The influence of Aeolus wind measurements on the representation of the West African Monsoon

Maurus Borne[1], Peter Knippertz[1], Martin Weissmann[2], Michael Rennie[3]

(1) KIT - Institute of Meteorology and Climate Research (IMK-TRO)
(2) University of Vienna - Department of Meteorology and Geophysics
(3)European Centre for Medium-Range Weather Forecasts (ECMWF)

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Motivation

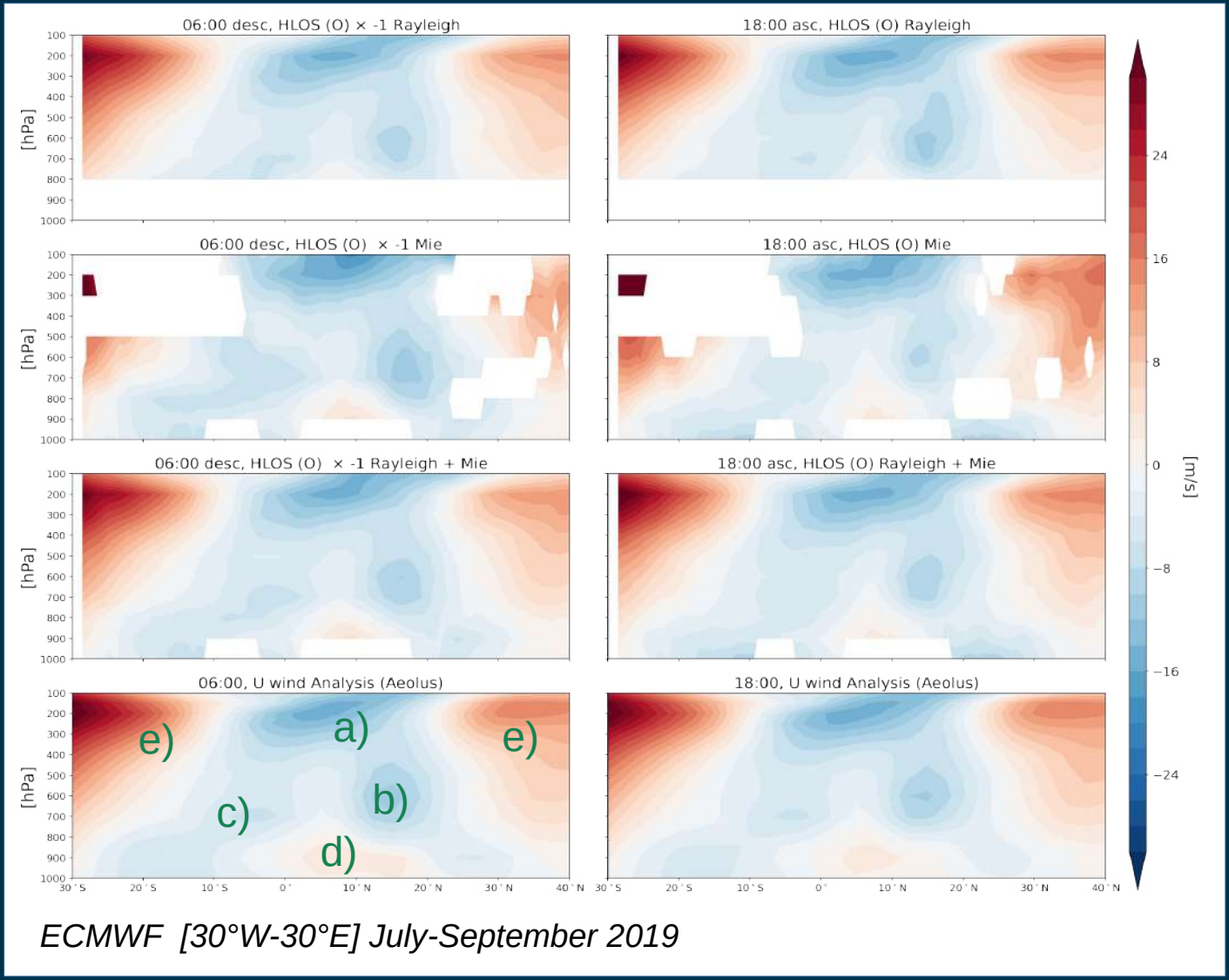
What are the sources of errors and biases in the Aeolus wind measurements?

What influence do Aeolus measurements have on the representation of the West African Monsoon?

Data

- Observation System Experiments of Aeolus at ECMWF (Boreal Summer 2019 and 2020)
  - Analysis and forecast fields for wind
  - Assimilated Aeolus Rayleigh and Mie measurements, corresponding model equivalents, associated errors…
  - Assimilated radiosonde measurements and corresponding model equivalents..
- ERA5 Reanalysis

What does Aeolus measure?



ECMWF [30°W-30°E] July-September 2019

a) Tropical Easterly Jet (TEJ)

b) African Easterly Jet - North (AEJ-N)

