AMV monitoring: results from the 4th NWP SAF analysis

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ABSTRACT

The main aim of the NWP SAF atmospheric motion vector (AMV) monitoring is to improve our understanding of the complicated error characteristics in the AMV data. This plays a key role in facilitating improvements to AMV derivation, quality control and assimilation, with the ultimate aim of improving NWP forecasts. The monitoring is freely accessible at http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/.

The core of the biennial analysis report is the maintenance of a record of features and anomalies identified in the O-B monitoring. For some of these, further investigations have highlighted possible causes and solutions. The report also provides feedback on new AMV data sets such as the Meteosat-8 rapid scan winds.

In this paper we highlight recent developments to the NWP SAF AMV monitoring, present examples of the features identified and propose some options for how we can take this work forward within the AMV community.

RECENT DEVELOPMENTS

The NWP SAF (Numerical Weather Prediction Satellite Application Facility) AMV monitoring has undergone a number of changes since the 9th International Winds Workshop (9IWWG). These include:

1. The 4th analysis report was published in January 2010.
2. New buttons have been added (July 2009) to enable easy switching between corresponding plots from different months and years. This is particularly useful for looking at seasonal patterns in the statistics.
3. An investigations section has been added to the website (September 2008) - see http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/investigations.html. This page houses links to one-off or occasional investigations of specific aspects of the AMV monitoring. Two investigations have been added which look at O-B statistics as a function of: (1) height assignment method and (2) time of day.
4. The information on how AMVs are used in different global NWP systems has been updated.
5. Several new datasets have been added including the NOAA-19 AVHRR polar winds, MODIS/AVHRR winds from new direct broadcast stations and the Meteosat-8 rapid scan winds.

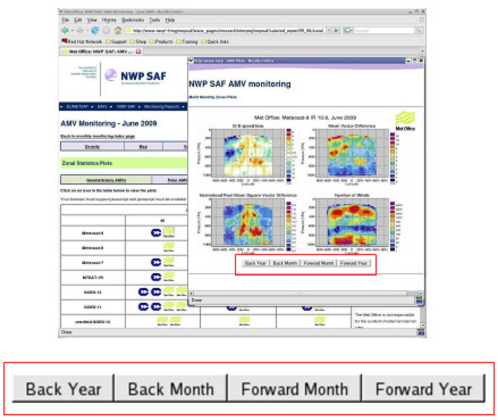

Figure 1: **Example of the NWP SAF pages highlighting the new buttons across the bottom of the monthly monitoring plots.**

OVERVIEW OF THE NWP SAF AMV MONITORING

Here we give a brief overview of the NWP SAF AMV monitoring methodology, but a more detailed description is given in the 4th analysis report (Cotton and Forsythe, 2010). The monitoring statistics are calculated by comparing wind observations with 6 hour model forecasts valid at the observation times (model background). There are four types of plots available from the NWP SAF AMV monthly monitoring pages:

1. Speed bias density plots of observation wind speed against model background wind speed.
2. Map plots of O-B speed bias, mean vector difference (mvd), normalised root mean square vector difference (nrmsvd) and number of observations.
3. Zonal plots O-B speed bias, mvd, nrmsvd and number of observations.
4. Vector plots of the mean observed vector, mean background vector and mvd.

Both the AMVs and the model forecast contribute to the differences seen in the plots; neither can be assumed to be true. But by comparing plots of the same observations against different NWP backgrounds, it may be possible to separate error contributions from the observations and models. The aim of the NWP SAF AMV monitoring is to provide easily comparable plots from different centres so that similarities and differences can be easily recognised. Monitoring is currently available for the Met Office and the European Centre for Medium-Range Weather Forecasts (ECMWF). Generally the plots from the Met Office and ECMWF are very similar.

All plots in this report, unless stated otherwise, are produced using observations with quality indicator (QI) values greater than 80 for the geostationary winds and greater than 60 for the polar winds (where the QI is the EUMETSAT-designed QI without first guess check). For more information on the EUMETSAT quality indictor see Holmlund (1998). Throughout this paper NH refers to the area north of 20N, SH refers to the area south of 20S and the tropics refers to the area between 20S and 20N.

