# WHAT CAN WE LEARN FROM THE NWP SAF ATMOSPHERIC MOTION VECTOR MONITORING?

**Mary Forsythe[1], James Cotton[1], Antonio Garcia-Mendez[2], Bryan Conway[1]**

(1) Met Office, FitzRoy Road, Exeter, EX1 3PB, United Kingdom
(2) ECMWF, Shinfield Park, Reading, RG2 9AX, United Kingdom

**Abstract**

The EUMETSAT satellite application facility for Numerical Weather Prediction (NWP SAF) exists to co-ordinate research and development efforts to improve the interface between satellite data and NWP. The NWP SAF is led by the Met Office, with partners ECMWF, KNMI and Météo-France.

The satellite-derived atmospheric motion vector (AMV) activities undertaken as part of the NWP SAF include provision of a rolling three year archive of monthly observation-background (O-B) statistics for AMVs compared with ECMWF and Met Office model background winds. Development is continuously ongoing to improve the range and quality of the plots and to enhance other information provided on the site. Examples include the provision of web pages summarising the AMV assimilation approach at several NWP centres and the recent addition of a new investigations section on the web site, where one-off studies are provided.

A major part of the NWP SAF AMV monitoring activities is the production of biennial analysis reports. The core of the reports is the maintenance of a record of features identified in the O-B monitoring, together with follow-up investigations to better identify possible causes and solutions. The aim is to address one of the key challenges for AMVs, which are their complicated error characteristics. The NWP SAF AMV monitoring can help increase our understanding of the AMV errors and may ultimately lead to improved impact in NWP through identification of improvements to the AMV derivation and assimilation.

## MONTHLY MONITORING PLOTS

The NWP SAF atmospheric motion vector (AMV) monitoring is freely accessible at http://www.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/index.html (a simple registration is required to enter the site).

Four types of NWP SAF AMV monitoring plots 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.

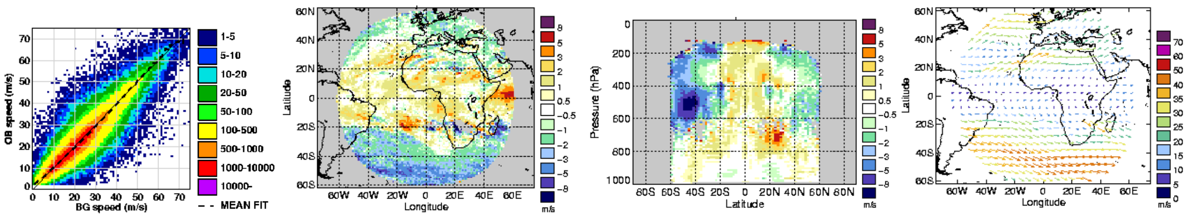


***Figure 1:*** **Examples of the NWP SAF AMV monthly monitoring plots**

The monitoring statistics are calculated by comparing wind observations with 6 hour model forecasts valid at the observation times (otherwise known as model background). Both the AMVs and the model background 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 quality indicator pre-filtering is 80 for geostationary data and 60 for polar data (using the EUMETSAT-designed quality indicator without first guess check). For more information on the EUMETSAT quality indicator see Holmlund (1998).

The monthly monitoring plots are produced separately for different satellite-channel-level-latitude band combinations and are kept for at least 3 years to allow investigation of seasonal characteristics and long-term trends in data quality. Pop-up windows are used to enable several plots to be compared side-by-side. A recent addition has been the provision of “back year”, “back month”, “forward month”, “forward year” buttons on the pop-up window to enable quick comparisons between different months and years (see Figure 2).

