NWP SAF

Satellite Application Facility
for Numerical Weather Prediction

Document NWPSAF-MO-TR-022

Version 1.2

14/02/07

Third Analysis of the data displayed on the NWP SAF AMV monitoring website

http://www.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/index.html

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This documentation was developed within the context of the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWP SAF), under the Cooperation Agreement dated 16 December, 2003, between EUMETSAT and the Met Office, UK, by one or more partners within the NWP SAF. The partners in the NWP SAF are the Met Office, ECMWF, KNMI and Météo France.

Change record			
Version	Date	Author / changed by	Remarks
1.1	14/12/07	Mary Forsythe	First draft ready for review
1.2	14/02/08	Mary Forsythe	Updated following review by Roger Saunders

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Mary Forsythe, Roger Saunders

1. Introduction

The main aim of the NWP SAF AMV monitoring analysis reports is to better understand errors in the AMV data in order to aid improvements to the derivation and the assimilation, with the ultimate aim of improving NWP forecasts. For a fuller discussion of the aims and background see the second analysis report (Forsythe & Doutriaux-Boucher, 2005). This analysis and follow on analyses will act as updates to the second analysis.

The format of the report is similar to the second analysis with sections highlighting recent developments, features identified in the monitoring and a revised action list. There is also a new section providing feedback on new data types.

2. Recent developments

The AMV monitoring on the NWP SAF site has undergone a number of changes in the two years since the second analysis report was produced.

- The site layout has been updated to enable easier navigation.
- Following a request at the 8th International Winds Workshop, 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 (the Met Office and ECMWF).
- An information page has been provided detailing the pre-filtering, statistics calculations and intermediate data formats for those NWP centres considering contributing to the monitoring.
- In the second analysis report it was noted that there were several inconsistencies between the Met Office and ECMWF AMV monitoring which made it harder to perform direct comparisons. The most problematic of these was due to inconsistent pre-filtering such that the plots did not always use the same data. This has been addressed.
- The density plots have been updated to use a standard colour scale to enable easier comparison and the numbers enlarged to improve clarity.
- Vector plots have been added for both centres. These provide useful additional information on the directional bias in the data and in some cases (e.g. Feature 2.7) have provided clues to possible height errors.
- The pre-filtering has been updated to use the EUMETSAT-designed model independent QI and is set to 80 for all geostationary winds and 60 for all polar winds.
- The colour scales used in the plots have been updated and expanded to provide more information and improve clarity.
- Several new datasets have been added over the last two years including the AVHRR polar winds, the direct broadcast MODIS winds and the unedited NESDIS GOES and MODIS winds. The aim is to continue to add new datasets as soon as is practically possible to provide users and producers with early feedback. The FY-2C winds are a candidate for the future. A new section has been added to this analysis report to provide a summary of new data types (see Section 4).

For further information on future plans see the action list at the end of this document.

3. Methodology

3.1. NWP SAF AMV monitoring

There are four types of plot available from the NWP SAF AMV monthly monitoring page (see Figure 1). The first is a density plot of observation wind speed against background wind speed for different satellite, channel, pressure level and latitude band combinations. The second type is a map of wind speed bias, mean vector difference (mvd), normalised root mean square vector difference (nrmsvd) and number plotted for different channels and satellites at different pressure levels. The third type is a zonal plot showing the same set of statistics as for the map plots but as a function of latitude and pressure. Together the map and zonal plots highlight geographical areas where there is significant mismatch between observations and model backgrounds. The most recent addition are the vector plots which show the mean observed vector, the mean background vector and the mean vector difference.

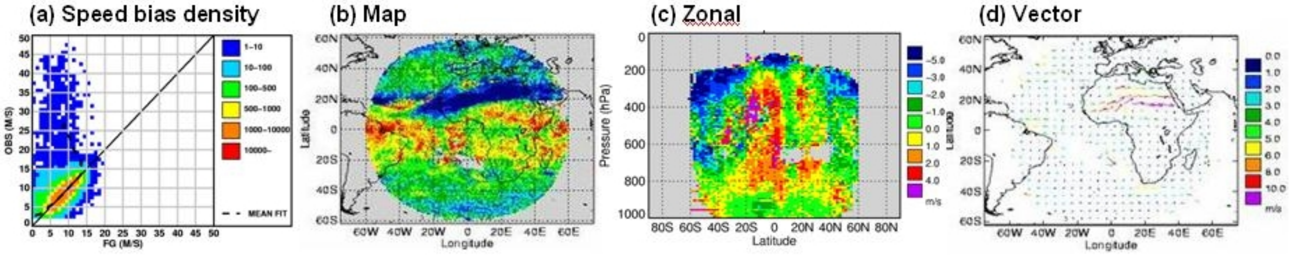
(a) Speed bias density
(b) Map
(c) Zonal
(d) Vector

Figure 1: Examples of the monthly O-B statistics plots displayed on the NWP SAF AMV monitoring site: (a) density plot of observation wind speed against background wind speed, (b and c) map and zonal plots of O-B wind speed bias and (d) vector plot showing the 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. 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. Currently only the Met Office and ECMWF model backgrounds are used, but more NWP centres may be involved in the future.

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). Throughout this document NH is used to refer to the area north of 20N, SH is used to refer to the area south of 20S and the tropics is used to refer to the area between 20S and 20N.

3.2. Model best-fit pressure comparisons

In order to better understand the features observed in the NWP SAF monitoring and to identify possible causes, it has been informative to make use of additional statistics. One of the statistics that can be very useful is a comparison of the 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. No vertical interpolation is carried out, but the model levels are typically only 30 hPa apart. Three filters are then applied to the data.

1. A model independent quality indicator threshold of 80 was applied in order to remove data where the vector may be in error.

2. Winds with a minimum vector difference of greater than 4 m/s were removed so as to avoid cases where there is no good agreement between the AMV and the model wind at any level.

3. Winds that have a vector difference less than the minimum vector difference + 2 m/s outside of a band +/- 100 hPa from the best-fit pressure level were removed. This is designed to eliminate cases where there are secondary minima or very broad minima; in both cases the best-fit pressure is not well constrained (see Figure 2).

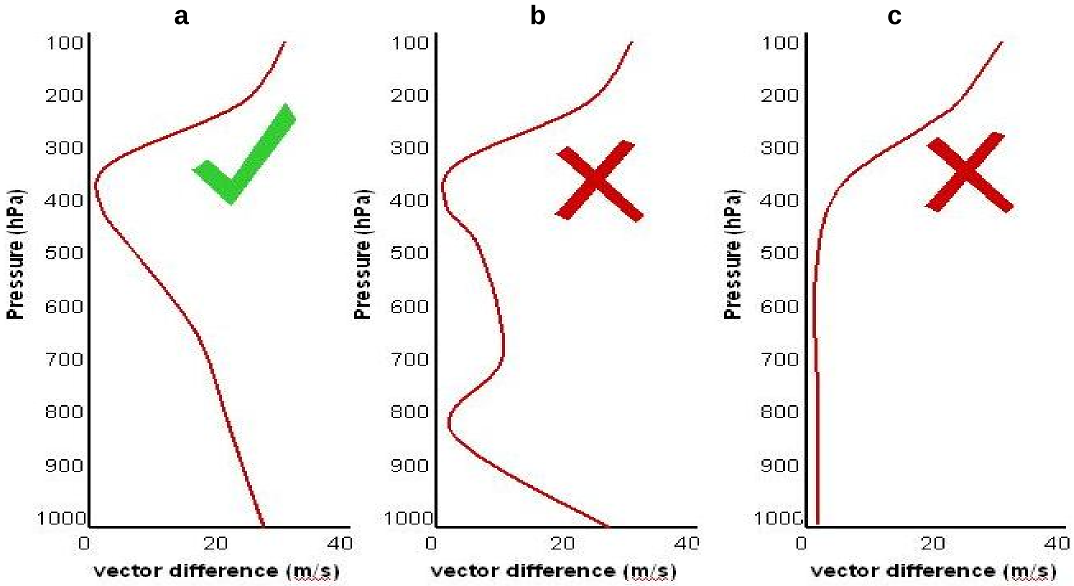

Figure 2: *Illustrations of vector difference profiles where (a) there is a unique well-defined minimum vector difference, (b) there is a prominent secondary minima and (c) the minimum vector difference is very broad. In (b) and (c) the best-fit pressure is not well constrained; these cases are removed from the statistics.*

The best-fit results can be displayed in a number of ways to better understand possible errors in the height assignment. For example it can be useful to compare the mean difference and root mean square difference between the AMV pressure and best-fit pressure as a function of pressure level, channel and height assignment method. As a final comment, it is worth remembering that care is required in interpreting these results as there will be contributions from errors in the model background wind field and some AMV cases will not yield unambiguous best-fit pressures.

4. Assessment of new AMV observation types

4.1. Introduction

A new feature in this analysis is the inclusion of a section providing an assessment of new observation types that have been added to the NWP SAF report. The new data types considered in this report are the unedited NESDIS winds, the direct broadcast MODIS winds and the NOAA 15-18 AVHRR polar winds.

4.2. The unedited NESDIS winds

This section expands on some initial results with the unedited GOES and MODIS winds presented in the second analysis report. The unedited winds were added routinely to the NWP SAF monitoring with the April 2006 plots following a request at the 8th International Winds Workshop. In this report I use the term unedited to refer to the wind data before the pressure and speed adjustment in the autoeditor step of the NESDIS and CIMSS processing, but note this is not the raw wind data; other checks are applied in the post-processing. For more information on the autoeditor see Hayden and Purser, 1995.

The main reason for using the autoeditor is to improve the quality of the final product and several NWP centres prefer this approach. There are, however, several disadvantages. Firstly, although the model background is given low weight in the autoeditor analysis, it introduces an extra dependency on the model, particularly in the more data sparse areas. The autoeditor may also increase the interdependency of the AMVs on their surrounding observations, potentially increasing the spatially correlated error. Thirdly, the quality indicators are calculated before the autoeditor step and so their relationship to the final winds may be less meaningful. Fourthly, the application of the speed increase is limited geographically and could lead to artificial speed gradients at the boundaries. Finally, the autoeditor modifications may make it harder to understand what the errors are due to. An example of this is the slow bias seen at high level in the unedited polar IR data discussed in Feature 3.4. This feature is masked in the edited product by the autoeditor speed increase. As one of the aims of this analysis is to better understand possible sources of error, it is primarily the unedited winds which are considered in Section 5 of this report. The operational assimilation of the unedited NESDIS winds instead of the final (edited) product is also a future possibility. Aside from the reasons noted above, it may be easier to represent the errors of the unedited data, which may have simpler error characteristics.

There are two main steps in the autoeditor. The first is to increase the speed of IR and cloudy WV winds above 300 hPa, faster than 10 m/s and polewards of 25N/S to counteract a frequently-reported slow bias in the jets. Figure 3 shows where the speed check is applied. This shows the expected pattern dependent on speed and latitude, with a couple of exceptions. Firstly there are some winds (~0.5%) that do not have their speed increased despite fulfilling the necessary criteria. On further investigation these winds have speeds above 60 m/s and have identical pre and post-autoeditor pressures. This may or may not be significant as there are examples of winds which fulfil one or other of these criteria and do have their speed increased in the expected way. Secondly there are some winds which have their speed increased even though they are below 300 hPa (~4% of data between 300-500 hPa). Both points have been raised with NESDIS.

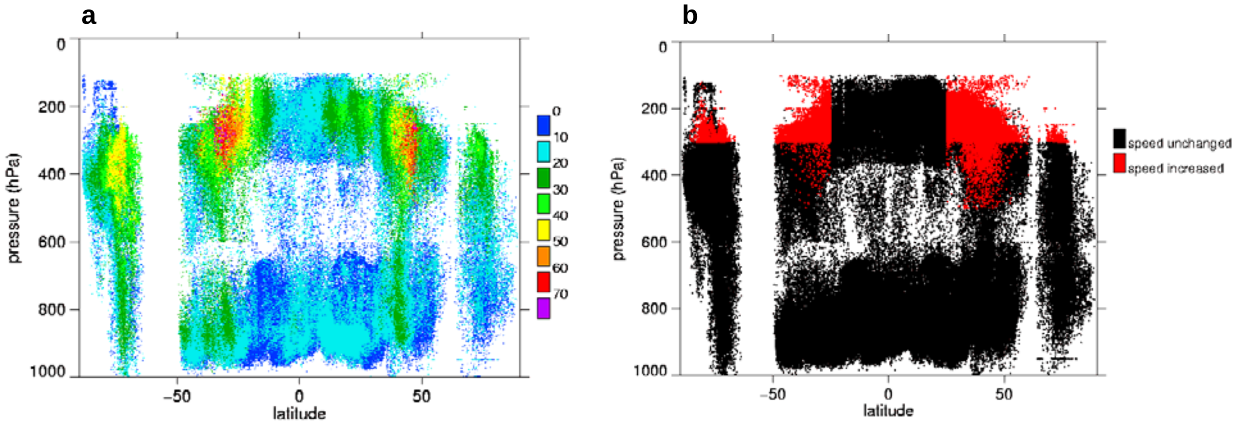

Figure 3: Plots showing (a) the unedited AMV speed and (b) whether the autoeditor speed increase is applied for one day of NESDIS GOES and MODIS winds.

The second step is to adjust the pressure of the AMVs to better agree with surrounding observations and a model background wind field. The density plot in Figure 4 shows that most winds are moved less than 100 hPa, but there are some, particularly at high level, which are moved by 250 hPa or more. In general there is a fairly even distribution about the 1:1 line.

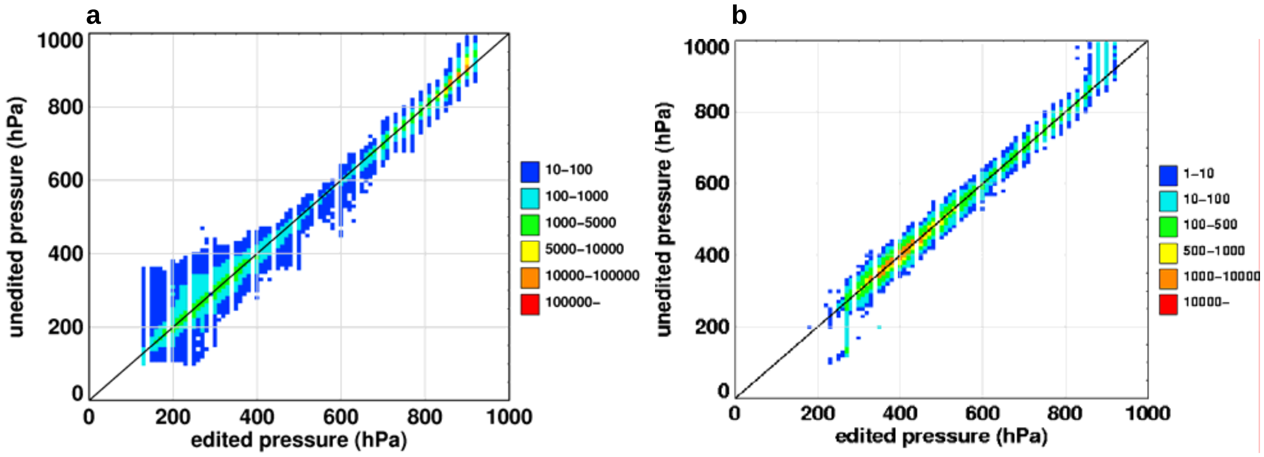

Figure 4: Density plot of unedited pressure against edited pressure for one day of (a) GOES-10 and GOES-12 winds and (b) one day of NESDIS MODIS winds.

Overall the autoeditor step improves the GOES O-B statistics with most obvious impact at high and mid level (e.g. Figure 5). It is less clear whether the autoeditor is advantageous for the MODIS winds (see Figure 6).

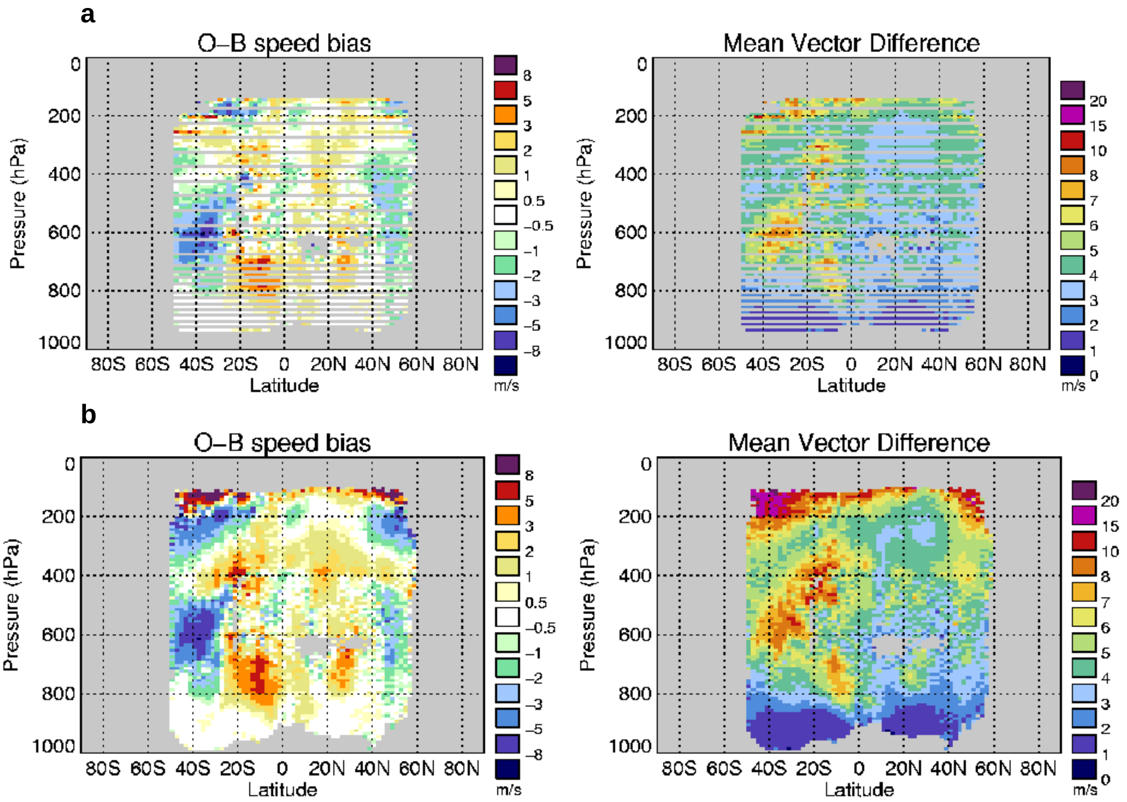

***Figure 5:** Zonal plots showing the O-B speed bias and mean vector difference for (a) the edited GOES-12 IR winds and (b) the unedited GOES-12 IR winds for August 2007 compared with the Met Office model background.*

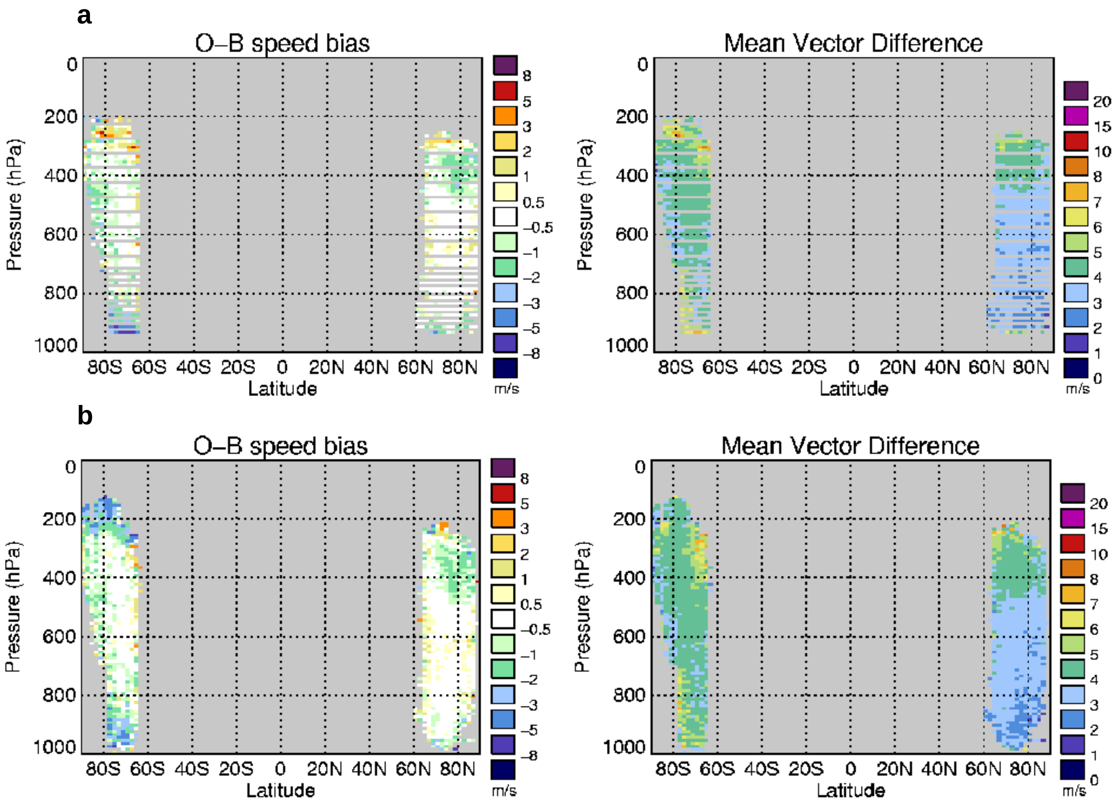

***Figure 6:** Zonal plots showing the O-B speed bias and mean vector difference for (a) the edited Terra IR winds and (b) the unedited Terra IR winds for August 2007 compared with the Met Office model background.*

The autoeditor speed adjustment removes much of the slow bias in the jet regions, although there is a suggestion that some winds are over-corrected leading to a fast bias (see Figures 5 and 6 and further discussion under Features 2.11 and 2.19 in the second analysis report). The speed adjustment was introduced several years ago when the slow bias in the jet regions was bigger. If a speed adjustment is still necessary it might be expected that a comparison of the edited speed and model speed at the best-fit pressure location (as shown in Figure 7a) would yield a better match than a similar comparison for the unedited speed (Figure 7b). This is not the case. They are largely similar, but the unedited speed shows a better match at higher wind speeds where the edited winds tend to be too fast.

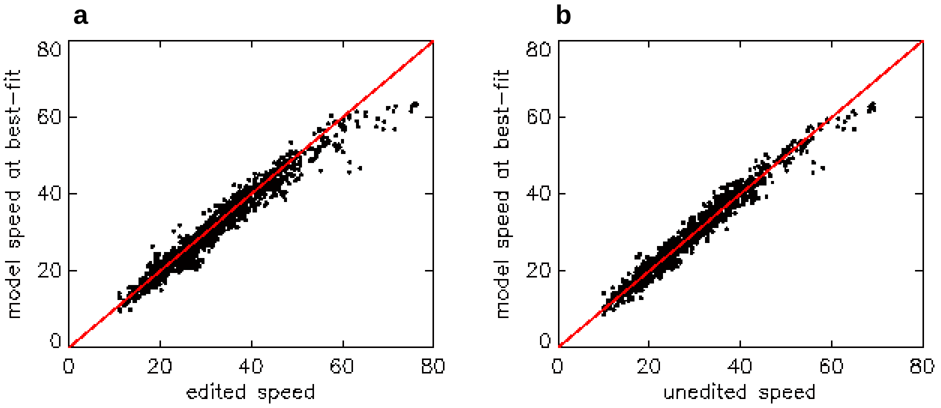

Figure 7: *Comparison of the model speed at the model best-fit pressure location to (a) the edited speed and (b) the unedited speed for a small sample of GOES-12 data on 29th March 2006. The data has been filtered to only include the AMVs where a speed adjustment was made.*

The best-fit pressure statistics in Figure 8 show that there is a similar pattern in the height bias for the edited and unedited winds relative to model best-fit, but the standard deviation is slightly improved for the edited data.

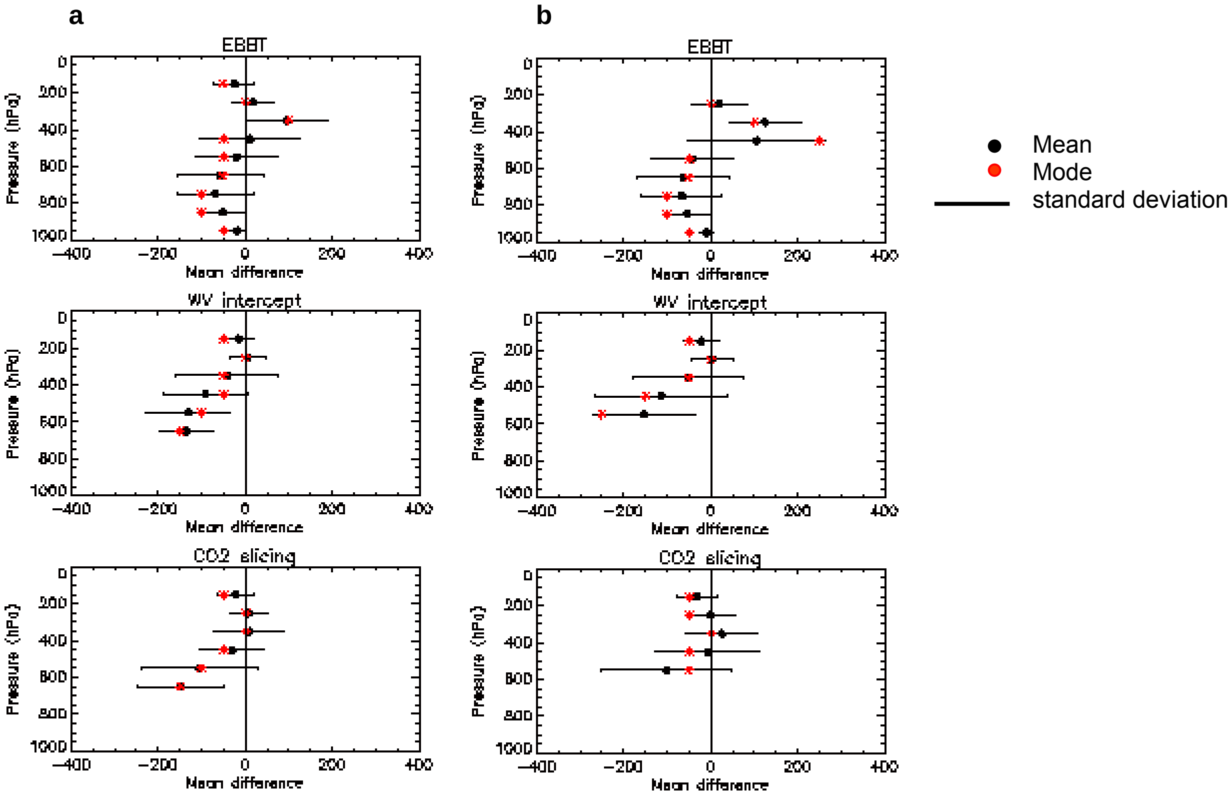

Figure 8: *Mean difference between the observed pressure and model best-fit pressure for (a) the edited GOES-12 IR winds and (b) the unedited GOES-12 IR winds, subdivided by height assignment method applied.*

Overall the autoeditor step improves the statistics, at least for the GOES winds, but significant biases remain in both the heights (relative to model best-fit pressure) and the speeds. It is less clear whether the improved statistics will automatically lead to better analyses and forecasts for a number of reasons described earlier.

