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
  – 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 $\nabla J(x_{T_0})=0$

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


**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

-2 -1 0 1 2

-2 -1 0 1 2
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

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

\[
\Delta RMSE = \frac{\sum_{j=1}^{m} (RMSE_j - RMSE_{j \, Base})}{\sum_{j=1}^{m} RMSE_{j \, Base}}
\]
Wind analysis scores

NH  TR  SH

Wind analysis scores (%)

Pressure (hPa)

Pressure (hPa)

Pressure (hPa)
Impact on forecasts

Wind, u v

RMS error 500 hPa vector wind

FG sdev (% normalized)

Pressure (hPa)

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

Baseline + HylR 3h in the end
Baseline + HylR
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.