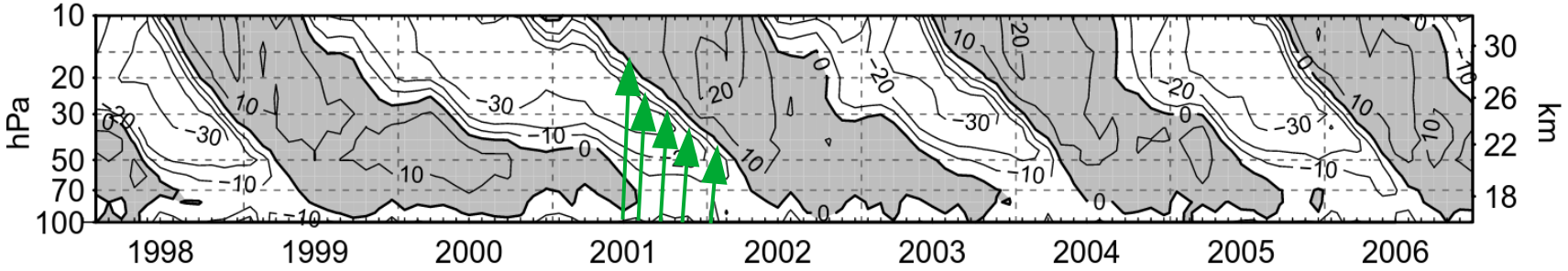
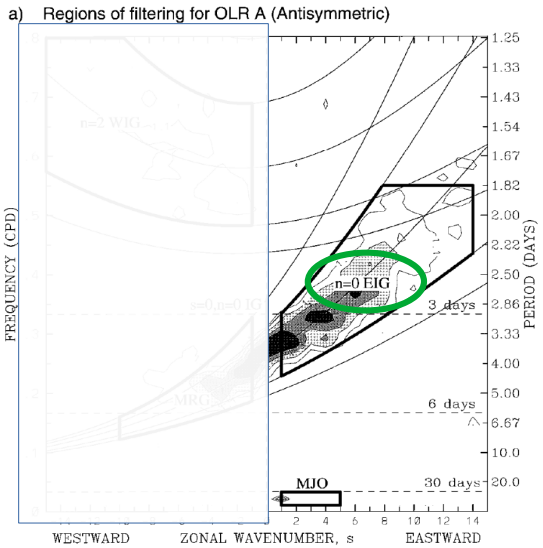
For more about MODES and its applications, visit poster this evening!

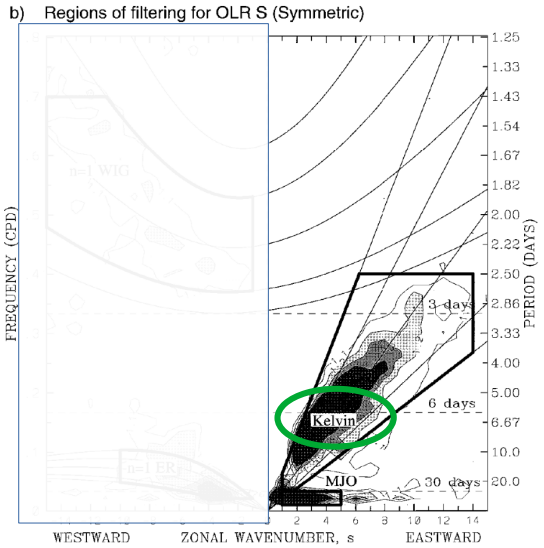


Equatorial waves and the QBO



https://www.geo.fu-berlin.de/en/met/ag/strat/produkte/qbo/index.html



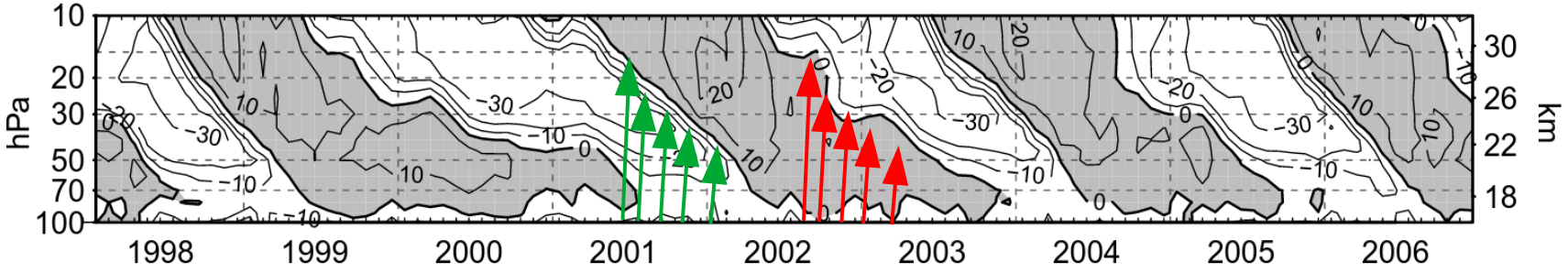


→ **KW** and **EIG** propagate eastward

→ Upward propagation within **easterlies**

Wheeler and Kiladis (1999), JAS

Equatorial waves and the QBO



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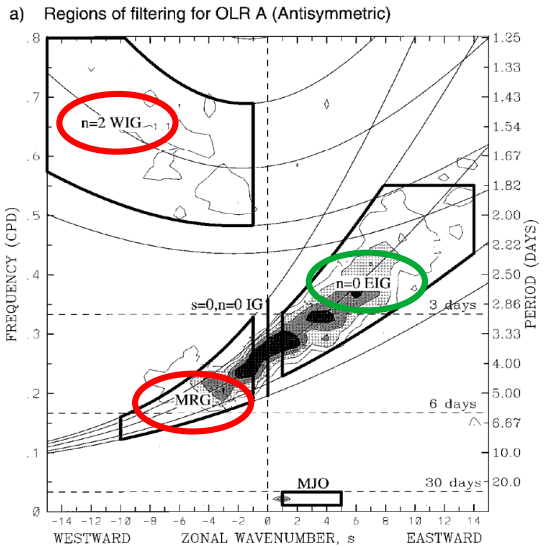

