AMV monitoring: results from the 3rd NWP SAF analysis

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ABSTRACT

The aim of the NWP SAF AMV monitoring is to better understand errors in the data in order to improve the derivation and assimilation, with the ultimate aim of improving NWP forecasts. The monitoring is freely accessible at http://www.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/index.html.

The core of the biennial analysis reports is the maintenance of a record of features identified in the O-B monitoring. For some features, investigations have highlighted possible causes and solutions. A new section in the third analysis provides feedback on new AMV datasets such as the AVHRR polar winds.

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

DEVELOPMENTS TO THE NWP SAF AMV MONITORING

The NWP SAF AMV monitoring has undergone a number of changes in the two years since the 8th International Winds Workshop (8IWWG). The main ones are listed below.

- The 3rd analysis report was released in February 2008.
- The site layout was updated in June 2007 to enable easier navigation.
- Following a request at 8IWWG, the site hosts information on how AMVs are used in global NWP systems. This was previously only available for the centres involved in the NWP SAF monitoring.
- Inconsistencies in pre-filtering and statistics calculations have been addressed.
- The pre-filtering has been updated to use the EUMETSAT-designed model independent QI.
- The colour scales have been updated to give more information and improve clarity (Figure 1).

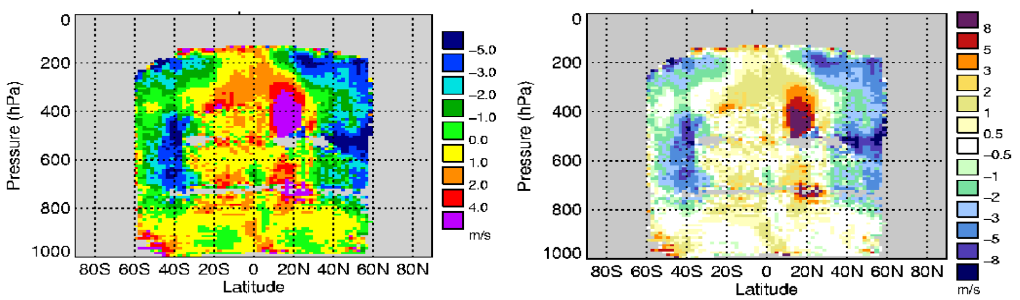

Figure 1: **A comparison of the old (left) and new (right) colour palettes, shown for the zonal O-B speed bias plot for Meteosat-9 IR 10.8 winds compared to the Met Office model background for November 2006.**

- Several new datasets have been added including the AVHRR polar winds, the direct broadcast MODIS winds and the unedited NESDIS GOES and MODIS winds.

PLANS FOR THE FUTURE

The following are planned NWP SAF AMV activities:

- Continue to produce analysis reports every 2 years to coincide with the IWWGs.
- Add new datasets to the monitoring as soon as is practically possible to provide users and producers with early feedback. The FY-2C winds are a candidate for the future.
- Improve the existing plots where deficiencies are identified.
- Extend the number of NWP centres contributing to the monitoring (dependent on provision of statistics from more centres).
- Maintain the information on AMV usage at NWP centres.

There are several potential development options, which can be pursued dependent on interest.

- Provision of real-time monitoring.
- Provision of additional plots on a one-off or occasional basis to investigate specific aspects of the AMV data. Examples include map and zonal plots filtered by height assignment method (e.g. Figure 2a and b) and Hovmoeller plots as a function of time of day (e.g. Figure 2c).
- Provision of extra monthly plots e.g. Hovmoeller plots. These can be used to investigate temporal variability in the bias characteristics (e.g. Figure 2d).

