Tropical analysis and forecast uncertainties: a process-based evaluation of observing-system assimilation experiments with Aeolus winds

Nedjeljka Žagar

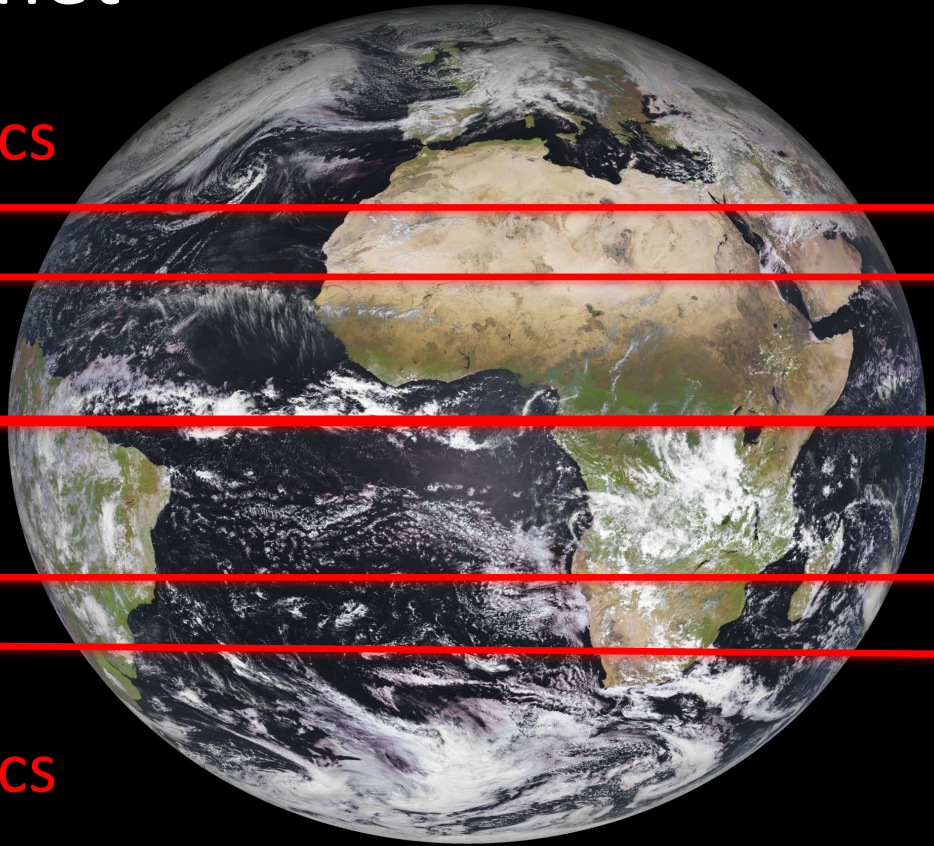
Universität Hamburg

DER FORSCHUNG | DER LEHRE | DER BILDUNG

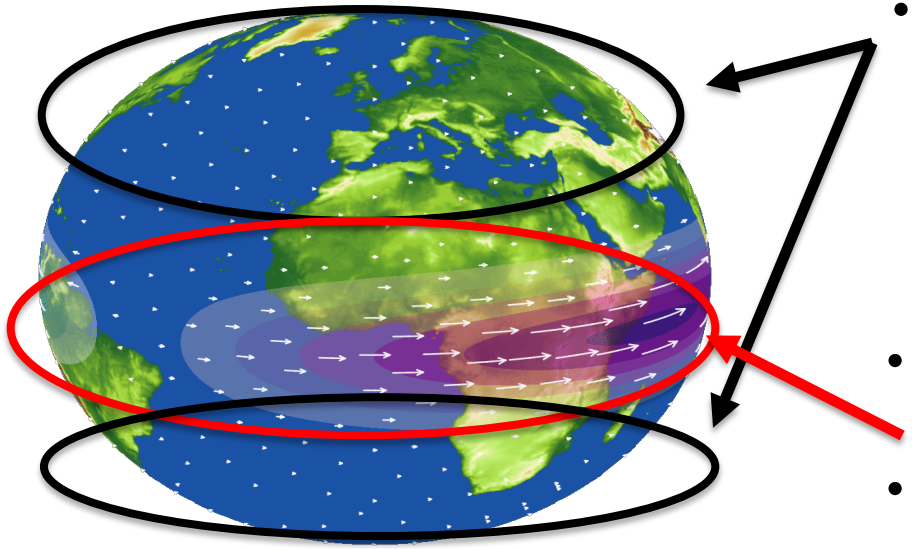
Michael Rennie and Lars Isaksen

Living Planet Symposium, 25 May 2022, Bonn

Living planet



Tropics versus extratropics

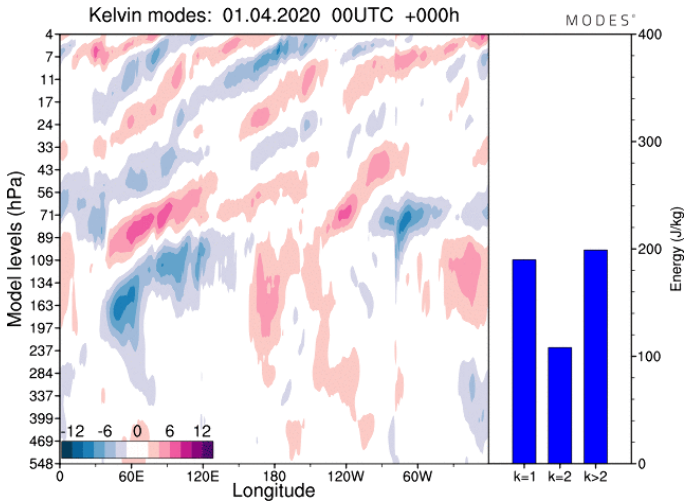


