AMVs – how to make better use of them in NWP?

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AMVs, what are they?

Wind observations produced by tracking clouds or water vapour features in consecutive satellite images.
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
What if height assignment goes wrong?

- 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

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

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

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

\[ E_{vp} = \sqrt{\sum W_i (v_i - v_n)^2} \]
\[ W_i = \exp\left(-\frac{(p_i - p_n)^2}{2E_p^2}\right) * dP_i \]

Tracking error (m/s) + \sqrt{E_p, Height error (hPa)}
Situation dependent observation errors

Total observation error (m/s)

Example: cloudy WV, high levels
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.
Single level or layer average?

- Typically 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\(^{\text{e.g. 1}}\) and lidar\(^{\text{e.g. 2}}\) observations and results from simulation framework\(^{\text{e.g. 3}}\) 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

- AMV assigned to representative height
  - Centred averaging
- AMV assigned to cloud top
  - Averaging below
How information is spread in vertical?

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

1. Single-level observation operator (black)

Boxcar layer averaging:

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

3. 80 hPa layer below the observation height (blue)
What next?

• More detailed investigations with the layer averaging
  ▪ Optimal layer depth
  ▪ Layer position
  ▪ Situation dependence

• Interpretation as a single-level wind but within the cloud.

• Could model best-fit pressure statistics provide some useful information.
Summary

- AMVs are an established part of the global observing system.
- To get full benefit from AMVs to NWP, the characteristics of the observation type need to be carefully accounted for.
- Use of situation dependent observation errors leads to clear improvements in model analyses and forecasts.
- Investigations with the observation operator are on-going.