Karlsruhe Institute of Technology

WAVES TO WEATHER

ASKOS-WIND – A Contribution to the Aeolus CAL/VAL Campaign in Cape Verde in June-July 2020

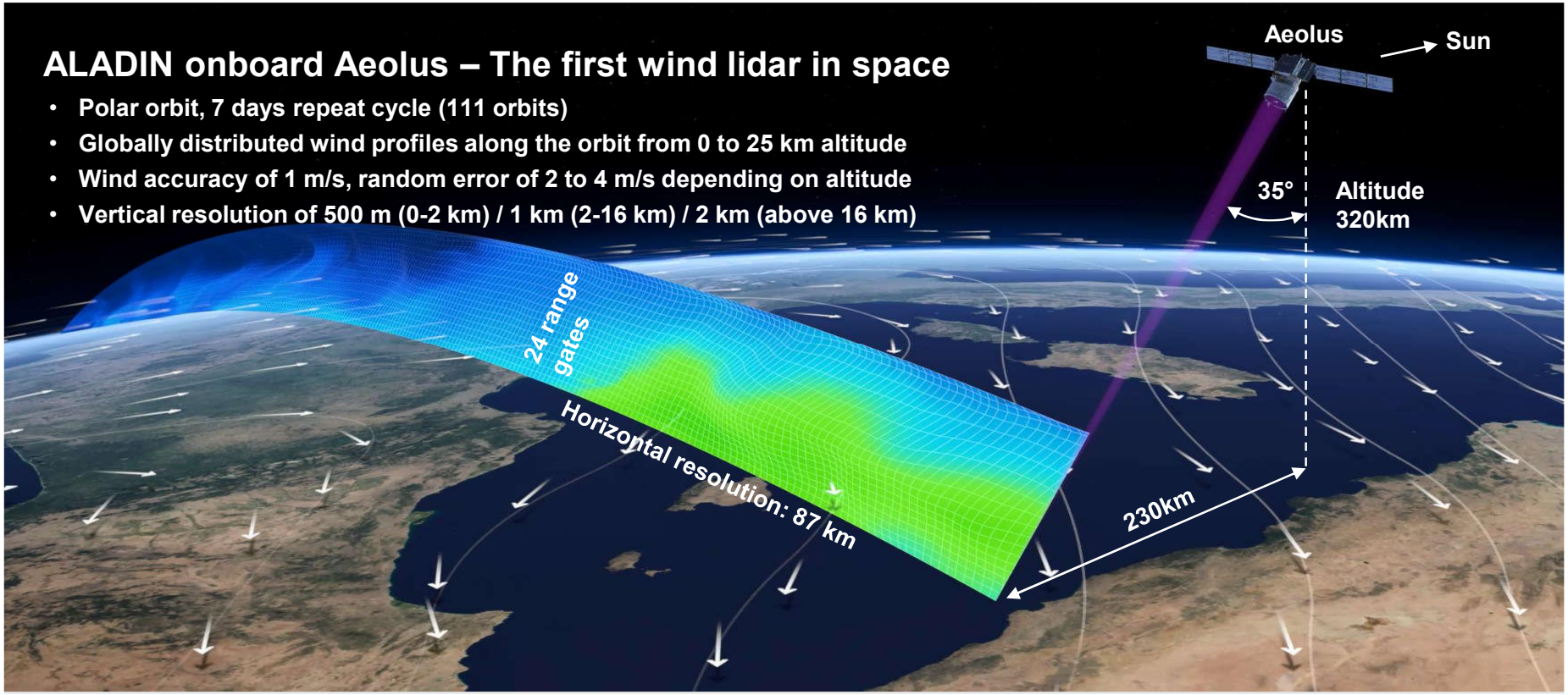
Peter Knippertz, O. Reitebuch, A. H. Fink, C. Flamant, M. Weissmann, J. Delanoë, M. Gaetani, A. Dabas, A. Cress, P. Nabat, M. Mallet, R. Roehrig, J.-F. Mahfouf, V. Pourret, M. Savli, F. Couvreux, D. Bouniol, P. Peyrillé & others

Institute of Meteorology and Climate Research (IMK)

Aeolus – Keeper of the winds

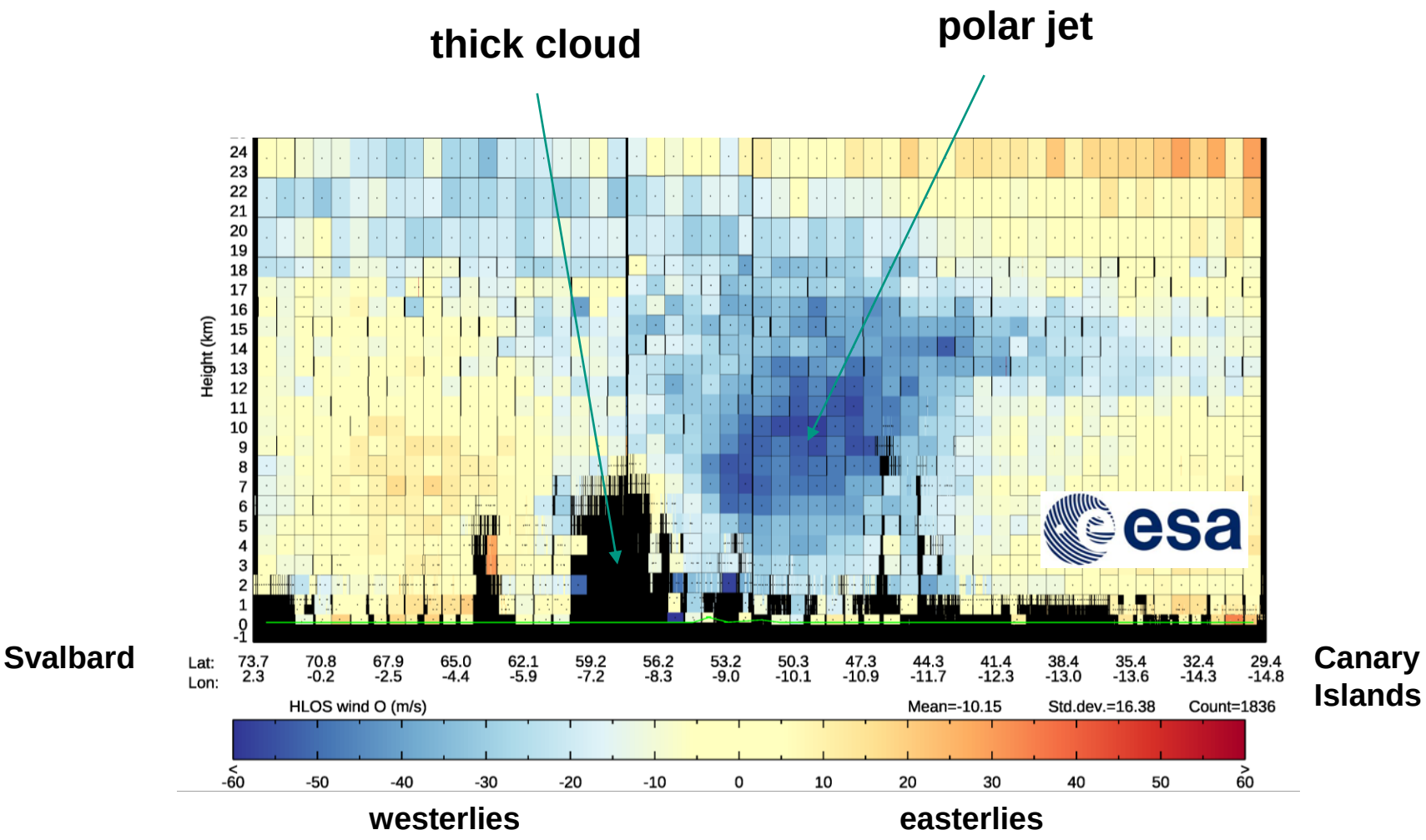
- Launched 22 August 2018 as part of ESA's Earth Explorer missions
- First Doppler wind lidar (ALADIN) in space
- Works in clear air and cloudy air (Rayleigh & Mie algorithms)
- Expected to improve analysis and forecasts, particularly in the tropics

