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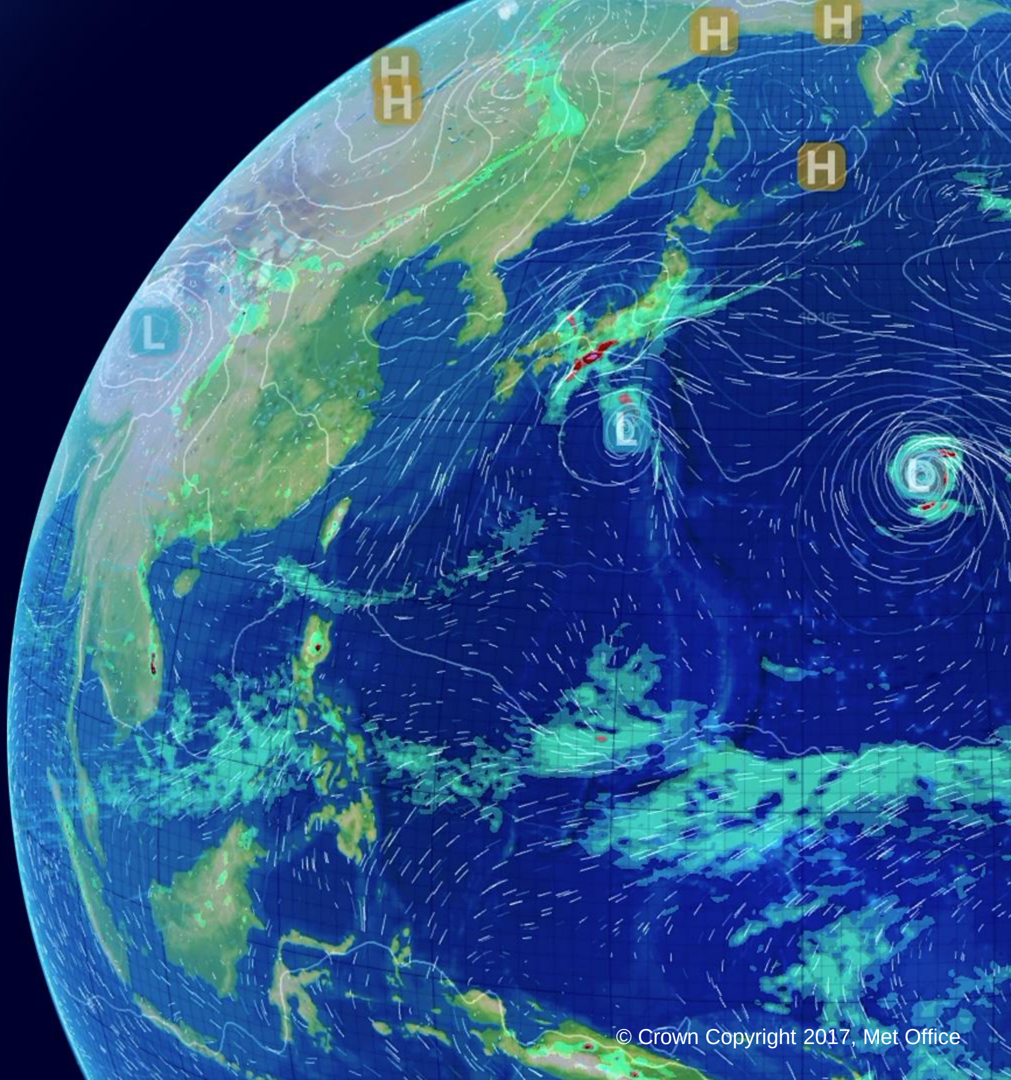
Treating uncertainties in the assimilation of AMVs

Mary Forsythe, **James Cotton**, Graeme Kelly

ECMWF/EUMETSAT NWP SAF workshop on the treatment of random and systematic errors in satellite data assimilation for NWP, 2-5 Nov 2020



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Talk outline

1. AMV challenges
2. Investigating the AMV errors
3. Using this information in NWP
4. Next steps

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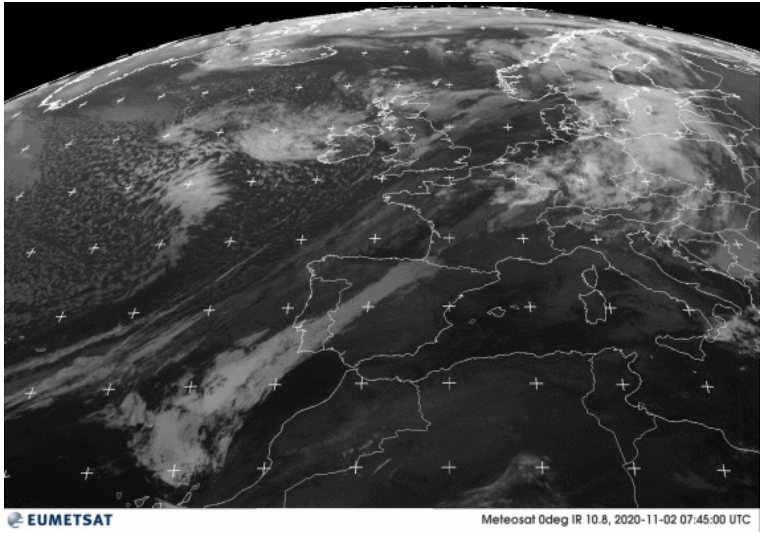
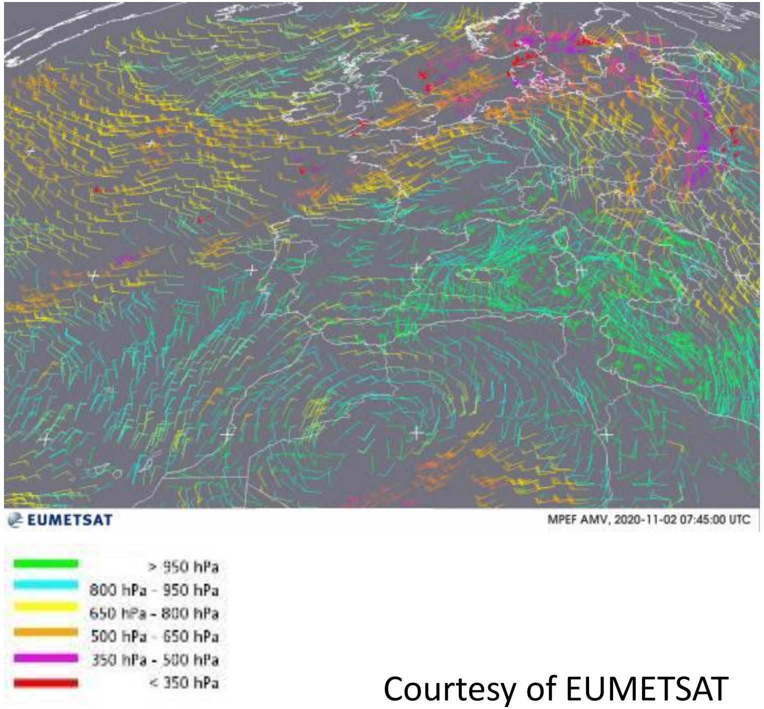
AMV challenges

Atmospheric Motion Vectors

a very brief intro….