4.3. The direct broadcast MODIS winds

MODIS winds have been available from direct broadcast stations in Tromsø (Norway) and McMurdo Station (Antarctica) since mid-2006; see Key et al., 2006 for more information. More recently they have been produced at Sodankylä in Finland, but these are not yet included in the NWP SAF monitoring. Potential future stations include Fairbanks in Alaska and another station in Antarctica. The main advantage of the direct broadcast data is the improved timeliness of ~100 minutes relative to the conventional NESDIS polar winds (see Figure 9), however, they have also provided extra robustness during recent outages of the conventional data stream.

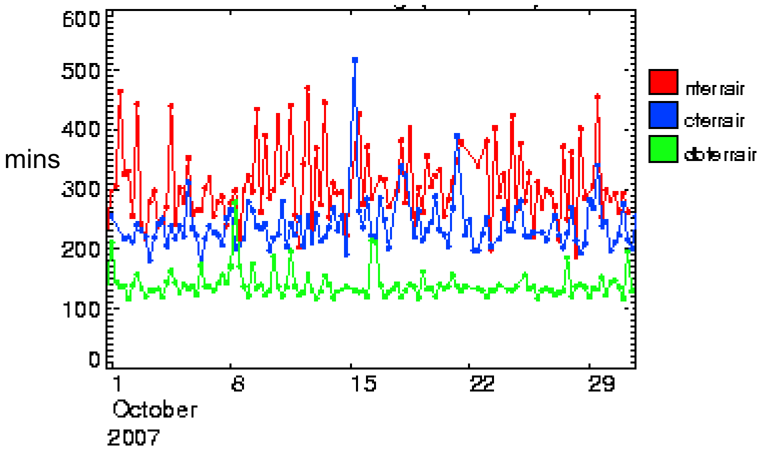

Figure 9: Mean time lag in minutes between observation time and receipt time for the NESDIS Terra IR winds (red), CIMSS Terra IR winds (blue) and direct broadcast Terra IR winds (green).

The direct broadcast winds only provide partial coverage (e.g. Figure 10) and only Terra can be received in the NH. Despite this, the improved timeliness means that ~25% more MODIS data was assimilated in the Met Office update runs when the direct broadcast winds were included. This is thought to be mainly due to improved coverage as the datasets are thinned together. The impact of the improved timeliness is most obvious in the shorter time cut-off main forecast runs where the percentage of MODIS data arriving in time is ~45% for the direct broadcast winds compared to only ~18% for the conventional NESDIS MODIS winds.

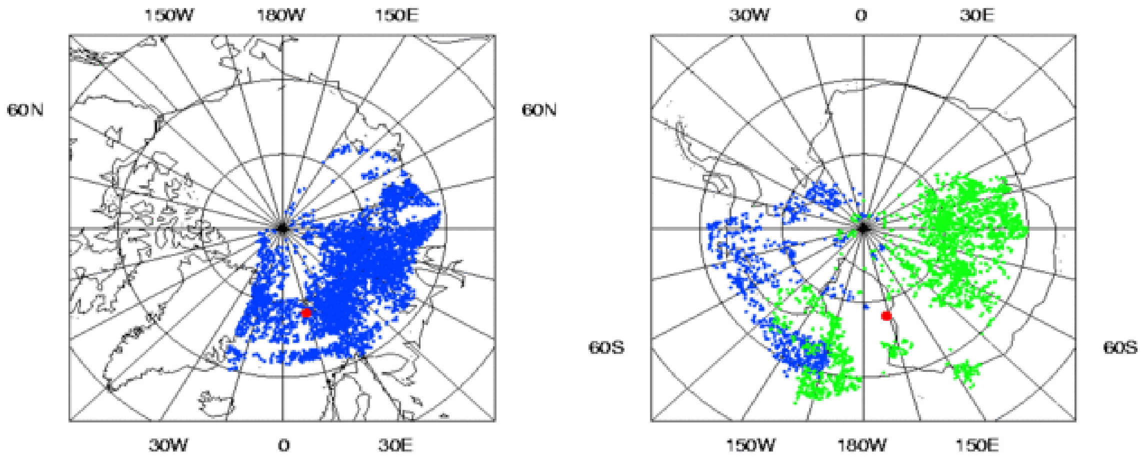

***Figure 10:** Data coverage plots showing the coverage of the direct broadcast MODIS winds from Tromsø (receiving station in Svalbard) and McMurdo Station for 0900-1500 on the 7 November 2006. Terra is shown in blue and Aqua in green. The red dots mark the approximate locations of the receiving stations.*

Until early 2008, there were some unexpected height assignment differences between the NESDIS and CIMSS AMVs. This is discussed further under Feature 3.6 in Section 5.5. The direct broadcast stations use the CIMSS processing software. It is therefore unsurprising that they show better agreement with the CIMSS MODIS winds than the NESDIS MODIS winds (see Figure 11). The largest differences are seen in the pressure comparisons, particularly at low level.

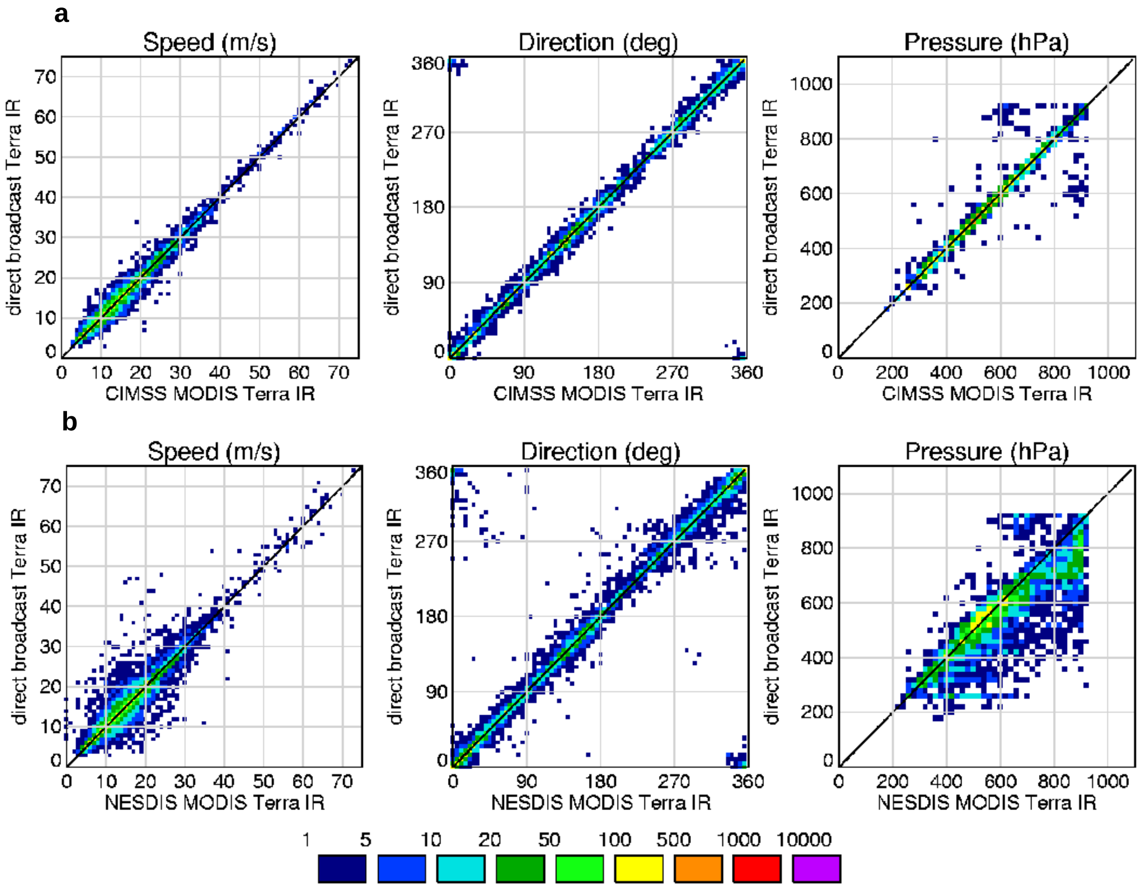

Figure 11: Plots comparing the speed, direction and pressure of collocated direct broadcast Terra IR winds and (a) CIMSS Terra IR winds and (b) NESDIS Terra IR winds for 10 days in November 2007. The collocation distance and time were 5 km and 10 minutes.

Ideally there should be good consistency between the NESDIS and direct broadcast MODIS winds as they are assimilated together. However, the overall quality of the direct broadcast winds is broadly comparable as shown by the root mean square vector difference statistics in Figure 12.

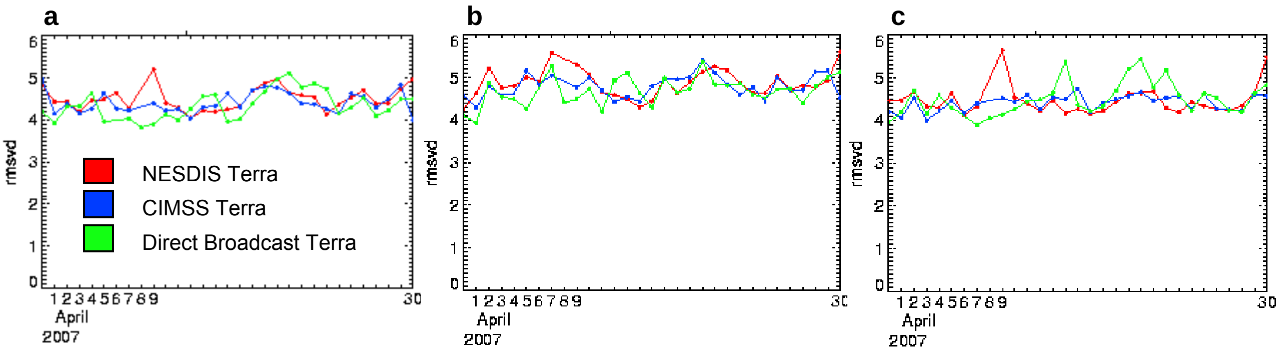

Figure 12: Time-series of root mean square vector difference for the NESDIS, CIMSS and direct broadcast Terra winds compared with the Met Office model background for April 2007: (a) IR, (b) cloudy WV and (c) clear sky WV.

4.4. The NOAA 15-18 AVHRR polar winds

The NOAA 15-18 AVHRR polar winds are produced at CIMSS using the same derivation software as used to generate the MODIS polar winds and have similar timeliness. The main difference between the MODIS and AVHRR winds is due to the channel availability. For MODIS, tracking is done in the IR and WV channels allowing AMV production in cloudy and clear sky areas. AVHRR does not have a WV channel and so AMVs are restricted to those generated from tracking clouds in the IR channel. The extra coverage with the WV channel can be seen by comparing the coverage of all MODIS winds (Figure 13a) and the coverage of only IR MODIS winds (Figure 13b). A second difference is that the global GAC AVHRR data is only available at 4 km resolution so the AVHRR winds are slightly sparser than the MODIS IR winds (compare Figures 13b and c). The number of AVHRR winds produced per satellite per month is approximately 50% of the number of MODIS IR winds produced per satellite per month.

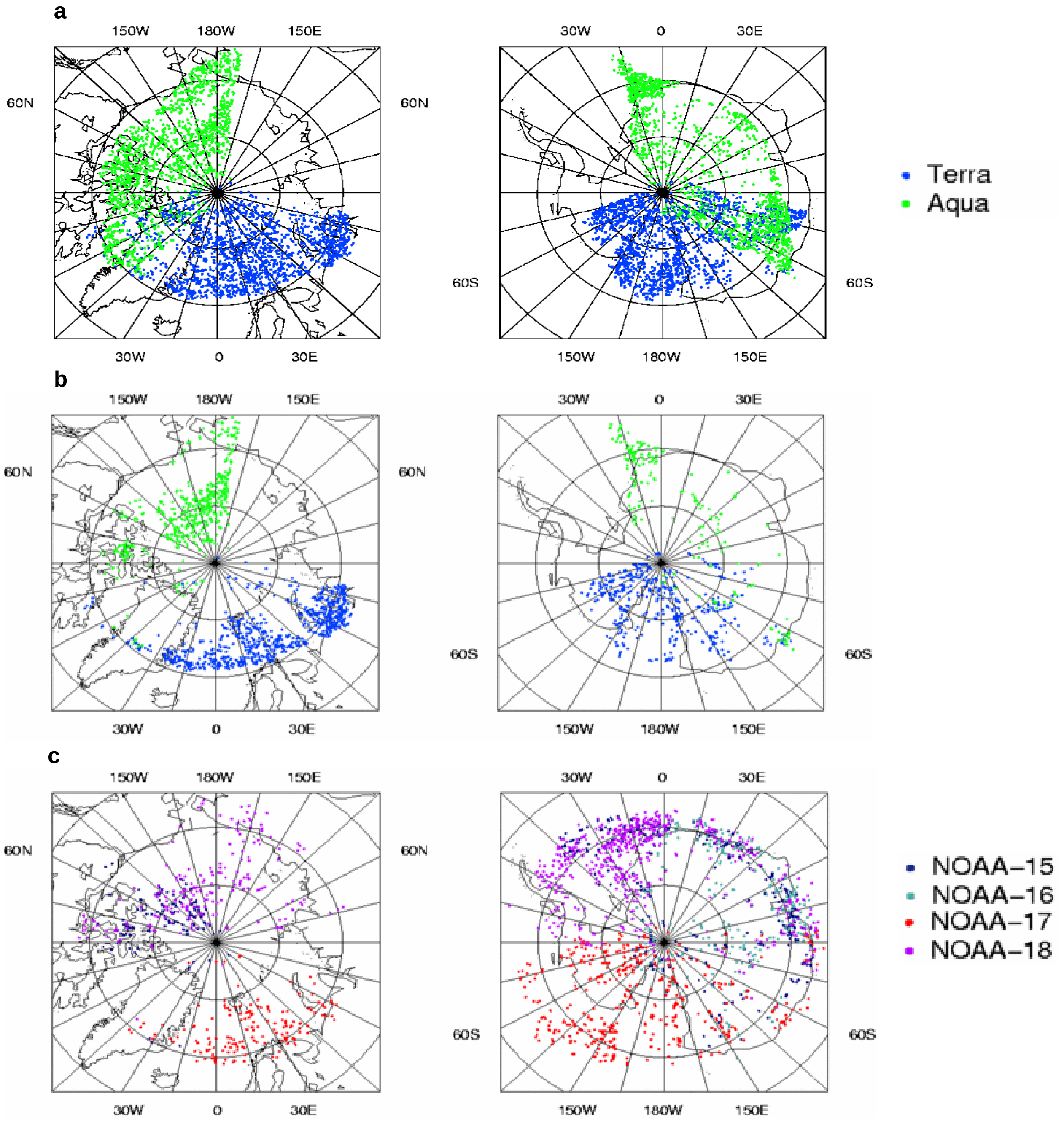

Figure 13: *Data coverage plots showing the coverage of (a)all NESDIS MODIS winds, (b) NESDIS MODIS IR winds and (c) CIMSS AVHRR IR winds for 1500-2100 on the 3 June 2007.*

The AVHRR IR winds show comparable patterns of bias and mean vector difference to the CIMSS and NESDIS MODIS IR winds (see Figure 14). Overall the statistics are similar, but there is a tendency for the AVHRR winds to have slightly poorer statistics at high level, particularly in the SH. In August the monthly root mean square vector difference compared with the Met Office model background was 6.2 m/s for the high level SH AVHRR winds compared to 5.3 m/s for the high level SH MODIS IR winds. There are a number of reasons why this may be including the unavailability of the WV intercept height assignment method, the lower resolution or differences between the IR channels on MODIS and AVHRR.

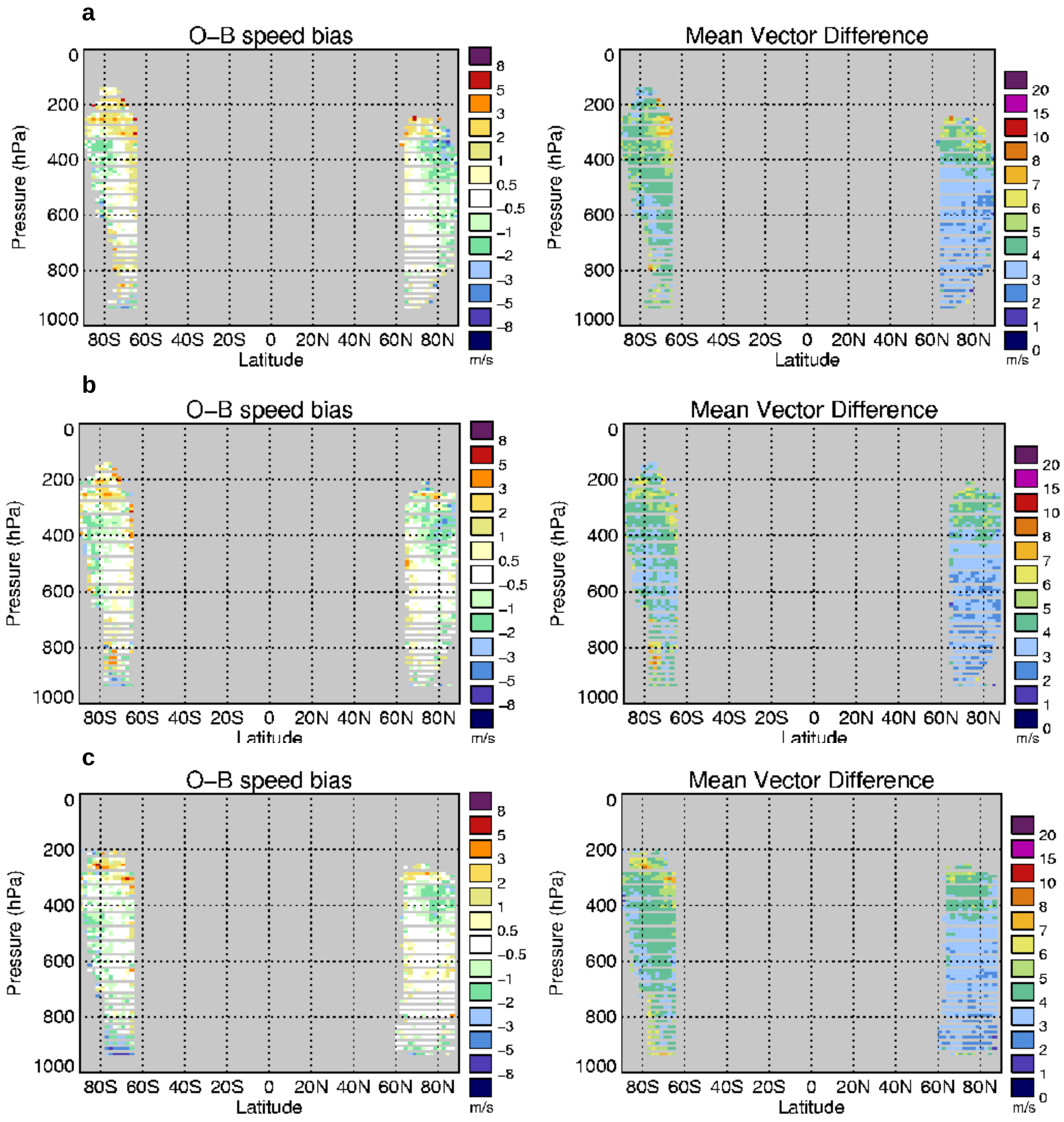

Figure 14: *Zonal O-B speed bias and mean vector difference plots for (a) NOAA-18 IR, (b) CIMSS Terra IR and (c) NESDIS Terra IR compared with the Met Office model background for August 2007.*

Collocations of AVHRR and CIMSS MODIS winds show good agreement (e.g. Figure 15). The biggest pressure differences are seen between 300 and 600 hPa, with the AVHRR winds more often located lower in the atmosphere. These cases are mostly where the WV intercept approach has been used for the MODIS wind height assignment (not available for AVHRR winds).

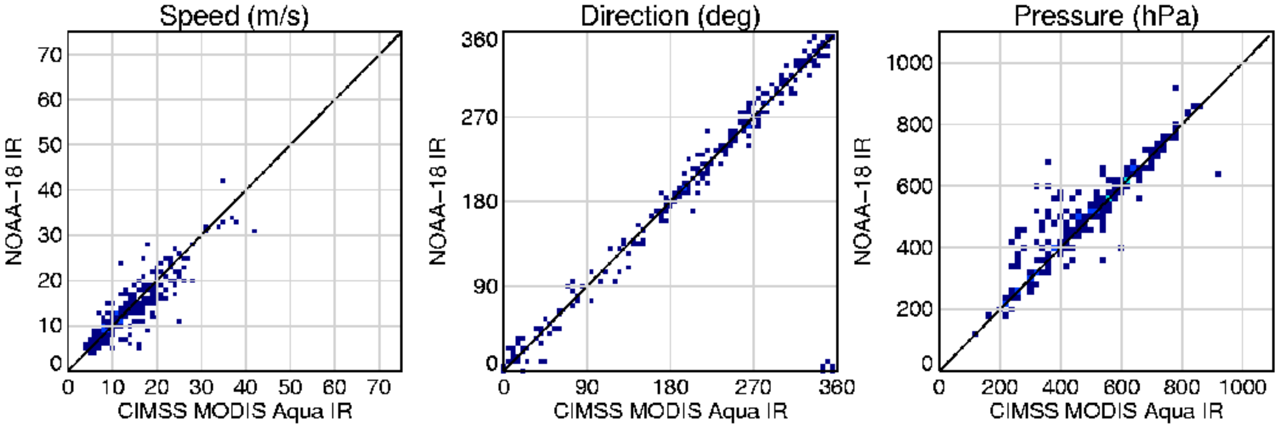

Figure 15: *Plots comparing the speed, direction and pressure of collocated NOAA-18 IR winds and CIMSS Aqua IR winds for August 2007. The collocation distance and time was 5 km and 10 minutes.*

The AVHRR winds cannot compete with the MODIS winds in coverage or number, but they do provide a source of historical polar wind data which can be assimilated in reanalyses (Dworak et al., 2007). They may also provide a small improvement in the coverage and resilience of real-time NWP. In a test case thinning the AVHRR and MODIS winds together, an extra 234 polar winds were assimilated; an increase of 12%. Looking ahead to the future, there is likely to be a gap in provision of WV polar winds. The AVHRR winds and follow on polar imager IR winds are likely to provide operational continuity. Data impact trials at ECMWF (e.g. Kelly & Thėpaut, 2007; Thėpaut et al., 2006) and GMAO (Riishogaard et al., 2006) suggest that assimilating only polar IR winds provides less benefit than assimilating IR and WV polar winds, but there is still a benefit.

5. Features observed in the O-B statistics plots

5.1. Introduction

In the second analysis report it was stated that the O-B statistics from the Met Office and ECMWF are very alike. This is still the case. The differences that exist are mostly in the tropics, which might be explained by the larger model biases in this region. Examples provided in this report are from the Met Office comparisons, but the ECMWF plots show similar results. Future analysis reports may look in more detail at the minor differences seen between the centres.

The format of Section 5 follows the structure of the second analysis report where features are discussed in turn; these are referenced x.y, where x is the number of the analysis report (3 for new examples and 2 for features noted in the second analysis) and y is the example number. Details are included of possible causes of the O-B features and, where relevant, actions that may help to alleviate the problems. For ease of reading, the geostationary AMV features are subdivided into low level (below 700 hPa), medium level (400-700 hPa) and high level (above 400 hPa), with a separate section for the polar AMVs.

Table 1 shows a summary of the status of the identified features and indicates whether further information is provided in this report. A few features described in the second analysis are no longer evident in the monthly O-B plots. In some cases this is due to known improvements in AMV derivation or bug fixes (e.g. Feature 2.17). These features are classed as closed and will not be reviewed in future analysis reports. Also note that the names of a few of the features from the second analysis have been updated to better reflect the pattern or cause.

As noted in the second analysis many of the features described 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 in the statistics for some satellites and channels in some areas as a result of improvements implemented to the AMV derivation by the producers.

Ref.	Feature	Resolved?	Update?
LOW LEVEL			
2.1.	GOES fast bias at low wind speeds	No	Yes
2.2.	Indian Ocean	No, but discussed under other sections - close	Discussed under other sections
2.3.	NE America winter slow speed bias	No	Yes
2.4.	Fast bias at 40S-60S for Meteosat satellites	No	No
2.5.	Trade wind fast bias	No significant signal - close	No
2.6.	Fast bias over Africa	No	Yes
2.7.	Spuriously fast Meteosat and MTSAT-1R winds at low level	No	Yes
MID LEVEL			
2.8.	Fast bias in the tropics	Improved	Yes
2.9.	Slow bias in the extratropics	No	Yes
3.1.	MTSAT-1R IR fast bias	No	Yes
HIGH LEVEL			
2.10.	Jet region slow bias	Improved	Yes
2.11.	NESDIS over-correction of slow bias in jets	No	No
2.12.	Indian Ocean fast bias at high level	Less obvious	No
2.13.	Tropics fast bias	No	Yes
2.14.	Very high level (above 180 hPa) Meteosat and unedited GOES fast bias	No	Yes
2.15.	Differences between channels	Improved	Yes
3.2.	Very high level (above 180 hPa) Meteosat tropical slow bias	No	Yes
3.3.	GOES-11 bias change at 180 longitude	No	Yes
POLAR AMVs			
2.16.	Number of MODIS IR winds	Improved	No
2.17.	CIMSS MODIS mid level fast winds	Yes (in May 2006)	No
2.18.	CIMSS MODIS slow winds	Yes	No
2.19.	High level fast speed bias in edited MODIS data	No	Yes
2.20.	Low level slow speed bias in polar IR data	No	Yes
3.4.	NESDIS MODIS IR slow streak	No	Yes
3.5.	CIMSS polar AMV problem in Sep-Oct 2007	Yes (in Oct 2007, second correction in Jan-Feb 2008)	Yes
3.6.	NESDIS-CIMSS polar AMV differences	Improved	Yes

Table 1: *A summary of the status of the features identified in the NWP SAF AMV monitoring.*

5.2. Low Level (below 700 hPa)

The main features of the low level wind field include: (1) faster winds below the jets in the extra-tropics (stronger in winter hemisphere), (2) faster winds associated with tropical cyclones, (3) tropical trade wind easterlies and (4) the seasonal Somali Low-level Jet (see Figure 9 in the second analysis report for example wind field plots). With a few exceptions, the low level AMVs have fairly low O-B mean speed differences, which partly reflects the lower wind speeds in this area.

