AMVs in the ECMWF system:

Overview of the recent operational and research activities

Kirsti Salonen and Niels Bormann

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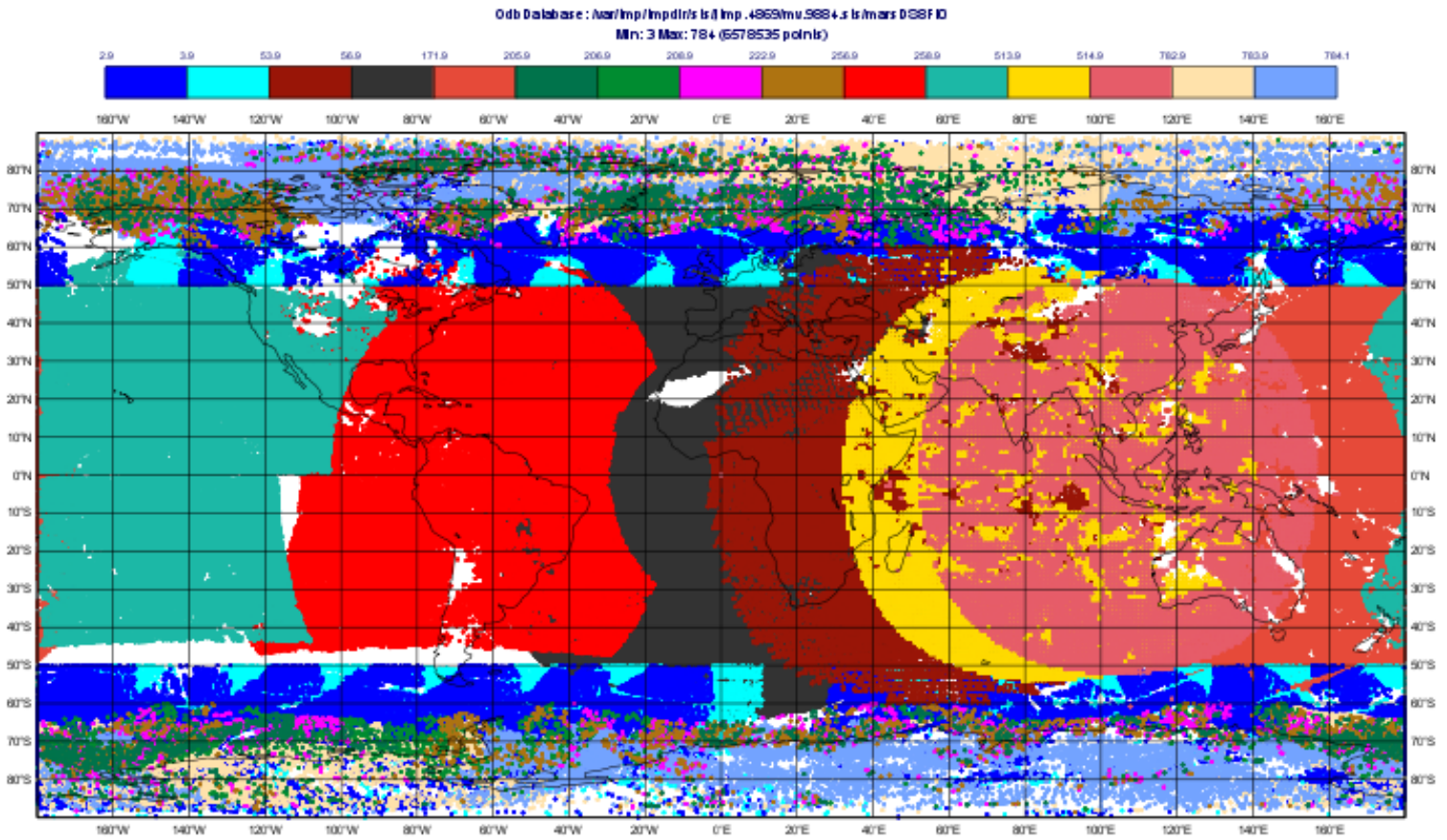
AMV sample coverage: monitored

GOES-15	GOES-13	MET-10	MET-7	MTSAT-2
NOAA-15	NOAA-16	NOAA-18	NOAA-19	FY-2D
FY-2E	AQUA	TERRA	METOP-A	METOP-B



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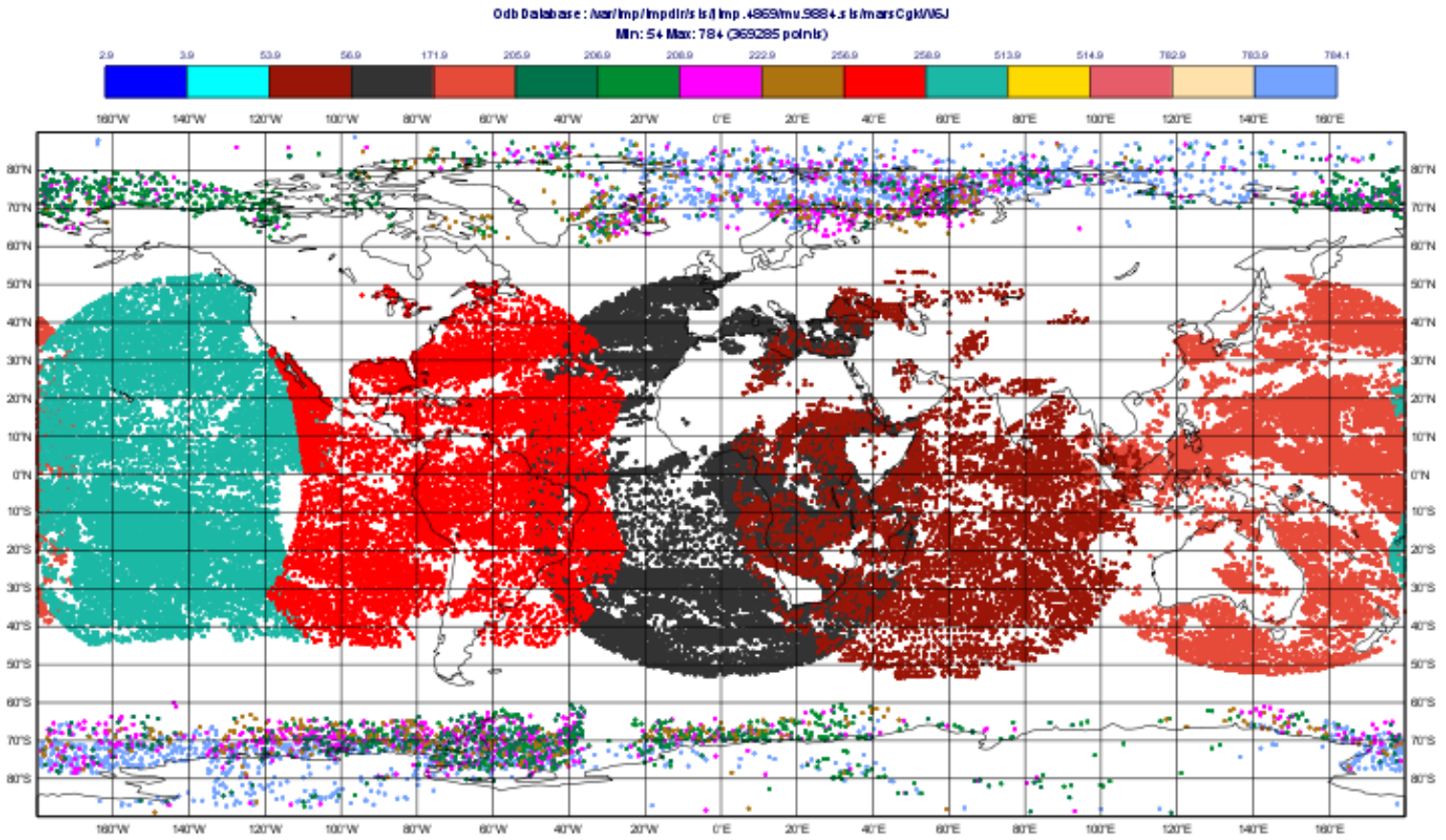
AMV sample coverage: active

GOES-15 GOES-13 MET-10 MET-7 MTSAT-2
NOAA-15 NOAA-16 NOAA-18 NOAA-19
AQUA



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Recent operational changes

Time	Event
2012 November	Activation of NOAA-15,-16,-18 AVHRR AMVs
December	Passive monitoring of MET-10 parallel to MET-9
2013 January	Switch from MET-9 to MET-10
February	Off-line monitoring for METOP-B test data
March	Passive monitoring of NOAA-19
April	Operational monitoring of METOP-B Fix for MET-10 low level winds introduced
June	MODIS AMVs from Terra passive
August	Activation of NOAA-19 AVHRR AMVs
October – January 2014	MTSAT-2 ground system maintenance, MTSAT-1R used as replacement
November	Revised AMV usage, IFS cycle 40R1
Postponed until further notice	Introduction of hourly GOES AMVs

Outline

- Revised AMV usage
- Investigations with GOES hourly AMVs
- Latest activities with polar AMVs
    1) Impact of AVHRR AMVs in the absence of MODIS AMVs
    2) Experimentation with METOP-A and METOP-B
    3) Monitoring of dual METOP-A/B AMVs
- Alternative interpretations of AMVs

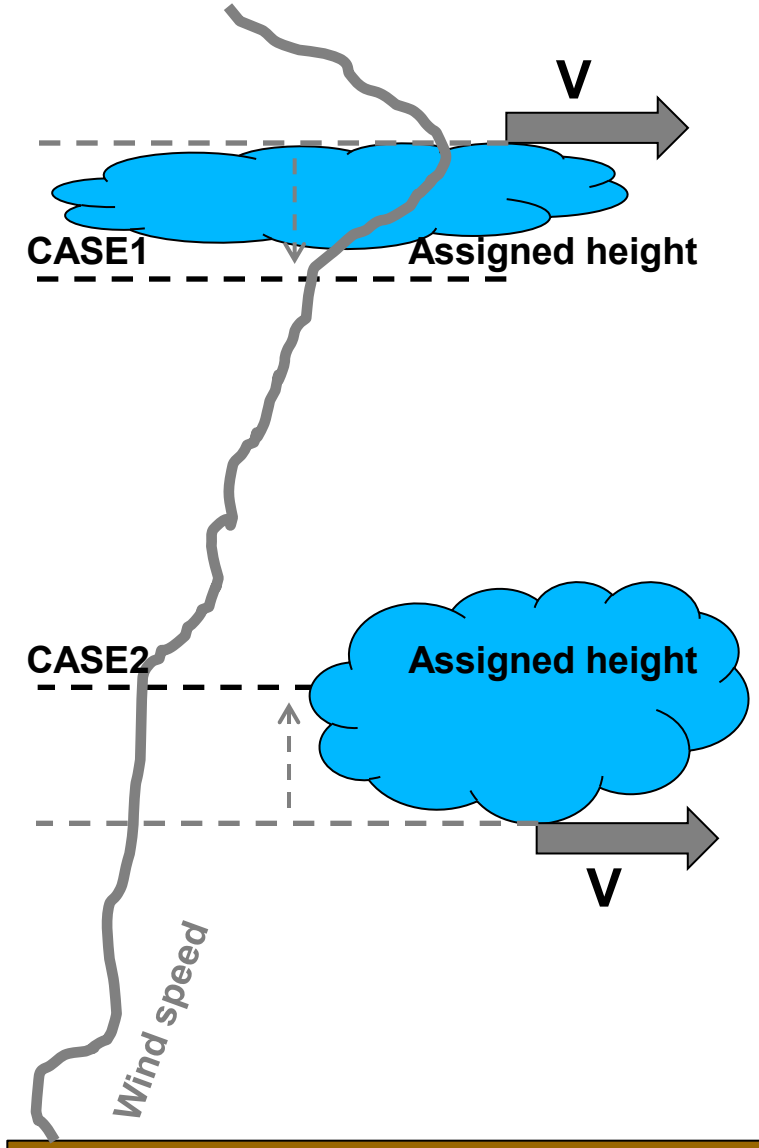
Salonen, K. and Bormann, N., 2013: Atmospheric motion vector observations in the ECMWF system: third year report. Available at http://www.ecmwf.int/publications/library/do/references/show?id=91001

Revised AMV usage:

Situation dependent observation errors and revised quality control

Salonen, K. and Bormann, N., 2013: Winds of change in the use of atmospheric motion vectors in the ECMWF system. ECMWF Newsletter 136, 23-27. Available at http://www.ecmwf.int/publications/newsletters/pdf/136.pdf

