Impact of hyperspectral IR radiances on wind analyses

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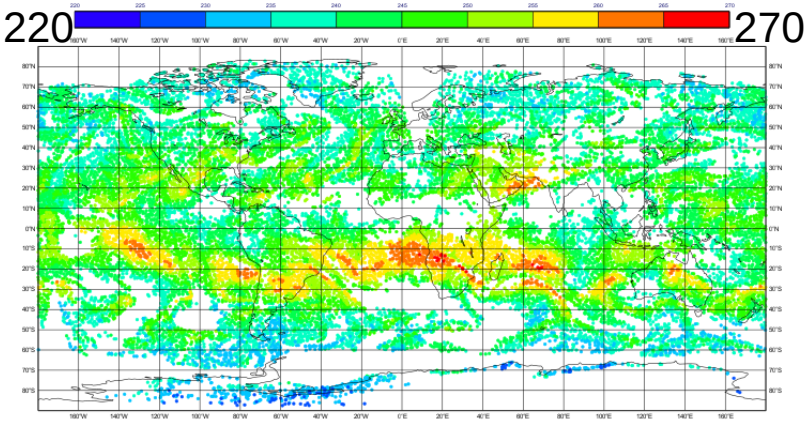
Motivation

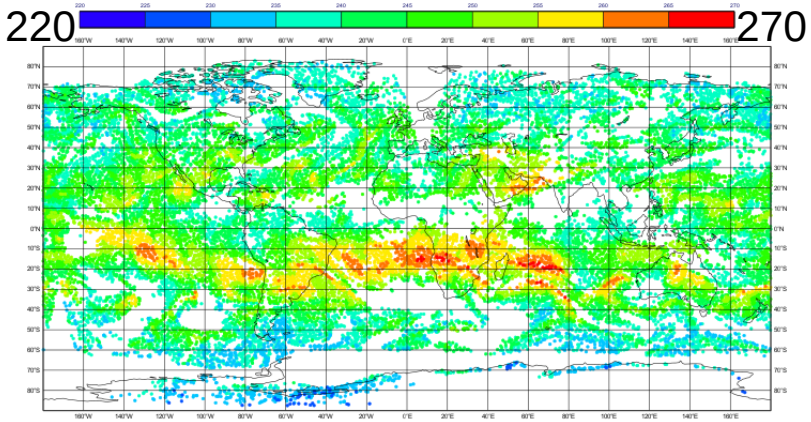
- The upcoming hyper-spectral IR instruments on geostationary satellites will provide information with high vertical and temporal resolution.
- Positive impact on wind analysis/forecasts has been demonstrated with
  - Geostationary radiances (Peuby and McNally 2009, Lupu and McNally 2012, Lupu and McNally 2013)
  - Microwave instruments in the all-sky framework (Geer et al, 2014).
- Here focus is on the current hyper-spectral IR instruments on board polar orbiting satellites.

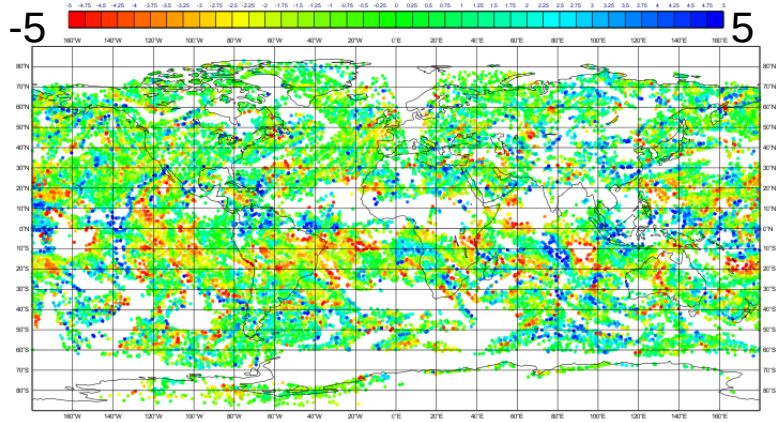
Radiance observations in 4D-Var, impact on wind analysis

- Adjustments in the mass fields of the atmosphere.
- Assimilation system has freedom to adjust the wind field of the initial conditions directly.

