Document NWPSAF-MO-TR-027

Version 1.0

08/02/12

Fifth analysis of the data displayed on the NWP SAF AMV monitoring website

http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/

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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 1 December, 2006, 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
0.1	16/01/12	J Cotton	First draft
0.2	30/0112	J Cotton	Updated following comments by M. Forsythe
0.3	01/02/12	J Cotton	Further minor updates
0.4	07/02/12	J Cotton	Updated following comments by R. Saunders
1.0	08/02/12	J Cotton	Final version for circulation

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1. Introduction

Satellite-derived atmospheric motion vectors (AMVs) are winds extracted from satellite imagery by tracking tracers such as clouds or water vapour features through a sequence of images. They are an important source of tropospheric wind information and are routinely assimilated into numerical weather prediction (NWP) models. Although they have been shown to have a positive impact on forecasts, issues with their derivation (particularly height assignment), quality control and assimilation still remain. One difficulty is that the AMV errors are hard to characterise. Improving our understanding of these errors may highlight areas for improvement in both their derivation and treatment in NWP.

The AMV monitoring report http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/ is delivered under the auspices of the NWP SAF (Satellite Application Facility on Numerical Weather Prediction), a EUMETSAT-funded project that exists to coordinate research and development efforts among the SAF partners to improve the interface between satellite data and NWP for the benefit of EUMETSAT member states. The NWP SAF AMV monitoring site provides background information on AMVs, details of how AMVs are used at various NWP centres and investigations on specific aspects of the monitoring. But perhaps most importantly of all it hosts an archive of O-B monthly monitoring plots that display differences between AMVs (O) and NWP model background winds (B) valid at the same location and time. The accompanying series of ‘analysis reports’ are an in-depth study of these statistics with the aim to improve our understanding of the AMV errors and analyse any changes in the data. The analysis reports are currently produced every 2 years to coincide with workshops organised by the International Winds Working Group (IWWG) where the key results are presented.

The format of the report is similar to previous analyses with sections highlighting recent developments to the monitoring, feedback on new data types, features identified in the monitoring and a revised action list.

This fifth analysis report builds on results from previous reports and where relevant refers back to these via references to the *fourth analysis* (Cotton and Forsythe, 2010), *third analysis* (Forsythe and Saunders, 2008) and *second analysis* (Forsythe and Doutriaux-Boucher, 2005).

2. Recent developments

For details of planned developments to the NWP SAF AMV monitoring see the action list in the Appendix. Changes to the AMV monitoring since the last report include:

- Updates were supplied for the information on how AMVs are used in different global NWP systems http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/amvinfo.html
- February 2012: review of all web pages and relocate relevant information under a new NWP tab
- March 2011: a new investigation was added http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/investigations.html
  This compared model best-fit pressure statistics produced by the Met Office and ECMWF and relates to an ongoing item on the NWP SAF AMV action list regarding further investigation of height assignment differences. The investigation was produced in collaboration with Kirsti Salonen, ECMWF.
- November 2010: Metop-A AVHRR polar winds produced by CIMSS and EUMETSAT were added to the monthly monitoring (see section 4 of this report).
- November 2010: new look vector plots were added.
- June 2010: plots were converted from jpegs to a higher resolution gif format. The archived plots were also updated.

3. Methodology

The primary sources of information for this report are the NWP SAF AMV monthly monitoring statistics available from
http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/monthly_mon.html

Table 1 below lists the different AMV data types which are routinely monitored.

Geostationary AMVs	Channels	Polar AMVs	Channels
Meteosat-9	IR10.8, WV6.2, WV7.3, VIS0.8, HRVIS	CIMSS, NESDIS and DB Terra	IR, WV, CSWV
Meteosat-8	IR10.8, WV6.2, WV7.3, VIS0.8, HRVIS	CIMSS, NESDIS and DB Aqua	IR, WV, CSWV
Meteosat-7	IR, WV, VIS	CIMSS NOAA-15	IR
MTSAT-1R/2	IR, WV, VIS	CIMSS and DB NOAA-16	IR
GOES-West (11/15): edited and unedited	IR10.7, IR3.8, WV, VIS	CIMSS and DB NOAA-18	IR
GOES-East (13): edited and unedited	IR10.7, IR3.8, WV, VIS	CIMSS and DB NOAA-19	IR
		CIMSS and EUMETSAT Metop-A	IR

Table 1: Data types available on the NWP SAF monthly monitoring. DB = direct broadcast, WV = cloudy water vapour, CSWV = clear sky WV

The monitoring statistics are calculated by comparing AMV wind observations with model background estimates from a recent short range forecast, 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. Wherever possible the NWP SAF AMV monitoring provides easily comparable plots from the Met Office and ECMWF global forecast models. Note that for GOES and MODIS winds, plots are also produced for the pre-autoeditor winds (unedited), i.e. without the final speed and pressure adjustments (see third analysis report).

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. The QI used is the EUMETSAT-designed QI without model first guess check (Holmlund, 1998). Throughout this document NH refers to the area north of 20N, SH refers to the area south of 20S and the tropics refers to the area between 20S and 20N.

To diagnose possible errors in height assignment it is often useful to compare the AMV assigned pressure to the model best-fit pressure. The model best-fit pressure is calculated by: (1) finding the model level below 100 hPa with the smallest vector difference between the AMV and model background wind and (2) vertically interpolating to find the minimum using a parabolic fit to this model level and the two neighbouring levels. Filters are then applied to the data to remove cases where the best-fit pressure is not well constrained (e.g. secondary minima) but note that there are likely to be error contributions from the model background wind field.

4. Assessment of new AMV observation types

This section provides an assessment of new observation types that have been added to the NWP SAF AMV monitoring.

4.1 CIMSS Metop-A AVHRR polar winds

Date added: November 2010
Received via: FTP

CIMSS AVHRR polar winds from the NOAA 15-18 satellites have been operationally assimilated at the Met Office since May 2008, whilst the NOAA-19 winds were added later in February 2010. The AVHRR winds have provided improved polar data coverage for use in NWP, complementing the MODIS winds from the ageing Aqua and Terra satellites. CIMSS also produce a polar winds product derived from AVHRR imagery on Metop-A and here we show the results of a 1-month comparison for December 2010 plus some later updates from November 2011. As AVHRR does not have a WV channel, only MODIS AMVs generated from tracking clouds in the IR channel are considered in this comparison.

Figure 1 shows the mean difference between observation time and receipt time in the Met Office MetDB for the AVHRR polar winds. In November 2010 the Metop winds appeared to be less timely at ~370 minutes, compared to the NOAA winds at about 200-300 minutes. This would have resulted in only 33% (66%) of Metop-A data making the main (update) assimilation cycle compared to about 49% (99%) for NOAA-19. However a more recent plot for November 2011 shows that the timeliness has improved significantly such that 42% (96%) of Metop-A data now makes the main (update) cycles. This improvement is due to the operational implementation of the Metop Antarctic Data Acquisition (ADA) service from 10 June 2011 which allows data dumps at McMurdo Station in Antarctica in addition to those at Svalbard. As the plots in Figure 2 show this has drastically reduced the time it takes to receive the wind products at the Met Office (down to about 220 mins), enabling more Metop-A data for use in operational NWP.

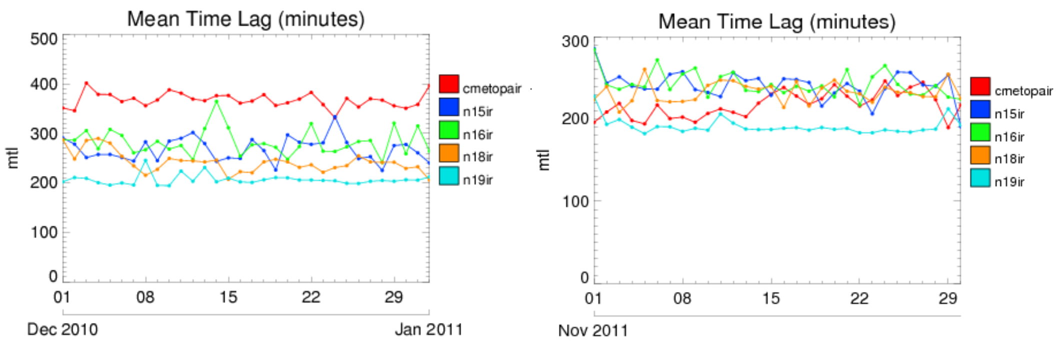

Figure 1: Mean difference between observation time and receipt time for the CIMSS AVHRR polar winds: December 2010 (left) and November 2011 (right). Notice the improvement for the Metop product.

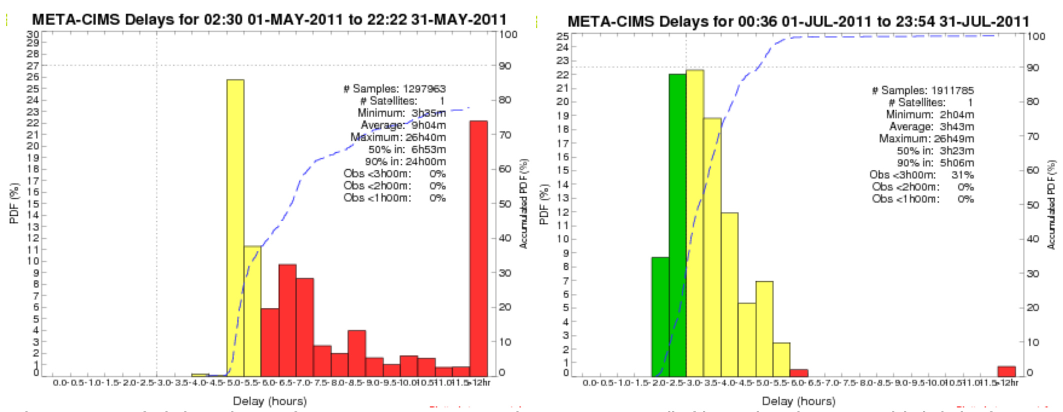

Figure 2: Histogram of delay times for CIMSS Metop-A in May 2011 (left) and July 2011 (right) before and after the implementation of the EUMETSAT ADA. Statistics courtesy of Dave Offiler, Met Office.

The time series plots in Figure 3 show that the data volume for Metop-A is about 4 times greater than for the NOAA winds and is comparable to the MODIS winds. This is because the AVHRR instrument on Metop-A has a global spatial resolution of 1 km which is then remapped to 2 km pixels - as is the case for the MODIS winds. The NOAA series winds however are produced using AVHRR Global Area Coverage (GAC) data at 4 km resolution, hence the MODIS and Metop products should have an advantage in that features for tracking are more distinct than in the GAC data.

In terms of data coverage, Metop-A is in a similar orbit to NOAA-17 which suffered a scan motor failure on 15 October 2010 and so provides a useful replacement (though coverage is often similar to Terra).

The standard NWP SAF plots (speed density, map and zonal) for Metop-A are generally very similar to those of the NOAA AVHRR winds and the MODIS winds. The time series plots in Figure 4 show that the Metop-A winds are of marginally better quality than the NOAA AVHRR winds and compare closest to the MODIS winds. This is probably due to the benefits of the enhanced 2km pixel resolution.

Comparison of vectors and pressures of collocated Metop-A and NOAA/MODIS winds for December 2010 show good vector agreement in both speed and direction e.g. Figure 5. The collocated pressures show some variation with RMS values between 47-58 hPa. The higher pressure RMS for the MODIS collocations is probably due in part to where the WV intercept method has been used for the MODIS winds (WV channel not available for AVHRR). In Figure 5 there is a small cluster of Metop winds around 700 hPa which are lower in the atmosphere than the collocated NOAA-15 winds. This is not visible in the collocations with MODIS and there is no obvious difference in the model best-fit pressure statistics (not shown). Figure 6 shows the collocations when the Metop winds are assigned to cloud base and the NOAA-15 winds are assigned to cloud top (winds below 600 hPa can be assigned to cloud base). It is evident that the cluster of winds occurs simply when the Metop winds are assigned to cloud base and NOAA-15 are not. The fact that there are much fewer NOAA-15 winds at low level means that the reverse event occurs far less frequently.

In conclusion the CIMSS Metop-A data is of a similar quality to that of the MODIS data and perhaps marginally better than the other AVHRR data sets. Data from Metop-A has been assimilated in Met Office operations since 15 February 2011 to improve polar coverage and to help mitigate the loss of NOAA-17.

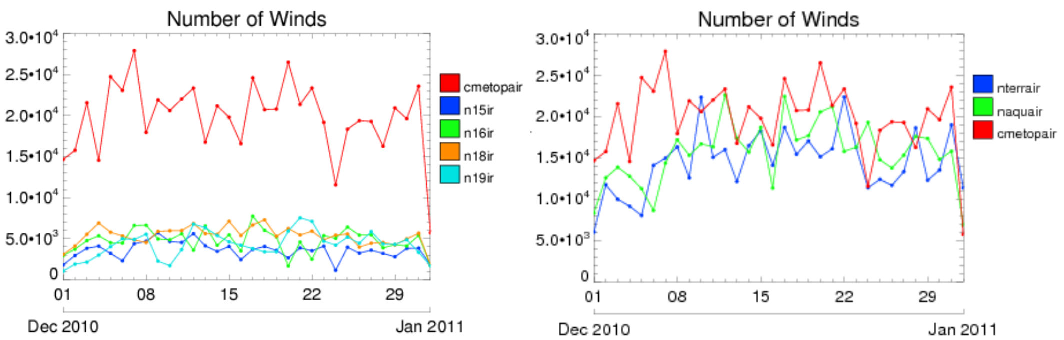

Figure 3: Number of observations from Metop-A compared with the AVHRR winds from the NOAA platforms (left) and the MODIS IR winds from Aqua and Terra (right).

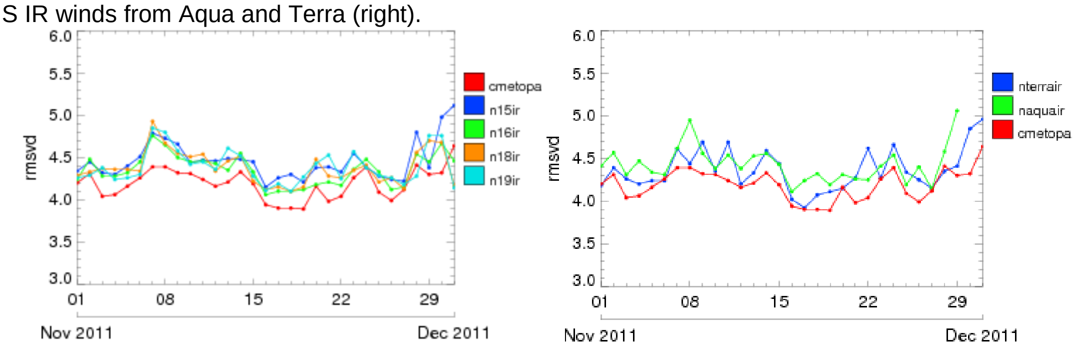

Figure 4: Root mean square vector difference comparing Metop-A with NOAA AVHRR winds (left) and MODIS winds (right) for November 2011.

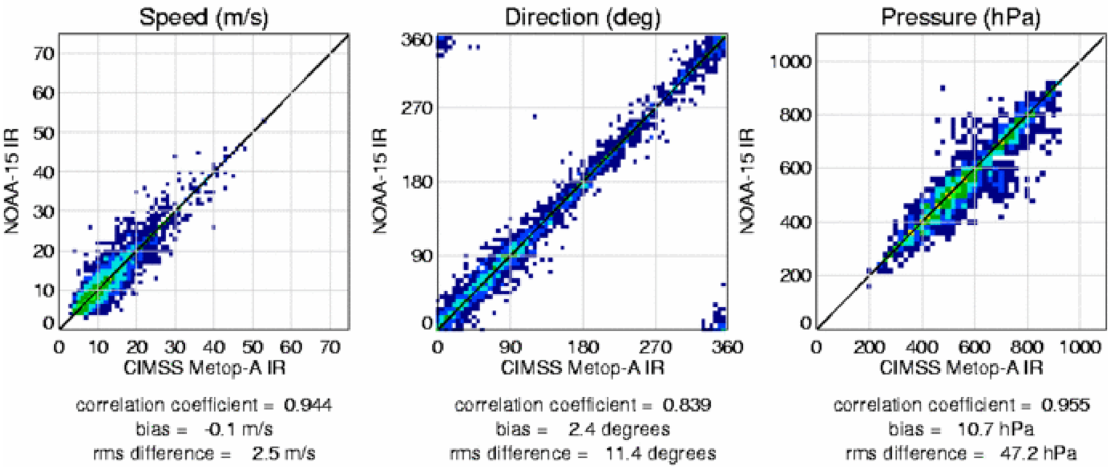

Figure 5: Collocation plots of speed, direction and pressure differences between NOAA-15 and Metop-A for December 2010. Observations were allowed to be up to 10 km apart and up to 30 minutes different in observation time. 4344 matches.

