AMVs in the ECMWF system:
Overview of the recent operational and research activities

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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
AMV sample coverage: active

GOES-15
NOAA-15
AQUA

GOES-13
NOAA-16

MET-10
NOAA-18

MET-7
NOAA-19

MTSAT-2
## Recent operational changes

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

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

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

Situation dependent observation errors

Tracking error (m/s)

\[ E_{vp} = \sqrt{\sum W_i (v_i - v_n)^2} \]

\[ W_i = \exp\left(-\frac{(p_i - p_n)^2}{2E_p^2}\right) \cdot dP_i \]

- \( p_i \) and \( v_i \) on model level
- \( p_n \) and \( v_n \) at observation location
- \( E_p \), error in height assignment
- \( dP_i \), layer thickness

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Situation dependent observation errors

Tracking error (m/s) + \sqrt{E_p H error (hPa)}

\[ E_{vp} = \sqrt{\sum W_i (v_i - v_n)^2} \]

\[ W_i = \exp\left(-\frac{(p_i - p_n)^2}{2E_p^2}\right) * dP_i \]
Situation dependent observation errors

Total observation error (m/s)

Example: cloudy WV, high levels

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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.
Relative change in the NO of used AMVs
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.
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.
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

Cy38r1, T511, 91 levels, 12-hour 4D-Var
Normalised difference in VW RMS error

**MODIS**

**MODIS+**

**AVHRR**

**AVHRR**
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

  - 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.
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
Dual Metop-A/B AMVs

- Global coverage.
QI

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

Dual Metop-A/B 15% 6%

Meteosat-10 84%

Metop-A 33%
Dual Metop-A/B

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

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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.

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


(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
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

![Graph showing bias and RMSVD for GOES-13 IR, 400 – 700 hPa]

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)
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