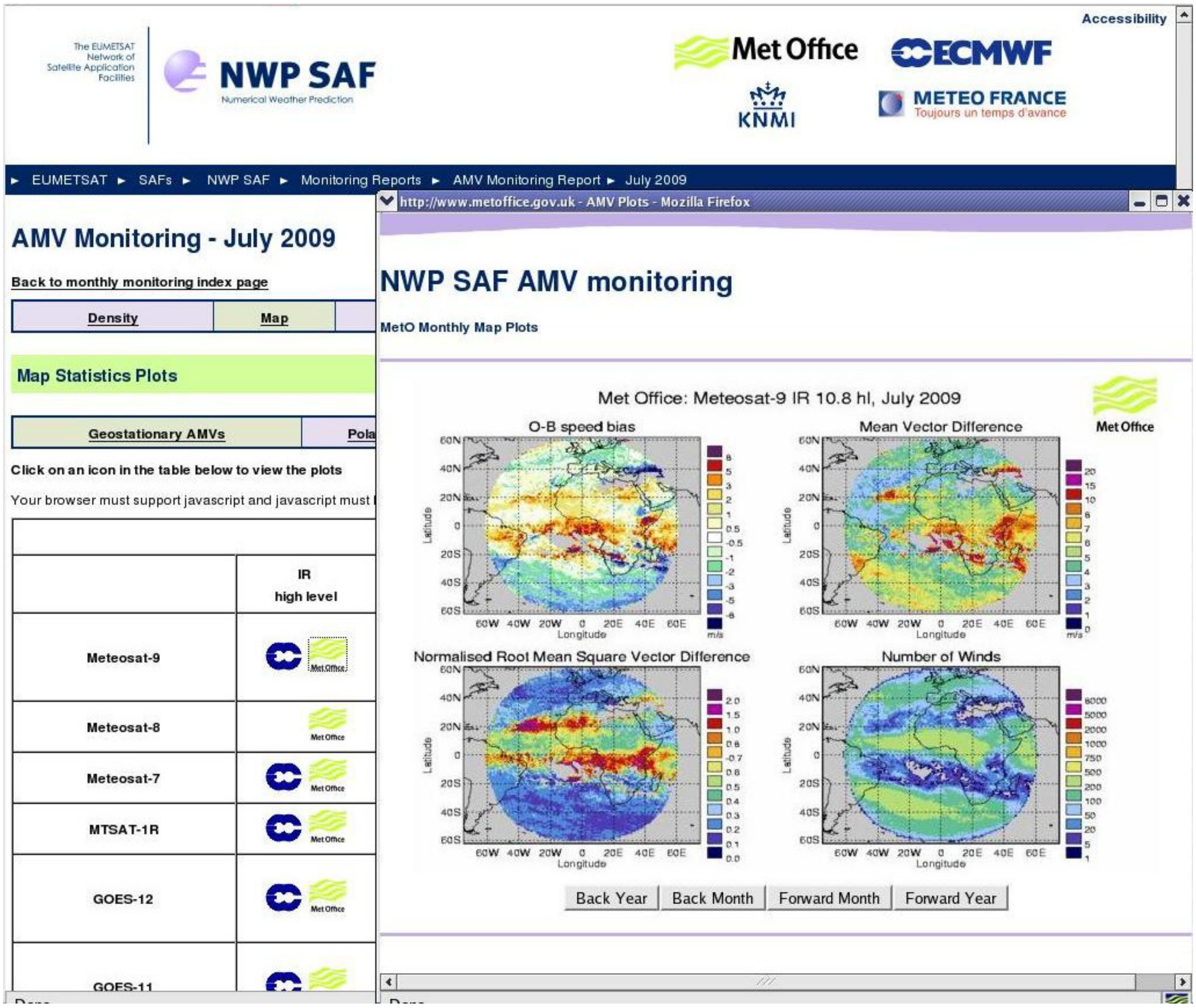


***Figure 2:*** **Example of the NWP SAF AMV monitoring web pages.**

The O-B statistics from the Met Office and ECMWF are very alike (e.g. Figure 3). This suggests that either errors in the observations dominate over errors in the short-period forecasts or that ECMWF and Met Office models share similar problems. Where differences are seen, they are generally located in the tropics, which might be explained by the larger model biases in this region.