In order to better understand the pattern and cause of features observed in the NWP SAF monitoring, it has been informative to make use of additional statistics. One example is a comparison of the AMV assigned pressure to model best-fit pressure. The model best-fit pressure is essentially the model level with the smallest vector difference between the AMV and model background wind. This is particularly useful when investigating possible height assignment errors.

Case studies are used increasingly as part of the NWP SAF AMV analysis work to improve our understanding of the relationship between O-B statistics and clouds in the imagery or synoptic flow patterns in the model background field. The potential of the approach was assessed as part of an NWP SAF visiting scientist mission (Galante Negri & Forsythe, 2009)

EXAMPLES FROM THE 4TH NWP SAF ANALYSIS REPORT

In this section we present examples of some of the features identified in the 4th analysis report.

Example 1. Low level fast bias over Africa

Fast biases are observed in the IR and visible channels over the Sahara desert, Arabia and Mediterranean. Although present all year, the bias distribution shows seasonal variability. The fast bias is most prominent during the winter months (November-April), when it is located at around 10-30N (e.g. Figure 2), which corresponds fairly well with the location of the high level sub-tropical jet.

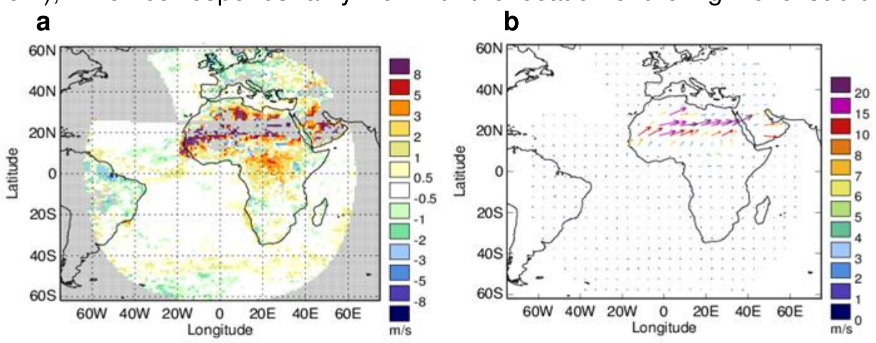

Figure 2: **(a) Map plot of O-B speed bias and (b) mean vector difference for Meteosat-9 HRVIS compared with the Met Office model background for February 2009.**

In these high wind shear regions a small height assignment error can lead to a significant speed bias. The model best-fit pressure plot (Figure 3) shows low level winds in this area have an average low height bias of around 100 hPa.

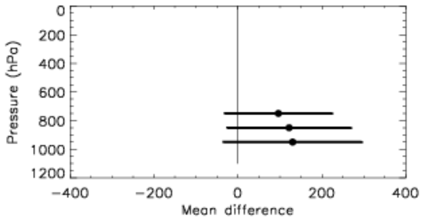

***Figure 3*: Mean difference (dots) and standard deviation (bars) of the observed pressure and model best-fit pressure for Meteosat-9 HRVIS AMVs for February 2009. The data has been filtered for those observations over land, 10N-35N.**

A case on 17 February 2009 was chosen for further investigation. On this day the fast bias is associated with a band of observations over land which stretch from North East Libya to Algeria (Figure 4a). The problem AMVs are generally much faster (speeds of up to 40m/s) compared with the surrounding low level observations in the Mediterranean (Figure 4b). The observed and best-fit pressure maps reveal, in the worst case, AMVs with assigned pressures below 900 hPa with model best-fit pressures at around 500 hPa.