Update on Feature 2.1. GOES fast bias at low wind speeds

It was noted in the second analysis that a fast bias is seen for the GOES low level winds in regions with a slow background wind speed (see Figure 16).

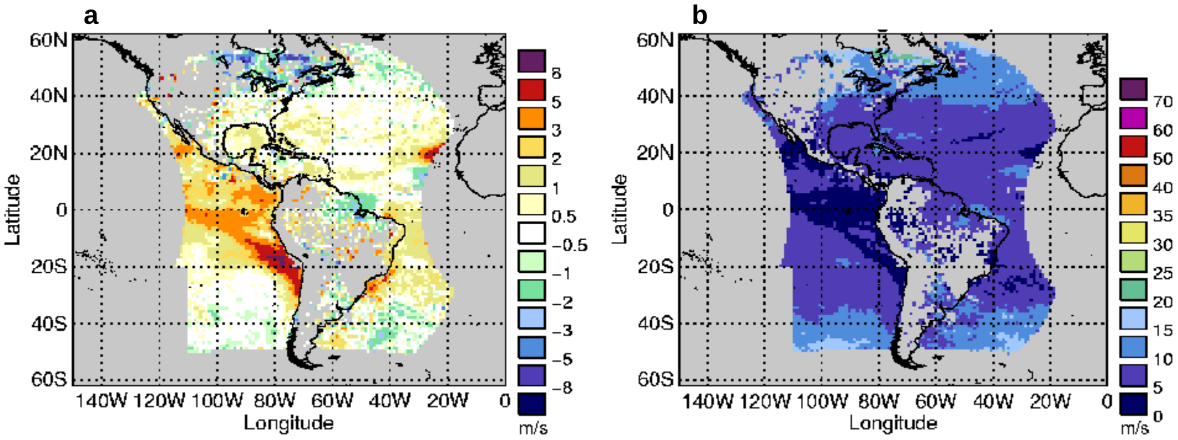

Figure 16: *Map plots showing (a) the unedited GOES-12 VIS O-B speed bias and (b) the mean background speed for October 2007 using the Met Office model background.*

The explanation put forward, which may still explain part of the problem, was that the slower AMVs are removed from the dataset in the NESDIS post-processing and this artificially generates a fast speed bias at low wind speeds. Recent results suggest that there are additional reasons for the fast speed bias. Figure 17 shows a density plot filtered by region and surface type. Some fast bias is inevitable due to the removal of the slow winds, but the data is also offset with the majority of winds being faster than the background.

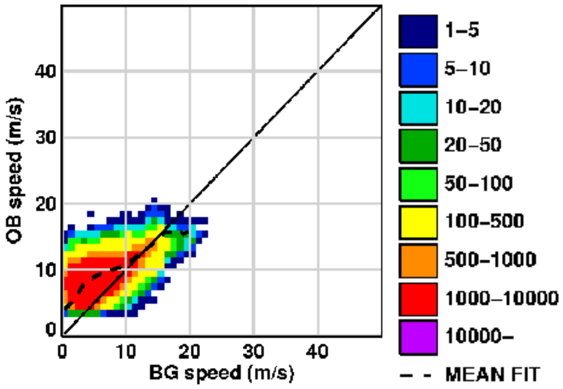

Figure 17: *Speed bias density plot for the unedited GOES-12 VIS winds for October 2007 compared with the Met Office model background. Data is restricted to over sea between 100W-70W and 20S-10N.*

Model best-fit pressure comparisons show that the GOES low level AMVs over sea, particularly those derived from the visible channel, are assigned much higher in the atmosphere than the model preferred position (see Figure 18). The EUMETSAT Meteosat-9 AMVs, by contrast, show less height bias.

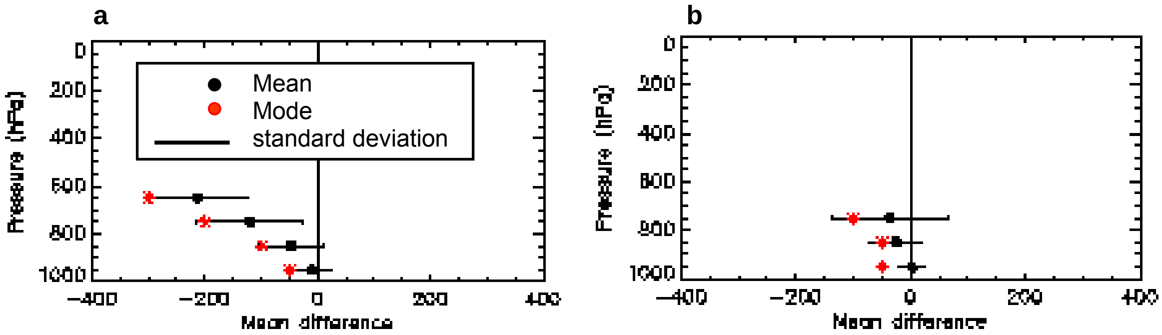

Figure 18: *Plots of mean difference between AMV assigned pressure and model best-fit pressure as a function of pressure in the atmosphere for (a) the unedited GOES-11 VIS winds and (b) the Meteosat-9 VIS 0.8 winds. The data is for the period 23 March – 23 April 2007 and restricted to AMVs over sea.*

The GOES high height bias is most evident in the stratocumulus inversion regions in the Pacific and Atlantic Oceans where the differences can be more than 200 hPa. Figure 19 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.

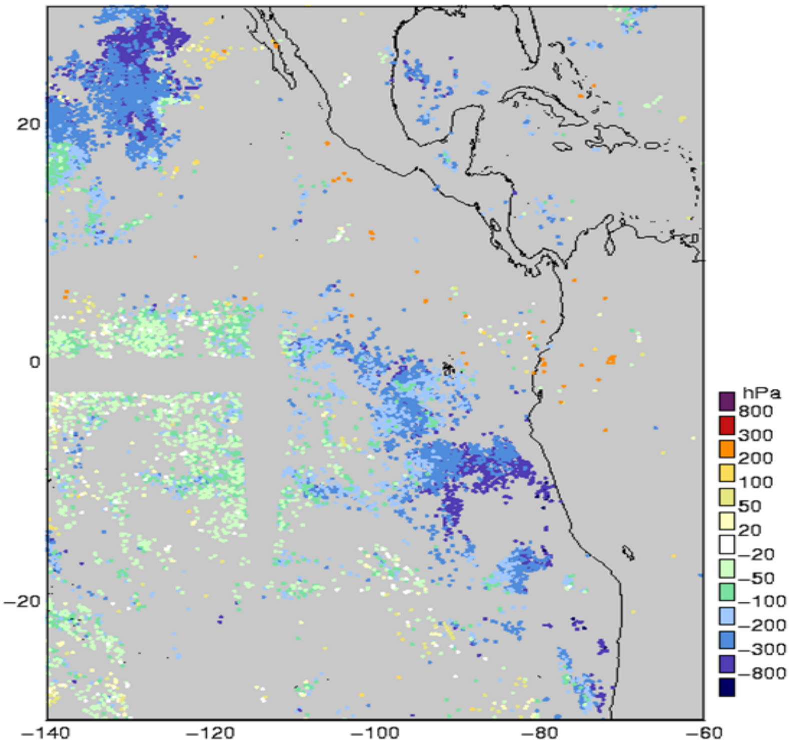

Figure 19: *Pressure difference between the observed AMV pressure and model best-fit pressure for the unedited GOES-12 VIS winds on the 3 July 2007 for data valid between 1500 and 2100 UTC. Note the large AMV high height bias (blue colours) off the coasts of Peru and Mexico.*

Assigning heights in inversion regions can be difficult; the results are very dependent on the resolution and quality of the forecast data and there can be multiple cloud top height solutions. The AMVs are not the only product to have difficulty in inversion regions. The MODIS cloud top height product was also found to have a high height bias relative to Calipso data (Robert Holz personal communication, Sep 2007). One situation that can give rise to a high height bias is if the inversion is not deep enough in the model profile as shown in Figure 20.

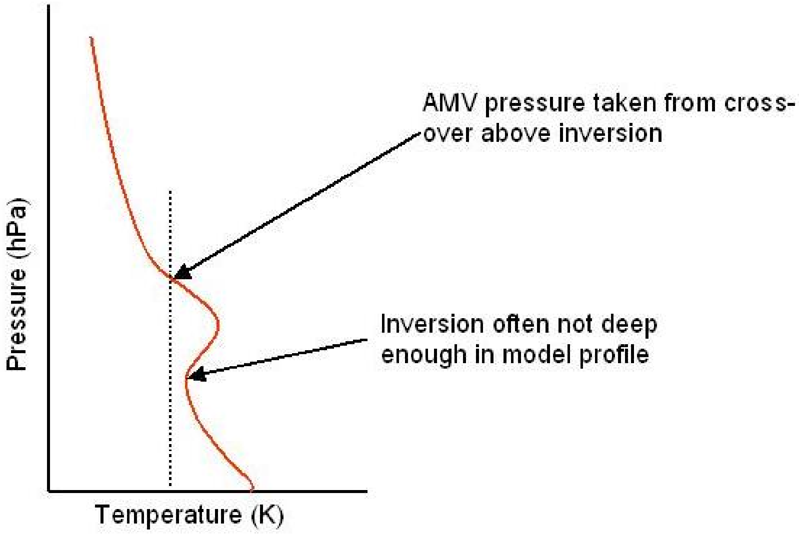

Figure 20: *Illustration of how a high height bias can occur in inversion regions.*

Can the derivation be improved to alleviate this high height bias tendency? Almost certainly yes, NESDIS use a limited number of forecast model levels in their height assignment. Improving the resolution and devising a strategy to handle multiple solutions in the inversion region are identified as candidates for reducing the problem in the future. EUMETSAT winds are less affected as an inversion correction is applied, but an improvement should be possible through use of the full model resolution forecast data (currently only use 32 levels).

From an NWP perspective, does the high height bias matter in these low wind speed regions? Investigations at ECMWF suggest that it does have an impact by tending to increase the speed of the analysis winds at ~700 hPa in the GOES inversion regions. ECMWF tested the application of an inversion correction in their observation processing, which led to improved consistency between forecasts and analyses. Although the height correction can be applied on the user side it would be preferable to fix this on the producer side. One remaining consideration for NWP is whether it is worth applying a low wind speed check which removes AMVs where the observation or background winds are less than the speed threshold required to move a cloud one pixel between image pairs in the AMV derivation. This would additionally help to alleviate any residual fast bias that is left as an artefact of the removal of slower AMVs.

Update on Feature 2.3. NE America winter low level slow speed bias

A slow speed bias is observed at low level over the Eastern USA and Canada (e.g. Figure 16a) during the winter months (September-March). The Hovmoeller plot in Figure 21 illustrates the onset of the speed bias during August-September 2007 at ~700 hPa.

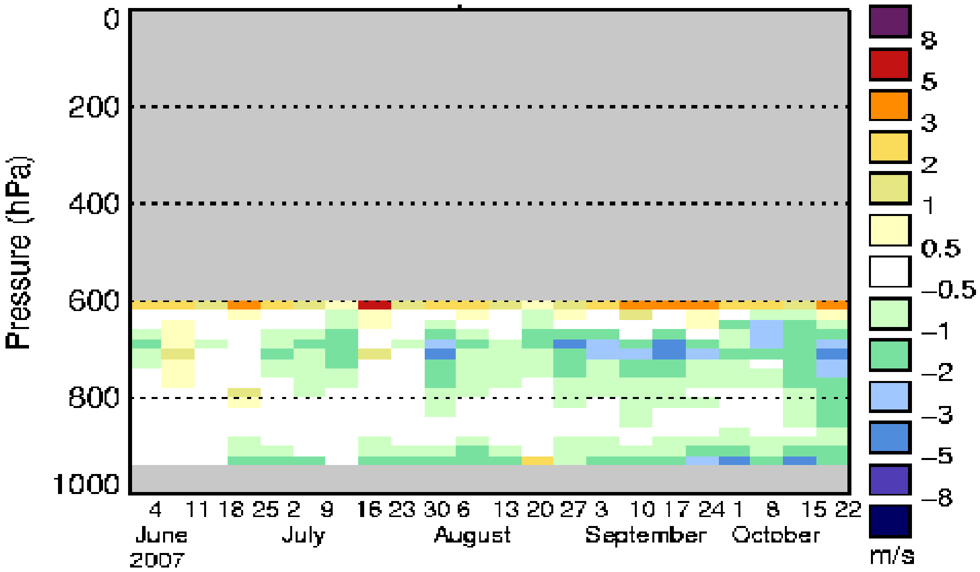

Figure 21: *Hovmoeller plot showing the unedited GOES-12 VIS O-B speed bias compared with the Met Office model background as a function of pressure for the NH from June to October 2007.*

It was noted in the second analysis that the location and timing broadly corresponded to the location and strength of the high level jet and that the feature is mostly confined to over land areas. Figure 22 shows an example where the slow speed bias over NE America is associated with observations which have a high height bias relative to the model best-fit pressure. A height bias will lead to a bigger speed bias when the vertical wind shear is greater. This is likely to occur when the high level jet is stronger, which may account for why the feature is seen only during the winter months. One reason why the feature may stop at the coastline could be a difference in the height assignment strategy between land and sea regions at NESDIS. A cloud base height assignment is used for low level winds over the sea, but not over land. By contrast, EUMETSAT apply a cloud base height assignment to low level winds over land and sea.

The limited investigations with model best-fit pressure are not sufficient to infer confidently that the AMVs are assigned too high, but this is certainly a plausible explanation. If correct, it may suggest either a need for improvements in cloud top height or that a cloud base method should be additionally applied over land.

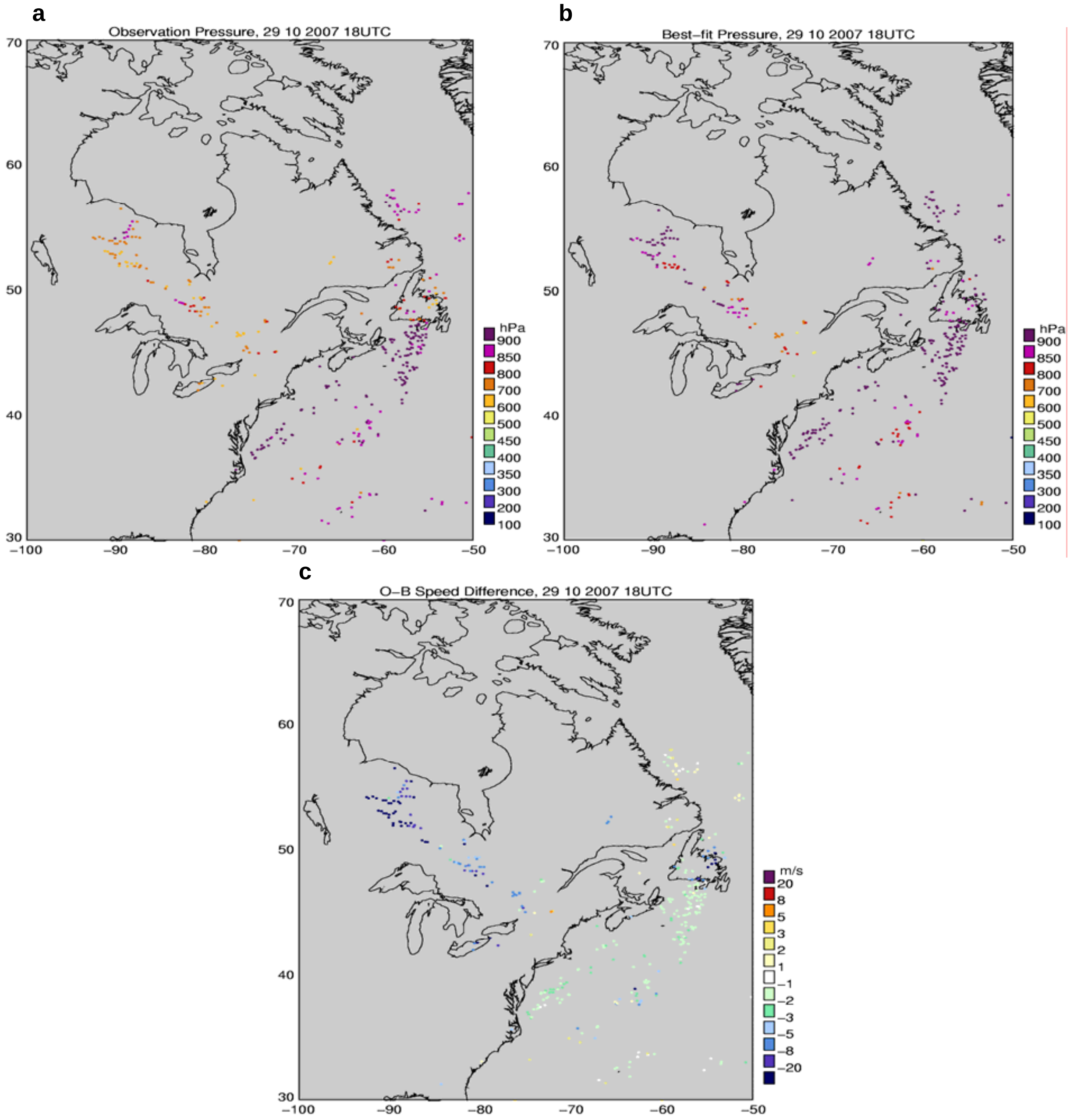

Figure 22: *Map plots showing (a) the unedited GOES-12 VIS pressure, (b) the model best-fit pressure for these observations and (c) the O-B speed difference for 1500-2100 UTC on 29 October 2007. The slow speed bias over Eastern Canada is mostly associated with winds which are assigned higher in the atmosphere than the model best-fit pressure.*

Update on Feature 2.6. Fast bias over Africa

In the second analysis report, a fast bias was identified during the summer months over the Sahara desert. A fast bias feature is still evident at around 15-20N as previously described, but there are also fast biases over other regions of Africa, Arabia and the Mediterranean region (e.g. Figure 23). It is also not clear that it is purely a summer feature, although there is some variation in the distribution of the bias from month to month, possibly reflecting variation in the wind field.

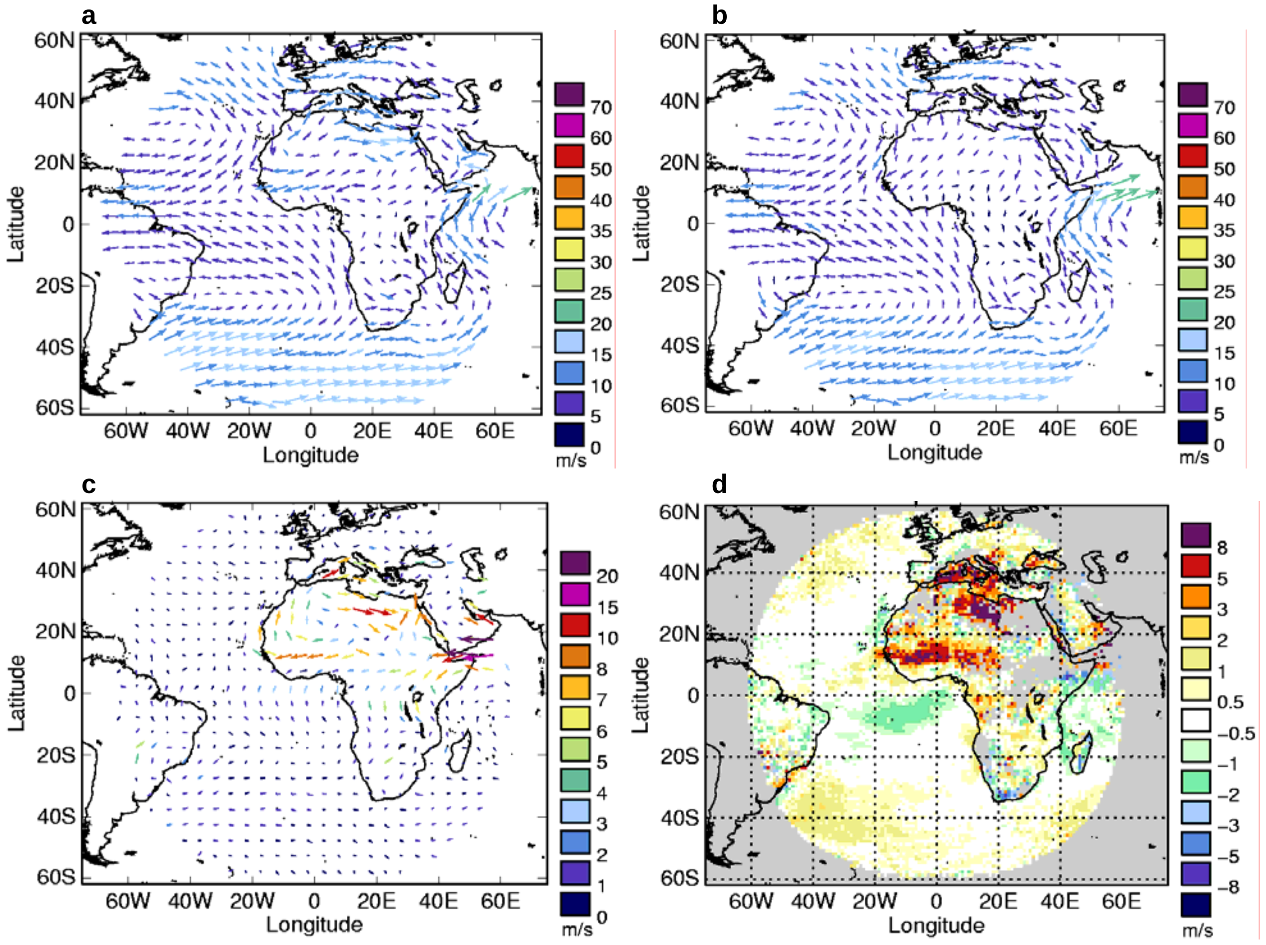

***Figure 23:** Vector plots showing (a) the mean observation, (b) the mean background and (c) the mean vector difference for Meteosat-9 IR low level winds for June 2007 compared with the Met Office model background. (d) shows the O-B speed bias plot of Meteosat-9 IR low level winds for June 2007 compared with the Met Office model background.*

This fast bias over land may have been exacerbated by a change to the MSG (Meteosat-8/9) derivation system in March 2007. This derivation change largely improved the MSG AMV statistics, but one exception was at low level over land. Figure 24 shows the observed-bestfit pressure distribution plots for the Meteosat-8 IR AMVs over land in the 800-900 and 900-1000 hPa categories. These show a subset of winds being assigned much lower than the best-fit pressure (by ~300 hPa). A low height bias could explain the observed fast speed bias over Africa. EUMETSAT are aware of height assignment problems over land and are looking at possible improvements to the height assignment strategy.

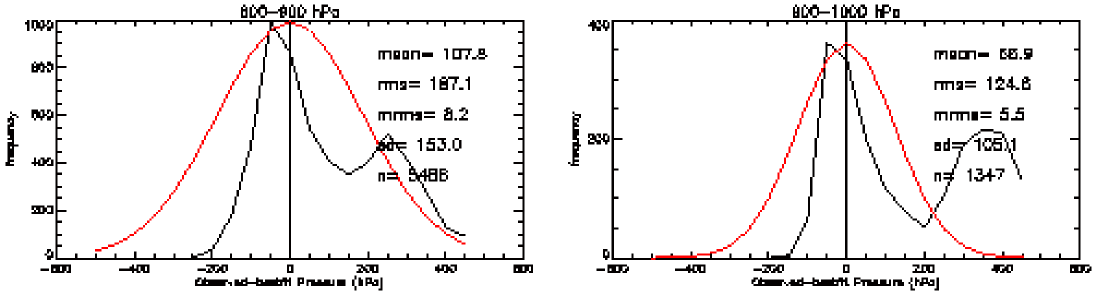

***Figure 24:** Distribution of observed-bestfit pressure (black curve) for Meteosat-8 IR AMVs over land for 23 March - 23 April 2007, separated into 100 hPa height bands. Note the secondary peak corresponding to AMVs which are assigned lower in the atmosphere than the best-fit pressure.*

Update on Feature 2.7. Spuriously fast Meteosat and MTSAT-1R winds at low level

The speed bias density plots, particularly for Meteosat and JMA winds, show a number of spuriously fast winds (e.g. Figure 25). The feature is most evident in regions with high vertical wind shear, but is not confined to regions beneath the jets.