Motivation: impact of height assignment errors

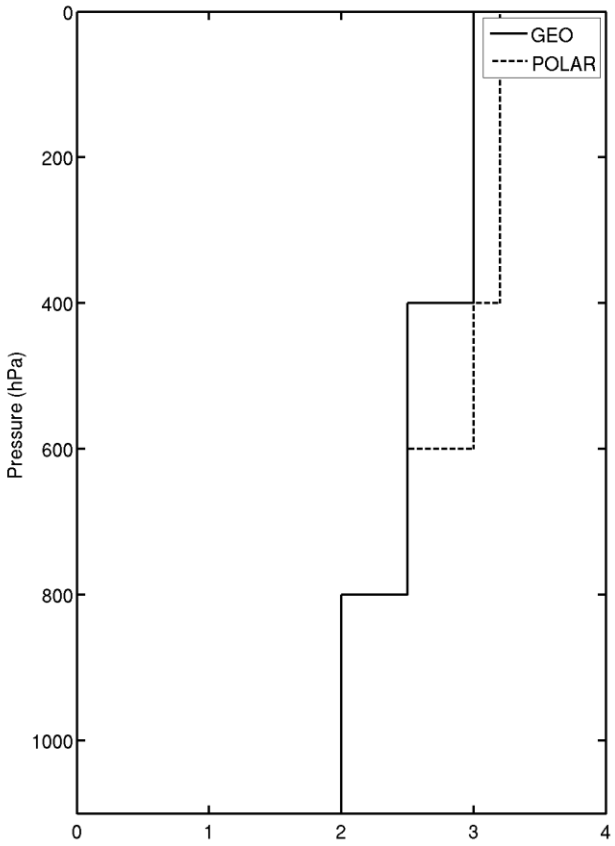


- Dominant source of error for AMVs:
  - Built-in assumptions in the methods
  - Difficulties linking the height assignment to features dominating the tracking
  - Errors in short-range NWP forecasts used in height assignment

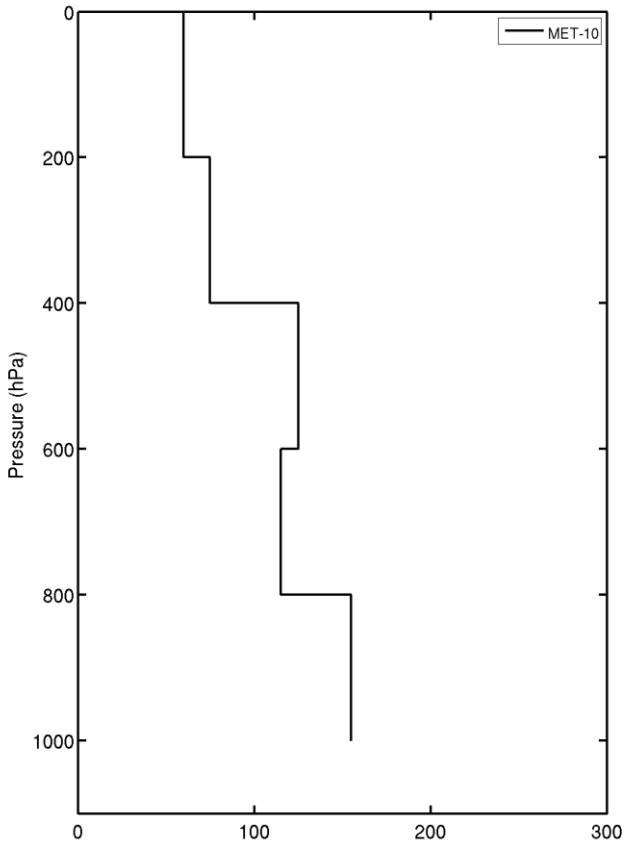
CASE 1: Wind shear in vertical, large error in wind speed.

CASE 2: Wind speed does not vary much with height, small error in wind speed.

Situation dependent observation errors



Tracking error (m/s)

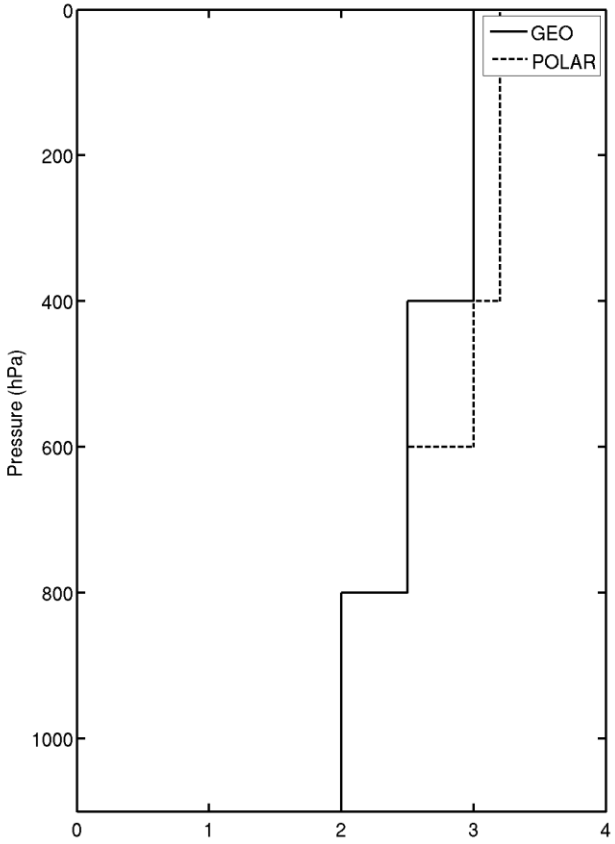


E_p , Height error (hPa)

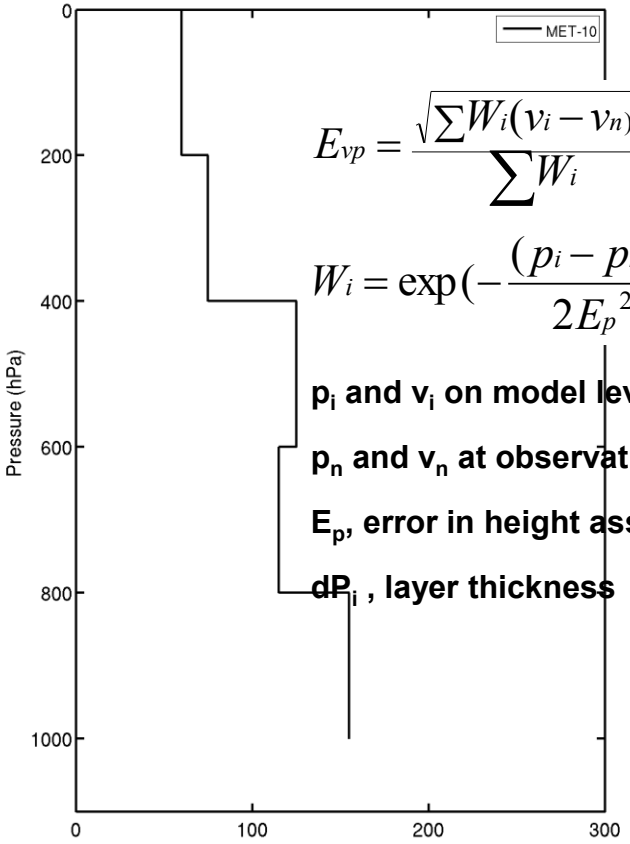
$$[\text{Total u/v error}]^2 = [\text{Tracking error}]^2 + [\text{Error in u/v due to error in height}]^2$$

Forsythe M, Saunders R, 2008: AMV errors: A new approach in NWP. Proceedings of the 9th international winds workshop.

Situation dependent observation errors



Tracking error (m/s)



$$E_{vp} = \frac{\sqrt{\sum W_i (v_i - v_n)^2}}{\sum W_i},$$

$$W_i = \exp\left(-\frac{(p_i - p_n)^2}{2E_p{}^2}\right) * dP_i$$

p_i and v_i on model level

p_n and v_n at observation location

E_p, error in height assignment

dP_i , layer thickness

E_p , Height error (hPa)

Situation dependent observation errors

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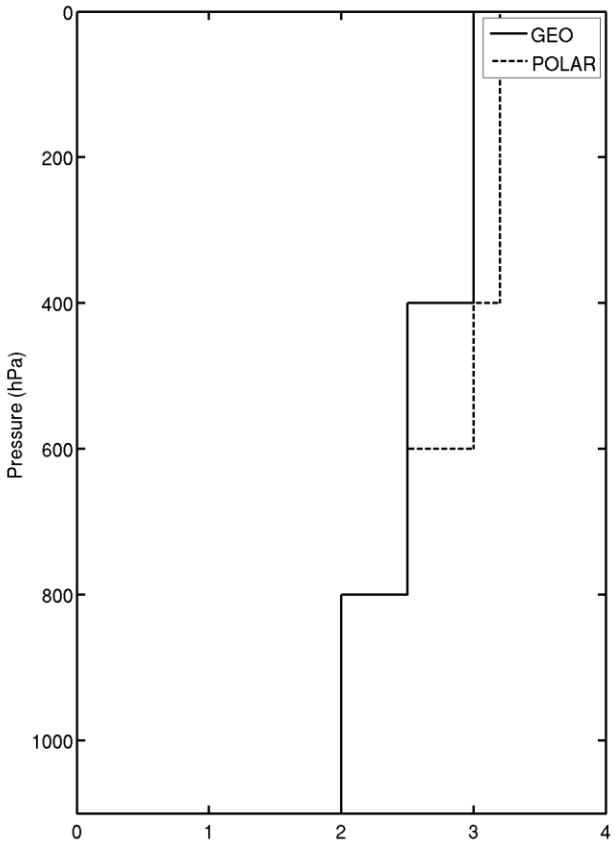

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Tracking error (m/s)

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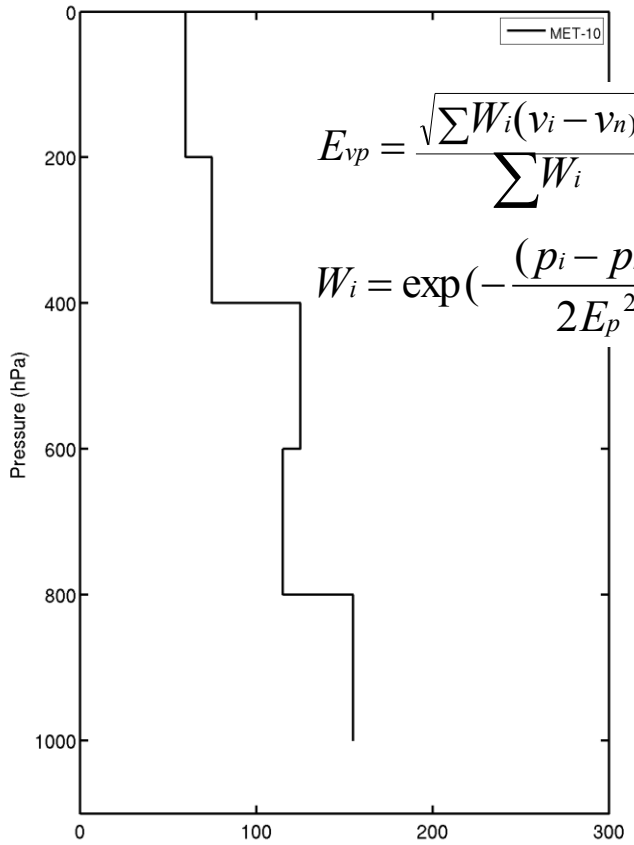

^{2}

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$$W_i = \exp\left(-\frac{(p_i - p_n)^2}{2E_p{}^2}\right) * dP_i$$

E_p , Height error (hPa)

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Situation dependent observation errors

Total observation error (m/s)

Example: cloudy WV, high levels

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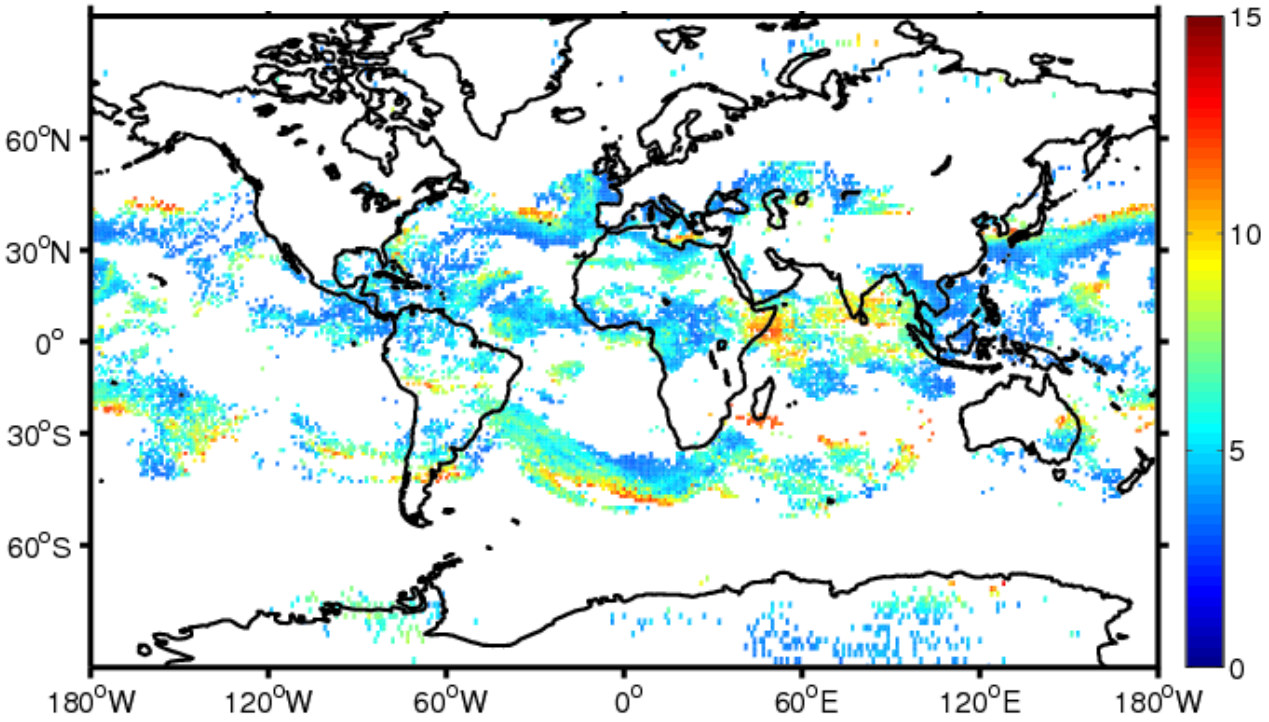