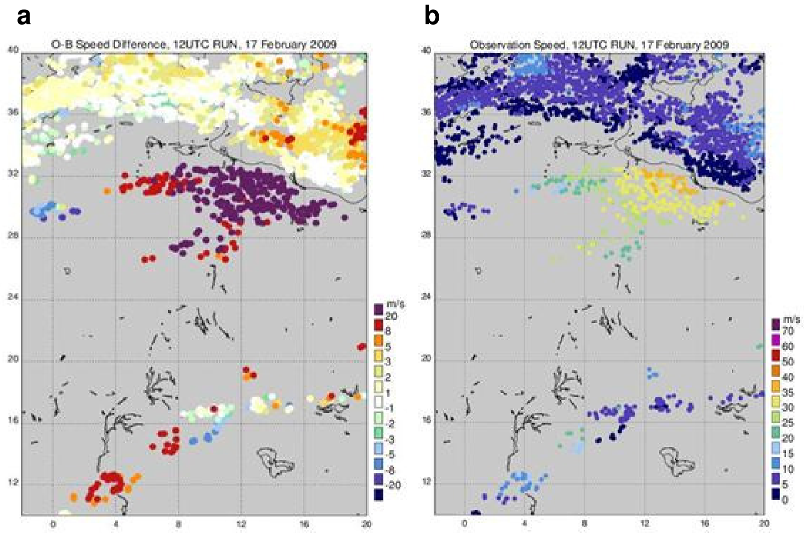

***Figure 4*: Map plots showing (a) O-B speed bias and (b) observation speed for Meteosat-9 HRVIS AMVs valid at 1200 UTC on 17 February 2009.**

The Met Office MSG cloud top height product and visible satellite imagery (Figure 5) are more consistent with a band of high semi transparent cloud. The cloud top height of approximately 20000ft (~ 465 hPa) agrees well with the model best-fit pressure. So why are the AMVs being put too low? The CO_2 slicing pressures of 500-700 hPa show closer agreement with the model but were not used as the cloud top temperatures (typically 260-270 K) were warmer than the 253 K threshold. The height assignment has therefore fallen back on the EBBT method which will tend to put semi-transparent cloud (as appears to be the case here) too low due to contributions from below the cloud. As a result the cloud top heights have been assigned below 700 hPa and EUMETSAT apply a cloud base height assignment to all low level winds which has further exacerbated the height error and, in turn, the speed bias. The IR10.8 AMVs for this case are generally assigned a little higher at 400-700 hPa, but there are still some low level winds with a large fast bias.

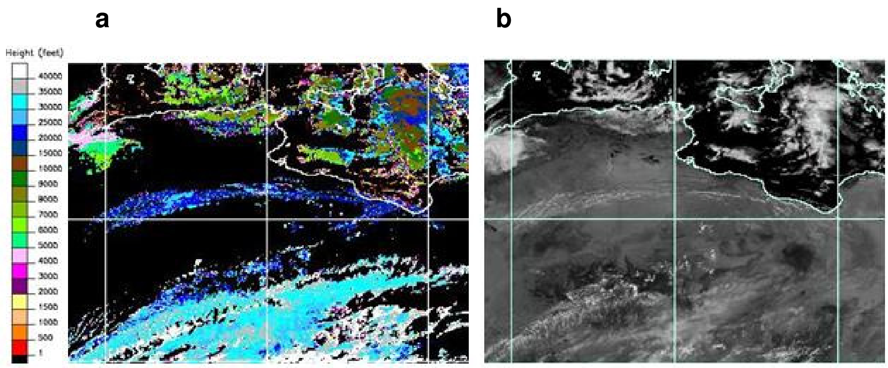

***Figure 5*: (a) Met Office MSG product showing the height of the cloud tops in feet for North Africa at 1200 UTC on 17 February 2009. The band of cloud corresponding to the fast bias is shown in dark blue at 20000ft ~ 465 hPa across the centre of the image. (b) Meteosat-9 visible image at 1200 UTC on 17 February 2009.**

During the summer months, the fast bias is normally less prominent and extends further north into the Mediterranean, probably reflecting the weakening and northward shift in location of the high level jet. A second fast bias is observed close to 15 N during June-July. This corresponds in location to the region of faster mid level easterly winds that cross this region at this time of year. As with the winter example shown earlier, the bias probably results from a low height assignment bias in a region of increased vertical wind shear.