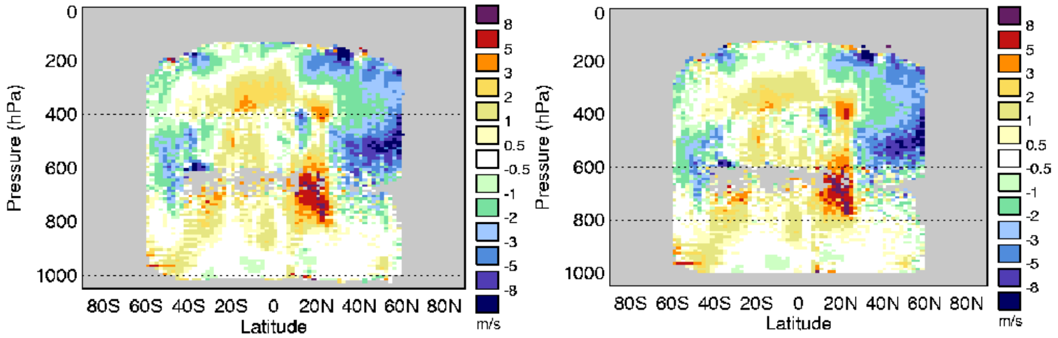


*Figure 3:* **Zonal O-B speed bias plots comparing Meteosat-9 IR 10.8 AMVs to the Met Office model background (left) and ECMWF model background (right) for December 2008.**

## ANALYSIS REPORTS

The analysis reports are produced every 2 years to coincide with the International Winds Workshops. The core of the biennial analysis reports is the maintenance of a record of features identified in the O-B monitoring. Follow up investigations are carried out to identify possible causes and solutions. Many of the features persist for several months or years and some show seasonal dependency. An encouraging sign is that some features have been reduced or eliminated over time following improvements to the AMV derivation.

Alongside the main section describing the O-B features, the analysis reports also include sections highlighting recent developments to the NWP SAF AMV monitoring and a revised list of recommendations for producers and users of the data. A new section was added with the 3rd analysis report providing feedback on new AMV datasets.

The full analysis reports are available from the NWP SAF AMV monitoring web site. To give a flavour of the type information provided, a couple of examples are provided below:

1. Example of an evaluation of a new dataset – Tromsø and McMurdo Station direct broadcast MODIS winds
2. Example of a feature observed in the routine monitoring – spuriously fast Meteosat and MTSAT-1R winds at low level

### Tromsø and McMurdo Station direct broadcast MODIS winds

Information about the direct broadcast polar AMVs can be found in Key et al. (2006 and 2008). For NWP the main advantage of the direct broadcast polar AMVs is their improved timeliness of ~100 minutes compared to the conventional polar winds from CIMSS and NESDIS (see Figure 4). As a result a greater proportion of the data arrives in time for the forecast runs (e.g. in the Met Office main forecast runs ~50-60% of direct broadcast data arrives in time compared to only ~20% conventional polar data).

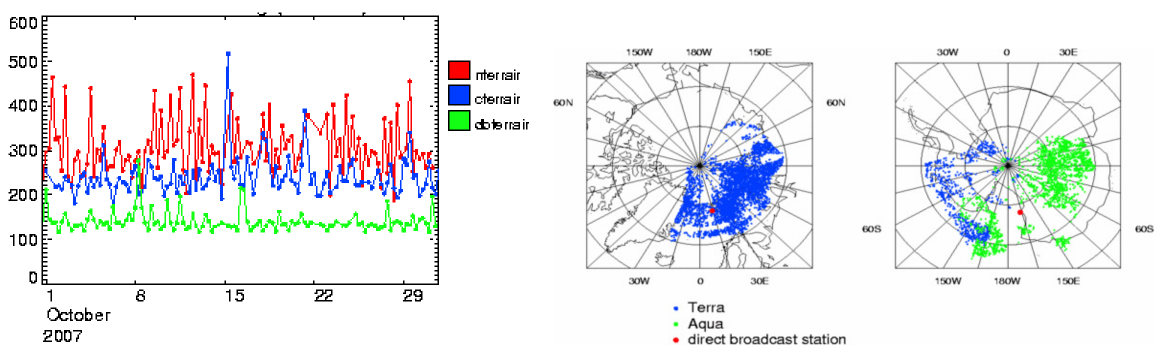


*Figure 4:* **(left) Mean time lag in minutes between observation time and receipt time for the NESDIS Terra IR winds (red), CIMSS Terra IR winds (blue) and direct broadcast Terra IR winds (green). (right) Data coverage plots showing the coverage of the direct broadcast MODIS winds from Tromsø (receiving station in Svalbard) and McMurdo Station for 0900-1500 UTC on the 7 November 2006.**

The direct broadcast winds only provide partial coverage (Figure 4). This has recently improved with the addition of new stations at Fairbanks and Barrow in Alaska, Sodankylä in Finland and Rothera on the Antarctic Peninsula.

Collocation comparisons between direct broadcast and conventional polar AMVs generally show good agreement in speed, direction and height assignment (e.g. Figure 5).