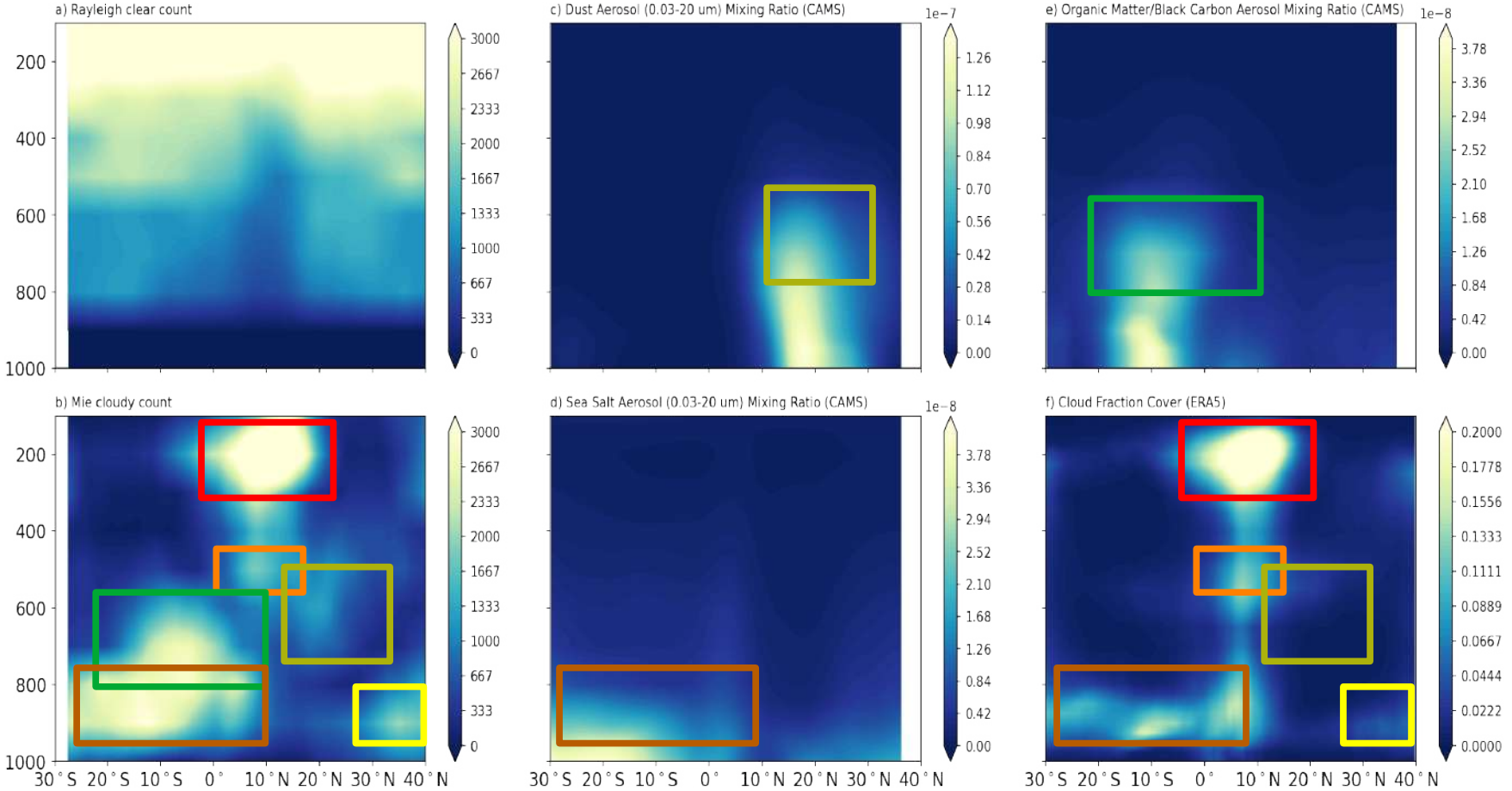
c) African Easterly Jet - South (AEJ-S)

d) Monsoon South-Westerly flow

e) Subtropical Westerly Jets (STJ)

Descending track multiplied by -1 for sign convention

How often does Aeolus measure?



ECMWF, CAMS, ERA5 [30°W-30°E] July-September 2019

Cumulonimbus

Tops of congestus clouds

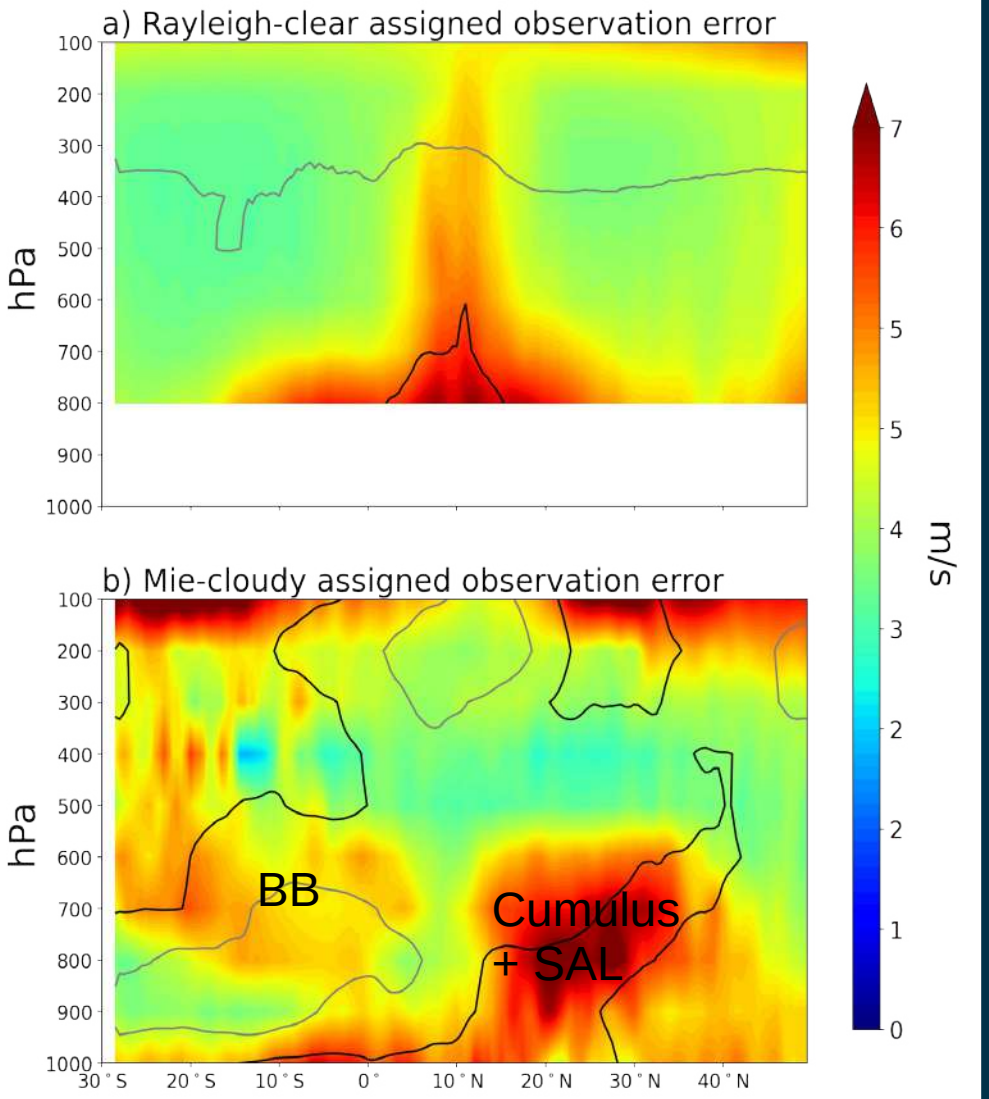
Cumulus + Saharan Air Layer (SAL)