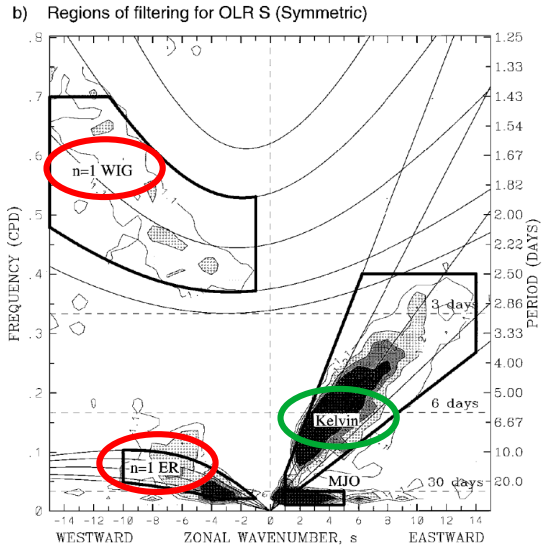

Wheeler and Kiladis (1999), JAS

→ **KW** and **EIG** propagate eastward

→ Upward propagation within **easterlies**

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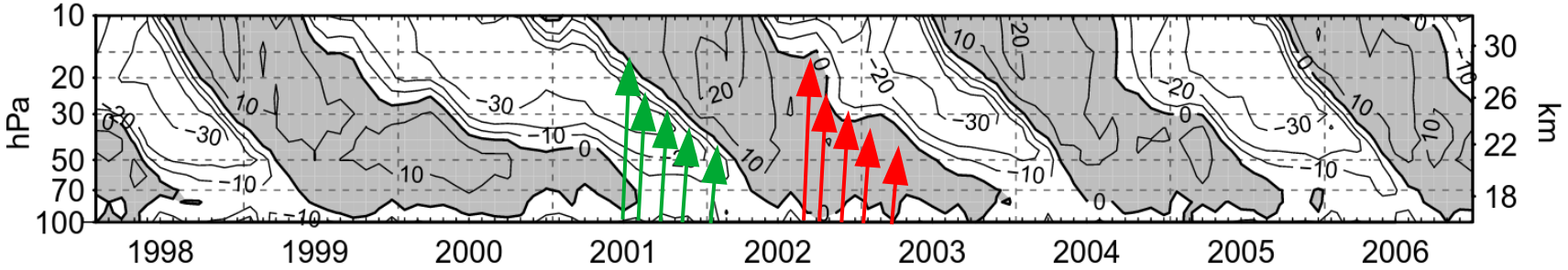
Equatorial waves and the QBO



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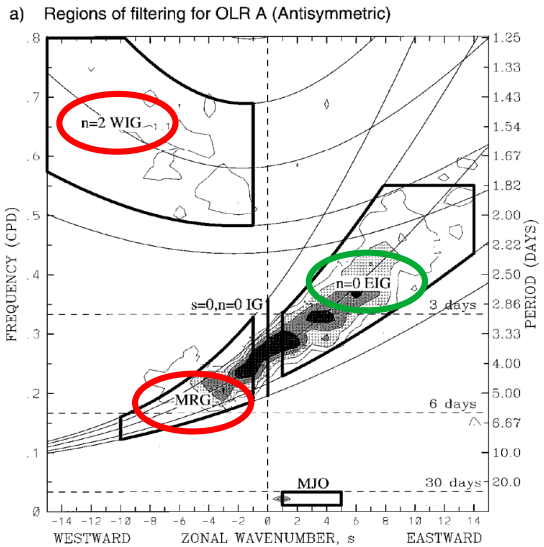

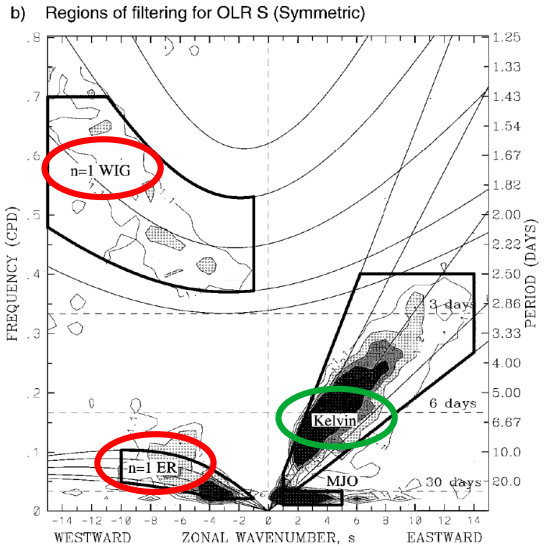

Wheeler and Kiladis (1999), JAS

→ **KW** and **EIG** propagate eastward

→ Upward propagation within **easterlies**

→ **n=1 Rossby, MRG, WIG** propagate westward

→ Upward propagation within **westerlies**

→ **Exert drag when they break near the zero wind line**

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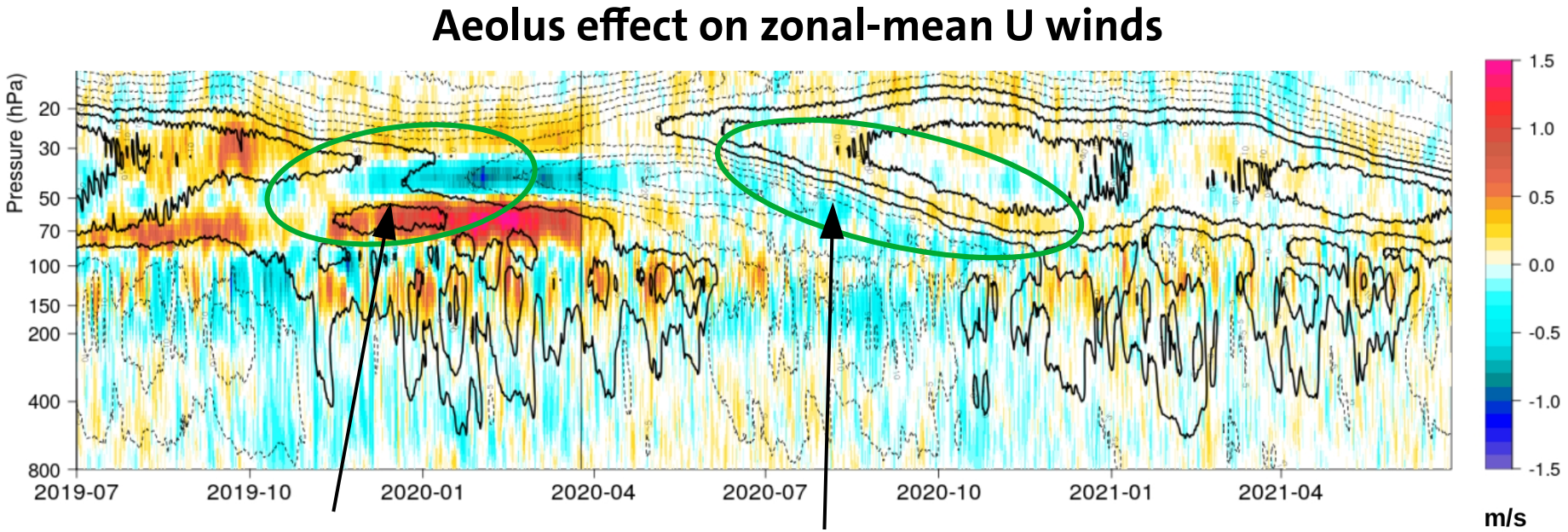
Aeolus assimilation effects on:

1: equatorial zonal-mean flow and the QBO

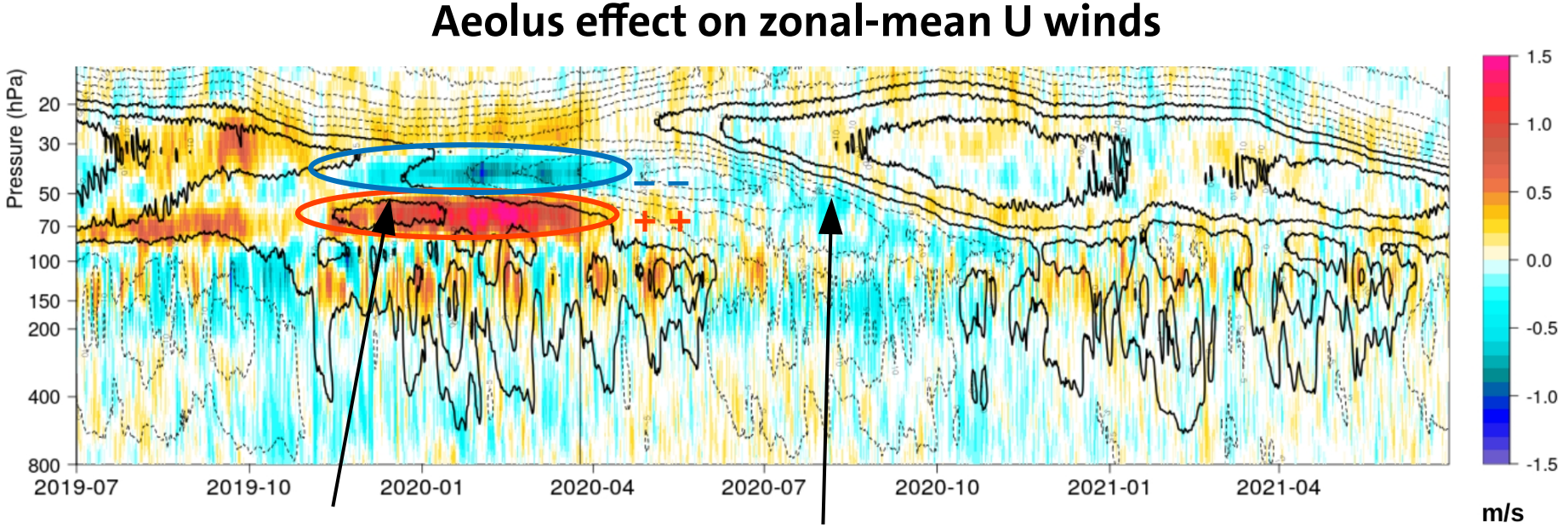
2: equatorial waves

3: wave-mean flow interactions

Equatorial zonal-mean circulation

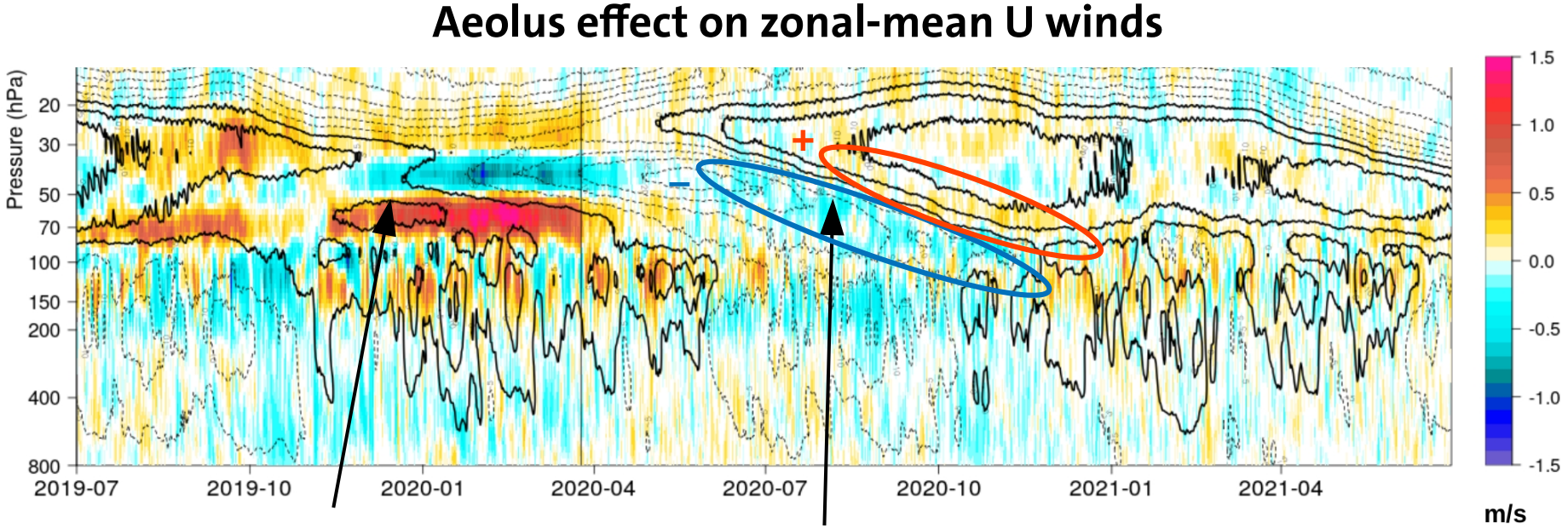


Equatorial zonal-mean circulation



→ **Increase of vertical shear, especially during QBO disruption**

Equatorial zonal-mean circulation



→ **Increase of vertical shear, especially during QBO disruption**

Aeolus assimilation effects on:

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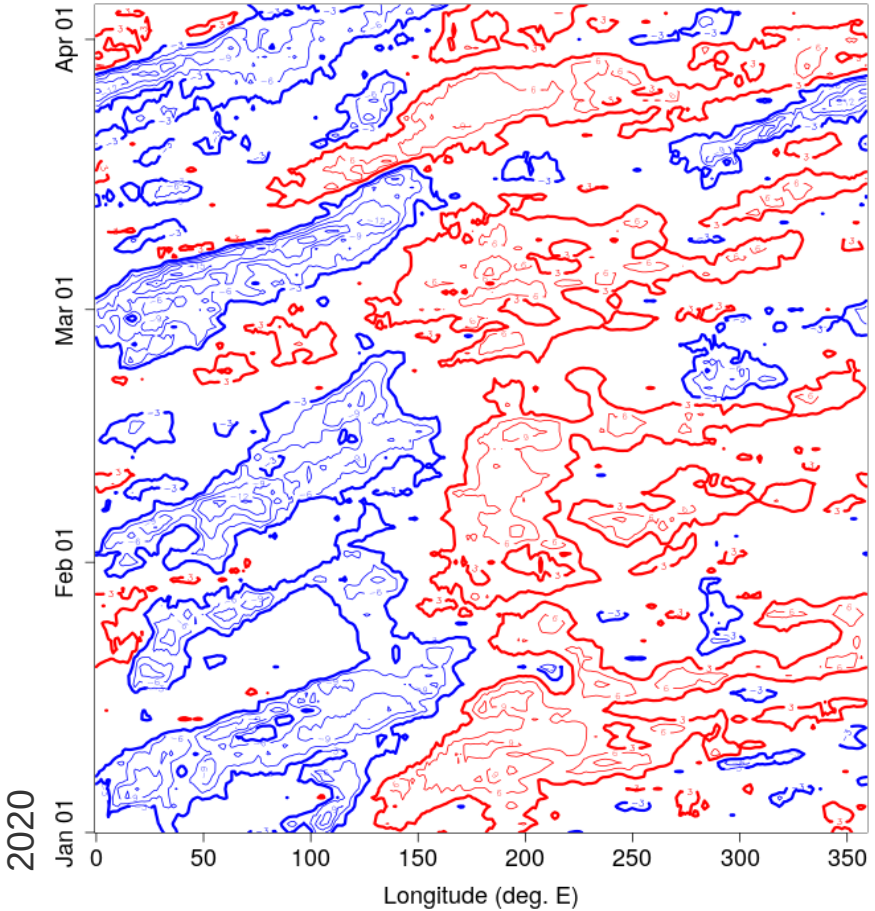
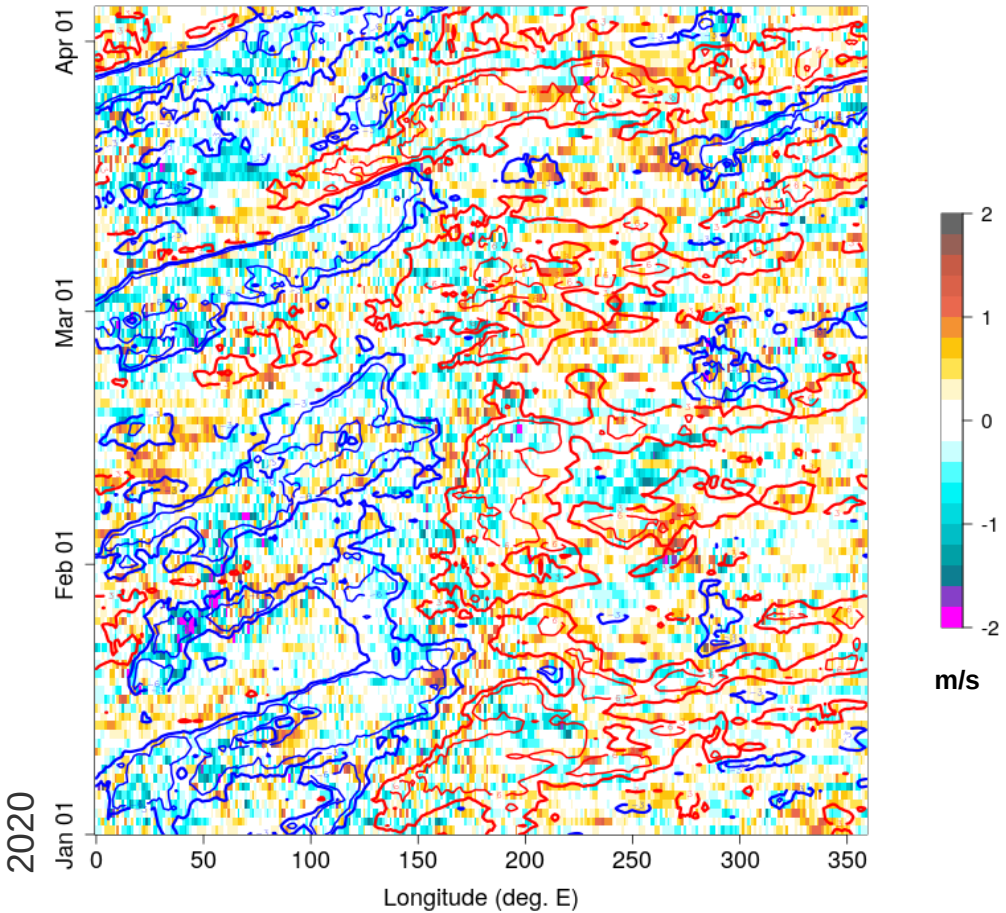
The wave compositing analysis