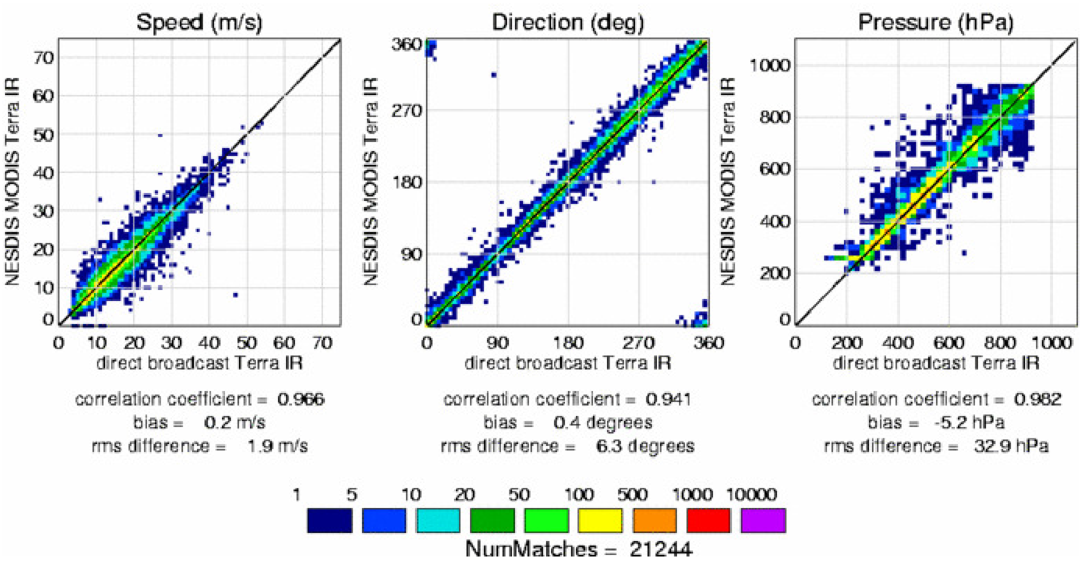


***Figure 5:*** **Plots comparing the speed, direction and pressure of collocated McMurdo Station direct broadcast Terra IR winds and the NESDIS Terra IR winds for October 2009. The collocation distance and time were 10 km and 30 minutes.**

The analysis of new datasets is useful for NWP centres to help decide whether to assimilate the data and provides valuable feedback to data producers.

### Spuriously fast Meteosat and MTSAT-1R winds at low level

NWP SAF speed bias density plots, particularly for Meteosat and JMA winds, show a number of spuriously fast winds (e.g. Figure 6). The feature is most evident in regions with high vertical wind shear.

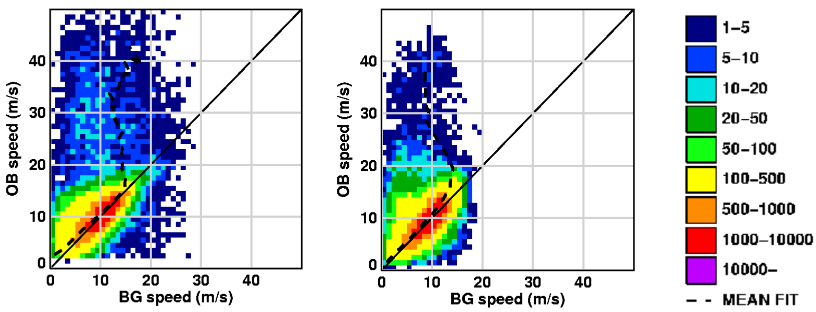


***Figure 6:*** **Density plots of observed wind speed against the Met Office model background wind speed for low level winds in the tropics in August 2007 for (left) Meteosat-7 IR and (right) MTSAT-1R IR.**

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 7. Some of the faster mean observed low level vectors (Figure 7b) show no resemblance to the mean low level model background wind field (Figure 7c); they agree best with mean background winds at or above 250 hPa (Figure 7d).