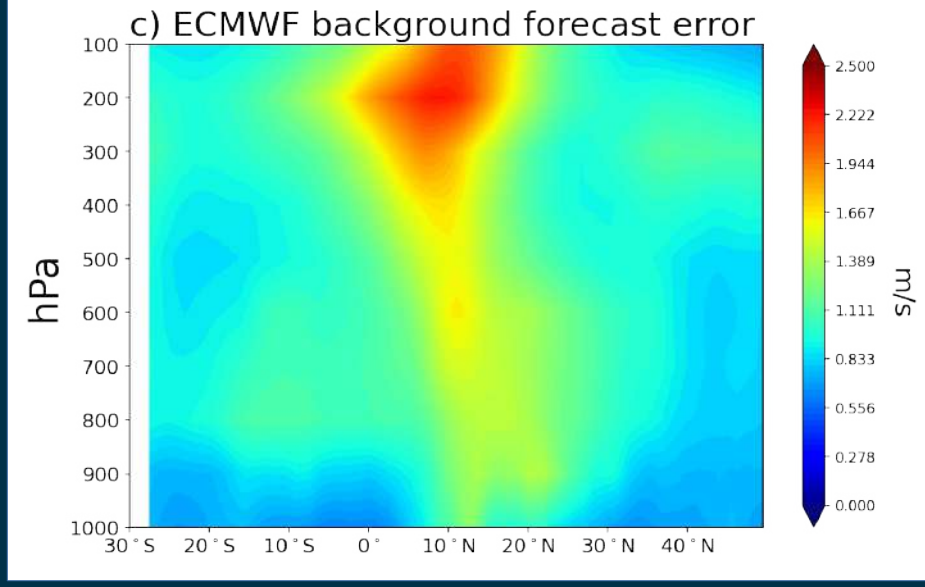
Biomass Burning (BB) aerosol, thermally lifted above clouds

Stratocumulus monsoon cloud layer + Sea Salt Aerosol

Shallow cumulus

Observation and Model errors





Data: ECMWF error types in HLOS space

Area: [30°W-30°E]