$\mathbf{x_a}$ = $\mathbf{x_b}$ + $\mathbf{K\,(y - \mathit{H}x_b)}$





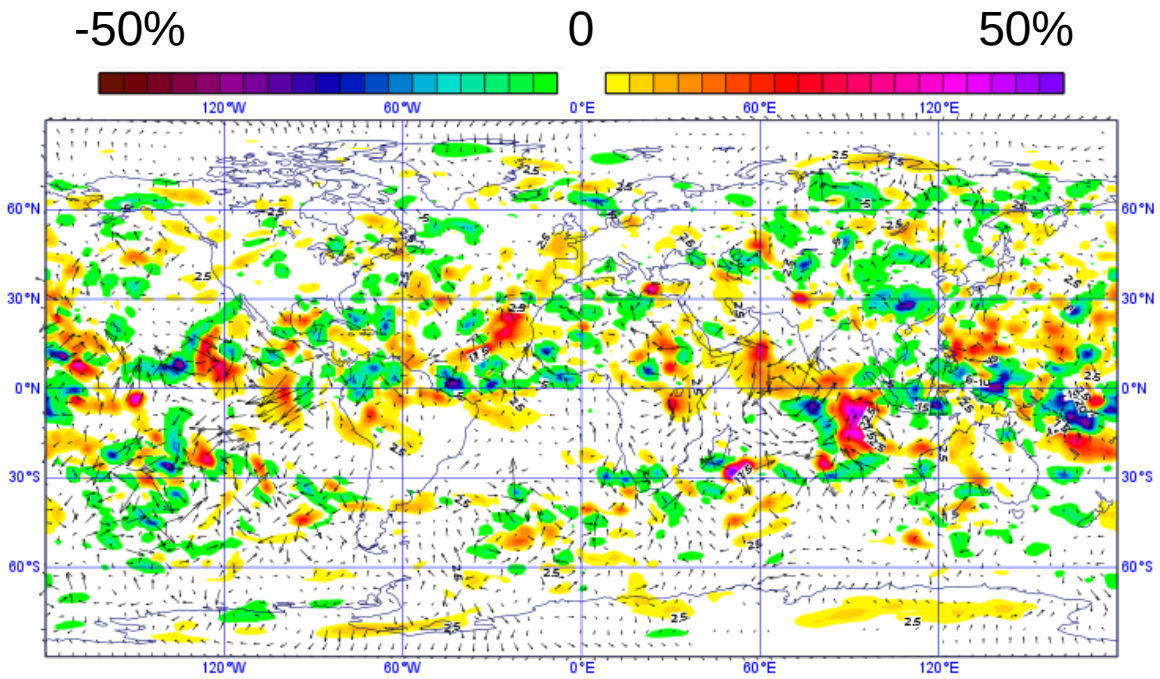


$\mathbf{K = BH^T(HBH^T+R)^{-1}}$

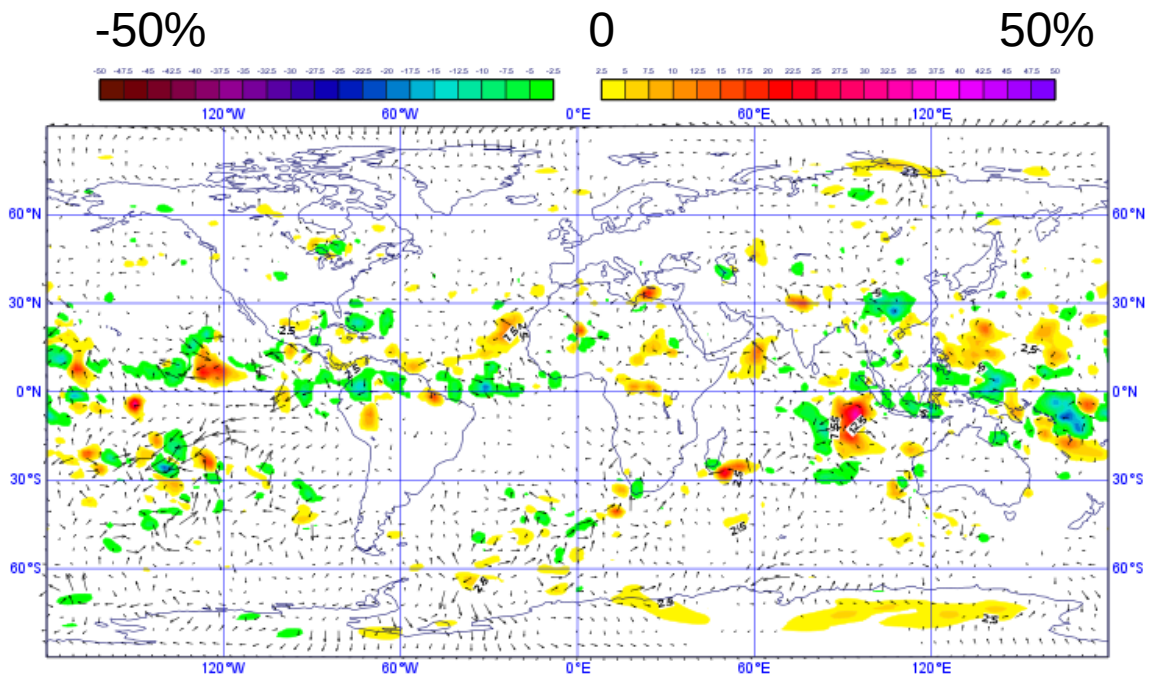
Example: IASI channel 3002

Example: 300 hPa R and wind analysis increments 1.11.2016 00 UTC

WV absorption band channels from IASI, CrIS and AIRS used in assimilation



No WV absorption band channels from hyperspectral IR instruments used in assimilation



Experimentation setup

IFS cycle 43R3, 1.11-31.12.2016

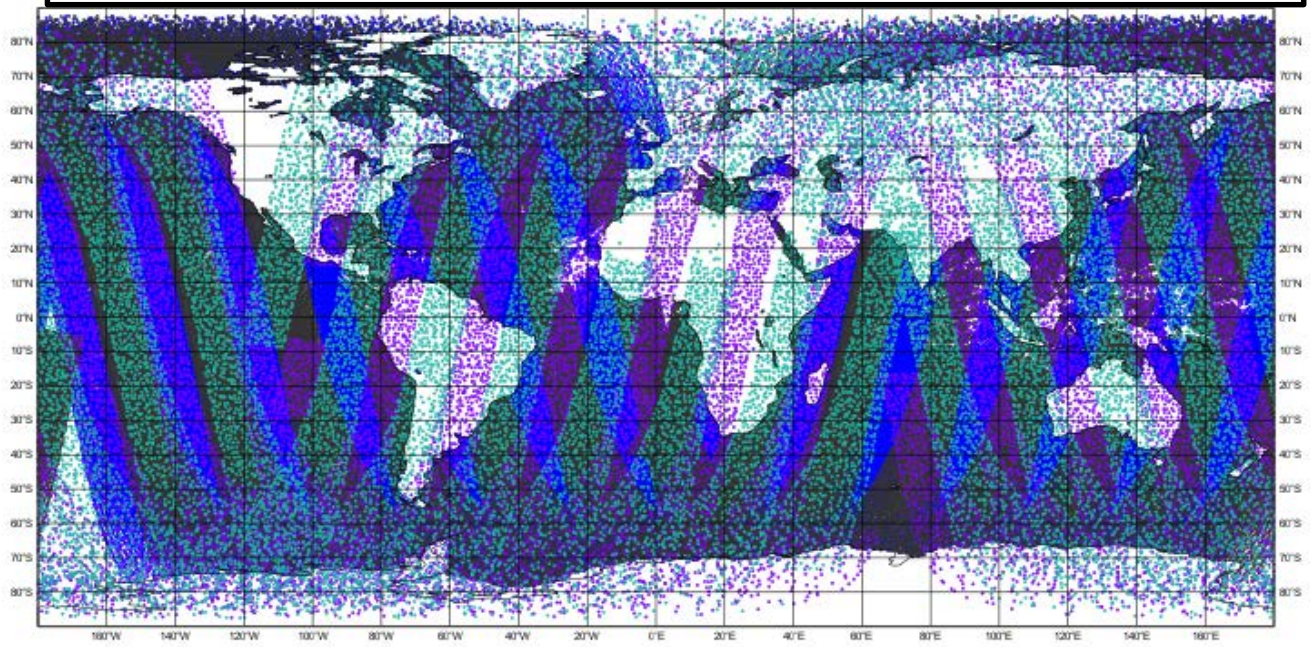
Baseline: Conventional observations + AMSU-A