Geopotential and winds of the Kelvin wave with the zonal wavenumber 1

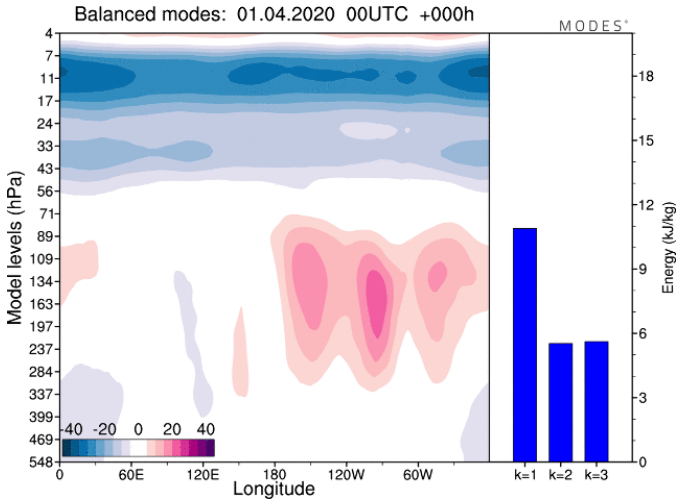
- Balanced dynamics (quasi-horizontal, quasi-geostrophic circulation)

- Unbalanced dynamics incl. special tropical waves
- Limited understanding of circulation coupled to convection

Tropical wind variability: ECMWF analyses



Kelvin wave zonal wind
(averaged in 15ºN-15ºS)

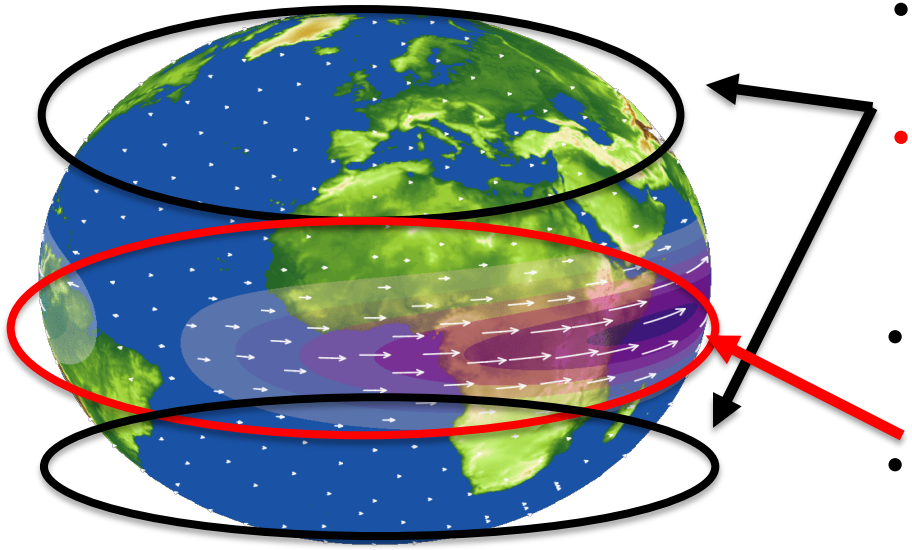


Balanced zonal wind
(averaged in 15ºN-15ºS)