Aeolus – Specifications



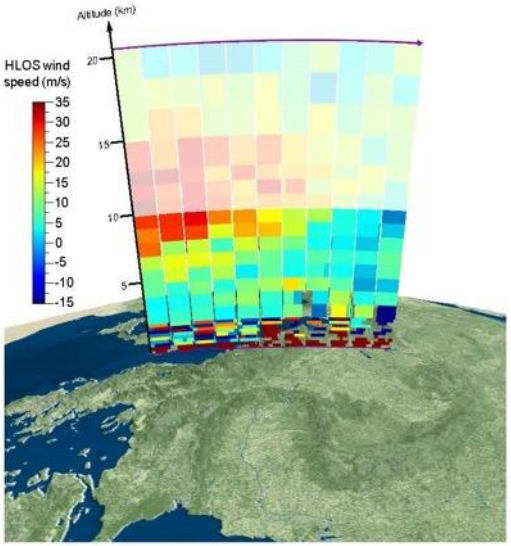
- Anticipated mission life: 3 years
- Horizontal resolution for cloud tops 10–15km

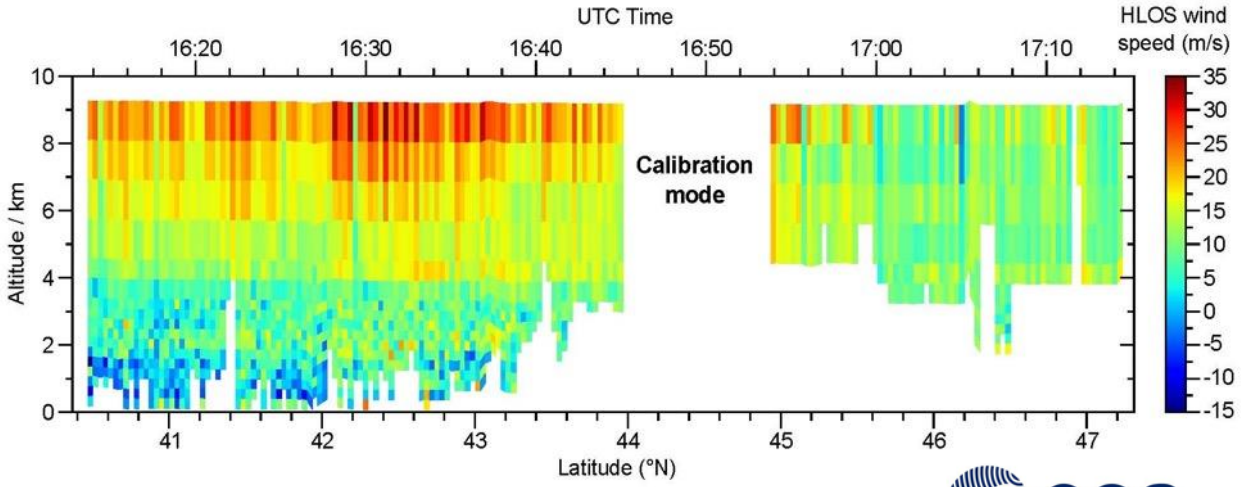
Aeolus – Example 10 March 2019 over eastern Atlantic



