Wind impact from different observing systems in the ECMWF 4D-Var system

Niels Bormann

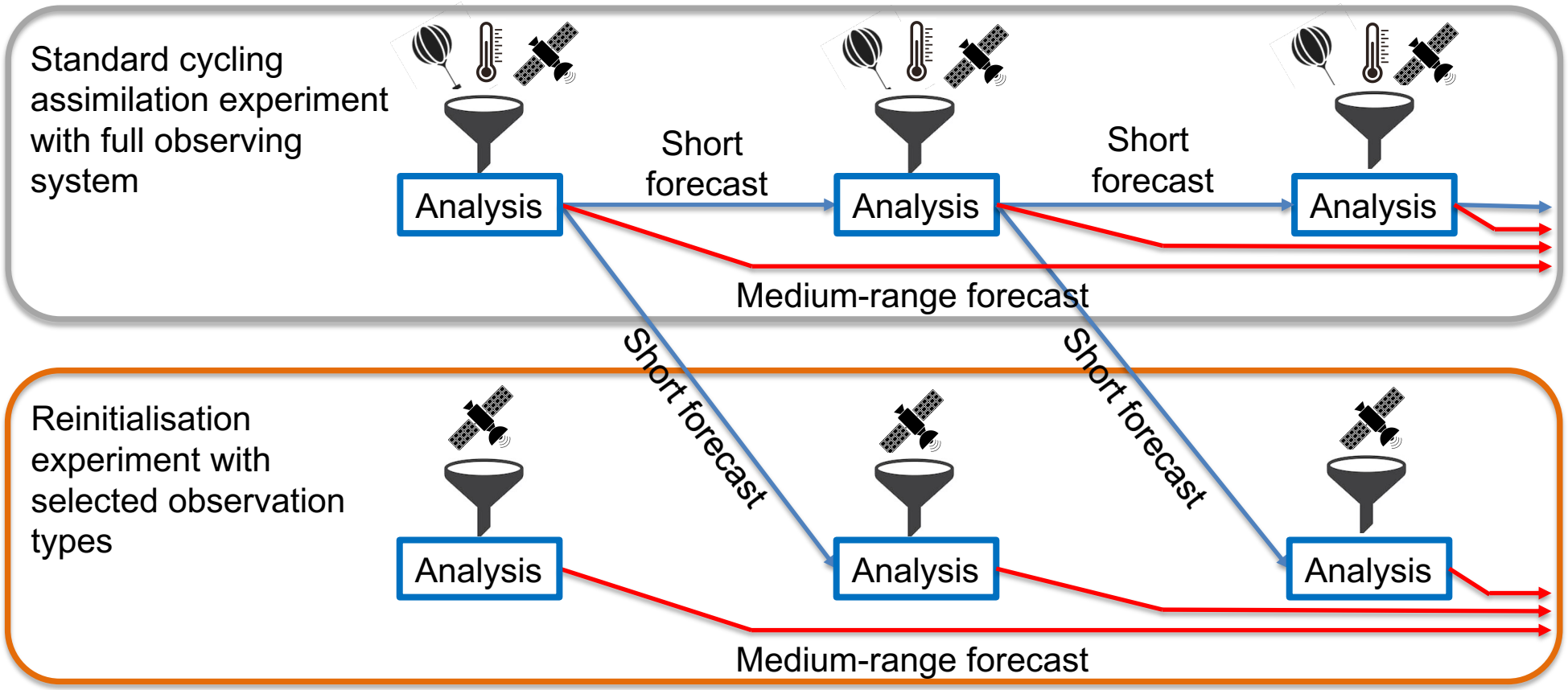
Thanks to Mike Rennie, Alan Geer, and many others

ECMWF

How do individual observing systems contribute to the ECMWF wind analysis?

- In 4D-Var, ***all*** observations can contribute to the wind analysis (e.g., balance relationships, “4D-Var tracing”)
- Use “reinitialization experiments” to investigate the impact from individual observing systems.

Reinitialisation experiments:



- No cycling.
- For single cycles, the analyses are produced with selected observing system.