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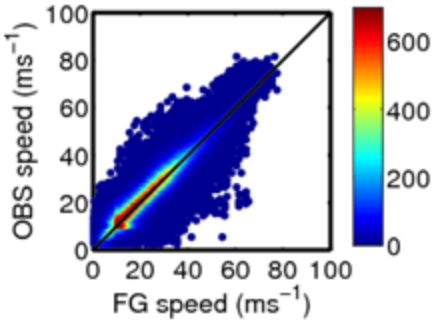
Revised quality control

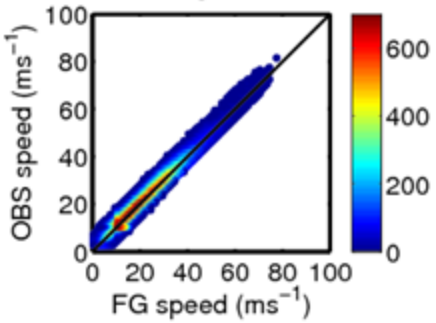
Blacklisting

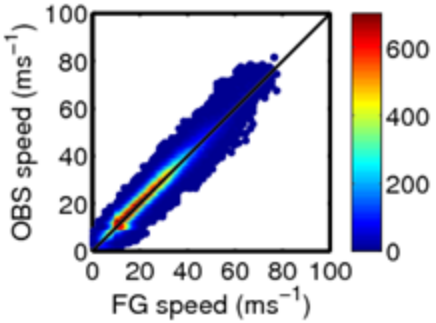
- Rejects observations based on long-term monitoring.



First guess check

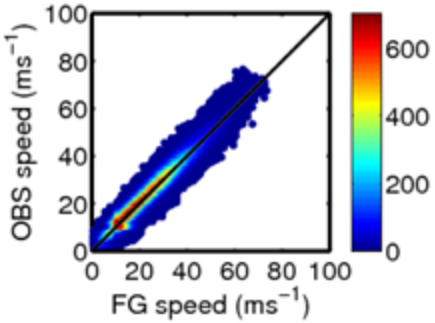
- Compares observation to the model counterpart.
- Observation rejected if it deviates too much.





New QC criterion

- $\sigma_{\text{due to error in height}} < 4\ \sigma_{\text{tracking}}$
- Motivated by the fact that height assignment errors are likely to be more correlated spatially.



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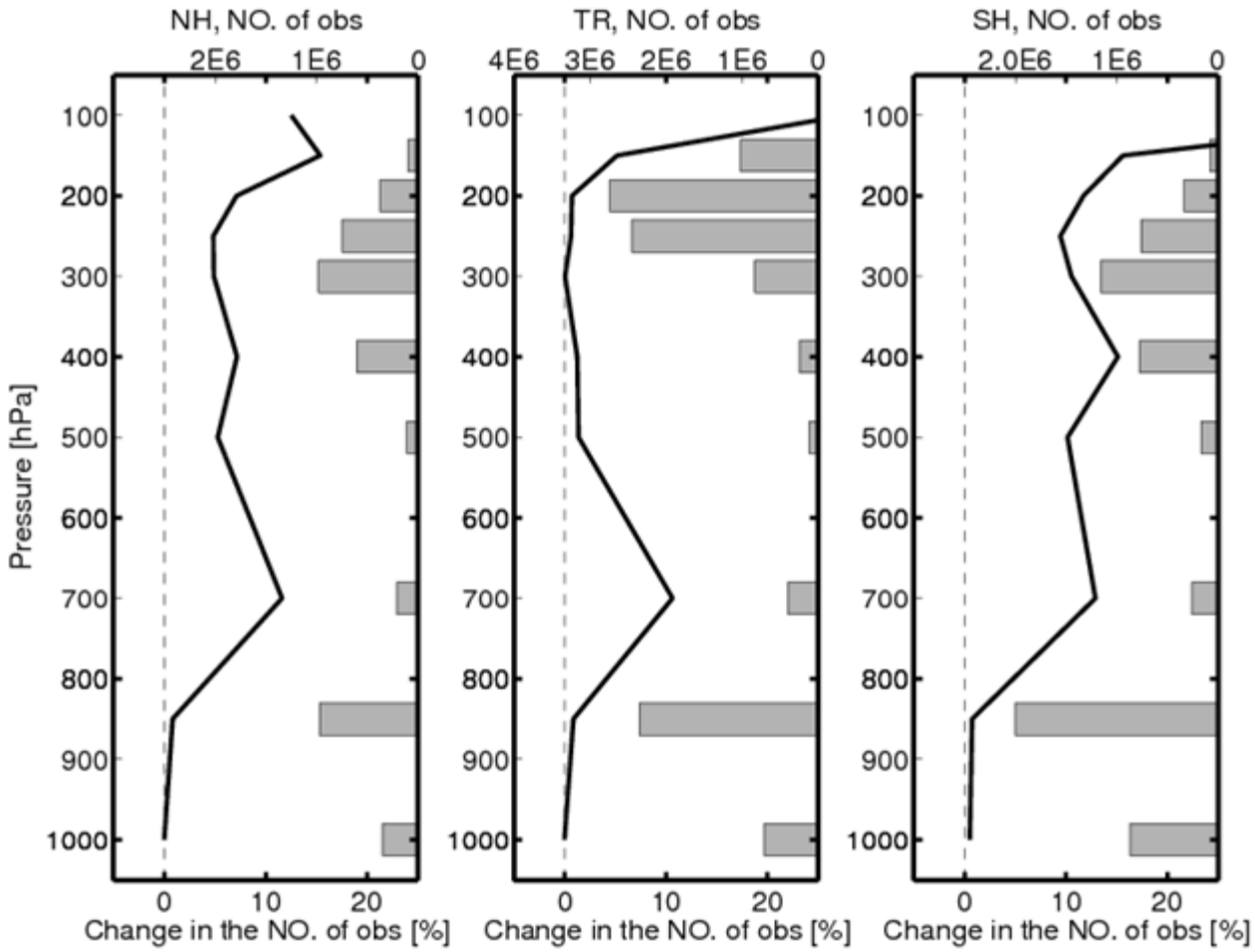
Relative change in the NO of used AMVs



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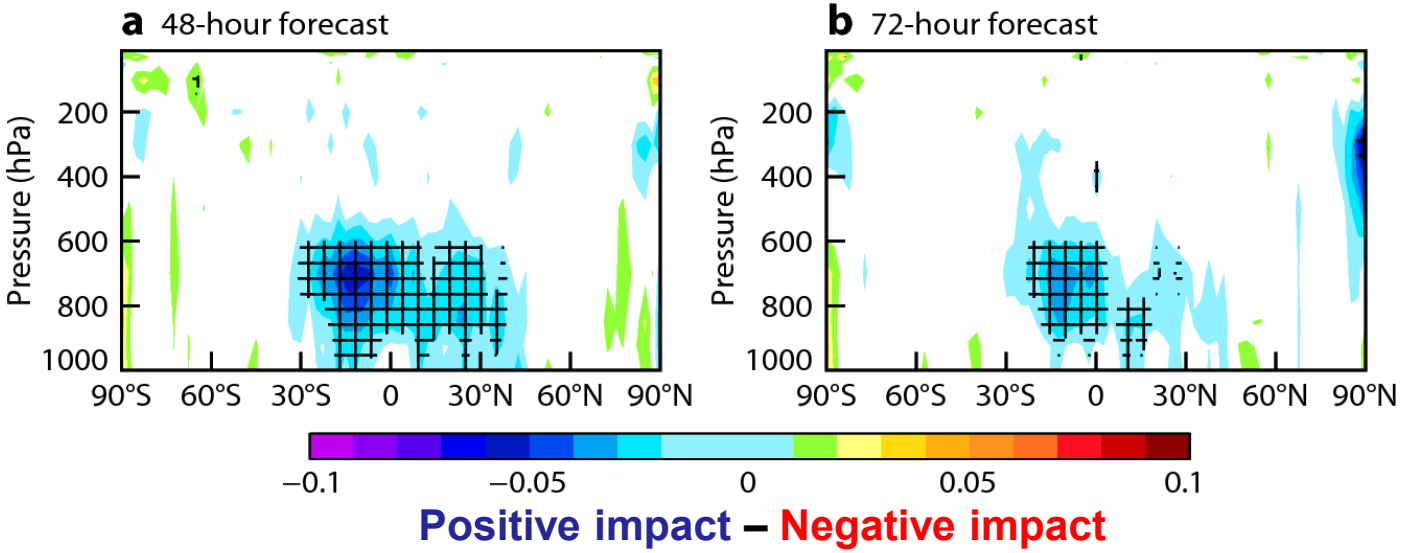
Impact on analysis and forecasts

Normalised difference in the RMS error for 48-h and 72-h wind forecasts



- Tested over summer and winter periods, 1.1-31.3.2012, 1.6-31.8.2012, CY38r2, T511, 137 levels, 12-hour 4D-Var.
- Operational since 19th November 2013, CY40R1.

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Investigations with GOES hourly AMVs

Testing with hourly GOES AMVs

- NESDIS is making preparations to disseminate hourly GOES AMVs
  - Additional quality indicator Expected Error (EE)
  - Actual scan line time to each AMV
  - Improvements to low level heights in areas over ocean where a low level temperature inversion exists
- Santek (2011) studied the monitoring statistics for the ECMWF system
  - At high and mid levels departure statistics are fairly similar for the hourly AMVs and operationally disseminated AMVs
  - In low level inversion regions considerable improvements in the quality

Experiments

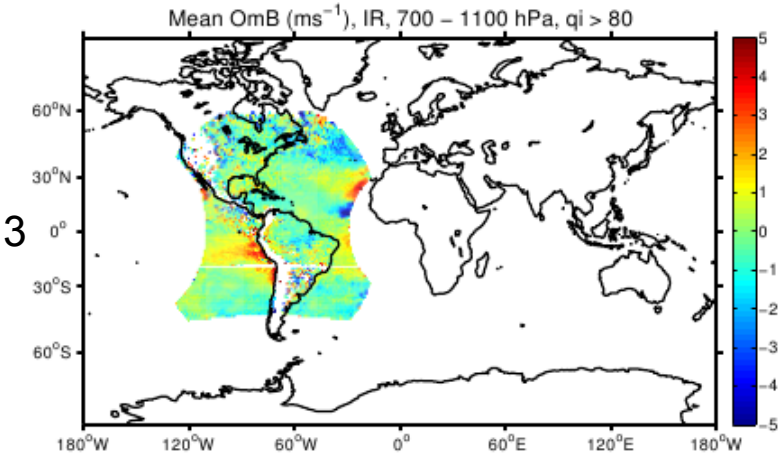
- **Experiments for 23.5-22.7.2012**
  - **No GOES:** No AMVs from GOES-13/15
  - **GOES operational:** Current operational GOES-13/15 3-hourly AMVs used
  - **GOES new hourly:** The new hourly GOES-13/15 AMVs used
  - **GOES new 3-hourly:** The new GOES-13/15 AMVs used 3-hourly
  - **IFS cycle 38r1, T511, 91 levels 12-hour 4D-Var, all operationally assimilated conventional and satellite observation used**