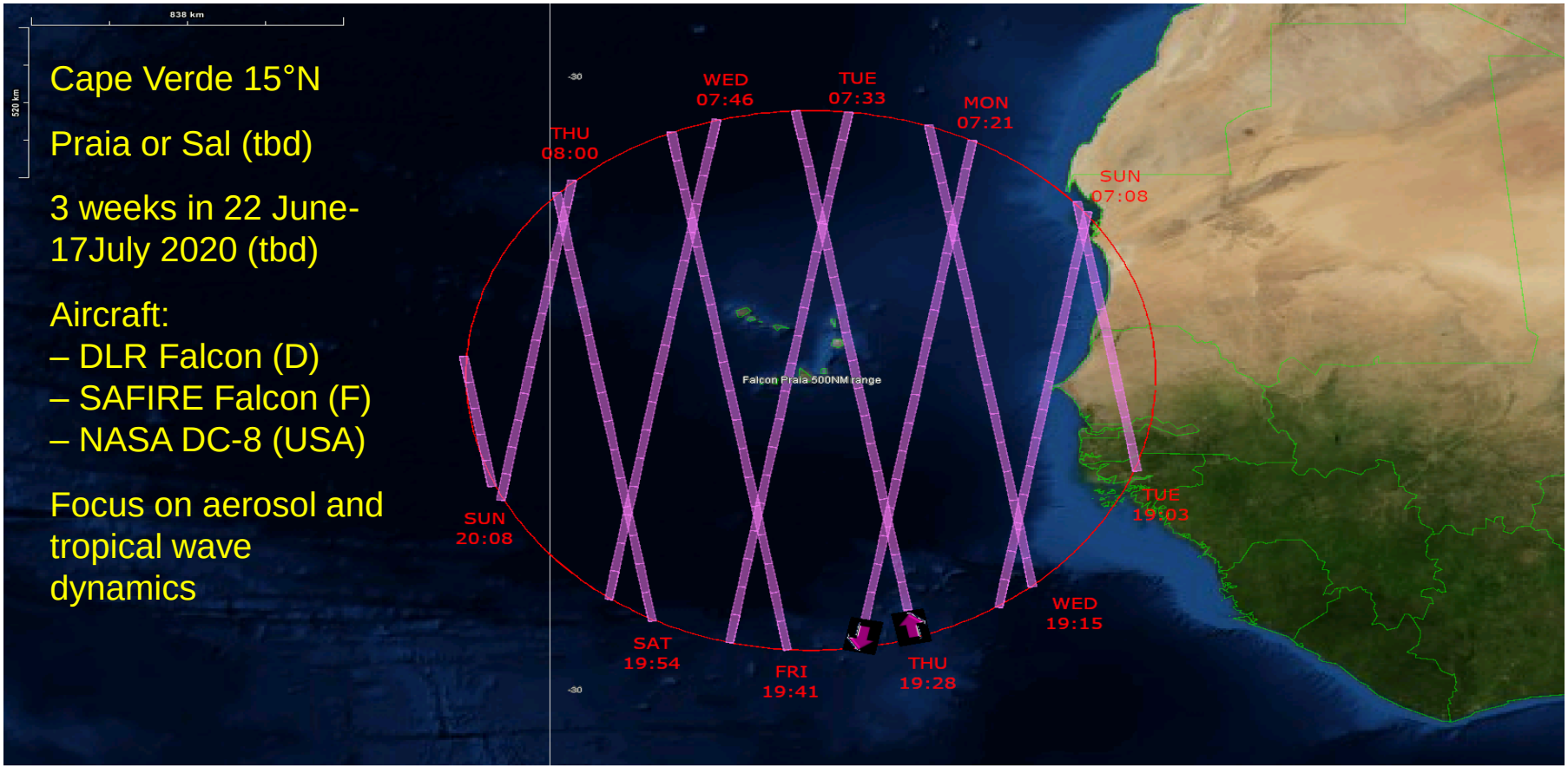
Aeolus – CAL/VAL campaigns

- Fly an aircraft with similar lidar instruments underneath the satellite track
- Use high-resolution aircraft data for calibration and validation
- First campaigns in central Europe (Nov-Dec 2018 and May 2019)
- Example shows DLR flight crossing the Alps





Aeolus – CAL/VAL campaign 2020

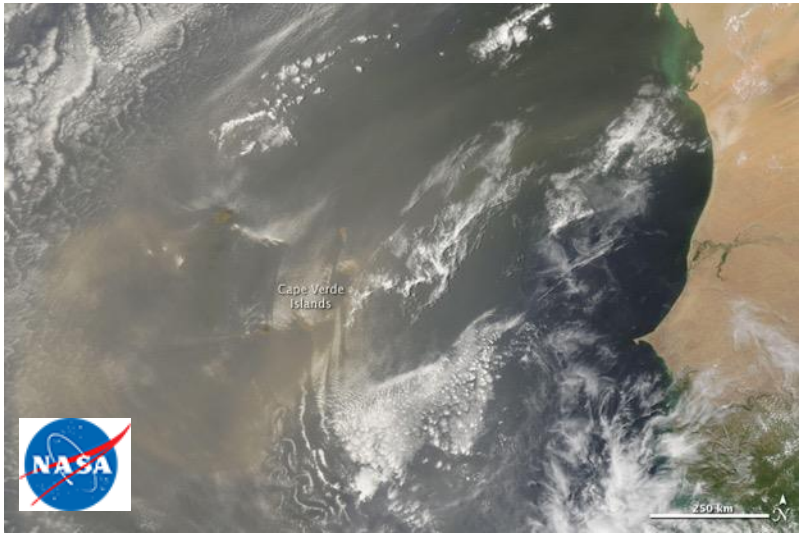


ASKOS science program

- **ASKOS** means the “windbag of Aeolus”.
- It is an international science program being developed around the 2020 Cape Verde campaign.
- It contains activities focused on
  – wind (**ASKOS-WIND**) → this talk
  – mineral dust (**ASKOS-AEROSOL)** → *A. Benedetti, V. Amiridis et al.*
- ASKOS will deploy instrumentation on Cape Verde to complement the aircraft measurements such as
  – Various lidars including ceilometer
  – Cloud radar
  – Microwave radiometer
  – Balloon and ground measurements

Why Cape Verde during boreal summer?

- Ideal conditions with generally **high aerosol loading** → good signal
- Concomitant measurement of aerosol optical properties, wind, and their interactions.
- The midlevel **African easterly jet** allows for the formation of synoptic-scale **African easterly waves** (AEWs) with maximum intensity close to West African coast.



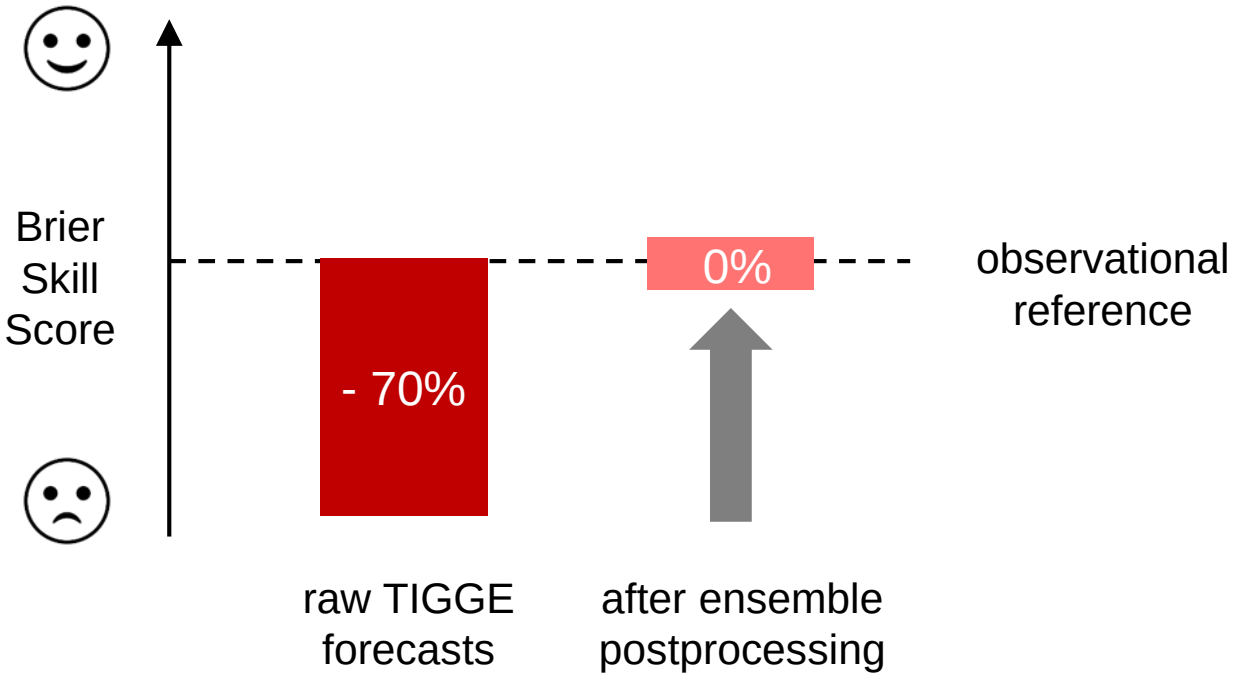
- AEWs organise **convection** through modifications in humidity, temperature and vertical wind shear.
- The tropical atmosphere sustains other types of **planetary waves** that modulate rainfall.