April-September 2020: period of ECMWF FM-B OSE discussed by Mike Rennie

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

Tropics versus extratropics



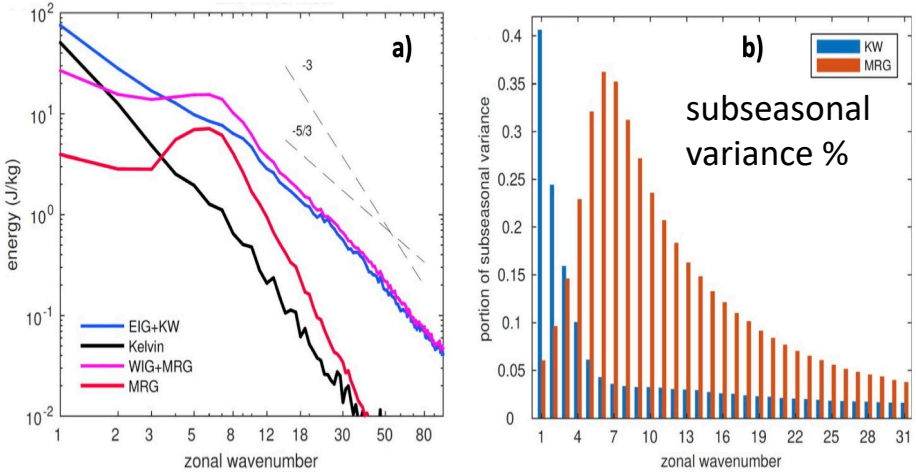
Geopotential and winds of the Kelvin wave with the zonal wavenumber 1

- Balanced dynamics (quasi-horizontal, quasi-geostrophic circulation)
- Predictability of day-to-day weather defined by baroclinic instability

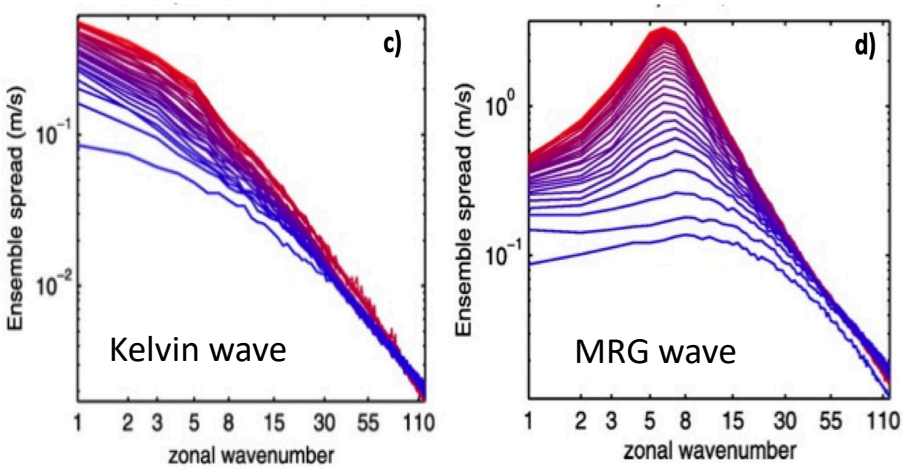
- Unbalanced dynamics incl. special tropical waves
- Limited understanding of circulation coupled to convection
- Fast initial growth of forecast errors, slowing down afterward

Tropical wave predictability

Kelvin wave and mixed Rossby-gravity wave variance spectra



Growth of forecast errors in Kelvin and mixed Rossby-gravity waves



Growth of forecast uncertainties occurs across all scales from the start of the forecast