Lines: KW U winds
near equator *(no Aeolus)*

~150 hPa

The wave compositing analysis

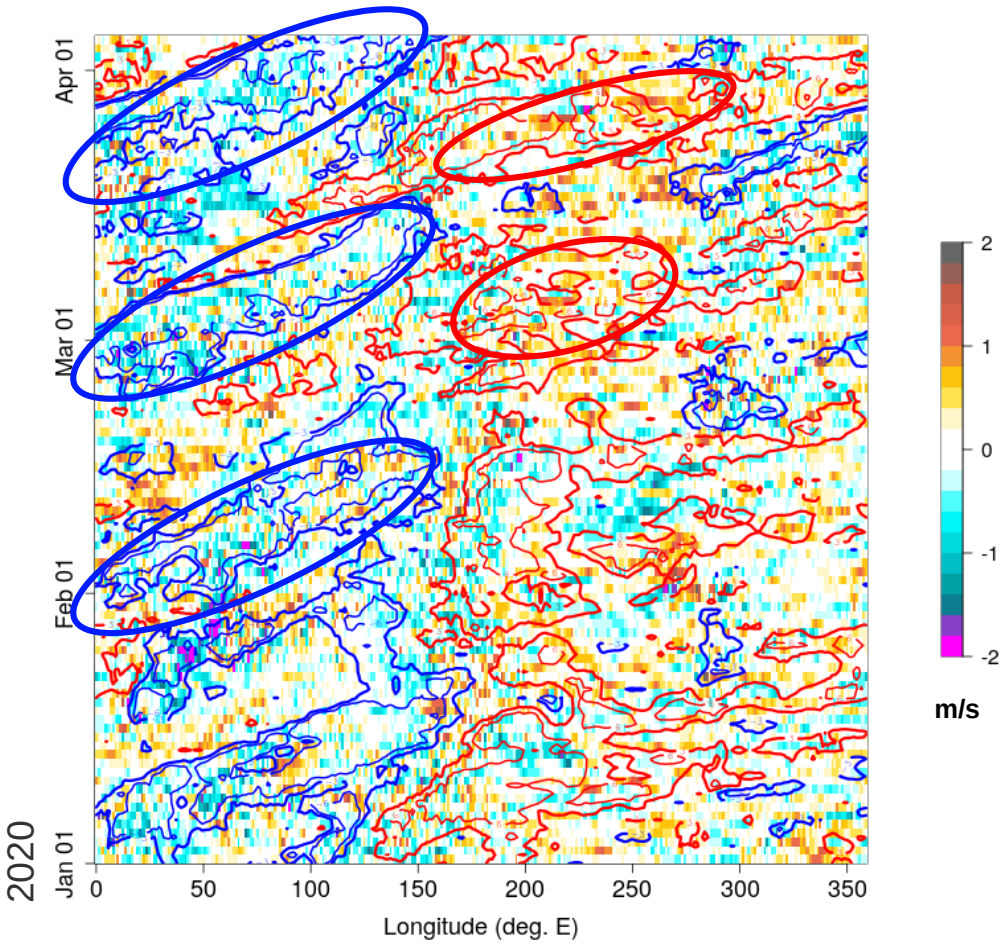


Lines: KW U winds
near equator *(no Aeolus)*

~150 hPa

Shading: KW U
- Easterly diff.
- Westerly diff.
Aeolus – no Aeolus

The wave compositing analysis



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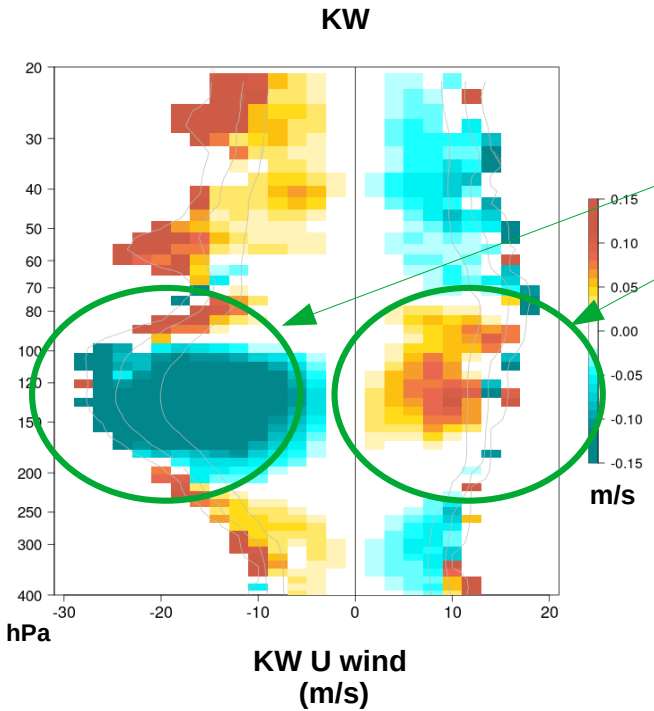
Aeolus – no Aeolus

KW example: mean differences



Assimilating Aeolus **increases** wave amplitude

2019-07 to 2021-06
all 00-12 UTC analyses

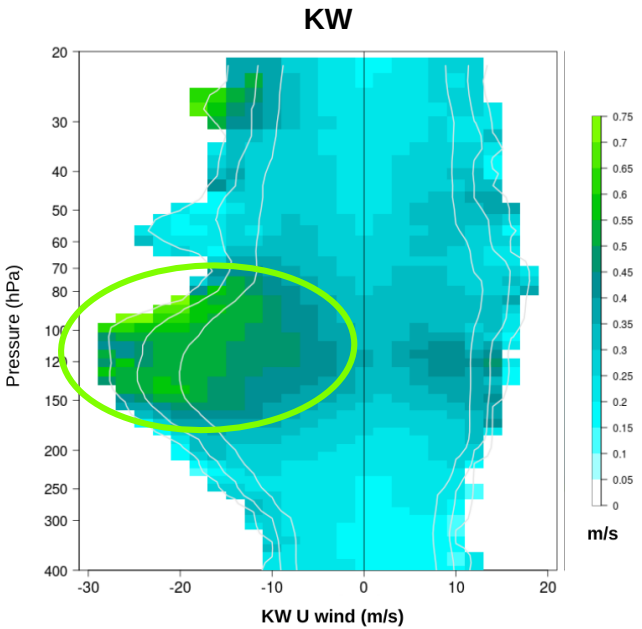
10°N-10°S

99% confidence level

Binned relative to equatorial wave anomaly *(no Aeolus)*

Increase of wave amplitude by ~1% in UT (100-180hPa)