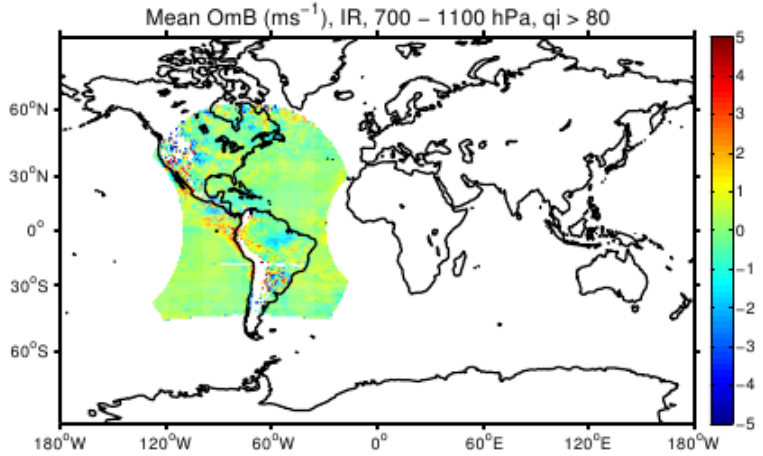
Mean OmB, IR low level winds

Operational AMVs

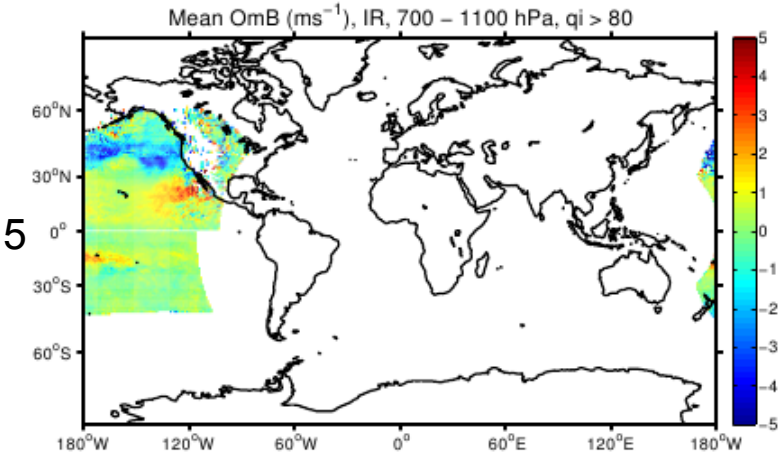
Hourly AMVs

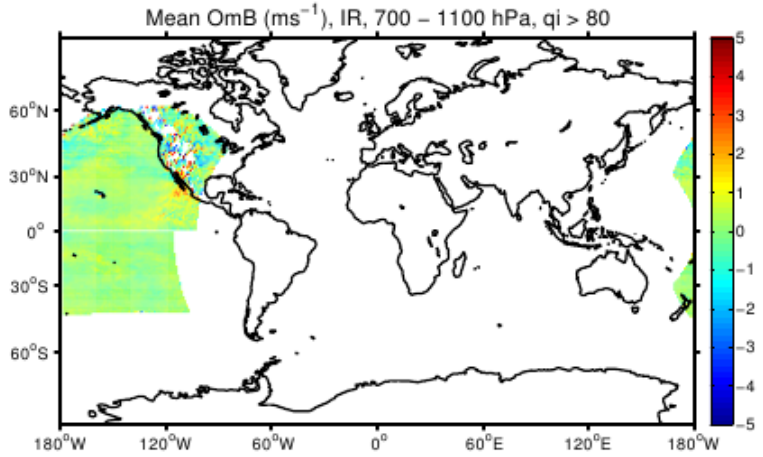
GOES-13





GOES-15





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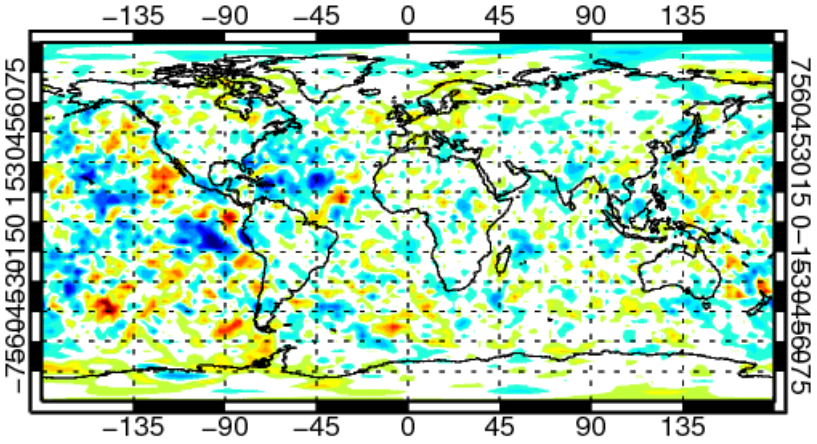
Forecast impact

- Using GOES-13/15 AMVs has in general neutral to positive impact on forecast quality.
- Using the new wind product has some positive impacts over using the current operational AMVs.
- In the current system it is more beneficial to use new wind product 3-hourly than 1-hourly.

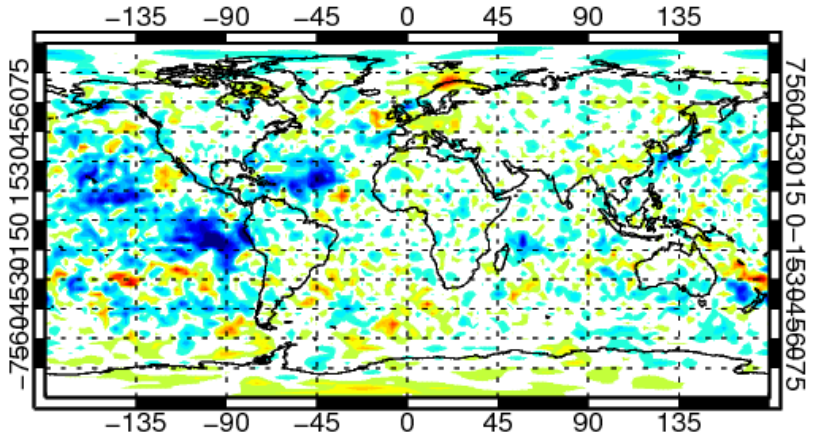
Normalised difference in VW RMS error

T+72; 850hPa

GOES 1-hourly – GOES operational



GOES 3-hourly – GOES operational



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Latest activities with polar AMVs

NOAA AVHRR AMVs

- **Reported 2012: Impact of NOAA AVHRR AMVs on top of MODIS AMVs is mainly neutral.**

- **Additional investigations:**

No polar AMVs: no MODIS or NOAA AVHRR AMVs

MODIS: only MODIS AMVs from AQUA and TERRA

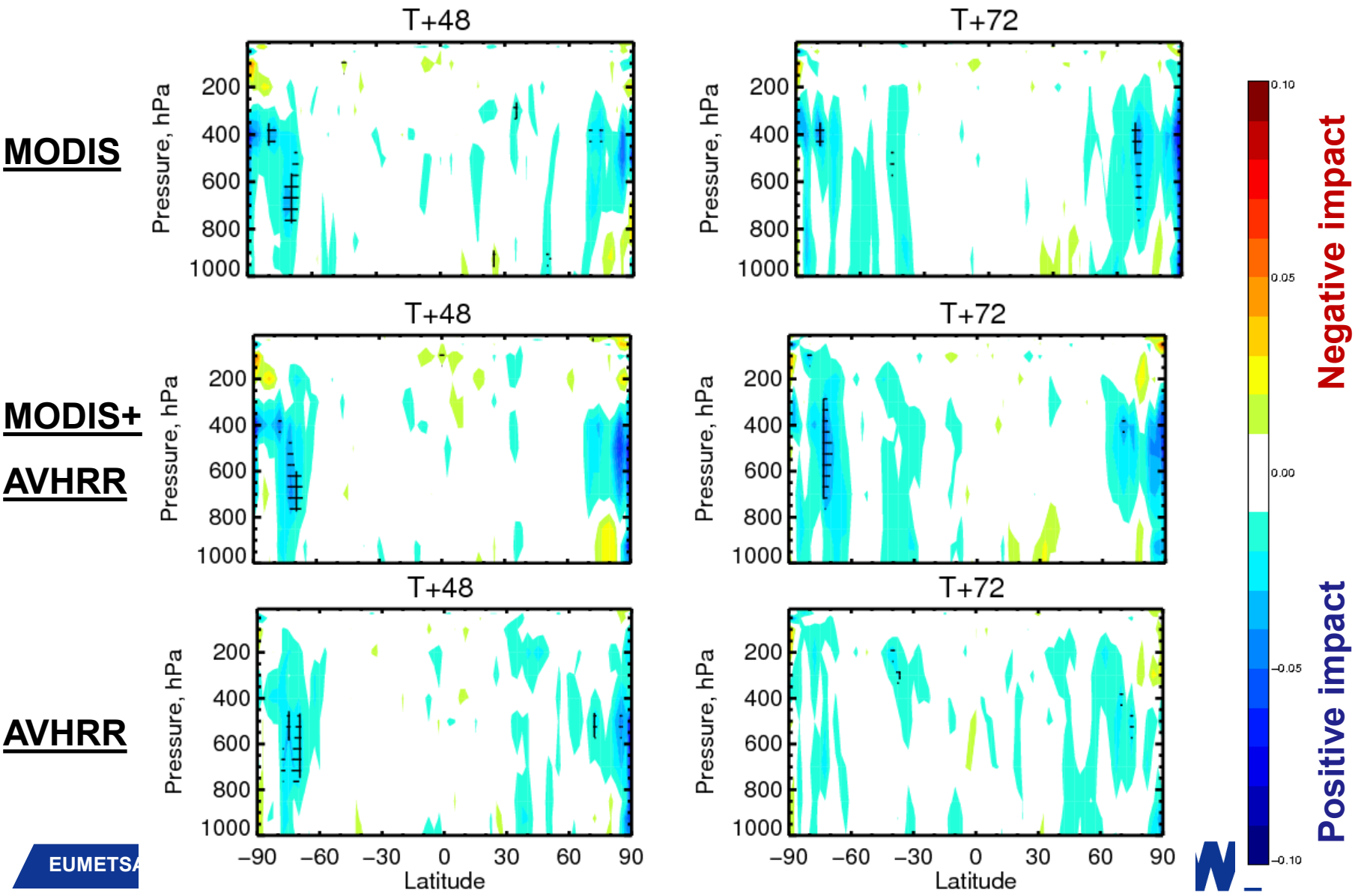
AVHRR: only AVHRR AMVs from NOAA-15,-16,-18

MODIS + AVHRR

Summer and winter periods: 1.6-31.7.2011, 1.12.2011-31.1.2012

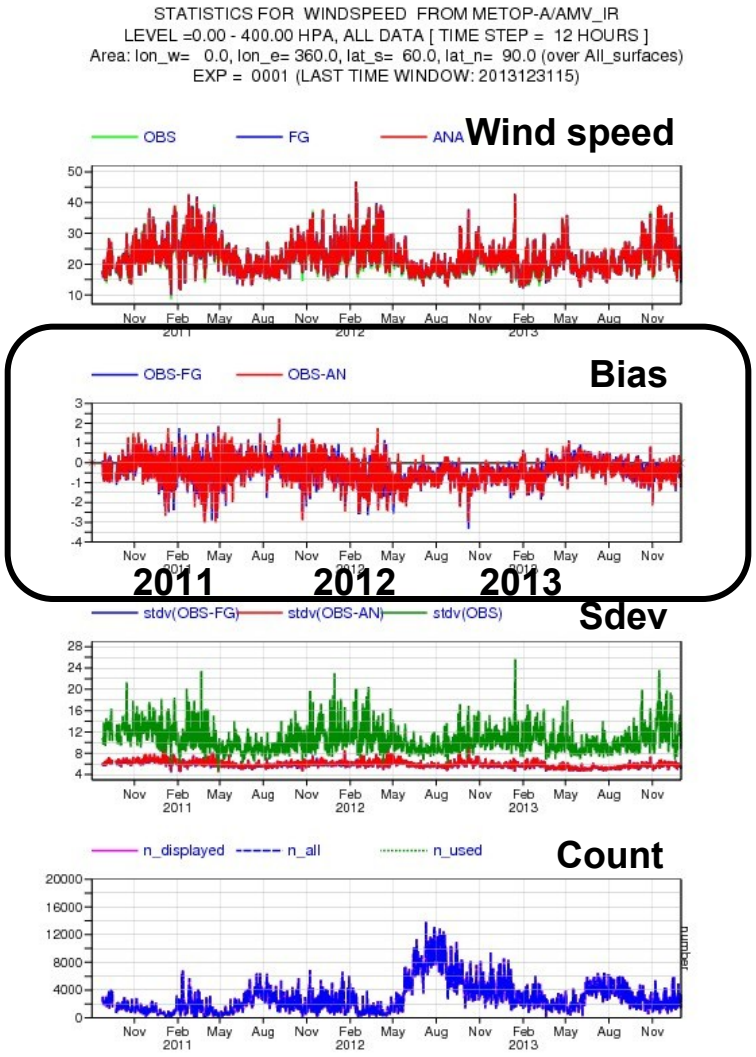
Cy38r1, T511, 91 levels, 12-hour 4D-Var

Normalised difference in VW RMS error



Metop-A and Metop-B AMVs

- Long-term monitoring of Metop-A indicates improvements in data quality at high levels.
- Metop-B added to operational monitoring 14th May 2013.
- Metop-A and Metop-B share similar characteristics
  - Small or zero bias at high levels
  - Increased positive bias at mid and low levels