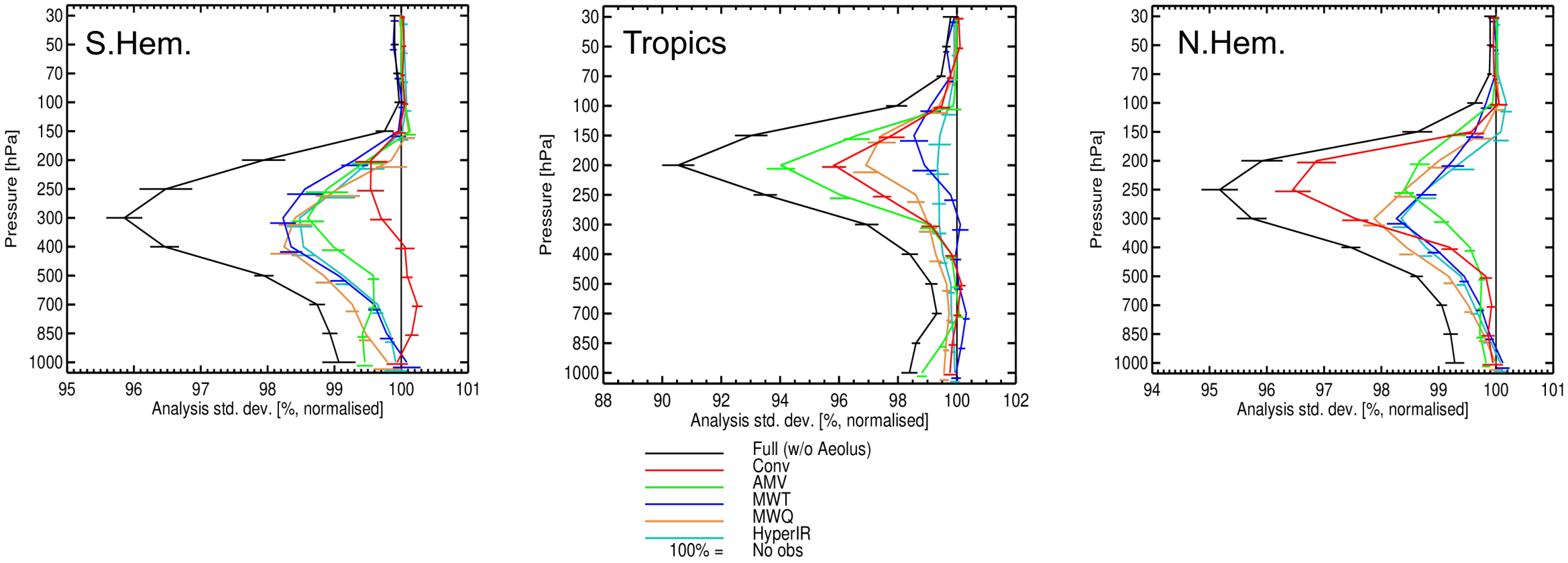
Experiments

- **Reinitialisation experiments** with these observing systems:
  - **NoObs:** No observations assimilated
  - **Conv:** Conventional in-situ data (radiosondes, aircraft, synop, etc)
  - **AMV:** Atmospheric Motion Vectors
  - **Scat:** Scatterometer
  - **MWT:** MW temperature-sounding radiances (e.g., from AMSU-A, ATMS)
  - **MWQ:** MW humidity-sounding radiances (e.g., from MHS, ATMS, MWHS-2)
  - **MWI:** MW window-channel radiances (from AMSR-2, SSMIS, GMI)
  - **HyperIR:** Hyperspectral IR (AIRS, IASI, CrIS)
  - **GeoIR:** Geostationary IR radiances (CSR or ASR products from GOES, METEOSAT, Himawari)
  - **Aeolus:** Doppler Wind Lidar
    - Aeolus used with geolocation-dependent bias correction, as in initial operational implementation. See Mike Rennie's talk for more recent updates.

- Background for all experiments comes from the full observing system (without Aeolus)
- Period: 3 August – 1 October 2019
- T_{CO} 399 (~25 km) model resolution, 12-hour 4D-Var

Using Aeolus to verify wind analyses from reinitialization experiments (1)

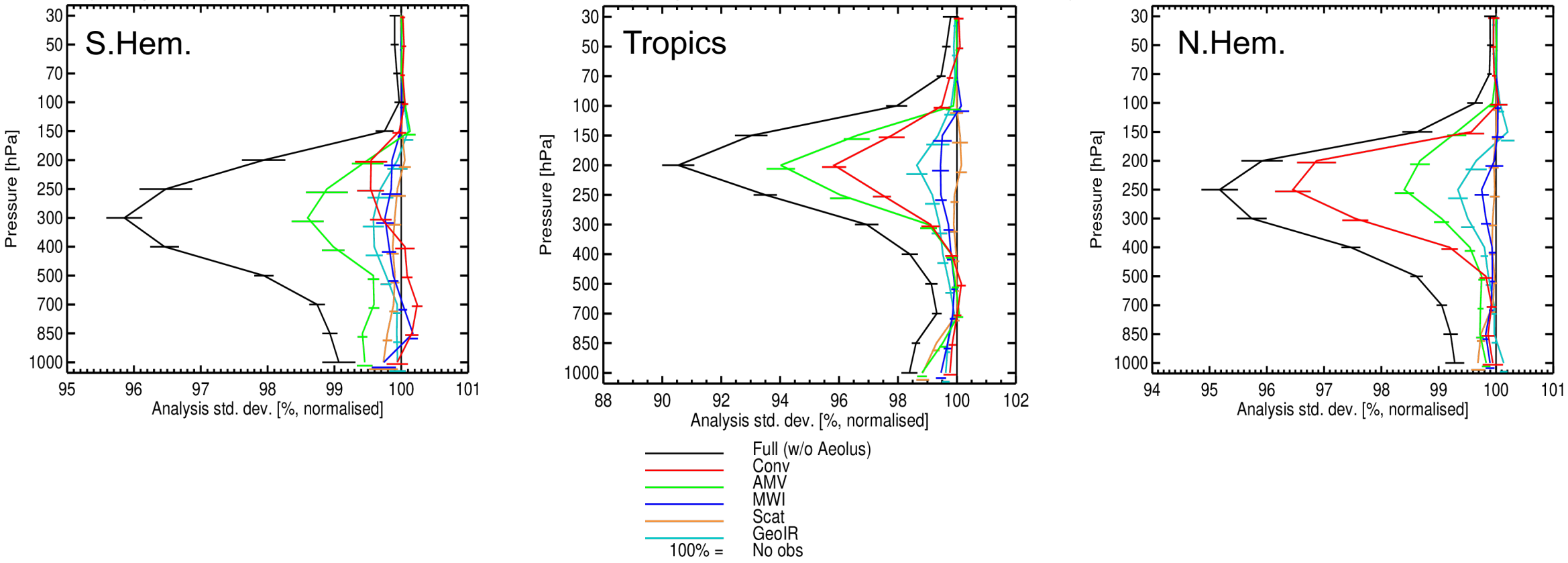
Aeolus HLOS winds used as independent reference (not assimilated in the experiments shown);
Rayleigh clear and Mie cloudy; after applying QC used in the ECMWF system