In sequence of images – movement of clouds and moisture





Courtesy of EUMETSAT

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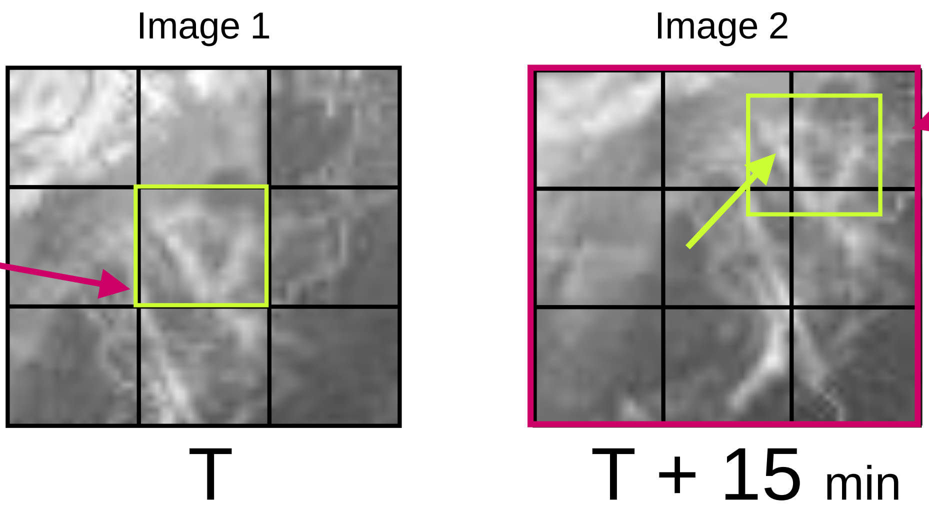
How are AMVs produced?

1. Initial corrections (image navigation etc.)
2. **Tracking**



Target Box / Tracer

e.g. 24 x 24 pixels

pixel – 3 km

Search Area

80 x 80 pixels centred on target box

New location determined by best match of individual pixel counts of target with all possible locations of target in search area.

3. Assign a **height** to the derived vector – moving towards use of optimal estimation - not always easy!

Normally repeat from image 2→3 to give a second vector for quality control

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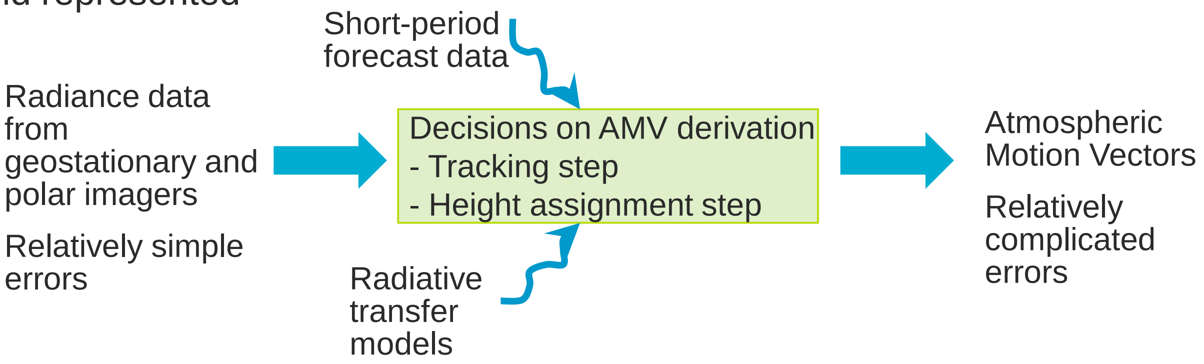
What are the challenges?

1. Complicated errors

To derive AMVs, we move a long way from the raw radiance data where the errors may be more easily understood and represented



2. Assumptions in derivation and assimilation

e.g. clouds act as passive tracers, assume point winds, spatially and temporally uncorrelated errors

3. Multiple data sources

Differences in the derivation software between producers

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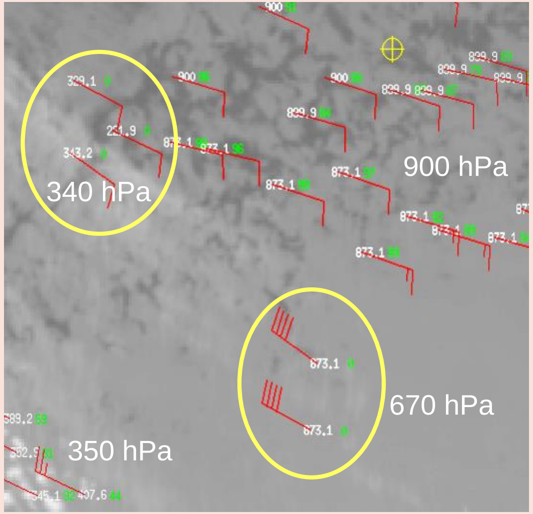
Height assignment

Height assignment thought to be biggest source of error

AMV height errors can be due to:

i)	Choice of pixels to use for height assignment	AMV specific problems
ii)	Appropriateness of using cloud top or cloud base estimates	
iii)	Limitations of cloud top/base pressure methods	Can learn from cloud community

Vector is derived by tracking a target that contains many pixels. In multi-level cloud situations can end up tracking one level of cloud and assigning height using the other!



Example courtesy of Jörgen Gustafsson, EUMETSAT

Cross Correlation Contribution (CCC) approach developed to help alleviate this issue.
See Borde et al, 2014, JAOT, 31,33-46

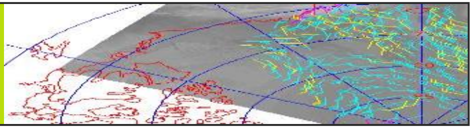
Investigating the errors

1. NWP SAF AMV Monitoring Analysis Reports

Rolling archive of monthly O-B plots versus Met Office and ECMWF backgrounds - attempt to separate error contributions:

Differences suggest dependency on model error

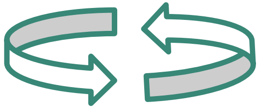
Similarities suggest problems with AMVs (or shared model errors)



Analysis Reports

- Published every 2 years
- Core is record of features identified in the monitoring
- Attempt to diagnose the cause of observed differences
- Use to improve AMV derivation and treatment in NWP models

Understand



Improve

To investigate use:

- Plots of O-B statistics
- Comparisons to model best-fit pressure
- Comparisons with other cloud top pressure products (e.g. MODIS, Calipso).
- Analysis of AMVs together with imagery

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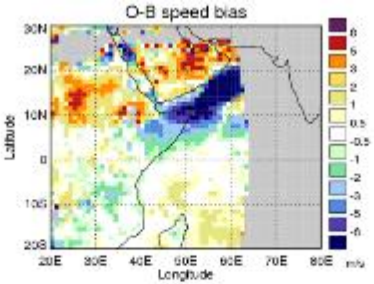
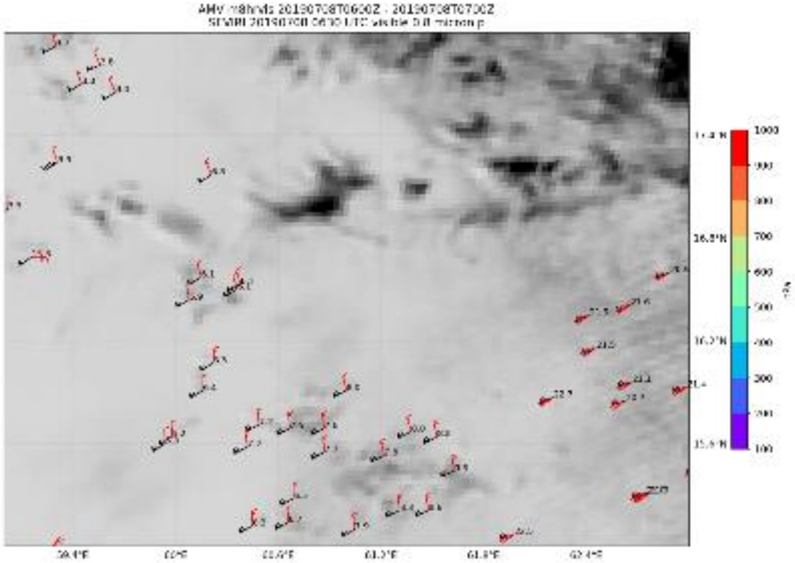
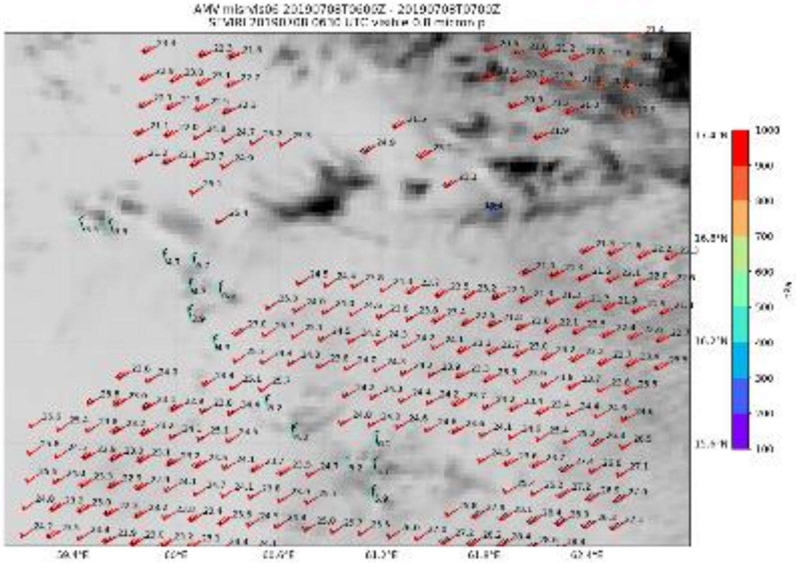
Example: Meteosat-8/11 negative bias during the Somali Jet