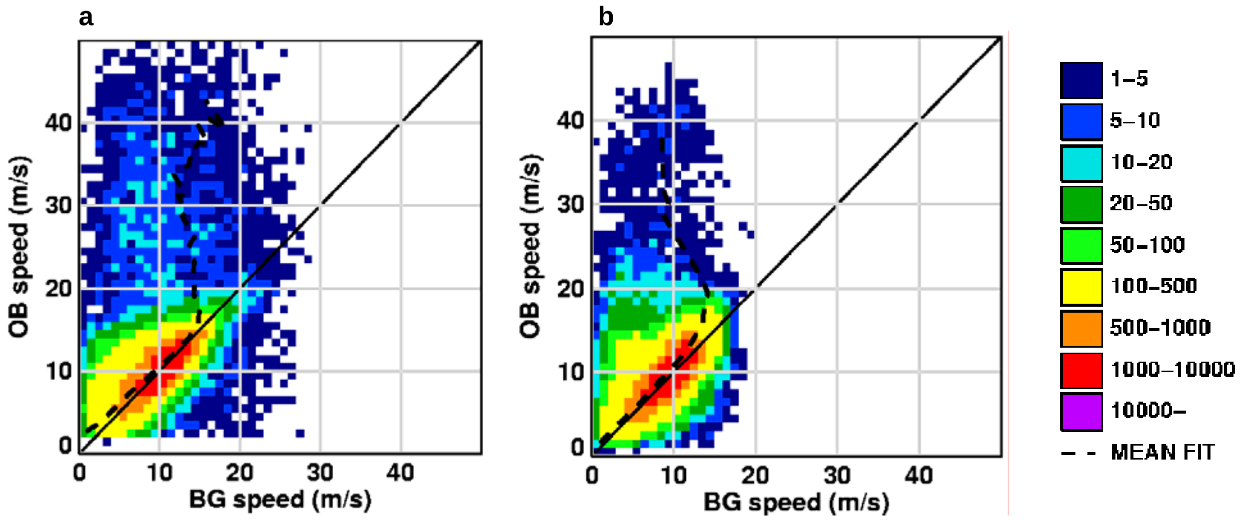

Figure 25: *Density plots of observed wind speed against the Met Office model background wind speed for low level winds in the tropics in August 2007 for (a) Meteosat-7 IR and (b) MTSAT-1R IR.*

There are three areas that tend to be affected most: (1) below the NH sub-tropical Jet over Asia and Africa during the NH winter, (2) near India during the monsoon season and (3) south-east Asia. The fast bias near India and over south-east Asia is shown in Figure 26. Some of the observed low level vectors show no resemblance to the low or mid level wind fields; they agree best with high level background winds at or above 250 hPa. The MTSAT-1R IR low level winds show a similar pattern to Meteosat-7 over south-east Asia.

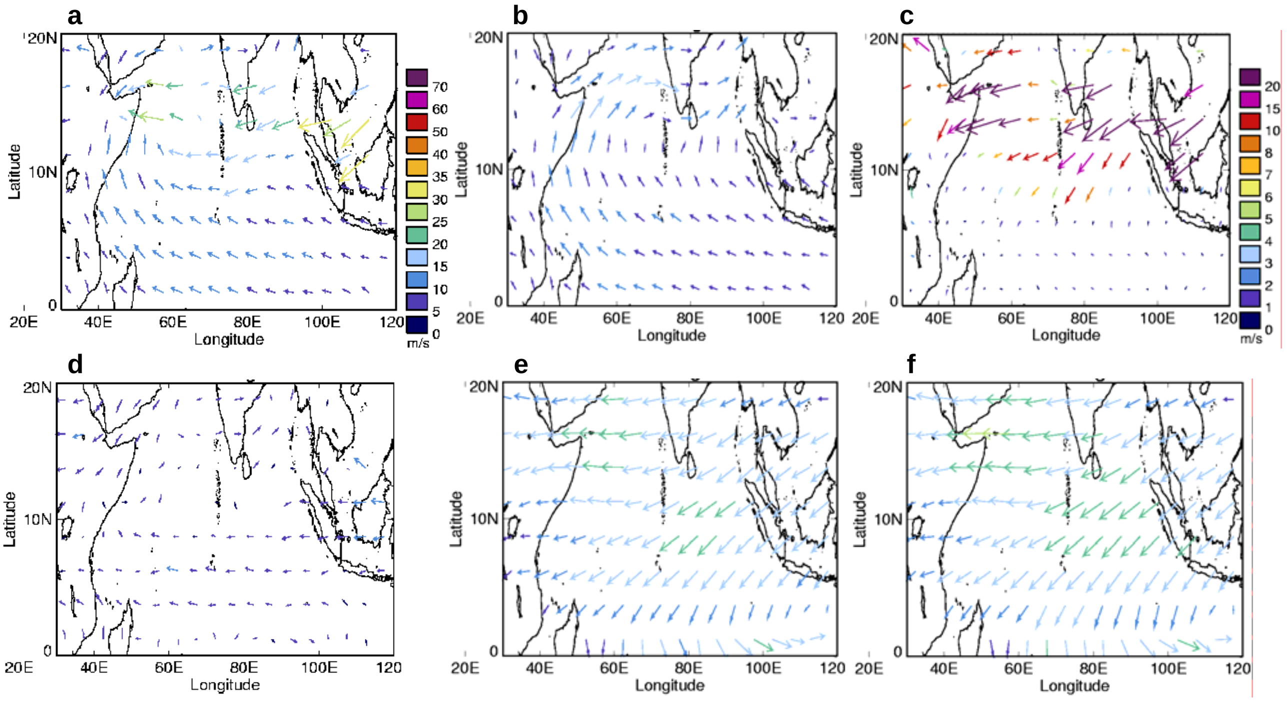

Figure 26: *Vector plots for Meteosat-7 IR and the Met Office model background for August 2007 showing (a) the mean observation at low level, (b) the mean background at low level, (c) the mean vector difference at low level, (d) the mean background at mid level, (e) the mean background at high level (above 400 hPa) and (f) the mean background above 250 hPa. The key for (a) also applies to (b), (d), (e) and (f).*

Based on these results it seems likely that the fast bias is linked to a large height assignment error of, in some cases, 500 hPa or more. 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 either improve the match up between tracking and height assignment or, at least, to flag likely problem cases.

5.3. Mid Level

The mid level wind field is dominated by faster winds beneath the extra-tropical jets (see Figure 22 in the second analysis report). The winds are generally faster than at 850 hPa, but slower than in the jet core between 150-400 hPa. The winds are strongest in the winter hemisphere and show greatest variation in strength in the NH (more land). There are far fewer geostationary AMVs produced at mid level (400-700 hPa) than at high or low levels. Those that are produced generally have poorer O-B statistics, often exhibiting a fast bias in the tropics and a slow bias in the extra-tropics. The poor O-B statistics are thought to result primarily from difficulties with height assignment at these levels.

Update on Feature 2.8. Fast bias in the tropics

A fast bias at mid levels in the tropics is seen for most geostationary AMV datasets (Figure 27). The most prominent feature before April 2007 was the Sahara winter fast bias. Other examples include: the equatorial Pacific, 15-20S in the eastern Pacific, ~15-20S in the Indian Ocean and the MSG WV channels. MTSAT-1R exhibits a fast bias in all regions, not just the tropics, and is considered separately under Feature 3.1.

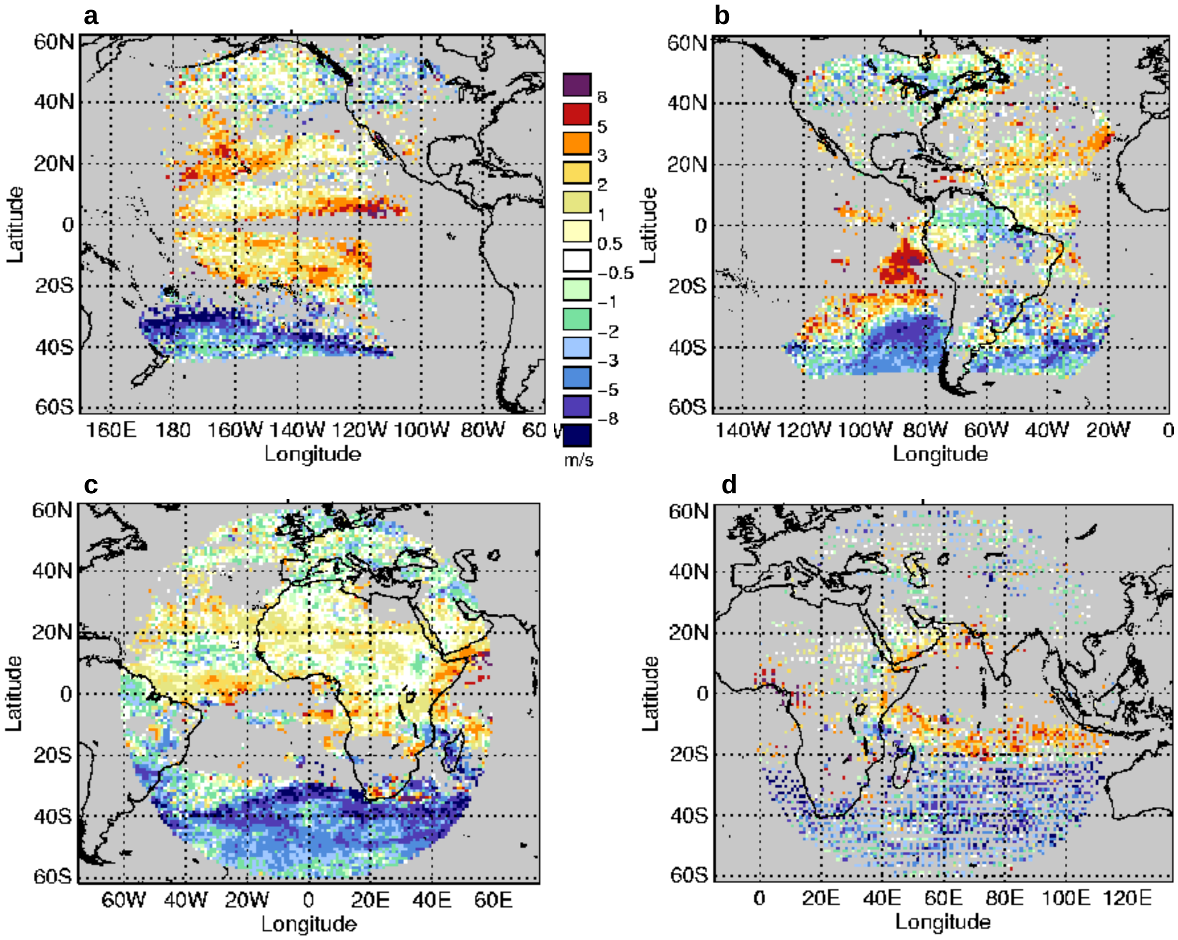

Figure 27: *Map plots of mid level O-B speed bias compared with the Met Office model background for August 2007 for (a) the unedited GOES-11 IR winds, (b) the unedited GOES-12 IR winds, (c) the Meteosat-9 IR 10.8 winds and (d) the Meteosat-7 IR winds.*

Some of the tropical fast bias features at mid level are discussed further below.

Fast bias at mid level below the sub-tropical jet
In the second analysis a fast bias was described over the Sahara region during the winter months. This was a very prominent feature in the speed bias map plots (e.g. Figure 28).

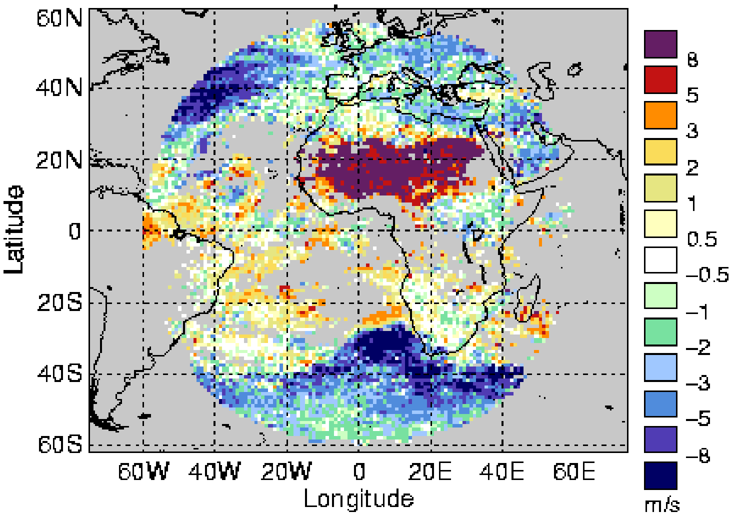

Figure 28: *O-B speed bias plot for Meteosat-8 IR mid level winds compared with the Met Office model background for November 2005.*

It was hypothesised that the fast bias was due to faster higher level winds being assigned too low. This is supported by model best-fit pressure investigations which show a low height bias for AMVs between 300 and 500 hPa in height (see Figure 29).

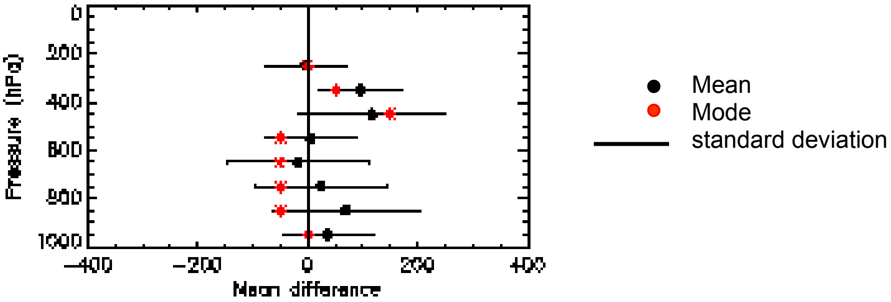

Figure 29: *Mean difference between the observed pressure and best-fit pressure for Meteosat-8 IR EBBT winds for November-December 2006.*

Comparisons have also been made with the MODIS cloud top pressure product (Figure 30). The AMV pressures are mostly in the range 350-500 hPa. By comparison the model best-fit pressure and MODIS cloud top pressure are consistently higher in the atmosphere between 150-350 hPa.

This can be taken one step further to consider the connection between the height bias and height assignment method. Figure 31 shows that the AMVs are assigned lower when the EBBT (equivalent black-body temperature) method is used, but agree better for the few cases where the CO_2 slicing method was used.

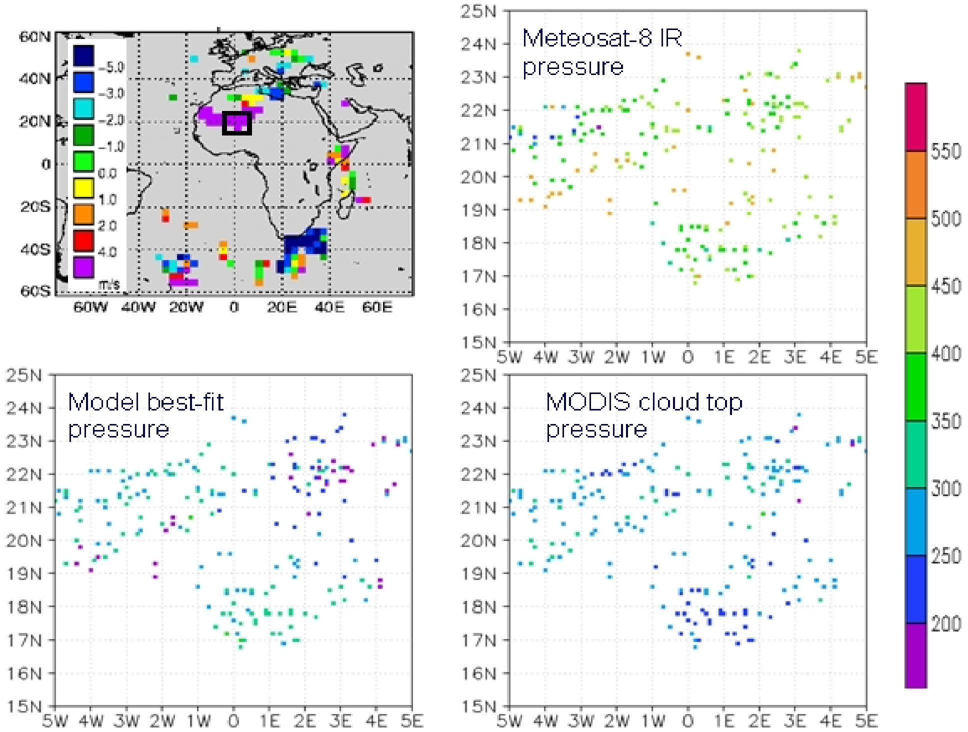

Figure 30: *A case study for 2100-0300 on 7-8 December 2005 showing the fast speed bias over the Sahara region. The AMVs are assigned to mid level (green colours), but both the model best-fit pressure and MODIS cloud top pressure are at higher levels (blue colours). Scale in hPa.*

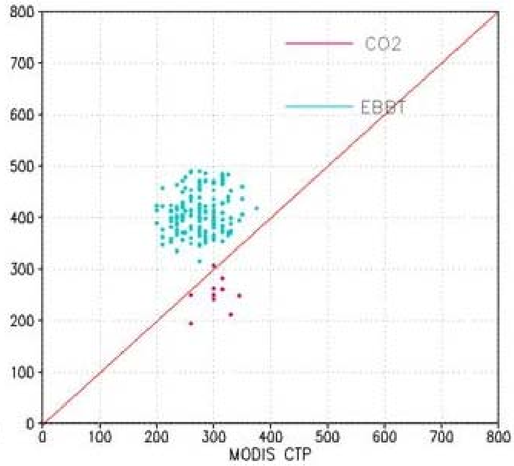

Figure 31: *Scatter plot comparing the Meteosat-8 IR assigned pressure to the MODIS cloud top pressure, subdivided by the AMV height assignment method used.*

It is not surprising that the EBBT method will put high thin cirrus cloud at mid level due to contributions from below the cloud. The more appropriate question is why the CO_2 slicing method is not used more often. Examination of a few cases indicates that the CO_2 method often fails or produces an unrealistically warm cloud top temperature. Further 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 indicated 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 32).

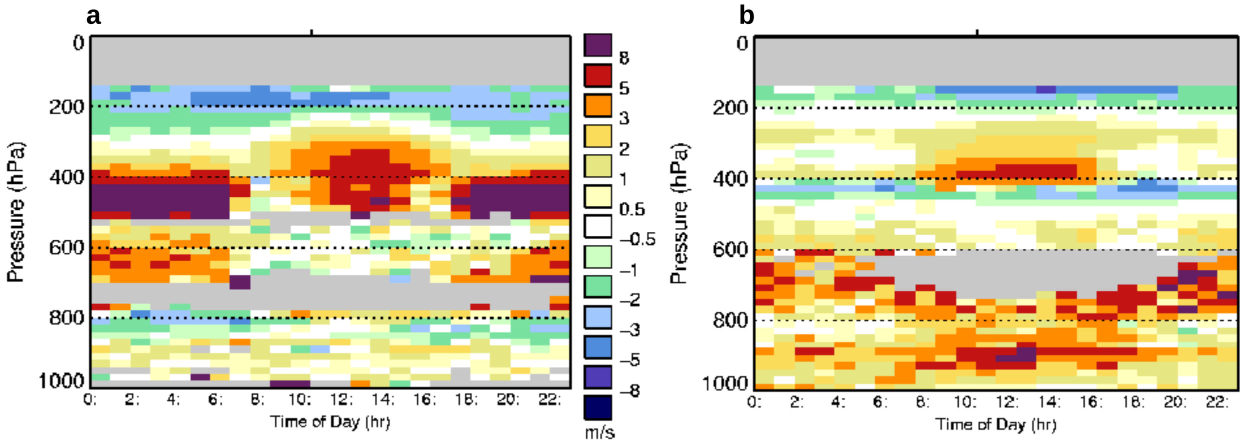

Figure 32: *Hovmoeller plots showing the O-B speed bias for Meteosat-9 IR 10.8 winds compared with the Met Office background as a function of time of day for (a) January 2007 and (b) January 2008. Only data between 0-20N and 20W-30E are included.*

The January 2008 plot in Figure 32 shows a marked improvement during the night-time hours; a fast bias is still present above 400 hPa during day time hours and at lower level.

Fast bias in low wind speed regions

The fast bias in the Pacific is located in a region of slow wind speed (see Figure 33).

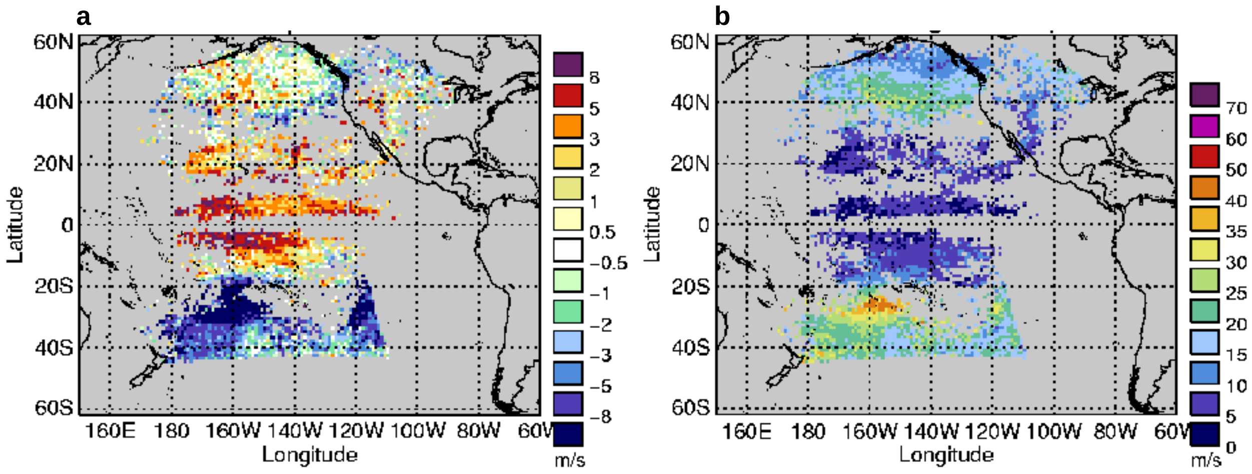

Figure 33: *Map plots showing (a) the O-B speed bias for the unedited GOES-11 IR mid level winds and (b) the mean Met Office background speed for June 2007.*

The fast bias may be partially linked to the removal of slower winds (as discussed in Feature 2.1), but is probably exacerbated by height assignment error. Unusually the wind speed in this region is faster at both high and low levels (see Figure 34c) so either high or low level winds wrongly assigned to mid level could result in a fast speed bias.

To investigate further we can look at the zonal O-B speed bias as a function of height assignment method. The majority of winds in this area are assigned a WV intercept height. Both height assignment methods (EBBT and WV intercept) show a fast speed bias (Figure 34 d and e).

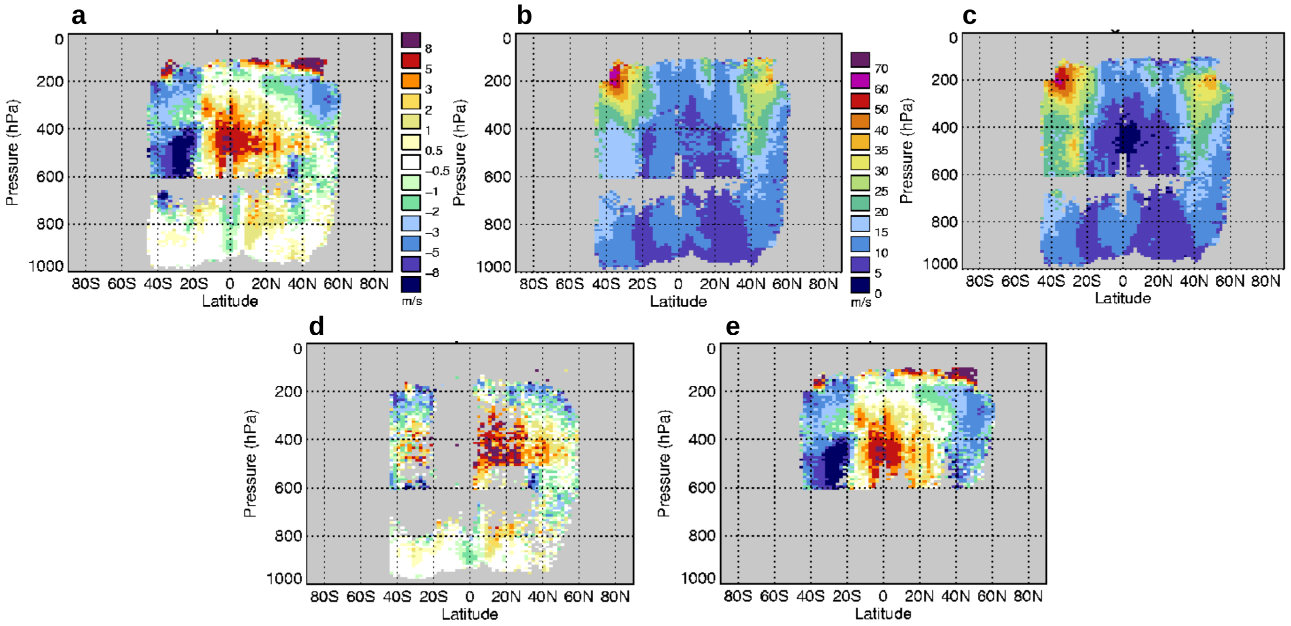

__Figure 34:__ Zonal plots for the unedited GOES-11 IR winds for June 2007 compared with the Met Office model background: (a) O-B speed bias, (b) mean observed speed, (c) mean background speed, (d) O-B speed bias for winds assigned an EBBT height and (e) O-B speed bias for winds assigned a WV intercept height.

The model best-fit pressure results show that the EBBT-assigned AMVs are assigned lower, by ~100 hPa, than the model preferred location and the WV intercept assigned AMVs are assigned higher, by ~ 200 hPa, than the model preferred location (see Figure 35).

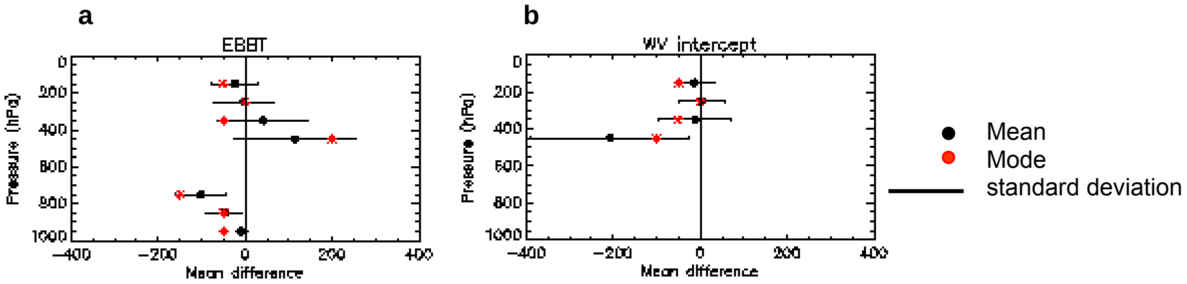

__Figure 35:__ Plots of mean difference between AMV assigned pressure and model best-fit pressure as a function of pressure in the atmosphere for unedited GOES-11 IR winds using (a) the EBBT height assignment method and (b) the WV intercept height assignment method. The data is for the period 23 March – 23 April 2007 and restricted to AMVs in the tropics.

Both height assignment method biases are not unexpected. The EBBT is known to put semi-transparent cloud too low, which could contribute to a low height bias. The high height bias from the WV intercept method is less well understood, but is seen for other satellites and channels and is probably linked to the limitations of this approach at mid levels. The mid level fast speed bias may be worse for GOES-11 than GOES-12 or the Meteosat satellites due to the wind speed pattern in this region (minima at mid level) and lack of CO_2 height assignment method (no CO_2 channel).