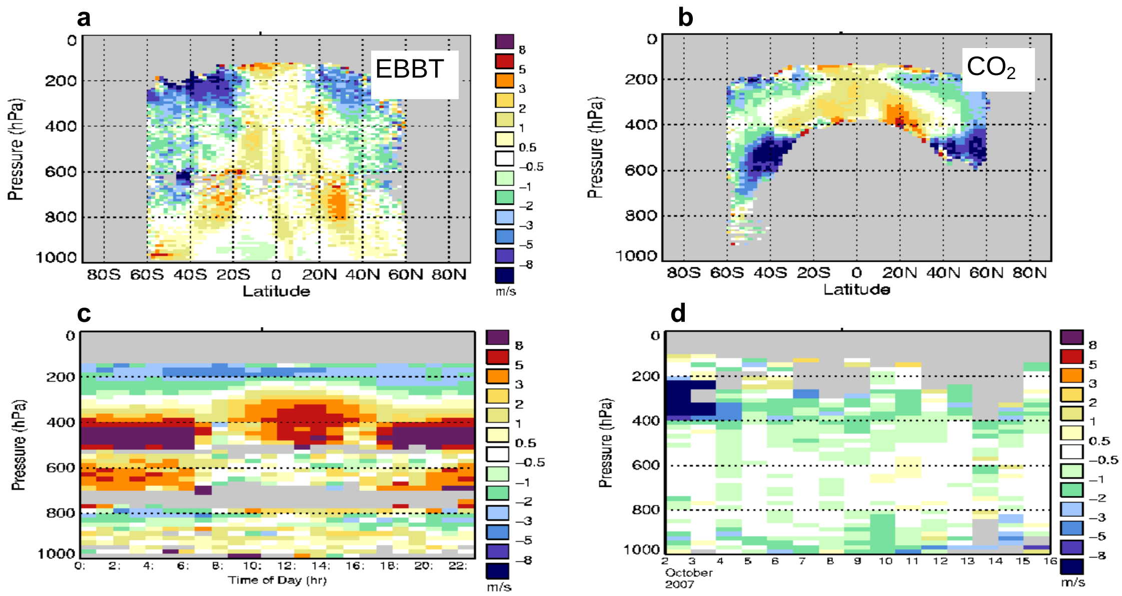

Figure 2: **Examples of possible future plots. (a and b) Zonal plots filtered by height assignment method. (c) Hovmoeller plot as a function of time of day (useful for investigating diurnal patterns). (d) Hovmoeller plot for part of October 2007.**

FEATURES IDENTIFIED IN THE NWP SAF AMV MONITORING

Details of the NWP SAF AMV monitoring and model best-fit pressure statistics are available in the 3rd analysis report (Forsythe & Saunders, 2008a), so only a brief summary is provided here. Four types of plot are provided each month.

1. Density plots of observation wind speed against background wind speed.
2. Map plots of speed bias, mean vector difference, normalised root mean square vector difference and number.
3. Zonal plots showing the same statistics as the map plots but as a function of latitude and pressure.
4. Vector plots showing mean observed vector, mean background vector and mean vector difference.

The monitoring statistics are calculated by comparing wind observations with 6 hour model forecasts valid at the observation times. 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. Throughout this paper low, mid and high level are used to refer to the pressure bands below 700 hPa, 400-700 hPa and above 400 hPa respectively, NH, TR and SH are latitude bands separated at 20N and 20S and the QI pre-filtering is 80 for geostationary data and 60 for polar data (model independent QI).

In order to better understand the features observed in the monitoring it has been informative to make use of additional statistics. One of the statistics used, particularly for investigating height error, is the comparison of AMV assigned pressure to model best-fit pressure. The best-fit pressure is taken as the model level with the smallest vector difference between the AMV and model background wind.

The O-B statistics from the Met Office and ECMWF are very alike. The differences that exist are mostly in the tropics, which might be explained by the larger model biases in this region. Many of the features persist for several months and some show seasonal dependency. Many features can be traced back over a number of years. On the positive side, there have been identifiable improvements to the statistics for some satellites and channels as a result of improvements implemented to the AMV derivation. Examples of features in the 3rd analysis report are provided below.

Example 1. GOES fast bias in inversion regions

The GOES low level winds show a fast bias in some regions (Figure 3a), thought to be linked to a height bias. Model best-fit pressure comparisons show that the GOES low level AMVs over sea, particularly the visible winds, are assigned much higher in the atmosphere than the model preferred position (Figure 3b). The Meteosat-9 AMVs, by comparison, show much less bias (Figure 3c).

