Impact of hyperspectral IR radiances on wind analyses

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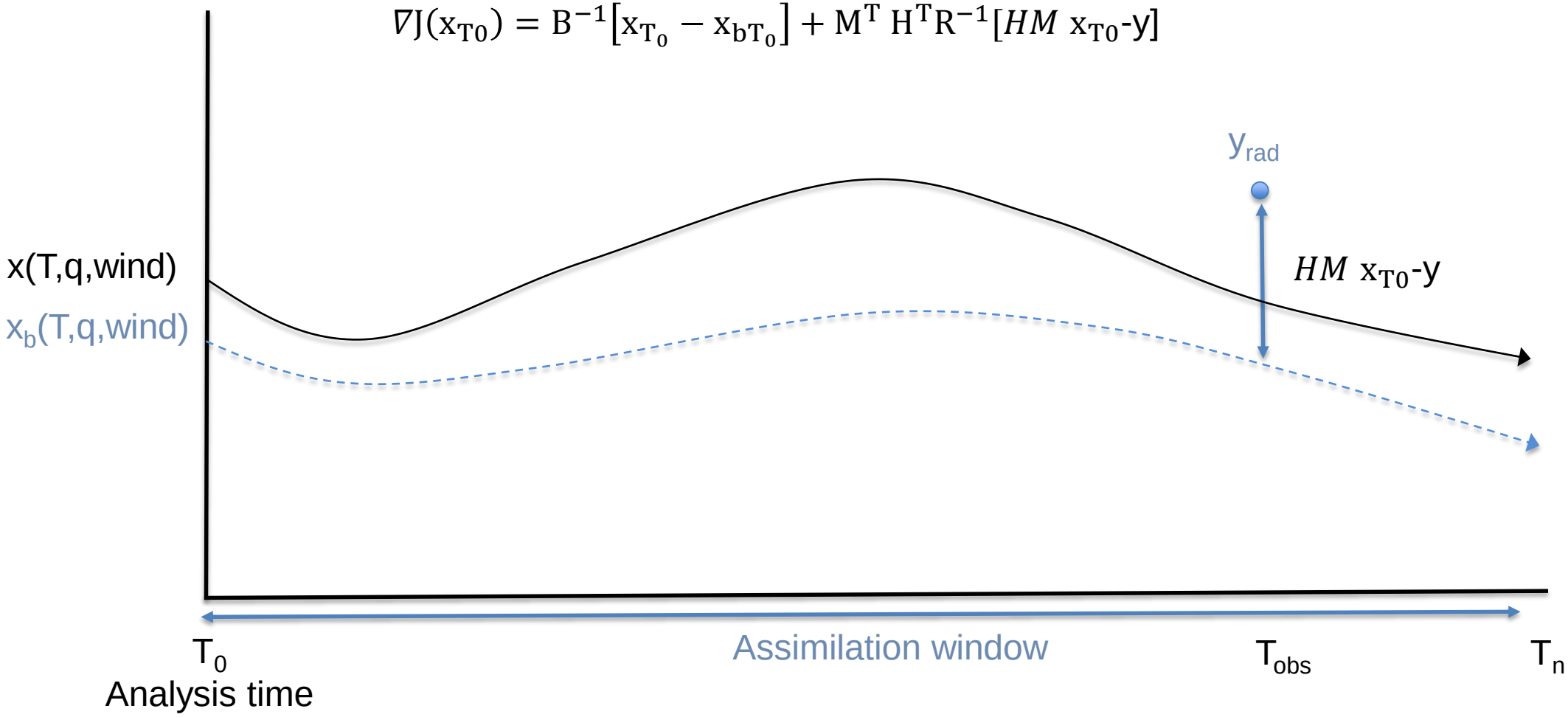
Motivation