GOES-12 EBBT

GOES-12 IR winds assigned using the EBBT height assignment show a marked fast speed bias in the 300-500 hPa band in the tropics, which is associated with a low height bias in the model best-fit pressure comparisons (see Figure 36).

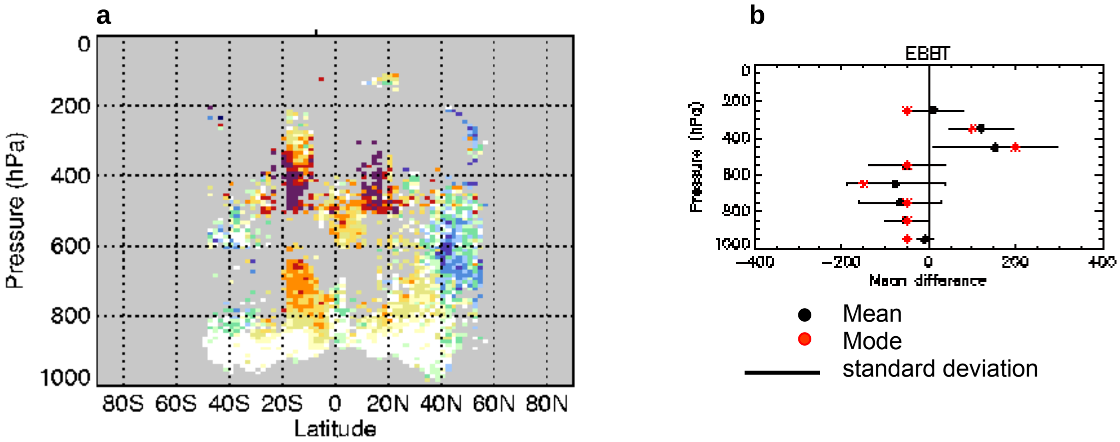

Figure 36: *(a) Zonal O-B speed bias plot for the unedited GOES-12 IR AMVs where the EBBT height assignment was used. Plot is for October 2007 compared with the Met Office model background. (b) Plot of mean difference between AMV assigned pressure and model best-fit pressure as a function of pressure in the atmosphere for the unedited GOES-12 IR winds where the EBBT height assignment was used. The data is for the period 23 March – 23 April 2007.*

The number of winds affected is quite low; they are largely located around 15S over and to the west of Peru and around 15N in the Atlantic. It is not surprising that the EBBT method will put some AMVs too low (e.g. if semi-transparent), but if these are genuinely higher level winds, the question becomes why was the CO_2 slicing method or WV intercept method not used in these cases.

Meteosat-9 WV 7.3

It should be possible to assimilate some mid level Meteosat-9 WV 7.3 winds as this channel can see deeper into the atmosphere than the traditional geostationary WV channels. The O-B zonal plots can be used as a guide to indicate a suitable lower pressure threshold for assimilation. One prominent feature is a marked seasonal fast speed bias at 10-30S and 10-30N below 500 hPa (see Figure 37). The AMVs in this region have a WV EBBT height assignment.

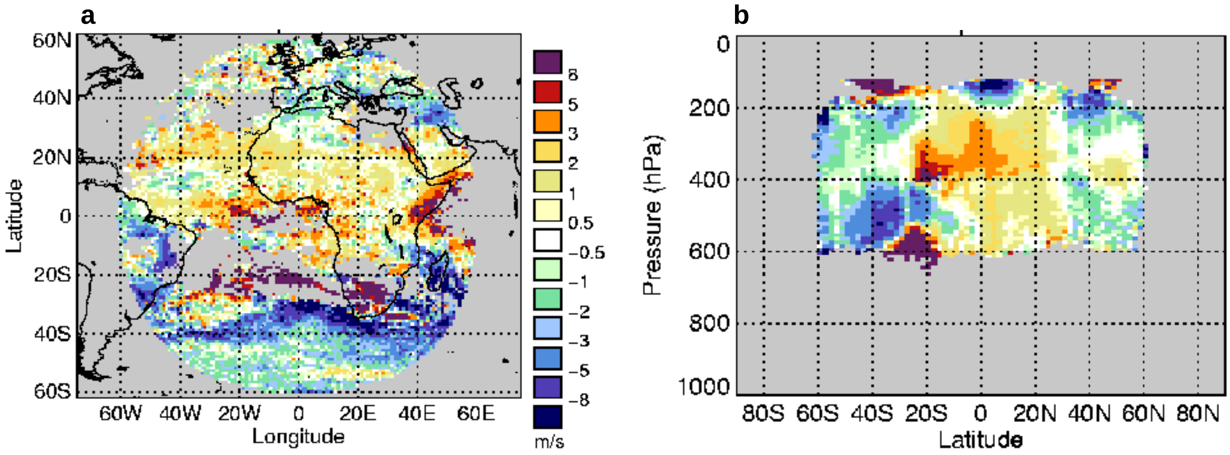

Figure 37: *(a) Mid level map and (b) zonal O-B speed bias plots for Meteosat-9 WV 7.3 for August 2007 compared with the Met Office model background*

The vector plots in Figure 38 show how the observed wind vectors are faster than the model background wind vectors in a region across the Atlantic and S. Africa. The location broadly correlates with the location of the high level sub-tropical jet.

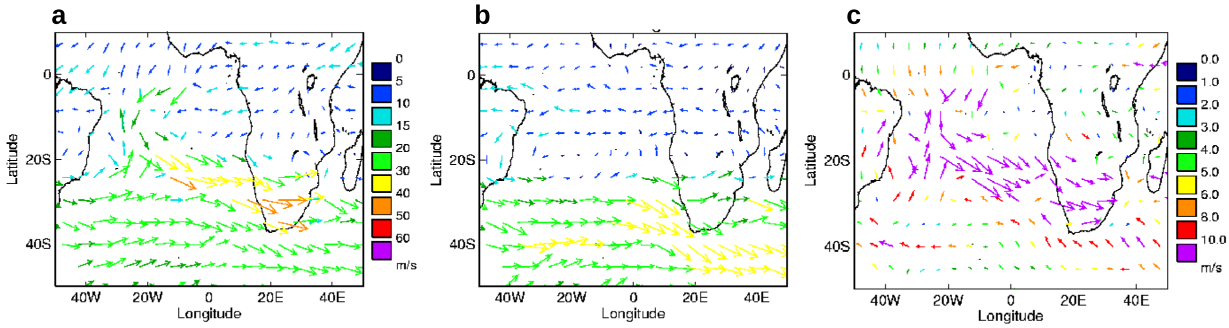

Figure 38: *Vector plots showing (a) mean observed wind, (b) mean background wind and (c) mean vector difference for the Meteosat-9 WV 7.3 mid level winds for August 2007 compared with the Met Office model background.*

One explanation for the fast bias is that some faster higher level winds are put too low in the atmosphere. Although the model best-fit pressure statistics for the EBBT method in Figure 39 show an overall high height bias tendency, there are a small number of AMVs in the 400-600 hPa height range with a low height bias of 200-400 hPa.

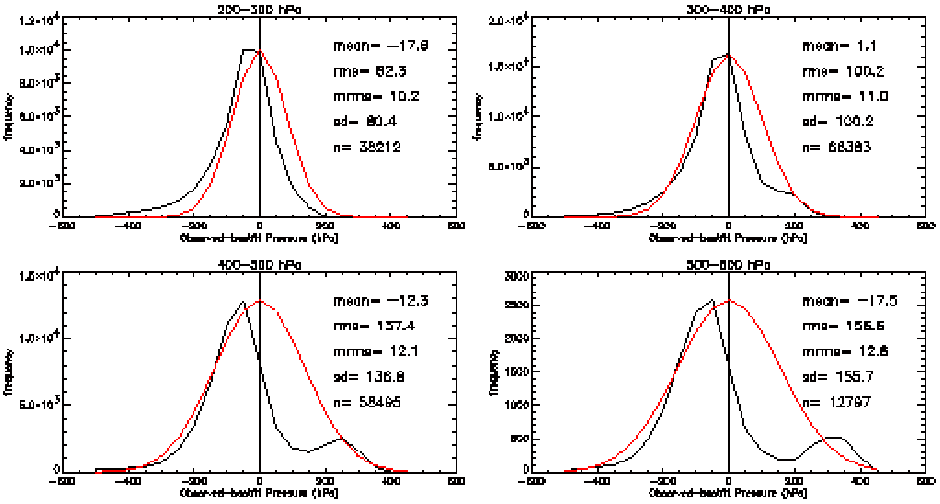

Figure 39: *Distribution of observed-bestfit pressure (black curve) for Meteosat-9 WV 7.3 AMVs for 23 March - 23 April 2007, separated into 100 hPa height bands. Note the second peak in the 400-500 hPa and 500-600 hPa bands, corresponding to AMVs which are assigned lower than the best-fit pressure.*

It is probable that the relatively small number of AMVs affected may be high level winds where the CO_2 slicing method has for some reason failed (possibly close to temperature restriction) and instead an EBBT method is used, which will put the AMVs too low. The fast bias is most marked in the winter hemisphere beneath the sub-tropical jet where the wind shear is greater.

Update on Feature 2.9. Slow bias in the extratropics

The slow speed bias at mid level is still very 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 Figures 40 and 41 show how the bias varies dependent on the height assignment method. The speed bias is worse for the Meteosat-9 winds assigned a height using the CO_2 slicing method and for the unedited GOES-12 winds assigned heights using the CO_2 slicing or WV intercept methods. By comparison, the EBBT method is less affected. This suggests the hypothesis put forward in the second analysis linking the problem to the EBBT method in multi-level cloud situations is not the main cause.

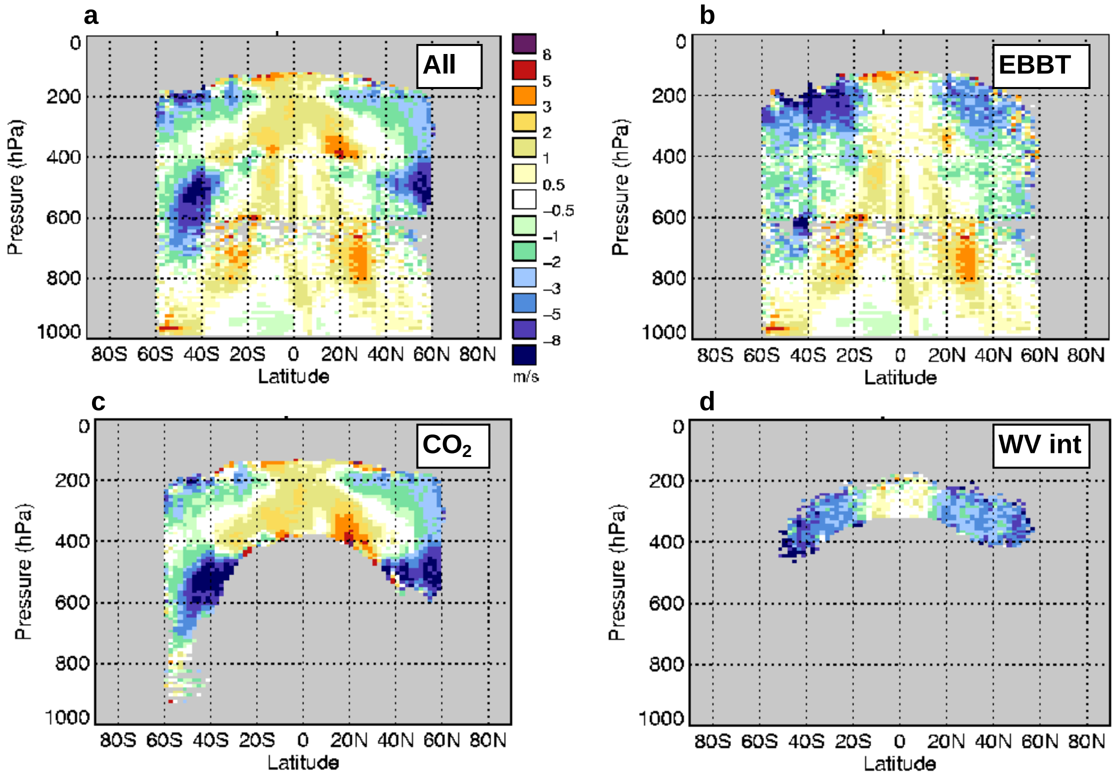

Figure 40: *Zonal O-B speed bias plots for Meteosat-9 IR 10.8 winds compared with the Met Office model background for October 2007 filtered by height assignment method: (a) all data, (b) data with an EBBT height assignment, (c) data with a CO_2 slicing height assignment and (d) data with a WV intercept height assignment.*

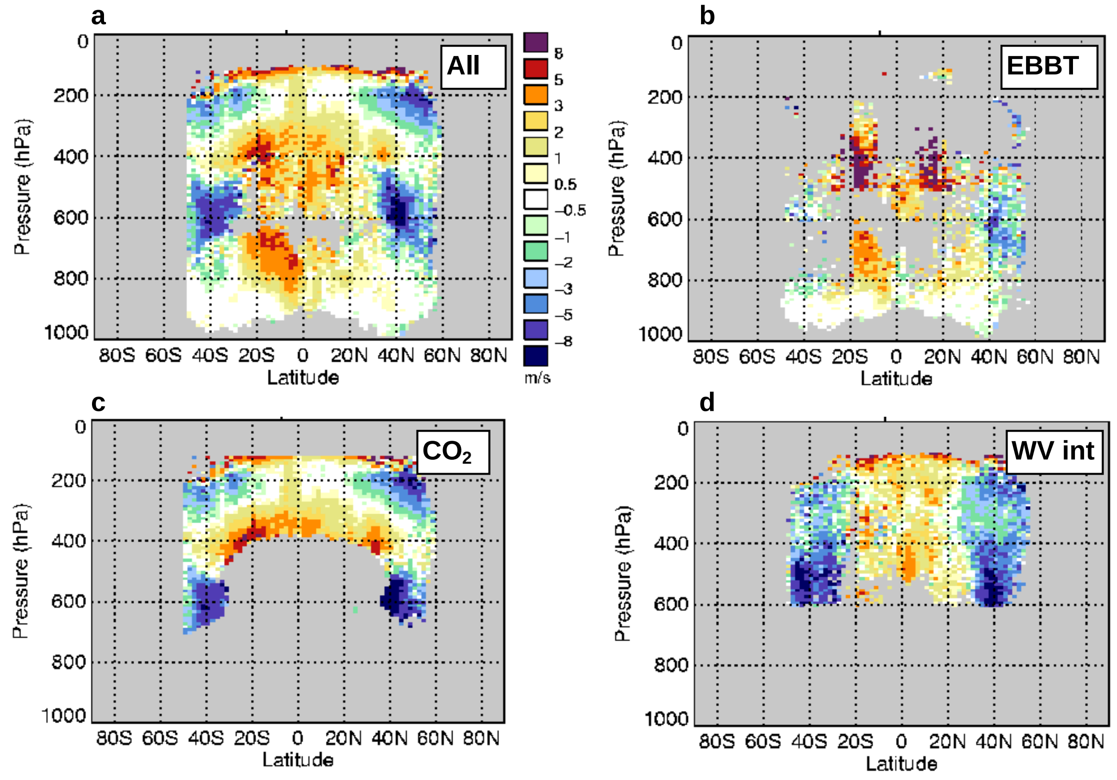

Figure 41: *Zonal O-B speed bias plots for the unedited GOES-12 IR winds compared with the Met Office model background for October 2007 filtered by height assignment method: (a) all data, (b) data with an EBBT height assignment, (c) data with a CO_2 slicing height assignment and (d) data with a WV intercept height assignment.*

It is not too surprising that the CO_2 slicing and WV intercept methods may be less accurate at these levels (below around 400-500 hPa) as the CO_2 and WV channels lose sensitivity.

Often slow speed biases are associated with high height biases in the model best-fit pressure statistics. This seems to be the case here. Figure 42 shows how a slow speed bias at mid level to the south of Africa is associated with AMVs which are assigned to higher levels than the model best-fit pressures.

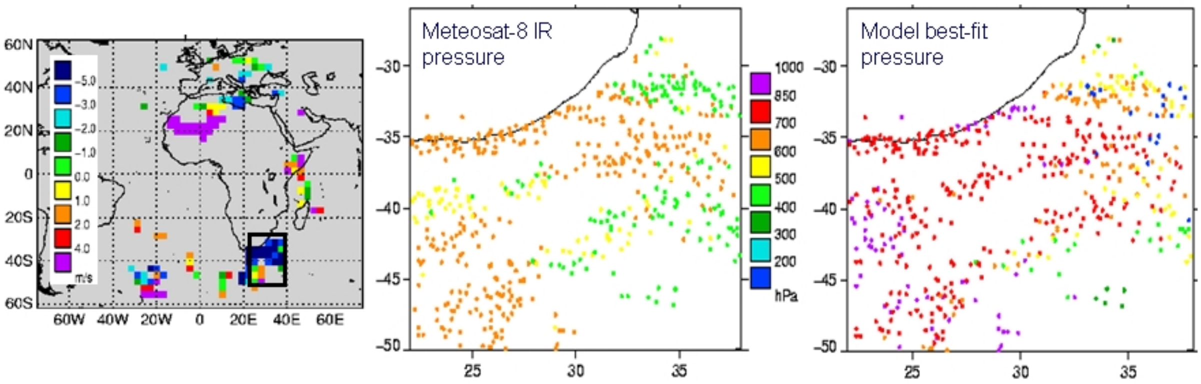

Figure 42: *A case study for 2100-0300 on the 7-8 December showing the slow speed bias towards the southern edge of the Meteosat-8 disc. For clarity a filter is applied to the pressure plots to only show the AMVs assigned to mid level.*

We can also look at longer time-period statistics comparing the AMV pressure to the model best-fit pressure for the WV intercept and CO_2 slicing techniques (see Figure 43). This confirms that there is a tendency for the mid level winds assigned heights with these two methods to be put higher than the model best-fit pressure. A high height bias was also seen compared with radiosonde best-fit pressures (Daniels et al., 2006). The reason the mid level slow bias is most prominent below the upper level jets is probably due to the higher wind shear in these regions so a height assignment error will feed into a bigger error in the speed.

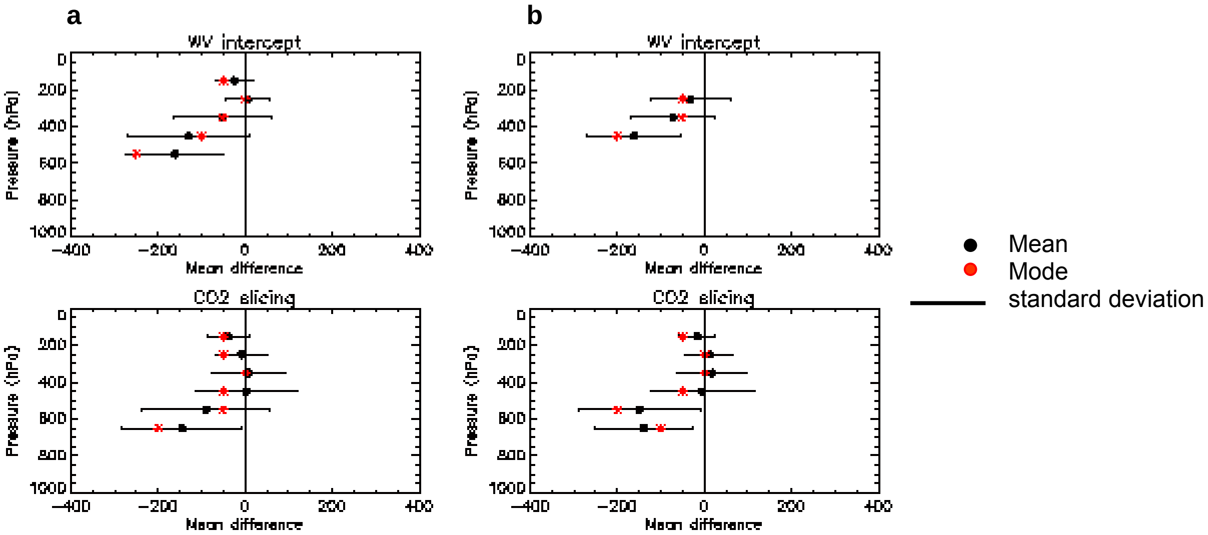

Figure 43: *Plots of mean difference between AMV assigned pressure and model best-fit pressure as a function of pressure in the atmosphere for (a) the unedited GOES-12 IR winds and (b) the Meteosat-9 IR winds using the WV intercept and CO_2 slicing height assignments. The data is for the period 23 March – 23 April 2007.*

These results may suggest that additional thresholds should be used to prevent the WV intercept and CO_2 slicing height assignment methods being used at mid levels. Currently the height assignment method used is controlled via a temperature threshold, but applying an additional pressure threshold may be useful. Figure 44 shows how, although far from perfect, the EBBT pressures for these border-line cases are in better agreement with the model best-fit pressure than those from the CO_2 slicing approach.

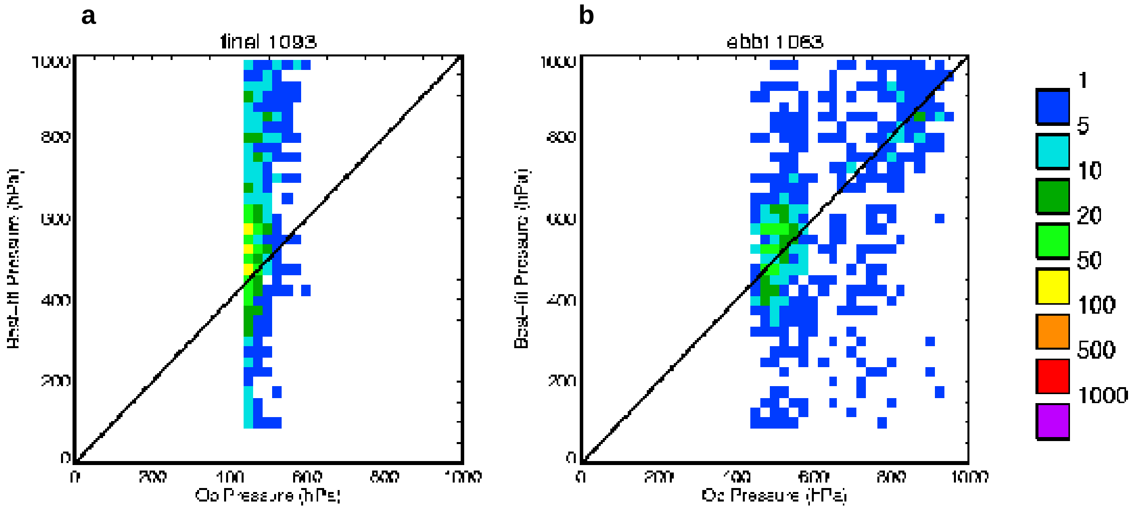

Figure 44: *Density plots comparing the model best-fit pressure to the observed pressure for 3 days of Meteosat-9 IR 10.8 data in November 2007. The data is filtered to only include winds below 450 hPa where the CO_2 slicing method was used as height assignment. (a) shows the CO_2 slicing pressure and (b) shows the alternative EBBT pressure for these winds.*

Feature 3.1. MTSAT-1R mid level fast bias

A marked fast speed bias is observed for MTSAT-1R IR winds below ~550 hPa in the atmosphere (see Figure 45).

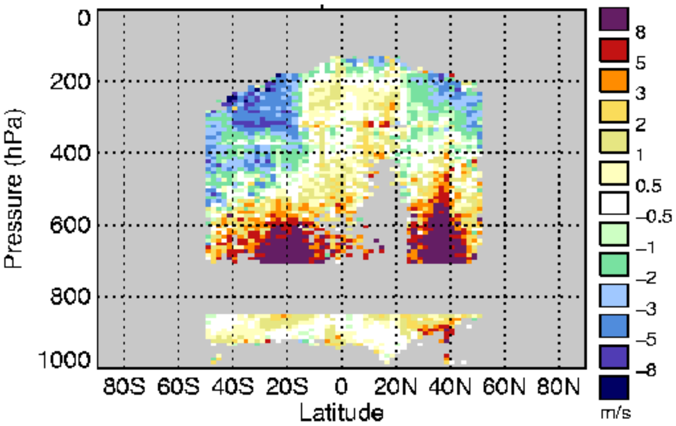

Figure 45: *Zonal O-B speed bias plot for MTSAT-1R IR winds compared to the Met Office model background for June 2007.*

The model best-fit pressure statistics show a marked low height bias for AMVs below 500 hPa (Figure 46), which could explain the observed fast speed bias at mid level. This feature has been brought to the attention of JMA, but until it has been fixed it is advisable not to assimilate the mid level MTSAT-1R IR winds.

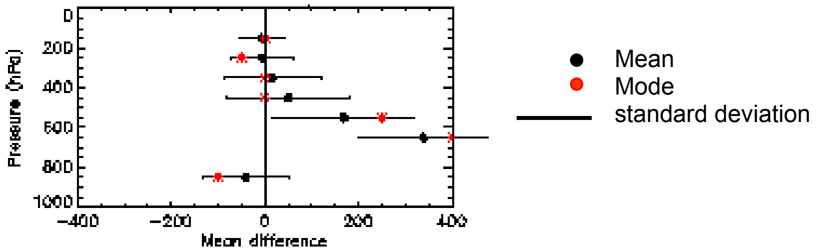

Figure 46: *Mean difference between AMV pressure and model best-fit pressure as a function of pressure in the atmosphere for the MTSAT-1R IR winds in the NH for June 2007.*

5.4. High Level

The high level wind field is dominated by fast winds in the jet regions (see Figure 27 in the second analysis report). The sub-tropical jets are fairly constant westerly flows at around 30S and 30N. The polar front jets are more variable, tend to be more meridional and are closer to the poles where the polar air meets the warmer air in the mid-latitudes. The two jets in each hemisphere are not always clearly separated and vary in strength and location dependent on the time of year (stronger and closer to the equator during the winter). Nearer the equator, there are some regions of moderate easterlies, particularly over Indonesia, India, the Indian Ocean and Africa. The high level statistics are dominated by a slow speed bias in the jet regions, which is worse in the winter hemisphere. There tends to be a positive speed bias in the tropics, but this is less pronounced than at mid level.