Example 2. Low level slow bias in Equatorial Pacific (Met Office plots only)
A slow bias is observed in the equatorial Pacific in the GOES-11 and MTSAT-1R Met Office plots which is not seen in the equivalent plots from ECMWF, as shown by Figure 6. The bias is more marked in the visible channel than it is in the IR and persists, to some extent, for most months of the year. A fast bias is also seen near 15N in the GOES-11 plots from both centres, but is slightly worse in the Met Office plots.

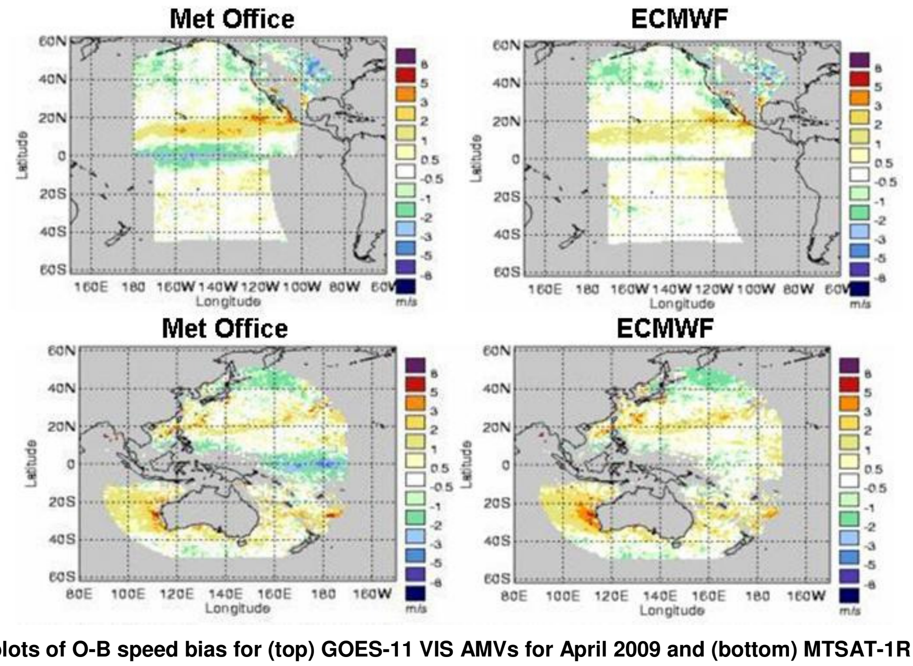

***Figure 6:* Map plots of O-B speed bias for (top) GOES-11 VIS AMVs for April 2009 and (bottom) MTSAT-1R VIS AMVs for February 2009 using the Met Office and ECMWF model backgrounds.**

The maximum easterly equatorial wind is located further south in the Met Office model compared to the observations resulting in the paired slow and fast bias at 0 and 15N. The ECMWF model shows better agreement near the equator, but a tendency to be slower than the observations to the north. Since the ECMWF plots show very little bias in the equatorial region it is possible the slow bias in the

Met Office plots is the result of a bias in the Met Office model and not an issue with the AMVs themselves.

Example 3. High level Jet Region slow bias

A slow bias in the jet regions is a frequently described problem. The slow bias is known to be worse in the winter months (when the jets are strongest) and it affects most satellite-channel combinations to some extent, but is particularly prominent for Meteosat-7 IR and WV and MTSAT-1R IR. To improve our understanding of the jet region slow bias we can investigate individual cases. One fairly persistent feature is a large swathe of slow bias for Meteosat-7 WV AMVs over the Indian Ocean, stretching from Madagascar to Western Australia (Figure 7), which is also observed in the Meteosat-7 IR and Meteosat-9 WV and IR plots. The bias is most prominent during May to September (SH winter), particularly in the region of the sub-tropical jet at around 20-30S (Figure 7b) but is also seen in the region of the polar front jet at around 45S in the SE Indian Ocean.