- 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 observation in 4D-Var

Analysis is obtained by finding solution of $\nabla J(x_{T0})=0$

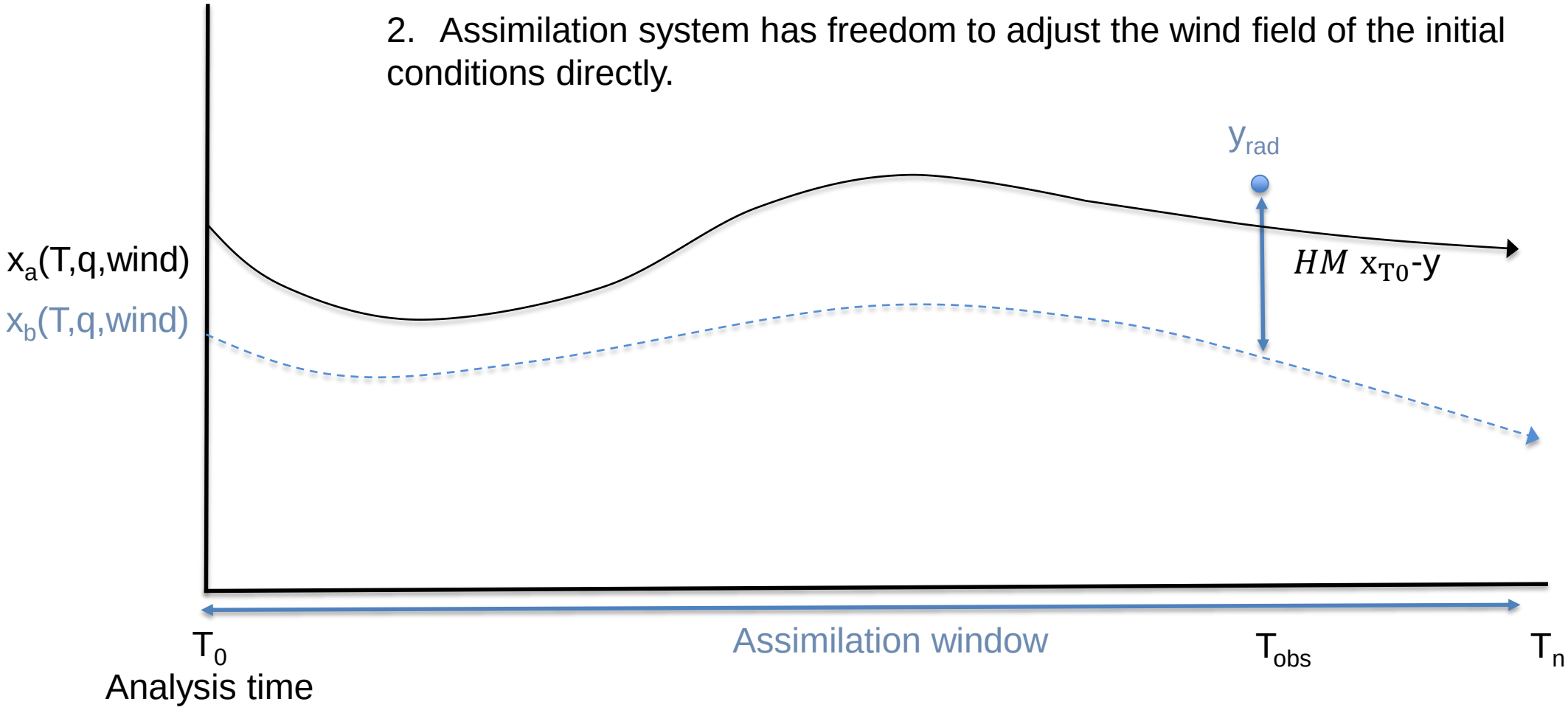
$$\nabla J(x_{T0}) = B^{-1}\left[x_{T_0} - x_{bT_0}\right] + M^T H^T R^{-1}[HM\ x_{T0}\text{-}y]$$



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

1. Adjustments in the mass fields of the atmosphere.

2. Assimilation system has freedom to adjust the wind field of the initial conditions directly.



Experimentation setup

IFS cycle 43R3, 1.11-31.12.2016

Baseline: Conventional observations + AMSU-A

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

All: Full observing system

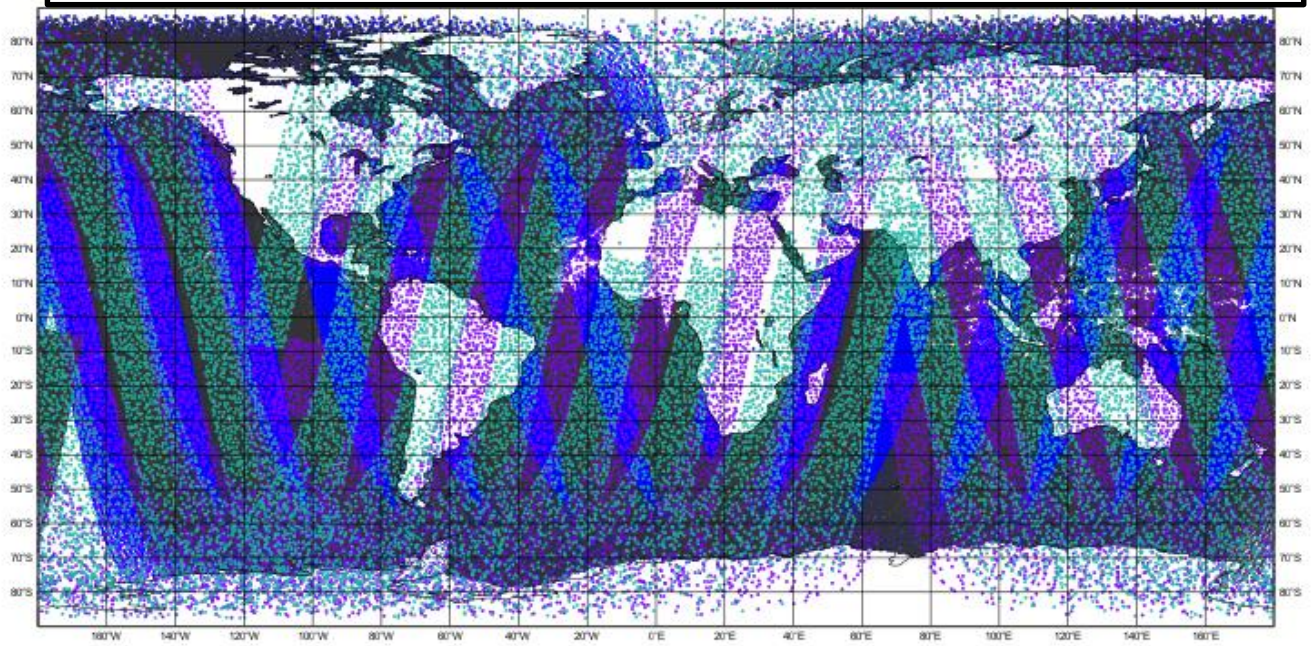
12-hour sample coverage of active hyperspectral IR data