HyIR: Baseline + IASI (Metop-A, Metop-B), Cris, AIRS

AMV: Baseline + all operationally used AMVs

All: Full observing system

12-hour sample coverage of active hyperspectral IR data



Metop-A IASI

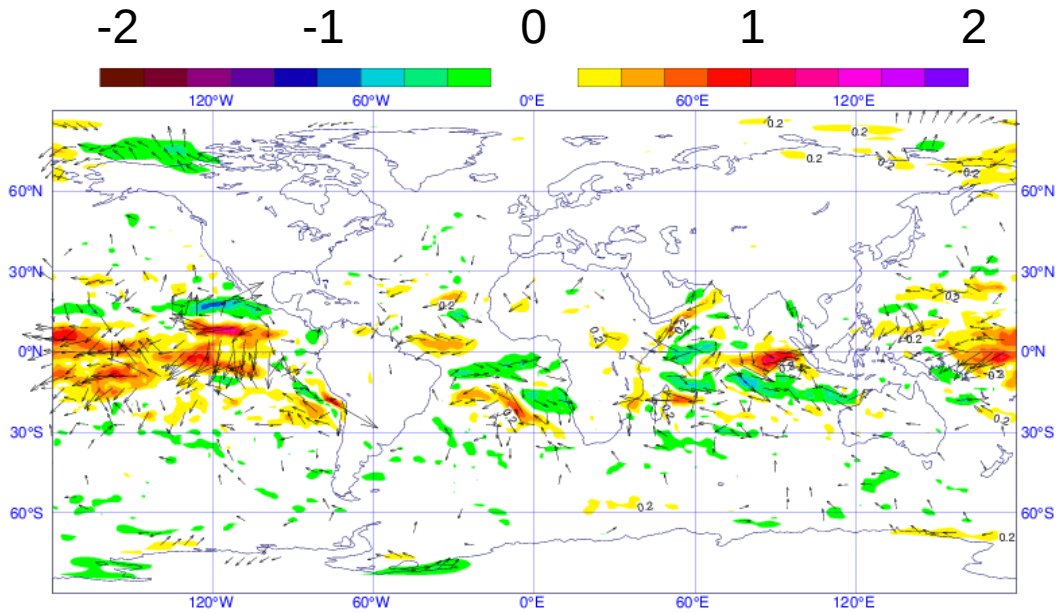
Metop-B IASI

Aqua AIRS

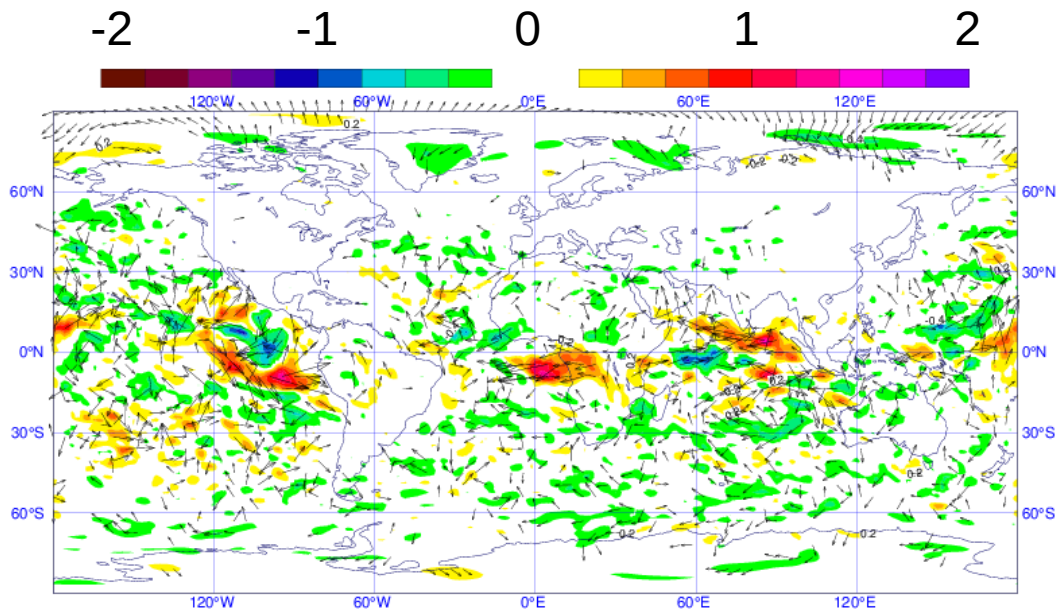
Suomi-NPP Cris

Differences in the mean wind analysis (HyIR-Baseline, 1.11-31.12.2016)