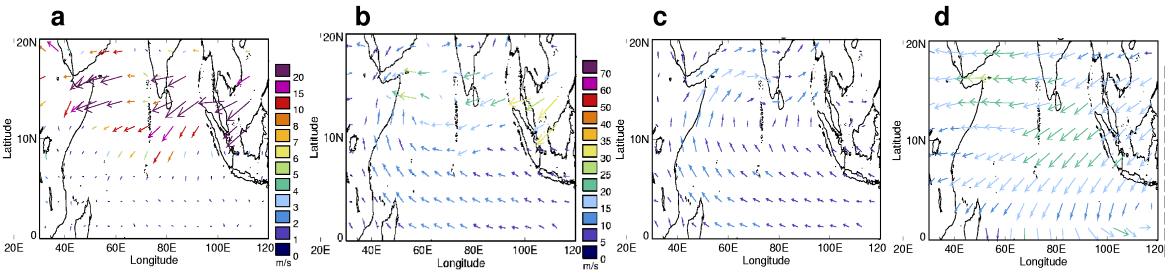


***Figure 7:*** **Vector plots for Meteosat-7 IR and the Met Office model background for August 2007 showing (a) the mean vector difference at low level, (b) the mean observation at low level, (c) the mean background at low level and (f) the mean background at 100-250 hPa.**

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.

## OTHER ACTIVITIES

At the 8th International Winds Workshop it was requested that the NWP SAF host pages on AMV usage at different centres. These are available for 6 centres: DWD, ECMWF, Environment Canada, Meteo-France, the Met Office and JMA, with 2 more in the pipeline (NRL and BoM). The web page summaries are in a standard format to allow easy comparisons and provide details on:

1. Model and data assimilation details (resolution, time window etc)
2. AMV types assimilated
3. Quality control (including blacklisting, QI thresholds, thinning and background check)
4. Observation errors
5. History of changes

Another more recent addition is the provision of one-off or occasional investigations to focus on specific aspects of the monitoring. Two studies have been provided.

The first shows the standard NWP SAF AMV monitoring plots, but where they have additionally been separated by the height assignment method applied (e.g. Figure 8).

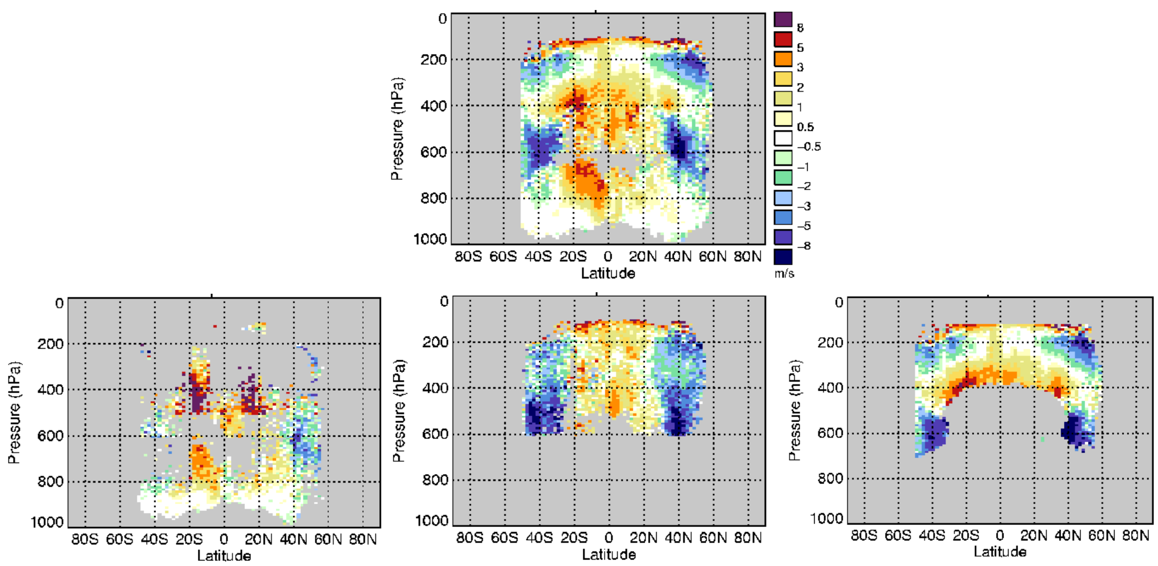


***Figure 8:*** **Zonal O-B speed bias plots for the pre-autoeditor GOES-12 IR winds compared with the Met Office model background for October 2007 filtered by height assignment method: (top) all data, (left) equivalent black-body temperature height assignment, (middle) $CO_2$ slicing height assignment and (right) WV intercept height assignment.**

By separating by height assignment we can sometimes learn more about what is causing a particular feature in the statistics. For example, the slow speed bias in the extra-tropics at mid level is associated with the $CO_2$ slicing and WV intercept height assignment methods.