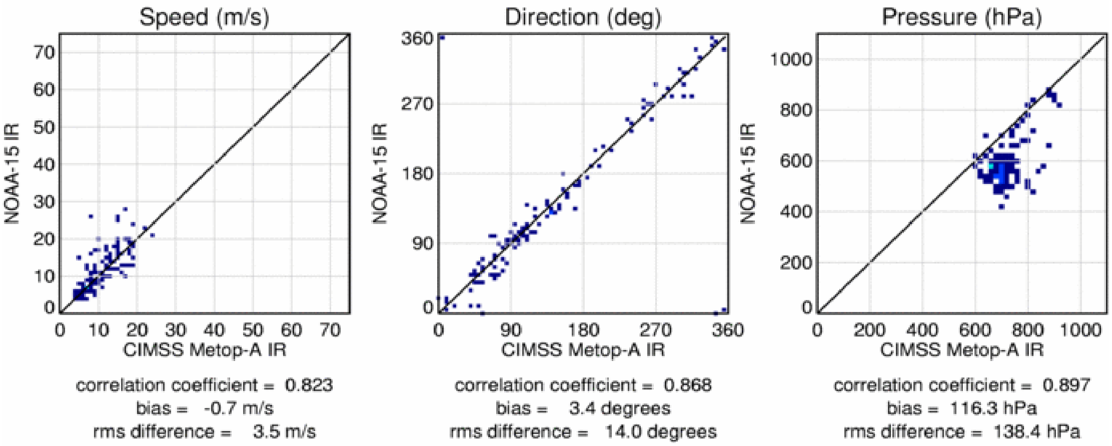

Figure 6: As per Figure 5 but this time filtering collocations for Metop winds assigned to cloud base and NOAA-15 assigned to cloud top. 158 matches.

4.2 EUMETSAT Metop-A AVHRR polar winds

Date added: November 2010
Received via: EUMETCast

EUMETSAT began disseminating an operational Metop-A polar winds product in January 2011 following an earlier trial period. One of the primary differences between this product and the one produced at CIMSS is the use of image pairs for tracking rather than the usual triplet of images (see Dew et al., 2010). The benefit of this new approach is the ability to extend the AMV derivation area down to lower latitudes and so help to fill the data void between the geostationary and traditional polar data sets. This high latitude region is of particular importance for NWP as it is frequently samples meteorologically interesting areas such as the location of the polar front jets (Forsythe et al., 2010). Figure 7 shows the improved coverage afforded by the EUMETSAT product at lower latitudes with winds processed polewards of 55 degrees N/S. Following an update in June 2011 the CIMSS product now provides 'good' coverage polewards of about 63 degrees N/S.

The EUMETSAT winds have undergone several upgrades during 2011

25/01/11 - New 'operational' version disseminated. Number of changes to improve data quality e.g. increasing the density of wind vectors, the proportion of high quality winds and amendments to QI methodology

24/02/11 - Fix for some winds crossing the 180° longitude boundary. Stop some intermittent timeouts.

13/12/11 - Operational version 2.0. Number of changes including use of collocated cloud top heights derived from IASI, cross correlation tracking (instead of Euclidean distance) and parallax correction.

The changes in January and February 2011 led to an improvement in high level O-B statistics, including the speed bias (Antarctic), RMS vector diff and direction standard deviation. At mid and low level speed biases were slightly worse but there was a significant improvement in direction standard deviation of around 40% at mid level (table 3). However, as shown in tables 2 and 3 the EUMETSAT product still shows higher levels of bias when compared to the CIMSS product. This difference might be explained by the use of image pairs for the EUMETSAT winds and the implementation of additional quality control checks against model first guess at CIMSS. It is also worth noting that as the CIMSS winds are assimilated at the Met Office we might expect their departures to be less than those from independent data sources such as the EUMETSAT polar winds.

At this stage it is too early to assess what impact the changes introduced in December 2011 have had on the departure statistics.

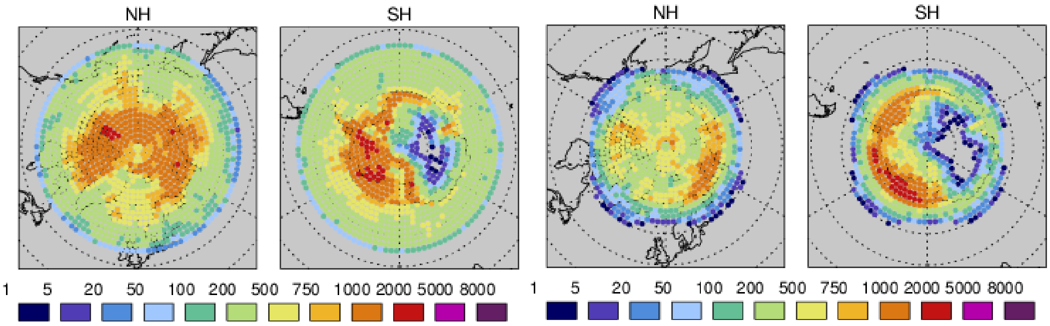

Figure 7: Data coverage plots comparing the Metop-A polar wind products from EUMETSAT (left) and CIMSS (right). Mid level winds for June 2011.

	ML	NH			SH		
Month	Product	Number	Bias (m/s)	Stdv (m/s)	Number	Bias (m/s)	Stdv (m/s)
Jan-11	EUM	153346	0.34	5.33	99582	1.62	4.59
Feb-11	EUM	612216	1.17	5.16	449903	1.49	4.95
Mar-11	EUM	1017028	1.41	5.02	760009	1.42	5.09
Apr-11	EUM	734873	1.74	4.93	705101	1.18	5.29
May-11	EUM	764766	2.13	4.75	716443	1.24	5.46
Jun-11	EUM	779524	2.21	4.48	654485	1.25	5.44
Jan-11	CIMSS	210880	-0.61	2.99	232676	0.11	2.92
Feb-11	CIMSS	153267	-0.64	3.12	220431	0.04	3.12
Mar-11	CIMSS	188987	-0.37	2.98	290772	-0.13	3.17
Apr-11	CIMSS	112274	-0.33	3.00	262672	-0.12	3.43
May-11	CIMSS	108759	-0.16	2.85	299908	0.00	3.70
Jun-11	CIMSS	294674	-0.04	2.66	320966	-0.23	3.53

Table 2: Summary of mid level O-B speed bias statistics for January 2011 to June 2011 comparing the CIMSS and EUMETSAT Metop polar winds. All data with QI2>60.

	ML	NH			SH		
Month	Product	Number	Bias (deg)	Stdv (deg)	Number	Bias (deg)	Stdv (deg)
Jan-11	EUM	153346	1.2	40.5	99582	-0.5	44.6
Feb-11	EUM	612216	0.0	23.4	449903	-0.4	27.7
Mar-11	EUM	1017028	0.1	24.4	760009	-0.7	26.7
Apr-11	EUM	734873	0.8	25.1	705101	-0.5	25.7
May-11	EUM	764766	0.5	25.7	716443	-0.4	26.1
Jun-11	EUM	779524	0.7	26.7	654485	-0.1	24.8
Jan-11	CIMSS	210880	-0.4	12.9	232676	-0.2	19.1
Feb-11	CIMSS	153267	-0.7	13.6	220431	-0.9	19.3
Mar-11	CIMSS	188987	-1.2	13.7	290772	-0.6	16.5
Apr-11	CIMSS	112274	-0.7	14.5	262672	-0.3	17.3
May-11	CIMSS	108759	-0.9	13.6	299908	-0.3	18.2
Jun-11	CIMSS	294674	-0.3	14.7	320966	-0.1	15.8

Table 3: Summary of mid level O-B direction bias statistics for January 2011 to June 2011 comparing the CIMSS and EUMETSAT Metop polar winds. All data with QI2>60.

5. Features observed in the O-B statistics plots

The format of Section 5 follows the structure of previous reports where features are discussed in turn. The features are referenced x.y, where x is the number of the analysis report where the feature was first described (i.e. 4 for features first noted in fourth analysis) and y is the example number. 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 polar AMVs.

Some of the features have been comprehensively described in previous analysis reports. An update is only included in this report for features where further investigation has yielded new results. The aim is to identify, where possible, the cause of O-B features and any relevant actions that may help to alleviate the problems.

Table 4 summarises the status of each feature and indicates whether further information is provided in this report. In some cases the names of features may have been updated to better reflect the pattern or cause (e.g. feature 4.1).

See http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/analysis.html for a full list of features including those closed in earlier reports.

Ref.	Feature	Previous	Resolved?	Update?
Low level (below 700 hPa)				
2.1.	GOES fast bias in inversion regions	2,3	Fixed in new product	Y
2.3.	NE America winter slow speed bias	2,3	No	N
2.6.	Fast bias over Africa	2,3,4	No	N
2.7.	Spuriously fast Meteosat and MTSAT-1R winds at low level	2,3,4	No	N
4.1.	Model differences in the Pacific	4	No, feature renamed	Y
5.1	Patagonia slow bias	new	No	Y
5.2	MSG slow bias during low level Somali Jet	new	No	Y
Mid level (400-700 hPa)				
2.8.	Fast bias in the tropics	2,3,4	No, but some improvements	Y
2.9.	Slow bias in the extratropics	2,3,4	No, but some improvements	Y
High level (above 400 hPa)				
2.10.	Jet region slow bias	2,3,4	No	Y
2.11	NESDIS over-correction of slow bias in jets	2	Less prominent - close	Y
2.13.	Tropics fast bias	2,3,4	No, but some improvements	Y
2.14.	Very high level (above 180 hPa) Meteosat and unedited GOES fast bias	2,3	No	N
2.15.	Differences between channels	2,3	No	Y
3.2.	Very high level (above 180 hPa) Meteosat tropical slow bias	3	No	N
3.3.	GOES-11 bias change at 180 longitude	3	Fixed in new product	Y
4.2.	GOES near equatorial slow bias	4	No	Y
5.3	MTSAT typhoon fast bias	new	No	Y
Polar AMVs				
2.19.	High level fast speed bias	2,3,4	No	Y
2.20.	Low level slow speed bias in polar IR data	2,3,4	No	N
3.6.	NESDIS-CIMSS polar AMV differences	3	Improved	Y
4.3.	Near-pole mid level slow bias	4	CIMSS improved	Y

Table 4: Status summary of the current features identified in the NWP SAF AMV monitoring. Green denotes a new feature, blue denotes a feature than is fixed or considered closed.

Examples provided in this report are mainly from the Met Office comparisons, but the ECMWF plots show similar results.

5.1. 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 2nd 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 in inversion regions

It has been observed that GOES AMVs located in inversion regions such as that found off the west coast of South America are persistently faster than collocated NWP model forecast winds and have large RMS vector differences (see Figure 8). In this region of the Pacific the bias appears to be worse between July-November and is more prominent when tracking in the visible channel than it is when tracking in the IR channel. A similar pattern of fast bias and high RMS can also be observed in the GOES-11 AMVs located in the Eastern Pacific near California and the Baja peninsula, Mexico.

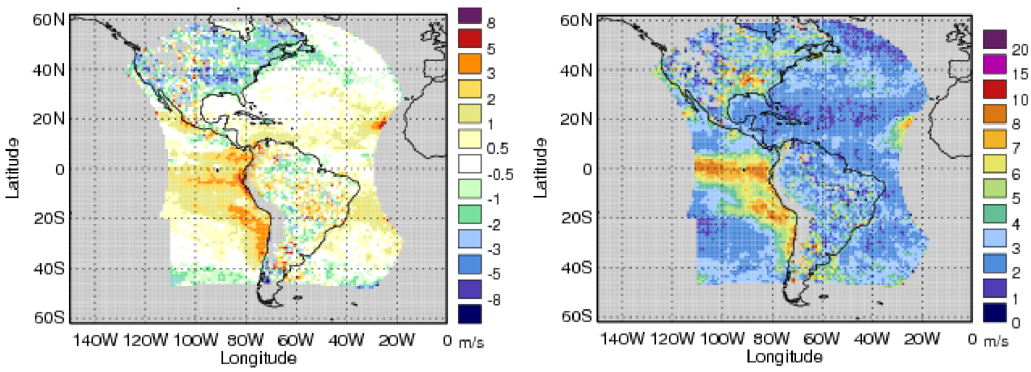

Figure 8: Map plots showing mean O-B speed bias (left) and root mean square vector difference (right) for the operational GOES-13 visible AMVs. Data plotted for November 2011 compared with the Met Office model background.

Figure 9 shows a tephigram for the Met Office global model for a 5 degree grid square located over the Pacific near Northern Chile during November 2011. The mean temperature analysis clearly shows the distinctive inversion profile below 700 hPa, particularly from the surface up to 850 hPa, with very dry air aloft. In inversion situations, marine stratocumulus cloud is likely to form at the base of the temperature inversion. The third analysis report noted that GOES AMVs in these stratocumulus inversion regions were being assigned heights much higher in the atmosphere than the model preferred position, often in excess of 200 hPa. Such a bias can arise when there are two heights in the model profile which match the observed cloud temperature. This could be due to of a lack of vertical resolution in the temperature profile meaning that the true depth of the inversion is not properly represented. Nevertheless, even with good vertical resolution multiple solutions can still occur.

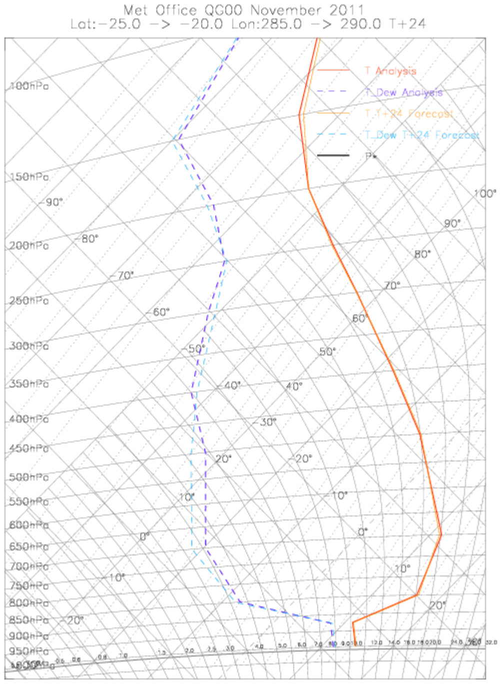

Figure 9: Met Office global model tephigram for November 2011 showing the mean temperature (red) and dew point analysis (purple) for a latitude/longitude box 20-25 S, 70-75W.

Since late 2010 a new GOES data stream has been made available on a routine but experimental basis from NESDIS/STAR. The new GOES-E and GOES-W AMVs are being derived every hour compared with only every 3 hours for the operational stream (as at 2011) and also include the addition of the expected error (EE) quality indicator. Comparing map plots for the new hourly AMVs (Figure 10) with the operational winds shown above, it is clear that there is a significant improvement in RMS vector difference in the problematic inversion region and a small reduction in fast bias. Figure 11 shows the impact on the difference between the GOES assigned pressure and model best-fit pressure for observations located over sea. In the case of the operational winds there is a large high height bias above 850 hPa in the southern hemisphere region, particularly around 20S. However, this bias is greatly reduced in the equivalent plot for the hourly data due to an improved handling of the low level height assignment and application of a inversion correction (not previously applied in the operational winds). Where an inversion is detected over sea the GOES hourly AMVs are now assigned to the base of the temperature inversion using an increased number of vertical model levels from the NCEP GFS forecast. This is the same methodology developed as part of the future GOES-R derivation scheme (see Daniels et al., 2010).