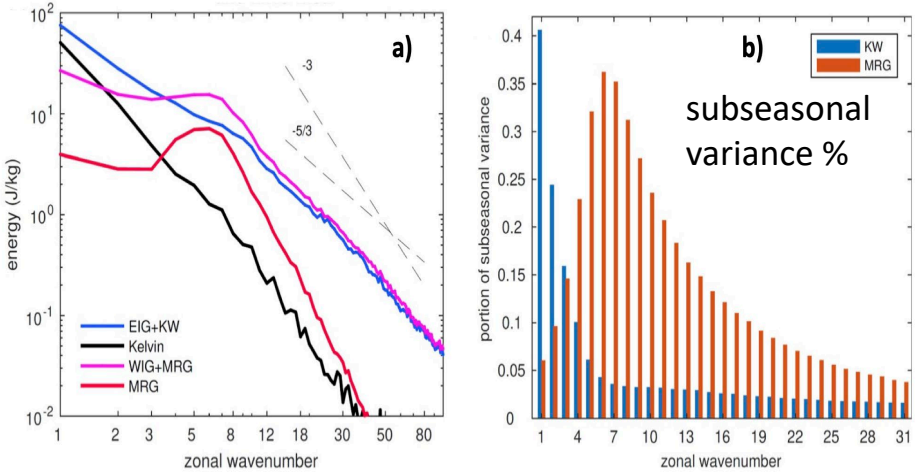
Kelvin wave errors large at k=1 coupled to convection, lack of wind observations

Wind matters more in the tropics

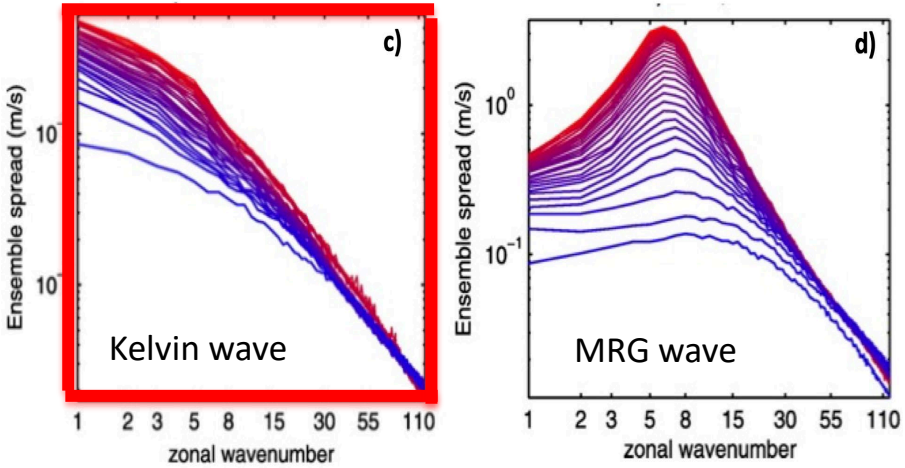
Žagar, 2017; Stephan et al., 2021

Tropical wave predictability

Kelvin wave and mixed Rossby-gravity wave variance spectra



Growth of forecast errors in **Kelvin** and mixed Rossby-gravity waves



Growth of forecast uncertainties occurs across all scales from the start of the forecast

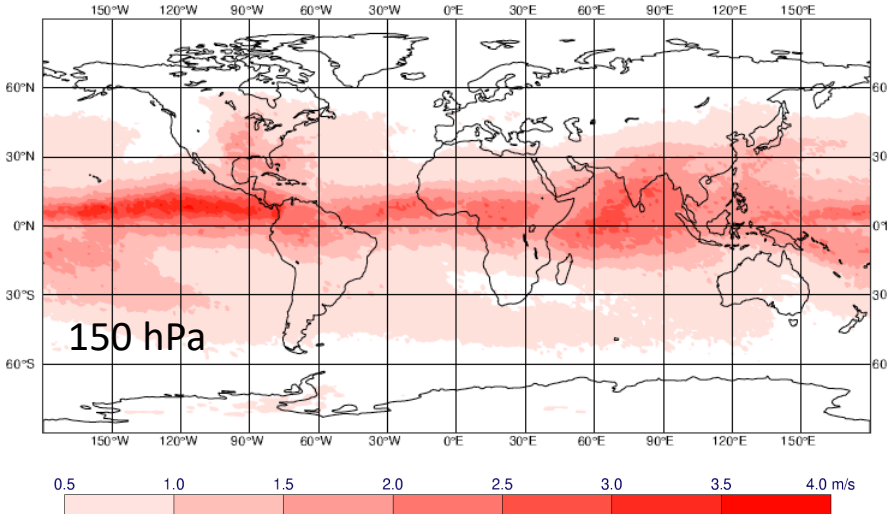
Kelvin wave errors large at k=1 coupled to convection, lack of wind observations