Metop-A IASI

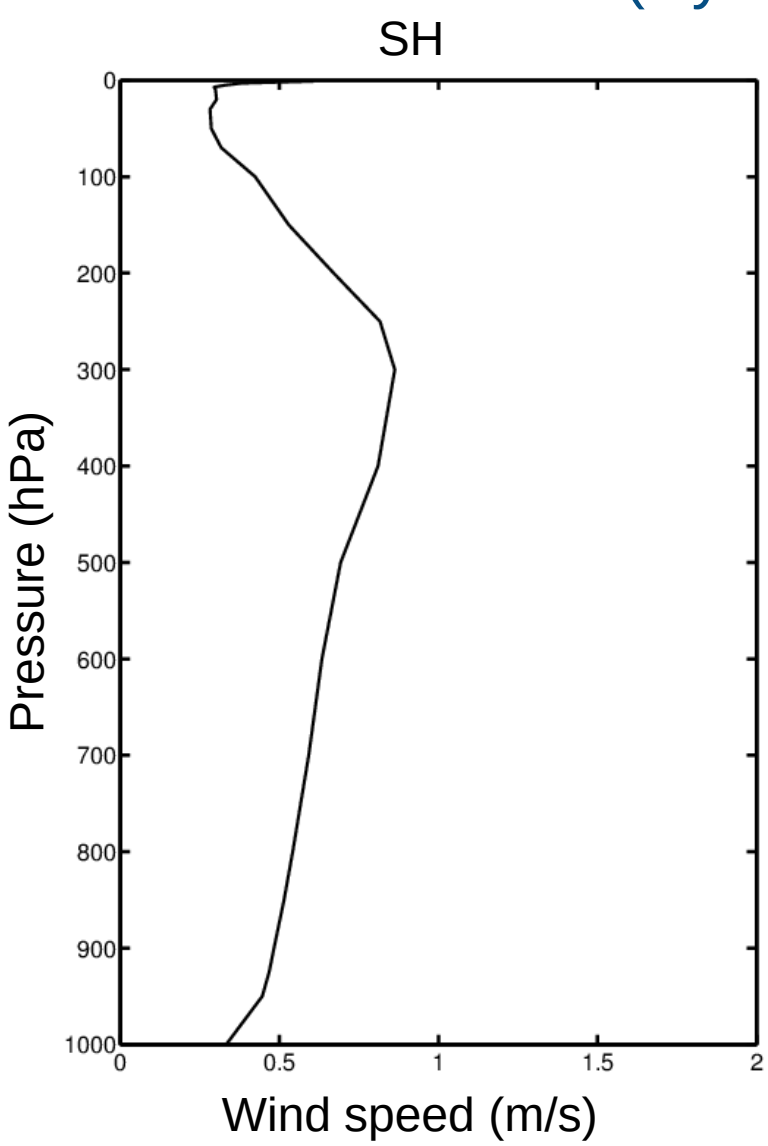
Metop-B IASI

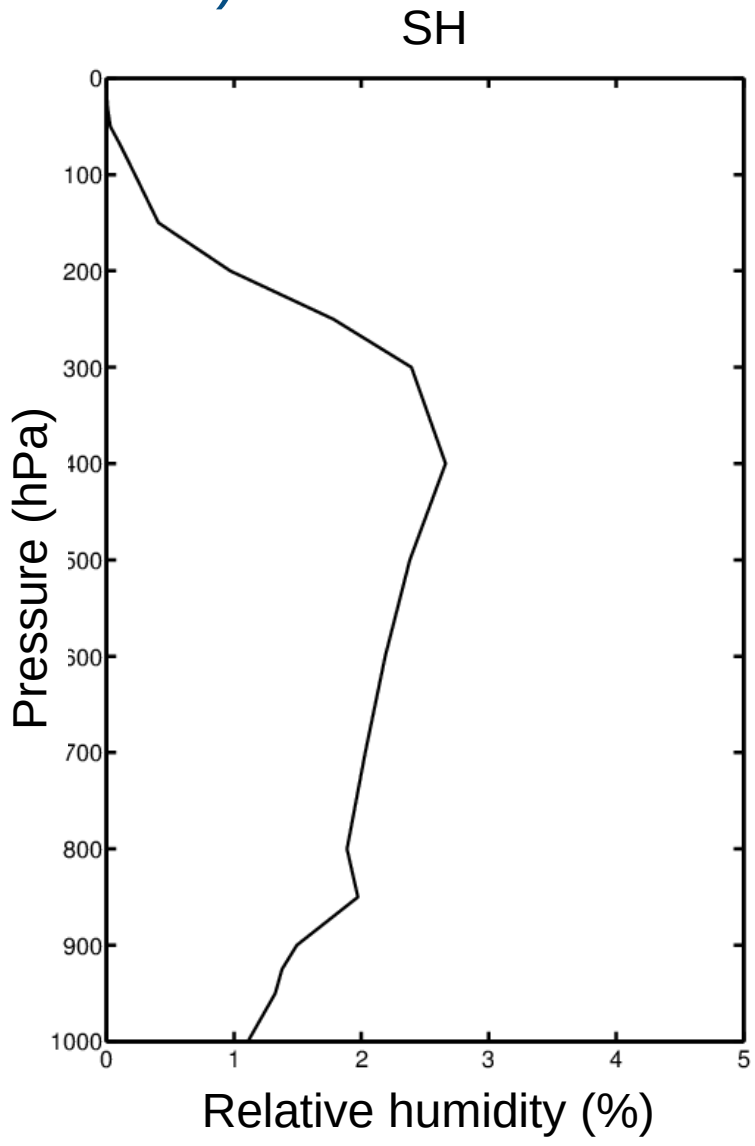