ASKOS-WIND science questions

- **DATA QUALITY**
  How well does Aeolus monitor winds at different vertical levels in comparison with aircraft measurements?
  What limits the quality of the retrievals?
- **WAVE DISTURBANCES**
  How well are characteristics of wave disturbances represented in analysis and forecast data relative to the satellite and aircraft measurements?
- **DATA DENIAL**
  How much deterioration do we get if we deny the satellite / aircraft measurements to the data assimilation system?
- **FORECAST IMPACT**
  Does a better analysis lead to better forecasts of waves, precipitation, dust emission and transport?

How good are current forecasts?

- Comprehensive recent evaluation of TIGGE ensemble forecasts for precipitation over northern tropical Africa by *Vogel et al. (2018, WAF)*.
- Different temporal (1–5 days) and spatial (0.25–5°) accumulations investigated.
- Probabilistic forecast based on past observations used as reference.



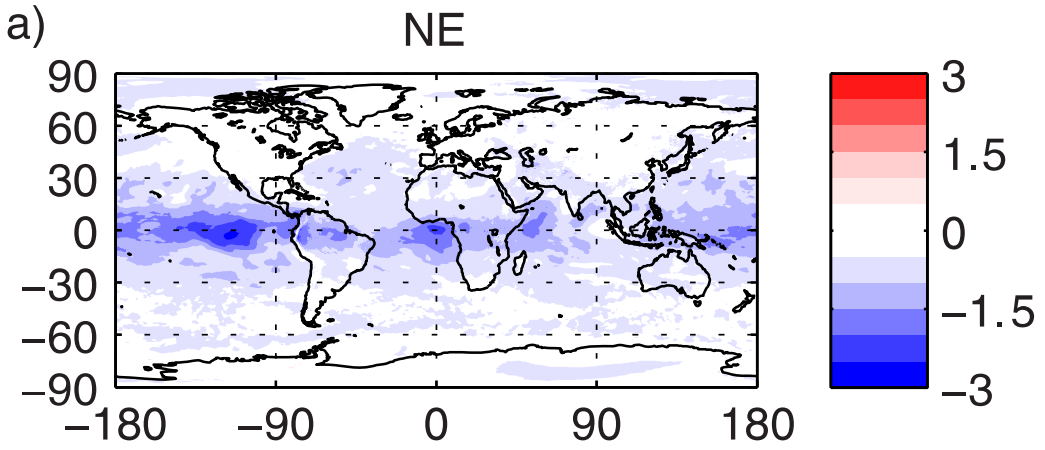
adapted from Vogel et al. (2018)

Likely reasons for low forecast skill

- Tropical Africa characterized by the world-wide largest degree of **mesoscale convective organization**
  → large challenge for convection schemes
- **Coupling to tropical waves** may enhance predictability but current models struggle to realize this
  → potential for statistical (-dynamical) models?
- **Observational network** over Africa very limited (e.g. radiosondes)
  → new satellite data may have large benefit
- **Analysis errors** are particularly large in the tropics
  → new approaches in data assimilation

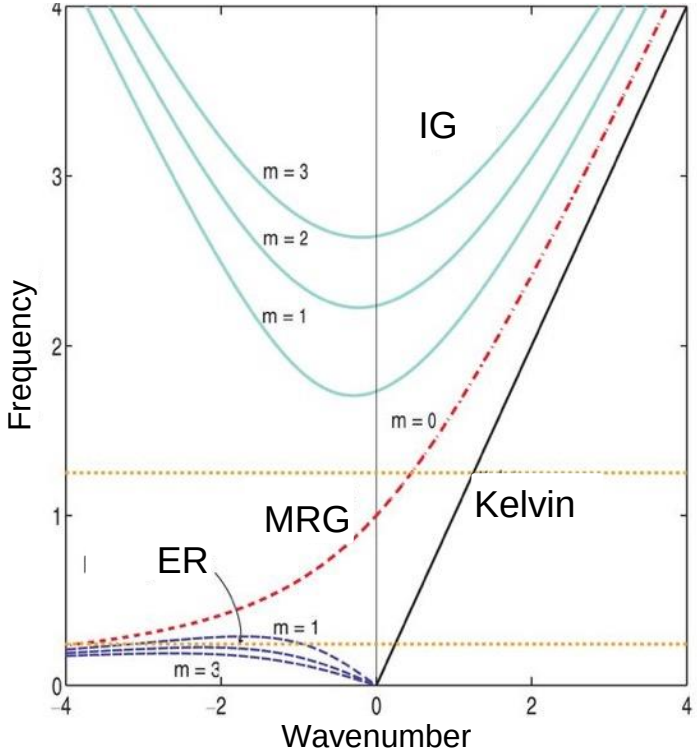
mean July analysis error in 500-hPa temperature

from Privé & Errico (2013)