Update on Feature 2.10. Jet region slow bias

The slow bias in the jet regions is perhaps the most frequently described problem with the AMVs. Many reasons have been put forward to explain why a slow bias exists including:

1. The winds are a spatial and temporal average and therefore will not reflect the strongest winds experienced at a point in time and space.
2. The AMVs represent the motion of a layer, but are currently assigned to a single height.
3. The clouds are typically located below or to the side of the high speed jet core and so will not reflect the highest wind speeds in the jet core.
4. The wind may blow through the tracer and therefore the movement of the tracer could be an underestimate of the actual wind speed.
5. There may be a systematic height assignment error.

I suspect a number of factors play a part. To understand more, it is worth reviewing what we have learnt from the monitoring so far. The slow speed bias is associated with the jet regions and is worse in the winter months when the jets are stronger. Although most satellite-channel combinations show a slow speed bias, they are not all equally affected. Meteosat-7 IR and WV and MTSAT-1R IR exhibit the largest biases (e.g. Figure 47).

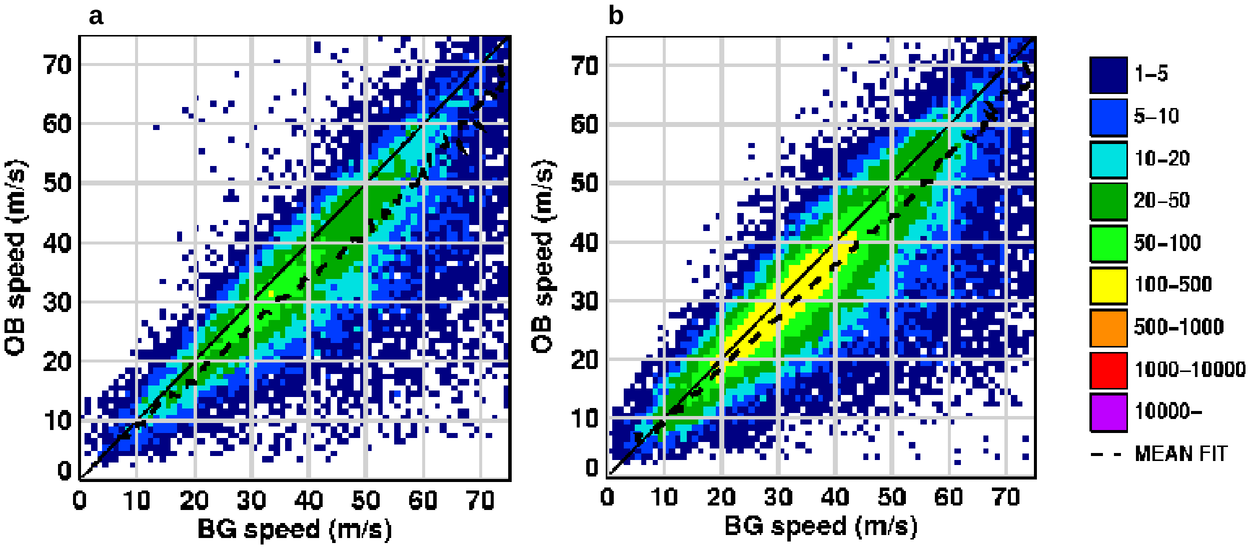

Figure 47: *Density plots of observed wind speed against the Met Office model background wind speed for high level winds in the SH in August 2007 for (a) Meteosat-7 IR and (b) MTSAT-1R IR.*

The map plots in Figure 48 show the speed bias and mean background speed for Meteosat-7, MTSAT-1R and Meteosat-9. The speed bias is associated with the faster wind speeds in the jet regions, but there is not always a direct correlation. This is perhaps most obvious for Meteosat-9, where the slow bias is worst to the south of Madagascar and in a region to the SW of the Caspian Sea. A slow bias is observed elsewhere, but is less bad. The extent of the bias varies from month to month, but the Caspian Sea and Madagascar regions show up as persistently bad, at least during the NH summer months when the jets cross these two areas. What makes the slow bias worse in some jet areas and not others is less clear.

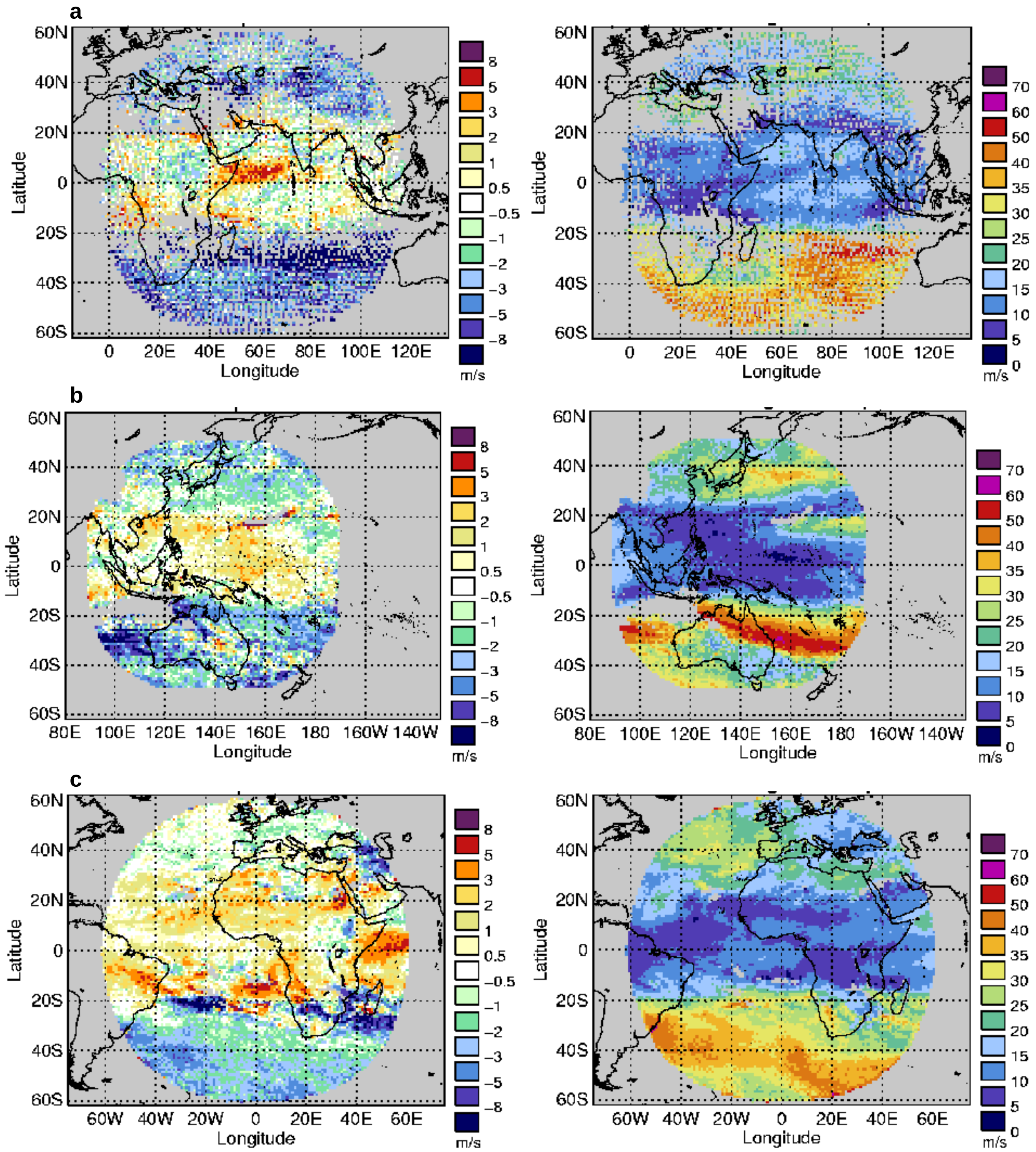

Figure 48: *Map plots of O-B speed bias and mean background speed for (a) Meteosat-7 IR, (b) MTSAT-1R IR and (c) Meteosat-9 IR for June 2007 compared with the Met Office model background*

Sometimes patterns can be hidden in monthly statistics. Investigation of individual cases may improve our understanding. Also, investigations at ECMWF using AMVs generated from simulated data may provide some guidance.

Update on Feature 2.13. Tropics fast bias

A fast speed bias in the tropical regions is observed at high level for most satellite-channel combinations against both the Met Office and ECMWF model backgrounds. Overall the bias is small (less than 2 m/s), but there are some regions which are worse affected (more than 6 m/s) and generally the WV channels are more affected than the IR window channels (see Figure 49).

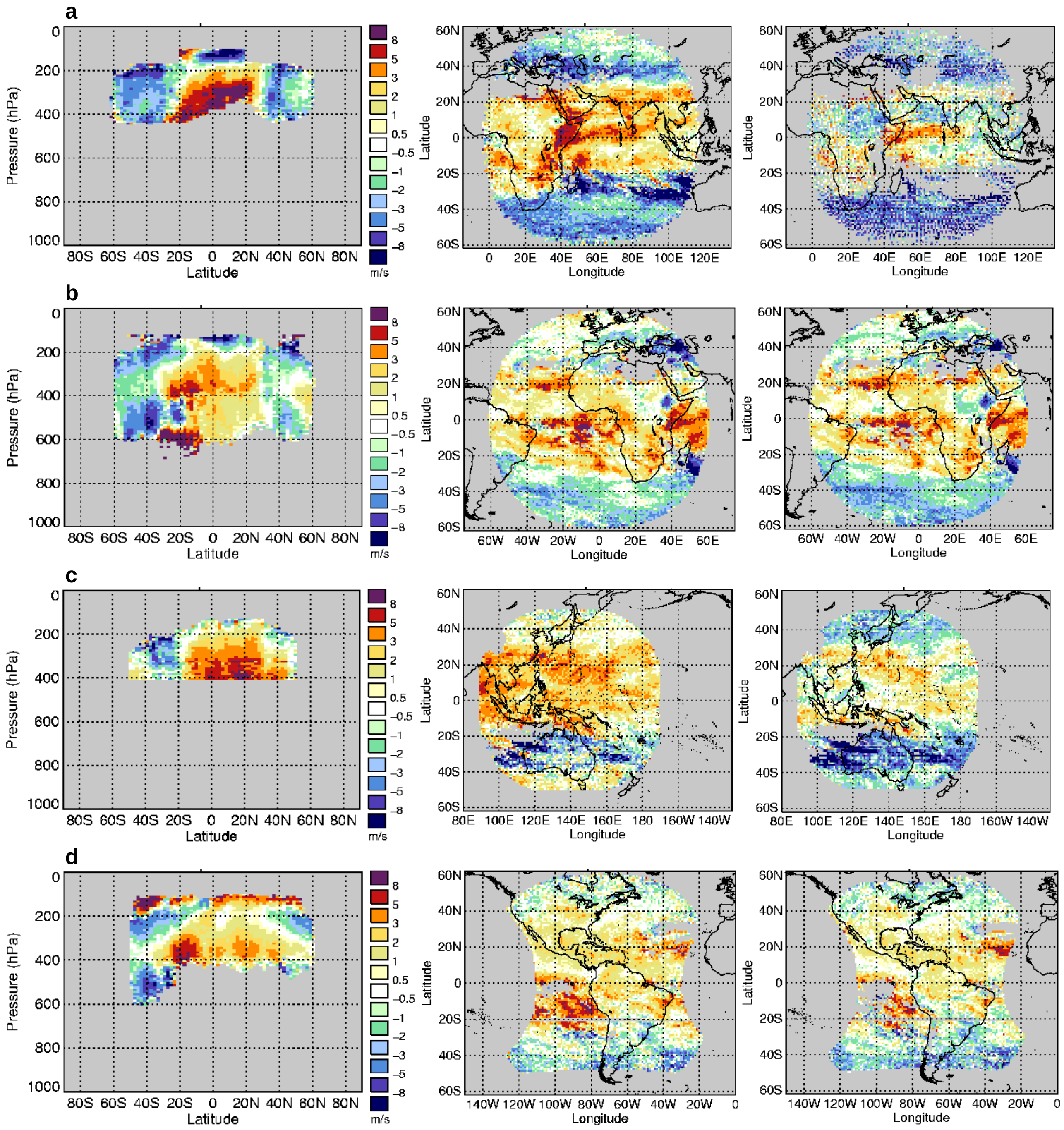

Figure 49: *Zonal and map O-B speed bias plots for the WV channel and map speed bias plot for the IR channel for (a) Meteosat-7, (b) Meteosat-9 (WV 7.3), (c) MTSAT-1R and (d) unedited GOES-12 compared with the Met Office model background for July 2007.*

The zonal plots in Figure 49 show that the speed bias is worse below 250-300 hPa in the atmosphere. This is true in other months, although the distribution and size of the bias shows some variation. The main geographic areas associated with a fast bias at high level include: 0-30S in the eastern Pacific Ocean, 0-20S in the Atlantic Ocean and near the equator in the Indian Ocean. MTSAT-1R WV shows a more evenly distributed tropical fast bias, possibly linked to a low height bias tendency evident in the best-fit statistics. This has reduced considerably since the May 2007 derivation change. Further information is provided under Feature 2.15.

Interestingly many of the geographic regions associated with the fast bias are away from the main high cloud regions in the jets and Inter-tropical Convergence Zone (ITCZ), particularly in the Atlantic and Pacific

Oceans. Investigation of a specific case in October in the Atlantic shows that the fast bias (see Figure 50) is associated with an isolated linear high cloud feature in the imagery (Figure 51).

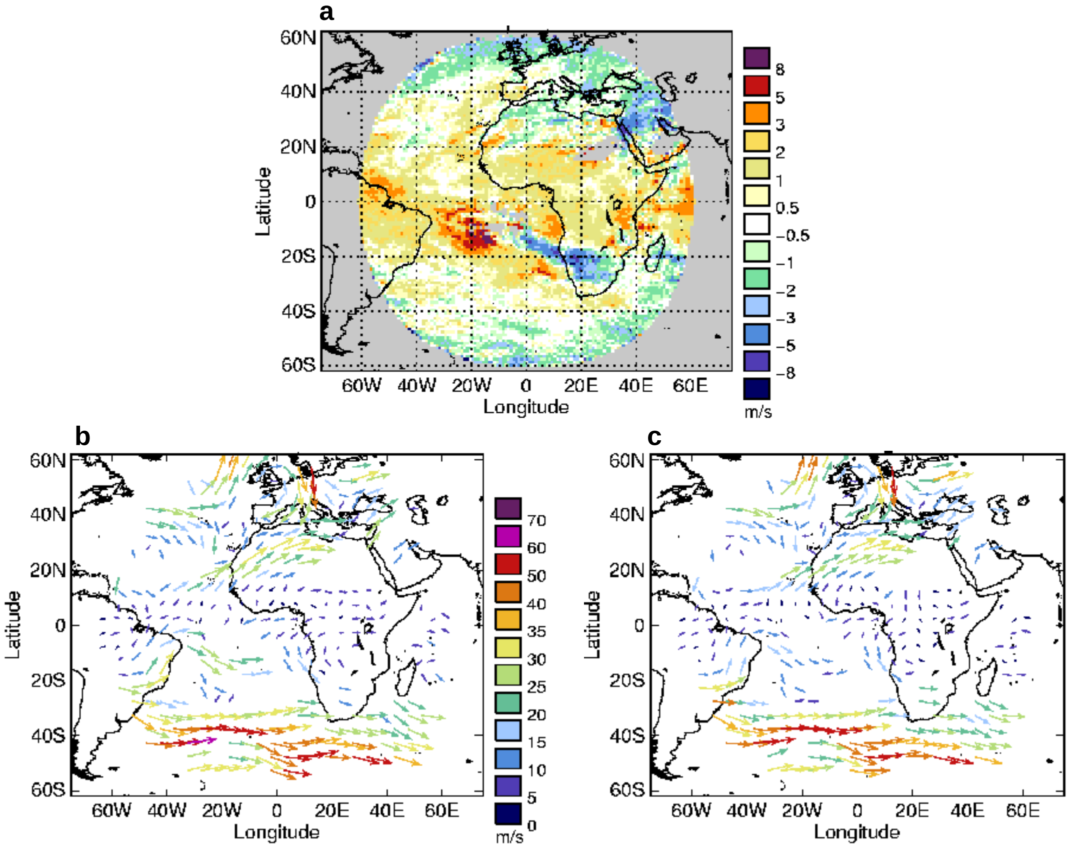

Figure 50: *(a) Map plot of O-B speed bias for Meteosat-9 WV 7.3 for October 2007 compared with the Met office model background, (b and c) mean observed vector and mean background vector for 0900-1500 on the 12 October.*

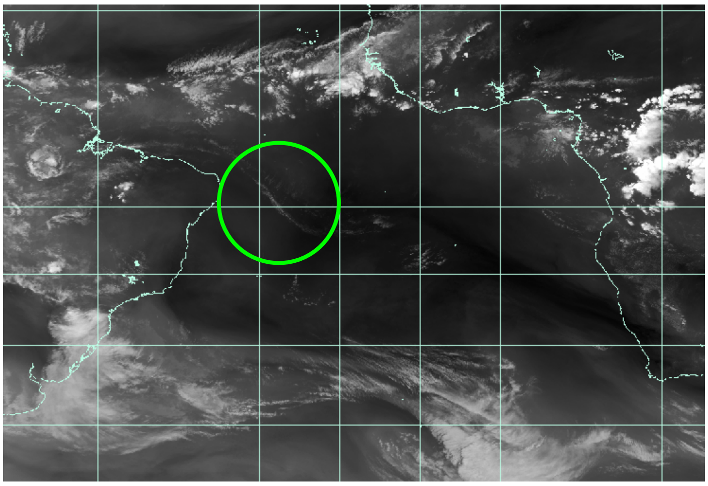

Figure 51: *1415 UTC Meteosat-9 WV 7.3 image on the 12 October 2007 showing a linear cloud feature off the coast of Brazil (inside green circle). Also notice the high level cloud associated with the ITCZ towards the top of the image and the cloud associated with the jet to the bottom of the image.*

Figure 52 compares the AMV pressures and model best-fit pressures for this case. The AMVs produced by tracking the linear cloud feature are assigned to 300-400 hPa, but the model preferred location is above 300 hPa in the atmosphere.

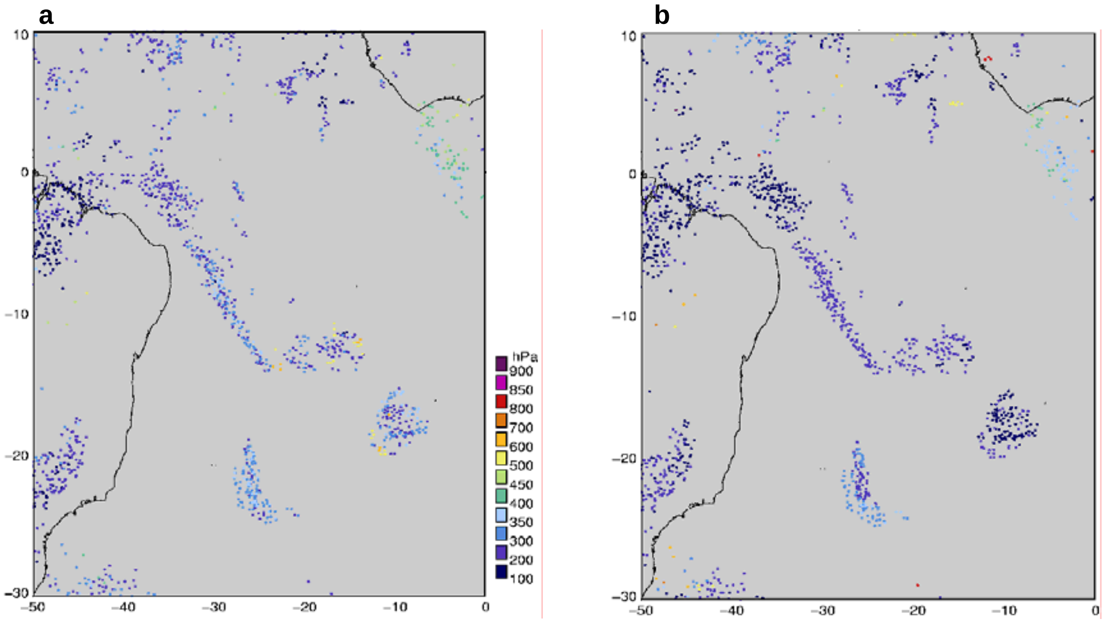

Figure 52: *(a) Meteosat-9 WV 7.3 AMV pressure and (b) model best-fit pressure for 0900-1500 UTC on the 12 October 2007.*

I suspect that some of the high level tropical fast speed bias is due to a tendency to assign some high level clouds a bit too low. This appears to be more problematic in regions away from the main high level cloud areas of the ITCZ and jets. Further investigation of individual cases may lead to a better understanding.

Update on Feature 2.14. Very high level (above 180 hPa) Meteosat and unedited GOES fast bias

In the second analysis report a fast bias at very high levels (above 180 hPa in height) was described. This is still visible in the zonal plots for the Meteosat and unedited GOES data (see Figure 53).

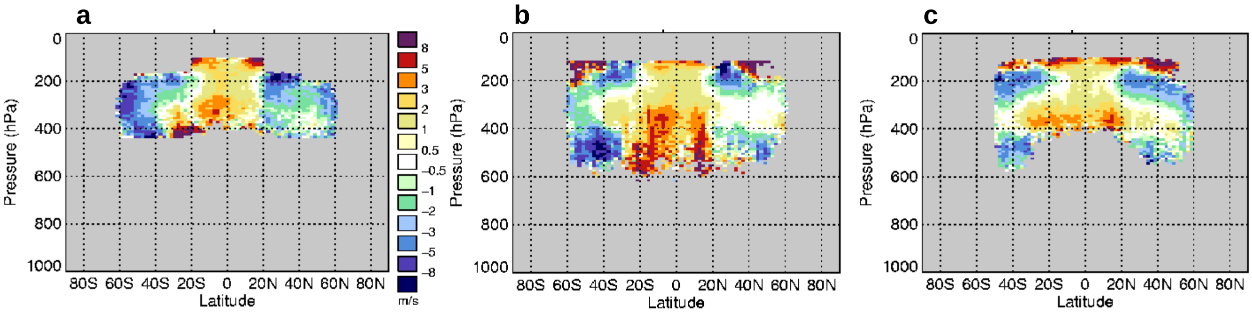

Figure 53: *Zonal O-B speed bias plots compared with the Met Office model background for (a) Meteosat-7 WV, (b) Meteosat-9 WV 6.2 and (c) unedited GOES-12 WV for April 2007.*

The fast bias is worse in the Meteosat-9 WV channels than the IR. It may be linked to a high height assignment bias as suggested by Figure 54, but does not appear to be linked to any particular height assignment method (e.g. Figures 40 and 41).

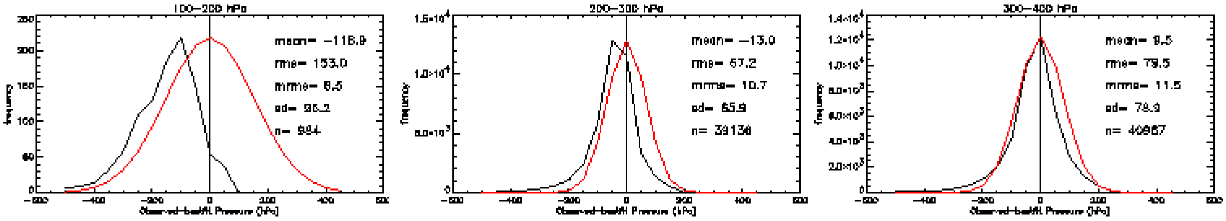

Figure 54: *Distribution of observed-bestfit pressure (black curve) for Meteosat-9 WV 6.2 AMVs assigned an EBBT height for 23 March – 23 April 2007, separated into 100 hPa pressure bands. .*

Update on Feature 2.15. Differences between channels

In the second analysis some unexpected differences were noted between the IR and WV statistics, which were particularly evident for the JMA and EUMETSAT winds. In the last two years both centres have made changes to their AMV derivation that have reduced the discrepancies. Further details are provided below.

The JMA IR and WV statistics for a period before and after the derivation change on 30 May 2007 are shown in Figure 55. Before the derivation change the dominant features were a slow speed bias in the jet region in the IR channel and a fast bias in the WV channel. The change has reduced the severity of both features. The fast bias seen in the MTSAT-1R IR channel at mid level was discussed in Feature 3.1.

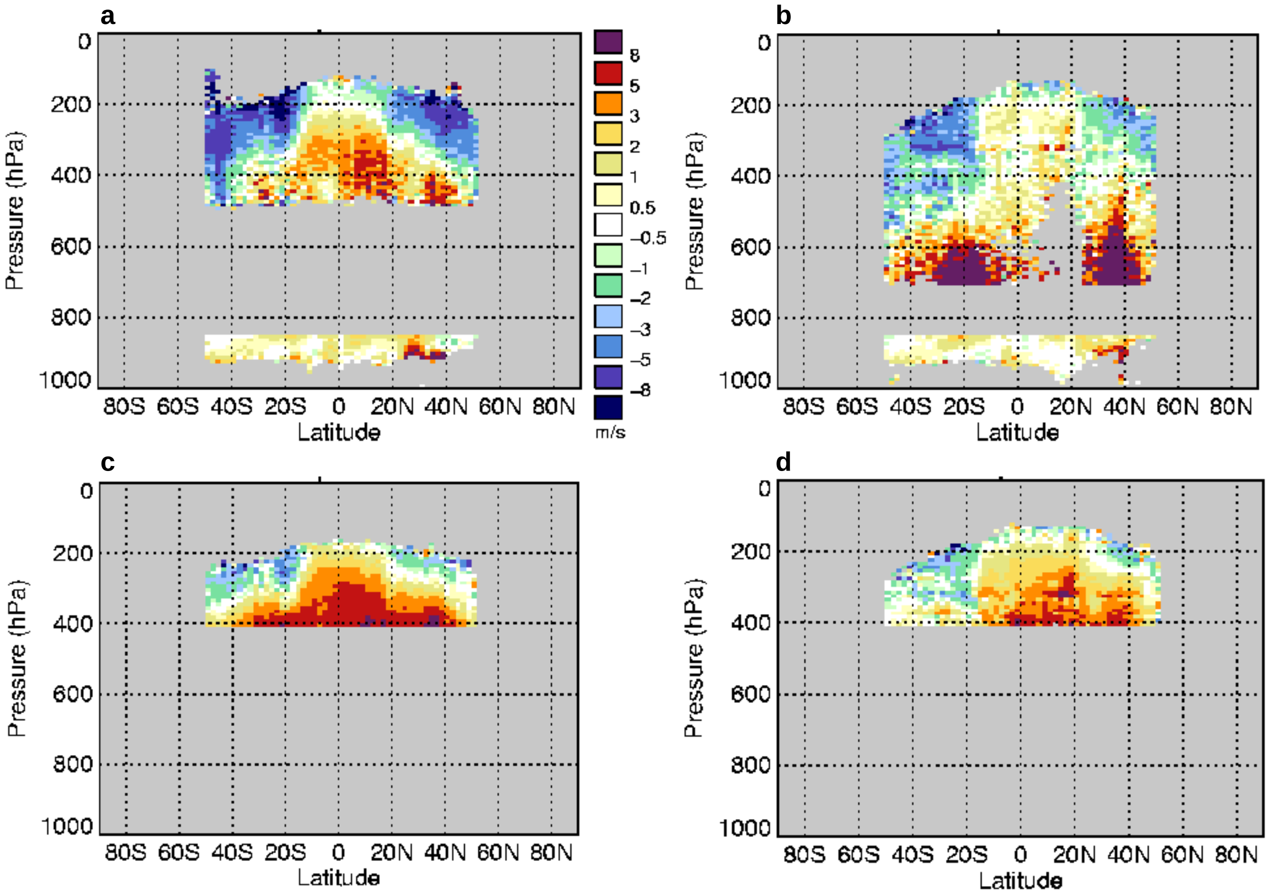

***Figure 55:** Zonal O-B speed bias plots comparing (a,b) MTSAT-1R IR and (c,d) MTSAT-1R WV against the Met Office model background for (a,c) May 2007 and (b,d) June 2007.*

Comparisons of the monthly O-B speed bias for the MTSAT-1R high level winds in the SH show that the largest speed bias through the SH winter for 2007 was -3.9 m/s in August, compared to -6.5 m/s in July 2006. The largest negative speed biases before the change were seen in the NH during the NH winter (minimum of -9.1 m/s in February 2007). In the NH winter season to January 2008 the largest monthly bias has been -4.8 m/s in January 2008.