… now root mean squared differences

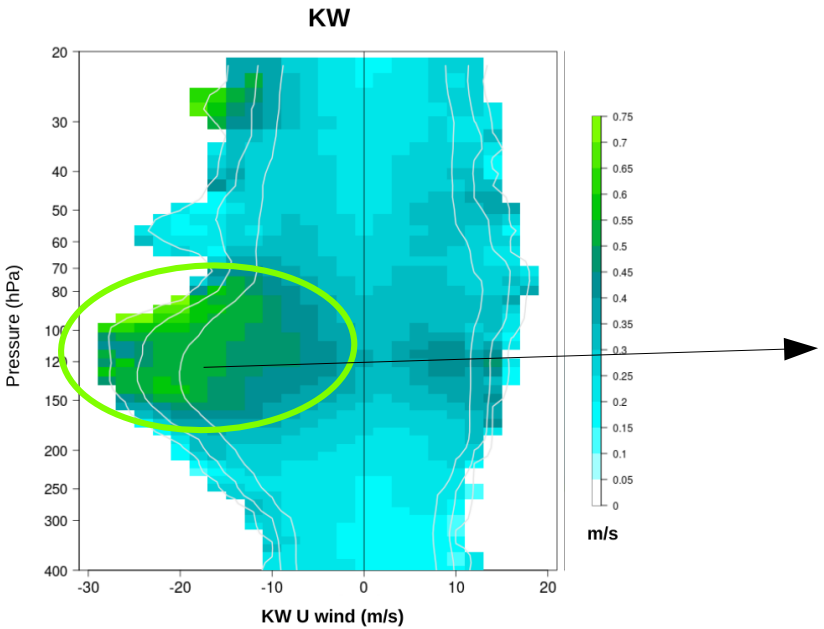


→ Asymmetry in easterly phase

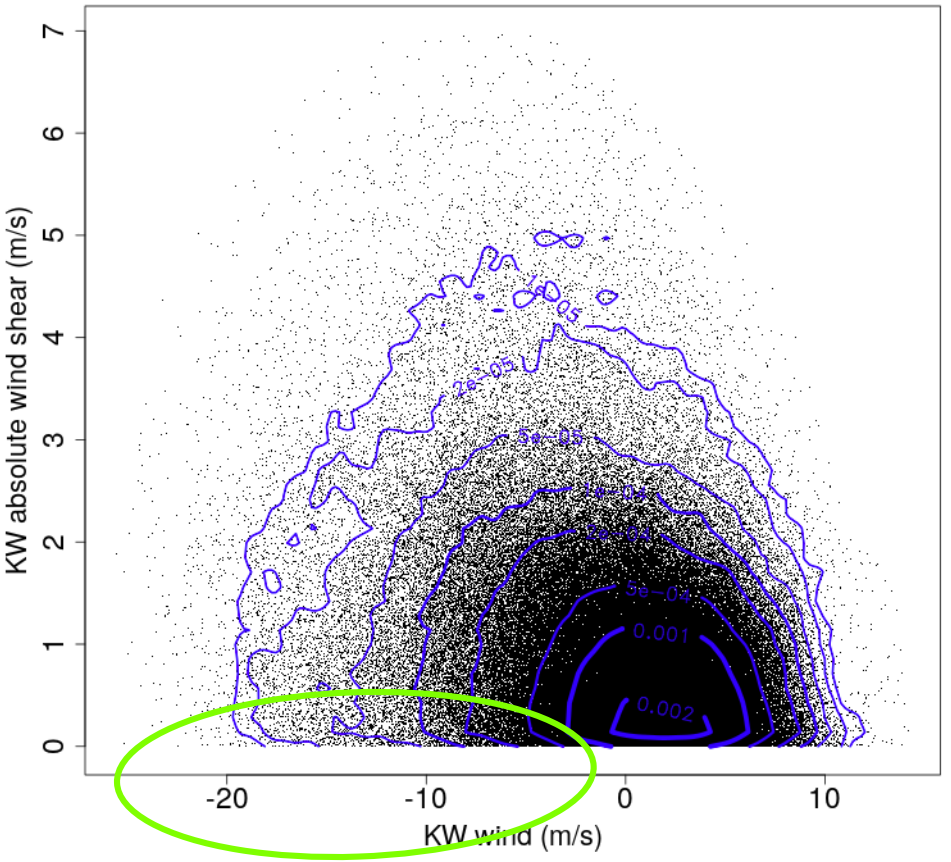
→ Linked to stronger shear zones

→ *Simplified interpretation: RMSD = overall amount of change from assimilation*

Link to vertical shear

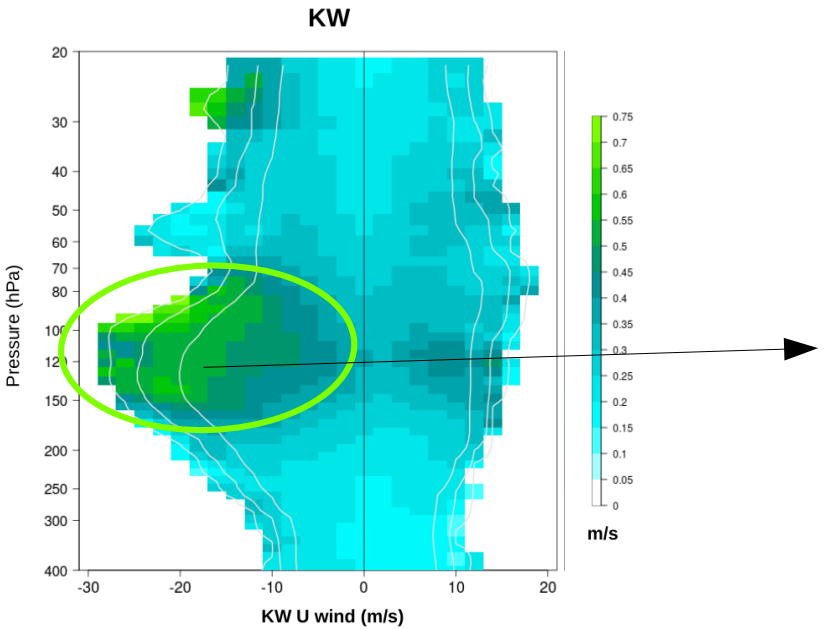


Distribution of KW shear, 118 hPa (NoAeolus)



Shear distribution much wider within U < 0

Link to vertical shear



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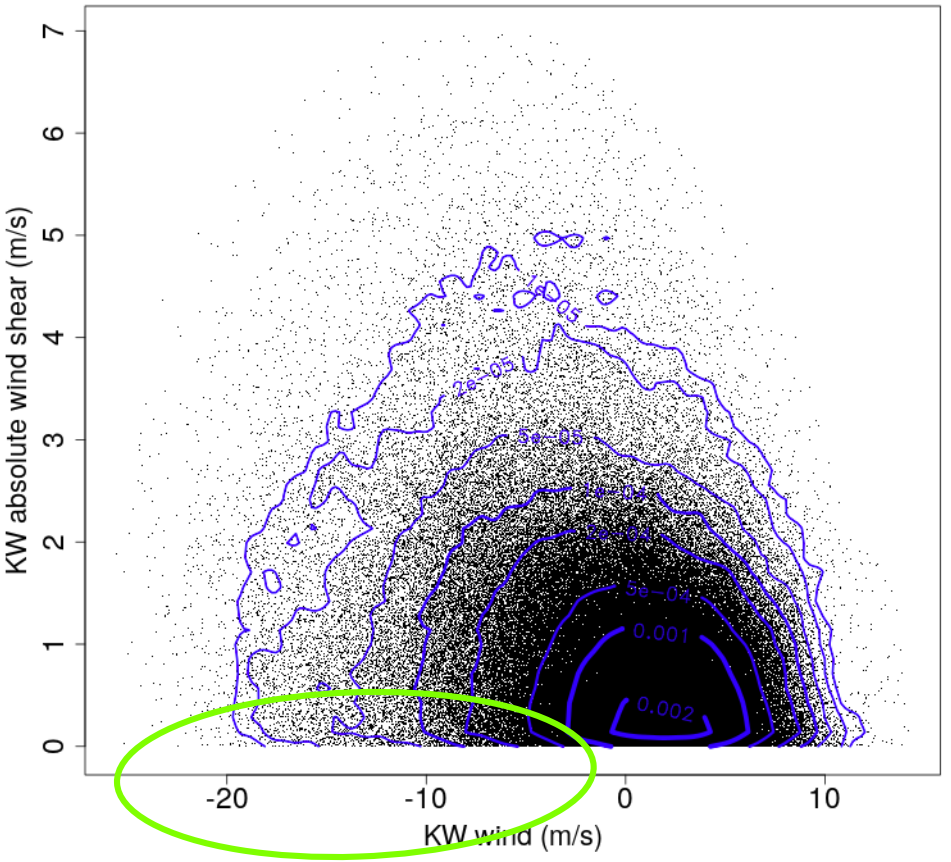

- Method applicable to all wave modes
+ total wind shear

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Aeolus assimilation effects on:

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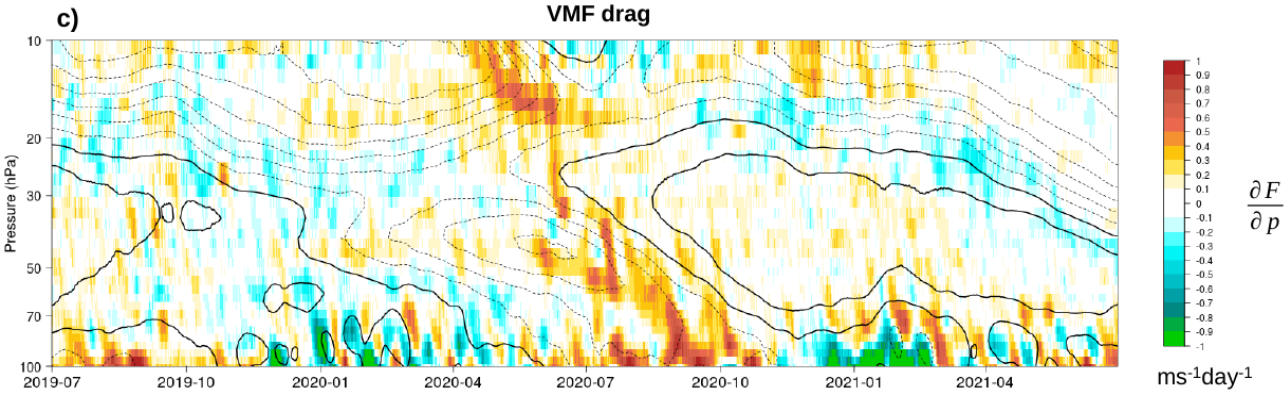
Wave-mean flow interactions from wave drag

$$F = \overline{u'\omega'}$$



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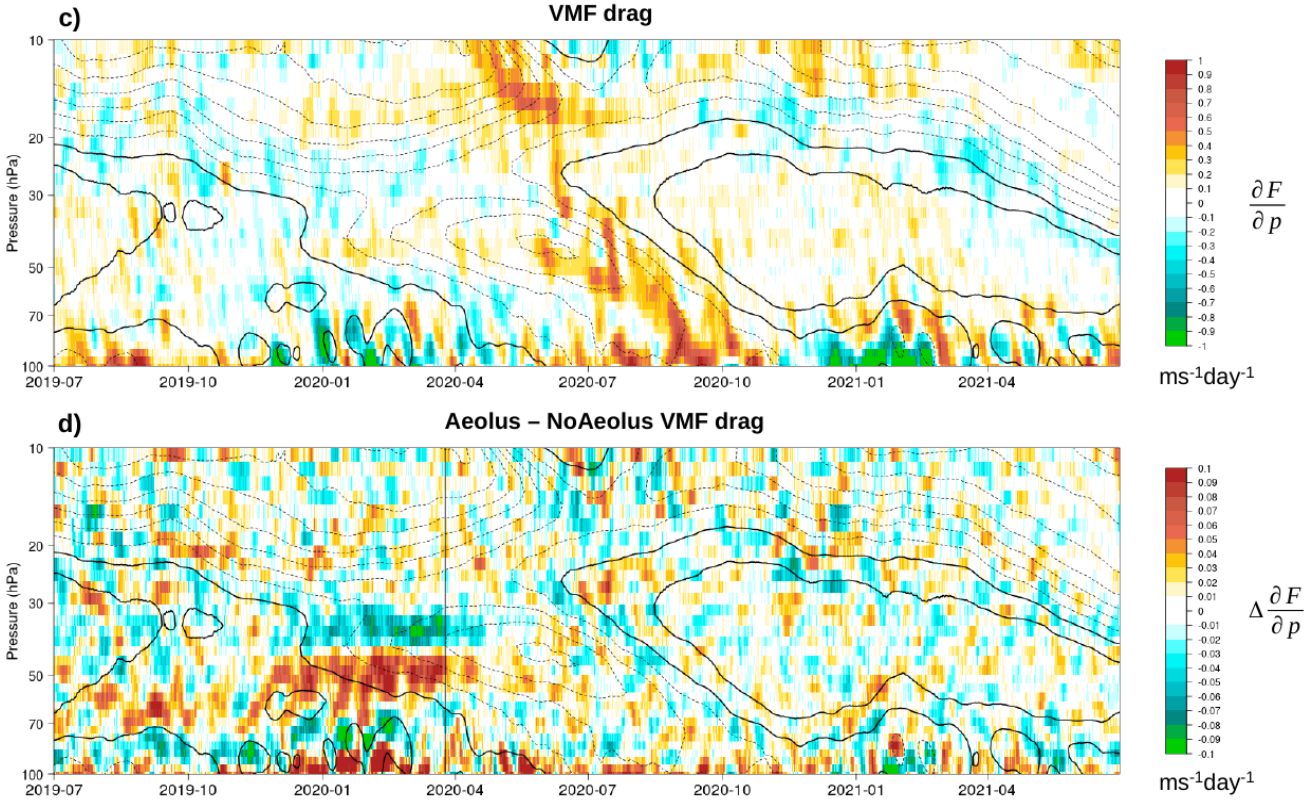

Wave-mean flow interactions from wave drag

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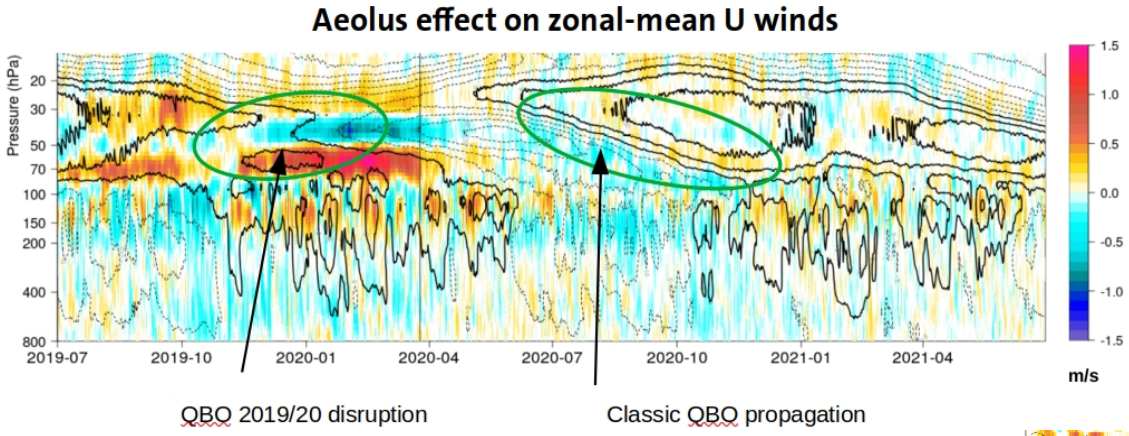