The second study examines the diurnal signal in the statistics using Hovmoeller plots for February 2009, binned as a function of time-of-day (e.g. Figure 9).

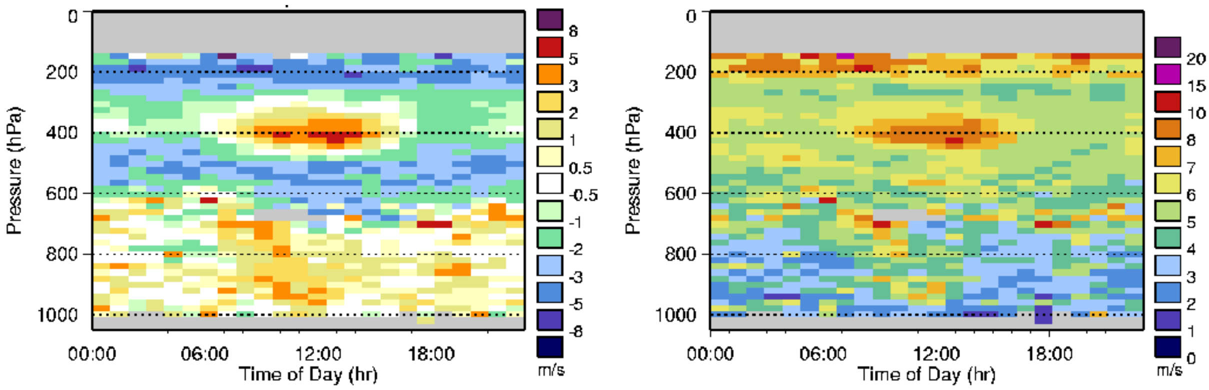


***Figure 9:*** **Hovmoeller plots as a function of time of day of (left) O-B speed bias and (right) mean vector difference for Meteosat-9 IR 10.8 NH AMVs over land for February 2009.**

The most prominent feature seen in this investigation was a fast speed bias (raised mean vector difference) during day time hours for the Meteosat-9 NH winds over land. On further examination this feature is most pronounced at 20N-30N over Africa, the location of the sub-tropical jet. In this region there is a large vertical wind shear. One possible explanation is that the speed bias difference is related to a systematic height assignment difference between day time and night time. AMV assigned heights for 0 UTC and 12 UTC on 16 February 2009 (Figure 10) are consistent with this hypothesis, with the night-time heights being higher in the atmosphere and more consistent with other cloud top pressure products. The day time fast bias could point towards an inadequate representation of the large diurnal temperature range of the desert surface, in turn leading to erroneous height assignments. EUMETSAT believe this is related to the poor temporal resolution of the forecast surface temperature used in the radiative transfer model. This is currently interpolated from a 12-18 hour forecast from ECMWF, but may be helped by using forecast data at 3 hour intervals in the future.