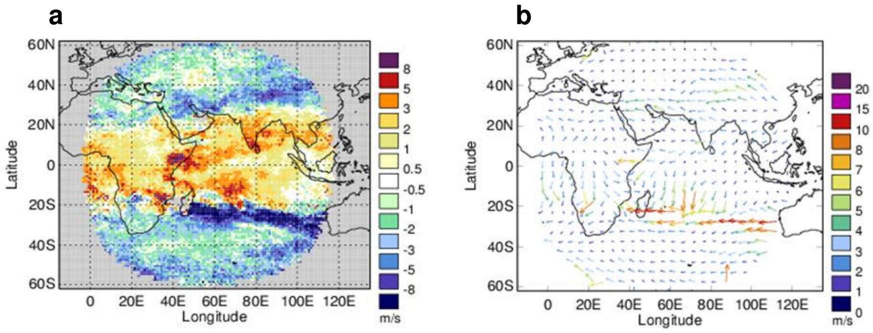

Figure 7: **Met 7 WV June 2009 Map plots of (a) O-B speed bias and (b) mean vector difference for June 2009 compared with the Met Office model.**

Figure 8 shows how this feature varies in magnitude from day to day. The largest biases associated with both jet regions coincide to some extent, but not exclusively, with the fastest model wind speeds. For example, there is a good relationship between the slow bias and stronger wind speeds around 50-60S for the period 18-23 June, but the bias is not apparent at 20-30S for 12-16 June, when the model speeds are again strong.

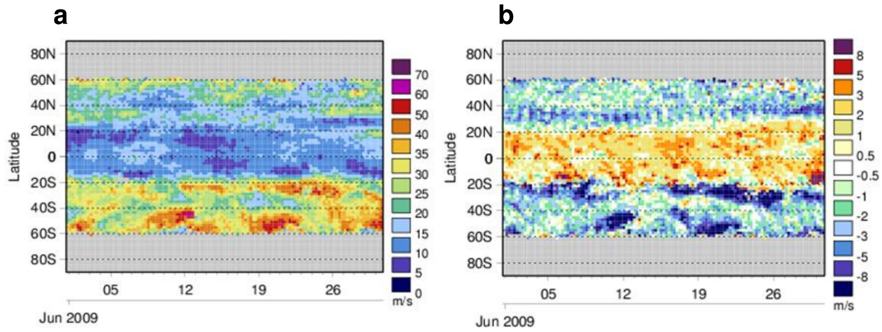

Figure 8: **Hovmöller plots of (a) mean background speed and (b) O-B speed bias for June 2009 for Meteosat-7 WV compared with Met Office model background.**

Visualisation of the data can be used to investigate further. Examples are shown here for 22 and 29 June 2009. On the 22 June 2009 the sub tropical jet is observed near 25S to the West of Australia with the polar front jet closer to the pole at 50S. Both jets exhibit AMVs with wind speeds in excess of 70 m/s or 136 knots (Figure 9b) and are associated with large slow biases (dark blue points in Figure 9a).

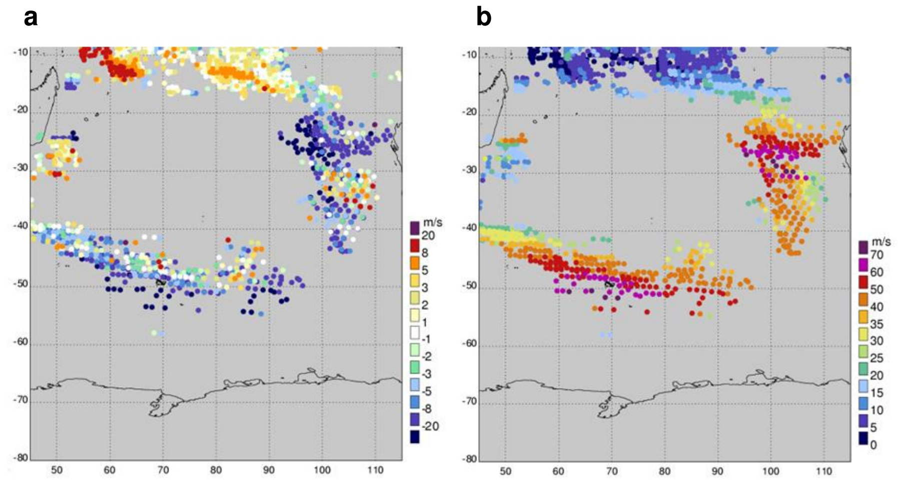

***Figure 9*: Visualisation of (a) O-B speed bias compared with the Met Office model and (b) model background wind speed for high level Meteosat-7 WV AMVs valid at 00 UTC 22 June 2009.**