Period: July-September 2019

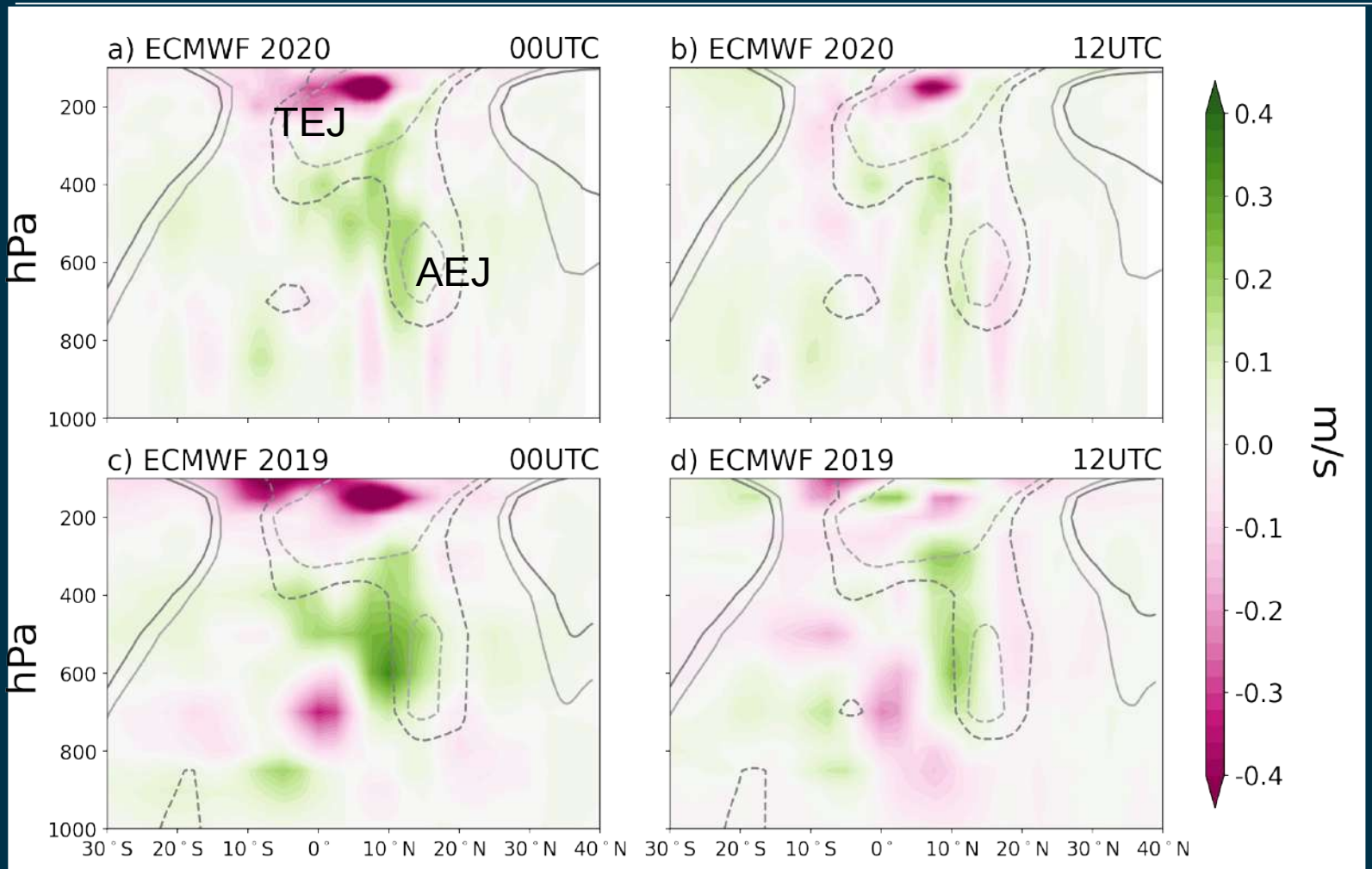
black/gray contours at 500/1500 counts

a) Rayleigh-clear largest errors over convective active region.

b) Mie-cloudy largest errors over Saharan Air Layer (SAL) and Biomass Burning (BB) aerosol. Lower error for cloud scattering.

c) Background forecast error largest in upper troposphere (cb clouds). ECMWF model is conservative: Model errors 3 times lower compared to observation errors.

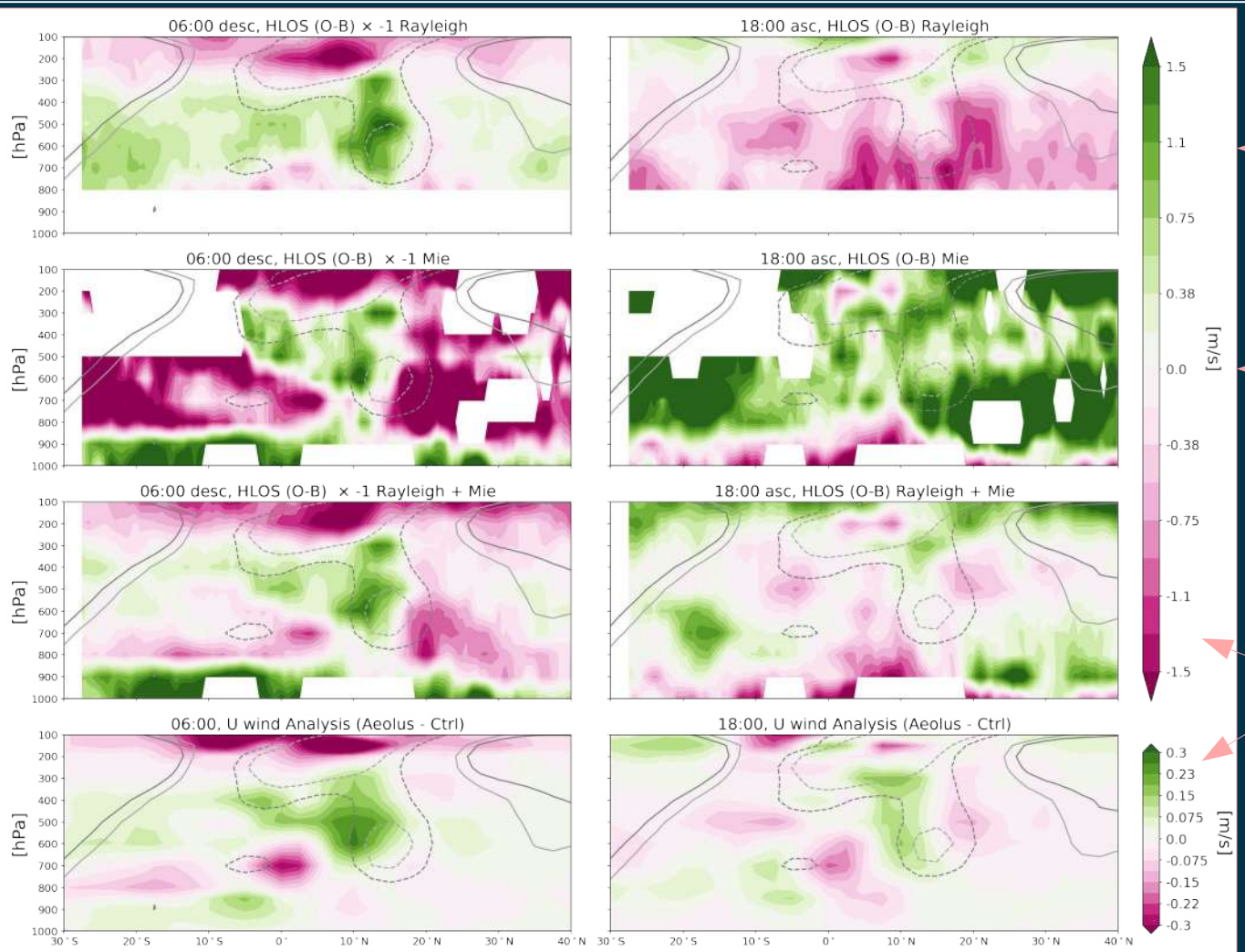
Analysis mean difference (Aeolus - Control)