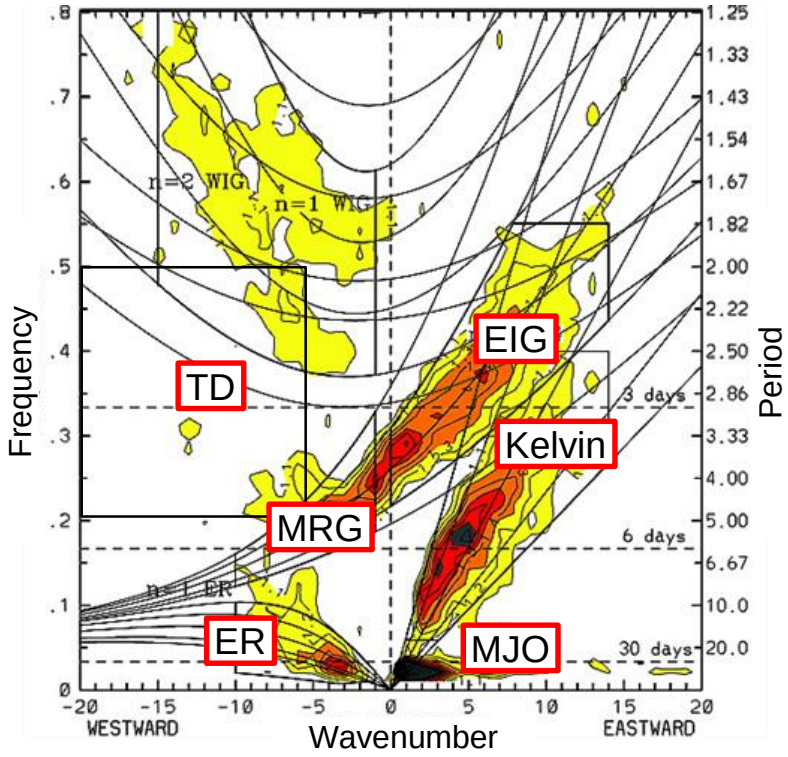
What are tropical waves?

Theoretical dispersion curves



Delplace et al. (2017)

Power spectrum of tropical convection

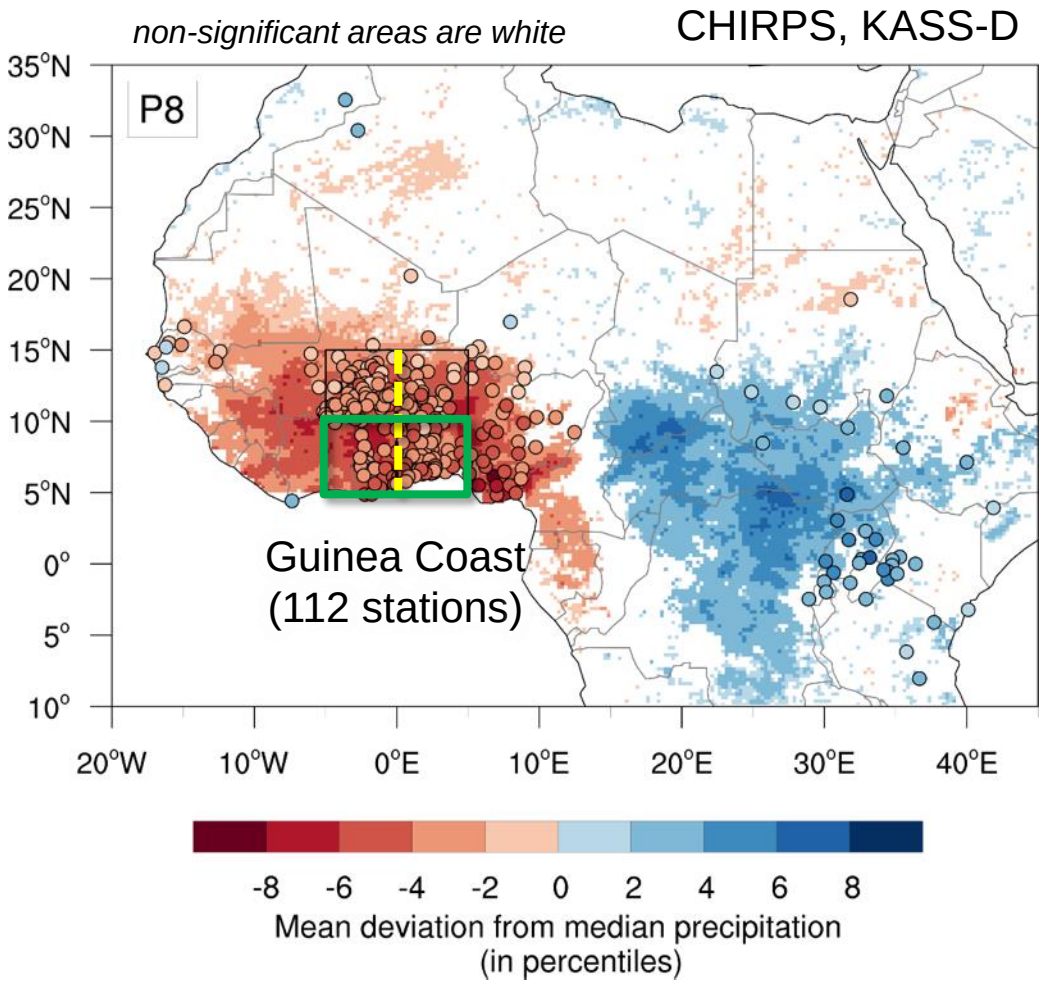


adapted from Kiladis et al. (2009)

- Solutions of shallow water theory (left) plus:
  - Madden-Julian Oscillation (**MJO**)
  - Tropical disturbances (**TD**) including African Easterly Waves (**AEW**)