The improvement of the hourly winds in the GOES inversion regions is an encouraging result for users as this has been a regularly reported feature of the GOES winds in previous analysis reports. The hourly winds are due to be implemented operationally by NESDIS around April 2012.

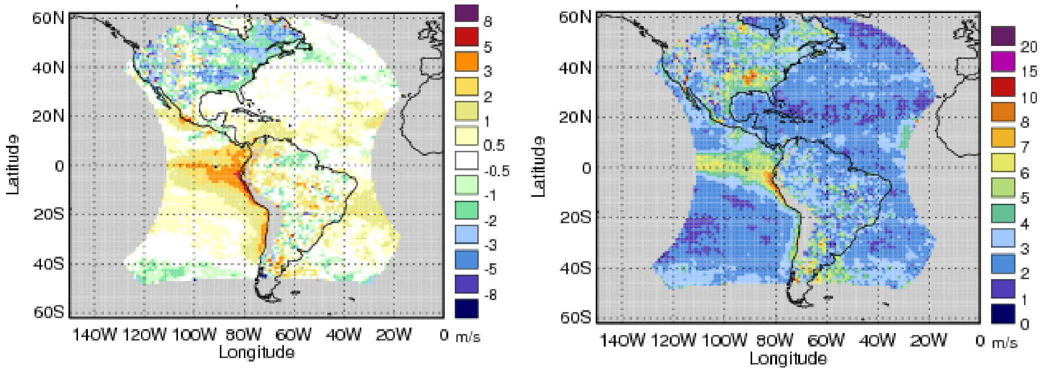

Figure 10: Map plots showing mean O-B speed bias (left) and root mean square vector difference (right) for the experimental hourly GOES-13 visible AMVs. Data plotted for November 2011 compared with the Met Office model background.

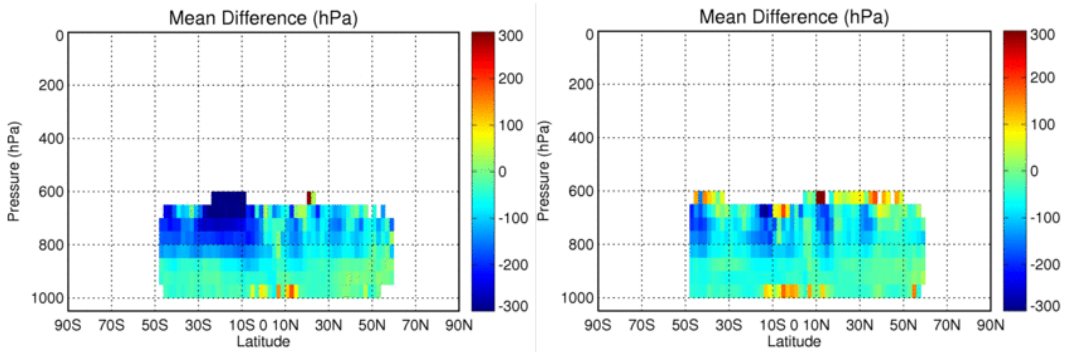

Figure 11: Zonal plots of mean difference between GOES-13 visible assigned pressure and model best-fit pressure for the 2011 operational stream (left) and the experimental hourly stream (right). Data is for period November 2011 and observations over sea only.

Update on Feature 4.1. Model differences in the Pacific

It was reported in the fourth analysis that a slow speed bias was evident near the equator in the GOES-11 plots versus the Met Office model background. The bias was more prominent in the visible channel than the IR and since the ECMWF plots showed little in the way of bias, it was concluded that this feature was likely due to a characteristic of the Met Office UM (i.e. the AMV slow speed bias was actually from model winds that were too fast).

Reviewing the GOES low level visible plots from the Met Office for the past few years shows that this particular feature is not present in the same form and cannot clearly be seen from about October 2009 onwards. The AMV fast bias that was observed further north of the equator in both the Met Office and ECMWF plots (which was worse in Met Office statistics) also appears reduced in 2011 e.g. compare March/April 2010 with the same period in 2011. However, it remains apparent from the monitoring in this region of the Pacific that the ECMWF model is still showing slightly better agreement with the AMVs.

The reason for the bias reduction versus the Met Office model since 2010 is unclear but it could be due to improvements made to the forecasts since the last analysis report. It also seems likely that the model bias is dependant on the prevailing large-scale synoptic conditions. Figure 12 shows that when the *apparent* AMV slow bias was present in April 2009, the low level model winds were much stronger across the equatorial Pacific than they were in April 2010. The difference in wind strength between April 2009 and April 2010 coincided with the transition to El Nino conditions [*] (lasted from mid 2009 until April 2010) under which the trade winds become much weaker. In April 2011, La Nina conditions were present and so the trade winds were enhanced, but with the stronger equatorial winds confined to just the western half of the Pacific. This time there is much better agreement between the Met Office model and the GOES AMVs compared to 2009. It appears that the model is better during some phases of ENSO than others.

[*] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

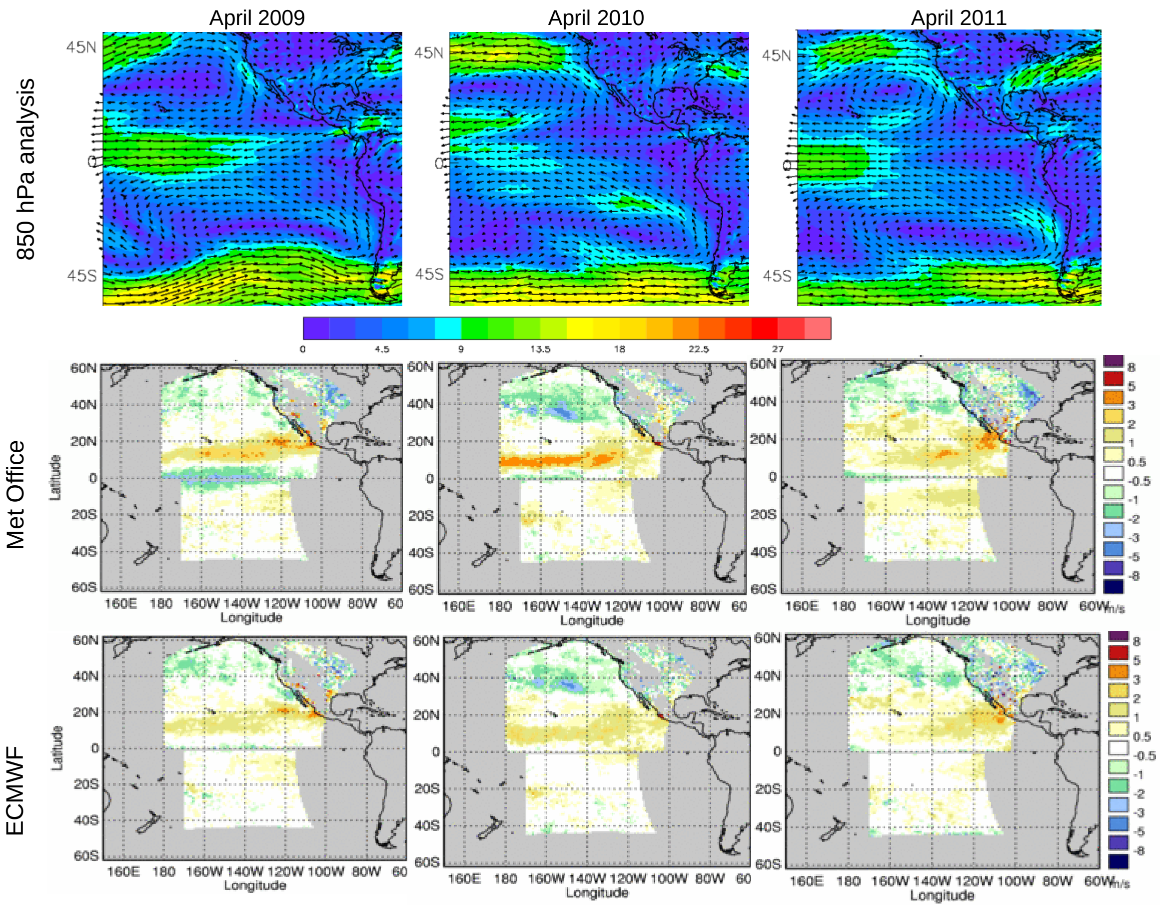

Figure 12: Top: mean Met Office model analysis wind vectors at 850 hPa for April 2009 (left), April 2010 (centre) and April 2011(right). Maps of O-B speed bias for GOES-11 visible AMVs for the same periods versus the Met Office (middle) and ECMWF (bottom) model backgrounds.

Feature 5.1. Patagonia slow bias

Previous analysis reports have documented a slow speed bias at low level over land in the Eastern USA and Canada (feature 2.3, last update in 3rd analysis). This feature is still present in the northern hemisphere winter but another feature can be seen in the GOES-13 visible AMVs that occurs at a similar time of year, however this time in South America during southern hemisphere summer.

During November 2010 to March 2011 a well defined slow bias feature can be seen in the Patagonian region of South America as shown by Figure 13. The area of slow bias is located near the Southern Andes in Argentina and Chile. Note that much of the Andes range can be distinguished from Figure 13 as the blank area in the map that runs down the west side of the continent where there are no low level AMVs extracted. The slow bias is not present in the GOES IR winds (there are in fact very few IR AMVs derived over land in this region) and Met Office model analysis winds indicate that the bias occurring in southern hemisphere summer is actually when the prevailing westerly, circumpolar winds are at their strongest in this region.

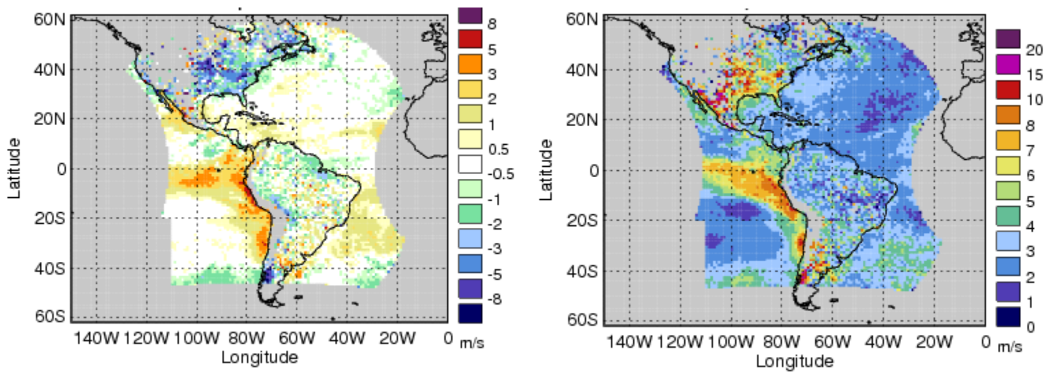

Figure 13: Map plots showing mean O-B speed bias (left) and root mean square vector difference (right) for GOES-13 visible AMVs. Data plotted for December 2010 compared with the Met Office model background

To investigate what might be causing the AMVs to be so much slower than the NWP model estimates we can look at data from a single model run in December 2010 as a case study. Temporal analysis of the bias reveals that although a slow bias is present to some extent for the majority of the month, the bias is particularly noticeable at 1800 UTC on 19 December 2010. A McIDAS visualisation of 1 km resolution GOES-13 0.63 μm visible channel imagery with overlays of both model and observed wind vectors valid at this time is shown in Figure 14. A sheet of marine cumulus can be seen on the left of the image moving from the Pacific over Chile (coastline plotted in black) and Argentina, with the high terrain of the Andes acting as a barrier to the westerly flow leading to the formation of lee waves. The presence of lee waves indicates low directional wind shear with speed increasing or constant with height, and a stable layer above.

The derived AMVs are tracking both the lee wave cloud formations and also some of the edges and holes in the stratocumulus sheet but comparing the observed and model winds show that nearly all AMVs are contributing to the observed slow bias. In the worst case an observed minus model speed difference of nearly 20 m/s can be seen for the vector at 71:3 W 41:3 S, 718 hPa. The more extreme biases are seen around the edges of the stratocumulus as it passes over the higher ground.

Figure 15 gives a better overview of the problem AMVs in context with the surrounding observations. Most of the AMVs below 800 hPa over sea have been assigned to the cloud base and consequently show more neutral speed bias. Over land the AMVs are assigned to cloud top which can lead to high height biases. For the AMVs tracking the stratocumulus edge, observed pressures are around 680-750 hPa but model best-fit pressure estimates are lower at around 850-900 hPa (Figure 16), suggesting a high height bias. However, there are many AMVs over sea assigned to cloud top which also exhibit a significant high height bias (over 100 hPa) but which do not show the same degree of slow bias compared to those over land.

It may be that the orographic influence of the Andes mountains is playing a role. As shown by the topography plot in Figure 15 the slow biased AMVs are nearly all located over terrain at 2000m elevation. As already stated the worst of the bias is associated with the main cumulus sheet (AMVs in top left quarter of Figure 14) and it is apparent from the visible imagery loops that these tracers may be being blocked or their motion altered by the terrain, so that their displacement is no longer representative of the local wind. The tracers associated with the lee waves are still propagating downstream (i.e. non-standing), though still perhaps too slowly due to the influences of the upwind orography.

One solution in these situations is to remove winds that are likely to be affected by orography. For example in the NWC SAF high resolution winds product an ‘orographic flag’ is calculated for each AMV to indicate land influences (Pereda, 2011). On the user side it is also possible to try and screen out some of these cases where we have reduced confidence in the winds. In July 2011 the Met Office implemented a topographic check as part of the AMV quality control process which rejects observations using a pressure threshold which is dependant on model surface height (Table 5). The effectiveness of this is of course dependent on the resolution of the model terrain which in a global model may not capture the highest terrain correctly.

Minimum surface height (m)	Pressure top (hPa)
1000	700
2000	500
3000	400
5000	300

Table 5: Met Office criteria used to reject AMVs dependant on topography, e.g. if the terrain is at 1500m elevation than all winds below 700 hPa are rejected.

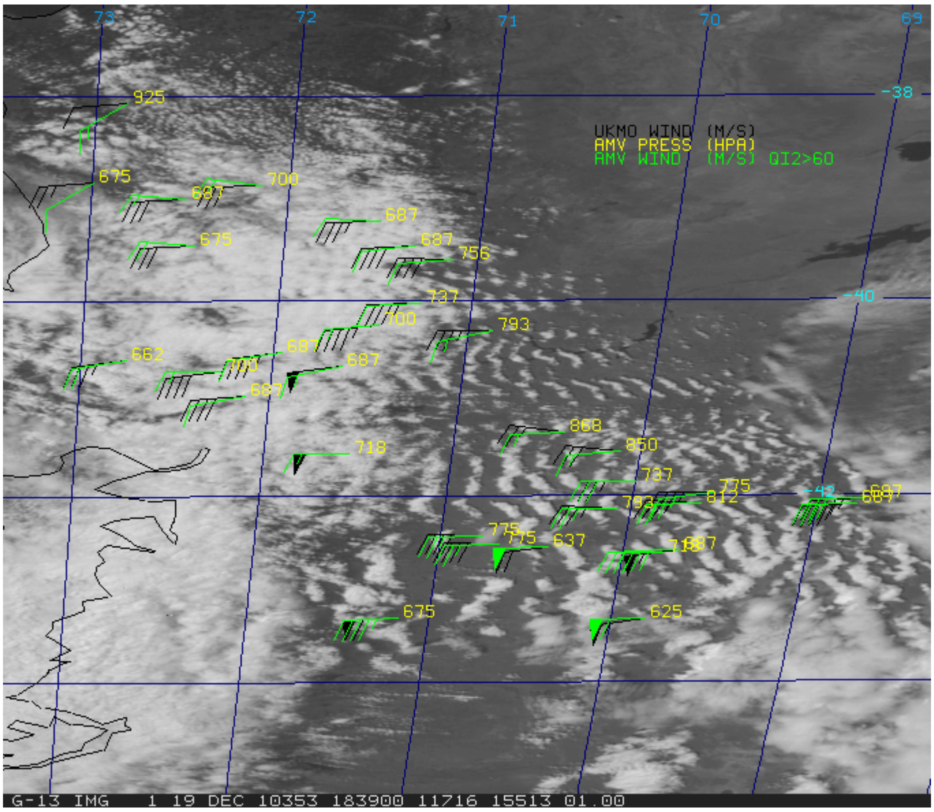

Figure 14: McIDAS visualisation of GOES-13 visible imagery at 1839z over Chile/Argentina. Collocated GOES-13 visible AMVs (green) and Met Office model winds (black) have been plotted along with the AMV assigned pressure. A long barb represents 5 m/s and a pennant 25 m/s.