- Statistics also reflect Aeolus sampling and different size of Aeolus errors (e.g., larger noise in Aeolus data in the stratosphere).
- Overall analysis quality is achieved by combining different observations; different strengths in different areas.
- Strong wind impact from sounding radiances (esp. extra-tropics).

Using Aeolus to verify wind analyses from reinitialization experiments (2)

Aeolus HLOS winds used as independent reference (not assimilated in the experiments shown);
Rayleigh clear and Mie cloudy; after applying QC used in the ECMWF system

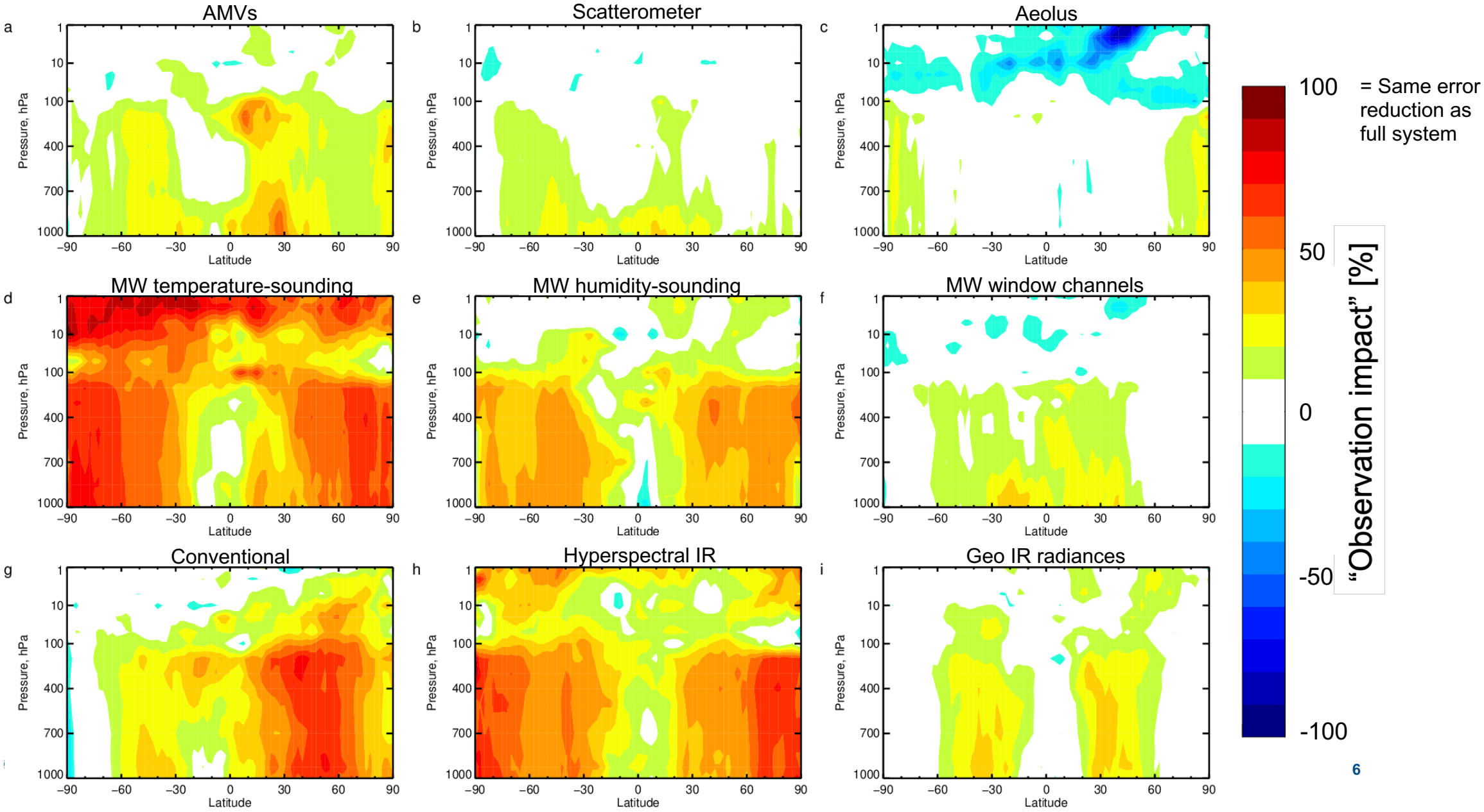


- Statistics also reflect Aeolus sampling and different size of Aeolus errors (e.g., larger noise in Aeolus data in the stratosphere).
- Overall analysis quality is achieved by combining different observations; different strengths in different areas.