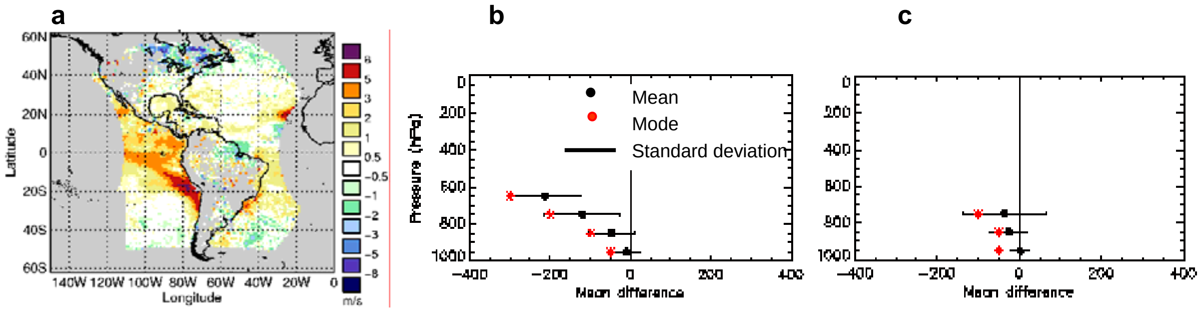

Figure 3: **(a) Unedited GOES-12 VIS O-B speed bias compared with the Met Office model background for October 2007. (b and c) Mean difference between AMV assigned pressure and model best-fit pressure for winds over sea derived from (b) unedited GOES-11 VIS and (c) Meteosat-9 VIS 0.8.**

The GOES high height bias is most prominent in the stratocumulus inversion regions in the Pacific and Atlantic Oceans where the differences can be more than 200 hPa. Figure 4 shows an example of the high height bias for a case on the 3 July 2007. The model best-fit pressure is below 900 hPa in the atmosphere, which is consistent with the Calipso cloud heights of ~ 1 km for this region and time.

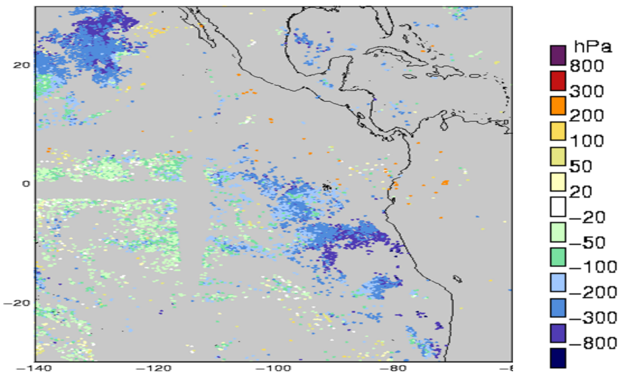

Figure 4: **Pressure difference between the observed AMV pressure and model best-fit pressure for the unedited GOES-12 VIS winds on the 3 July 2007 for data valid between 1500 and 2100 UTC.**

Assigning heights in inversion regions can be difficult; the results are dependent on the forecast data quality and resolution and there can be multiple solutions. NESDIS have identified an improved strategy (Daniels et al., 2008), which should reduce the height bias in the future.

Example 2: Spuriously fast Meteosat and MTSAT-1R winds at low level

Speed bias density plots, particularly for Meteosat and JMA winds, show a number of spuriously fast winds (e.g. Figure 5). The feature is most evident in regions with high vertical wind shear.