Aqua AIRS

Suomi-NPP Cris



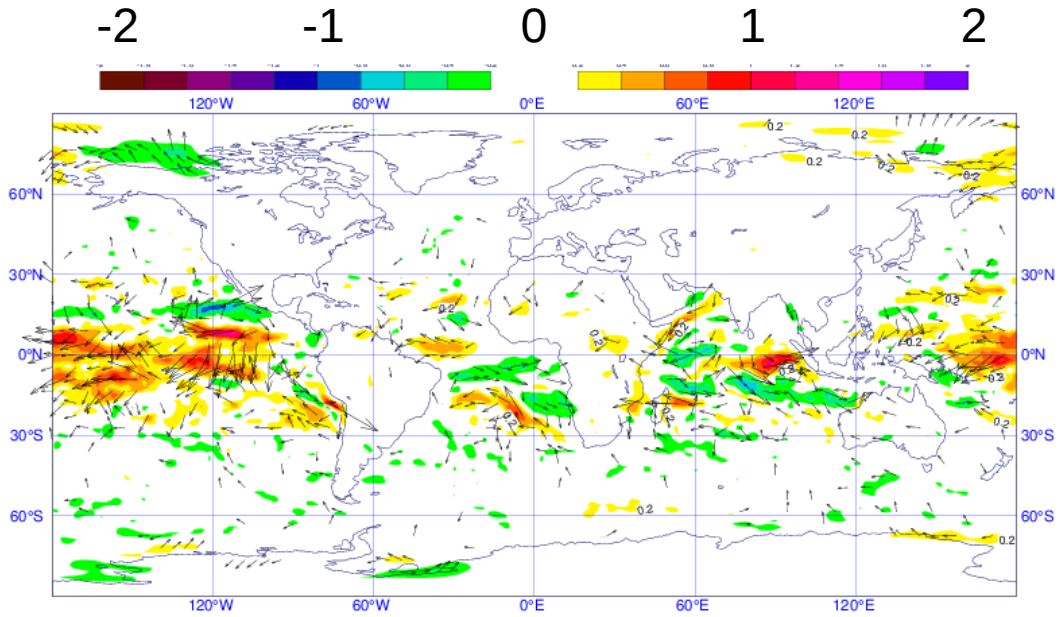
RMS of increment differences (HyIR – Baseline)