“Impact” on wind forecasts at T+48h

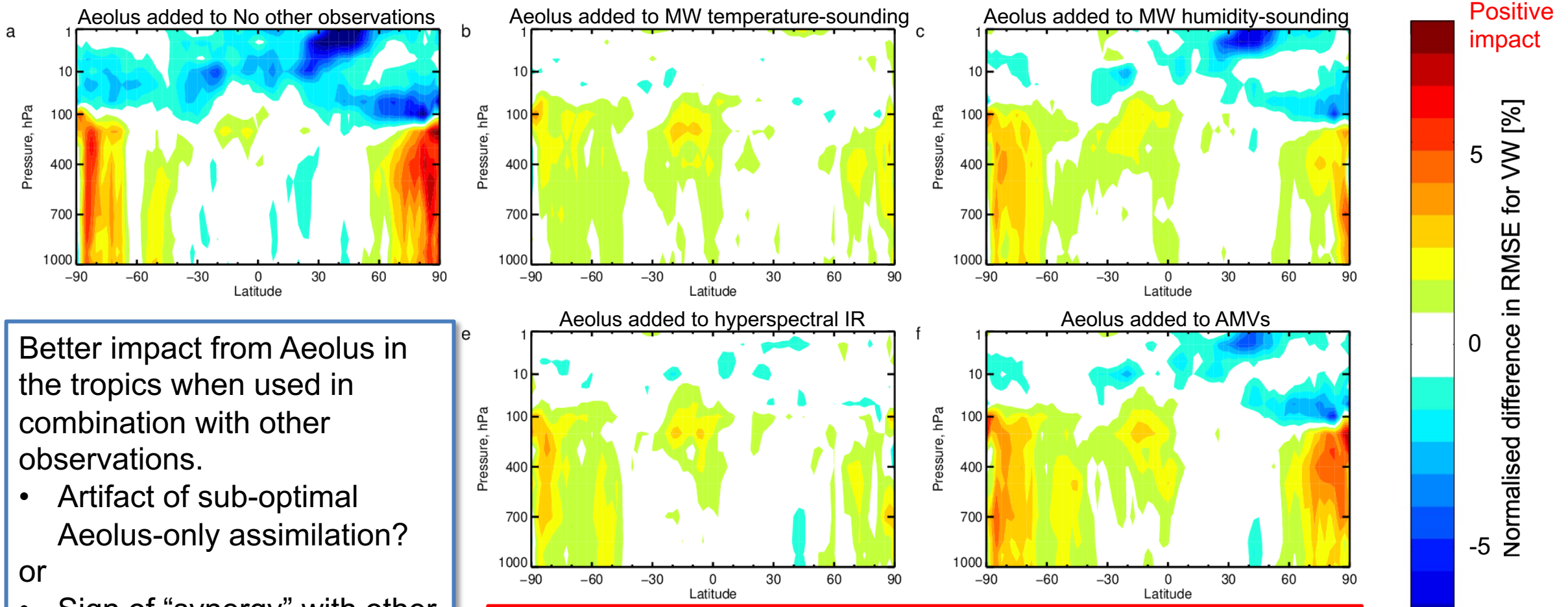
(vs analyses from the full system, including Aeolus)

$$\text{Impact} = \frac{\text{RMS}(fc_{Exp} - an_{Full}) - \text{RMS}(fc_{NoObs} - an_{Full})}{\text{RMS}(fc_{Full} - an_{Full}) - \text{RMS}(fc_{NoObs} - an_{Full})}$$



Reduction in forecast error from Aeolus when combined with other observing systems

Normalised difference in RMSE for VW forecasts at T+48h,
verified against analyses from the full system, including Aeolus



Better impact from Aeolus in the tropics when used in combination with other observations.

- Artifact of sub-optimal Aeolus-only assimilation?