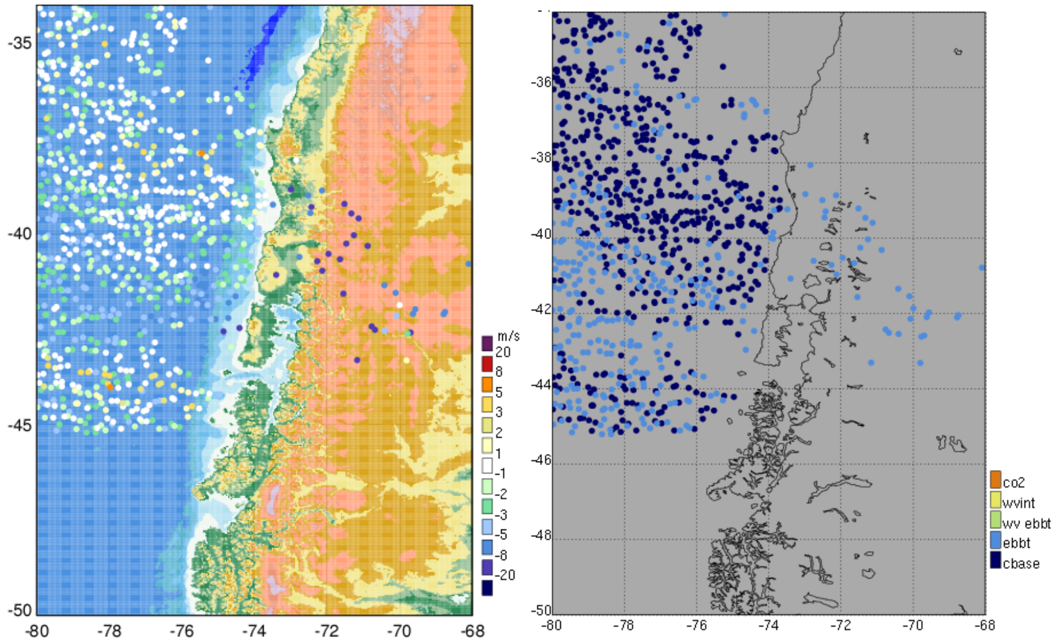

Figure 15: Maps of O-B speed difference with topography (left) and height assignment method (right) for GOES-13 visible winds. Data valid at 18z 19 December 2010 compared with the Met Office model background.

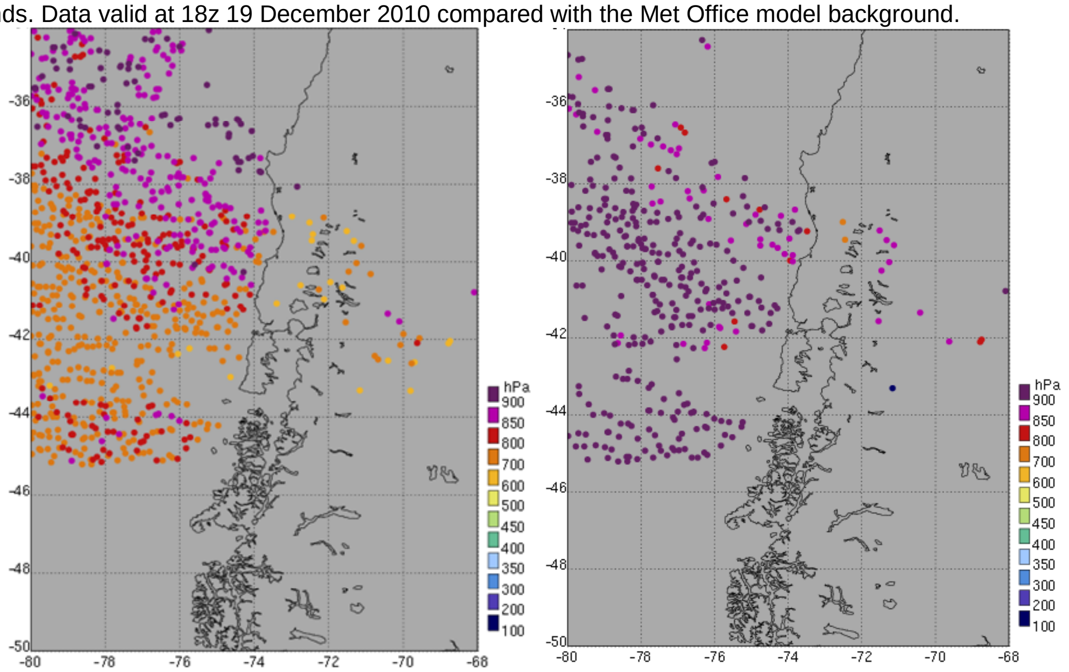

Figure 16: Maps of AMV assigned pressure (left) and model best-fit pressure (right) for GOES-13 visible winds. Data valid at 18z 19 December 2010 compared with the Met Office model background.

Feature 5.2. MSG slow bias during low level Somali Jet

For several years Meteosat-9 visible AMVs have shown a marked slow bias during July and August around the Gulf of Aden, near the north east tip of Somalia (Figure 17). The feature is present in Meteosat-9 visible 0.8µm and high resolution visible AMVs versus both the Met Office and ECMWF models, but is not as noticeable in data derived from the IR channel. As this feature lies in the overlap region between the Meteosat-9 and Meteosat-7 disk we can compare their statistics. Figure 17 shows markedly different results near the Gulf of Aden: the visible AMVs for Meteosat-7 are faster than the model, rather than slower like Meteosat-9. This is in agreement with previous work that has shown Meteosat-7 to exhibit spuriously fast winds at low level in this area as described in Feature 2.7 in the fourth analysis report.

Mean Met Office analysis wind vectors for August 2011 show that slow bias for Meteosat-9 is associated with the strengthening of the Arabian branch of the South Asia summer monsoon winds (Figure 17). This feature is commonly known as the Somali Low Level Jet and normally peaks in July and August which coincides with the appearance of the slow bias in the visible AMVs. It has been shown that for previous monsoon seasons the strength of the Somali jet in the ECMWF analysis is quite different compared to the Met Office analysis and forecasts (Milton et al., 2011). Met Office analyses at 925 hPa were found to be systematically stronger by 2.5 m/s within the jet (10% of the observed wind speed) with a similar picture for short range T+24 forecasts. This is in agreement with the fact that although the apparent AMV slow bias is extensively similar for both models, it is slightly worse versus the Met Office background forecast (Figure 17). One suggested reason for the differences between the models is that the ECMWF analysis is fitting closer to the observations and if true for the AMVs this would act to reduce the speed of the jet winds. Although there are clearly some systematic differences in the models the magnitude of the AMV speed bias (20 m/s) suggests that the AMV errors are dominating.

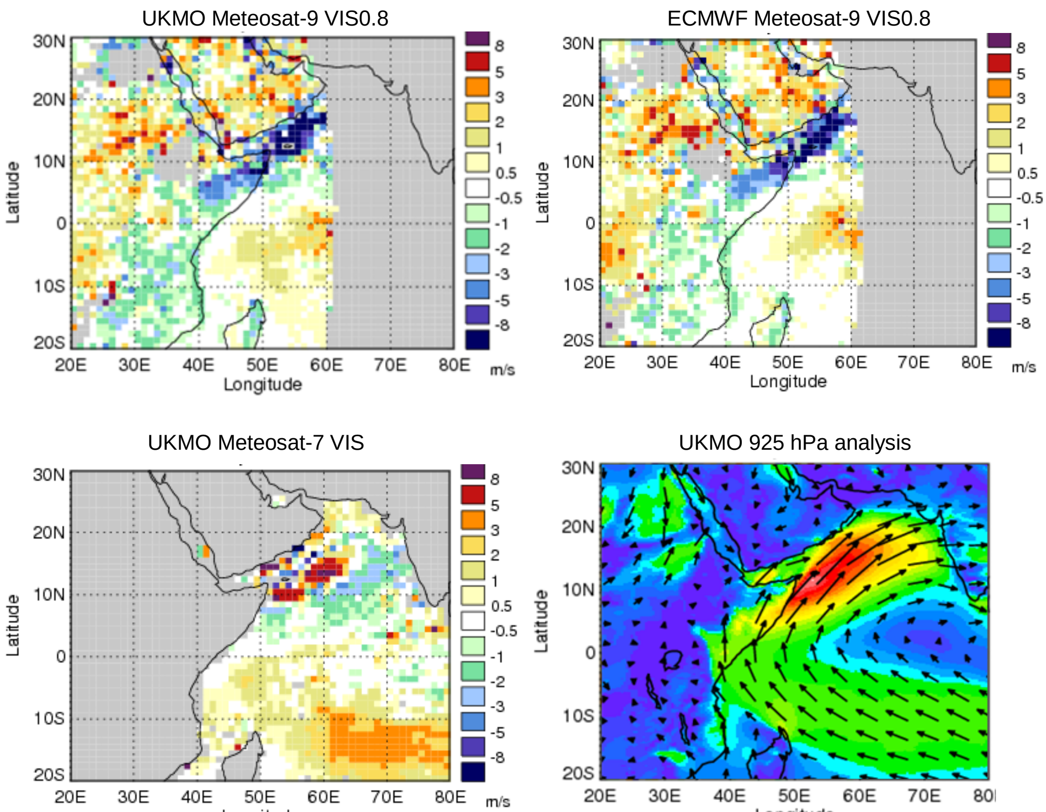

Figure 17: Map plots of mean O-B speed bias for Meteosat-9 visible AMVs versus the Met Office (top left) and ECMWF (top right) model backgrounds for August 2011. Also shown is the mean O-B speed bias for Meteosat-7 visible AMVs versus the Met Office model background (bottom left) and the mean Met Office model analysis wind vectors at 925 hPa for August 2011 (bottom right).

Although a small slow bias is present for most of August, there is a clear spike for the 12z run on 10 August which would seem to be the root cause of the marked signal seen in the map averages. Looking closer within the 12z model run shows that there are many Meteosat-9 high resolution visible AMVs with negative speed biases exceeding 20 m/s (Figure 18) and that this occurred most frequently for data extracted at 1230z.

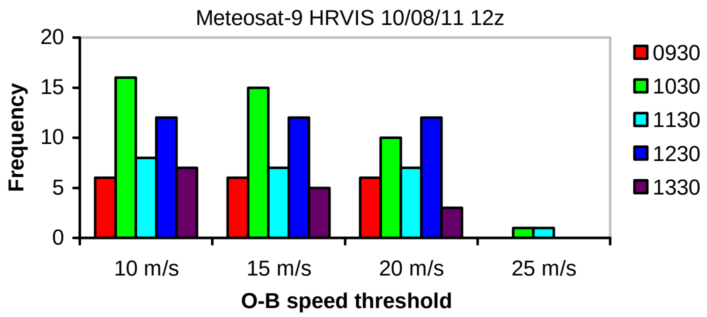

Figure 18: Frequency at which different thresholds of slow speed bias were exceeded, separated by observation time for Meteosat-9 HRVIS AMVs valid at 12z 10 August 2011. AMVs located in box 11-14N, 52-58E.

Figure 19 shows ocean surface (10m) winds as observed by the ASCAT scatterometer on-board Metop-A from earlier in the day on 10 August 2011. This shows strong Monsoon winds running northeastward from the coast of Somalia, intersecting the island of Socotra (located mid swath).

Map plots (Figure 20) of O-B speed bias for high resolution AMVs valid at 12z on this day show a swathe of observations biased low compared to the model, located in a region of strong Somali Jet winds as seen by ASCAT. Comparisons with Met Office model best-fit pressure estimates indicate that these slow winds may have been assigned too low in the atmosphere by in excess of 200 hPa. This suggests that slower, mid level winds have been incorrectly assigned down at low level within the Somali Jet. To verify whether this is the case we can investigate a McIDAS visualisation of the high resolution visible data at 1230z (Figure 21) which, as shown earlier, is the time when there were most vectors biased by 20 m/s or more. Interpretation of the imagery and data allows a number of features to be identified:

A) In the area southeast of the island of Socotra there are moderately strong AMVs assigned at ~840 hPa that are tracking narrow lines of clouds. These tracers are aligned parallel to the African coast and are easily distinguished as part of the low level south westerly monsoon flow which is gently curving clockwise. These closely-spaced cloud bands indicate relatively strong low-level winds and the AMVs show good agreement with the model.
B) Faint cirrus plumes within the upper level Easterly Jet.
C) Cloud formation along the southern, windward slopes of Socotra Island indicating the low level wind direction (see also Figure 22). As the clouds are suppressed from flowing over the terrain in the southerly flow this indicates a low level inversion. An inversion is known to persist over the western Arabian Sea during the Southwest Monsoon (Hubert et al., 1983). The rather stationary wave like cloud just to the south of the island could be a gravity wave on the inversion interface and the AMVs tracking this show very poor agreement in both speed and direction. It is possible that island effects together with the presence of an inversion are dominating the errors here.
D) Brighter, shallow convective clouds indicating a weakening of the low level inversion or clouds that have broken through. The AMVs are slow at ~5 m/s, tracking from the west or northwest and assigned much lower at around 920-960 hPa. In this case the collocated model winds are clearly part of the Somali Jet with speeds in excess of 25 m/s (50 knots) from the south or southwest. It seems likely the AMVs have been assigned too low as model best-fit pressure statistics of around 700 hPa are well constrained. Note also that the two vectors assigned higher at ~750 hPa near 10:56N 54:22E show better fit with the model.

Overall the slow bias appears to be the result of some instances of height assignment error (e.g. case D), as well as the influence of islands (C) with high mountainous terrain (up to 1500m) located within a very strong low level jet.

If we look at the Meteosat-7 visible data for this case (Figure 23) then we see that no AMVs have been extracted at very low level i.e. below 900 hPa. In particular, there are no Meteosat-7 AMVs tracking the problematic clouds south of the island of Socotra. This suggests that one reason why the slow bias is present in the MSG visible and high resolution visible data, and not in the Meteosat-7 visible data, is the enhanced spatial resolution of the imagery (3km/1km versus 5km respectively).

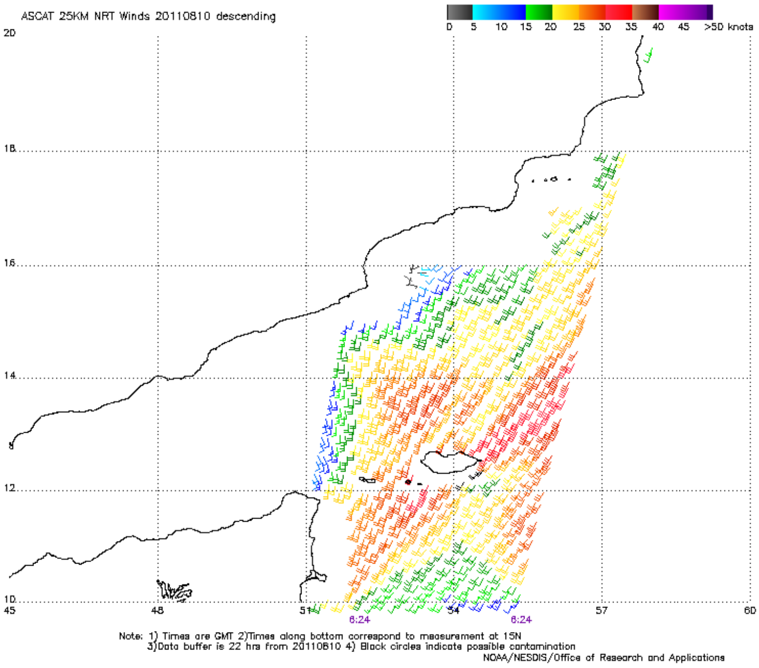

Figure 19: ASCAT 25 km (12.5 km sampling) ocean surface wind vectors observed at 0625z 10 August 2011 near Somalia and Gulf of Aden. Image from NOAA/NESDIS.