Wind matters more in the tropics

Žagar, 2017; Stephan et al., 2021

Then Aeolus was launched

Improvements in analyses of tropical zonal wind in ECMWF OSEs

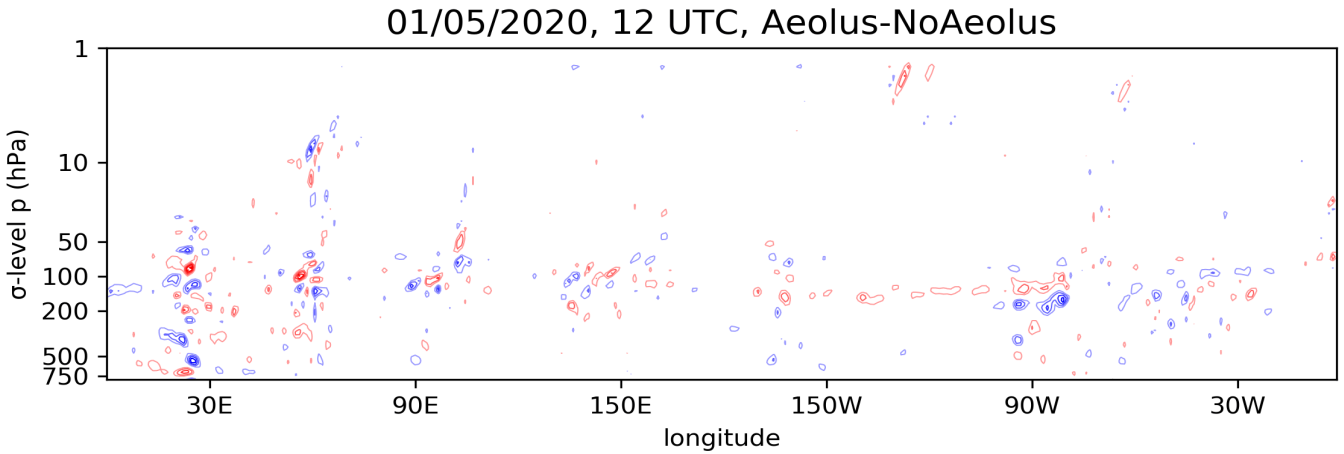


Rennie et al., 2021

Given Aeolus impact in the tropics, how (if) Aeolus HLOS winds improve the representation of Kelvin waves, especially their vertical propagation across the tropopause?

Aeolus impact on Kelvin wave analyses

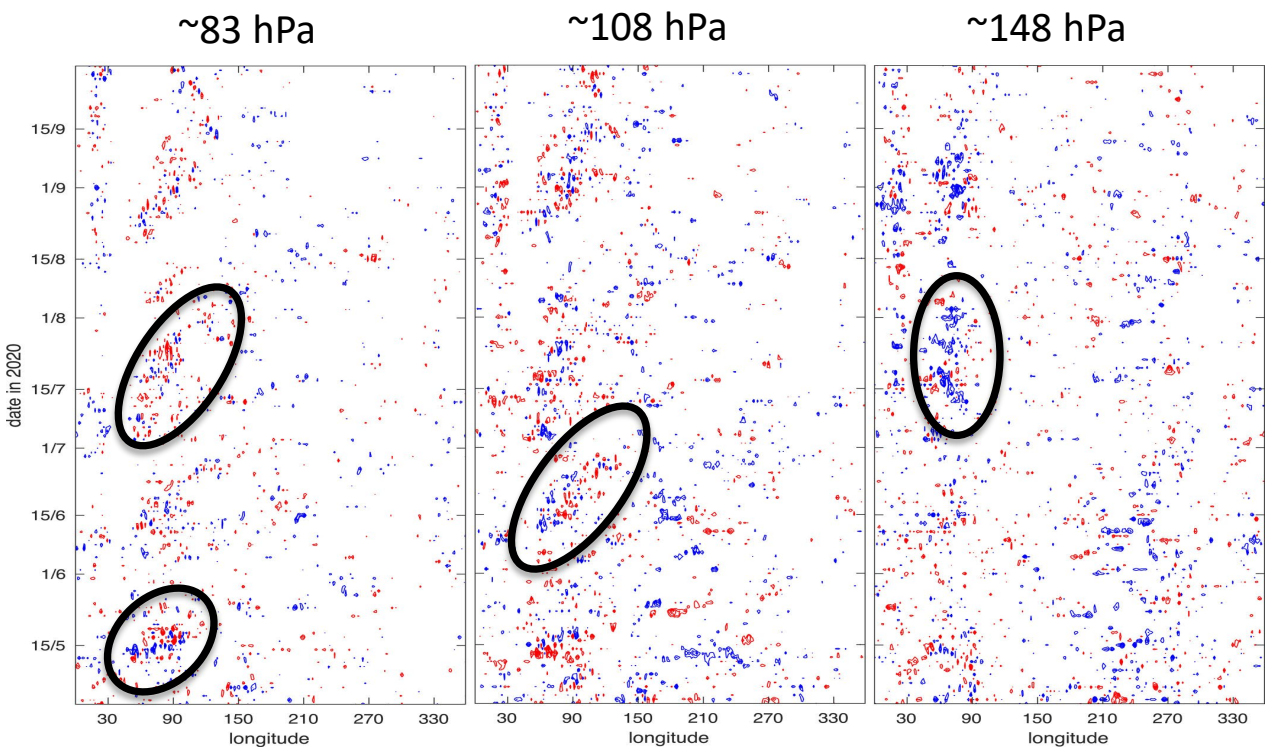
Difference in the Kelvin wave zonal winds in analyses with and without Aeolus data along 0.5ºN