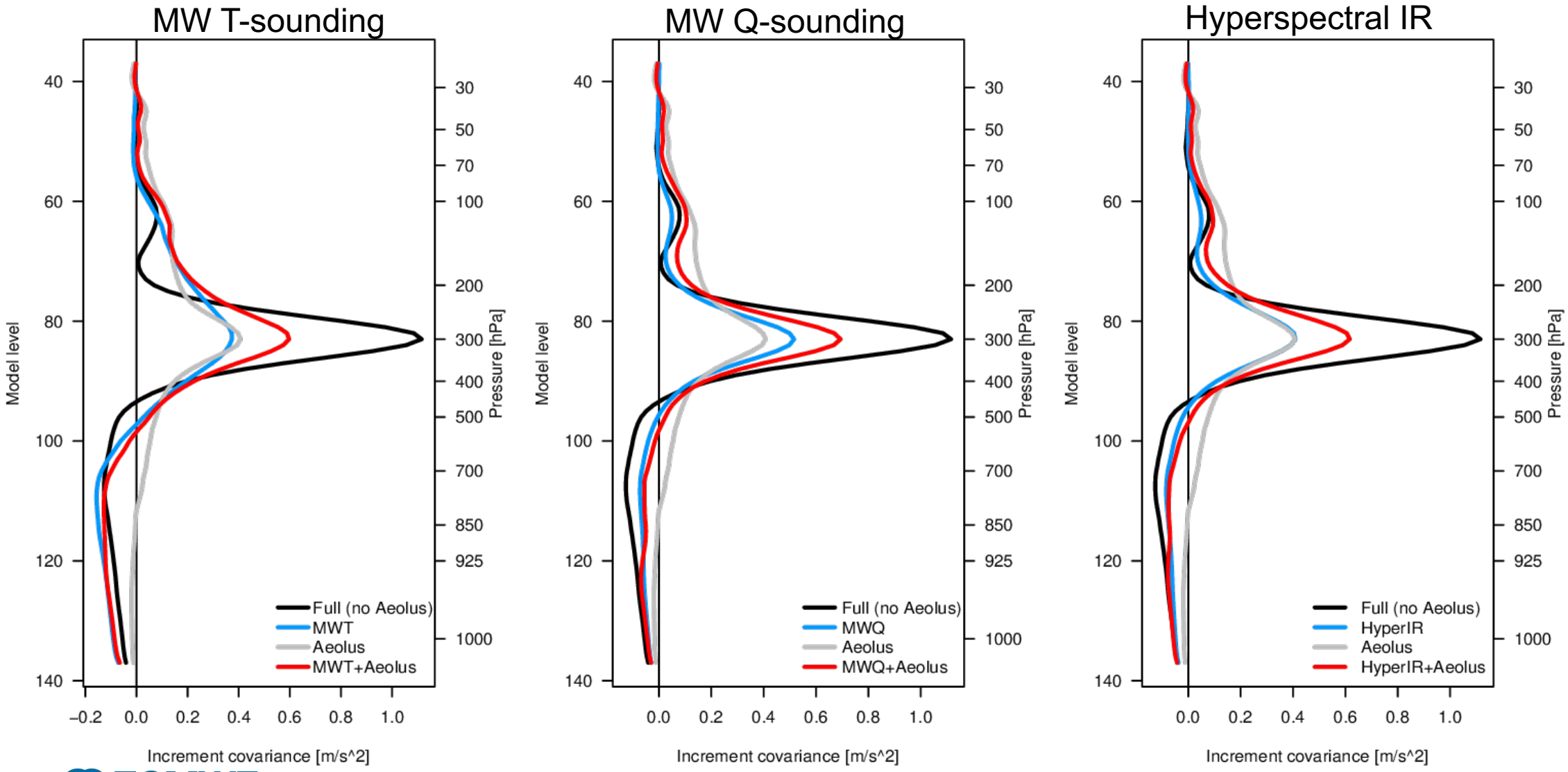
or

- Sign of “synergy” with other observing systems?

→ Mike Rennie’s presentation later today on excellent impact of Aeolus when added to the full observing system.

Effect on vertical covariances of zonal wind increments* from combining Aeolus with radiances, averaged over the Tropics

* Increment = adjustment made to the background during the assimilation



Summary

- **A wide range of observing systems affects wind analyses in the ECMWF system.**
  - The assimilation system combines the different strengths of different observing systems.
  - Clear impact on wind analyses from sounding radiances, via balance constraints and 4D-Var tracing.
  - Clear impact from AMVs especially in the tropics, and Scatterometer winds for low-level winds.

- **For day-2 wind forecasts (and beyond), conventional observations and sounding radiances provide the strongest impact in the extra-tropics in the reinitialization experiments shown.**

- **Aeolus adds strengths that the current global observing system is lacking (ie vertical resolution for wind observations with global sampling).**
  - Better Aeolus impact when added to other observing systems: due to synergies with other existing observations?

Bonus material

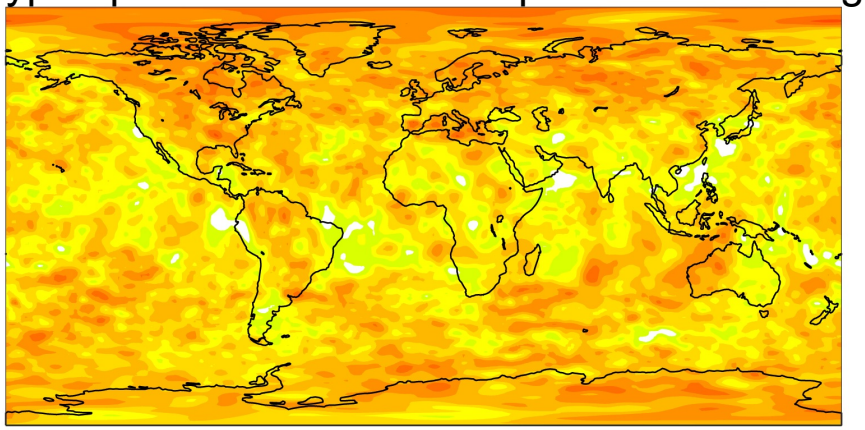
Similarity of wind increments* from radiance observations