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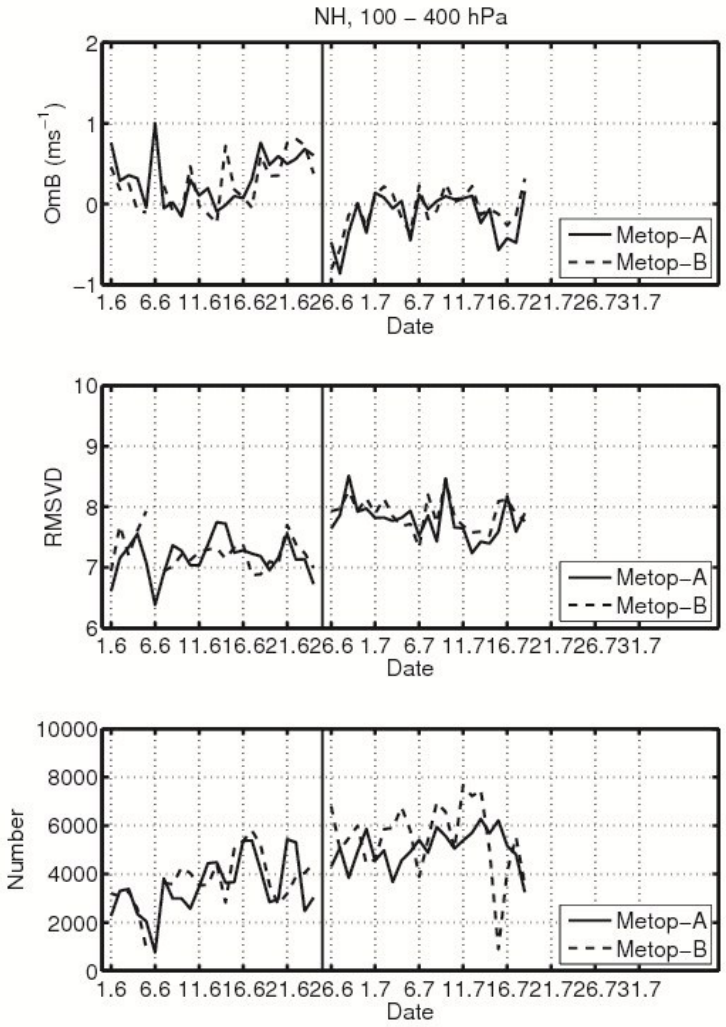
Passive monitoring

- **25th June 2013 EUMETSAT introduced further changes and improvements to the polar wind processing:**
  - **Tropopause determination**
  - **Temperature inversion determination**
  - **Extended coverage to 50°S/N**
  - **Stronger test to use IASI CTG to set the altitude**



Experiments

- **Summer and winter periods 1.7-31.8.2013, 1.12.2013-31.1.2014.**
  - **Both periods will be extended to cover 3 months.**
- **CY40R1, T511, 137 levels, 12-hour 4D-Var**

Control: All operationally assimilated conventional and satellite observations used.

Experiment: Metop-A and Metop-B AMVs used in addition

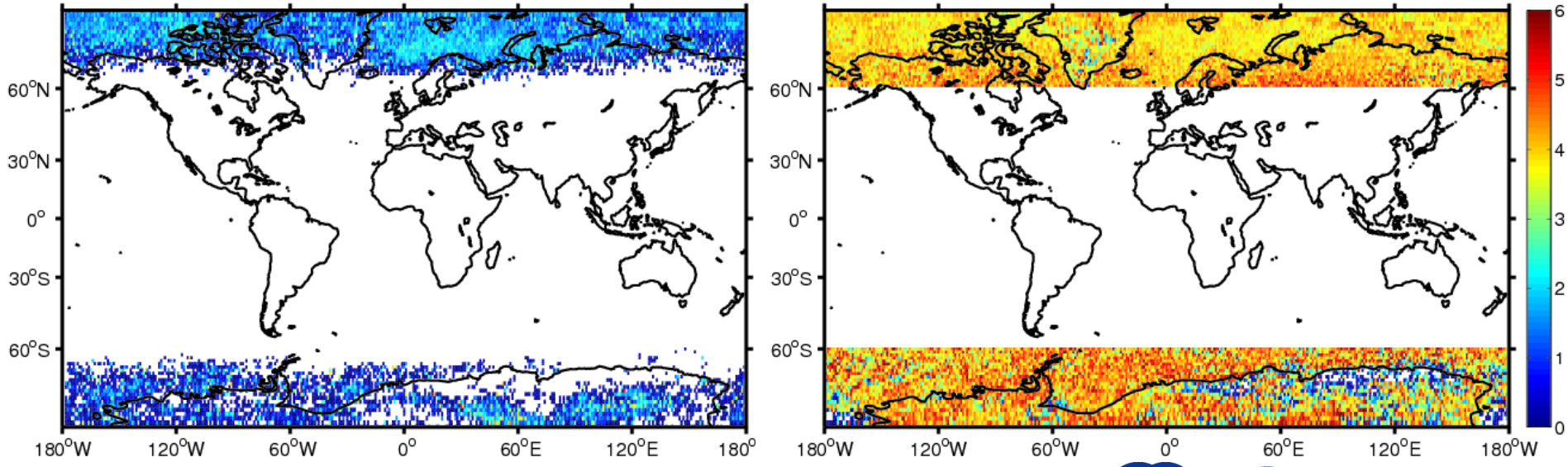
- **Above 400 hPa**
- **Forecast independent QI > 60**
- **Tracking error 4.2 m/s**

Observation errors for Metop AMVs

- Height errors around 170 hPa based on best-fit pressure statistics.
- Tracking error 4.2 m/s, 3.2 m/s for other polar AMVs above 400 hPa.
- Observation errors on average 4.9 m/s, for other polar AMVs 3.8 m/s.

Aqua and Terra **Metop-A and Metop-B**

OmB standard deviation in cases where error due to error in height is small



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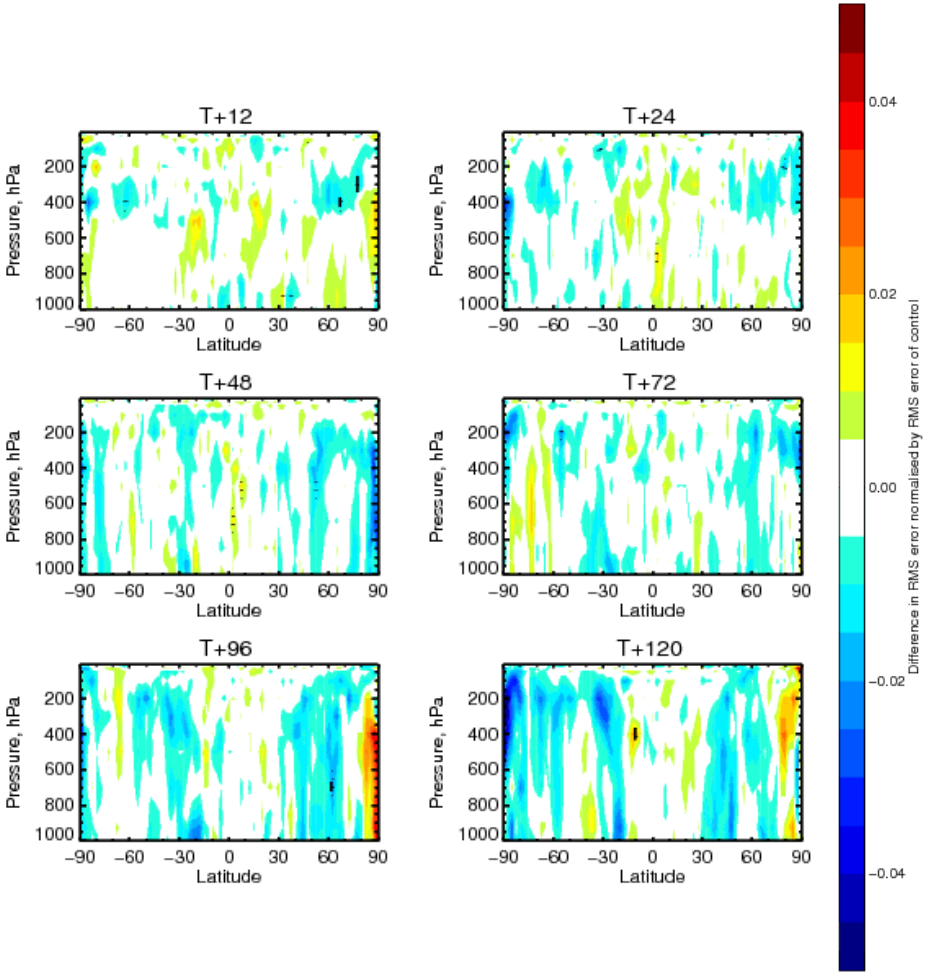
Preliminary results

- Neutral to slightly positive impact.
- Results look similar for both periods.
- Advantage: Metop AMVs cover the 50-60° N/S areas where no AMVs are currently used.
- Operational use will be considered based on the final results from the experimentation.

Normalised difference in VW RMS error



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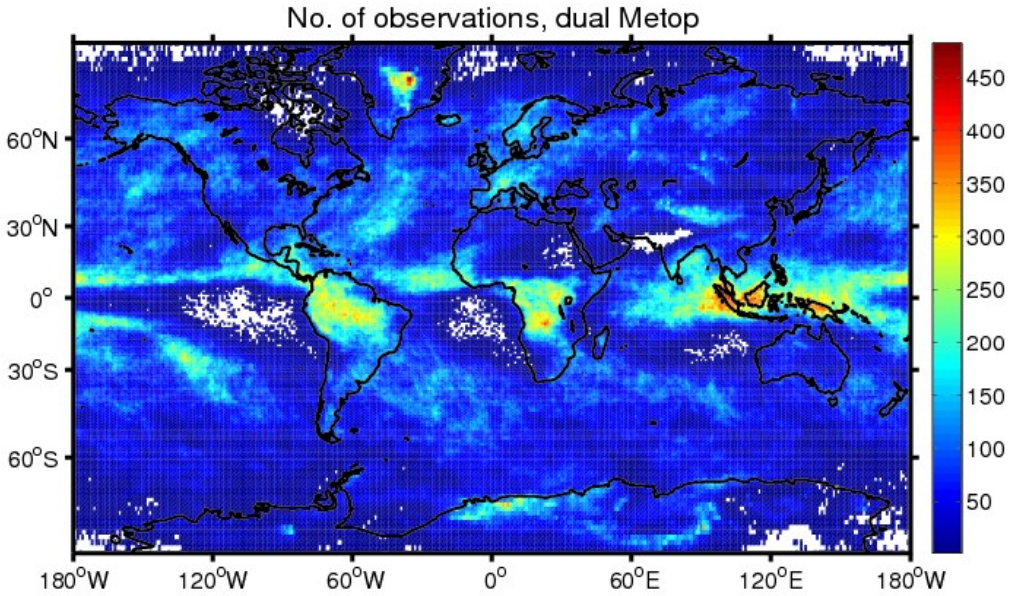
Dual Metop-A/B AMVs

- Global coverage.
- Data available for testing 20.10.2013-31.1.2014.
- Passive monitoring of the test data is ongoing, preliminary results cover one month, 20.10-19.11.2013.