850 hPa



300 hPa



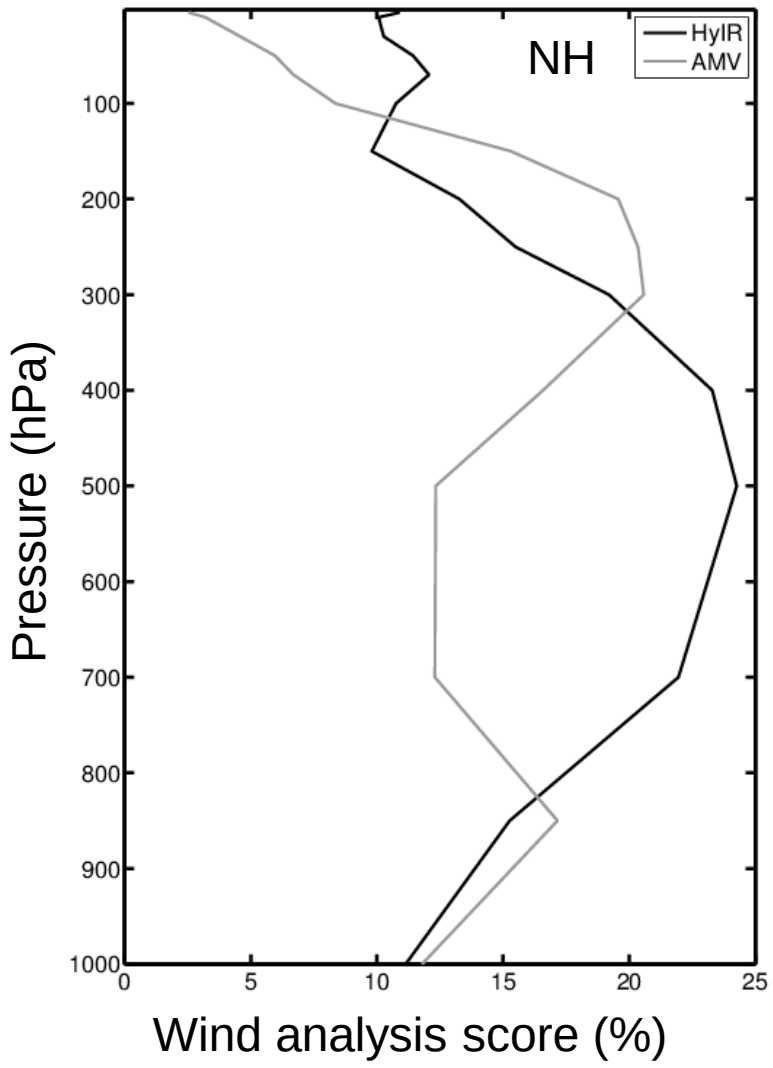
Wind analysis scores

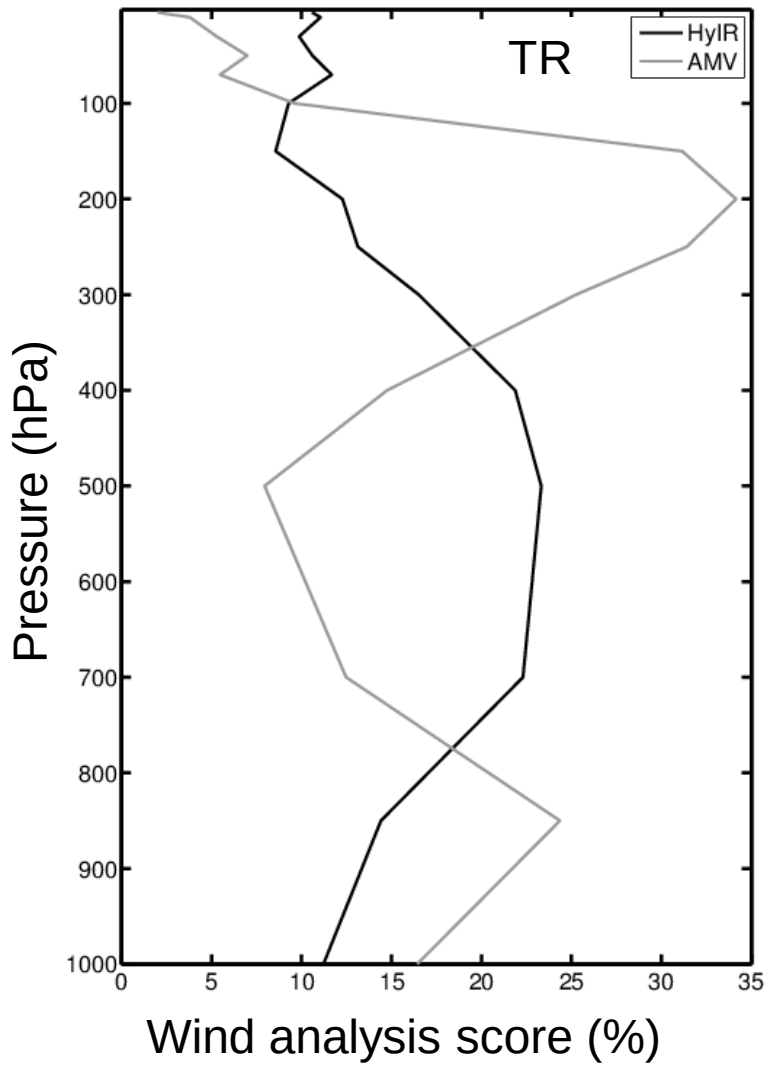
- Wind analysis error: departure from the ECMWF analysis using full observing system.
- The analysis error is compared to that of Baseline experiment.
  - Wind analysis score = 0%, no improvement over the baseline experiment (conventional + AMSU-A)
  - Wind analysis score = 100%, no error with respect to the full observing system analysis

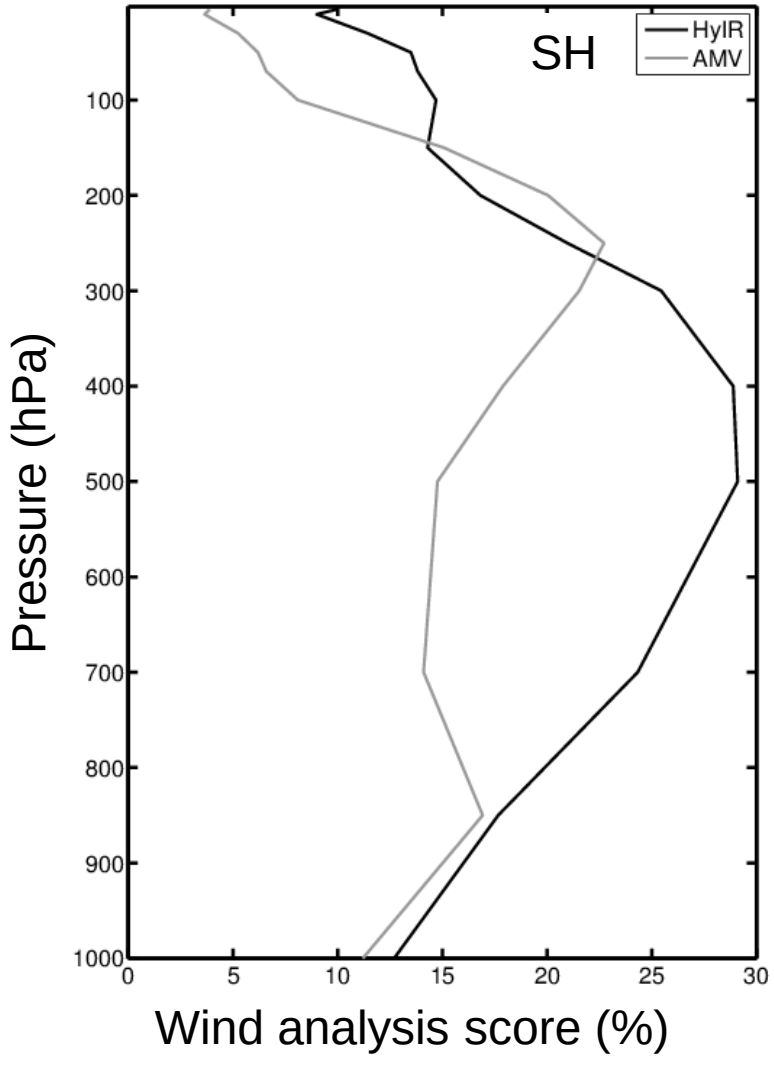
$$RMSE_j = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\left(u_i - u_i^r\right)^2 + \left(v_i - v_i^r\right)^2\right]}$$

$$\Delta RMSE = \frac{\sum_{j=1}^{m}\left(RMSE_j - RMSE_j^{Base}\right)}{\sum_{j=1}^{m} RMSE_j^{Base}}$$