It was hypothesised in the second analysis that the differences between the IR and WV channels were due to the height assignment. This was based on collocation plots such as the one shown in Figure 56a, which shows the WV winds located consistently lower in the atmosphere than the IR winds. Since the JMA derivation change the IR and WV wind pressures show much better consistency (Figure 56b).

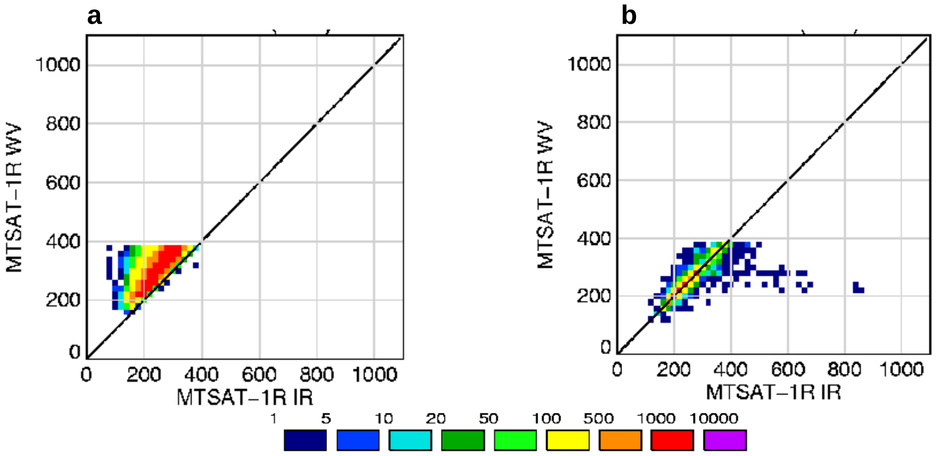

Figure 56: Collocation plots for MTSAT-1R IR and WV winds (match if within 10 km and 10 minutes) for 10 days in (a) May 2007 and (b) June 2007. The bias between the two channels for the pressure assignment is much reduced in the June plot.

The model best-fit pressure statistics for the WV winds show much less bias, particularly in the 300-400 hPa band, than seen previously (see Figure 57).

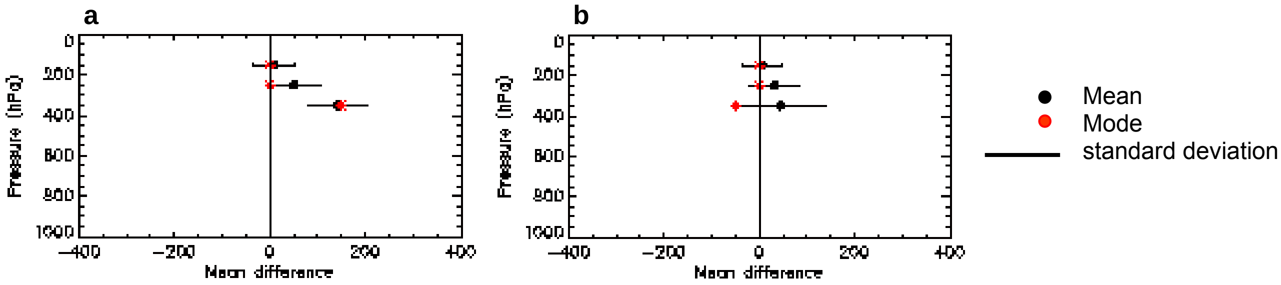

Figure 57: Plots showing the mean difference between the AMV pressure and best-fit pressure as a function of pressure in the atmosphere for MTSAT-1R WV winds in the Tropics for (a) 23 March – 23 April 2007 and (b) June 2007.

Overall the JMA derivation change implemented on 30th May 2007, which involved a revision to the height assignment methodology, has led to an improvement in the statistics for the MTSAT-1R winds and improved consistency between the AMVs produced using the IR and WV channels.

In the second analysis, differences were also described between the Meteosat-8 IR and WV AMVs. Scatter plots of collocated IR and WV winds showed good agreement at high level: above ~230 hPa for WV 6.2 and above ~ 350 hPa for WV 7.3. Below this, the heights started to diverge with the WV winds located systematically higher in the atmosphere (e.g. Figure 58a and d).

Some variation might be expected between the channels in multi-level clouds as they are sensitive to different layers of the atmosphere, but good agreement of the speed and direction of the collocated winds suggests that mostly the channels are tracking the same feature. So what is causing the different AMV height assignment? Investigations at EUMETSAT revealed that atmospheric absorption above cloud top was not being allowed for in the MSG processing stream. This was corrected with a change on the 1 December 2005. A comparison of the pressures after the change shows better agreement (Figure 58b and e), but there is still a tendency for the WV winds to be located higher than the IR winds at mid level and a few WV AMVs are put significantly lower. EUMETSAT implemented a second derivation change on the 22 March 2007. This consisted of a number of changes some of which impacted on the WV AMVs. Since then the agreement of the IR and WV winds has further improved (Figure 58c and f).

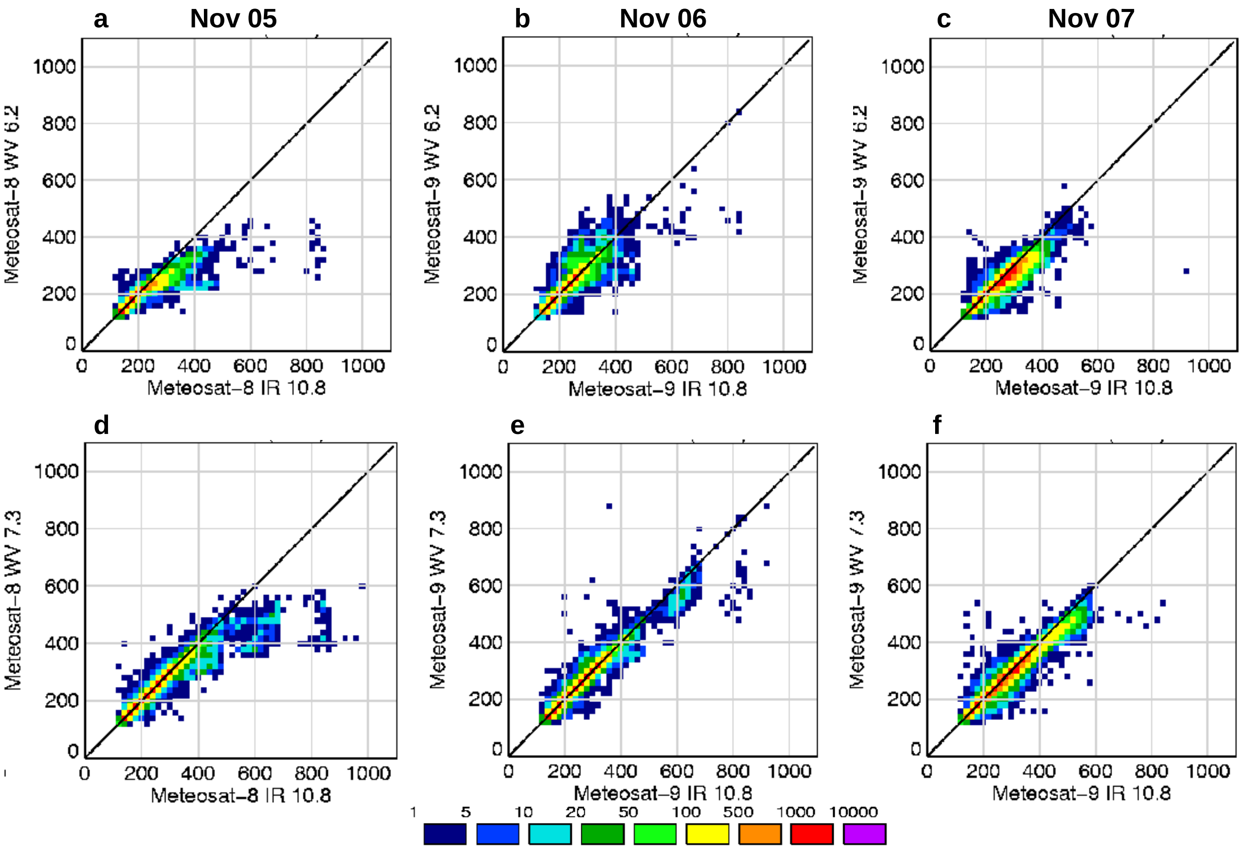

Figure 58: *Collocation plots comparing the assigned pressure of Meteosat-8/9 IR 10.8 with the assigned pressure of (a-c) WV 6.2 winds and (d-f) WV 7.3 winds (match if within 5 km and 10 minutes) for three 2 day periods in (a,d) November 2005, (b,e) November 2006 and (c,f) November 2007.*

The NWP SAF zonal plots in Figure 59 compare the O-B speed bias for the month of November in 2005, 2006 and 2007 and provide an indication of the impact of both derivation changes.

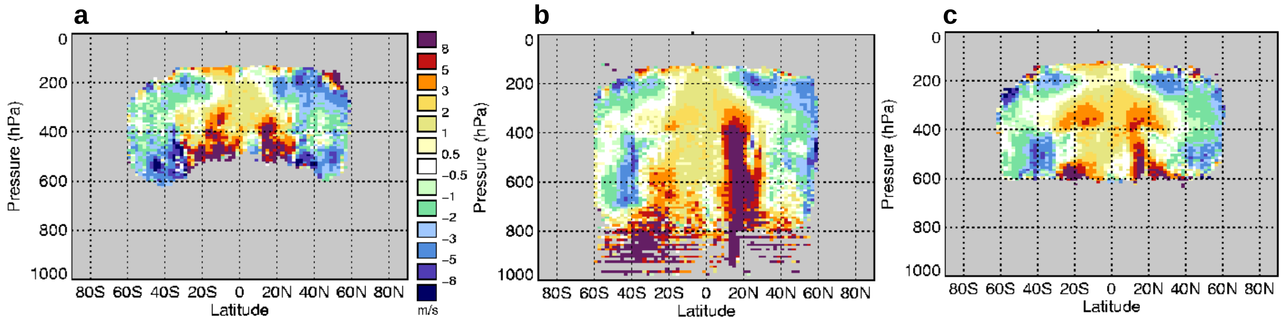

Figure 59: *Zonal O-B speed bias plots for Meteosat-8/9 WV7.3 compared to the Met Office model background for (a) November 2005, (b) November 2006 and (c) November 2007.*

A comparison of Figure 59a and Figure 59b gives an indication of the impact of the 1 December 2005 derivation update. As expected there is an increase in the number of mid level WV AMVs and a reduced slow bias in the extra-tropics, but there is still a significant fast bias linked to the Sahara problem discussed under Feature 2.8 and a few winds are put very low and associated with a fast speed bias. A comparison of Figure 59b and Figure 59c gives an indication of the impact of the 22 March 2007 derivation update. The low level winds with fast speed bias have been removed and the fast bias in the Sahara region is reduced. A similar trend is seen with the WV 6.2 plots.

Feature 3.2. Very high level (above 180 hPa) Meteosat tropical slow bias

In the second analysis report a fast bias at very high levels (above 180 hPa in height) was described (Feature 2.14). An observation that wasn't noted before, although it was present, is that a slow bias is instead seen at high level between June and September in the tropics for Meteosat-7 and Meteosat-9 (see Figure 60). This is also seen in the plots compared with the ECMWF model background.

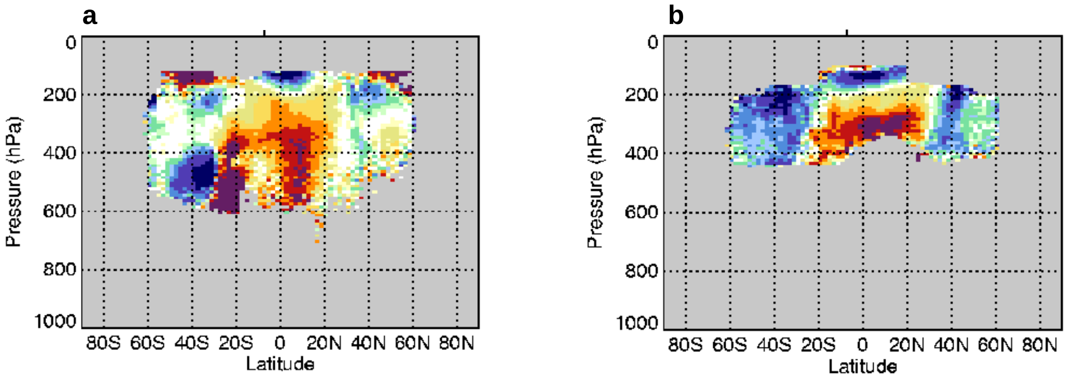

Figure 60: *O-B speed bias plots compared with the Met Office model background for (a) Meteosat-9 WV 6.2 and (b) Meteosat-7 WV.*

The geographical distribution of the slow speed bias is shown in Figure 61 and is associated with background wind speeds of more than 20 m/s. These fast high level easterly winds are a seasonal feature sometimes referred to as the Tropical Easterly Jet.

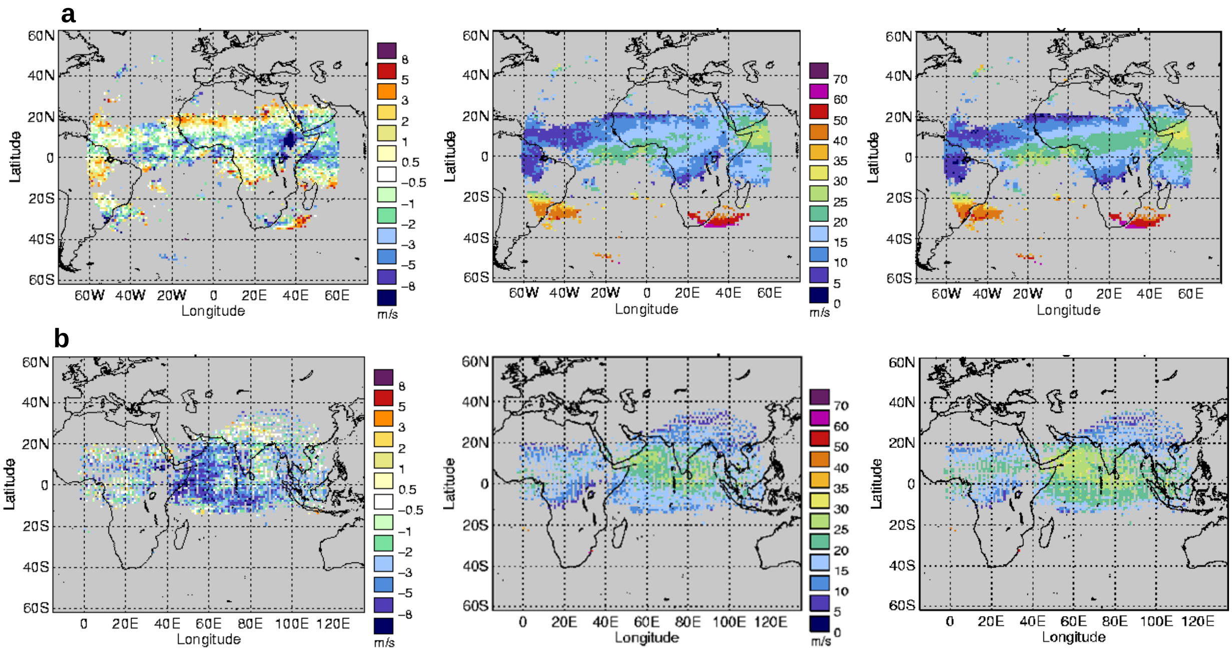

Figure 61: *Map plots showing the O-B speed bias, mean observed speed and mean background speed for a) Meteosat-9 IR and b) Meteosat-7 IR compared with the Met Office model background for August 2007 for winds above 250 hPa in the atmosphere.*

What is less clear is whether the bias is due to the AMVs being too slow, possibly due to a height assignment error, or the model winds being too fast.

Feature 3.3. GOES-11 bias change at 180 longitude

There is a noticeable change in the bias of the high level GOES-11 AMVs at 180° longitude, particularly in the NH. This signal is consistently seen from month to month in the high level IR and WV map plots compared with both the Met Office and ECMWF model backgrounds (e.g. Figure 62). The unedited GOES-11 winds are less affected, which suggests it may be linked to the autoeditor step of the processing.

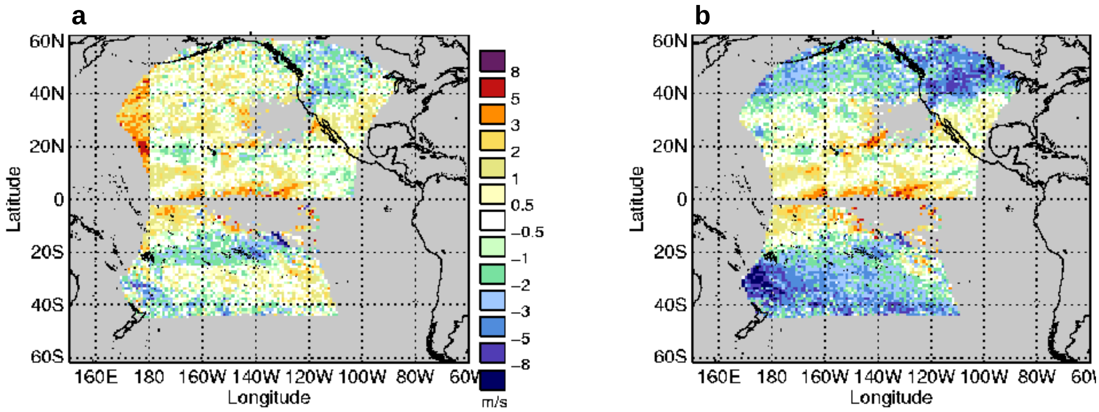

Figure 62: *Map plots showing the O-B speed bias for high level (a) GOES-11 WV and (b) unedited GOES-11 WV compared with the Met Office model background for August 2007.*

5.5. Polar winds

The NWP SAF monitoring includes a range of polar AMV datasets including the CIMSS, direct broadcast and NESDIS MODIS datasets. For the latter both the unedited and edited winds are shown. More recently the NOAA 15-18 AVHRR AMV datasets have been added. The NWP SAF AMV monitoring only includes data that arrives in time for the model cut-offs. Generally the statistics are similar for all datasets, but some differences are noted below.

Feature 3.4. NESDIS MODIS IR slow streak

The speed bias density plots for the NESDIS MODIS IR winds show a streak of very slow speeds (see Figure 63). This is visible at all levels in both the edited and unedited MODIS winds, but is not seen for the AMVs produced using the CIMSS processing or those derived from the WV channel.

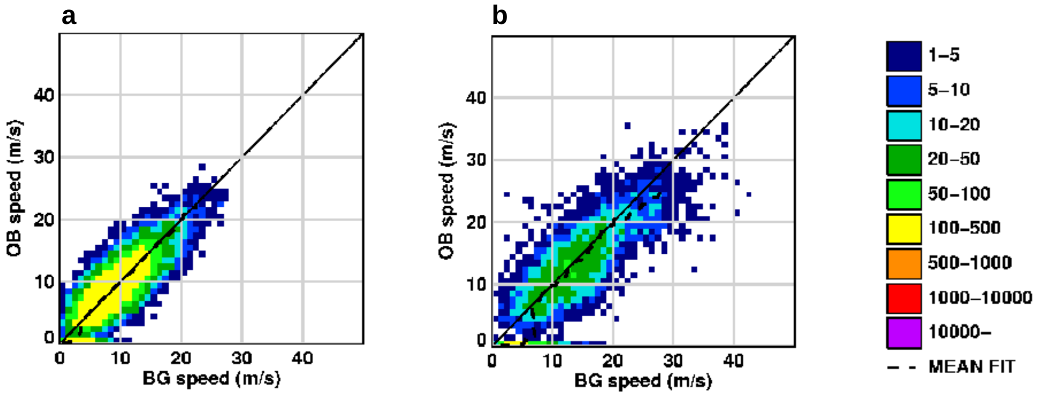

Figure 63: *Speed bias density plots for NESDIS Terra IR low level winds for August 2007 compared with the Met Office model background in (a) the NH and (b) the SH.*

Figure 64 shows the distribution of the AMV data with wind speeds less than 1 m/s.

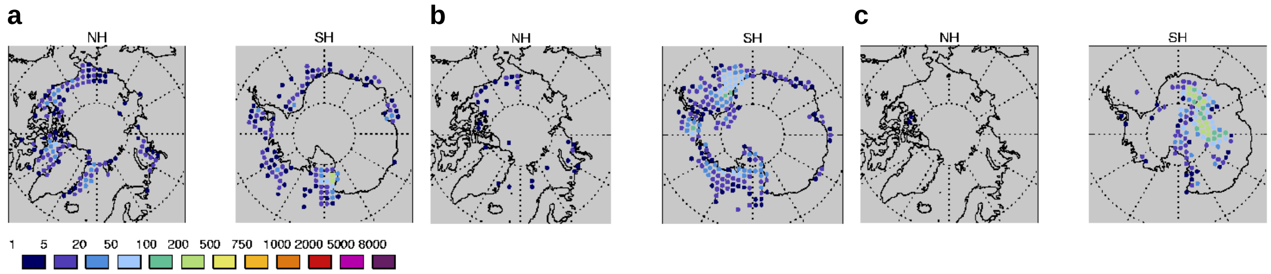

Figure 64: *Maps showing the distribution of winds at (a) low level, (b) mid level and (c) high level with wind speeds less than 1 m/s for July 2007.*

At low and mid level the very slow AMVs are generally located around the edges of the polar continents. At high level the AMVs are located over the high Antarctic land mass.

The presence of a large number of winds with wind speeds less than 1 m/s can give rise to a slow speed bias in some regions. Figure 65 illustrates the impact on the zonal speed bias of removing winds with speeds less than 1 m/s. The slow speed bias above 200 hPa is completely removed and the slow speed bias at low levels is reduced.

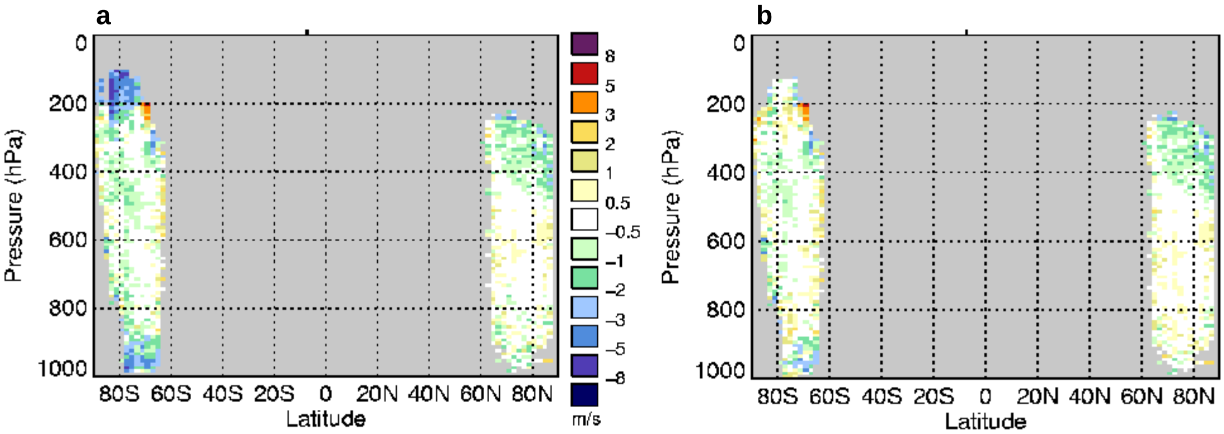

Figure 65: *Zonal O-B speed bias plots for the unedited NESDIS Aqua IR winds for July 2007 compared with the Met Office model background: (a) all data and (b) all data with observation speed > 1 m/s.*

Update on Feature 2.19. High level fast speed bias in edited MODIS data

A fast speed bias at high level is seen in the edited polar IR and cloudy WV data (e.g. Figure 66a and 66c). This is at least partially due to the speed increase applied in the autoeditor as the unedited data shows less bias (e.g. compare Figures 66c and 66d).