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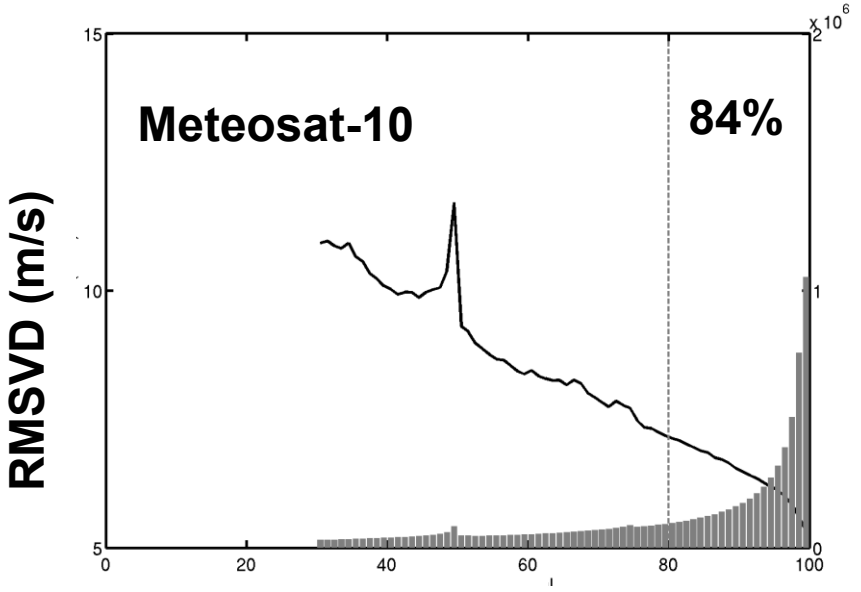
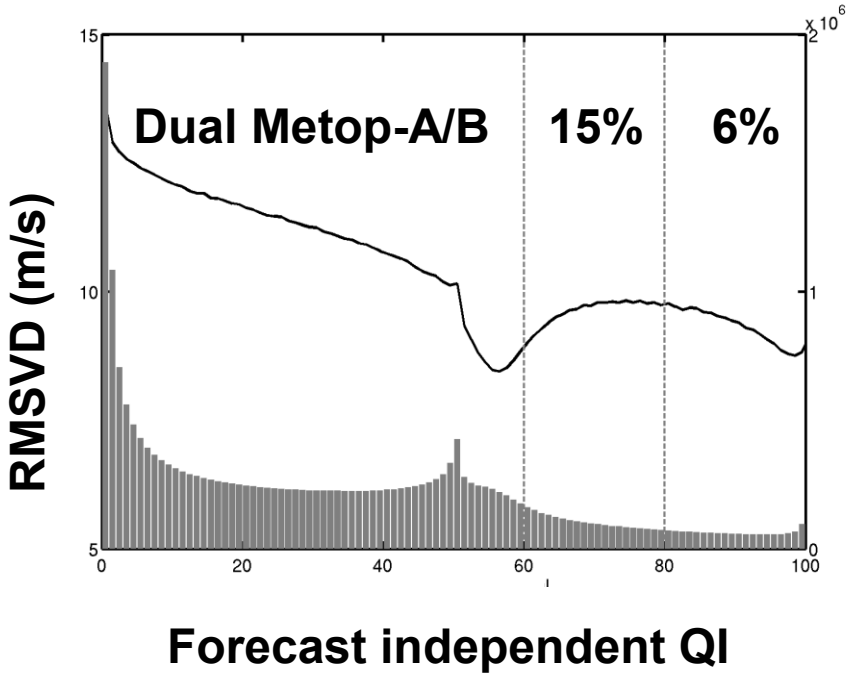
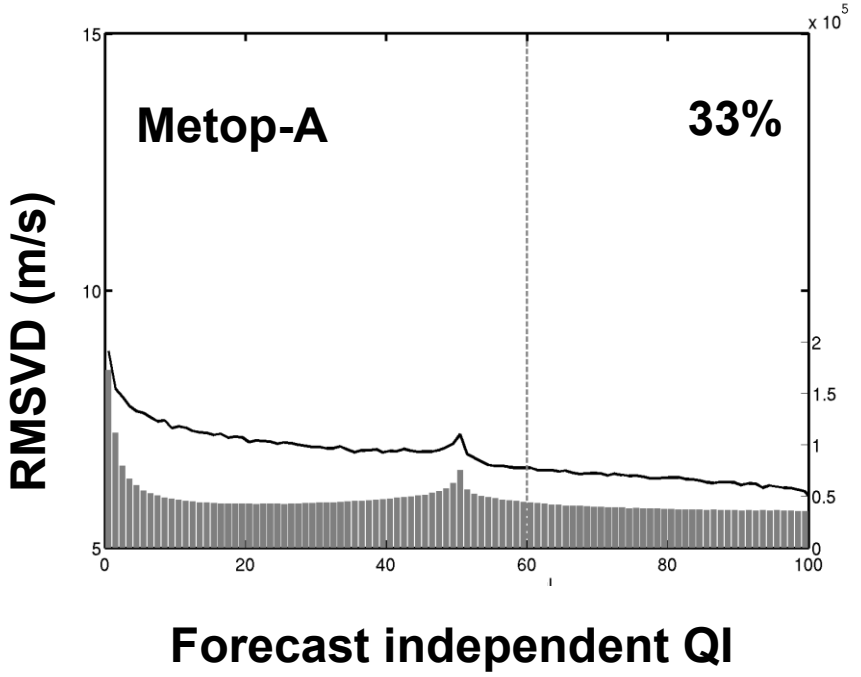
QI

- **NWP SAF QI thresholds for monitoring:**
  - **80 GEO AMVs**
  - **60 polar AMVs**



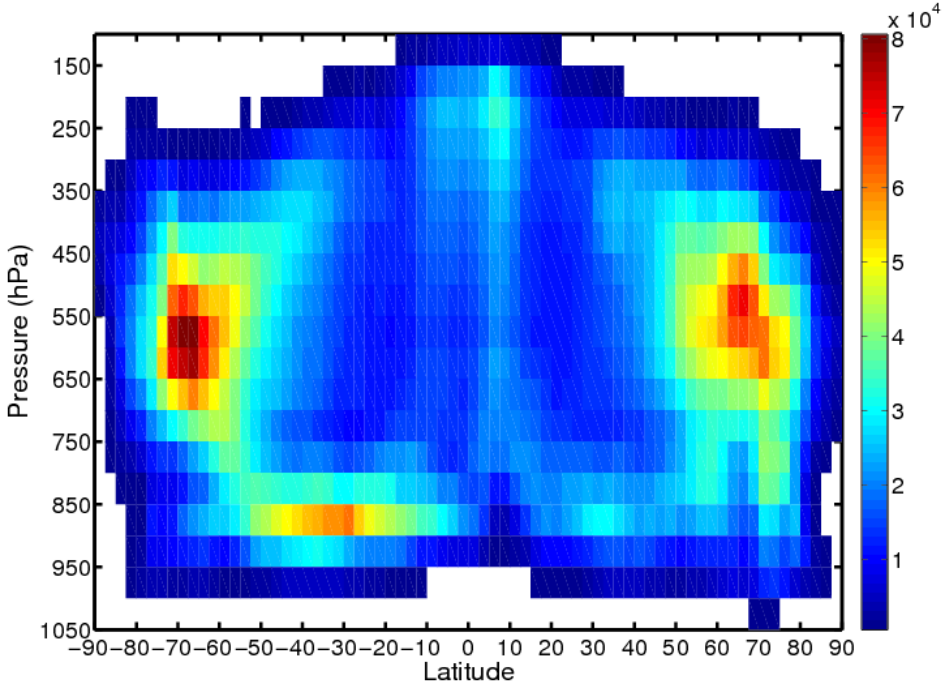


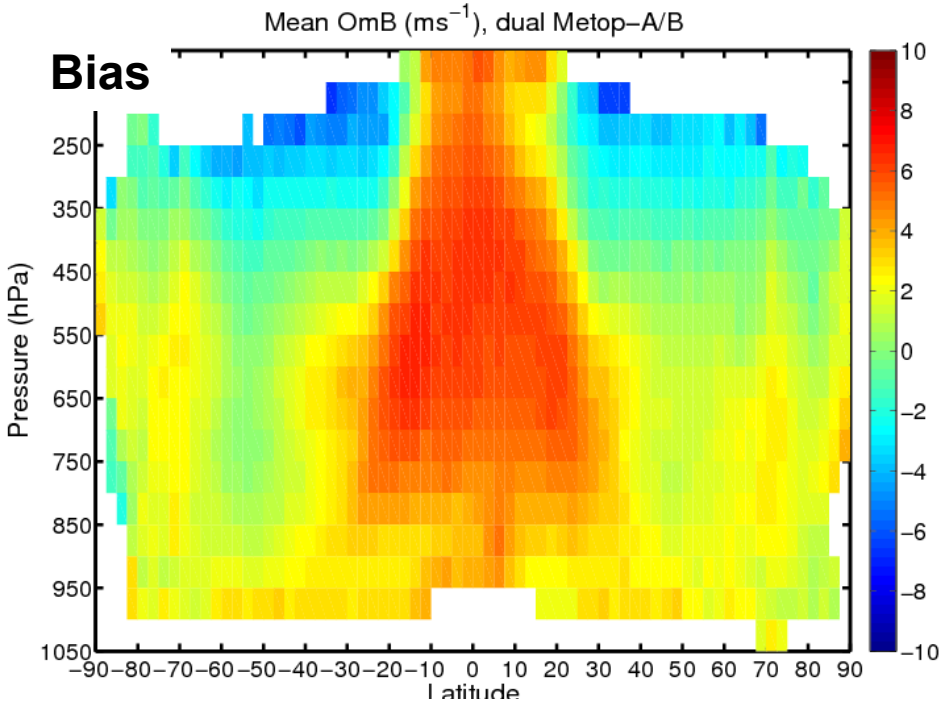


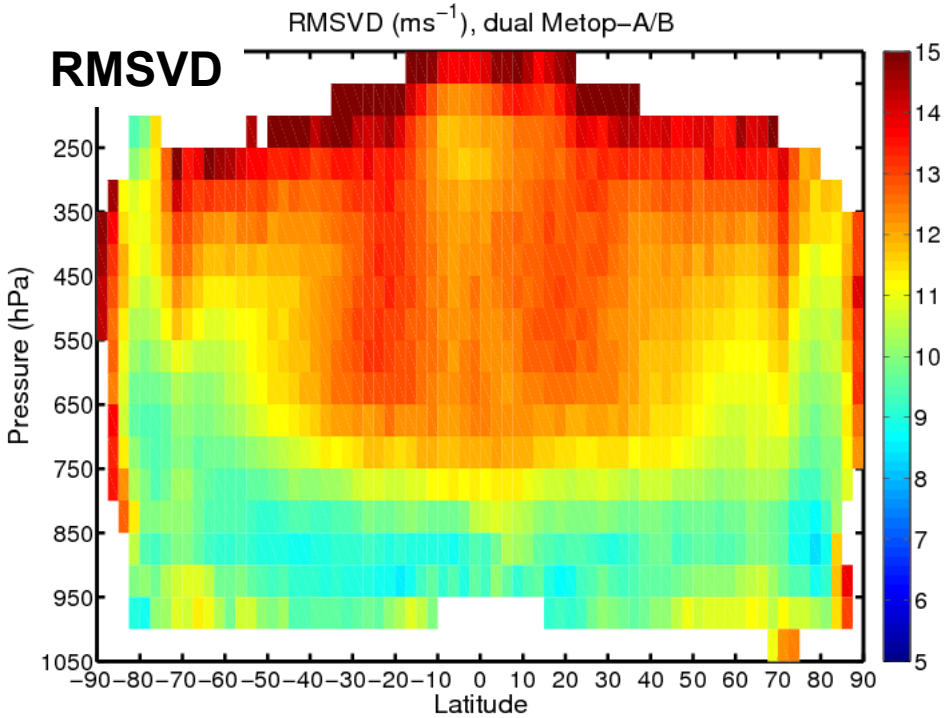
Dual Metop-A/B

- Large positive speed bias in the tropics, observed wind stronger than model wind.
- RMSVD increasing towards higher altitudes.