Correlations between zonal wind increments at 300 hPa: Radiances

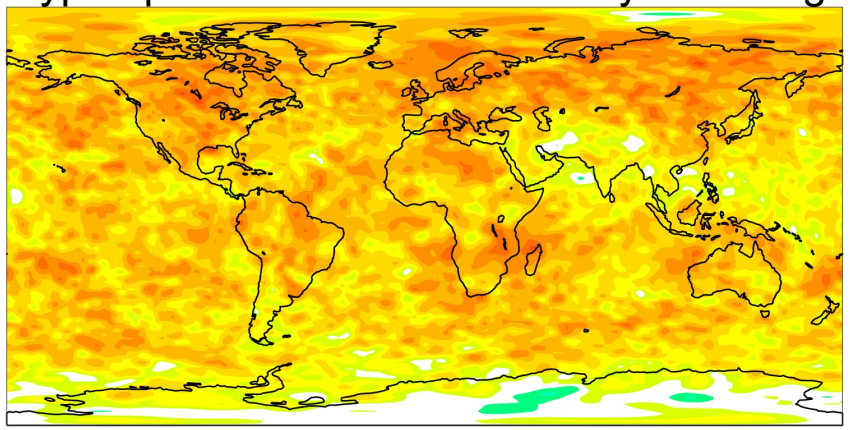
* Increment = adjustment made to the background during the assimilation

- Strongest correlations between wind increments from radiances
  - Good consistency
- Partly due to similarities in the measurements?
  - Sensing similarities
  - Similar mechanisms to obtain wind information (4D-Var, balance)
  - Coverage similarities

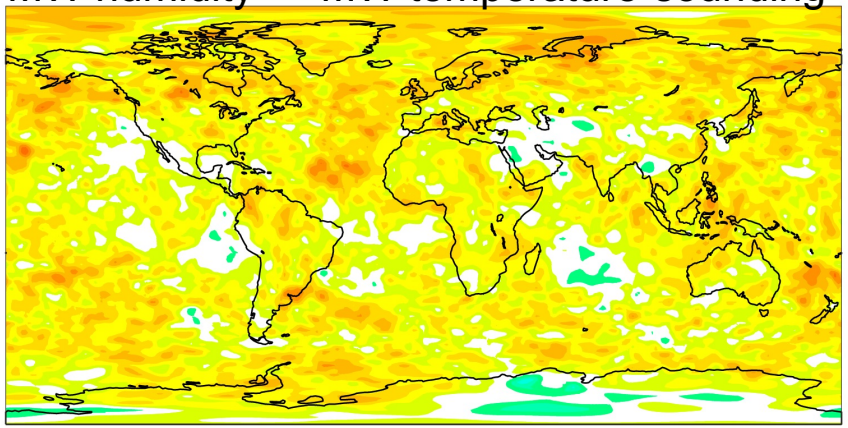
Hyperspectral IR ↔ MW temperature-sounding