ECMWF [30°W-30°E] July-September 2019 and 2020
black/grey contour at 9/6 m/s

- Largest difference over convective active region at 00UTC
- AEJ / south of AEJ weaker with Aeolus (within rain belt) to 0.5m/s.
- TEJ stronger with Aeolus.
- **Where do these differences come from?**

Mean impact of Aeolus on Analysis fields



ECMWF [30°W-30°E] July-September 2019
black/grey contour of analysis with Aeolus at 9/6 m/s

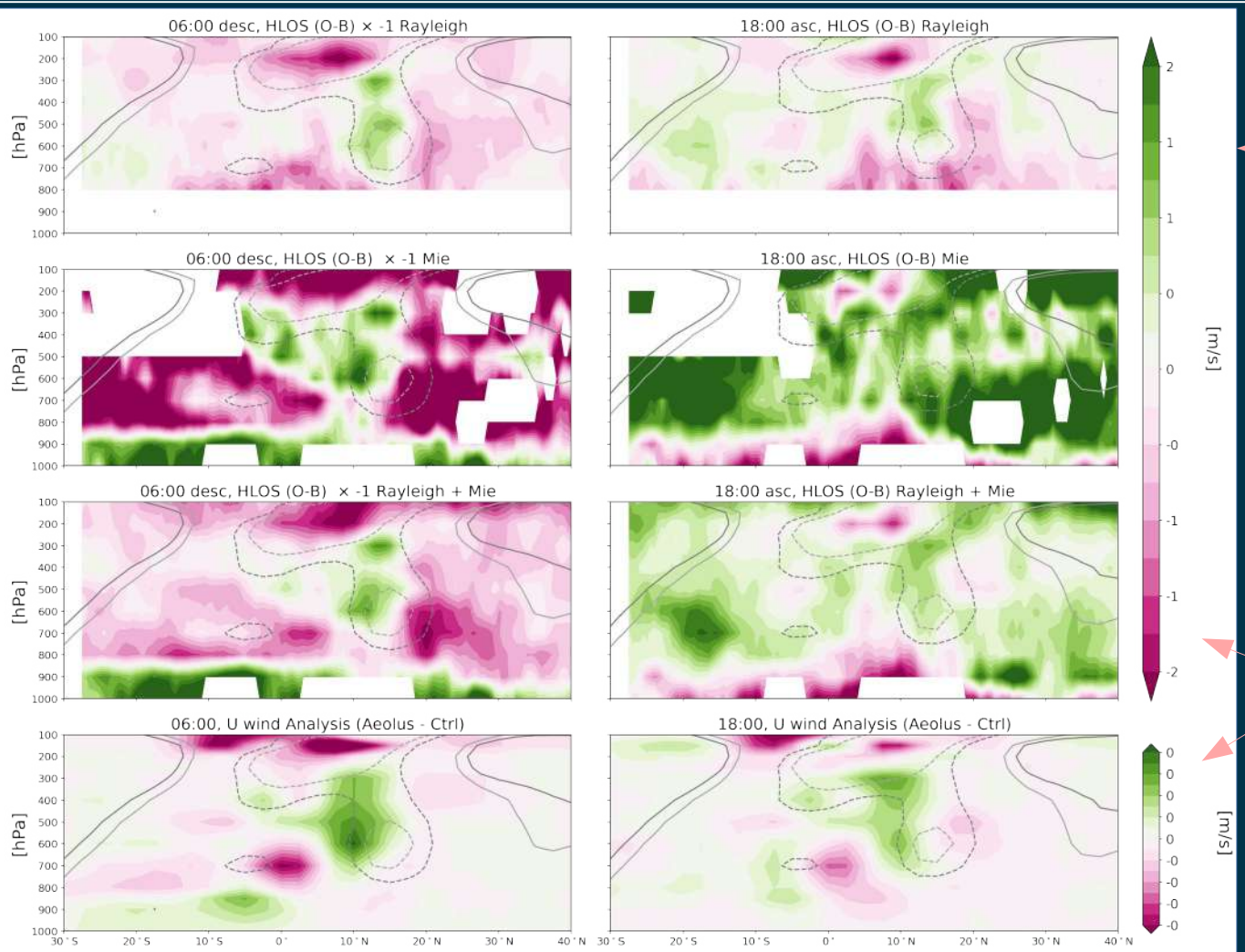
Ascending/descending “bias” and vertical dependent in Rayleigh-clear channel

Ascending/descending “bias” in Mie-cloudy channel

Similarities between O-B and analysis mean difference: **mean difference could be caused by a combination of biases**

Descending track multiplied by -1 for sign convention

Temperature-based bias-correction for Rayleigh-clear



ECMWF [30°W-30°E] July-September 2019
black/grey contour of analysis with Aeolus at 9/6 m/s

Temperature-dependant BC in Rayleigh channel partially removes asc/desc bias, better consistency between ascending and descending orbits.

BC effect on analysis is small but analysis difference is more consistent between ascending and descending orbits.