Number of observations

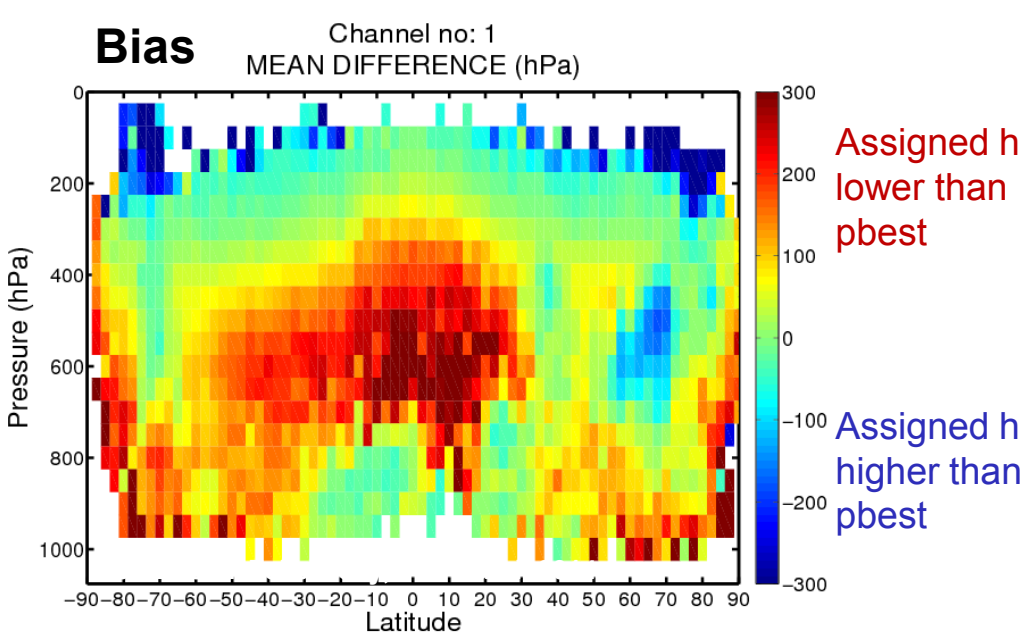


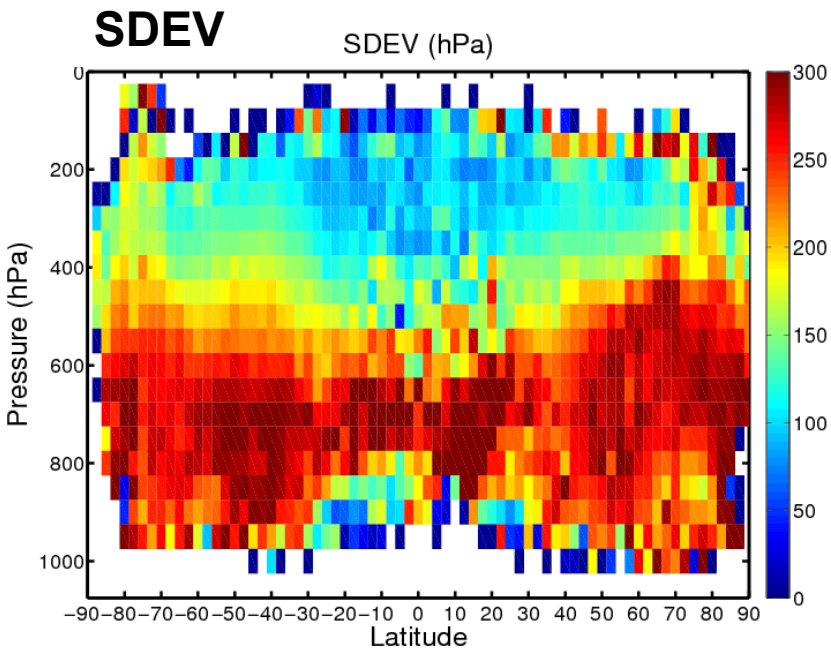




Best-fit pressure

- In the tropics and over SH significant positive bias indicating assigned observation height is lower in the atmosphere than the best-fit pressure height.
- Large height assignment errors below 400 hPa.

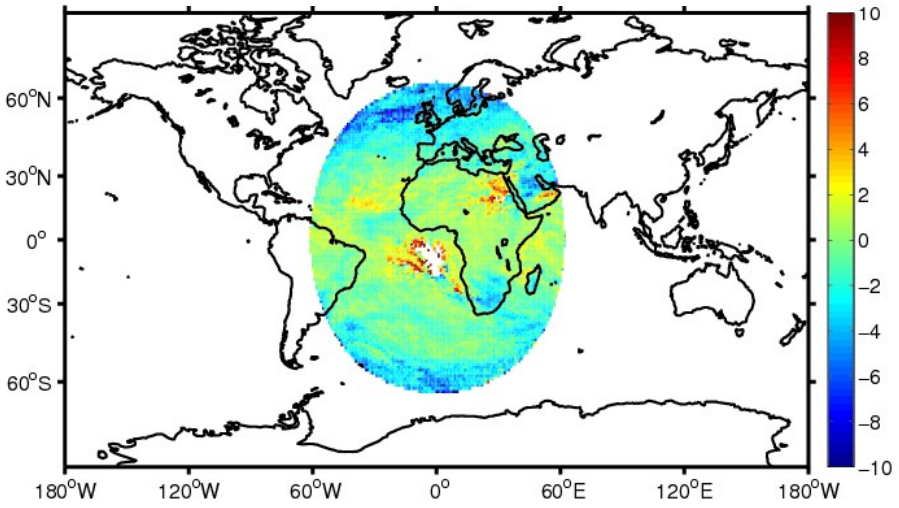




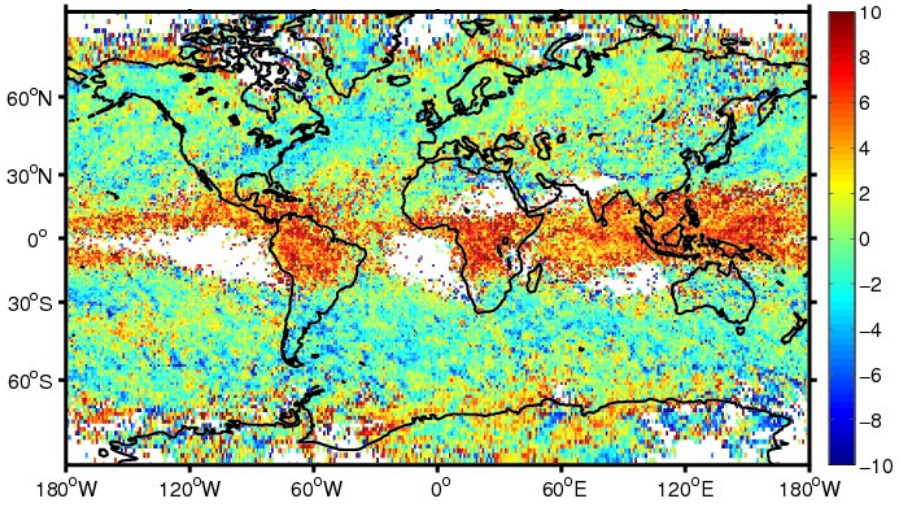
For comparison

- Speed bias 100 – 400 hPa

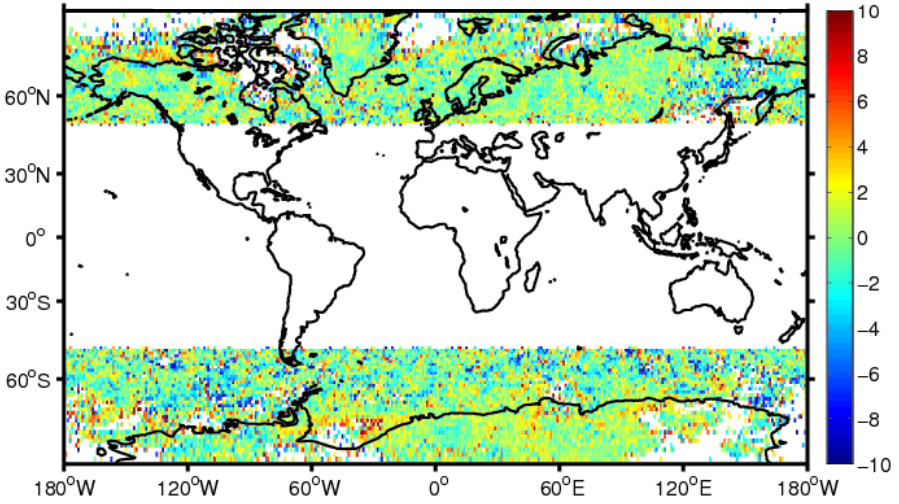
Meteosat-10, QI > 80



Dual Metop-A/B, QI > 60



Metop-A, QI > 60



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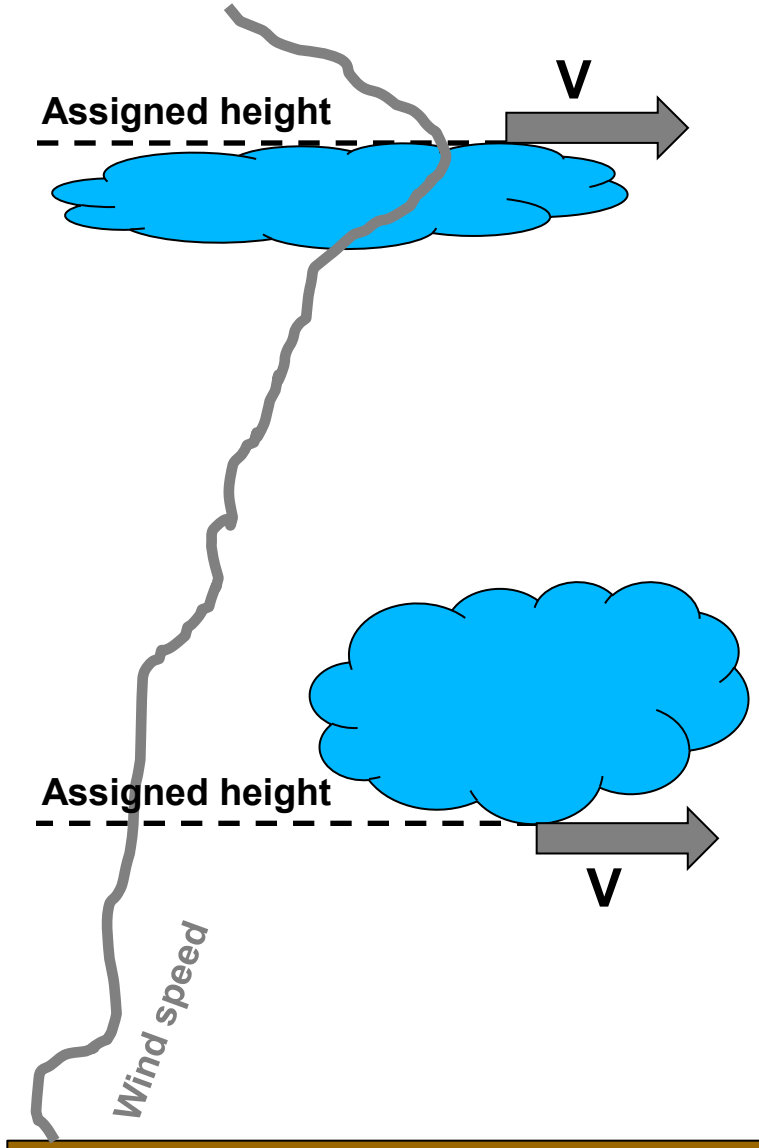
Conclusions so far

- Global coverage AMVs.
- Testing in a very early phase:
  - Less high QI observations than for Meteosat-10 or single Metop.
  - Smallest speed bias at high level mid latitudes, lowest RMSVD at low levels.
  - Large speed bias in tropics, observed wind stronger than model wind.
  - RMSVD increased for higher altitudes.
  - Timeseries indicate that the statistics are stable.

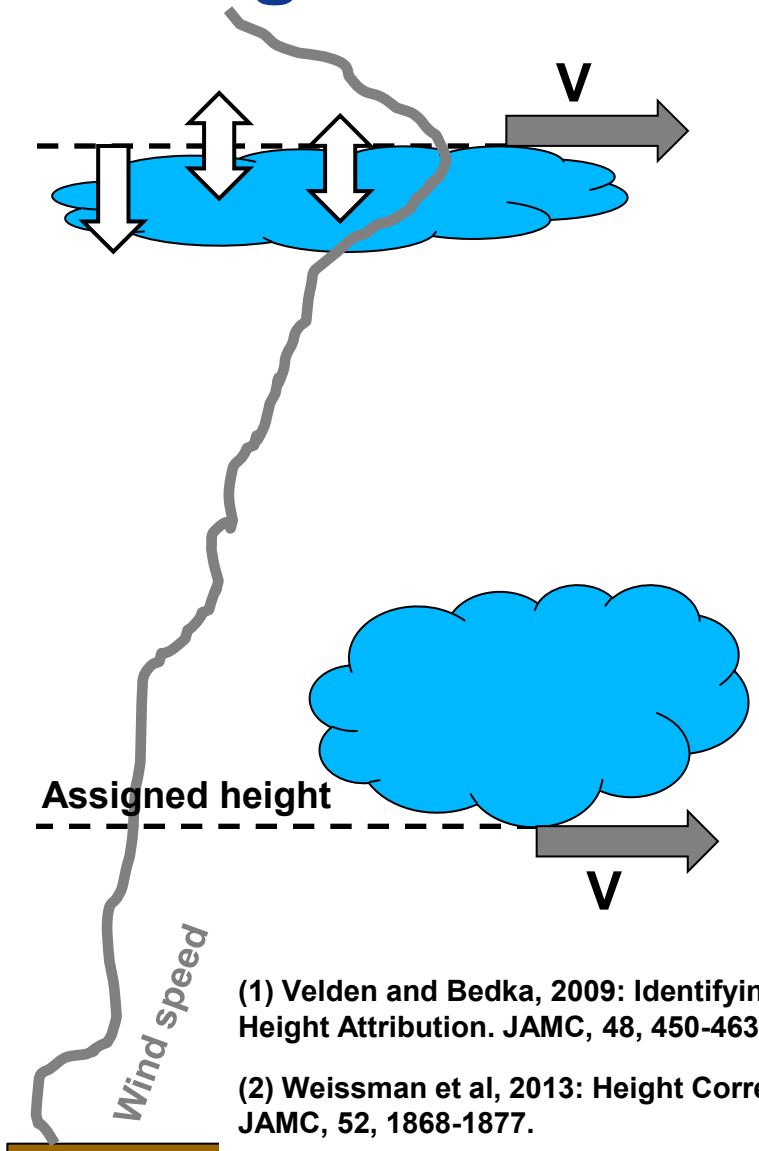
Alternative interpretations of AMVs

Traditional interpretation



- Assumption: tracked features act as passive tracers of atmospheric flow.
- Single-level wind observations assigned to representative height
  - Cloud top for high and mid-level clouds
  - Cloud base for low level clouds

Single level or layer average?