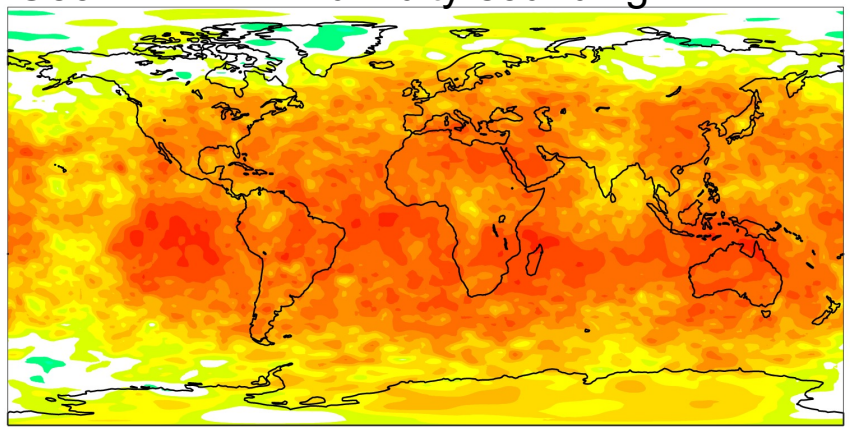
Hyperspectral IR ↔ MW humidity-sounding

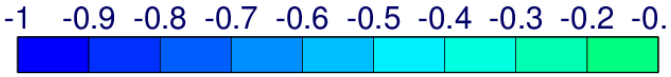


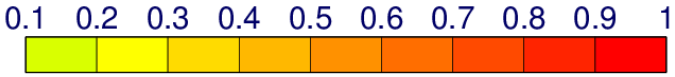
MW humidity ↔ MW temperature-sounding



Geo IR ↔ MW humidity-sounding



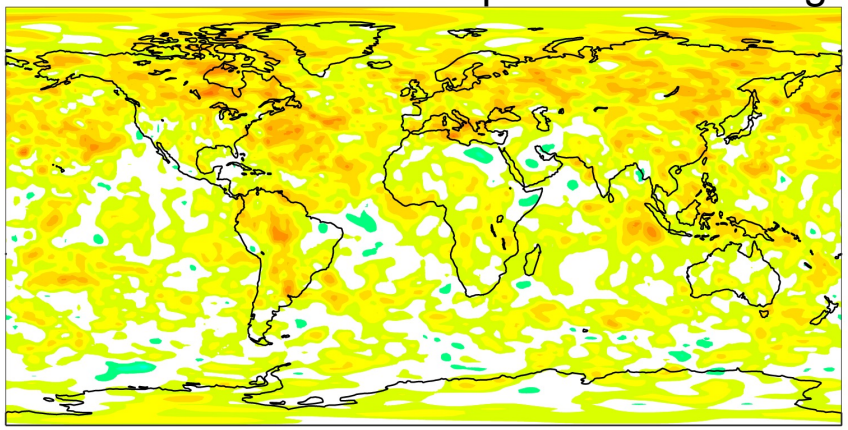




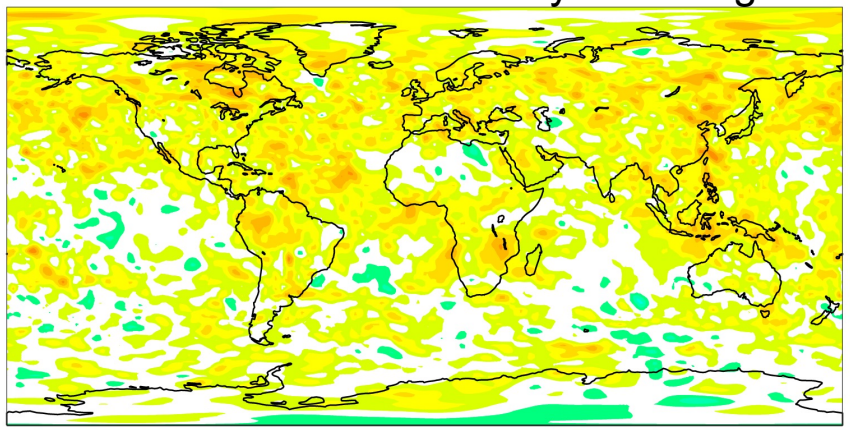
Correlations between zonal wind increments at 300 hPa: Conventional obs

- Positive correlations in areas covered by both observing systems.
  - Strongest with radiances
  - Coverage affects where correlations can be expected
- Correlations are weaker than seen before between increments from different radiances.
  - Due to different sensitivity (greater complementarity)?