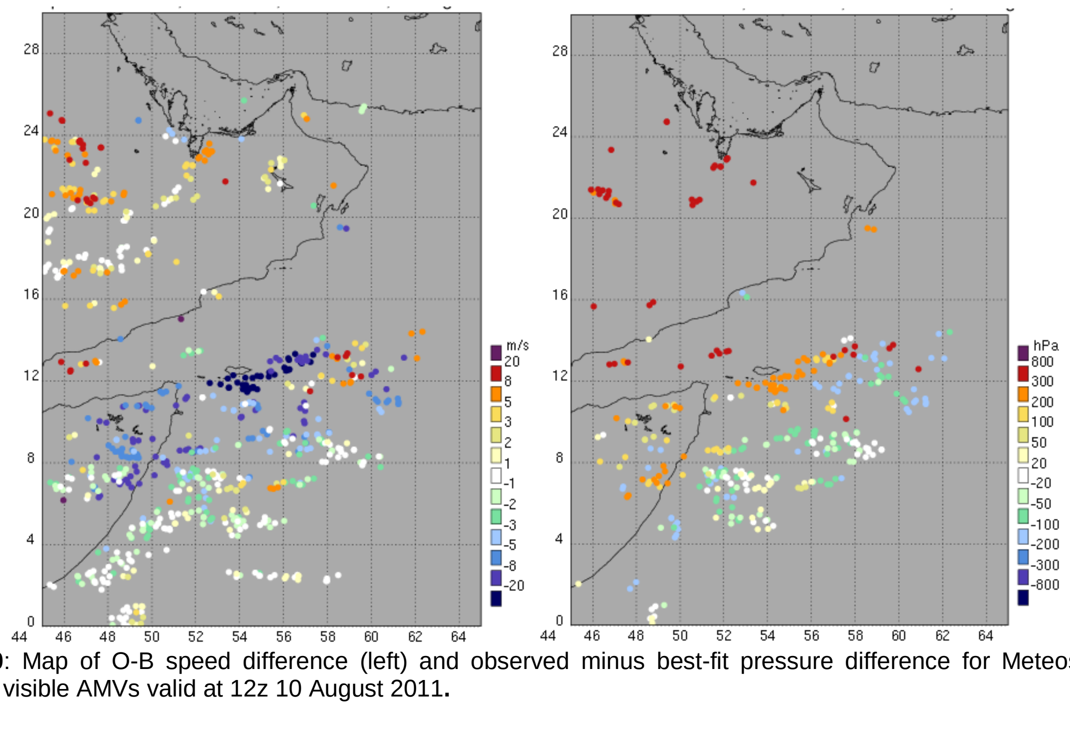

Figure 20: Map of O-B speed difference (left) and observed minus best-fit pressure difference for Meteosat-9 high resolution visible AMVs valid at 12z 10 August 2011.

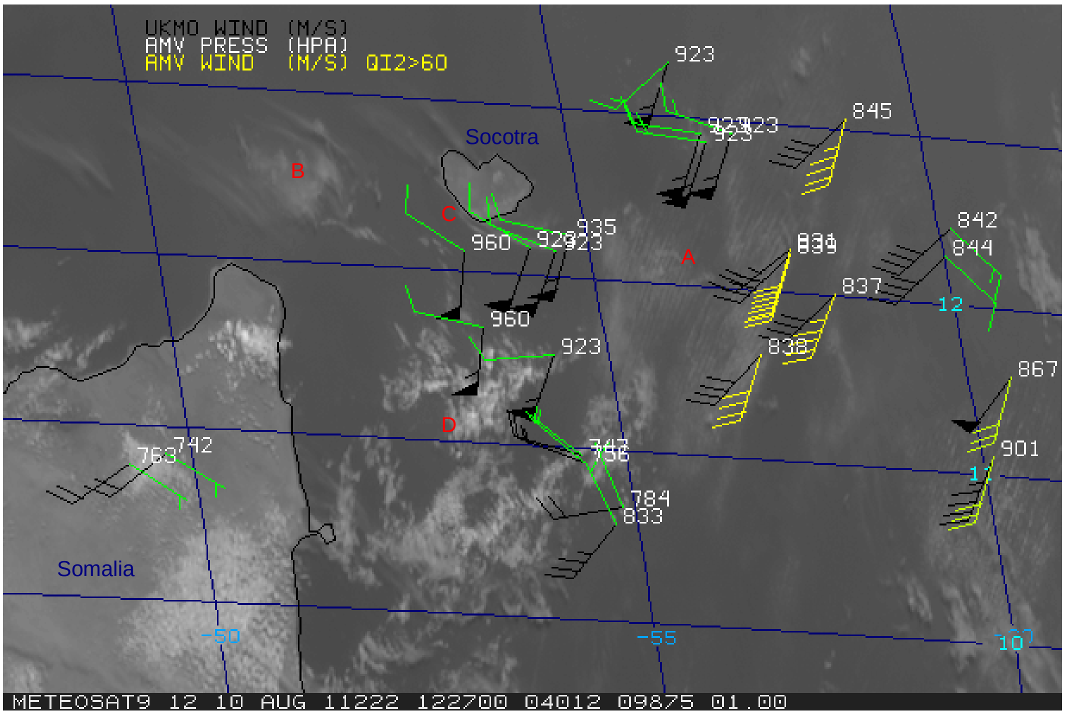

Figure 21: McIDAS visualisation of 1km Meteosat-9 high resolution visible imagery at 1227z over the tip of Somalia. Collocated Meteosat-9 high resolution visible AMVs (coloured by speed) and Met Office model winds (black) have been plotted along with the AMV assigned pressure. A long barb represents 5 m/s and a pennant 25 m/s. AMVs extracted at 1230z only.

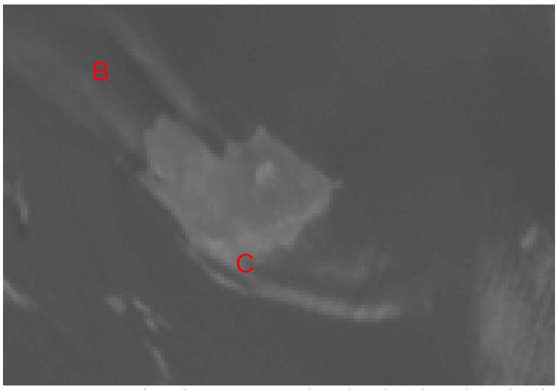

Figure 22: Close-up of the narrow tracer south of Socotra Island. The low-level wind direction can be seen from the cloud formations on the windward slopes of the island.

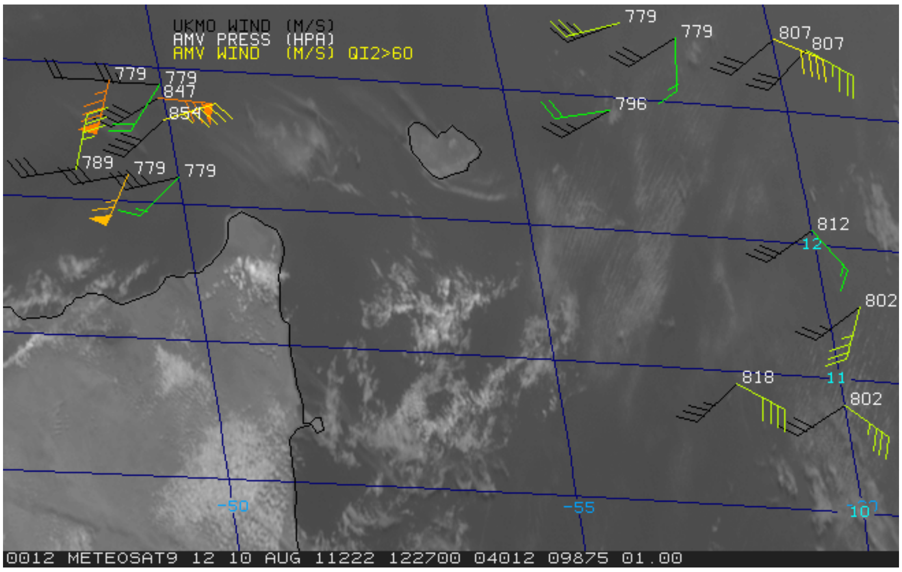

Figure 23: McIDAS visualisation of Meteosat-9 high resolution visible imagery at 1227z over the tip of Somalia. Collocated Meteosat-7 visible AMVs (coloured by speed) and Met Office model winds (black) have been plotted along with the AMV assigned pressure. A long barb represents 5 m/s and a pennant 25 m/s. AMVs extracted at 0900z, 1030z, 1200z and 1330z.

5.2. Mid Level

The mid level wind field is dominated by faster winds beneath the extra-tropical jets. 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).

Update on Features 2.8 and 2.9: Fast bias in the tropics and slow bias in the extratropics

Geostationary AMVs derived at mid level (400-700 hPa) have generally tended to show quite poor O-B statistics overall, but countered by the fact there are much fewer winds extracted here compared to at low or high level. Two dominant features that have been described in previous analysis reports are AMVs that are much faster than the model in the tropics (Feature 2.8) and AMVs much slower than the model in the extra-tropics (Feature 2.9). The errors are thought to be largely the result of height assignment errors e.g.

Feature	Resulting from	Likely cause
Tropical fast bias	AMVs assigned too low in comparison to model best-fit pressure and other cloud top pressure products.	– Limitation of EBBT method for semi-transparent clouds (contributions from below cloud) – Multispectral techniques not used often enough (or fails) for genuine high level clouds
Mid latitude slow bias	AMVs assigned too high in atmosphere compared to model best-fit pressure	– CO2 and WV channels less sensitive at mid levels. – High wind shear below upper level Jet winds – Multilayer cloud scenarios

In the 4th analysis it was shown that it may be beneficial to implement additional pressure checks to control the use of winds assigned to mid level using multispectral methods. From PS27 (July 2011) the Met Office have implemented new quality control checks to reject winds assigned too low using either the CO_2 slicing or

WV intercept methods. However it may be better to be able to fall back on the alternative EBBT height in these cases rather than rejecting the observation outright.

One particular fast bias feature that has been investigated at length is for daytime MSG winds over the Sahara during the winter months. The systematic difference seen in day/night assigned heights is thought to be due to an inadequate representation of the diurnal surface temperature range. Using forecast data with a higher temporal resolution could help, but there are currently no plans from EUMETSAT to reduce the 6 hour interval data used on the MSG ground segment (G. Dew, pers. comm., Nov 2011). Conversely there are plans to implement use of forecast data at 3 hour intervals from late 2011 on the METOP ground segment for use in the AVHRR polar winds product.

From analysing zonal and map plots of GOES-11 IR winds, there is an apparent improvement in mid level biases during 2011 versus the Met Office (and to a smaller extent ECMWF) models. For example comparing plots from the same months for the first quarters of 2010 and 2011 as in Figure 24 seems to show a significant reduction in speed bias and vector differences in both the tropics and extra-tropics. For GOES East (GOES-12 until mid April 2010, then GOES-13) any improvement in statistics is much more subtle.

To verify whether this apparent change in the mid level GOES-11 statistics is real or part of some inter-annual variability we can make use of long term time-series. These can be constructed from CGMS (Coordination Group for Meteorological Satellites) approved monthly statistics calculated routinely at the Met Office. Figure 25 shows how the RMS vector difference and mean speed bias have evolved for mid level GOES-11 IR AMVs since the beginning of 2009. This shows an improved fit to the model for all latitudes, particularly from April/May 2010 onwards. As expected there are clearly some seasonal variations, with the greatest differences in the winter hemisphere, but at the very least there is a noticeable downwards trend (improvement) in the RMS statistics. For O-B speed bias the improvement is not quite as clear-cut, though still discernable. Generally the negative speed bias in the extra-tropics is worse in the winter hemisphere (clearest in the northern hemisphere) and even taking account for the seasonal variation there is an upwards/improving trend in speed bias. In the tropics, although the mean level of fast bias remains constant about +1 m/s throughout, the variation around this tends to dampen down from around April/May 2010 onwards.

Why have the GOES-11 winds improved and not those from GOES-E? One factor may be that, compared to the other geostationary satellites, the mid level biases for GOES-11 were worse to start with. Reasons put forward for this include the lack of a CO_2 channel (only introduced with GOES-12) for assigning high level clouds and also the slightly unusual wind characteristics found in the Pacific which make height assignment more difficult. For example, in the tropics of the GOES-11 region a wind speed minima is often found at mid level and therefore any error in assigning heights to low or high level clouds will likely lead to a fast bias.

The key question is have the GOES-11 mid level winds improved due to changes in the observations (e.g. algorithm upgrades) or due to changes in the model winds? Figure 26 shows equivalent GOES-11 CGMS statistics produced by NOAA but this time verifying against collocated radiosonde observations. The time series show no clear indication of any significant changes in the AMVs during this time. RMS levels in the northern hemisphere have remained relatively constant since January 2009, varying seasonally between 6-7 m/s. It should be noted that there are very few radiosonde matchups in the tropics and southern hemisphere hence the statistics are noisier in comparison.

The above results would suggest that the improved fit of GOES-11 with the Met Office models is due to changes in the forecast winds in the Pacific region (see also the update on Feature 4.1 at low level). The Unified Model (UM) underwent several major upgrades during late 2009 and early 2010 that could have played a role in reducing the biases seen versus the Met Office model. In November 2009 the vertical resolution of the model was upgraded from 50 to 70 levels with a number of performance benefits, particularly in the tropics. A second large package of changes was implemented in March 2010 with the key upgrade being an increase in horizontal resolution to 25 km (N512) which, amongst other things, led to an improvement in extra-tropical wind biases. Further changes in July 2010 included an updated cloud scheme which resulted in more accurate tropical temperature profiles and therefore better tropical winds.

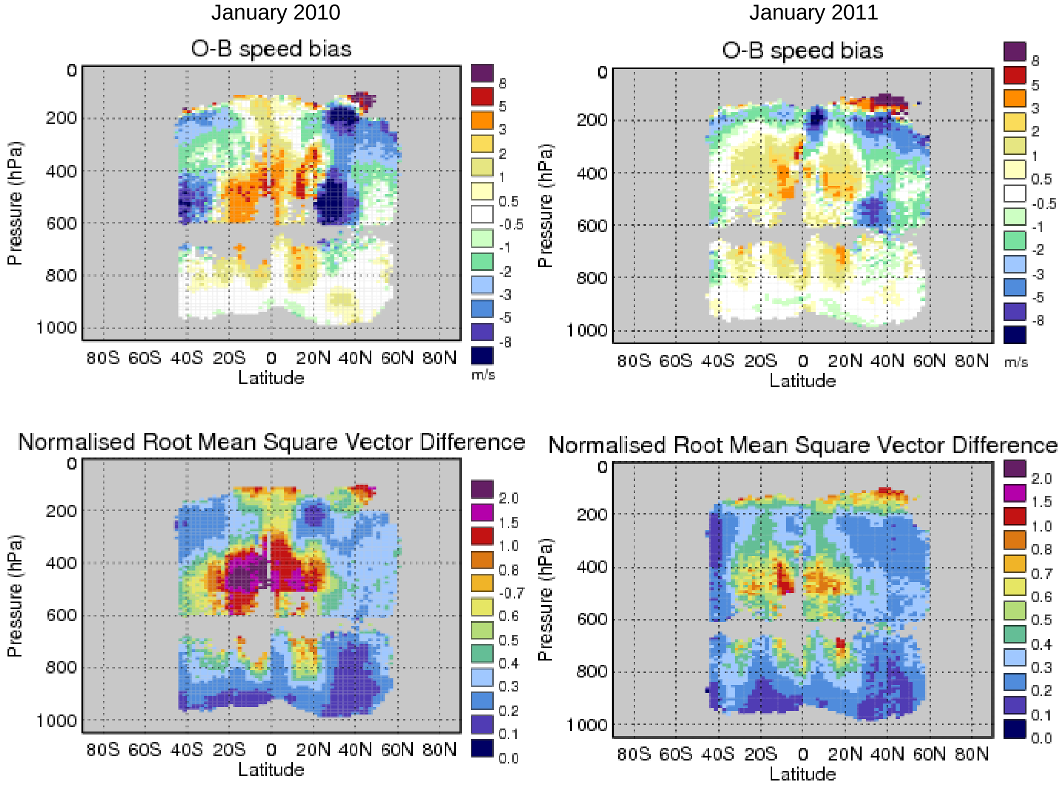

Figure 24: Zonal plots of O-B speed bias (top) and normalised RMS vector difference (bottom) for unedited GOES-11 IR AMVs for January 2010 (left) and January 2011 (right). Data compared with the Met Office model background.