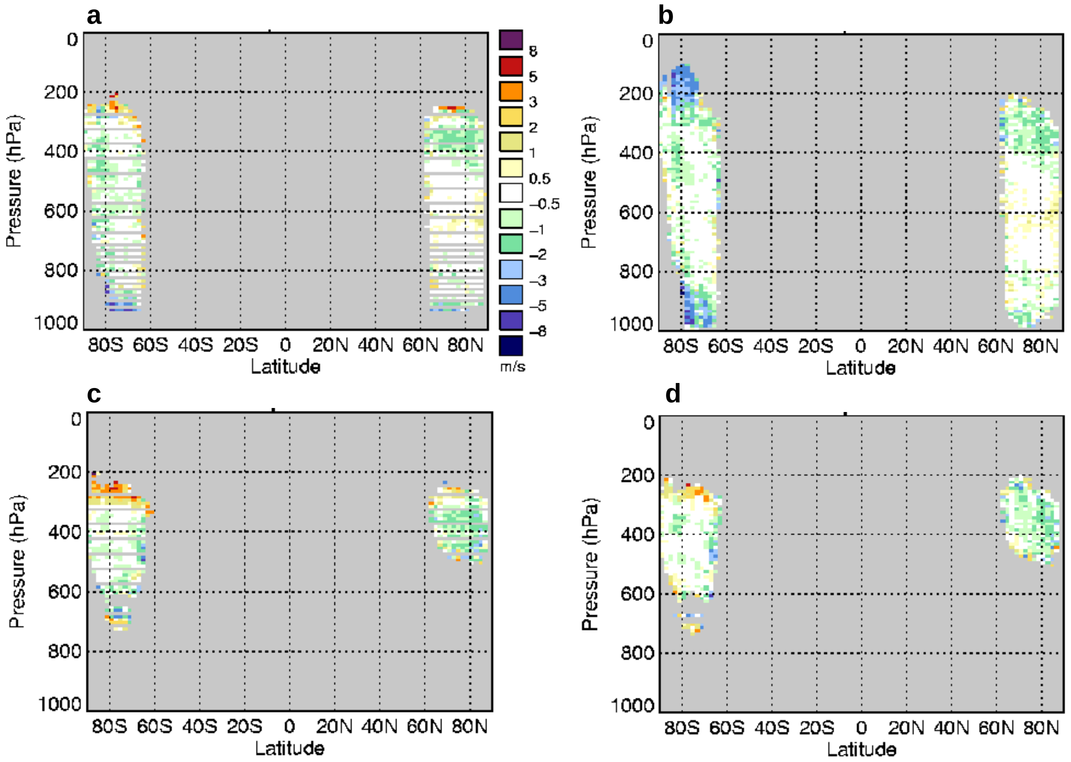

Figure 66: *Zonal O-B speed bias plots compared with the Met Office model background for July 2007 for (a) NESDIS Terra IR, (b) NESDIS unedited Terra IR, (c) NESDIS Aqua WV and (d) NESDIS unedited Aqua WV.*

Figure 67 shows the distribution of the fast speed bias for the high level edited NESDIS polar winds for July 2007. The bias shows some relationship with the background speed, but there is not a precise match.

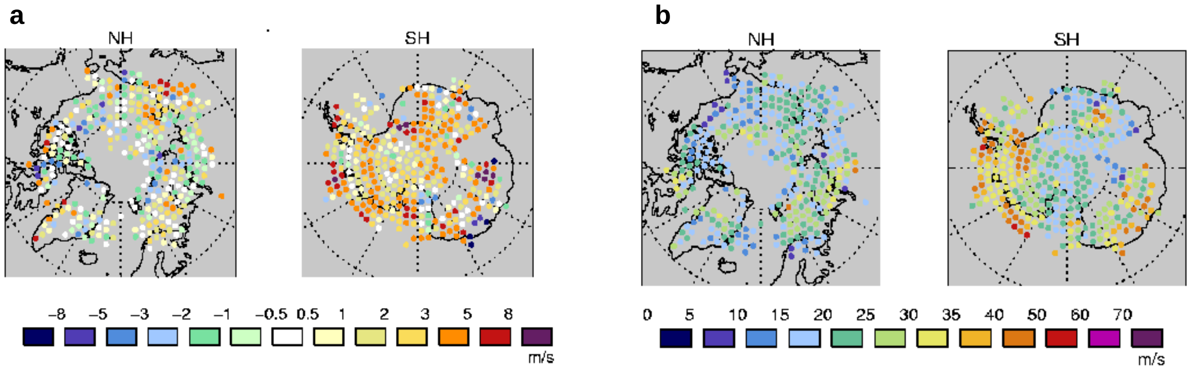

Figure 67: *Maps showing (a) the O-B speed bias and (b) the mean background speed for the edited NESDIS Aqua IR winds compared with the Met Office model background for July 2007. A filter is applied so only AMVs above 300 hPa with a wind speed > 1 m/s are included.*

Update on Feature 2.20. Low level slow speed bias in polar IR data

A slow speed bias is seen below 900 hPa in the unedited and edited polar IR datasets from both NESDIS and CIMSS (e.g. Figure 68). The slow bias is present over both poles during the NH winter, but is only present over the south pole during the NH summer.

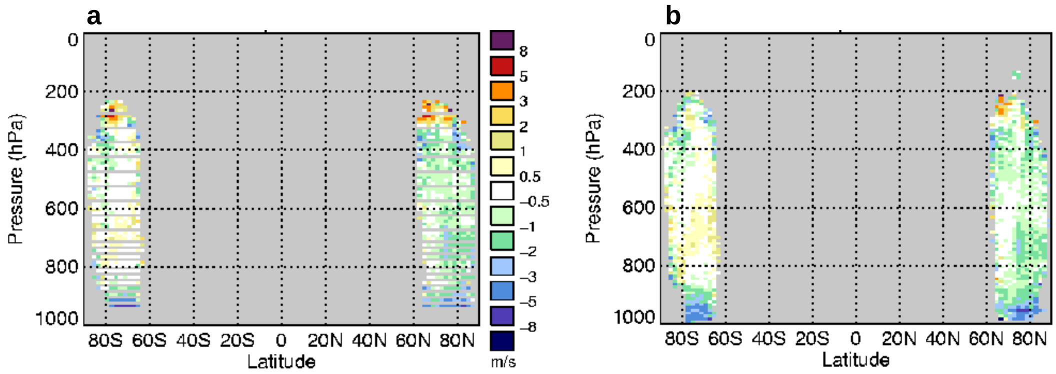

Figure 68: *Zonal O-B speed bias plots for (a) the edited Aqua IR winds and (b) the unedited Aqua IR winds compared with the Met Office model background for November 2007.*

Figure 69 shows slow mean observed speeds at these levels, in some cases less than 5 m/s.

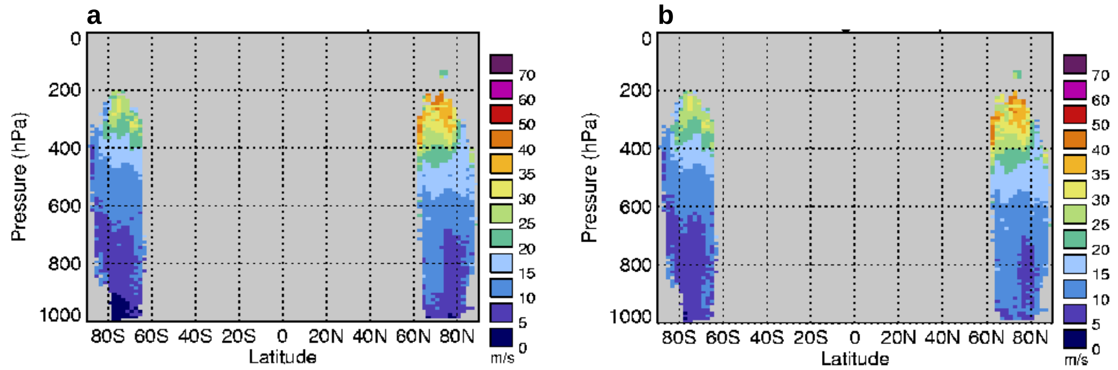

Figure 69: *Zonal (a) mean observation speed and (b) mean background speed for the unedited Aqua IR winds and Met Office model background for November 2007.*

The slow bias is exacerbated by AMVs with speeds less than 1 m/s as discussed under Feature 3.4. After removing these winds the slow bias is reduced, but not eliminated (compare Figure 70a and b).

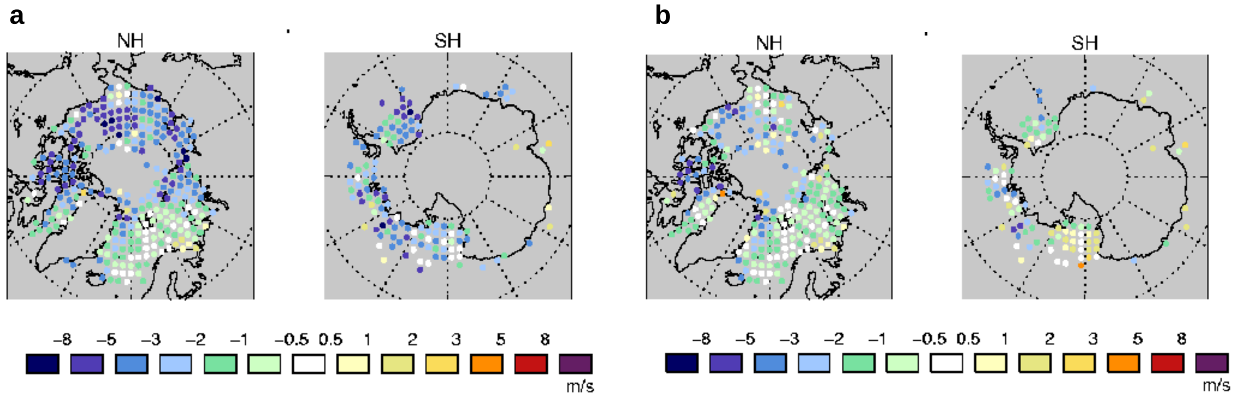

Figure 70: *Map plots showing O-B speed bias for (a) all unedited NESDIS Aqua IR winds below 900 hPa and (b) as (a) but further excluding winds with speeds < 1 m/s. Results are compared with the Met Office model background for November 2007.*

Feature 3.5. CIMSS polar AMV problem in Sep-Oct 2007

All the AMV data produced using the CIMSS processing system, including the CIMSS MODIS and AVHRR winds and the direct broadcast MODIS winds, were affected by a change to the GFS data at NCEP that occurred on the 25 September 2007. The most obvious impact was a large slow bias and raised mean vector difference in the unedited wind data above 400 hPa (see Figure 71). The NESDIS winds were not impacted. A fix was implemented in the CIMSS system on the 4 October 2007, which largely resolved the problem.

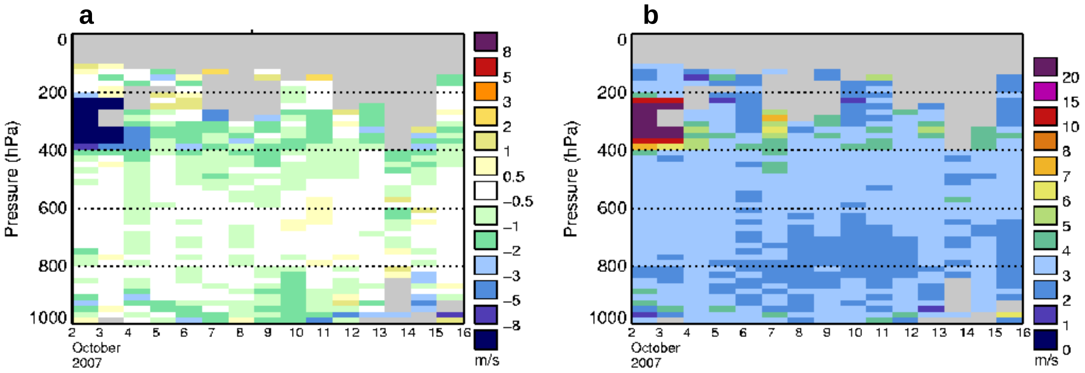

Figure 71: *Hovmoeller plots showing (a) the O-B speed bias and (b) the mean vector difference for the unedited Tromsø Terra IR winds (NH) compared with the Met Office model background for a fortnight in October 2007.*

Figure 72 compares the high level speed bias density plot for a 6-hour case during the problem period with a 6-hour period of normal operations. There are a large number of AMVs with much slower wind speeds than the model background.

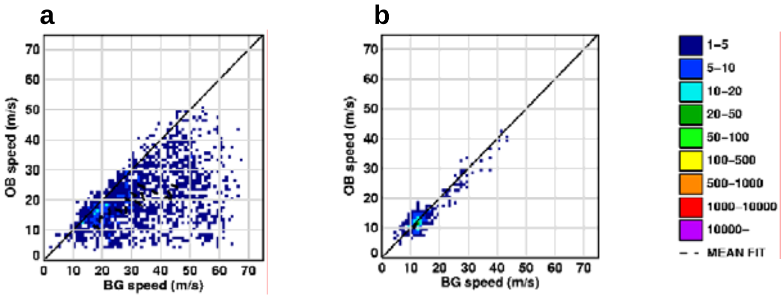

Figure 72: *Speed bias density plots for the unedited Tromsø Terra IR winds (NH) compared with the Met Office model background for (a) 0900-1500 UTC on the 2 October 2007 and (b) 0900-1500 UTC on the 6 October 2007.*

Although the main bias was removed by the 4 October change, a couple of small differences remained: (1) a fast bias in the edited (but not unedited) SH high level CIMSS derived winds (Figure 73a) and (2) a lower number of CIMSS SH winds (Figure 73b). Both discrepancies have since been addressed by a change implemented at CIMSS in late January - early February 2008.

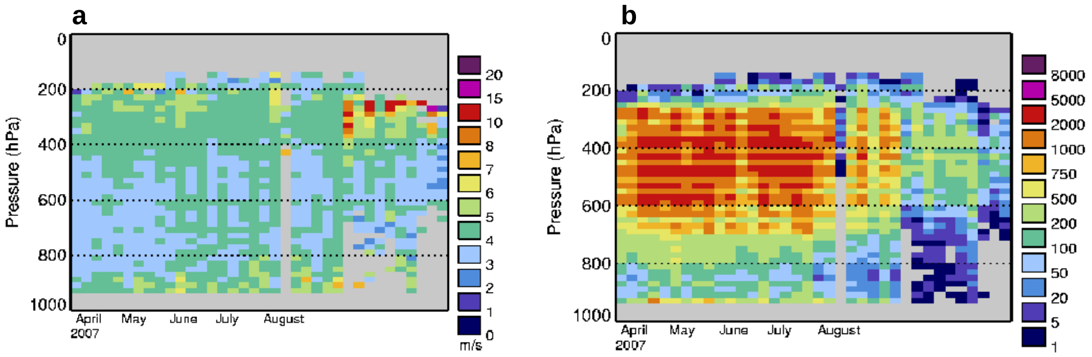

Figure 73: *Hovmoeller plots of weekly (a) mean vector difference and (b) number of winds for CIMSS Terra IR in the SH compared with the Met Office model background for April-November 2007.*

Feature 3.6. NESDIS-CIMSS polar AMV differences

CIMSS and NESDIS have been working to reduce the differences between the NESDIS and CIMSS MODIS datasets. One difference noted in the second analysis was a bulge in some CIMSS mid level density plots (Feature 2.17). This was resolved with a fix in May 2006. Another discrepancy was, until recently, evident in the pressure comparisons of collocated observations (see Figure 74).

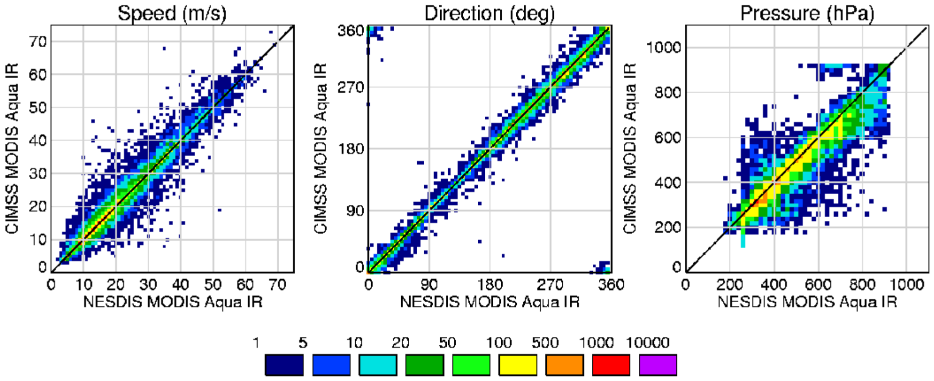

Figure 74: *Plots comparing the speed, direction and pressure of collocated CIMSS and NESDIS Aqua IR winds for the 1-15 July 2007. AMVs were collocated if within 10 minutes in time and 5 km in distance.*

Restricting comparisons to cases when the height assignment methods are the same in the two datasets shows better consistency except in the case of the cloud base height assignment. In this case the CIMSS AMVs were located around 900 hPa and the NESDIS AMVs range in height from 600-900 hPa (Figure 75c).

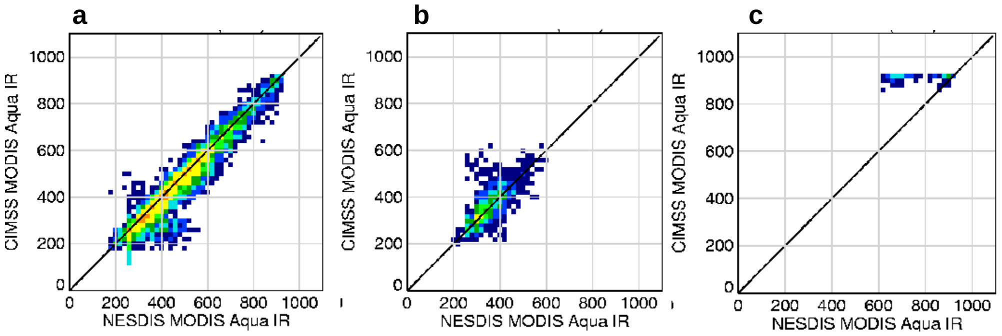

Figure 75: *Plots comparing the pressure of collocated CIMSS and NESDIS Aqua IR winds for the 1-15 July 200: (a) EBBT height assignment used, (b) WV intercept height assignment used and (c) cloud base height assignment used. AMVs were collocated if within 10 minutes in time and 5 km in distance.*

The differences in height assignment have been reduced by a change at CIMSS in late January - early February 2008. Figure 76 compares the speed, direction and pressure of collocated CIMSS and NESDIS Aqua IR winds for a week after the change was implemented.

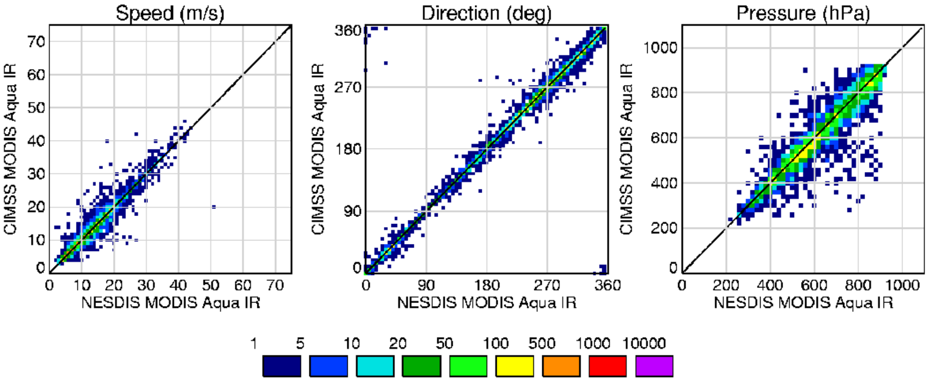

Figure 76: *Plots comparing the speed, direction and pressure of collocated CIMSS and NESDIS Aqua IR winds for the 1-7 February 2008. AMVs were collocated if within 10 minutes in time and 5 km in distance*

6. Improving the impact of AMVs in NWP

The aim of this section is to highlight what I believe are the three key areas to address in order to optimise the contribution of AMVs to forecast skill. For a fuller discussion of AMV data assimilation options see the second analysis report.

The first area to address is AMV data quality by identifying improvements to the derivation and height assignment. 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 (Borde, 2007). Progress has been made in this area since the second analysis report was produced; noticeable improvements have been observed particularly in the MTSAT-1R, MSG and CIMSS MODIS AMVs. But it is very important to continue this work.

The second and third items are very much inter-linked and will require the producers and users to work together. The second is for the users to pursue improvements to the AMV assimilation. The results provided in Sections 4 and 5 of this report provide some guidance on which new datasets to assimilate and what extra blacklisting to apply. For example it may be sensible to consider removing all NESDIS MODIS AMVs with wind speeds less than 1 m/s (Feature 3.4) and to blacklist mid level MTSAT-1R IR AMVs (Feature 3.1). This is useful information for tweaking the current assimilation set-up, but only goes so far. To optimise the assimilation it is important to consider larger developments for example improving the observation error representation, developing layer observation operators and allowing for spatially correlated error directly in the assimilation. This is where it becomes more important to work with the data producers and brings me to the third line of work, which is for producers to develop extra quality and representativeness information using data available during the derivation. One example is the development of a height error to reflect the uncertainty in the height assignment. This might be based on height errors, like those already produced in the MSG data stream as part of the individual height assignment techniques, in combination with a measure of how variable the cloud heights are within the target area. The inference being that the height assignment may be less reliable in multi-level cloud situations. Estimates of height and vector errors can be used by NWP centres to generate individual observation errors (e.g. Forsythe, 2007). Another example of potentially useful information is the provision of an estimate of the vertical representativeness of the AMV 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.

7. Conclusions

Several improvements have been made to the NWP SAF AMV monitoring site since the second analysis report was released in December 2005. These are described in Section 2 and include modifications to the site layout, the addition of AMV NWP usage information from more centres and developments to the NWP SAF AMV monitoring plots.

A new section has been added to the AMV analysis report to provide feedback on new observation types (Section 4). The idea is to provide guidance for NWP centres considering assimilating new AMV datasets e.g. the AVHRR polar winds, as well as providing feedback to the data producers.

The core of the NWP SAF AMV analysis reports is the maintenance of a record of features identified in the O-B monitoring (Section 5). 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. In some cases investigations have highlighted possible causes and solutions. For example the fast speed bias observed in the GOES low level AMVs in the inversion regions (Feature 2.1) is linked to a high height bias, which could be alleviated by improving the height assignment methodology.

Improvements have already been seen since the second analysis report was released in December 2005. Features such as the CIMSS MODIS mid level fast winds (Feature 2.17), the fast bias over the Sahara (Feature 2.8) and the unexpected differences between IR and WV winds from MSG and MTSAT-1R (Feature 2.15) have either been removed or considerably reduced. But there is still more work to be done. Many of the features described persist from year to year, with the largest biases seen in or beneath the jet regions where the wind shear is greater and therefore any height error will lead to a bigger vector difference. Some derivation or height assignment improvements that have been identified 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 (unexpected results described in Section 4.2 and Feature 3.3)
j. Consider checks to avoid high level winds being assigned to low level (Feature 2.7)

I believe more work in these areas will improve the AMV quality, but 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 is probably best 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.

8. Revised Action List

The NWP SAF AMV action list can be viewed at: http://www.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/action_list.html; the completed actions are available as a link from this page. The action list is updated every few months and is fully revised on the completion of each analysis of results. The revised action list is included below and provides suggestions of possible developments to the site and ideas for investigating some of the observation-background inconsistencies further. It is important to realise that the items in the action list represent ideas for future work as opposed to a formal task list. The items will be addressed, when time allows, in priority order. We welcome feedback including any additional suggestions for follow-up work.

8.1. Discrepancies between contributors

Ref	Action	Details	Centre(s)
1.4	Ensure consistent display of speed bias density plots	Most of the ECMWF plots are produced at the Met Office to ensure uniformity of format. The one exception is the density plots, which are still produced at ECMWF. Work is ongoing to improve the consistency of display (e.g. standard colour ranges, larger numbers for clarity).	ECMWF
1.9	ECMWF to provide polar map data using distance bins	A one degree grid is used for the geostationary data, but this is less meaningful over the poles. Instead the Met Office polar map plots use a distance box.	ECMWF

8.2. Improvements to site design

No open actions.

8.3. Development of plots

Ref	Action	Details	Centre(s)
3.10	Develop time series and/or Hovmoeller plots	Software exists to produce these at the Met Office, but they have not been added to the site due to the large number of plots already displayed. This could be reviewed if there is sufficient interest.	MetO, ECMWF
3.11	Develop plots comparing AMVs to other observations	Lower priority unless strong demand	MetO, ECMWF
3.12	Inclusion of plots from other centres	Guidance available. Awaiting provision of data from other NWP centres.	MetO and other contributors

8.4. Analysis of results

Ref	Action	Details	Centre(s)
4.2	Provide routine updates	Update analysis every two years. Update action list every 6 months or when significant changes take place.	MetO

8.5. Follow up investigations

Ref	Action	Details	Centre(s)
5.1	Investigate model-model differences	Investigate particular areas where the plots differ between the Met Office and ECMWF.	MetO, ECMWF
5.6	Diurnal variation	Investigate diurnal O-B patterns. This has been tested in some cases, but could be more widely investigated.	MetO, ECMWF
5.7	General height assignment investigations	Continue investigations into differences between channels and satellites in regions of overlap and comparisons with level of best-fit in model wind profiles.	MetO, ECMWF

9. Further recommendations

This section does not form part of the NWP SAF AMV action list, but is provided as a summary of some of the ideas voiced over the last few years on how to improve the AMV derivation and assimilation.

Ref	Action	Details	Centre(s)	Status
6.1	Documentation of 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 the interpretation of the O-B plots, particularly where the problems differ from producer to producer.	All producers	-
6.2	Comparison of methods	Production of AMVs from each other's imagery to directly compare different derivation schemes.	All producers	Ongoing
6.3	Use of simulated imagery as a test of the AMV derivation	Analysis of AMVs derived from simulated imagery (Bormann et al., 2006)	ECMWF and all producers	Ongoing
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	Improvements to 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 (see Conclusions for more details)?	All producers	Ongoing
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	Information on 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	Ongoing
6.8	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	Ongoing
6.9	Improvements to data assimilation	e.g. use of more model independent data, development of individual observation errors and modifications to the observation operator to treat the AMVs as layer observations. Share experiences with other NWP centres.	All users	Ongoing
6.10	Where are AMVs most important?	Run AMV data denial experiments to get a better feel for where the AMVs have most to offer and where they can be more problematic. Feed back findings to producers.	All users	Ongoing
6.11	List of known problem areas	Users to work with the producers to collect a list of known problem areas. Currently addressed through the NWP SAF AMV analysis reports.	All	Ongoing

10. Acknowledgements

We would like to thank Antonio Garcia-Mendez for providing the ECMWF monthly statistics and Una O'Keefe for managing the NWP SAF website. The work has also benefited from discussions with others in the AMV community.

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