- Interpreted as single-layer observations even though
  - Clouds have vertical extent
  - Radiances represent contribution of deep vertical layer when tracking clear-sky features
- Comparison to radiosonde[(e.g. 1)] and lidar[(e.g. 2)] observations and results from simulation framework[(e.g. 3)] suggests benefits from layer averaging.

(1) Velden and Bedka, 2009: Identifying the Uncertainty in Determining Satellite-Derived Atmospheric Motion Vector Height Attribution. JAMC, 48, 450-463.

(2) Weissman et al, 2013: Height Correction of Atmospheric Motion Vectors Using Airborne Lidar Observations. JAMC, 52, 1868-1877.

(3) Hernandez-Carrascal and Bormann, 2013: Atmospheric Motion Vectors from Model Simulations. Part II: Interpretation as Spatial and Vertical Averages of Wind and Role of clouds. Accepted to JAMC.

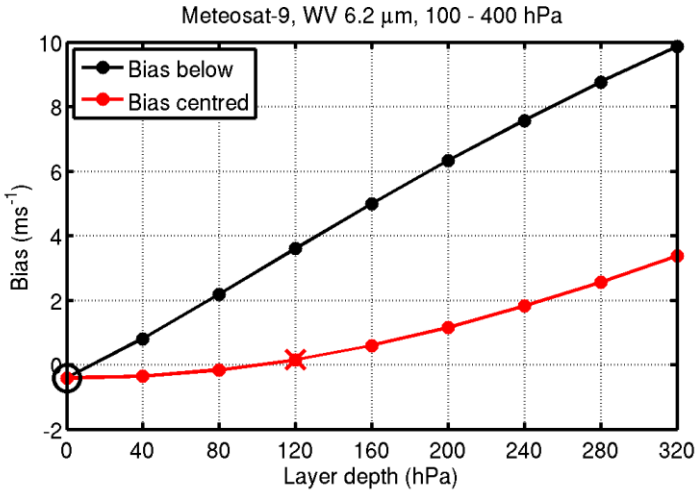
Experimentation with layer averaging

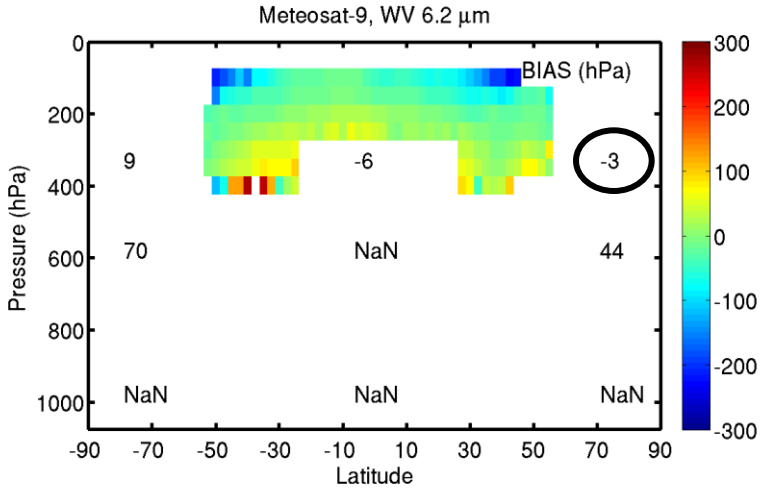
- Set of monitoring experiments
  - Varying layer depths: 0 … 320 hPa
  - 1.1-29.2.2012, CY38R1, T511, 91 levels
- Centred averaging
  - AMV assigned to representative height
- Averaging below
  - AMV assigned to cloud top

Example: MET-9 WV 6.2 µm, 100 – 400 hPa

Best-fit pressure statistics indicate small bias

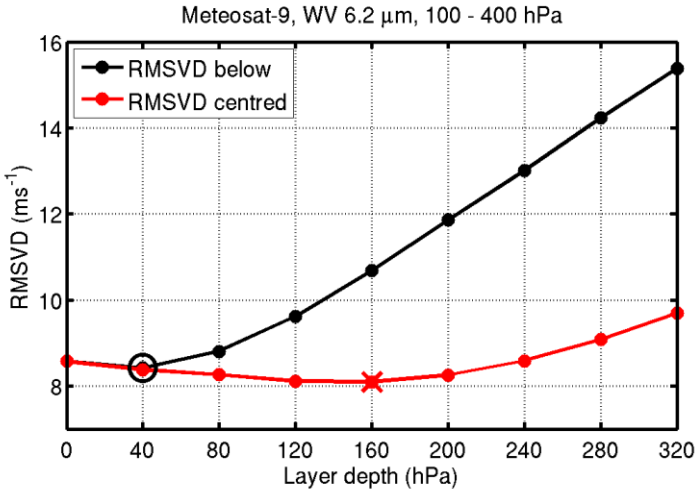
- **Averaging below: 2% improvement in RMSVD**
- **Centred averaging: 6% improvement in RMSVD**





Assigned h lower than pbest

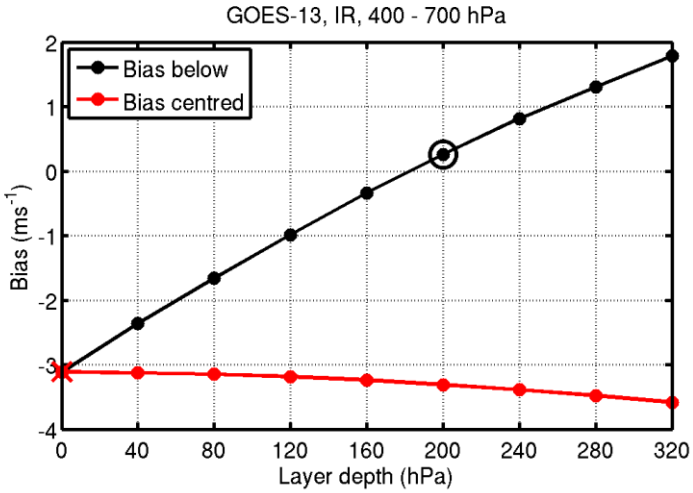
Assigned h higher than pbest

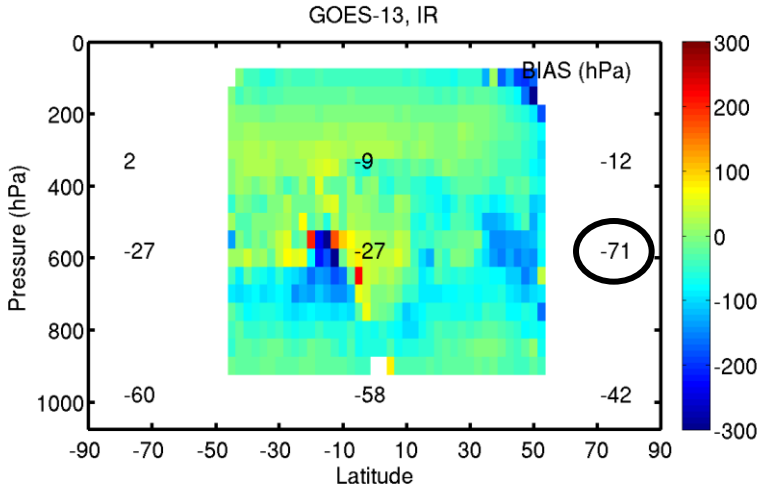


Example: GOES-13 IR, 400 – 700 hPa

Best-fit pressure statistics indicate large negative bias

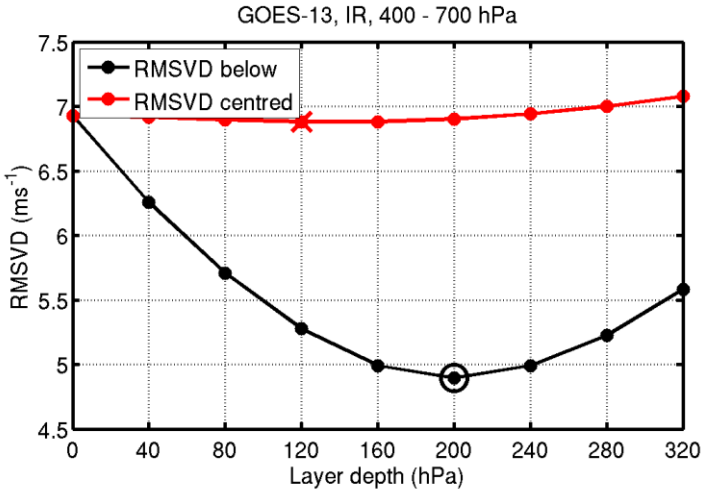
- **Averaging below: 29% improvement in RMSVD**
- **Centred averaging: 1% improvement in RMSVD**





Assigned h lower than pbest

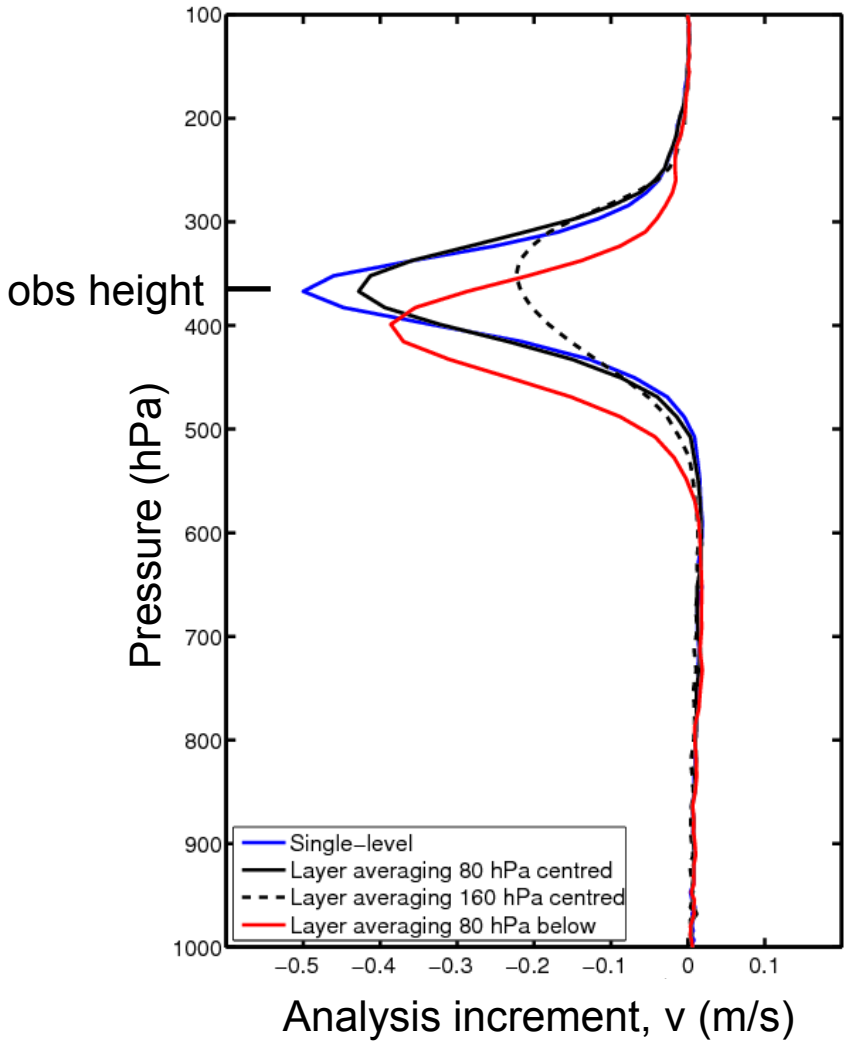
Assigned h higher than pbest



Notes on layer averaging

- Up to 30% reductions in RMSVD, typically 5-10%.
- Centred averaging generally better when best-fit pressure statistics indicate small biases.
  - Minimum RMSVD typically reached with 120-160 hPa layer averaging.
- Averaging below shows significant improvements especially when best-fit pressure statistics indicate that the assigned AMV height is too high
  - Minimum RMSVD typically reached with 40-80 hPa layer averaging.
  - Would similar improvements be obtained with re-assignment of the AMV height?

How information is spread in vertical?



- **Single observation experiment**
  - **First guess departure the same in all four cases**

1. Single-level observation operator (blue)

Boxcar layer averaging:

2. 80 hPa layer centred at the observation height (black solid)

3. 160 hpa layer centred (black dashed)

4. 80 hPa layer below the observation height (red)

ECMWF

Ongoing work

- Test layer averaging or/and AMV height re-assignment in data assimilation experiments.
- Challenge to design general observation operator that would overperform the single level observation operator
  - AMVs from different satellites, channels, applying different height assignment methods have their own characteristics
  - Geographical and seasonal variations in height assignment biases