Isolines are every +/- 0.5 m/s, starting at +/- 1 m/s.
Red-positive, blue-negative difference

Žagar et al., 2021

Aeolus impact on Kelvin wave analyses

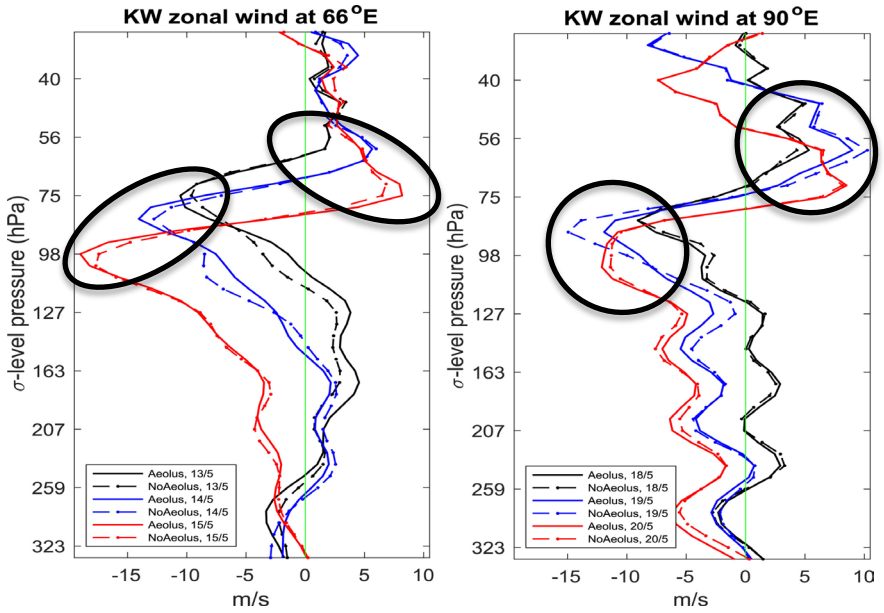


Difference in Kelvin wave zonal winds in analyses with and without Aeolus along 0.5°N