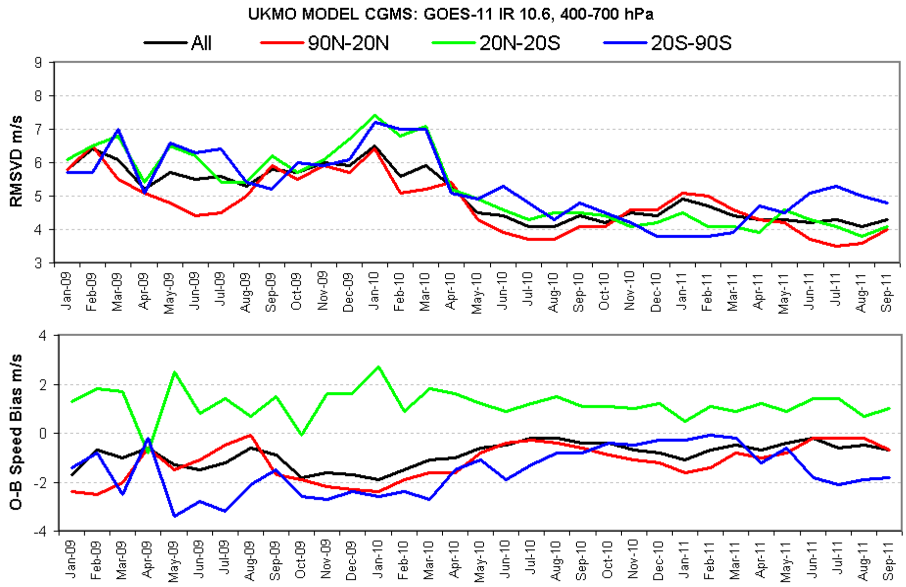

Figure 25: Time series of Met Office monthly CGMS statistics for GOES-11 mid level IR AMVs: root mean square vector difference (top) and O-B speed bias (bottom) for January 2009 to September 2011. Statistics calculated against the Met Office global model background for AMVs with QI1 > 80% (with first guess).

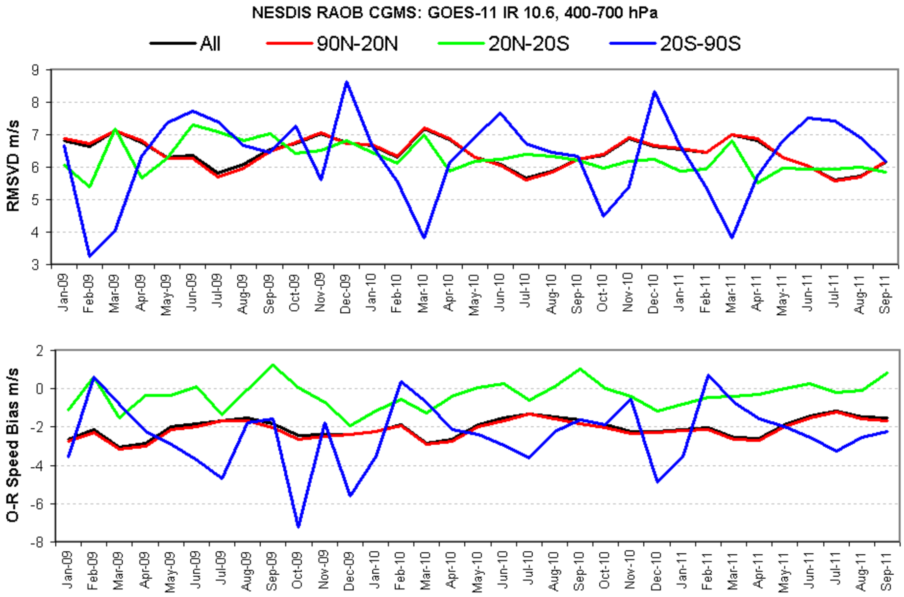

Figure 26: Time series of NOAA/NESDIS monthly CGMS statistics for GOES-11 mid level IR AMVs: root mean square vector difference (top) and O-B speed bias (bottom) for January 2009 to September 2011. Statistics calculated versus radiosonde matchups for AMVs with QI1 > 80% (with first guess). Data courtesy of Hongming Qi, NOAA.

5.3. High Level

The high level wind field is dominated by fast winds in the jet regions (see Figure 27 in the 2nd 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 occur 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 Features 2.10 and 2.11. Jet region slow bias and NESDIS over-correction of slow bias

A negative speed bias at high level in the extra-tropics continues to be a prominent feature of geostationary AMVs.

A good example of this feature can be seen in the MTSAT-2 IR AMVs during January 2011 (Figure 27). The AMV slow bias centred on 30N is clearly linked to the presence of a very strong confluent jet stream found in the Asia-Pacific region during northern hemisphere winter. This jet stream is typically very strong as the polar and sub-tropical jets converge over Japan and in this case the strongest mean analysis wind vector is around 90 m/s. With such strong wind shear present, a small error in AMV height assignment will lead to a much larger (negative) error in wind speed. However, as case studies in previous analysis reports have shown, the slow bias in the jet regions can also arise from representative errors as well as errors in the tracking step (e.g. see 4th analysis).

In the case of MTSAT-1R/2 the jet region slow bias was a prominent feature in both winter hemispheres up until mid 2009. Following derivation updates in 2009 it had appeared that the level of slow speed bias had improved (at least in the southern hemisphere) but as the example for January 2011 demonstrates this is still an issue for MTSAT AMVs. For NWP, options to consider are 1) inflation of observation errors in these cases, e.g. using an individual observation error scheme (Forsythe and Saunders, 2008) 2) seasonal blacklisting of high level MTSAT-1R/2 IR AMVs north of 20N during the northern hemisphere winter months.

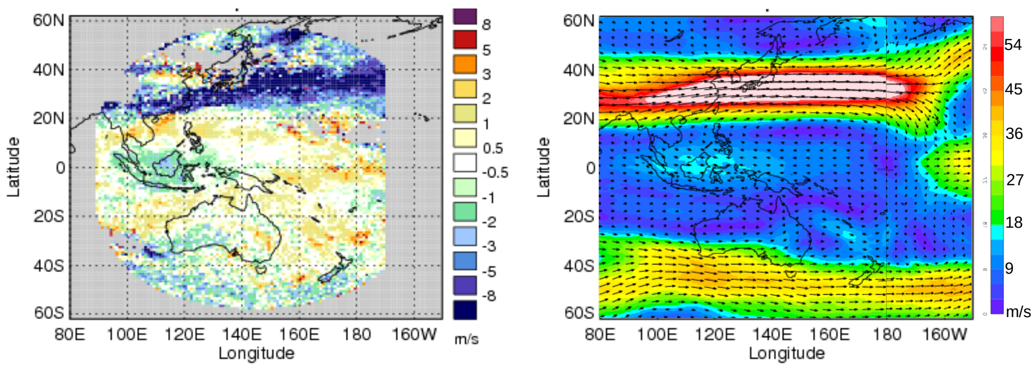

Figure 27: Map plot of O-B speed bias for high level MTSAT-2 IR AMVs in January 2011 (left). Data compared with the Met Office model background. Also, Met Office mean analysis wind vectors at 250 hPa for January 2011 (right).

MSG winds also exhibit a marked slow speed bias in the jet regions versus the Met Office and ECMWF models. Recent prominent examples include July 2011 in the southern hemisphere and February 2011 in the northern hemisphere as shown in Figure 28. Although the bias is present in AMVs derived from both IR and WV imagery, it is more marked and widespread in the IR10.8. The NWP SAF monitoring archive clearly shows that the current high degree of slow bias seen for MSG has not always been the case. Looking back to the equivalent winter periods in 2009 reveals much more neutral speed bias statistics in comparison to both 2010 and 2011. The perceived worsening of the high level IR winds over time can be verified by examining long term time series constructed from CGMS approved monthly statistics produced routinely at the Met Office. Figure 29 shows a general increasing trend in RMS vector difference for MSG winds in the extratropics. In the northern hemisphere the peak RMS occurs in either January or February and the level at which it has peaked has increased significantly from 2009/2010/2011 at 6.6 m/s (Feb 09), 7.5 m/s (Jan 10) and 8.6 m/s (Feb 11) respectively. A similar pattern is evident in the southern hemisphere, though the peaks in RMS are even higher here at 7.1 m/s (Sep 09), 8.9 m/s (July 10) and 9.5 m/s (July 11). Figure 29 shows that the peaks in negative speed bias generally occur at the same time as the peaks in RMS and again are worse in the southern hemisphere at around -3.5 m/s in July 2010 and July 2011.

It is noticeable that when we consider data from all latitudes there is fairly steep increase in RMS of +0.8 m/s from October to November 2009. If this change was just due to the normal seasonal bias cycle then we would expect only the northern hemisphere statistics to be worsening. In fact the NWP SAF map plots show that the negative speed bias and vector difference degraded in both hemispheres at this time which indicates that the change in RMS wasn't just due to seasonal variations. The maps plots also show that the MSG derivation area increased in its northern and southern extent (65 N/S) in November 2009 signifying that these changes may be tied to updates made at EUMETSAT. Figure 30 shows high level IR CGMS statistics in the southern hemisphere but this time showing both model and radiosonde bias. The radiosonde bias appears consistently lower than the model and in the latter part of the time series there is a clear correlation between the radiosondes and model errors. The black vertical lines on the plot indicate when changes have been made to the AMV derivation algorithm and prior to the 2009 changes there is a clear seasonal variation in model bias. It is evident that following the algorithm changes in the second half of 2009, at a time when the southern hemisphere bias should be improving, the statistics actually worsen against both the model and sondes. Figure 29 then shows that the seasonal cycle in the southern hemisphere resumes at a much lower mean level.

It appears that the EUMETSAT algorithm changes made in late 2009 have had a detrimental impact on the high level slow speed bias in the extra-tropics. The major changes at this time include:

30 July 2009

- New radiative transfer model (RTTOV)
- New monthly surface emissivity maps based on MODIS data.
- improved cloud detection over ocean

September 2009
- Reduction of the overlap allowed during the optimal target identification process

2 November 2009:
- Number of radiosonde levels increased from 50 to 200 (improved AMV verification system)
- Increased derivation area

The increase in derivation area to 65N/S would have a negative impact on the mean speed bias as this would increase the AMV coverage further into the jet regions.

From August 2009 EUMETSAT changed the MSG radiative transfer model (RTM) from SYNSATRAD to the Radiative Transfer for TOVS model (RTTOV) (Saunders, et. al., 2007). The change in RTM would have had a direct impact on the AMV height assignment, but also indirectly via the cloud detection. An assessment of the winds at ECMWF found that although the quality was consistent globally, in the extra-tropics the high level winds with RTTOV showed slightly worse negative bias (Genkova et al., 2010). It found that AMVs in the jet region were generally assigned higher with the use of RTTOV. The RTM validation report (EUMETSAT, 2009) also found that for high and mid level clouds, RTTOV cloud top heights were assigned slightly higher in the atmosphere. This was thought to be due to the difference between the IR10.8 and WV6.2 simulated radiances becoming larger and so impacting the heights of semi-transparent clouds. Although the validation of high level AMVs using radiosondes showed a larger speed bias, this was attributed to the change in collocation method (all levels of a radiosonde observation now taken into account rather than just 50) rather than a change in the AMV product. Also worth noting is that the validation was performed from mid May to mid June 2009 so this period wouldn't have captured a period when the jet regions slow bias was at its worst.

Another possible reason (and cited likely by EUMETSAT) is the reduction of the overlap allowed during the optimal target identification process which was introduced during September 2009. Consequently cloud edges are selected less frequently and so a greater proportion of AMVs are extracted in the middle of the cloud and therefore assigned a higher cloud top height.

What the reasons suggested so far cannot explain is the increasing trend observed in the winter 'peak' RMS in the extratropics since late 2009. Figure 31 compares Met Office CGMS statistics for high level Meteosat-9 and Meteosat-8 IR 10.8 winds in the northern hemisphere. Both satellites show the previously described step change from October to November 2009. However, the trend in RMS peaking higher each winter can only be observed in the Meteosat-9 data, with Meteosat-8 remaining comparatively 'flat' (though still with some inter-annual variability). The trend may therefore be linked to the known increasing bias in the Meteosat-9 CO_2 channel (see Hewison, 2009). Met Office collocation plots of Meteosat-9 and Meteosat-8 IR AMVs assigned CO_2 slicing heights showed that in October 2008 the bias between the satellites was 13.5 hPa (Meteosat-9 assigned higher). In January 2012 this bias has risen to around 18 hPa. Although the impact on cloud top heights from the increasing bias in the IR 13.4 channel is thought to be minimal, it is possible that in high wind shear environments this is still enough to degrade the AMV speed bias over time.

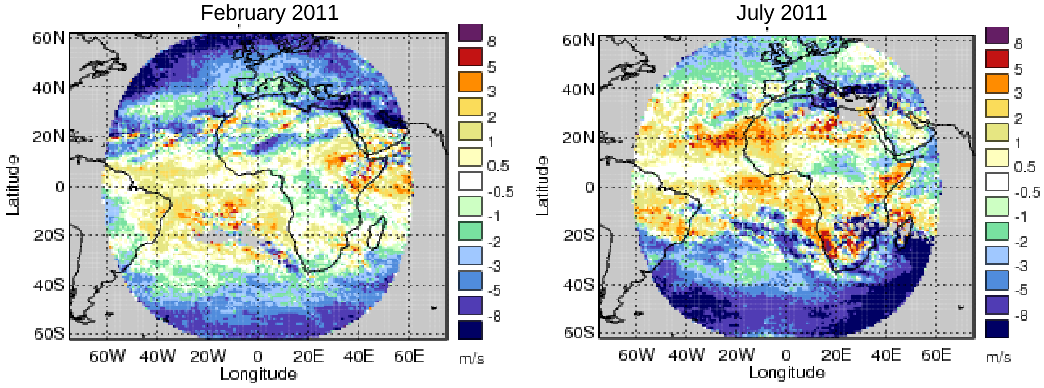

Figure 28: Map plot of O-B speed bias for high level Meteosat-9 IR10.8 AMVs in February 2011 (left) and July 2011 (right). Data compared with the Met Office model background.

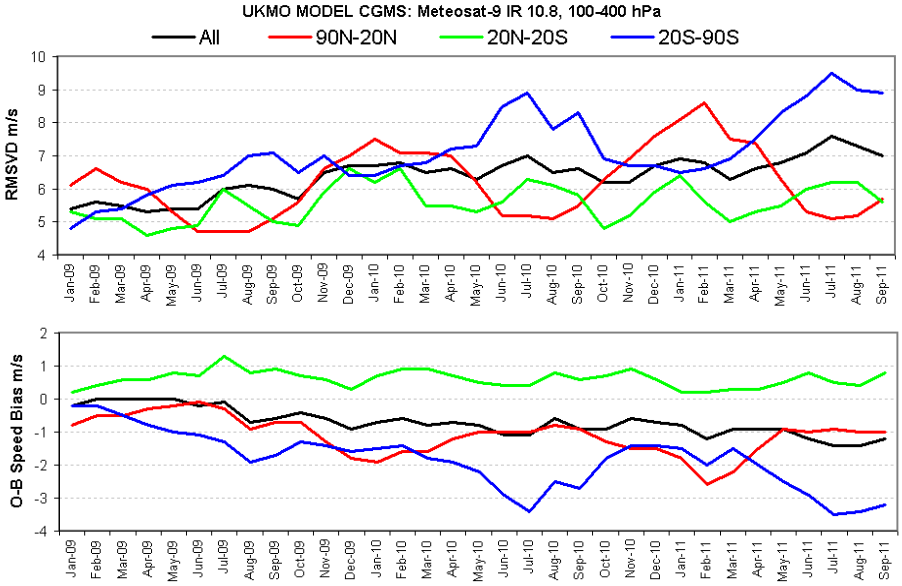

Figure 29: Time series of Met Office monthly CGMS statistics for Meteosat-9 high level IR AMVs: root mean square vector difference (top) and O-B speed bias (bottom) for January 2009 to September 2011. Statistics calculated against the Met Office global model background for AMVs with QI1 > 80% (with first guess).