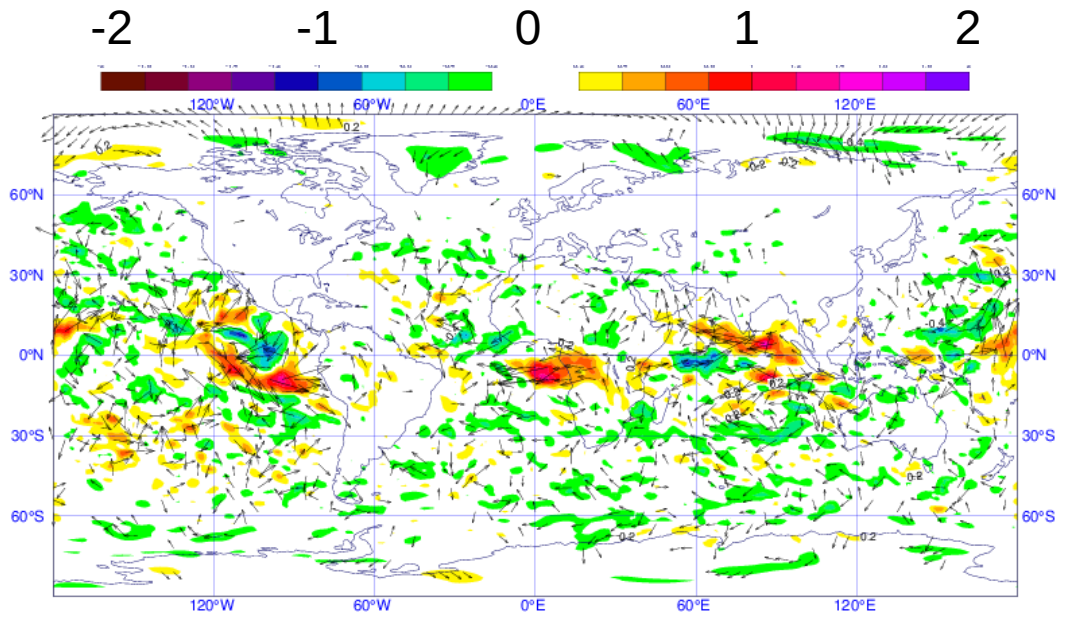


Differences in the mean wind analysis (HyIR-Baseline)

850 hPa



300 hPa

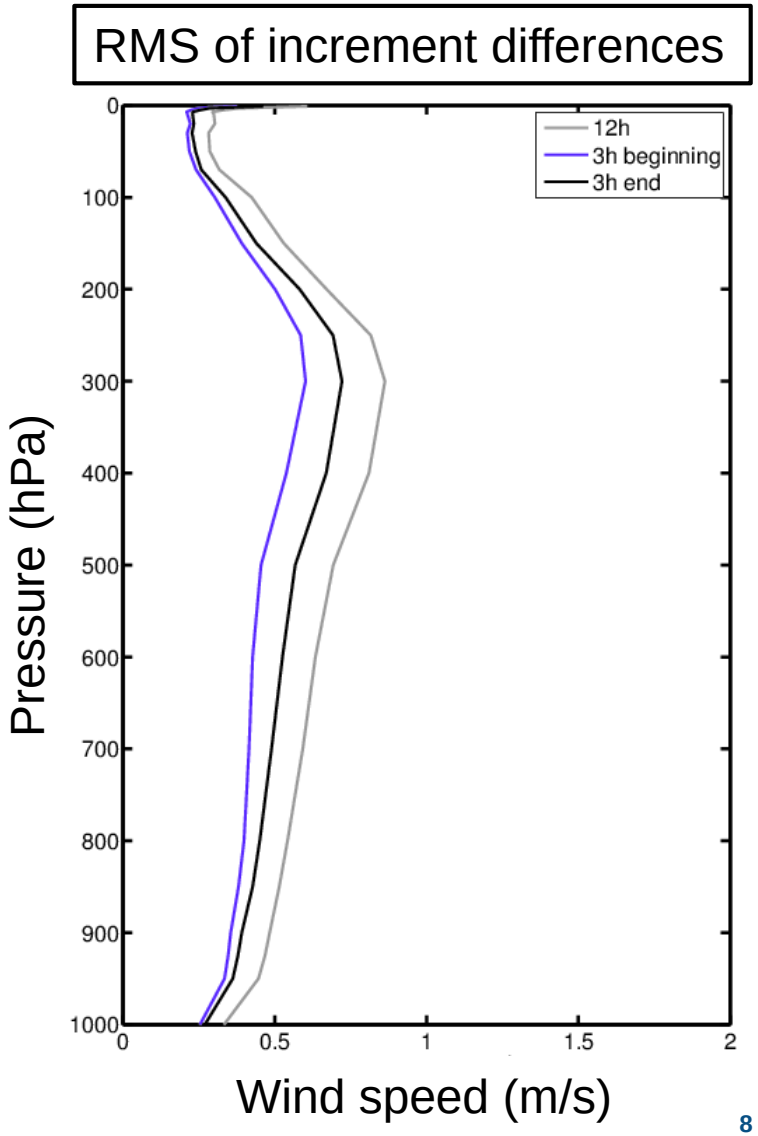


RMS of increment differences (HyIR – Baseline)