Similarity with the Kelvin wave dynamics

Žagar et al., 2021

Aeolus impact on the vertical propagation of Kelvin waves



Upward- propagating Kelvin waves between 10 and 20 May 2020

Aeolus

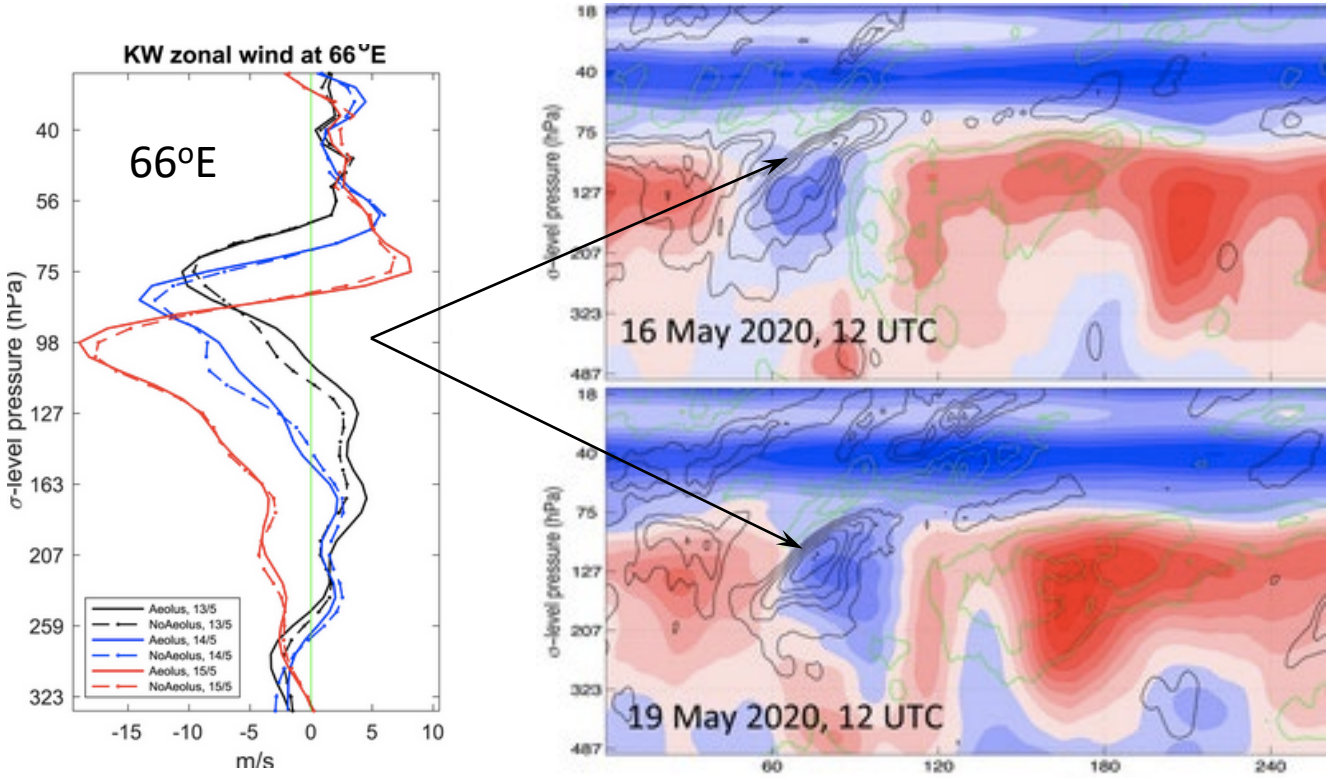
NoAeolus

D D+1 D+2

Kelvin wave zonal wind 12 UTC analyses at 3 subsequent days in May 2020 in Aeolus (full lines) and NoAeolus (dashed lines)

Žagar et al., 2021

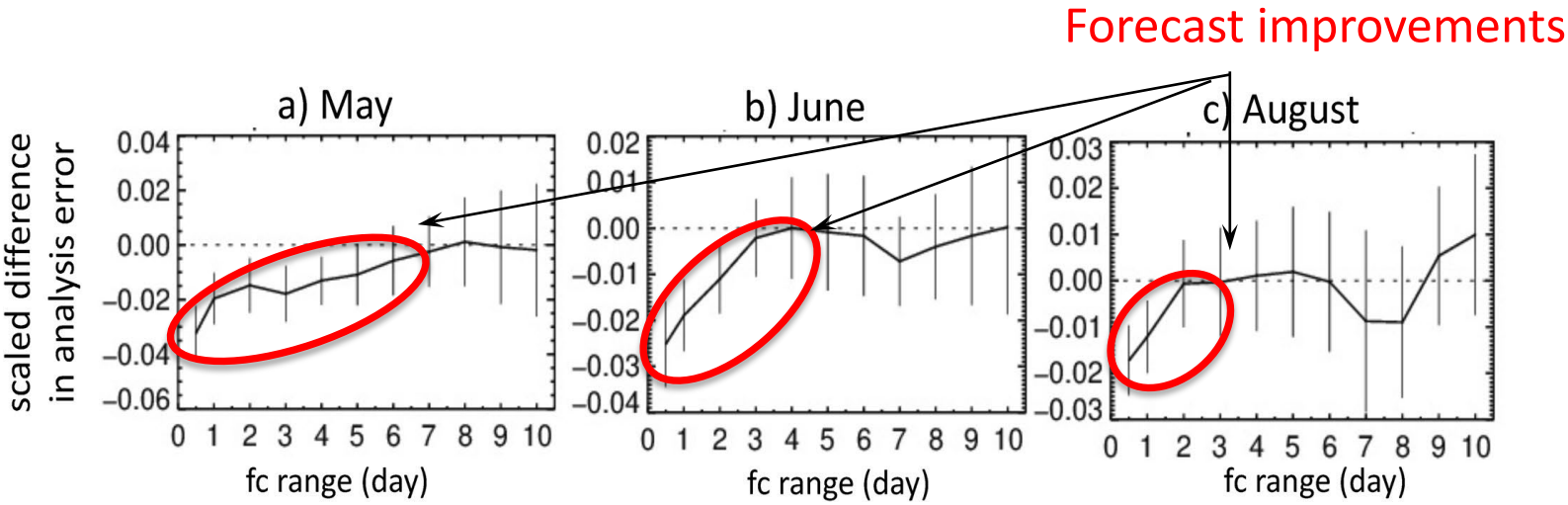
Aeolus makes a difference in regions with a strong wind shear (vertical and longitudinal)