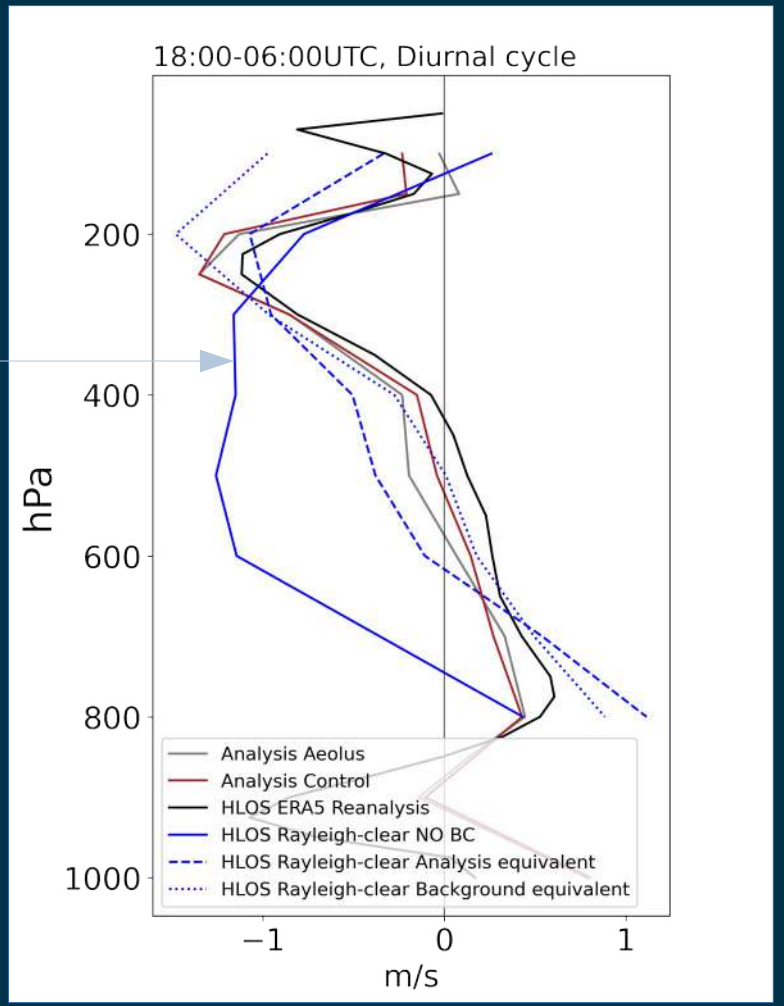
Descending track multiplied by -1 for sign convention

Diurnal cycle: Rayleigh-clear

Rayleigh-clear

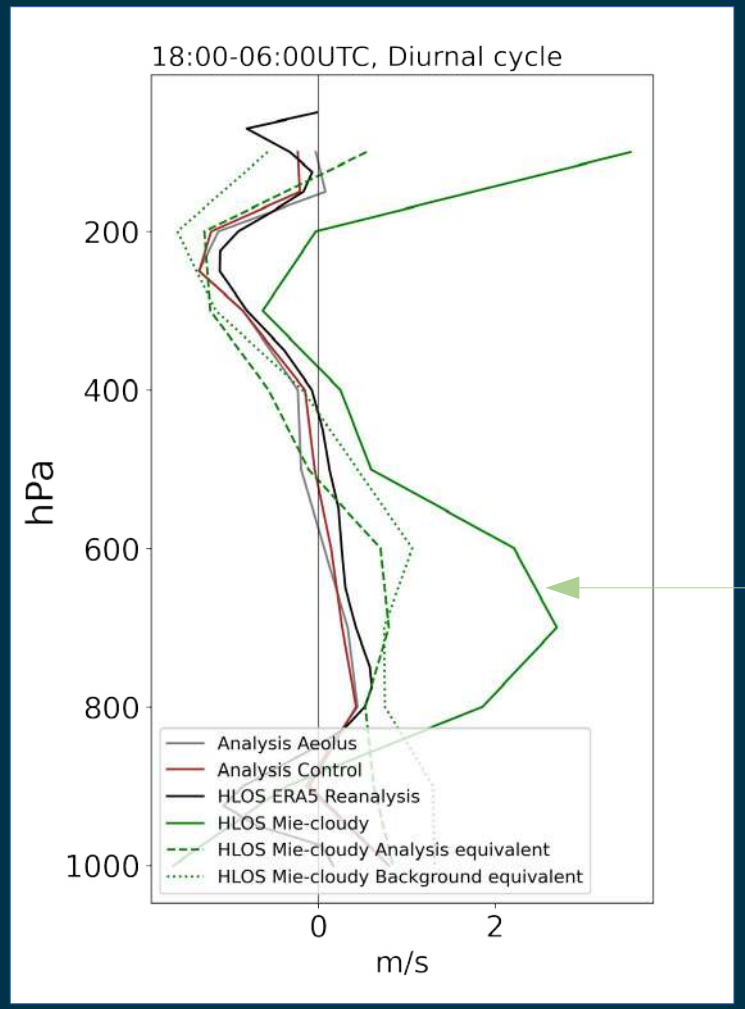
Not following diurnal cycle.

Temperature-dependant bias? Could be inconsistency between Rayleigh response calibration curve for cold and warm temperatures.