Meteosat-8

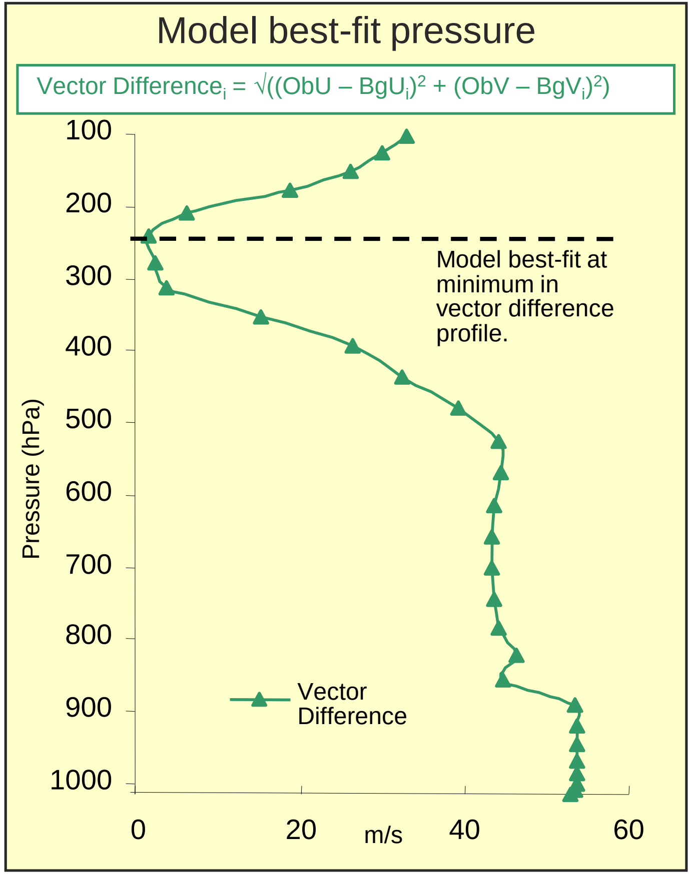


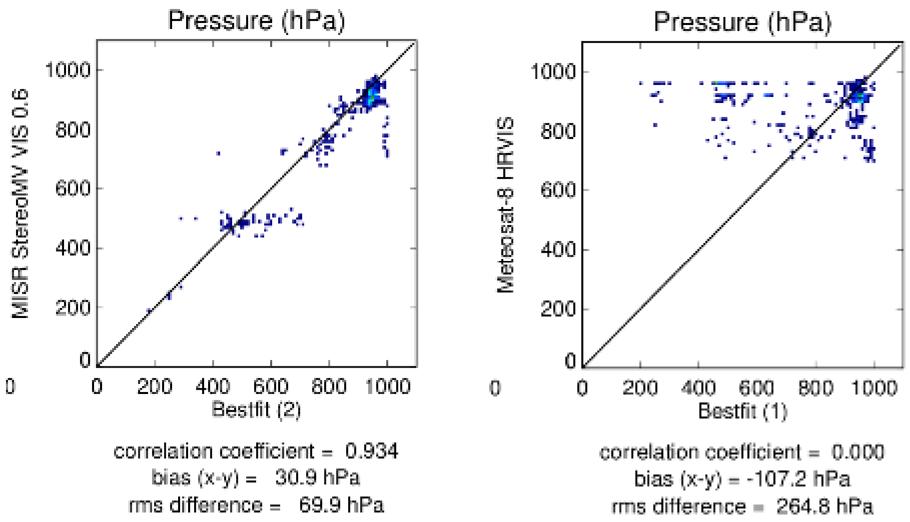
MISR



In this case, the geometric (stereo) height assignment utilised by MISR is performing much better than the radiometric height assignment used by Meteosat-8.

2. Best-fit pressure





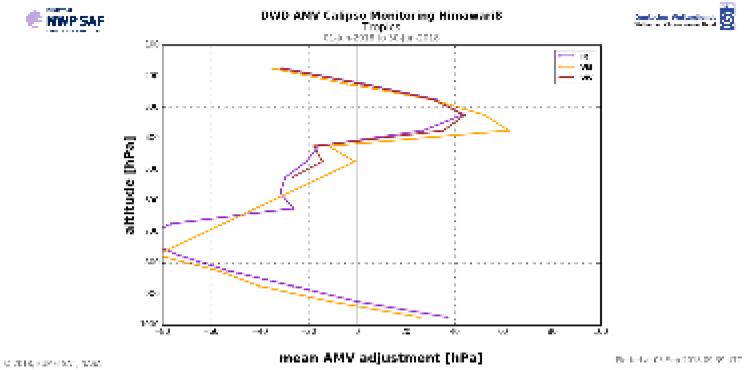
In this case the MISR heights correlate well with model best-fit pressure, whilst Meteosat-8 heights are often too low

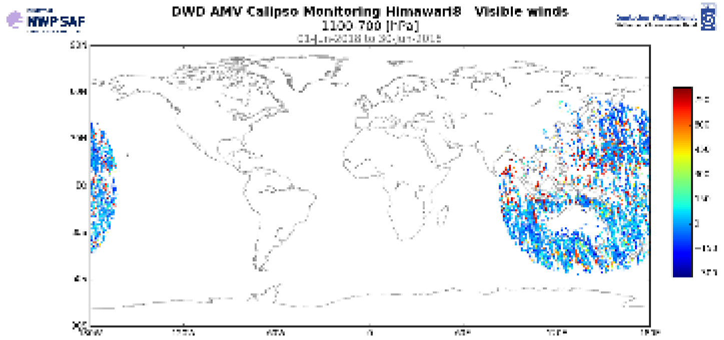
Best-fit pressure can also be found using wind profile observations such as sondes e.g. Velden & Bedka, 2009, JAM, 48, 450-463.

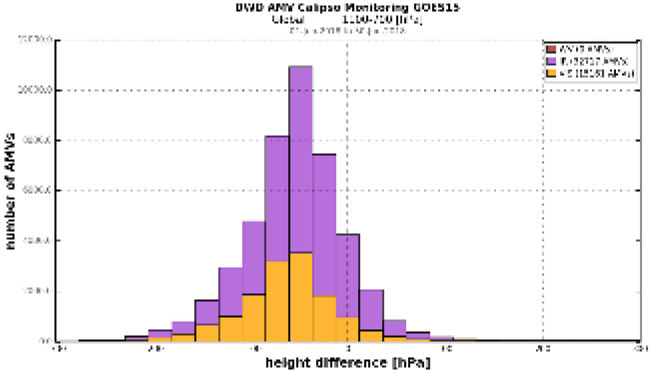
3. Lidar cloud top height

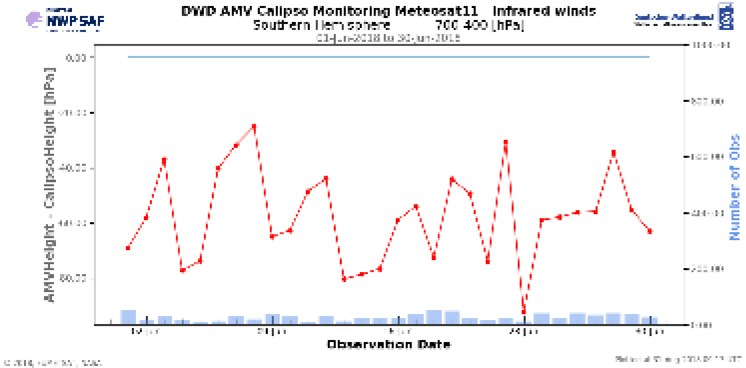
Independent information to assess AMV height assignment includes:

- Lidar cloud top pressure (routine monitoring will be added to NWP SAF soon)
- Stereo AMV height assignment (uses geometric approach for height assignment)









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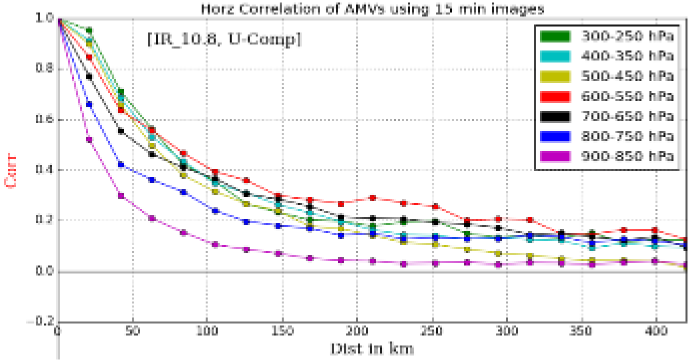
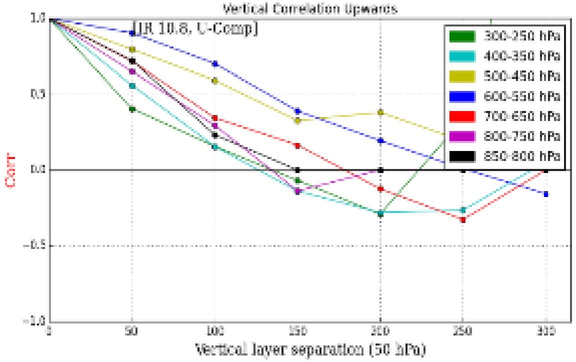
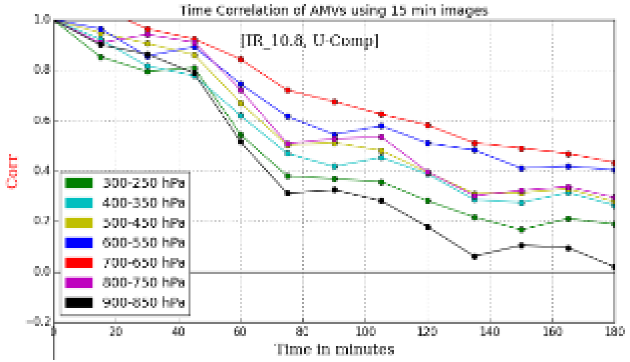
4. Correlated errors







- UK NWC SAF vs UKV model – Desroziers method, 20 km bin
- Horizontal correlations ~140-210 km – low level smallest correlations, mid level highest correlations
- Vertical correlations for IR ~150 km
- Temporal correlations – some levels not dropped below 0.2 after 3 hrs.

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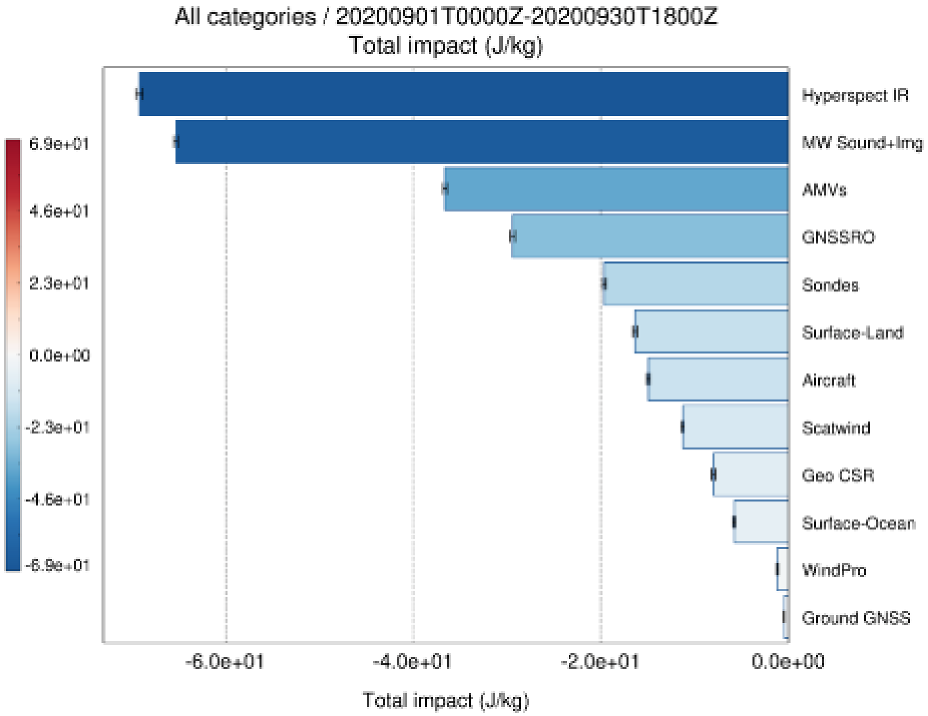
Using this information in NWP



Overview

AMVs are treated as wind observations at a single pressure level.

Options to handle errors include:

- *A-priori* blacklisting of known problem areas with large systematic errors (Cotton and Forsythe, 2012) and removing data with low quality indicators (QI)
- Down-weighting observations through specification of situation-dependent observation errors (Forsythe and Saunders, 2008; Salonen and Bormann, 2013)

Observation errors

A good specification of the observation error is essential to assimilate in a near-optimal way

Two independent sources

Error in vector

- Linked to accuracy of tracking step

Error in height

- Linked to accuracy of height assignment
- More problematic if large vertical wind shear

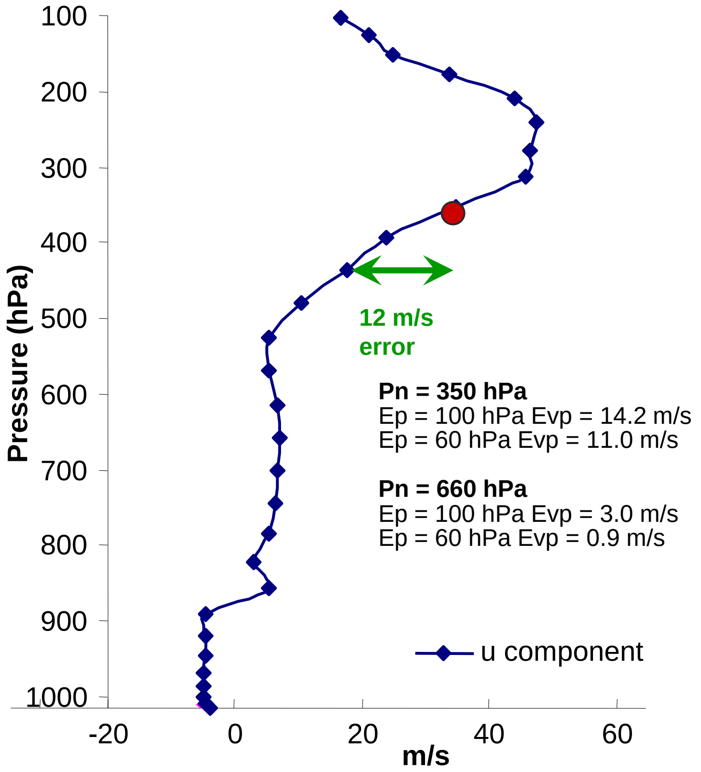
Total u/v error = √ (u/v Error^2 + Error in u/v due to error in height^2)

For this we need an estimate of:

1. u and v error (Eu and Ev)
2. height error (Ep)

Ideally from data producers

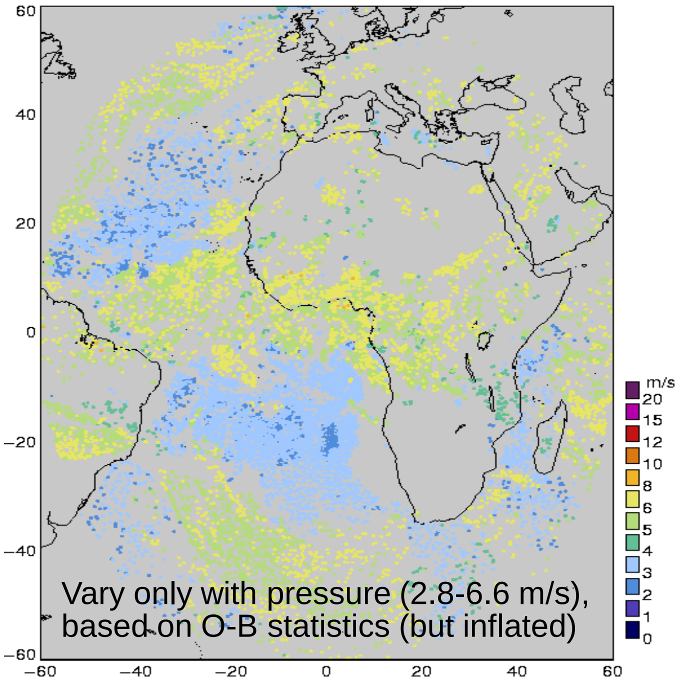
Until then estimate Ep using best-fit pressure stats as a guide.



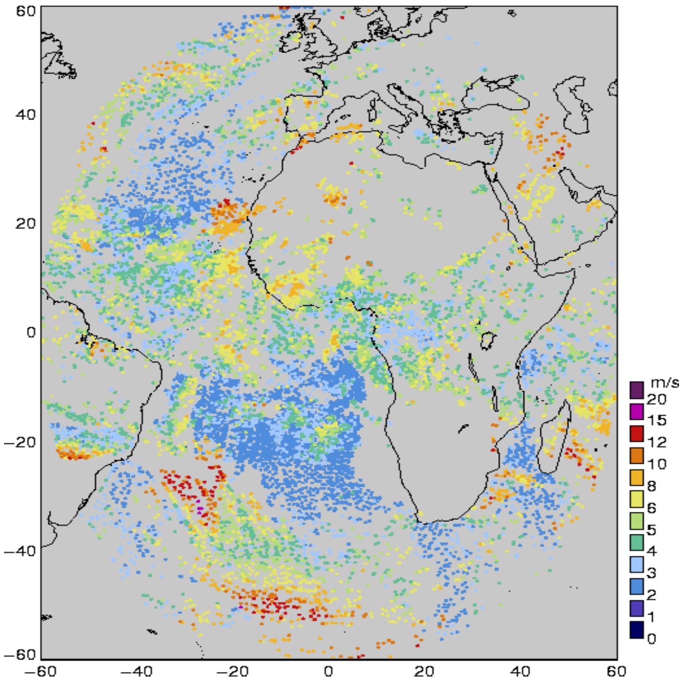
See Forsythe & Saunders, IWW9, 2008; Salonen et al, 2014, JAMC

Observation errors

Errors vary only with pressure



Situation dependent errors



Benefit seen in assimilation experiments at the Met Office (and subsequently ECMWF and Environment Canada)

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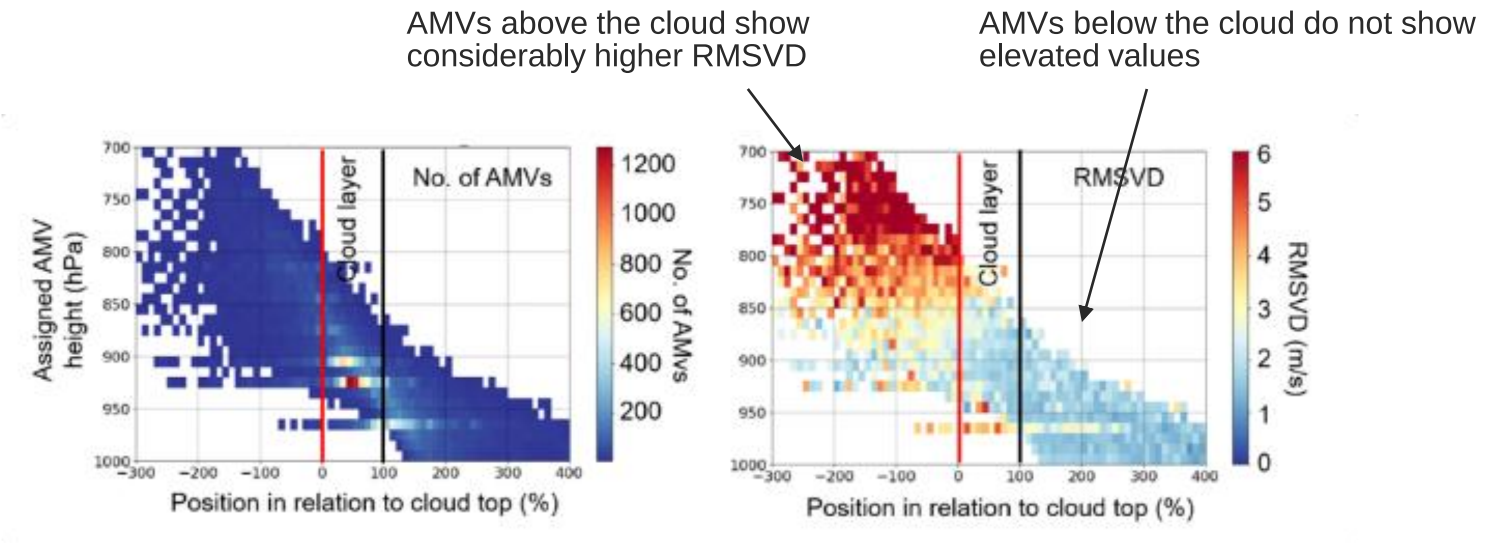
- Down-weighting observations through specification of situation-dependent observation errors (Forsythe and Saunders, 2008; Salonen and Bormann, 2013)
- Bias correcting mean height errors - in regional (Lean, P. et al., 2015) and global models (Salonen and Bormann, 2016)
- Bias correcting low level AMVs - inversion height correction (Cotton et al., 2016) and model cloud (Lean, K., in prep)

AMV pressure bias correction



- Investigating use of model cloud information to correct heights of low level AMVs
- Find that AMVs placed above where the model estimates the cloud have generally poorer statistics (speed bias and RMSVD), likely due to increase in wind shear above boundary layer top
- Correcting to average cloud pressure shows promising impact in assimilation.

Katie, Lean (ECMWF)

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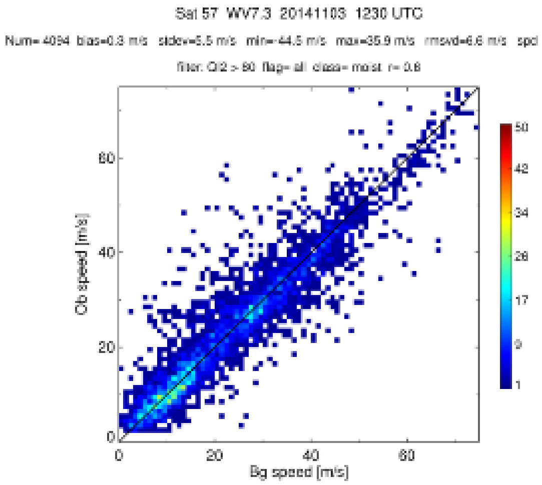
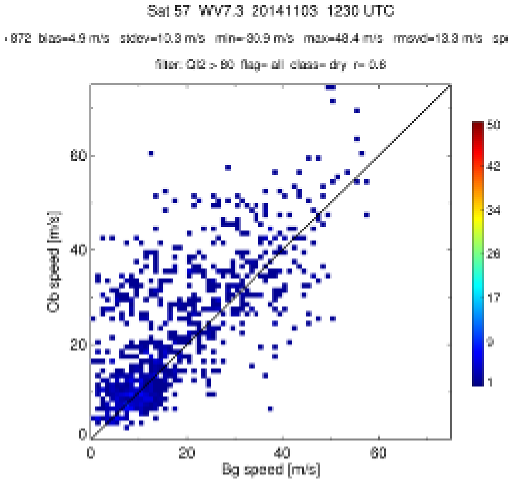
- QC using model humidity (Cotton et al., 2016)
- Adapting the observation operator to treat as layer average winds
- Data thinning/superobbing to reduce impact of correlated errors
- Background check to remove likely rogue winds that make it though all the above!