Wind analysis scores

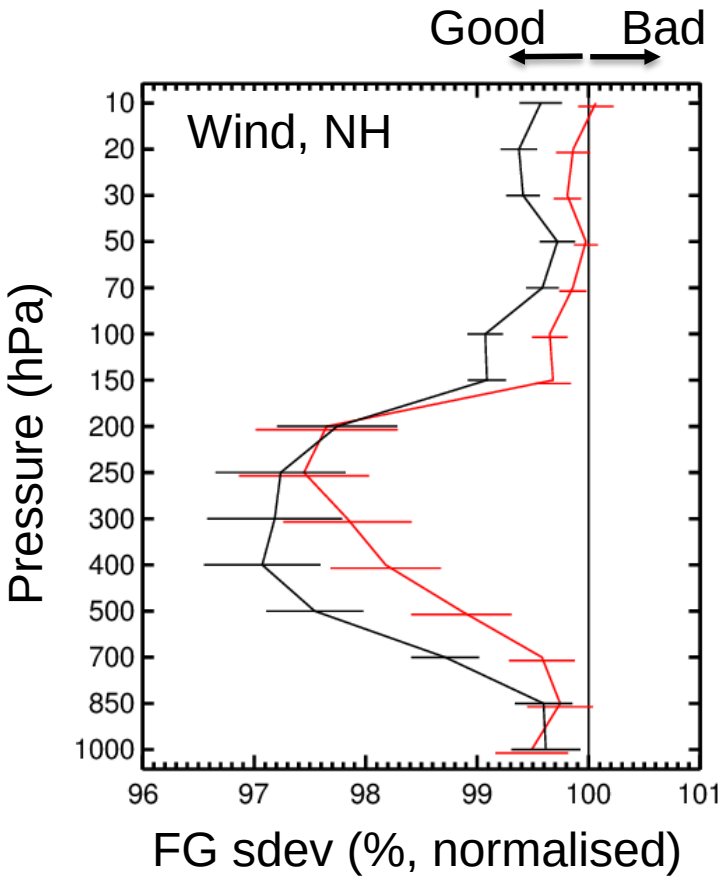


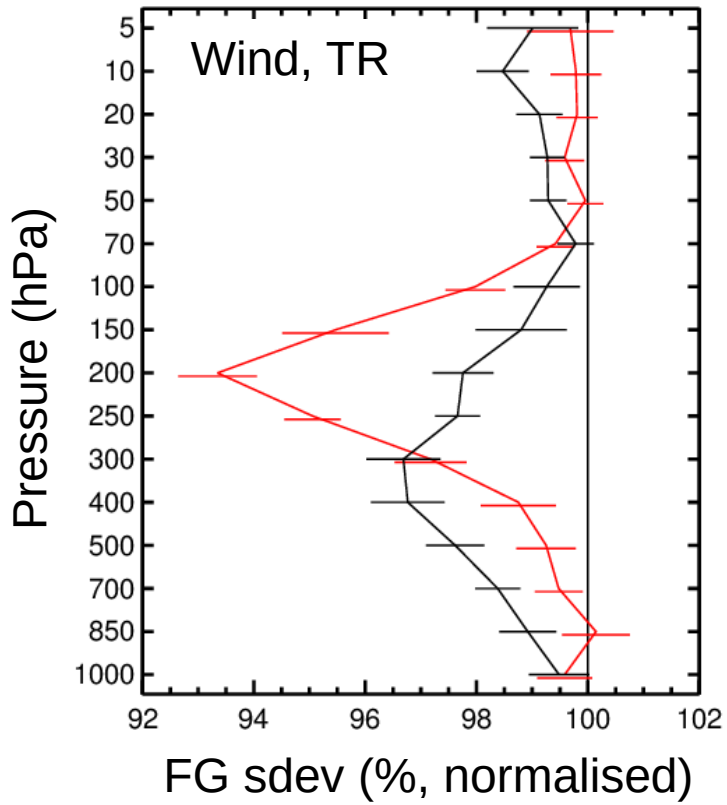


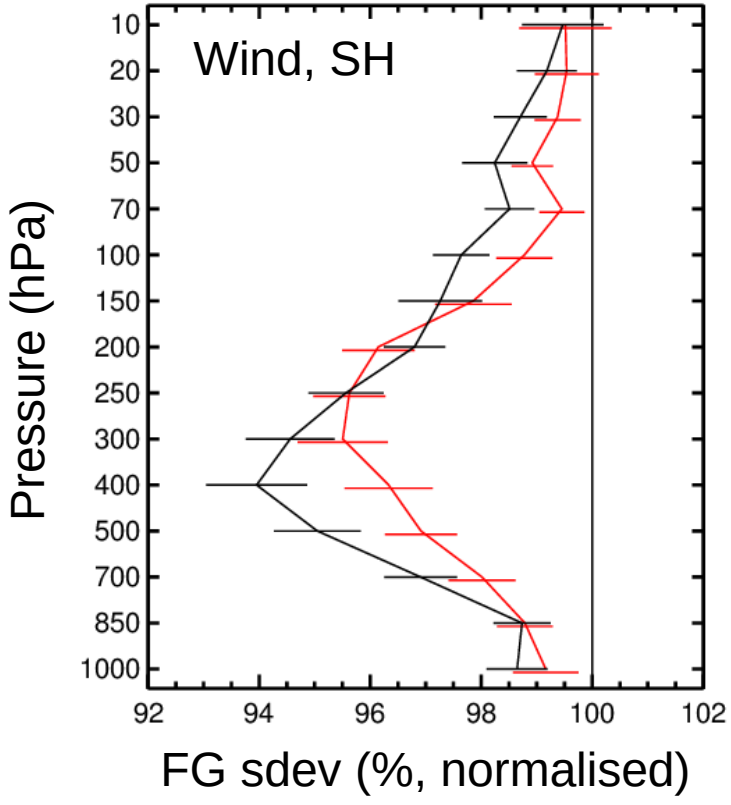


Impact on short range wind forecasts

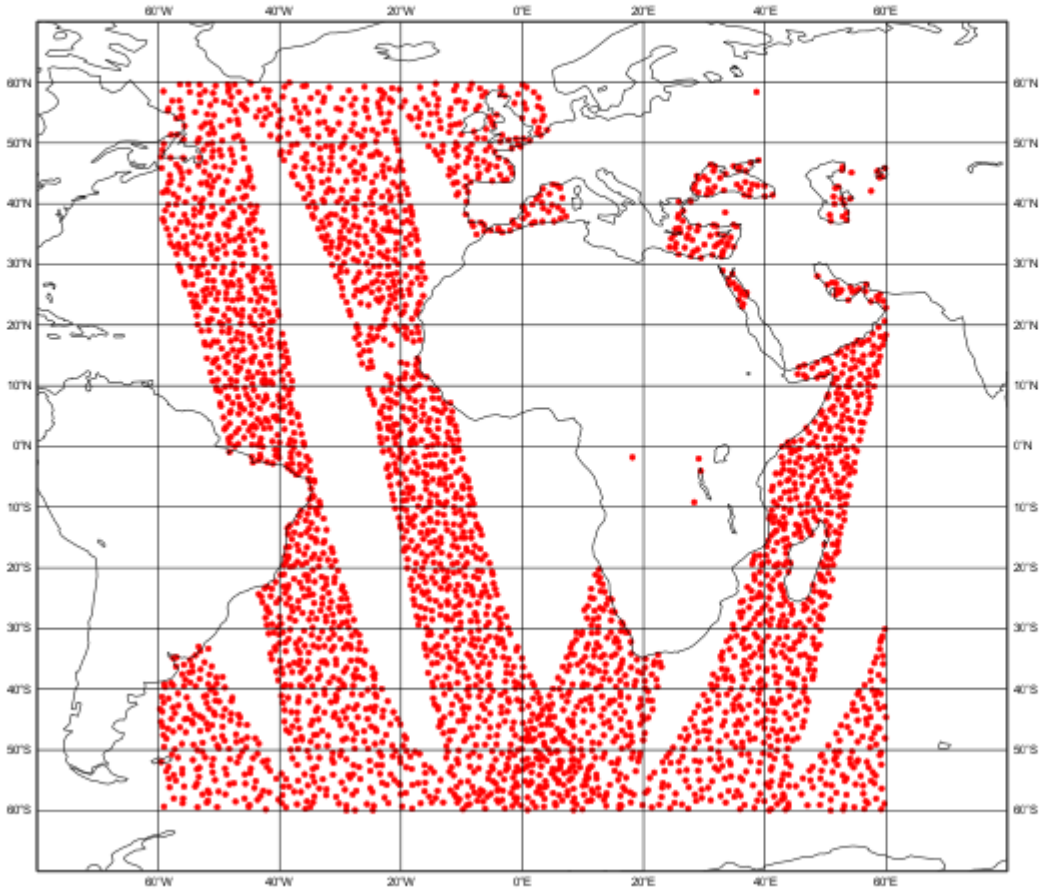
HyIR: CTL + 2 IASI + CrIS + AIRS
AMV: CTL + All operatinally used AMVs