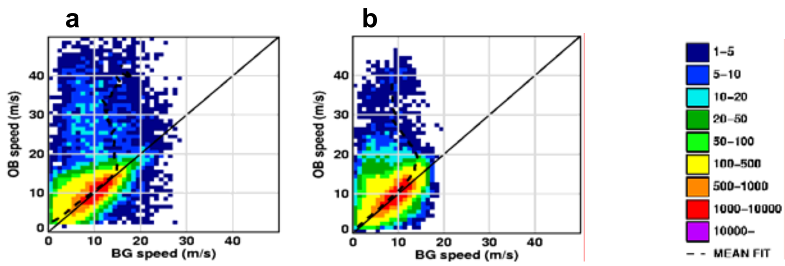

Figure 5: **Density plots of observed wind speed against the Met Office model background wind speed for low level winds in the tropics in August 2007 for (a) Meteosat-7 IR and (b) MTSAT-1R IR.**

The three areas affected most are: (1) below the NH sub-tropical Jet over Asia and Africa during the NH winter, (2) near India during the monsoon and (3) south-east Asia. An example is shown in Figure 6. Some of the faster observed low level vectors (Figure 6b) show no resemblance to the low level model background wind field (Figure 6c); they agree best with background winds at or above 250 hPa (Figure 6d).

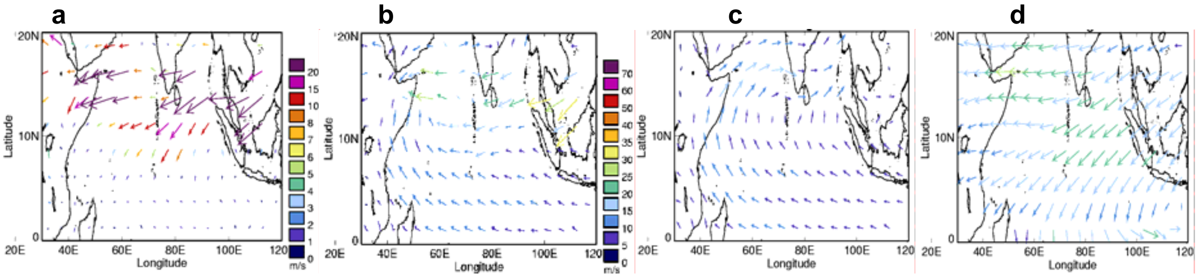

Figure 6: **Vector plots for Meteosat-7 IR and the Met Office model background for August 2007 showing (a) the mean vector difference at low level, (b) the mean observation at low level, (c) the mean background at low level and (f) the mean background at 100-250 hPa.**

It is probable that much of the fast bias is linked to a large height assignment error of, in some cases, more than 500 hPa. Examination of Calipso data for one case in August showed a mixture of high and low level clouds in the region associated with the spuriously fast low level winds. It is likely that the problem AMVs were due to the target containing both levels of cloud with the tracking following the high level cloud and the height assignment erroneously based on the low level cloud. These mixed cloud cases can be hard, but there may be ways to develop the derivation to improve the match up between tracking and height assignment (e.g. Borde & Oyama, 2008; Oyama et al., 2008) or, at least, to flag likely problem cases.

Example 3: The Sahara mid level fast bias revisited

At 8IWWG (Forsythe et al., 2006) a fast bias was described over the Sahara region during the winter months (e.g. Figure 7).

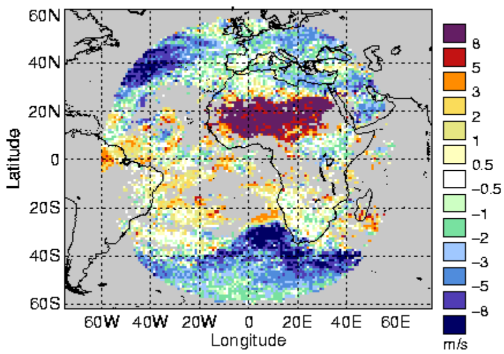

Figure 7: **O-B speed bias plot for Meteosat-8 IR mid level winds compared with the Met Office model background for November 2005.**

It was hypothesised that the fast bias was due to faster higher level winds being assigned too low. This was supported by comparisons to model best-fit pressures and a MODIS cloud top pressure product (e.g. Forsythe et al., 2006). Follow-up investigations at EUMETSAT highlighted a problem with the CO_2 slicing method in cases of low level inversions where there can be more than one cloud-top pressure solution. An improvement to the strategy was identified and implemented operationally on 22 March 2007. Subsequent investigations have shown that the new approach has markedly reduced, but not eliminated, the fast speed bias with most improvement seen at night-time when a low level inversion is likely to be present (see Figure 8). A fast bias remains above 400 hPa during day time hours and the low level bias has deteriorated.