QC using model humidity



QC Accept

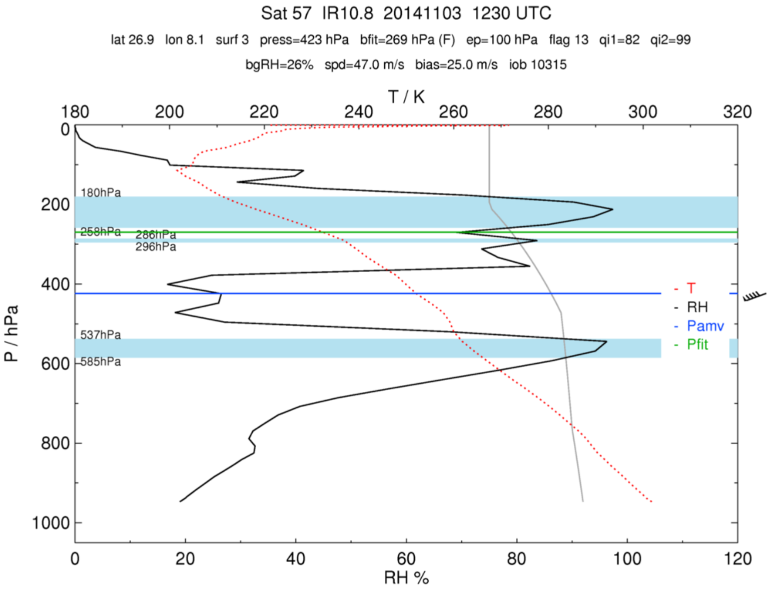
N	4094
Bias	0.3 m/s
Sdev	5.5 m/s
RMSVD	6.6 m/s



QC Reject

N	872
Bias	4.9 m/s
Sdev	10.3 m/s
RMSVD	13.3 m/s

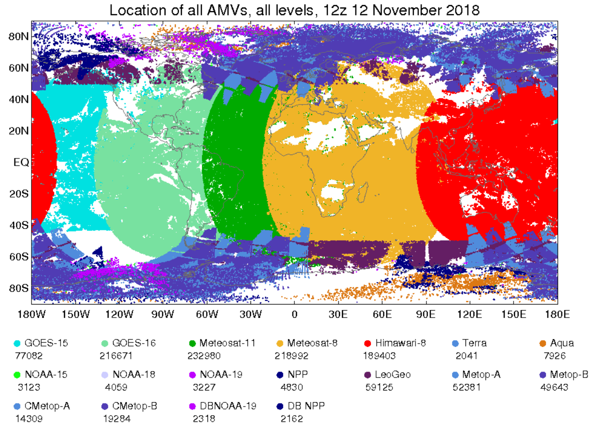
E.g. AMV assigned in dry slot between 2 moist layers. Large speed bias



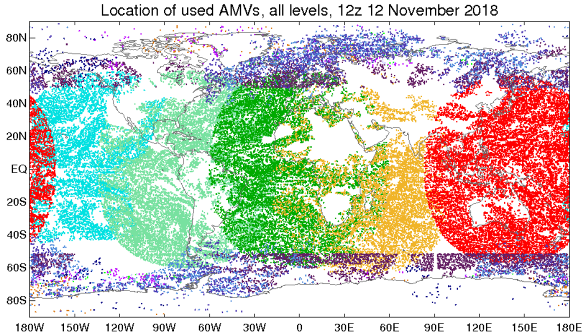
P=423 hPa, V=47 m/s, O-B=+25 m/s, BgRH=26%

James Cotton, Met Office

AMV assimilation at the Met Office

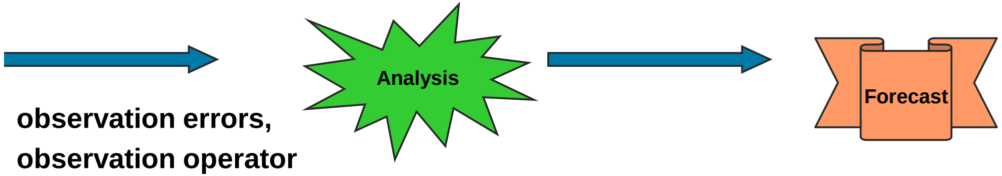


blacklisting, thinning and background check



- **Apply inversion correction**
- **Blacklisting**
  - QI thresholds (model independent QI)
  - Spatial checks
  - Remove some satellite-channel combinations e.g. CSWV
  - Reject in model dry layers
  - Reject winds slower than 4 m/s
- **Thinning**
  - One wind per 200 km x 200 km x 100 hPa x 2 hr box.
- **Background check**
  - Remove if deviates too far from background.
- **Observation errors**
- **Observation operator**

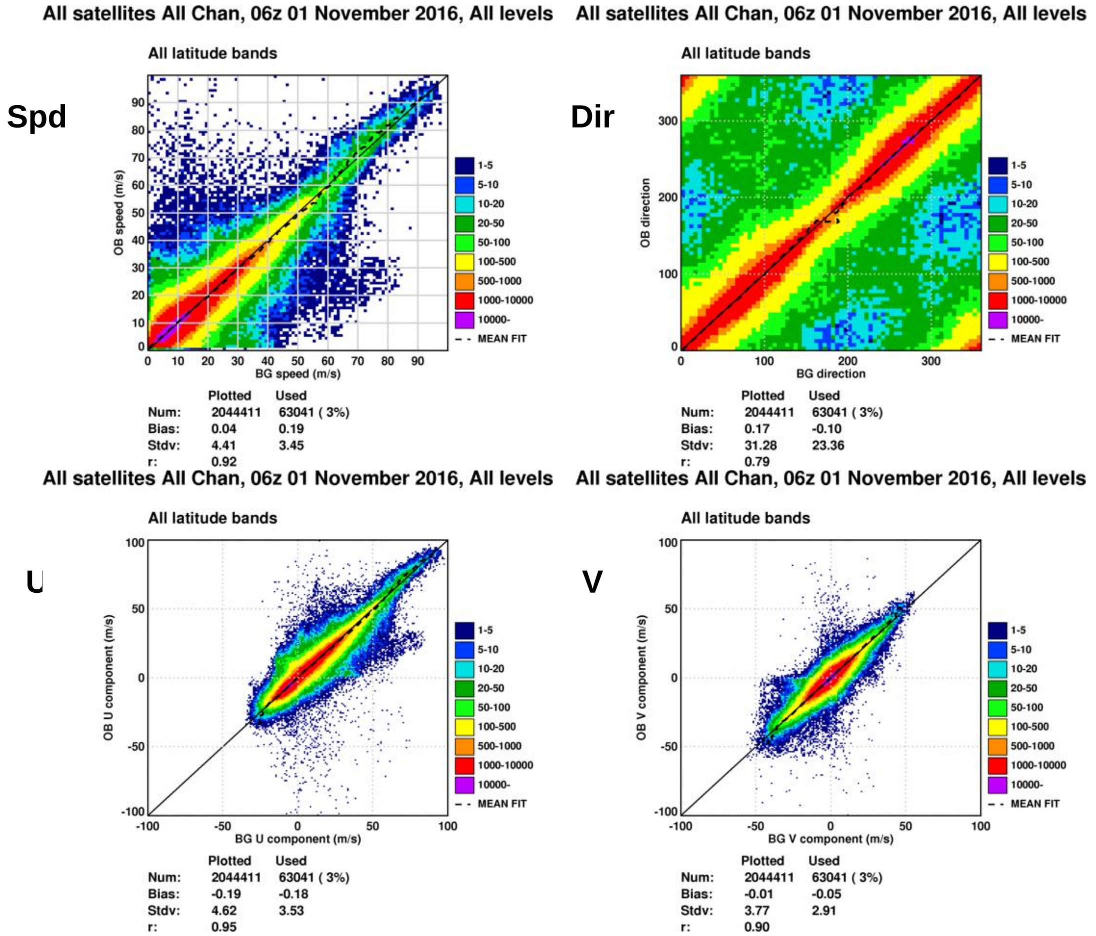
For more information see NWP AMV usage pages on NWP SAF website