Tropical waves cause continent-wide modulation

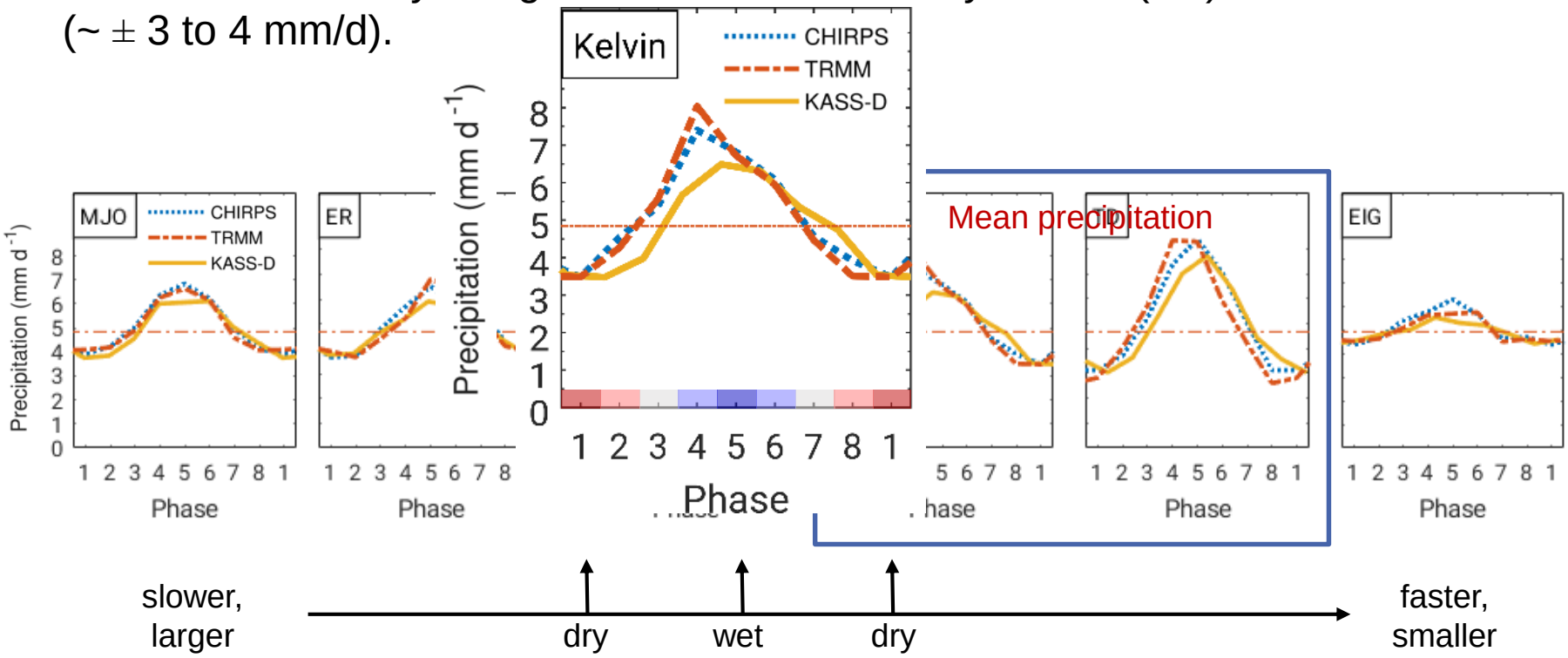
- Example: Kelvin wave
- Composites of cases with significant **local** wave activity (0°E, 5°–15°N).
- To make rainfall anomalies in different climates comparable, anomalies are quantile based.
- Rainfall is modulated **continentally**.
- Wind pattern should be captured by Aeolus.



adapted from Schlueter et al. (2019a)

Tropical waves cause large variations

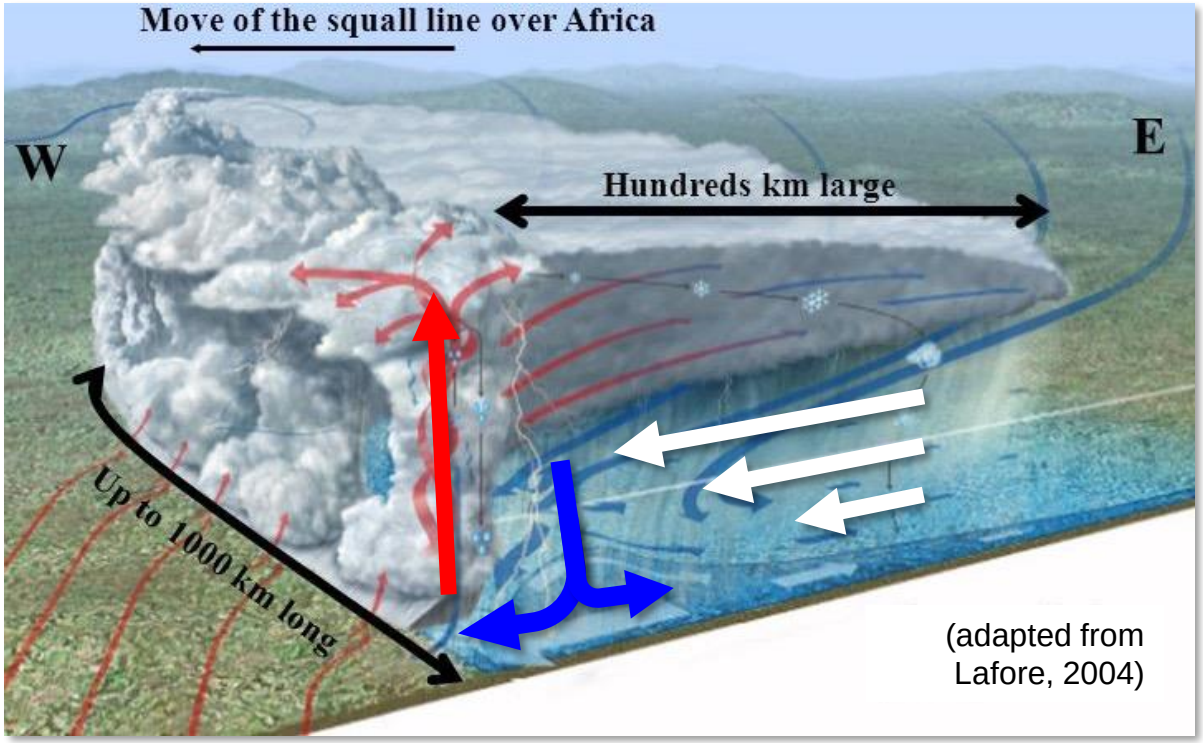
- Mean precipitation in all eight phases at the Guinea Coast.
- The modulation intensities agree well for all three datasets.
- Modulation intensity is highest for African Easterly Waves (TD) and Kelvin waves (~ ± 3 to 4 mm/d).



Schlueter et al. (2019a)

Modulation of mesoscale convective organisation

The majority of rainfall in northern tropical Africa stems from mesoscale convective systems (Fink and Rainer, 2003)



Needed ingredients:

↑ Convective available potential energy (CAPE)

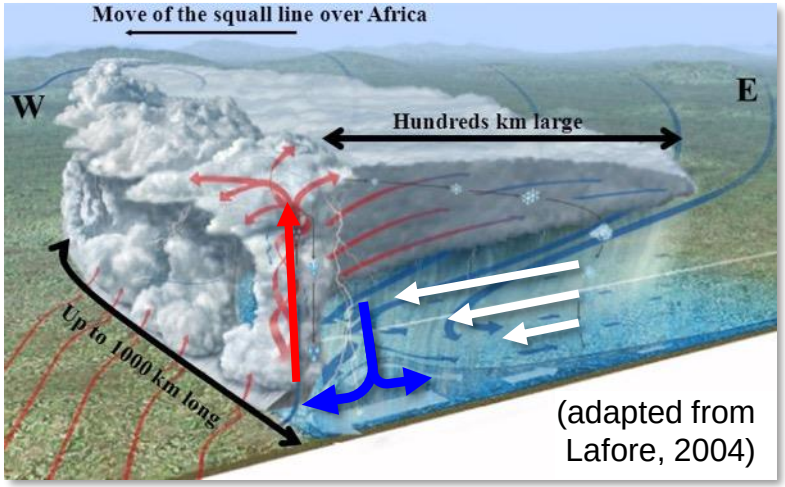
↓ Mid-tropospheric humidity (RH 500hPa)