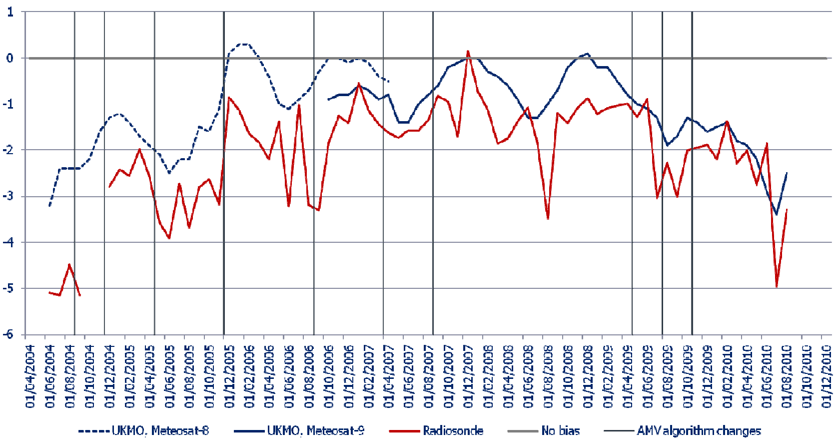

Figure 30: Time series of EUMETSAT monthly CGMS statistics for Meteosat-8/9 high level IR AMVs in the southern hemisphere. Statistics calculated against the Met Office global model background (blue lines) and versus collocated radiosonde observations (red line) for AMVs with QI1 > 80% (with first guess). Courtesy of Manuel Carranza and Arthur de Smet, EUMETSAT.

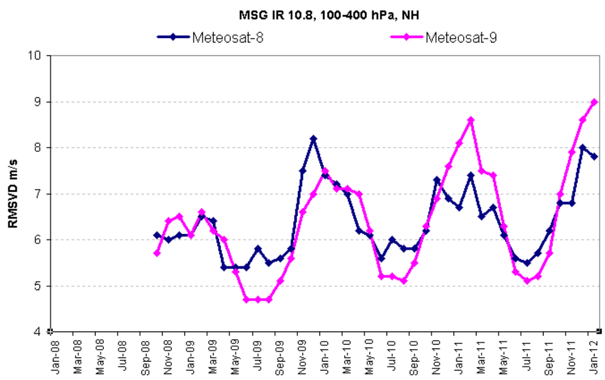

Figure 31: Time series of Met Office monthly CGMS statistics for Meteosat-9 and Meteosat-8 high level IR AMVs: root mean square vector difference for October 2008 to January 2012. Statistics calculated against the Met Office global model background for AMVs with QI1 > 80% (with first guess).

For GOES derived AMVs the jet region slow bias is present in the NWP SAF plots for the unedited high level IR and WV data sets. The autoeditor step applied as part of the NESDIS processing (as described in the third analysis report) does a good job in correcting for this such that the slow bias in the final 'edited' product is much reduced. Despite this correction however, the jet region slow bias can still cause problems in the edited product. In the 00z forecast run on 23 January 2011 the operational Met Office observation monitoring system flagged up unusually high levels of RMS error for GOES-13 IR AMVs. Further investigation showed this was associated with a large area of slow biased AMVs located in the Atlantic off the US East Coast. A McIDAS visualisation of 4 km resolution GOES-13 10.7 µm IR channel imagery with overlays of both observed and model background wind vectors valid at this time is shown in Figure 32. The imagery shows a developing storm system (996 mb) centred approximately 72W, 34N with a cold front curving back across Cuba. The well-defined trailing edge of the cold front can be seen clearing from the US coast on the left of the image. The high level AMVs are tracking cloud tops associated with a generally west or south-westerly flow and the strongest winds (in excess of 70 m/s) are found within the jet core located across the warm front near the top of the image. IR brightness temperature enhancement shows the coldest cloud top temperatures are around 220 K (-53C). It is clear from the plot that the majority of the AMVs west of 65W are considerably slower then the model estimates, particularly for the tracers northeast of Cuba where O-B values frequently exceed -10 m/s (up to -21.6 m/s in the worst case). CO_2 assigned heights for these winds are around 300-350 hPa; model best-fit pressure estimates would suggest the AMVs in this area have been assigned too high by 50-100 hPa. As shown by previous analysis reports it is probable that the slow bias for winds located around the jet core results from errors in the tracking step.

In the second analysis report it was noted that in some months the autoeditor may actually over-correct the wind speeds (Feature 2.11). This no longer appears to be a significant issue in the plots therefore it is proposed to close this feature, particularly since NESDIS plan to remove the autoeditor in the new derivation scheme (see below).

Rather than rely on a correction method like the autoeditor it would be better if the slow biased could be reduced by improvements to the AMV derivation method itself, e.g. by improving the height assignment and the feature tracking. One possibility is to reduce the size of the tracer target box used in tracking (Sohn and Borde, 2008), although this can result in a larger RMS unless different tracer selection is allowed for when comparing the same scenes. A promising approach is the combined nested tracking and cluster analysis technique developed at NOAA/NESDIS (Daniels and Bresky, 2010). This has shown to be effective at removing much of, if not eliminating, the AMV jet region slow speed bias and negates the need for the autoeditor altogether. This new algorithm has been developed for generating AMVs from the future GOES-R imager but is also likely to be implemented in the current NESDIS GOES processing at some stage.

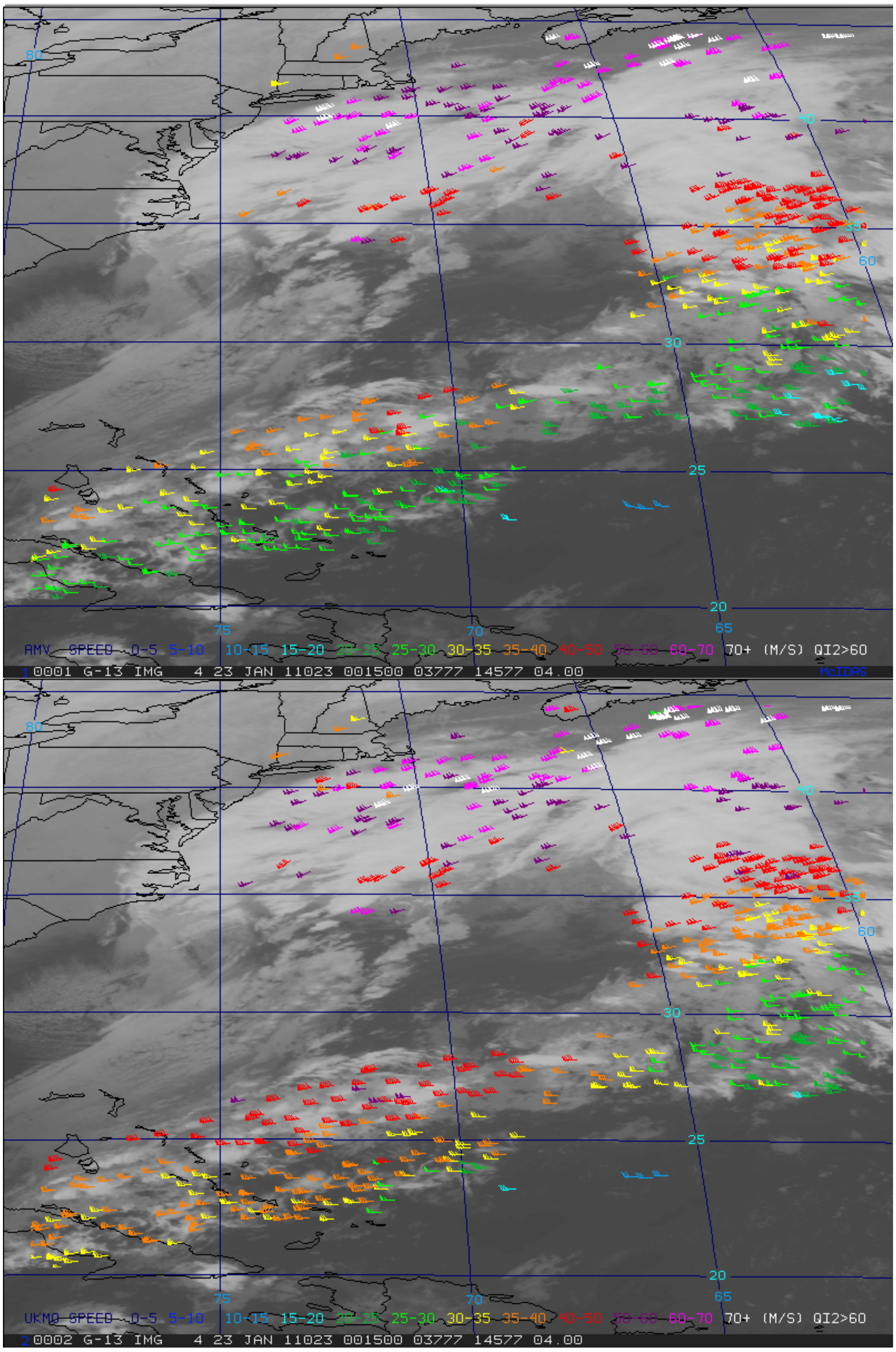

Figure 32: McIDAS visualisation of GOES-13 IR10.7 imagery at 0015z off the East Coast of the US. Overlays of GOES-13 IR 10.7 AMVs (top) and collocated Met Office model winds (bottom) have been plotted for high level winds with QI2 > 60. A long barb represents 5 m/s and a pennant 25 m/s.

Update on Feature 2.13: Tropics fast bias.

In the fourth analysis, linear-shaped fast bias features were identified in the Meteosat-9 and unedited GOES-12 data located around 20N in the Atlantic. These are still present in the AMVs derived from Meteosat-9 IR and WV channels but as shown in Figure 33 they are not just restricted to the Atlantic region. Linear biases also be observed in the MTSAT-1R/2 IR and WV data near 20N in the Pacific (e.g. May 2011).

Prior investigation of the bias found it to be associated with problems assigning heights to the edges of high level clouds. Cloud edges are frequently where clouds are thinnest and where potential tracers can change shape and evolve between successive images. Meteorological conditions also clearly play a part as the speed bias can be exacerbated in regions of high vertical wind shear and multi-level cloud scenarios.

In 2011 the linear fast bias features appear to be less prominent in the Meteosat-9 data, particularly over the Atlantic. This may in part be explained by the increased slow bias seen in the extra-tropics (see update on Feature 2.10) which can be seen to intrude into the northern tropics during northern hemisphere winter, acting to suppress these features. Another factor may be the derivation change made by EUMETSAT in September 2009 which reduced the overlap allowed during the optimal target identification process (see also update on feature 2.10). This acts to reduce the frequency at which cloud edges are selected as targets (M. Carranza pers. comms. November 2011). In future, this may also be achieved through implementation of the Cross Correlation Contribution (CCC) method (Borde and Oyama, 2008) in tandem with accurate cloud top heights from an Optimal Cloud Analysis (OCA) scheme (Watts et al, 1998). The CCC method better links the individual pixels used for tracking with those used in the height assignment step. Usually the coldest and warmest pixels in the target contribute most to the tracking using the CCC scheme and identifying the correct pixels to be used in the height assignment allows pixels from the problematic cloud edges to be discounted.

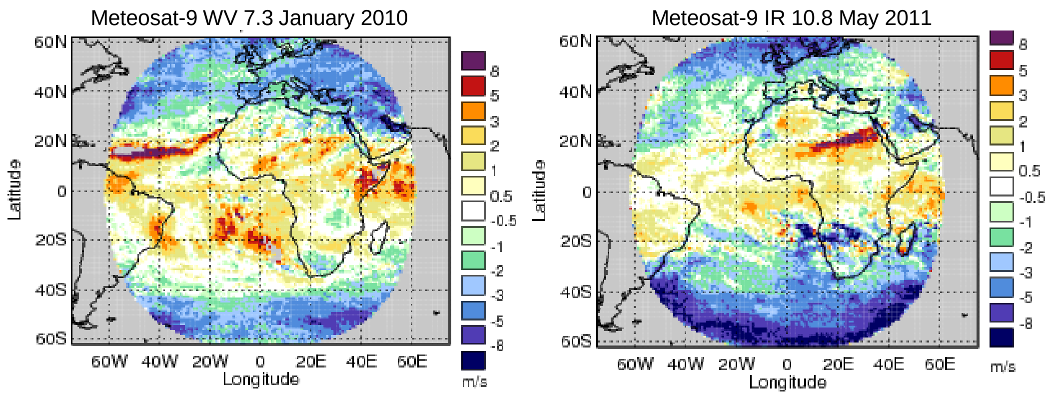

Figure 33: Map plots of O-B speed bias for high level Meteosat-9 WV 7.3 AMVs in January 2010 (left) and IR 10.8 AMVs in May 2011 (right). Data compared with the Met Office global model background.

Feature 5.3. MTSAT typhoon fast bias

MTSAT AMVs retrieved from WV imagery show a more general widespread fast bias at high level, even in the extra-tropics, though still punctuated by areas of slow bias during intense jet periods. More structured and well-defined areas of fast bias can be observed in the North West Pacific during July-September as shown in Figure 34 for August 2011.

Hovmoeller plots (not shown) of the temporal variation in O-B for MTSAT-1R WV winds between longitudes 120E-140E show a strong bias signal and high vector RMS for data valid on 5-6 August 2011 at around 20-35N. Figure 35 shows the geographical distribution of the O-B speed bias statistics for the 0600 UTC model run on the 6 August 2011. A large swathe of AMVs curving across South Korea, Japan and the Philippine Sea are considerably faster than the collocated model estimates. In the worst cases the O-B speed bias is in excess of 20 m/s for some winds. Comparing this with a McIDAS visualisation of 4 km resolution IR imagery at this time shows that the problem AMVs are tracking the high level outflow from Typhoon Muifa centred to the south west of Japan (Figure 36). Visually the AMVs appear broadly consistent, with a smooth clockwise flow following the upper level cirrus outflow with evidence of transverse banding in the imagery. This general consistency is also reflected in the high QI (without first guess) values assigned to the winds.

Figure 37 shows a comparison between observed and model best-fit pressure for IR and WV winds located in the same region as plotted in Figure 35 (box 10-40N, 120-140E). On average the WV winds have been assigned nearly 40 hPa lower than the model preferred location (left plot). The IR winds show a much closer fit to the model with a mean (observed - model) pressure difference of just +3 hPa (right plot) and consequently show better O-B statistics compared to the WV winds.

The middle plot in Figure 37 shows what happens if we consider only WV observations with O-B speed biases exceeding 8 m/s, as is the case for the problem winds associated with the outflow from Typhoon Muifa. The result is a cluster of winds assigned WV intercept heights between 180-280 hPa whilst model best-fit heights are much higher in the atmosphere at 110-180 hPa (mean pressure difference +80 hPa).

The model best-fit pressure comparisons, combined with some large directional disagreements with collocated model vectors, indicate that the AMVs have likely been assigned too low in the atmosphere. Cloud top height information from CALIPSO is not available for this case study due to the instrument payload being switched off between 4-10 August 2011.

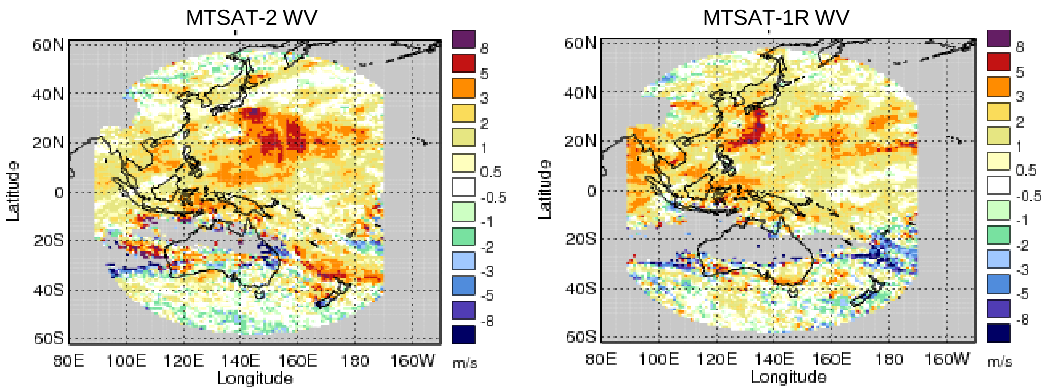

Figure 34: Map plots of O-B speed bias for high level MTSAT-2 WV (left) and MTSAT-1R (right) WV AMVs in August 2011. MTSAT-1R was used as backup from 3-15 August inclusive, MTSAT-2 during the remainder of the month.