AMV quality control

All data

2,044,411
Spd Stdv = 4.41 m/s



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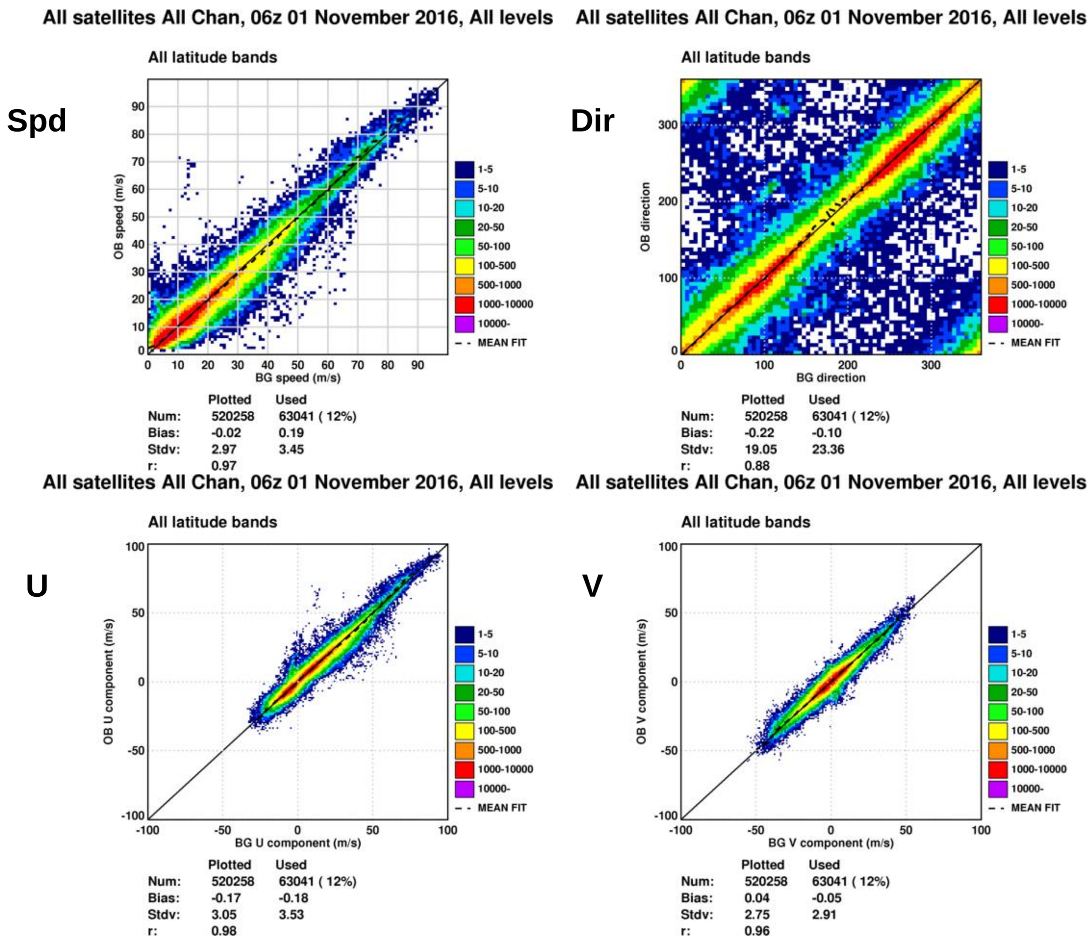
AMV quality control

After QC (blacklisting)

520,258 (25%)

Spd Stdv = 2.97 m/s



AMV quality control

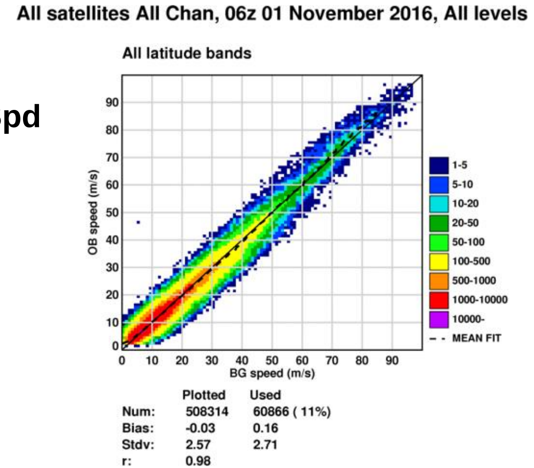
After QC (blacklisting)
+ Background check

508,314 (25%)
Spd Stdv = 2.57 m/s

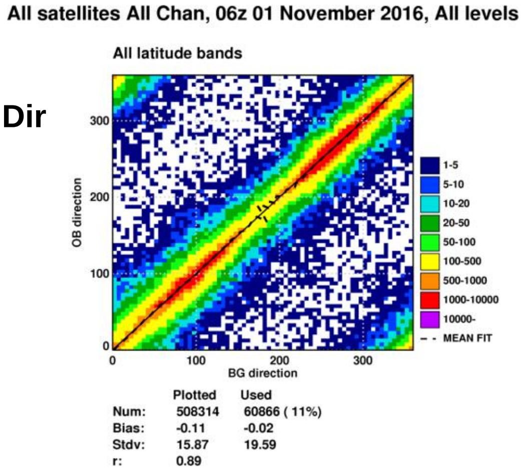
After thinning

55,289 (3%)

Spd



Dir



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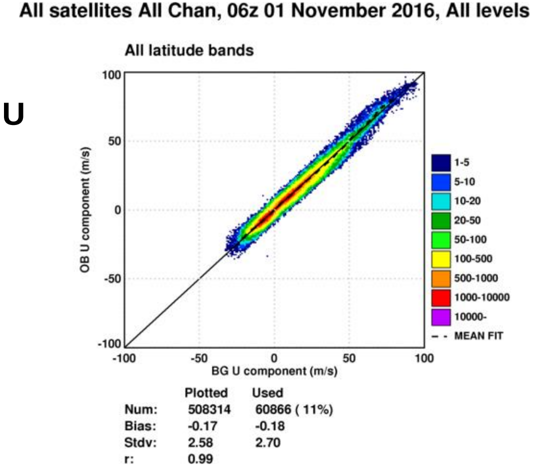
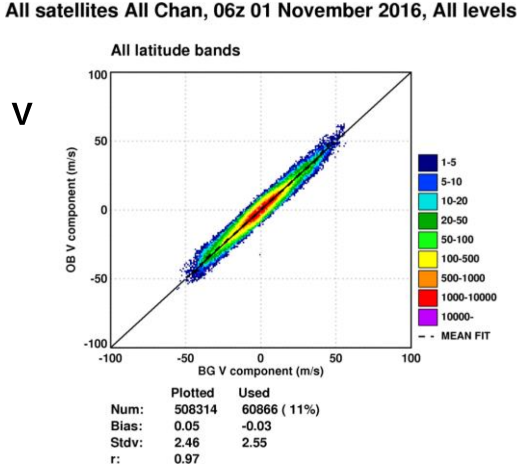


V



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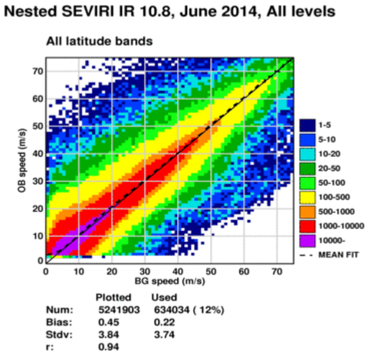
Where next?