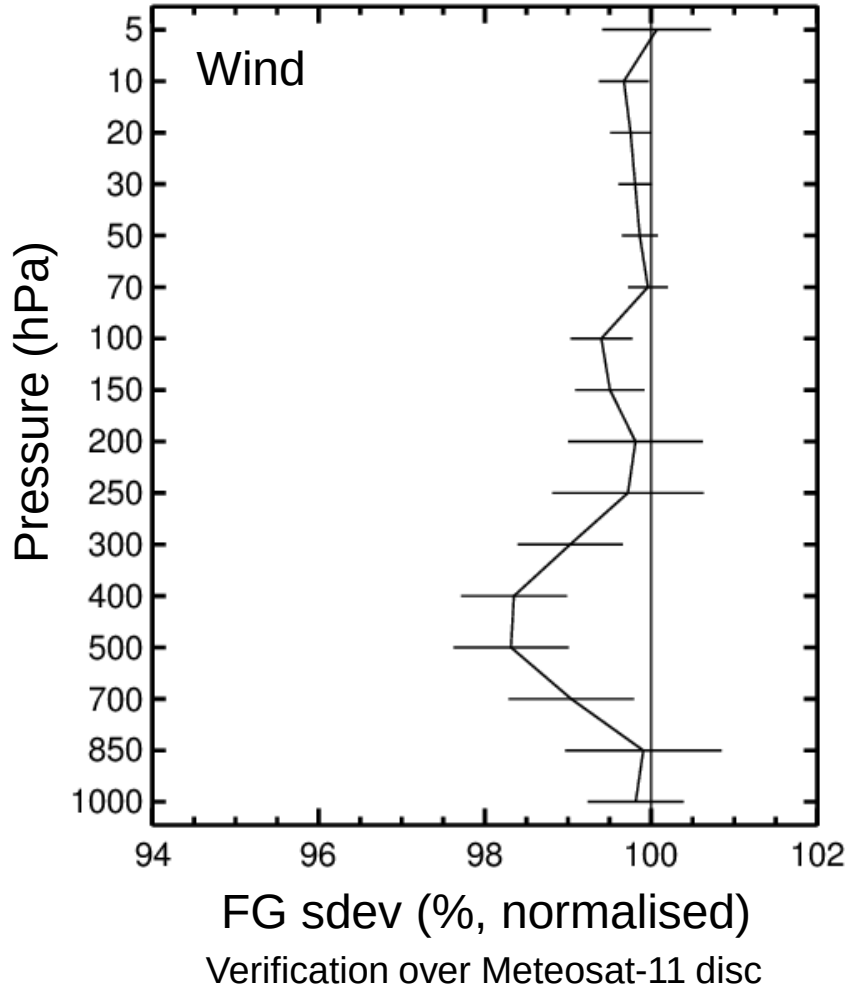


Role of spatial and temporal sampling



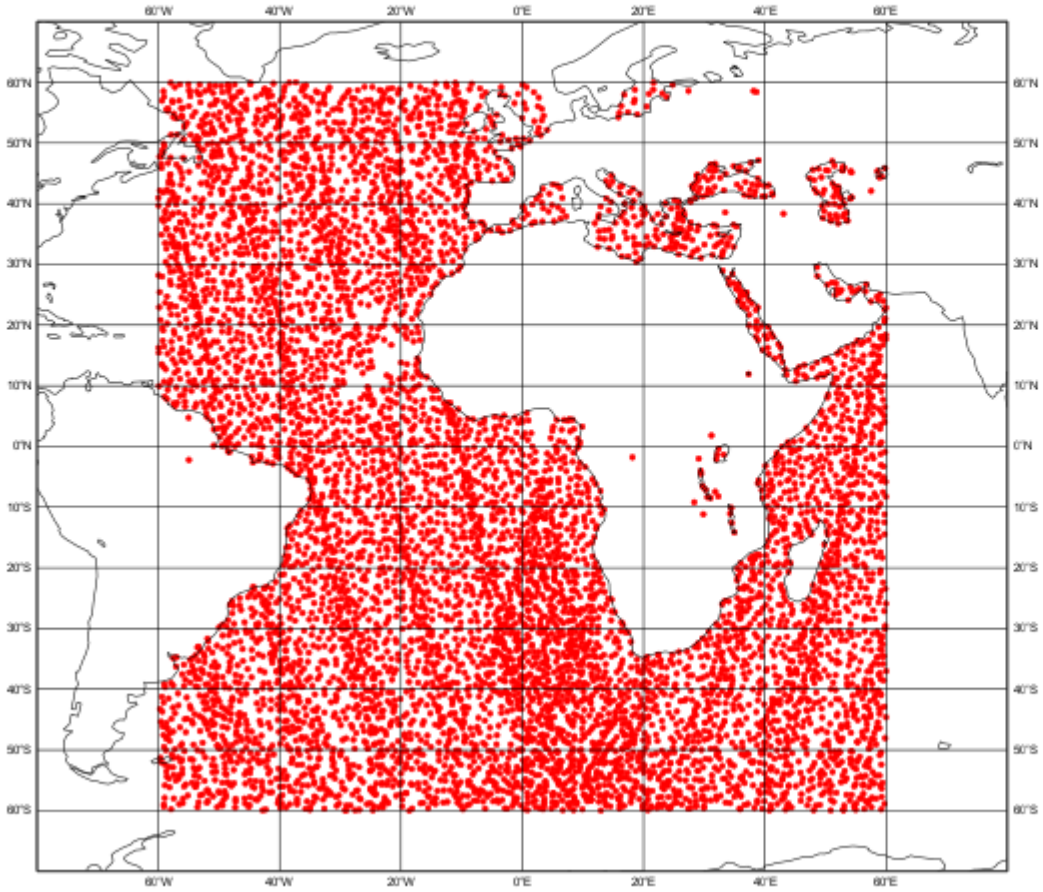
Metop-A

CTL: Conv + AMSU-A
EXP: CTL + Metop-A IASI



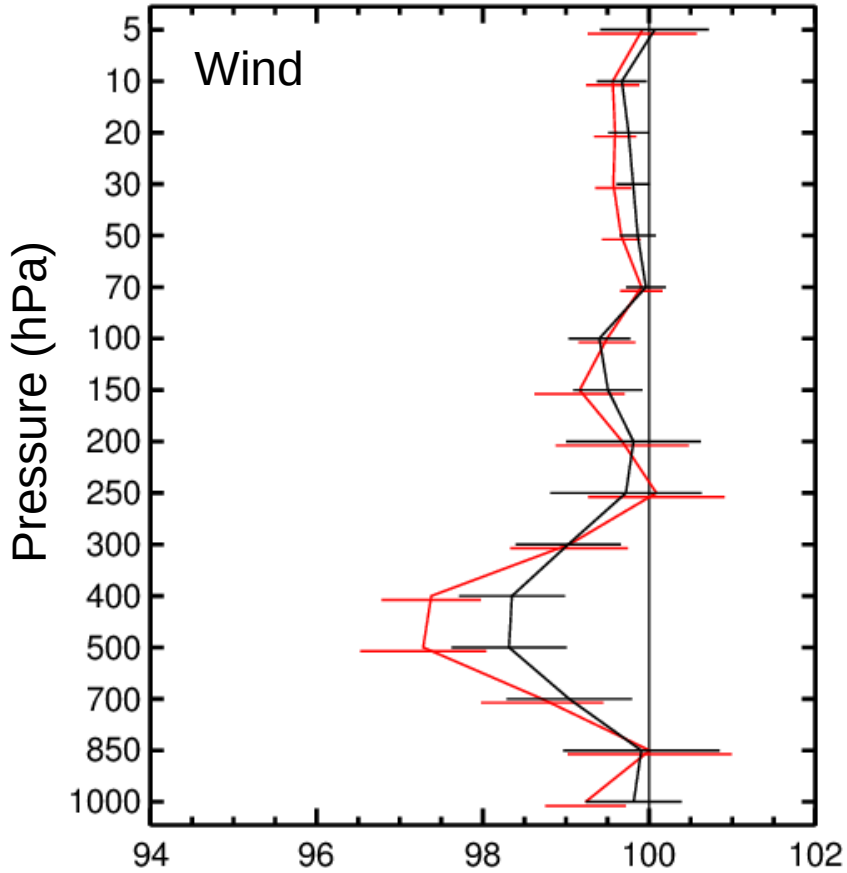
Verification over Meteosat-11 disc

Role of spatial and temporal sampling



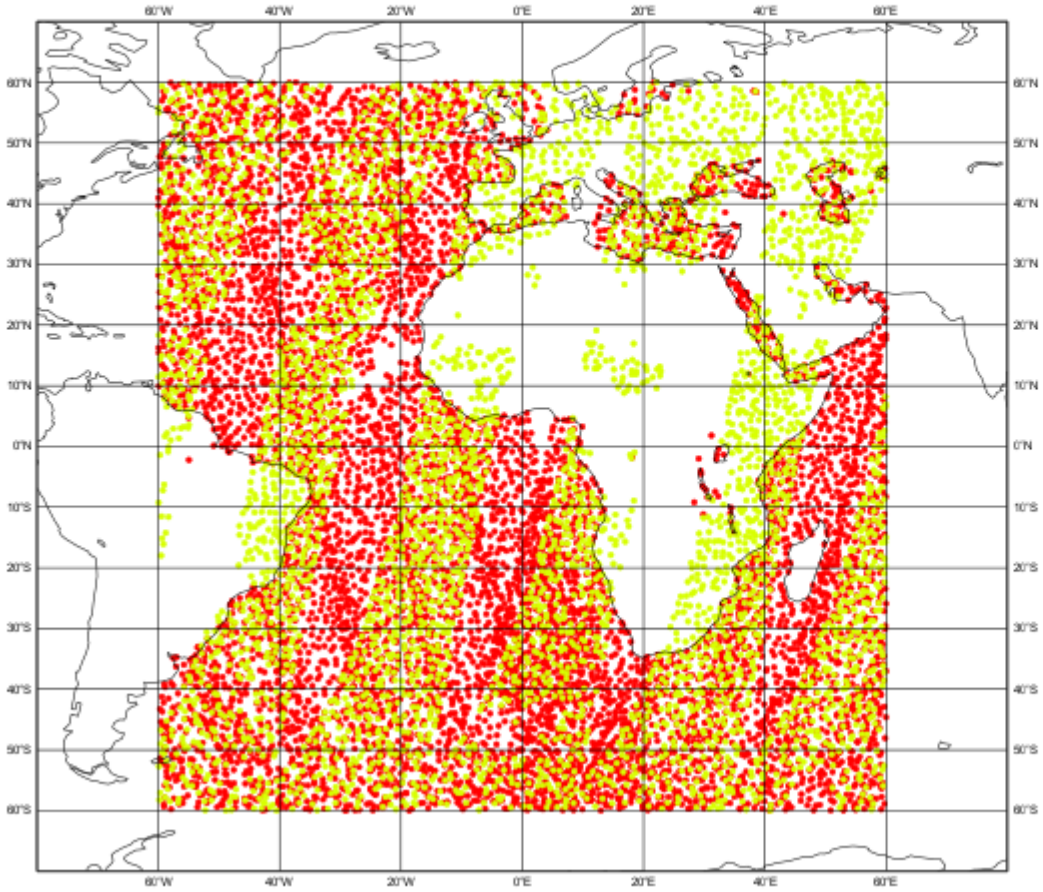
Metop-A Metop-B

CTL: Conv + AMSU-A
EXP: CTL + 2 IASI



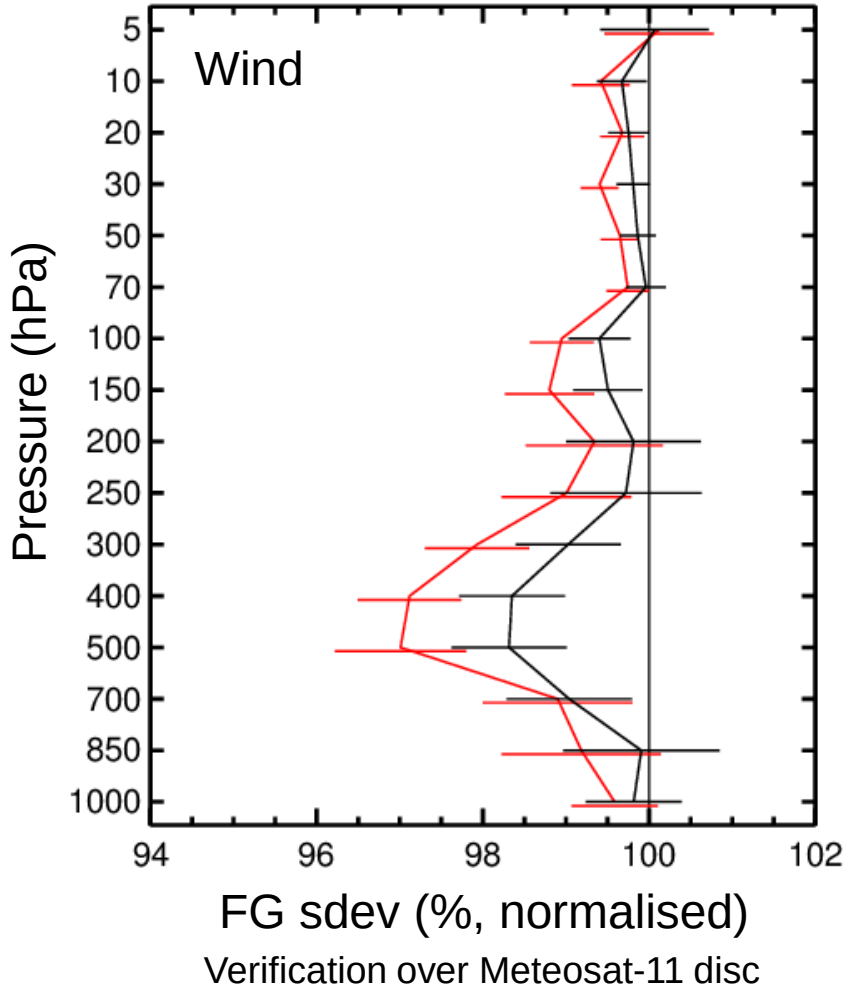
Verification over Meteosat-11 disc

Role of spatial and temporal sampling