ECMWF [30°W-30°E; 10°S-20°N] July-September 2019

Diurnal cycle: Mie-cloudy



ECMWF [30°W-30°E; 10°S-20°N] July-September 2019

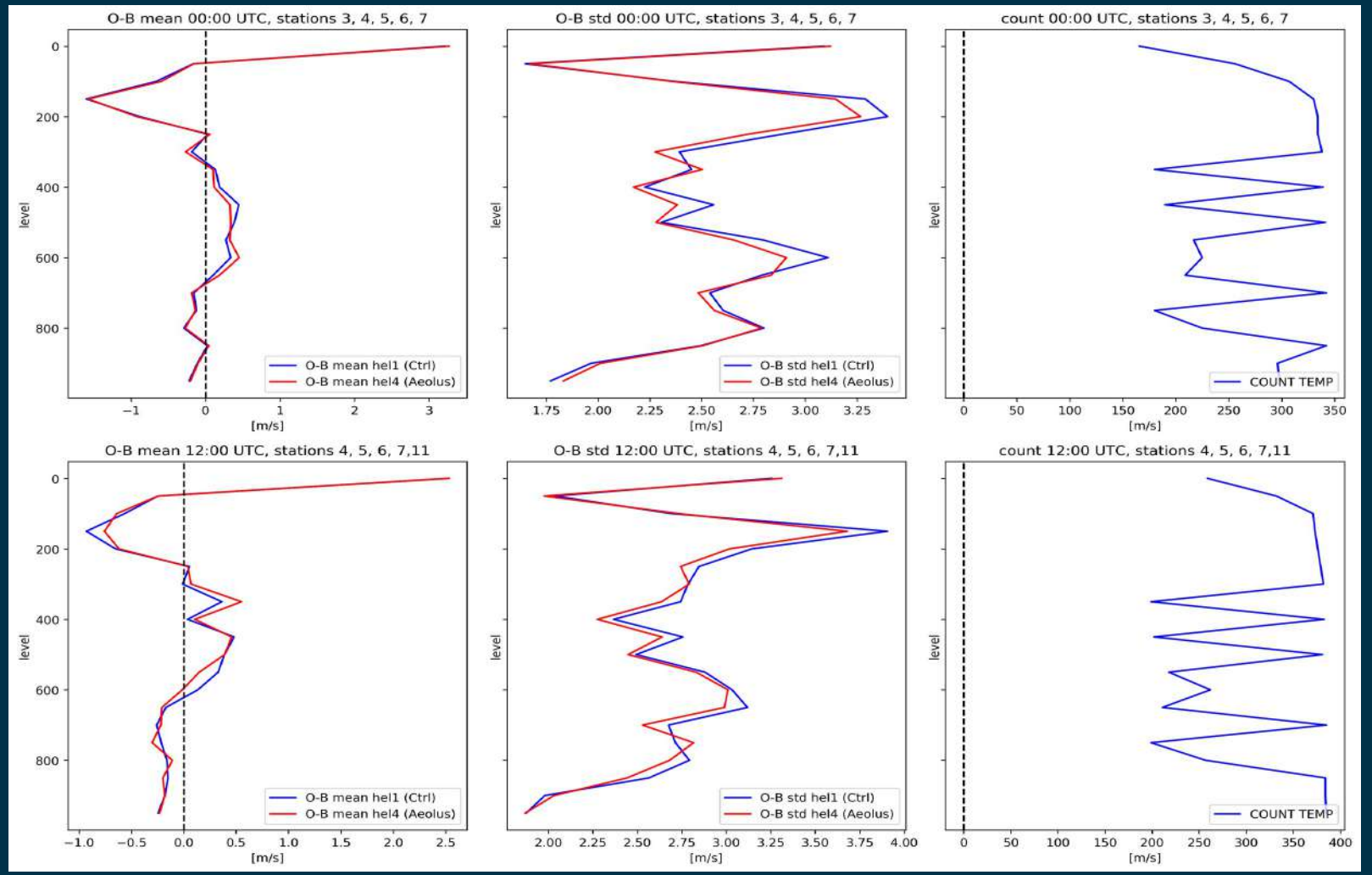
Mie-cloudy

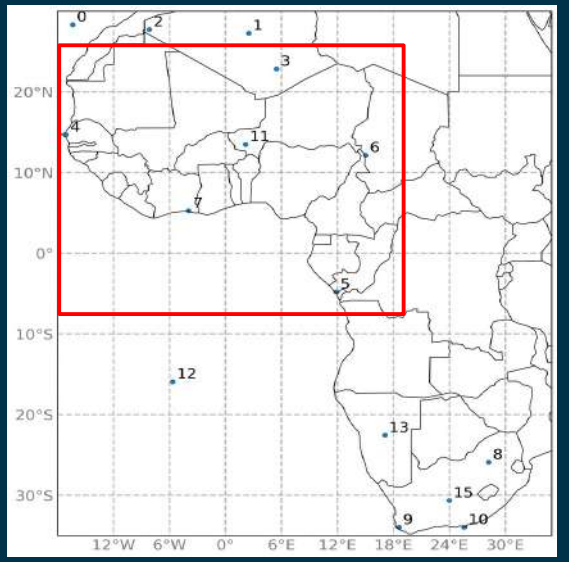
Follows shape of diurnal cycle with a bias of ~0.5 m/s.

Largest difference with diurnal cycle at 700 hPa (i.e Saharan Air Layer, Bio Mass Burning with largest obs errors).

Analysis pushed toward Rayleigh-clear observation.