↑ Low-level wind shear

Modulation of mesoscale convective organisation

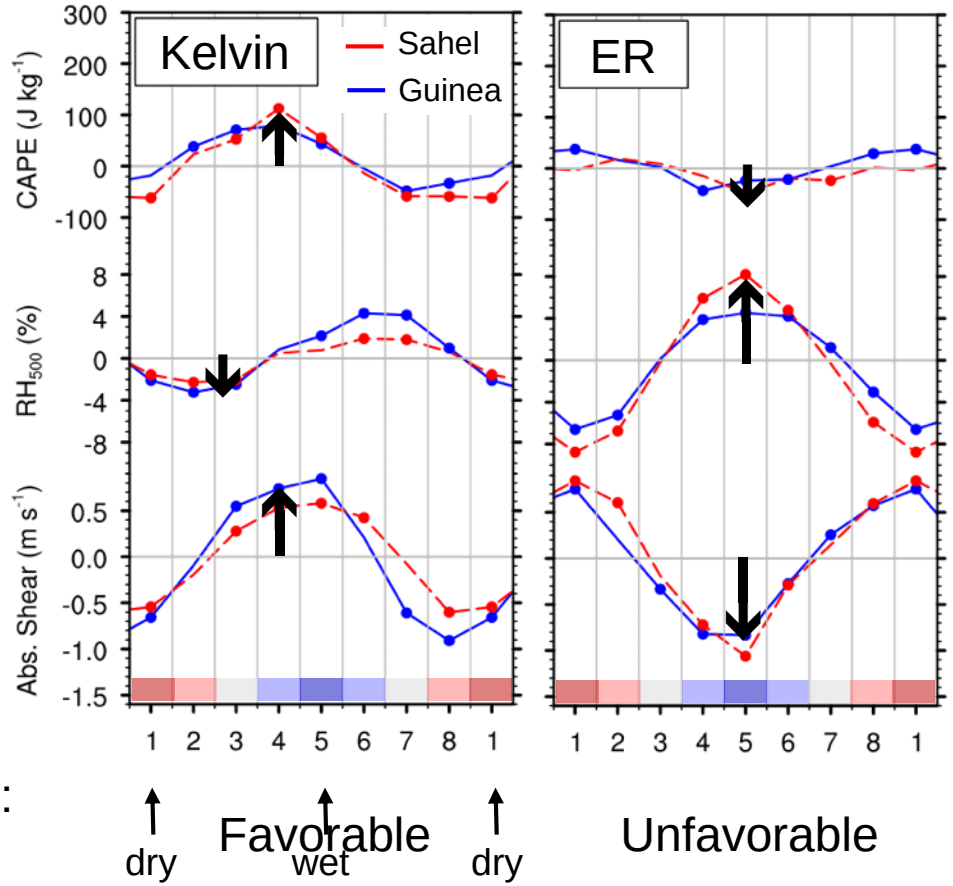
Needed ingredients:

CAPE ↑, RH500 ↓, Shear ↑



Kelvin wave
TD, MJO, EIG similar

ER wave
MRG are similar



Conditions for mesoscale organization:

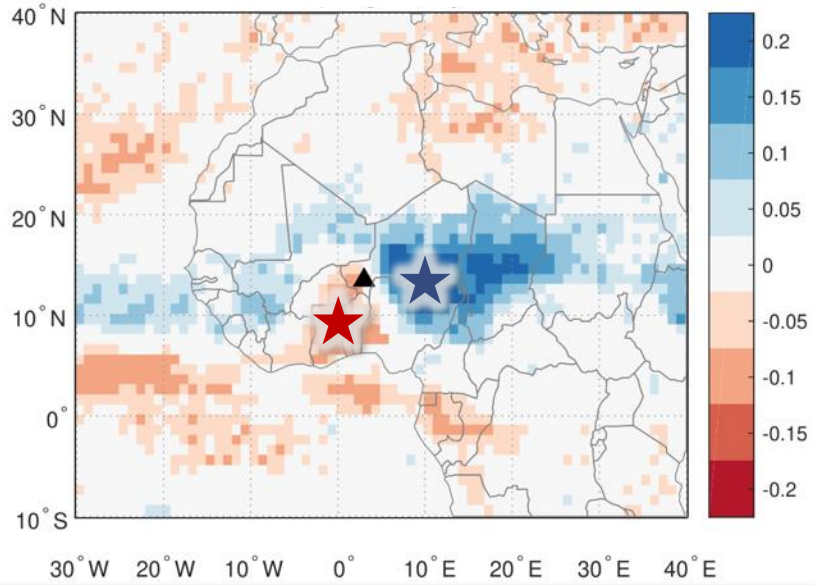
Filled circles: significant anomalies (p<5%)

Schlueter et al. (2019b)

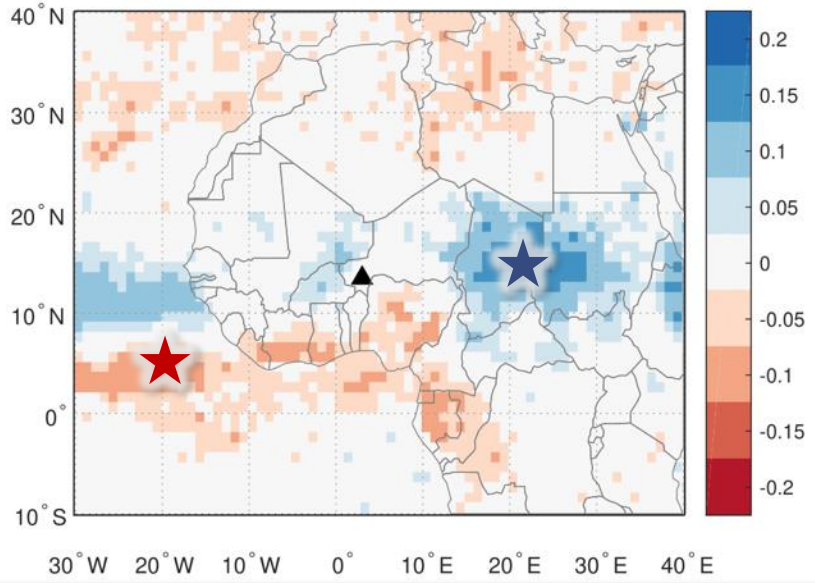
Potential for better forecasts?