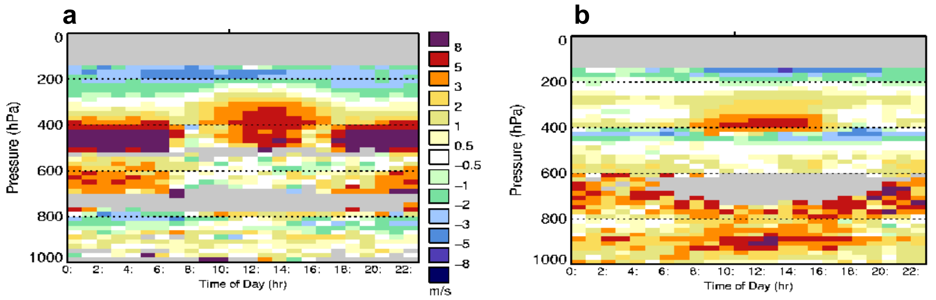

Figure 8: **Hovmoeller plots of O-B speed bias for Meteosat-9 IR 10.8 winds (0-20N and 20W-30E) compared with the Met Office background as a function of time of day for (a) January 2007 and (b) January 2008.**

Example 4: Slow bias in the extratropics

A slow speed bias at mid level is prominent in the Meteosat and GOES zonal plots and is clearly a separate feature from the slow bias seen at jet levels. The plots in Figure 9 show how the bias varies dependent on the height assignment method. The speed bias is worse for Meteosat-9 winds assigned a height using the CO_2 slicing method and for the unedited GOES winds assigned heights using the CO_2 slicing or WV intercept methods. By comparison, the EBBT method is less affected.

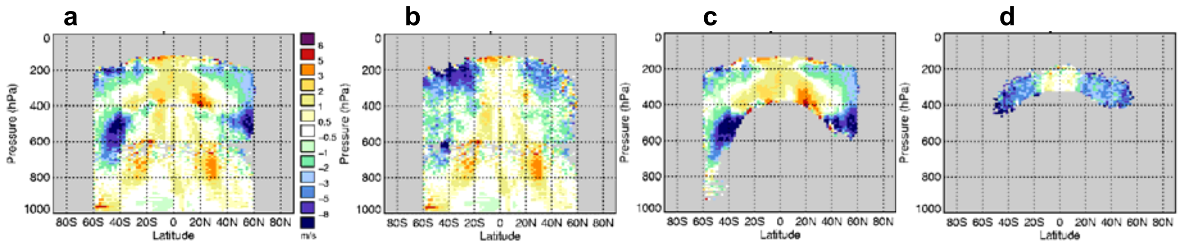

Figure 9: **Zonal O-B speed bias plots for Meteosat-9 IR 10.8 winds compared with the Met Office model background for October 2007 filtered by height assignment method: (a) all data, (b) data with EBBT heights, (c) data with CO_2 slicing heights and (d) data with WV intercept heights.**

Model best-fit pressure statistics show a tendency for the mid level winds assigned WV intercept and CO_2 slicing heights to be higher than the model best-fit pressure (Figure 10). A high height bias was also seen compared with radiosonde best-fit pressures (Daniels et al., 2006).