Radiosonde verification over West Africa 2020





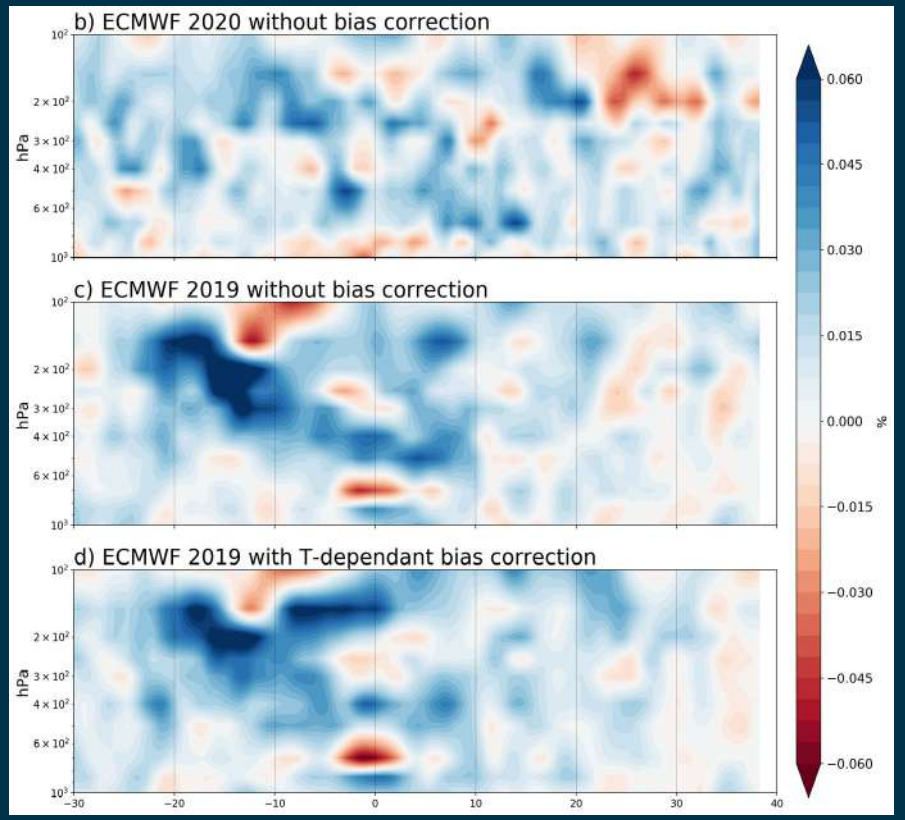
- No mean improvement of the background
- Small improvement of the background std
- The assimilation of Aeolus reduces the random error of the model wind

ECMWF July-September 2020

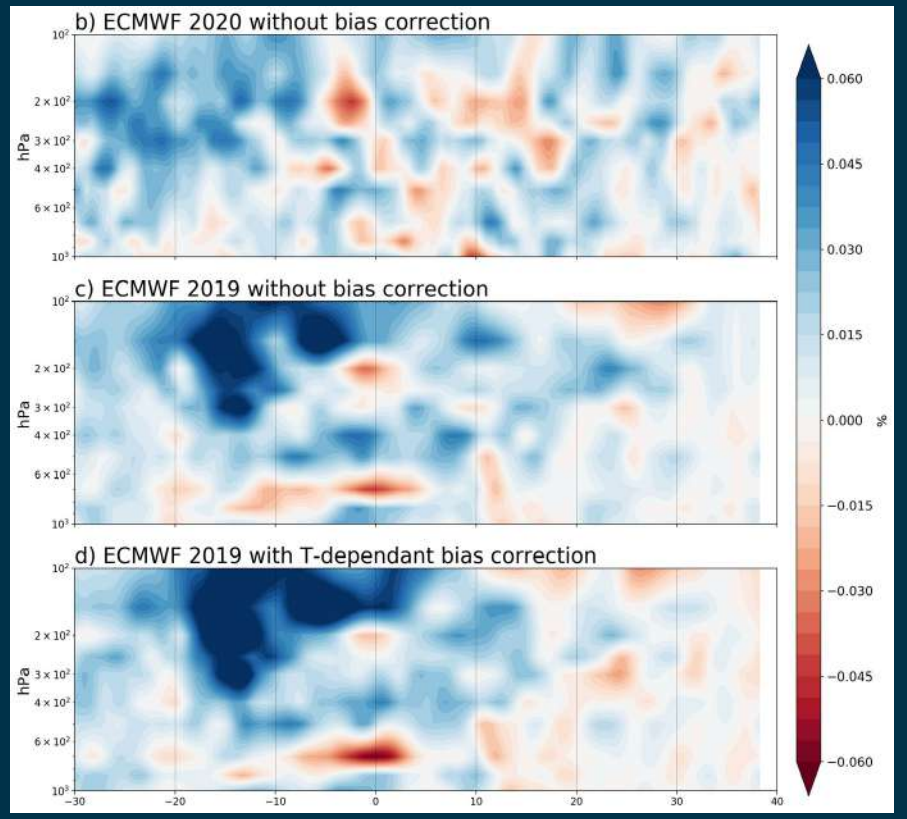
Forecast impact Zonal Wind vs ERA5 (+48h)

Relative improvement =(RMSE(CONTROL−RMSE(AEOLUS))/RMSE(CONTROL))
Blue Improvement / Red Deterioration

00 UTC



12 UTC



- **Overall positive impact of Aeolus over Africa**
- **Highest impact in the SH upper troposphere.**
- **Mixed impact over WAM region between 00UTC and 12 UTC.**
- **Mixed impact of bias-correction.**

ECMWF [30°W-30°E] July-September 2019 and 2020

Conclusion

- **Assimilation of Aeolus data improves wind forecasts overall**: Forecast relative-improvement + Radiosonde verification over West Africa.
- **Rayleigh-Clear bias**: ascending/descending bias directly influencing the mean analysis difference. Temperature-dependant bias-correction removes bias, but no particular forecast improvement. Possibly other reason of bias.
- **Mie-cloudy bias**: More complex, might be linked to diurnal cycle with a systematic bias of 0.5 m/s.
- **Mie-cloudy observation error**: Larger in region with presence of aerosols (Biomass Burning and Saharan Air Layer) compared to clouds.
- **Correcting and understanding these complex biases and errors could further improve the NWP impact over Africa and the tropics.**