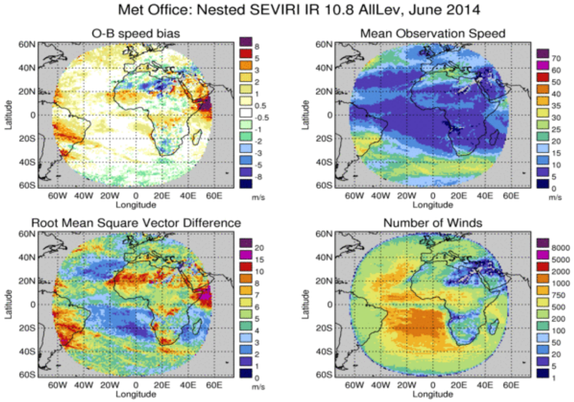
Where next?

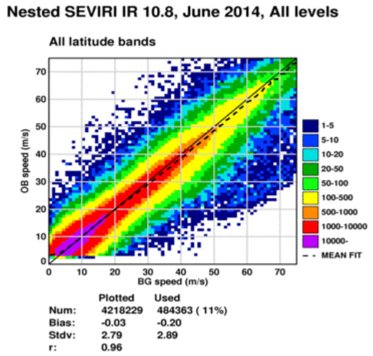
Use extra quality information from producers

We have a new AMV BUFR format – scope to provide more information from the derivation step e.g. cloud top height error, cloud optical depth etc.

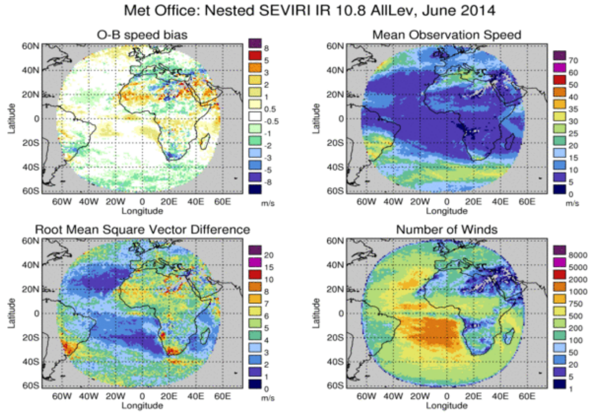
- Help understand AMV errors
- Potential to filter out poor data
- Could use to develop better vector and height errors for NWP observation error scheme
- Potential also for height reassignment or layer representation







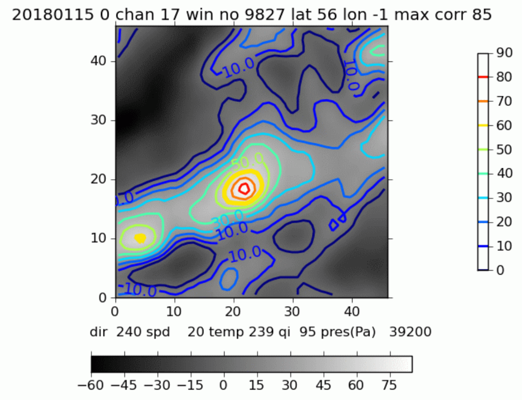
Remove AMVs with Ep > 100 hPa

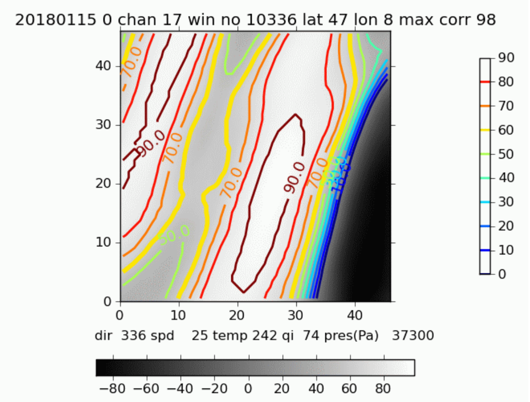


Francis Warrick, Met Office

Where next?

Can we extract useful information from the correlation surface?



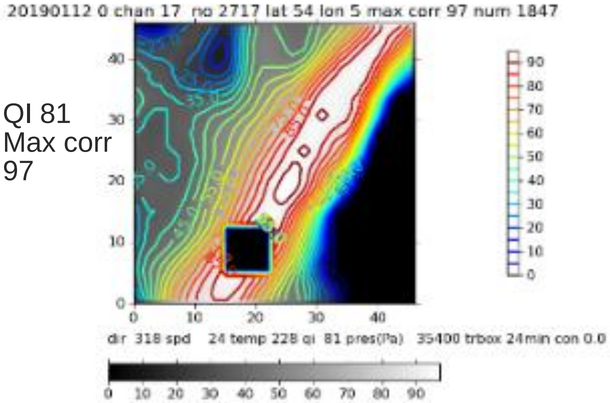


- For many global AMVs – height assignment remains the main source of error
- For polar AMVs and high resolution AMVs, the tracking step is problematic due to longer image intervals (polar) or smaller target sizes (high resolution).
- There are also cases where traditional AMVs struggle due to smoother cloud features – motion often better constrained in one dimension.
- There is information in the correlation surfaces that could be used to filter out poorly constrained cases or provide estimates of errors in the tracking step for use in NWP.

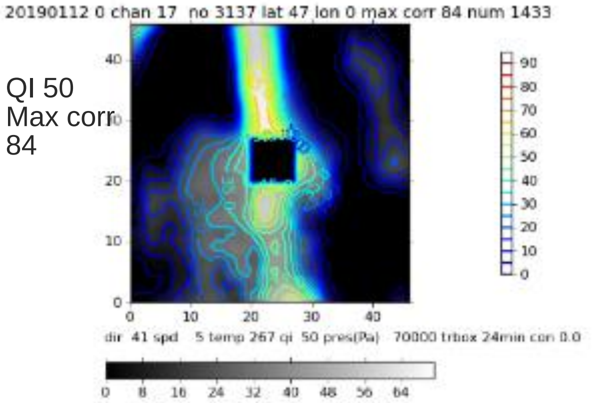
Correlation surface classification (CSC)

Method tests the hypothesis that AMVs derived from a correlation surface with a clearly defined maxima should give indicator of AMV quality.

QI 81
Max corr
97



QI 50
Max corr
84



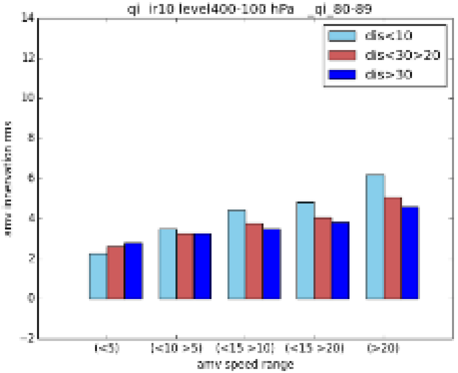
First find the position and strength of the largest maximum.

Remove an 8x8 pixel square centred on this first maximum.

Find the next maximum (the second).

Find the normalised difference in max correlation between the first and second maxima.

<u>Dec 2018 – Jan 2019</u>



AMVs with a clearly defined maximum (bigger values of dis) show better O-B agreement.

The results hold for different channels, QI bins and speed ranges.

Suggests might be a useful additional measure to help filter or set observation errors for use in NWP.

Graeme Kelly, Met Office

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Talk Summary

1. AMVs are an important source of wind information for the models.
2. A major limitation of AMVs is their complicated errors.
3. A wide range of investigations has been undertaken to better understand the issues including as part of the NWP SAF AMV analysis reports.
4. This in turn should enable greater benefit of AMVs in NWP through improvements to the AMV derivation and assimilation strategy.
5. New information from the derivation may enable improved filtering and setting of observation errors.
6. Information from the tracking correlation surface may also be important for removing AMVs where the tracking step is poorly constrained. This may be particularly important for high resolution AMVs.