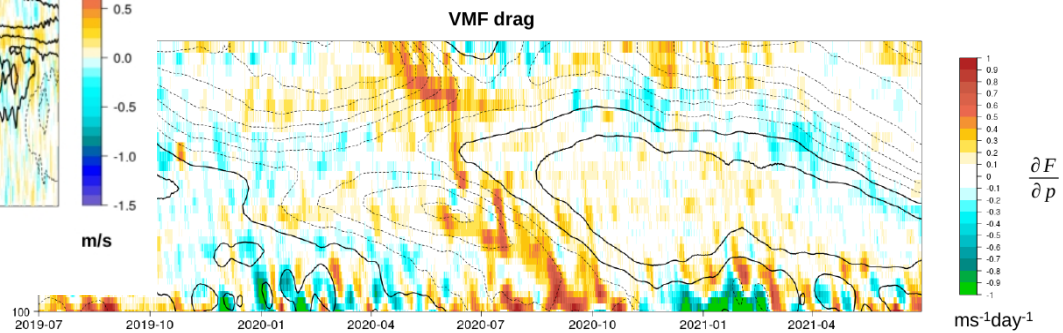

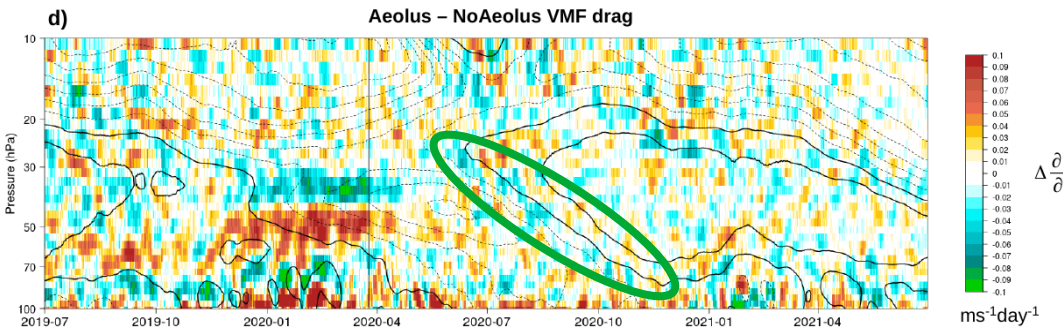

→ Wave drag changes **collocated with** zonal-mean U changes

→ Drag changes ***contribute to*** zonal-mean U changes

Wave-mean flow interactions from wave drag

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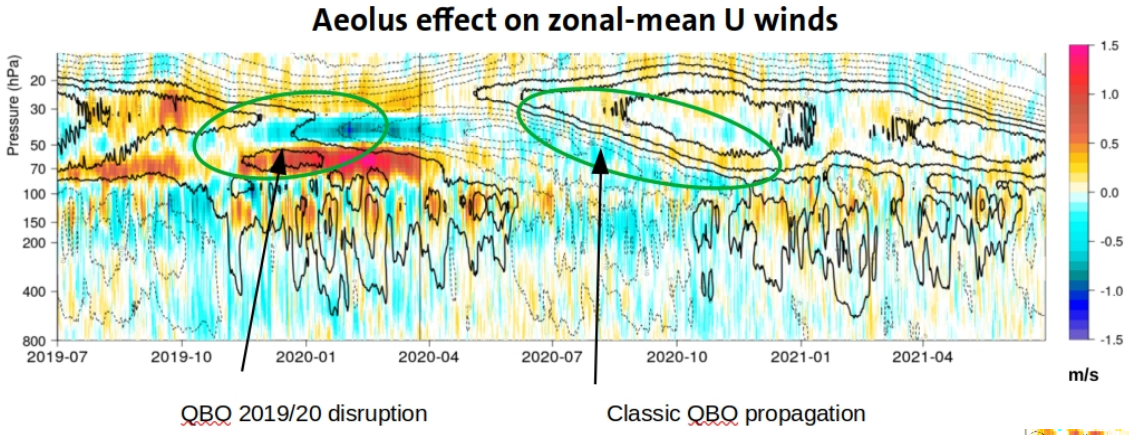

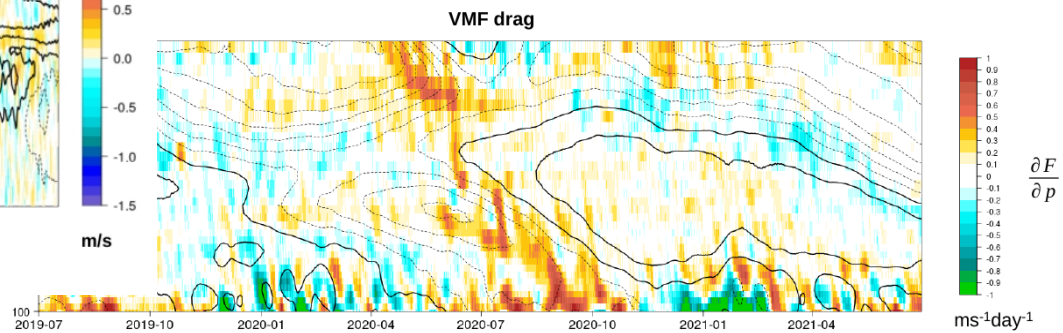

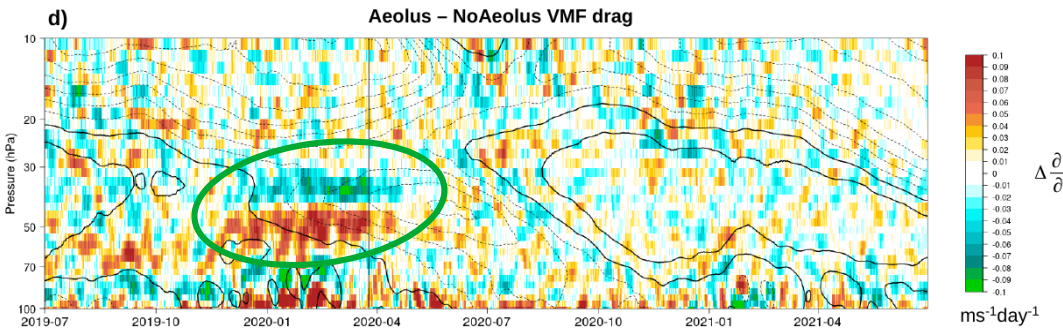

→ Wave drag changes **not** in phase
with zonal-mean U changes

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We presented diagnostics covering Aeolus assimilation effects on:

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2: equatorial waves
3: wave-mean flow interactions

Powerful all-round set of diagnostics – and there's more (see poster)

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Powerful all-round set of diagnostics – and there's more (see poster)

→ Methodology applicable to any OSE!