12-h assimilation window

HyIR 3h in the beginning of the DA window

HyIR 3h in the end of the DA window



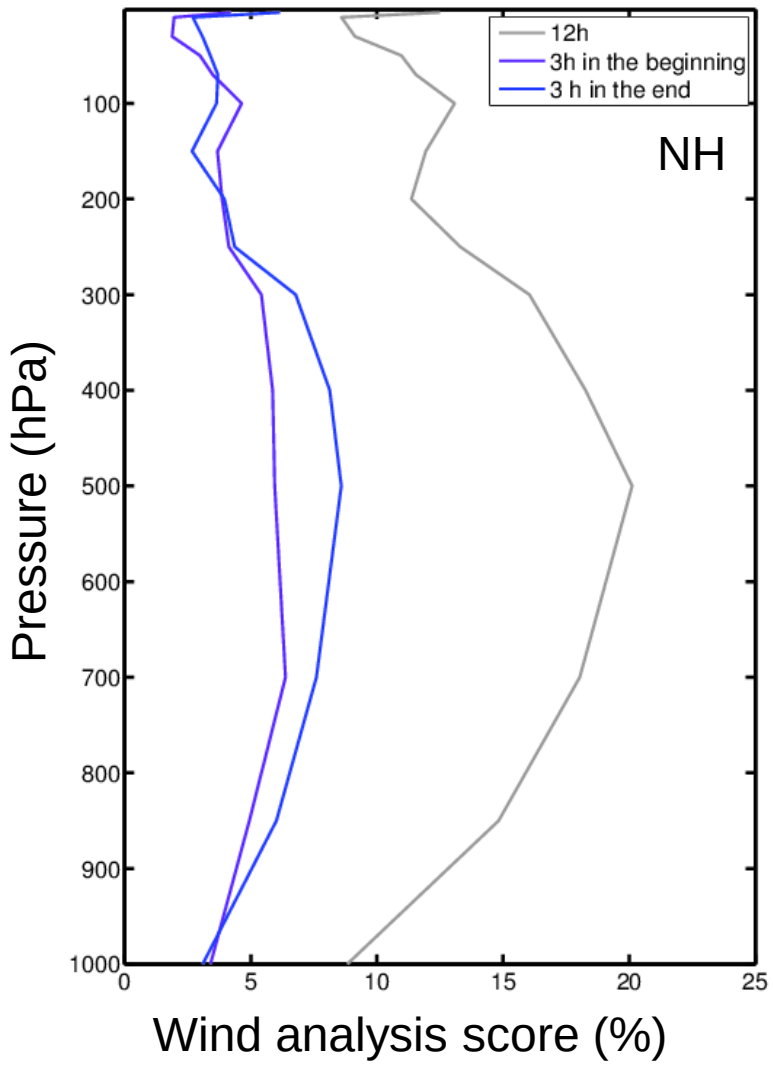
Wind analysis scores

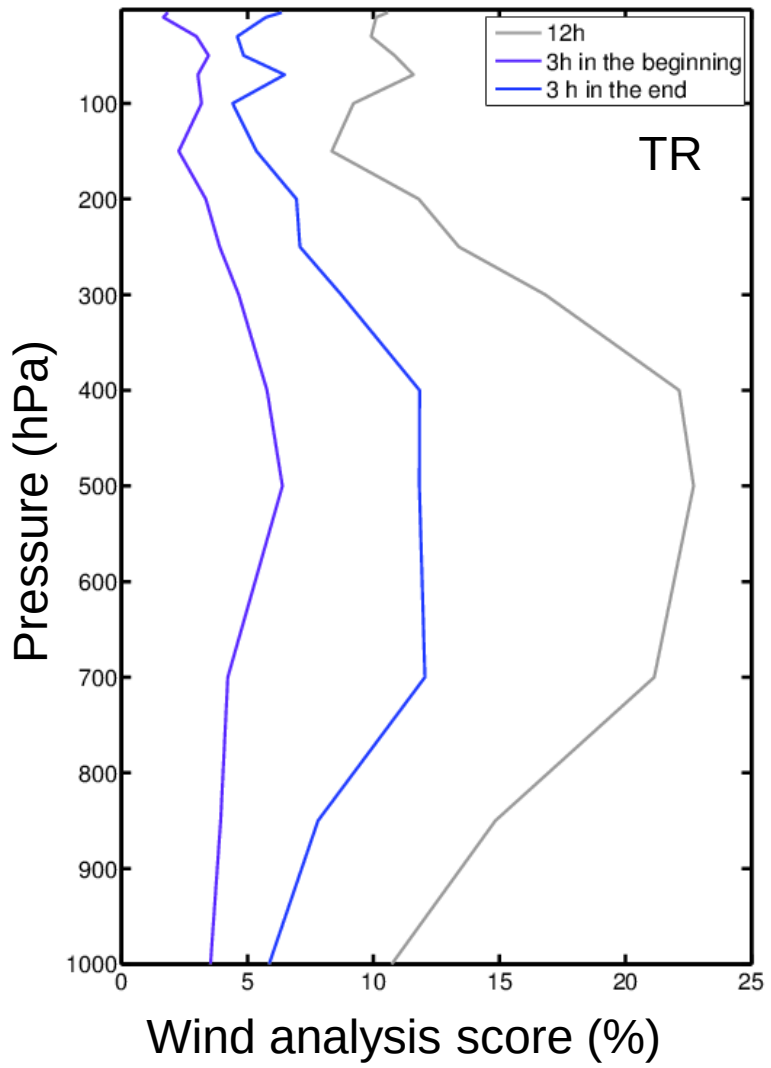
- Wind analysis error: departure from the ECMWF analysis using full observing system.
- The analysis error is compared to that of Baseline experiment.