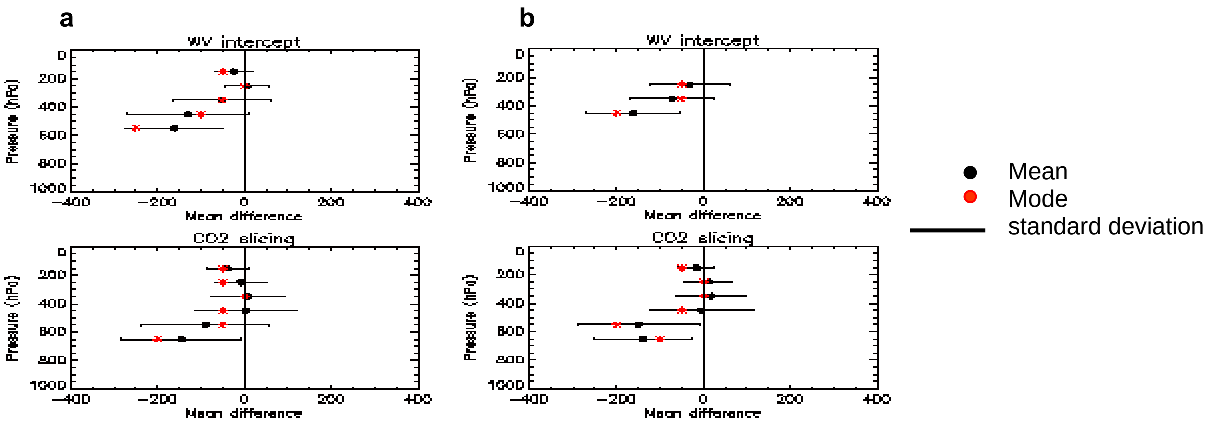

Figure 10: **Mean difference between AMV assigned pressure and model best-fit pressure as a function of pressure in the atmosphere for (a) the unedited GOES-12 IR winds and (b) the Meteosat-9 IR winds using the WV intercept and CO_2 slicing height assignments. The data is for the period 23 March – 23 April 2007.**

It is not surprising that the CO_2 slicing and WV intercept methods are less accurate at mid level as the CO_2 and WV channels lose sensitivity, but it is not clear why there is a high bias. These results suggest that additional thresholds should be considered to prevent use of the WV intercept and CO_2 slicing methods at mid levels. Figure 11 shows how, although far from perfect, the EBBT pressures for these border-line cases agree better with the model best-fit pressures than those from the CO_2 slicing approach.

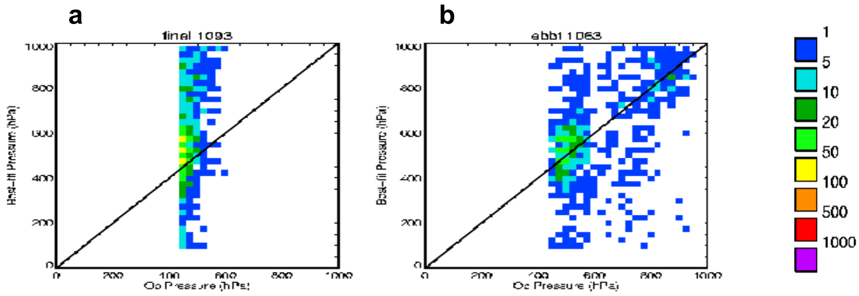

Figure 11: **Density plots comparing model best-fit pressure to (a) CO_2 slicing and (b) alternative EBBT pressures for 3 days in November 2007 of Meteosat-9 IR 10.8 winds below 450 hPa with CO_2 slicing assigned heights.**

Example 5: NESDIS MODIS IR slow streak

The speed bias density plots for the NESDIS MODIS IR winds show a streak of very slow speeds (Figure 12). This is seen at all levels for both the edited and unedited MODIS data, but is not seen for the AMVs produced using the CIMSS processing or those derived from the WV channel.

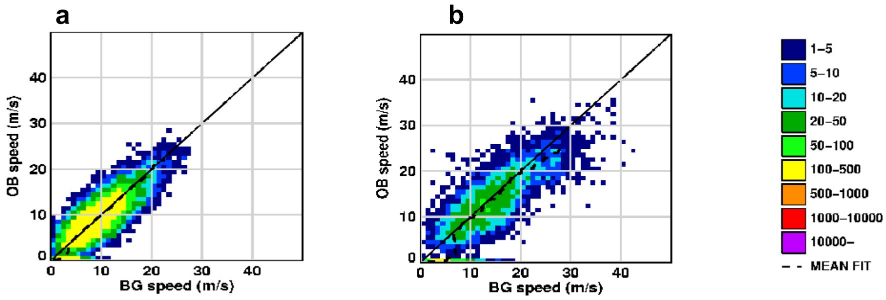

Figure 12: ***Speed bias density plots for NESDIS Terra IR low level winds for August 2007 compared with the Met Office model background in (a) the NH and (b) the SH.***

Figure 13 shows their distribution. At low and mid level they are concentrated around the edges of the polar continents. At high level they are located over the high Antarctic land mass.