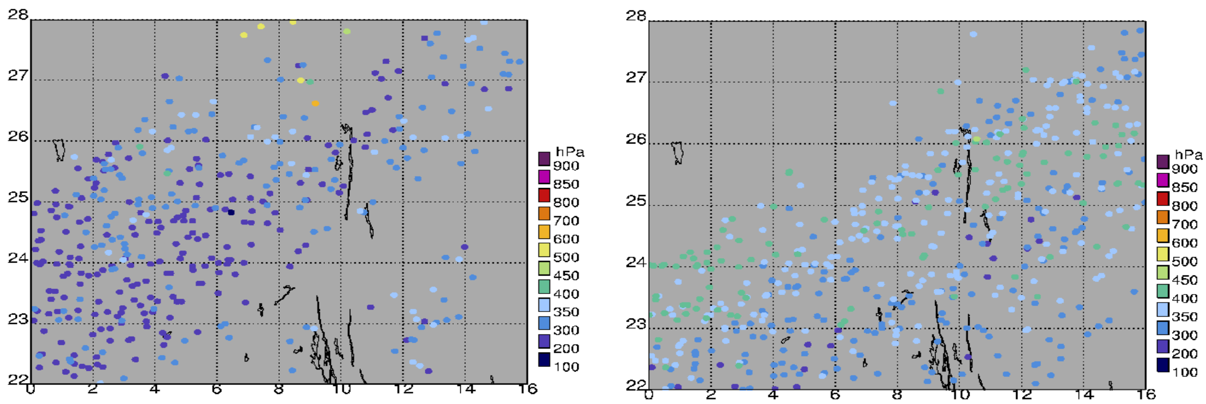


***Figure 10:*** **Plots of Meteosat-9 IR 10.8 AMV height assignment for (left) 2100-0300 UTC and (right) 0900-1500 UTC on 16 February 2009.**

## FUTURE WORK

Future work will involve:

- Continuing to add the latest monthly monitoring plots each month
- Producing analysis reports every 2 years to coincide with the International Winds Workshops.

- Adding new datasets to the monitoring as soon as is practically possible to provide users and producers with early feedback. The FY-2C/D winds are a candidate for the future.
- Improving the existing plots where deficiencies are identified.
- Maintaining the information on AMV usage at NWP centres and increasing the number of NWP centres contributing.
- Extending the range of one-off investigations

Other possible developments dependent on interest include:
- Provision of real-time monitoring.
- Provision of extra monthly plots e.g. Hovmoeller plots. These can be used to investigate temporal variability in the bias characteristics (e.g. Figure 11).

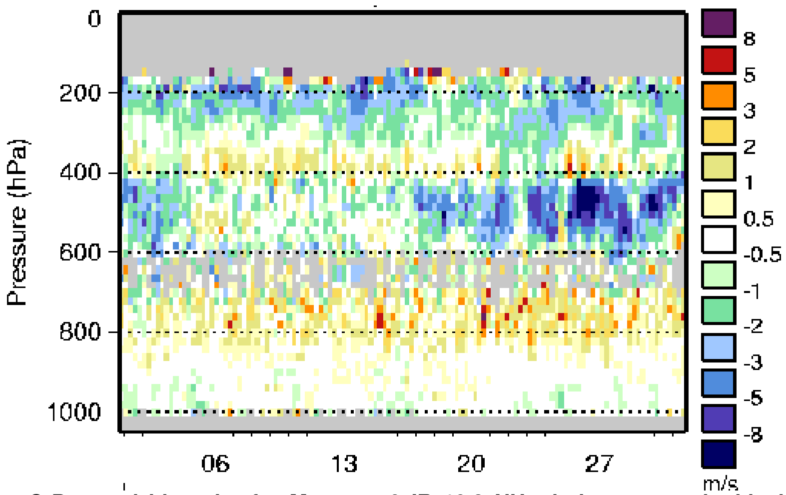


***Figure 11:*** **Hovmoeller O-B speed bias plot for Meteosat-9 IR 10.8 NH winds compared with the Met Office model background for October 2008.**

## SUMMARY

The NWP SAF AMV monitoring has been available since 1999. The main aim is to address one of the key challenges for AMV data which are their complicated error characteristics. Over the last 10 years the monitoring pages have undergone rolling developments to make it a more useful resource for AMV producers and users. This has included introduction of new types of plot, redesign of the web page lay out and introduction of new sections e.g. showing AMV usage in NWP and one-off investigations. We have also committed to generating analysis reports every 2 years to coincide with the International Winds Workshops. The intention is to present highlights at the workshop and to discuss key results. We are always keen to receive feedback on features identified in the reports and ideas for future developments. These can be emailed directly or sent via the NWP SAF feedback form.

## REFERENCES

Holmlund, K., 1998. The utilization of statistical properties of satellite-derived atmospheric motion vectors to derive quality indicators. *Weather Forecasting*, **13**, 1093-1104.

Key, J., W. Straka III, D. Santek, C. Velden and R. Dworak, 2006. Satellite-derived winds at direct broadcast sites in the polar regions. Proceedings of the 8th International Winds Workshop, Beijing – available from http://cimss.ssec.wisc.edu/iwwg/iwwg_meetings.html

Key, J., D. Santek, C. Velden, J. Daniels and R. Dworak, 2008. The polar wind product suite. Proceedings of the 9th International Winds Workshop, Annapolis, USA – available from http://cimss.ssec.wisc.edu/iwwg/iwwg_meetings.html