  - Wind analysis score = 0%, no improvement over the baseline experiment (conventional + AMSU-A)
  - Wind analysis score = 100%, no error with respect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

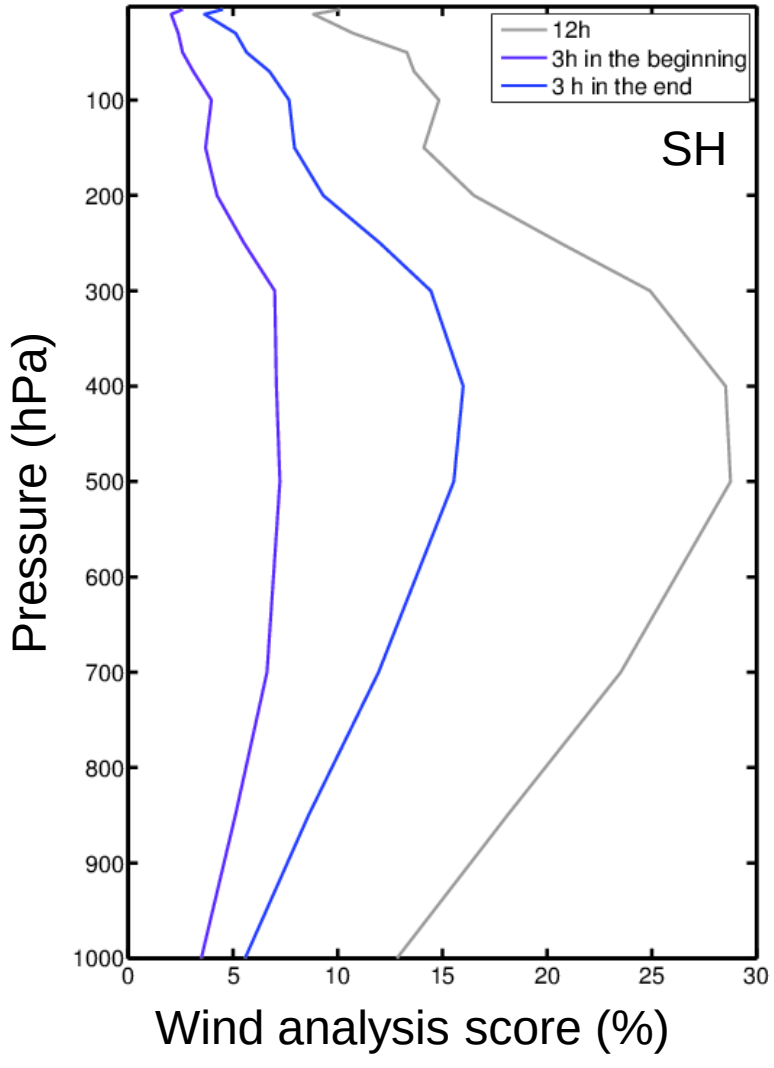
$$RMSE_j = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\left(u_i - u_i^r\right)^2 + \left(v_i - v_i^r\right)^2\right]}$$