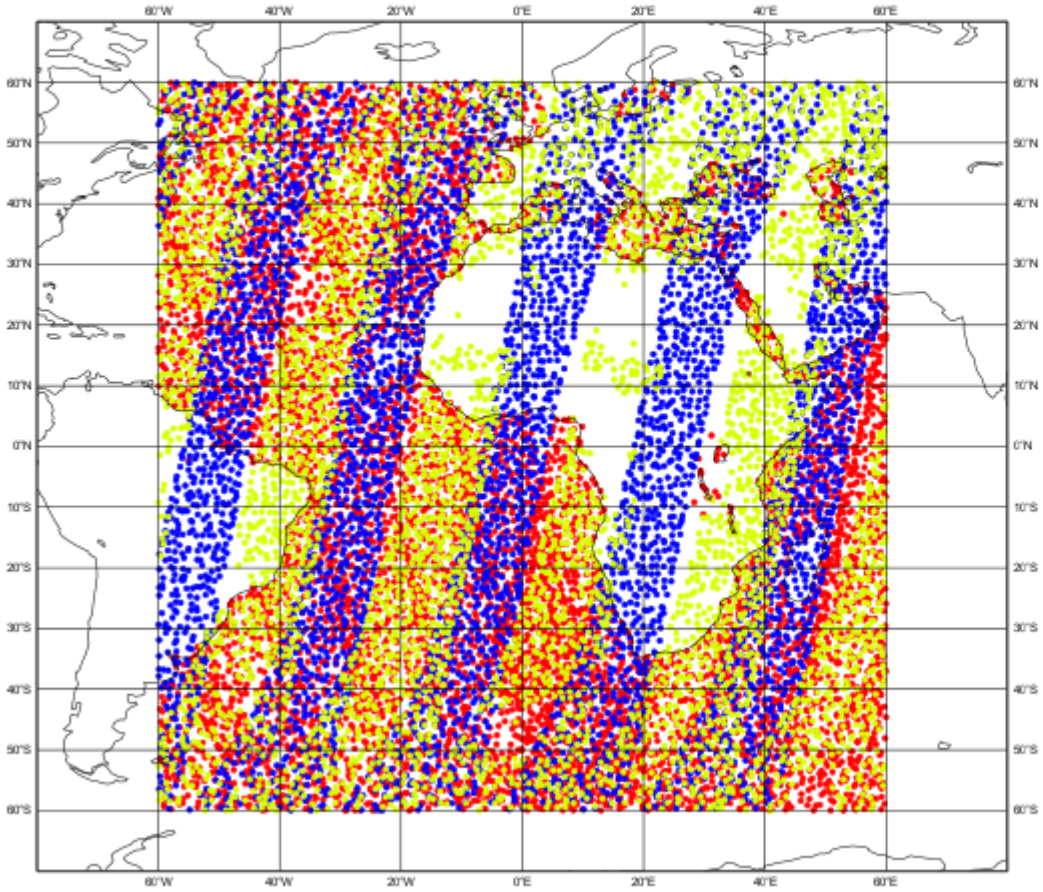
Metop-A Metop-B CrIS

CTL: Conv + AMSU-A
EXP: CTL + 2 IASI + CrIS



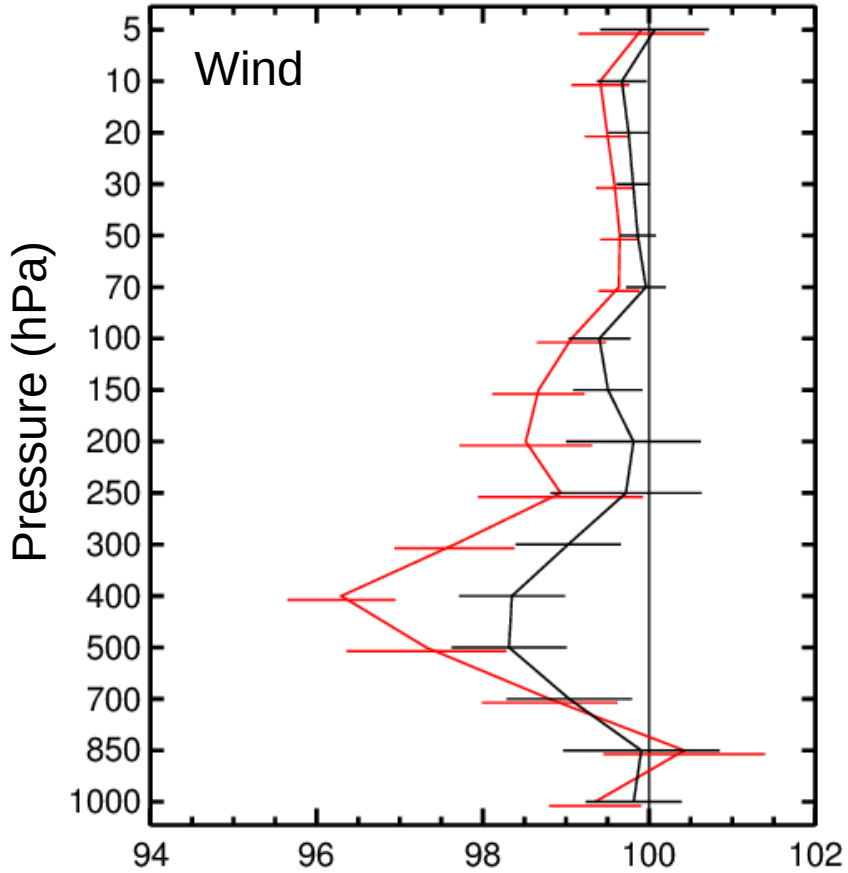
Verification over Meteosat-11 disc

Role of spatial and temporal sampling



Metop-A Metop-B CrIS AIRS

CTL: Conv + AMSU-A
EXP: CTL + 2 IASI + CrIS + AIRS



Verification over Meteosat-11 disc

Conclusions

- Assimilation of humidity sensitive radiance observations in 4D-Var impact the wind analysis via
  - Adjustments in the mass fields of the atmosphere.
  - Adjustments in the wind field directly
- Hyperspectral IR observations from polar orbiting satellites have clear positive impact on wind analysis and forecasts.
  - Majority of the impact comes from the water vapour channels
  - Currently only 10 water vapour channels from IASI and 7 channels both from CrIS and AIRS are used operationally
- Upcoming hyperspectral IR instruments on geostationary satellites will provide observations up to 30 min time resolution and have enormous potential for NWP.