Spatiotemporal correlation patterns for rainfall over Niamey

Lag: -1 day



Lag: -2 days



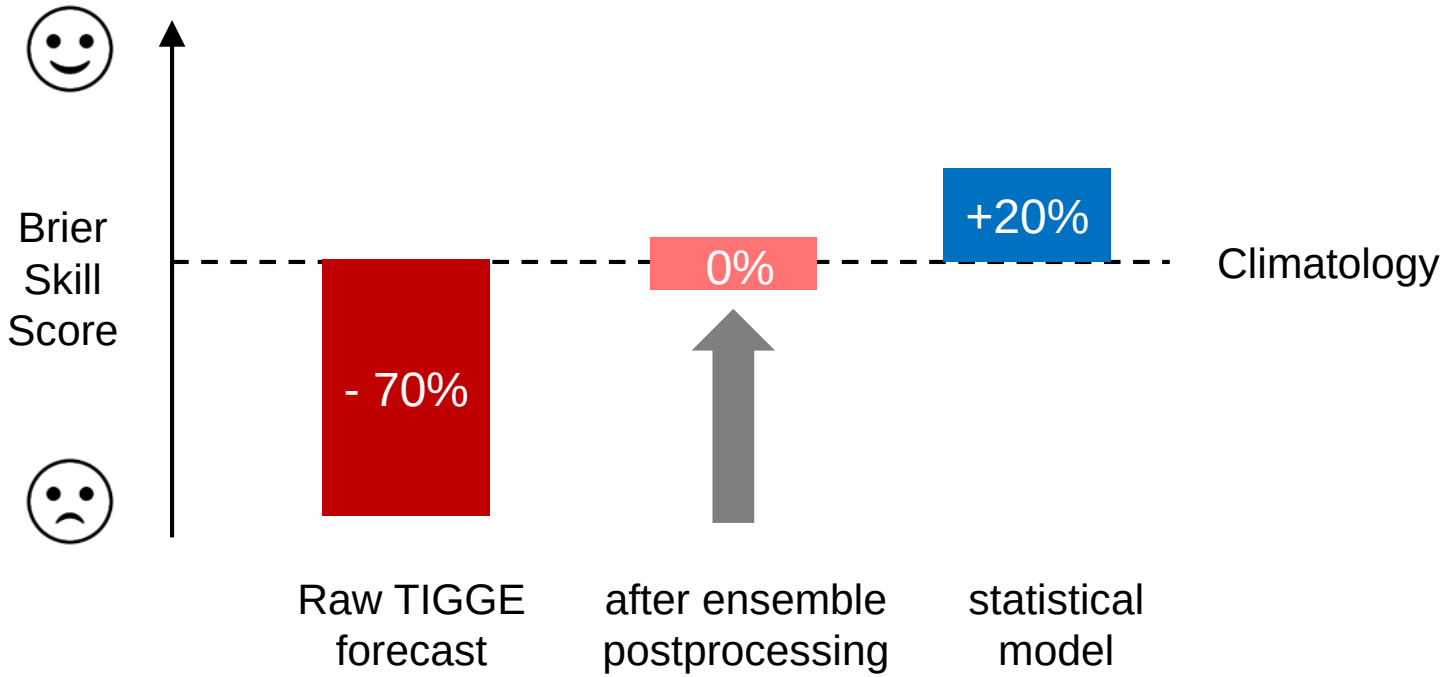
Statistical rainfall forecast:

The probability of rainfall occurence for day +1 is predicted using rainfall in locations of max. (★) und min. (★) correlations one and two days prior.

(*Klar, 2017; Vogel, 2019*)

Performance of the statistical model

- Overall, the model outperforms climatology by 20%.
- It is significantly better than current weather models, even after postprocessing.
- The model is relatively simple and can be extended in several ways.

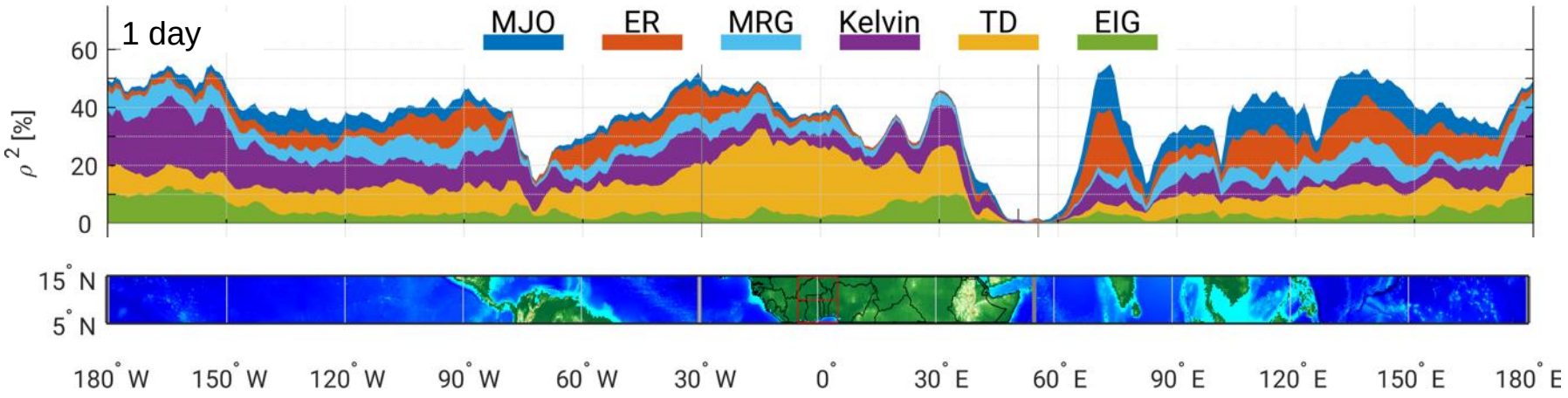


Adapted from Vogel et al. (2018)

Conclusions

- **Rainfall forecasts** over tropical Africa remains a huge challenge.
- Promising new avenue is to better represent the coupling of convection with **tropical waves**, both in dynamical and statistical models.
- **Aeolus** satellite and Cape Verde **ASKOS** campaign in June-July 2020 offer great opportunities to further investigate this issue with new data.
- Planned activities:
  – comparison of wind fields from satellite and aircraft
  – validation of operational analyses (ECMWF and others)
  – wave filtering and composite analysis
  – evaluation of forecasts for tropical waves and rainfall
  – data denial experiments
  – comparison to statistical (-dynamical) models
- Coupling between waves, rainfall and dust emission / transport creates exciting link to **ASKOS-AEROSOL**.
- Could partly be realised through **Waves to Weather**

Extension of method to entire tropics



- Tropical waves explain large portions of rainfall variability in the entire tropics.

  → The proposed statistical method has also large potential for the rest of the tropics.

WAVES TO WEATHER