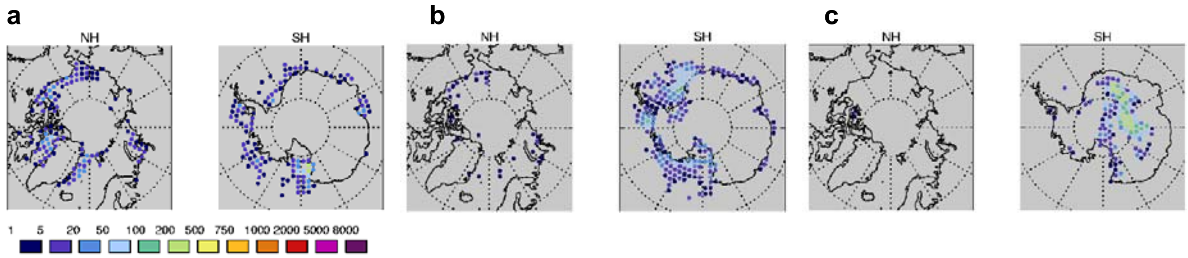

Figure 13: **Distribution of winds with speeds ≤ 1 m/s for July 2007at (a) low, (b) mid and (c) high level.**

The presence of a large number of winds with speeds less than 1 m/s affects the bias statistics. On removal the slow speed bias above 200 hPa is removed and the slow speed bias at low levels is reduced (Figure 14).

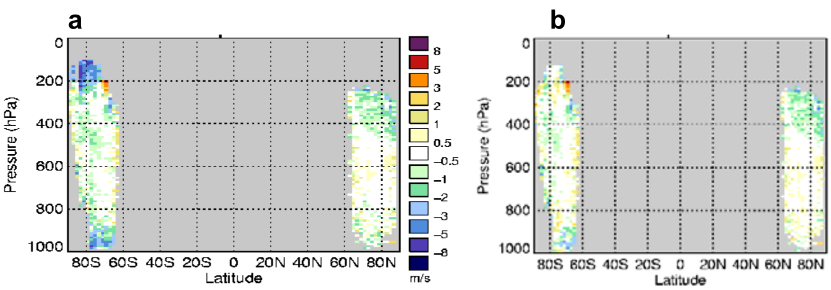

Figure 14: ***Zonal O-B speed bias plots for the unedited NESDIS Aqua IR winds for July 2007 compared with the Met Office model background: (a) all data and (b) all data with observation speed > 1 m/s.***

WHERE TO GO FROM HERE?

There are several areas to address in order to optimise the contribution of AMVs to forecast skill. The first area is to identify improvements to the derivation and height assignment in order to continue improving AMV quality. In some cases there are known developments; for example the use of full vertical resolution forecast data for height assignment. In other cases, further investigation and testing are required e.g. ongoing work to improve the link between the tracking and height assignment steps. Suggestions from the NWP SAF 3rd analysis include:

a. Use of full vertical resolution forecast data in the height assignment
b. Strategy to handle multiple height solutions in inversion regions
c. Revisit where the cloud base should be applied and what is the best method to use
d. Introduce a pressure threshold for use of the CO_2 slicing and WV intercept methods
e. Investigate why the CO_2 slicing and WV intercept methods fail for some high level AMVs
f. Removal of NESDIS MODIS IR winds with speeds less than 1 m/s
g. Consider reducing target size and improving links between tracking and height assignment
h. Investigate MTSAT-1R IR mid level poor statistics
i. Check the autoeditor speed application
j. Consider checks to avoid high level winds being assigned to low level

The second and third items are inter-linked and will require the producers and users to work together. The second is for users to pursue improvements to the AMV assimilation. The NWP SAF AMV analysis reports provide some guidance on which new datasets to assimilate and what extra blacklisting to apply, which is useful for tweaking the current assimilation set-up, but only goes so far. To optimise the assimilation we need to consider larger developments such as improving the observation error representation, developing layer observation operators and allowing for spatially correlated error directly in the assimilation. This is dependent on a third area of work, which is for producers to develop extra quality and representiveness information using data available during the derivation. One example is the development of u, v and height errors. These can be used by NWP centres to generate individual observation errors (e.g. Forsythe & Saunders, 2008b). Another example of potentially useful information is the provision of an estimate of the vertical representiveness so that a suitable layer thickness can be used in the NWP observation operator.