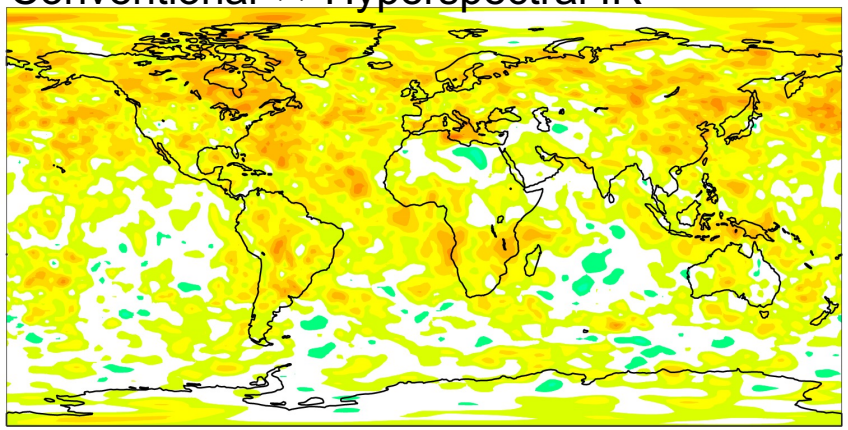
Conventional ↔ MW temperature-sounding



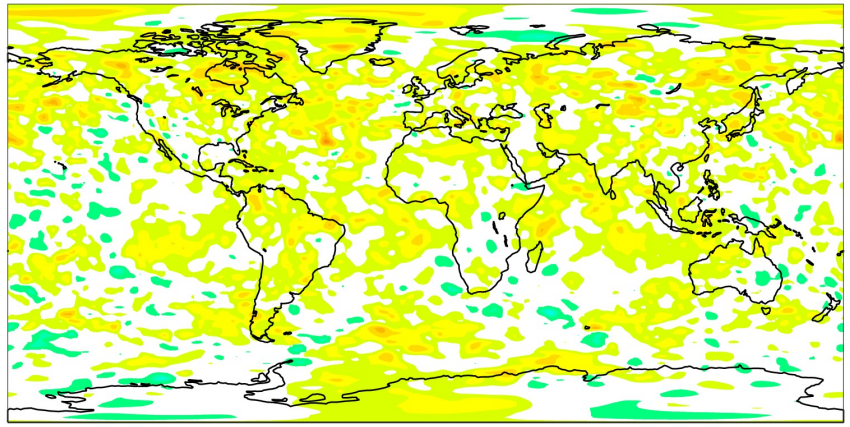
Conventional ↔ MW humidity-sounding

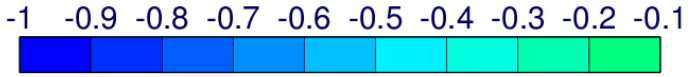


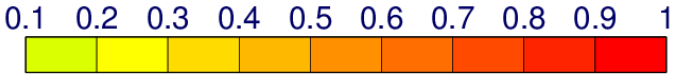
Conventional ↔ Hyperspectral IR



Conventional ↔ Aeolus



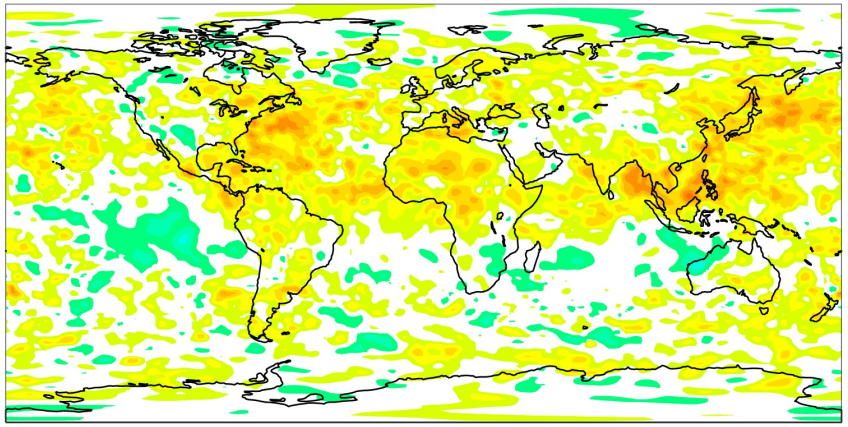




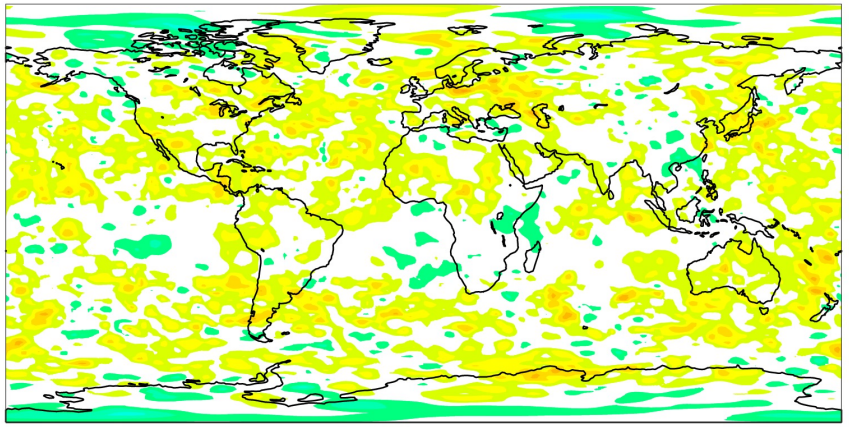
Correlations between zonal wind increments at 300 hPa: AMVs

- Wind increments from AMVs and other observing systems also show mostly positive, but weaker correlations.
  - Sign of complementarity?
- In some areas, there is no or negative correlation with several other observing systems (trop. E Pacific; SE Africa).
  - Very few AMVs assimilated

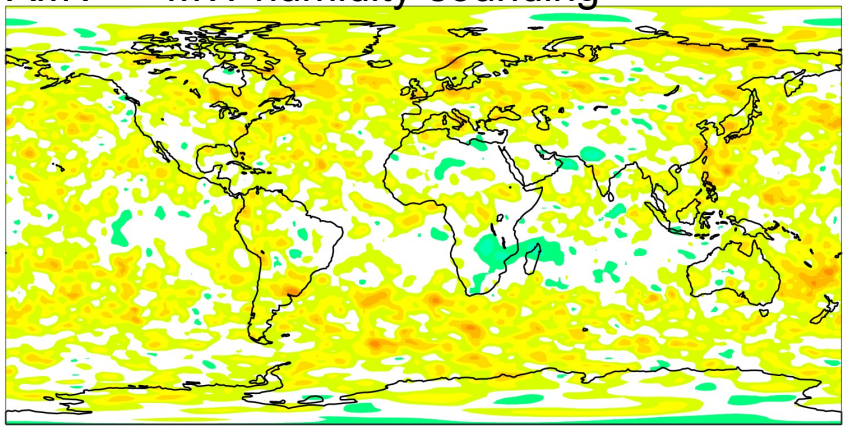
AMV ↔ Conventional



AMV ↔ Aeolus



AMV ↔ MW humidity-sounding



AMV ↔ geo IR radiances