The 29 June 2009 case is less straightforward (Figure 10). There are fast winds to the west of Madagascar and a cluster around 105E, 35S which as before are considerably slower than the model background winds. However, for a large section of the jet centred around 55E, 40S the AMVs show more neutral bias or in some cases fast bias compared to the model. The question is why are large slow biases associated with very fast winds on some occasions and not others? Looking at the satellite imagery may provide some clues.

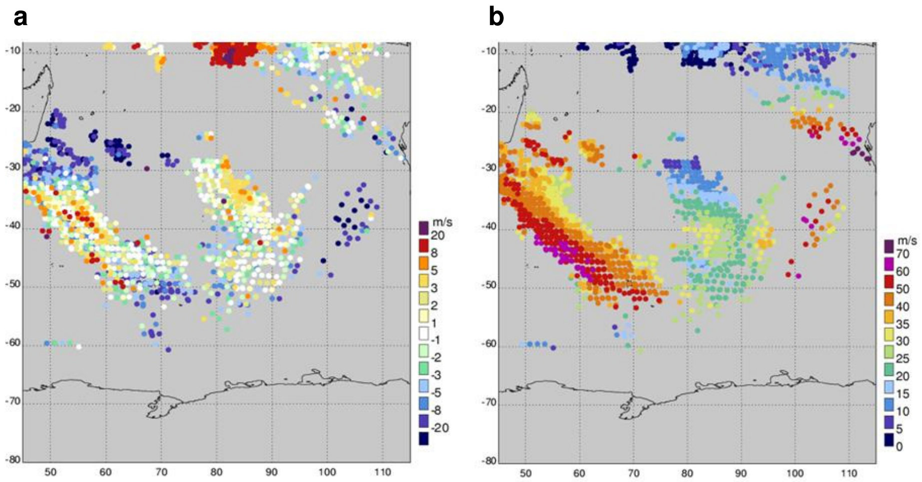

***Figure 10*: Visualisation of (a) O-B speed bias compared with the Met Office model and (b) model background wind speed for high level Meteosat-7 WV AMVs valid at 00 UTC 29 June 2009.**

Figure 11 shows Meteosat-7 WV imagery for the two cases on the 22 and 29 June. Some features of interest are indentified via labels 1 to 4. Feature 1,3 and 4 correspond to jet regions which exhibit fast winds with a significant slow bias. Feature 2 highlights a region of jet strength winds, but where there is more neutral bias. Visually the key difference between the examples is the shape and texture of the WV features in the imagery. Features 1, 3 and 4 are relatively narrow jets with smooth linear features within the jet core aligned parallel to the direction of motion. Contrast this with feature 2 which is much wider, with much less regular texture and some contrast details running perpendicular to the flow direction. Without examining individual targets it is hard to be certain, but the differences in texture may affect the success of the tracking, with increased biases when the imagery is more smooth and linear. Considering the 29 June case it is interesting to note that the model background wind is of similar strength in Features 2 and 3, whereas the observed speed is much less in Feature 3. If we believe the model winds this suggests that the bias, at least in this case, is a result of the tracking step rather than the height assignment.