With limited resources at any one centre it is important for the AMV community to discuss and prioritise the development options and to work together on achieving them. The table below summarises some of the ideas voiced over the last few years (some are ongoing).

Ref	Action	Details	Centre(s)
6.1	Document methods	AMV producers to provide a document comparing the main steps in the AMV derivation and height assignment so differences can be easily identified. This should help in interpretation of the O-B plots, particularly where the problems differ from producer to producer.	All producers
6.2	Compare methods	Production of AMVs from each other's imagery to directly compare different derivation schemes.	All producers
6.3	Carry out simulated imagery studies	Analysis of AMVs derived from simulated imagery (von Bremen et al., 2008)	ECMWF and producers
6.4	Develop vector and height errors	To consider each step in the derivation and assess the possible sources of error. What information can be used to develop vector and height errors?	All producers
6.5	Improve height assignment	Including investigations into whether a better link can be made between the pixels that dominate in the tracking and the pixels used for height assignment. Can other improvements to the height assignment be made?	All producers
6.6	AMVs as a representation of the local wind field	The AMVs do not always represent the local wind field. In some situations the cloud is not moving passively with the wind field (e.g. Holmlund & Schmetz, 1990). Are the AMVs still useful in these areas and can they be identified? There is also the consideration of scale of interest. Should higher resolution NWP models use AMVs generated using smaller target sizes and shorter time intervals?	All producers
6.7	AMVs as a layer	Is it important to represent the AMVs as a layer wind in the assimilation and if so what layer thickness should be used? Is there information available from the derivation step to help with this?	All
6.8	Carry out height assignment investigations	Comparisons to other cloud top pressure information (e.g. A-Train, MODIS cloud top pressure etc.) and further best-fit pressure investigations	All
6.9	Improve AMV	e.g. use of more model independent data, development of individual observation	All users

	assimilation	errors, allowance for correlated error in the assimilation and modifications to the observation operator to treat the AMVs as layer observations. Share experiences with other NWP centres.	
6.10	Identify where AMVs are most important	Carry out adjoint studies and AMV impact experiments to get a feel for where the AMVs have most to offer and where they can be more problematic.	All users
6.11	Maintain list of known problems	Users to work with the producers to collect a list of known problem areas. Currently addressed through the NWP SAF AMV analysis reports.	All

CONCLUSIONS

Developments to the NWP SAF AMV monitoring since the 8th International Winds Workshop include an update to the site layout, provision of more NWP usage information and improvements to the monitoring plots. The third analysis was released in February 2008 and for the first time includes a section on new observation types. Future development options are being considered and user feedback is welcomed.

The core of the NWP SAF AMV analysis reports is the maintenance of a record of features identified in the O-B monitoring. The similarities between the Met Office and ECMWF plots suggest that many of the features are dominated by AMV error, with model error making a smaller contribution. In many cases the O-B speed biases can be explained by systematic height assignment errors, with the largest biases seen in or beneath the jet regions where the wind shear is greater. In some cases investigations have highlighted possible causes and solutions.

AMV quality has improved over the last two years, but there is still more work to be done. It is inevitable that some problems will prove hard to fix due to limitations of the derivation and the fact that not all AMVs are representative of the local wind field. In these situations the best strategy may be to identify likely problem cases; this could be done through the development of vector and height errors that can be used in NWP to downweight AMVs we should have less confidence in. It is hoped that the NWP SAF AMV analysis reports, together with other information available from the NWP SAF AMV pages, will stimulate further discussion within the AMV community and lead to more progress in improving the AMV data quality and assimilation.

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