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

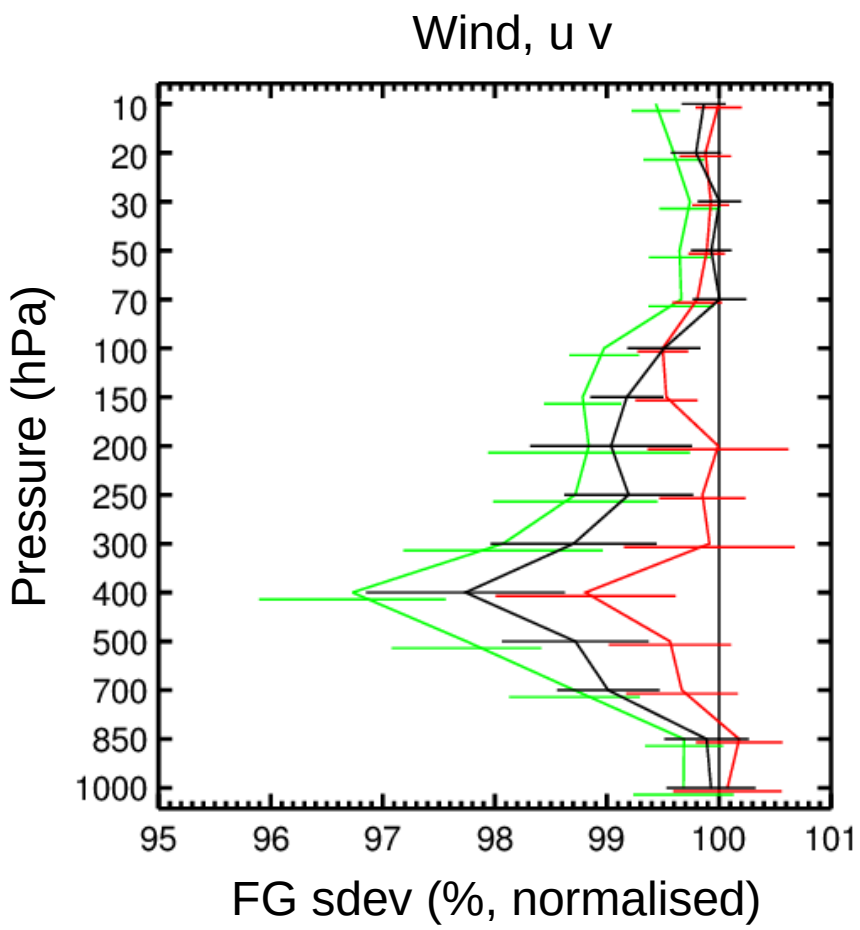
Wind analysis scores





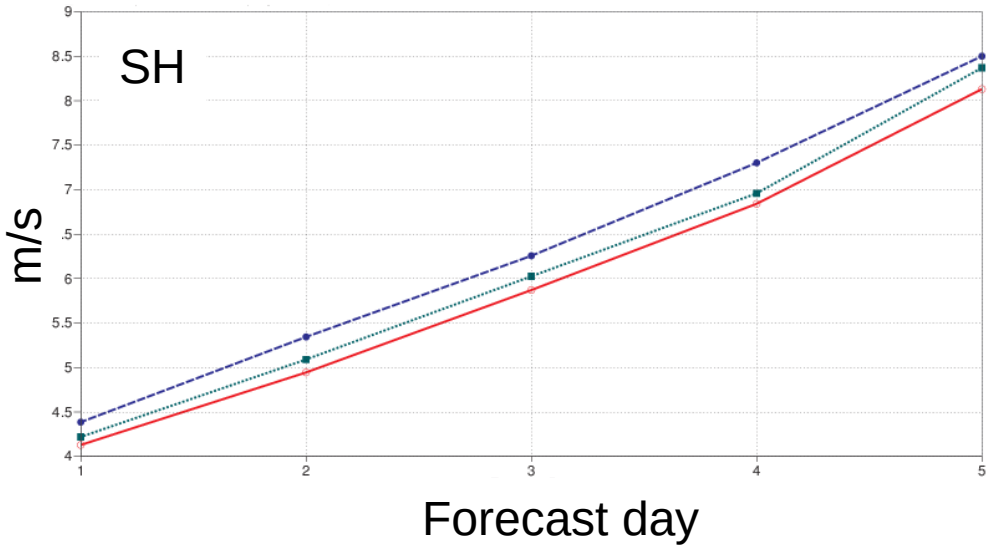


Impact on forecasts



All HyIR data 12 h DA window
HyIR 3 h in the end of DA window
HyIR 3 h in the beginning of the DA window

RMS error 500 hPa vector wind



Baseline + HyIR 3h in the end
Baseline + HyIR
Baseline

Conclusions

- Assimilation of 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.
  - Observations in the end of the DA window have larger impact than observations in the beginning of the window
- Upcoming hyperspectral IR instruments on geostationary satellites will provide observations up to 30 min time resolution and have enormous potential for NWP.