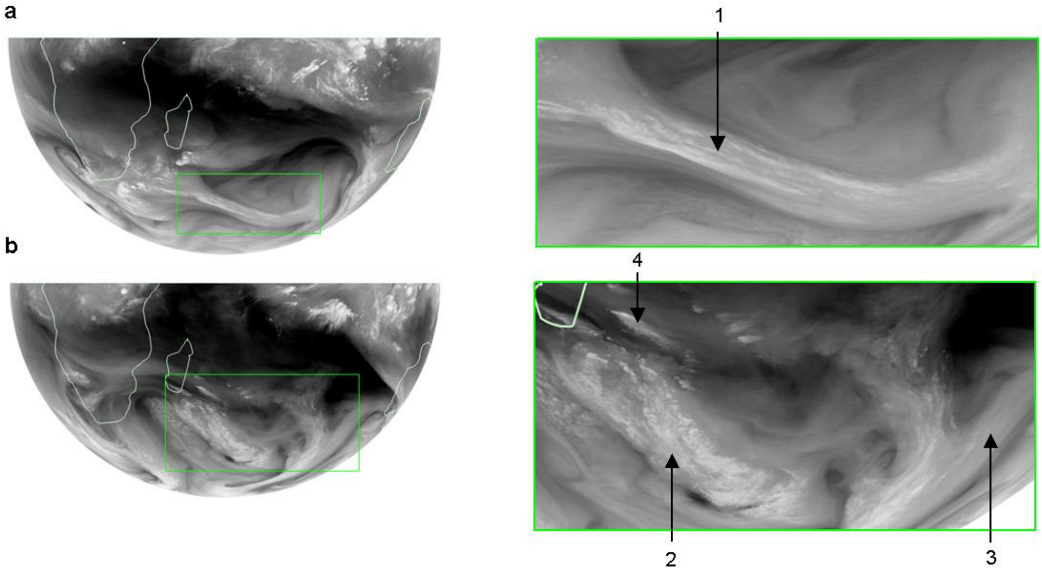

***Figure 11*: Meteosat-7 WV imagery for (a) 00 UTC 22 June 2009 and (b) 00 UTC 29 June 2009, showing the SH disc and also cropped to the area of interest.**

CONCLUSIONS

The NWP SAF AMV monitoring site has improved in several ways since the 9th International Winds Workshop. These include an upgrade to the site navigation, the addition of follow-up investigations on specific aspects of the AMV monitoring and updates to the information on how AMVs are used in different global NWP systems. The 4th analysis report was released in January 2010 and continues to deliver feedback on new observation types, providing guidance for NWP centres considering assimilating new AMV datasets as well as feedback to the data producers.

A key focus of the NWP SAF AMV analysis reports is the maintenance of a record of features identified in the O-B monitoring. The plots versus the Met Office and ECMWF models are usually very similar suggesting that AMV errors dominate in most cases. Model errors make a smaller contribution but are still present as shown by the second example in this paper. The O-B speed biases can often be explained by systematic height assignment errors. In some cases investigations have highlighted possible causes and solutions.

Improvements to AMV derivation often have a visible impact on the O-B statistics. However, many of the bias features described in earlier analysis reports persist. The most prevalent problems remain the fast bias in the tropics (see 4th analysis report for examples) and the slow bias in the jet regions (third example in this paper) at both mid and high levels. They often relate to difficulties in height assignment in multi-level cloud regions and the bias is often exacerbated by high vertical wind shear. Improvements should be seen from more accurate height assignments and by identifying less-trusted observations so that they can be down-weighted (through more realistic representation of the observation errors) or blacklisted in NWP.

The NWP SAF AMV analysis reports, monthly monitoring pages and investigations aim to improve knowledge of the AMV errors and help focus areas of development in the AMV derivation and assimilation. It is hoped that these resources will stimulate discussion and further investigation within the AMV community.

FUTURE DEVELOPMENTS

We plan to continue producing NWP SAF AMV analysis reports every 2 years to coincide with the International Winds Workshops. The AMV monitoring website will be updated with new data sets as and when they become available and also the information on AMV usage at different NWP centres will be expanded as this is recognised as an extremely useful resource for both users and producers.

Future development options are being considered and user feedback is welcomed. Those currently under consideration include:

1. Routine production of Hovmöller plots for monthly monitoring which have proven useful for looking at temporal variability.
2. More NWP centres to provide statistics for the monthly plots.
3. Updates on significant AMV monitoring events e.g. several JMA derivation changes were made during production of the 4th analysis report.

REFERENCES

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