Kelvin wave zonal wind shown by contours. Background balanced zonal wind shown in colours

Žagar et al., 2021

Aeolus impact on Kelvin waves depends on the QBO



Normalized difference of the root-mean-square errors (rmse) of forecasts minus respective analyses for zonal winds in the tropics at 100 hPa.
Normalized difference = [rmse (Aeolus) – rmse (NoAeolus)] / rmse (Aeolus)

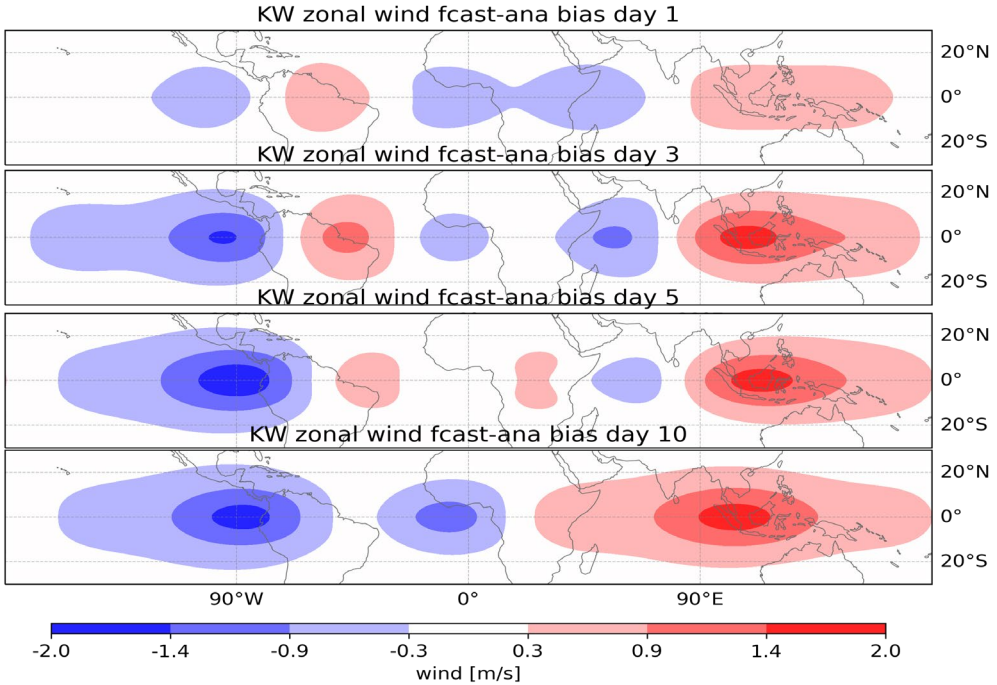
Žagar et al., 2021

Summary

- ✓ Assimilation of Aeolus winds effects the representation of vertically propagating waves in the upper tropical troposphere and lower stratosphere.
- ✓ Aeolus impact is best seen in the layers with the strongest zonal wind shear. This is believed to contribute to better forecasts in the tropopause layer and the lower stratosphere.
- ✓ The Aeolus impact depends on the phase and stage of the QBO.

Outlook: reducing biases

Systematic forecast errors (biases) in the Kelvin wave



ECMWF operational deterministic system

Level near 150 hPa

Error = Forecast-analysis

Averaging period:

Nov 2019-April 2022

Master thesis work by Paolo Andreozzi

Outlook

Expanding tropical belt => stronger convective forcing => stronger wave perturbations & effects on global weather

Aeolus follow-on mission

Thank you for your attention!