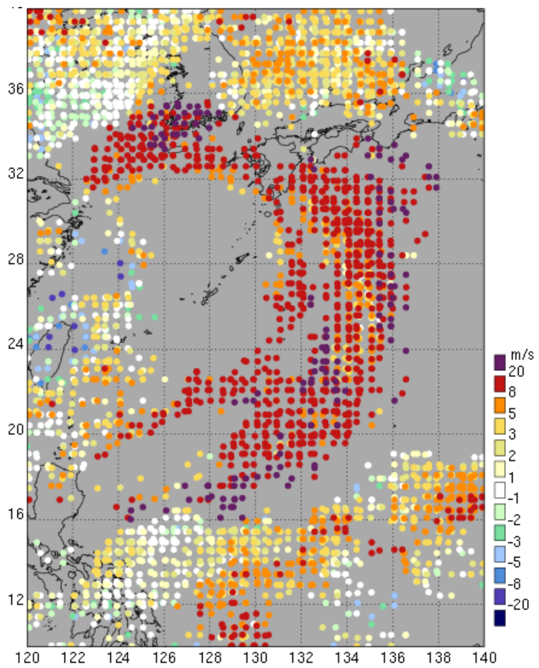

Figure 35: MTSAT-1R WV AMVs valid at 06z 6 August 2011(left) and O-B speed bias (right).

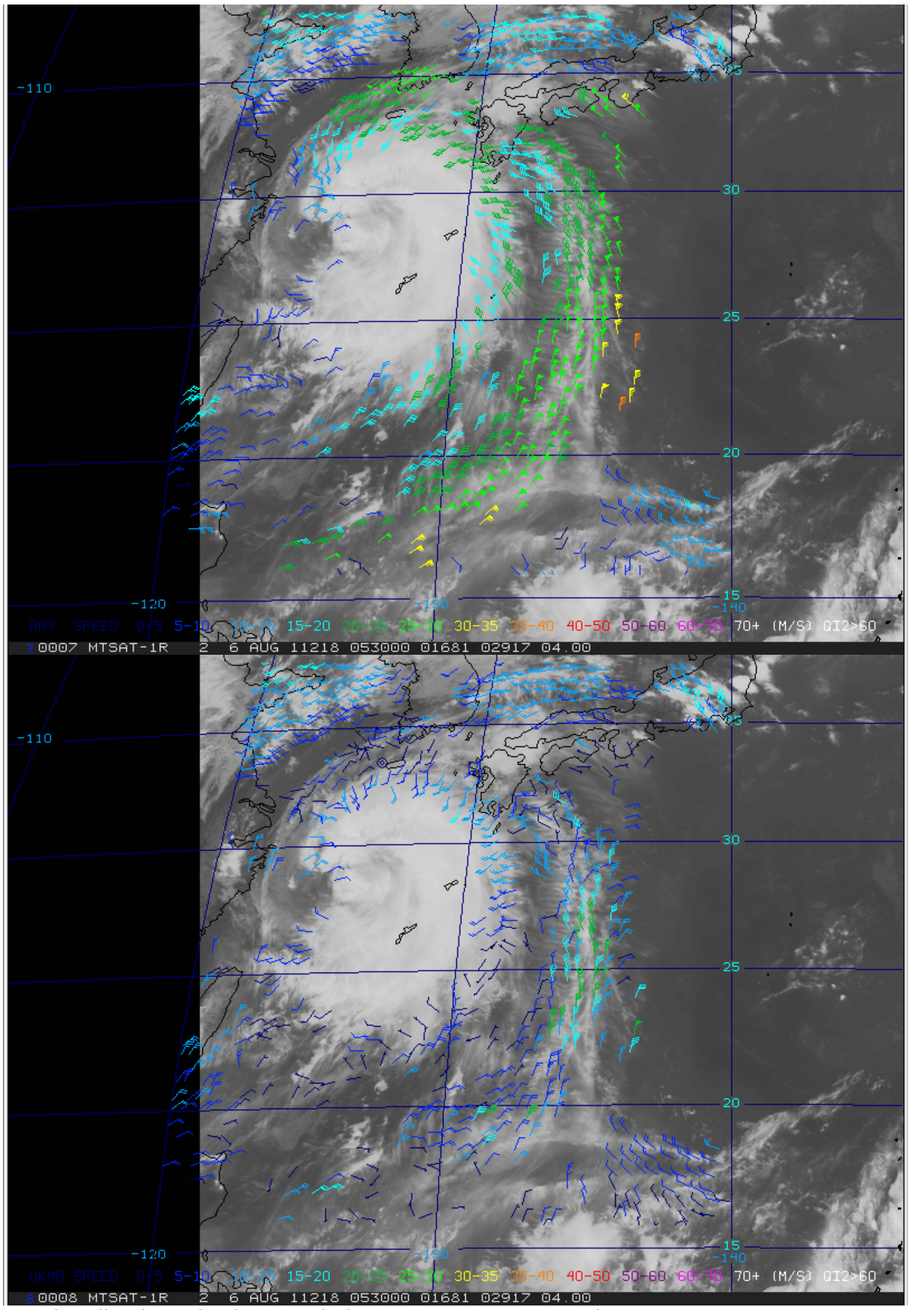

Figure 36:. McIDAS visualisation of 4 km resolution MTSAT-1R IR10.8 imagery at 0530z, 6 August 2011. Overlays of MTSAT-1R cloudy WV AMVs (top) and collocated Met Office model winds (bottom) have been plotted for high level winds with QI2 > 60. Winds extracted at 0530z only. A long barb represents 5 m/s and a pennant 25 m/s.

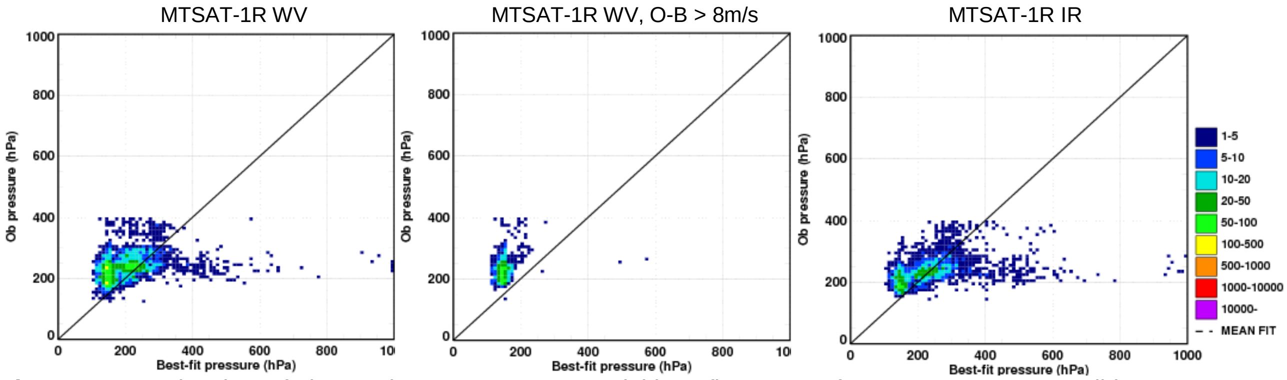

Figure 37: Density plots of observed pressure versus model best-fit pressure for MTSAT-1R AMVs valid at 0600 UTC 6 August 2011. Data filtered to a geographical box 10-40N, 120-140E for AMVs above 400 hPa. All WV winds (left), WV winds with O-B speed bias of greater than +8 m/s (middle) and all IR winds (right),

Update on Feature 2.15. Differences between channels

There are still some noticeable differences between the IR and WV AMVs retrieved from some satellites, with the largest differences observed from MTSAT-1R/2. As noted in the fourth analysis report some significant changes were made to the JMA derivation scheme in 2009. This led to some improvement in the jet region slow bias for the IR winds but the net impact on the WV winds was a general increase in fast bias, even in the extra-tropics (Figure 38). The change in WV characteristics would now appear to be the dominant reason for the differences seen in the quality of the IR and WV winds.

Figure 39 shows that although there is excellent agreement in direction between the collocated MTSAT-2 WV and IR vectors, the speed of the WV winds is clearly greater. The collocated pressures of the high level winds show generally good consistency in assigned heights. There is a tendency for the WV winds to be assigned lower in the atmosphere for AMVs below 300 hPa which is where the worst of the fast bias is located.

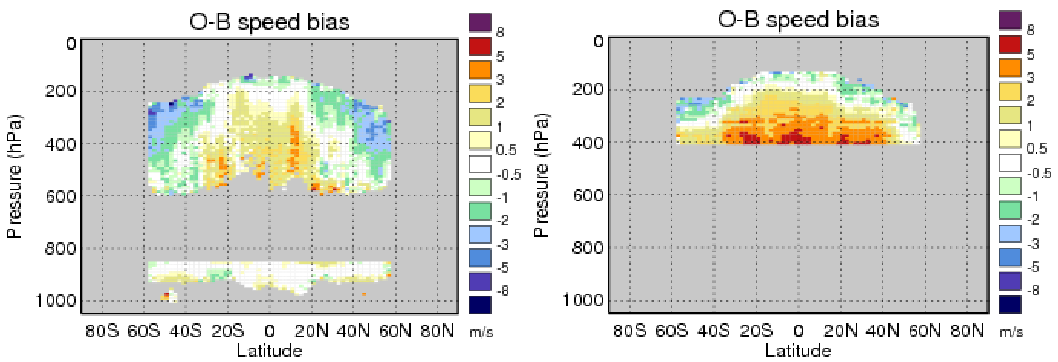

Figure 38: Zonal plots of O-B speed bias compared with the Met Office model background for MTSAT-2 IR (left) and WV (right) AMVs for April 2011. Though improved, a slow bias can still be seen in the extra-tropics for the IR data whereas a fast bias is prevalent in the WV data.

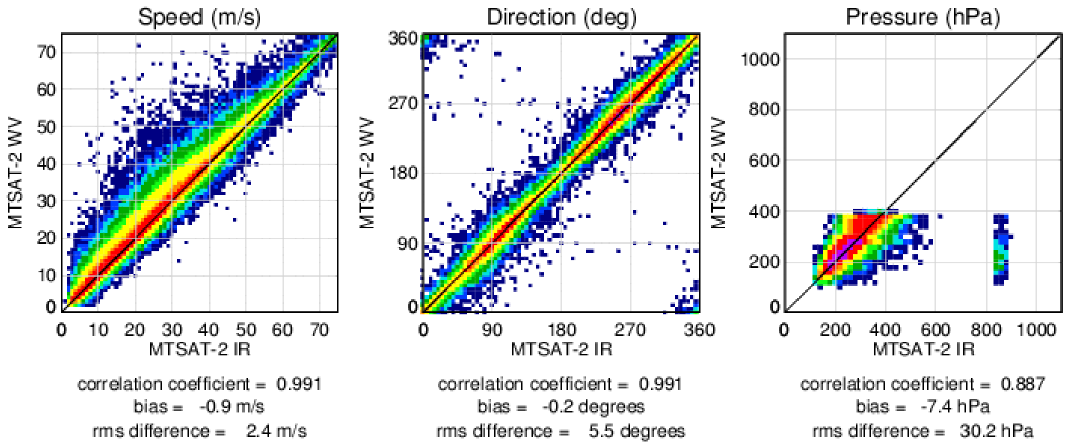

Figure 39: Speed, direction and pressure density plots for collocated MTSAT-2 IR and WV AMVs in April 2011. Collocated observations are within 10km and 10 minutes.

Update on Feature 4.2: GOES near equatorial slow bias

In January and February 2009 a slow bias was observed for the GOES satellites near the Pacific equator versus both the Met Office and ECMWF models. It was thought that this was related to the increased westerly flow at this time of year and the complications of tracking developing convective cloud associated with the ITCZ. It is interesting to note that although the slow bias feature is present again in 2011, the plots for 2010 show no such bias versus either model. As Figure 40 shows the mean observed winds for January 2010 and 2011 are quite different in the tropics. The absence of slow bias in 2010 appears to coincide with a large region of less sustained winds indicating that this feature is synoptically dependant. Also of note is that the slow bias is less prominent in the ECMWF plots for 2011 compared to the Met Office plots meaning that model errors are also likely to be contributing to the O-B signal (Figure 41).

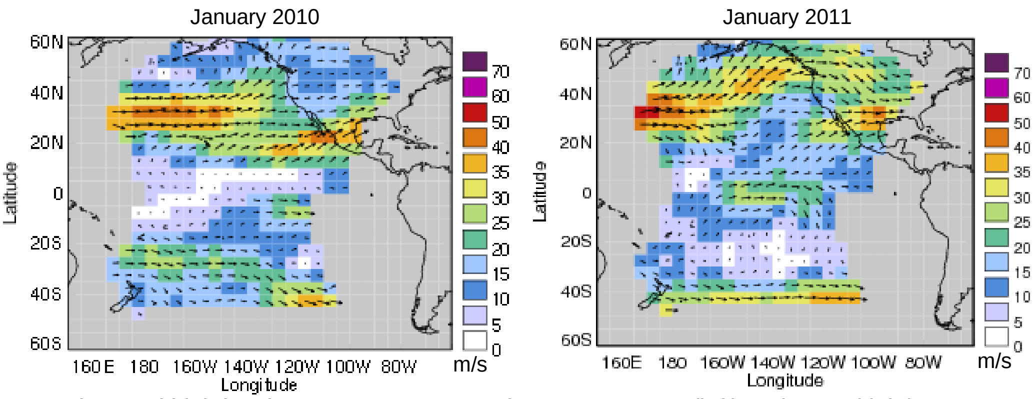

Figure 40: Mean observed high level GOES-11 IR vectors for January 2010 (left) and 2011 (right).

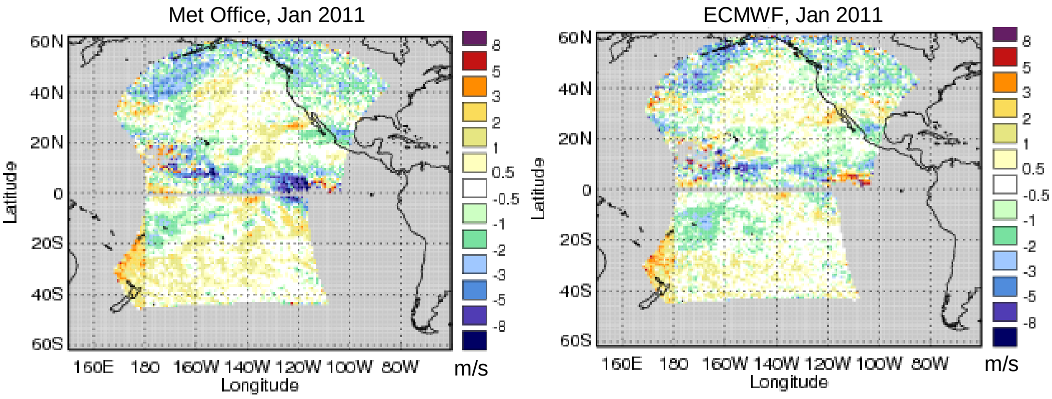

Figure 41: Map plots of O-B speed bias for high level GOES-11 IR AMVs in January 2011. Departures versus the Met Office (left) and ECMWF (right) models.

Update on Feature 3.3: GOES-11 bias change at 180 degrees

A change in the speed bias of the high level GOES AMVs at 180 degrees longitude has been a persistent feature of the NWP SAF monitoring versus both Met Office and ECMWF models. As shown in Figure 42 the anomaly seen in the current operational data (likely related to the autoeditor) is not present in the new hourly test stream available from NOAA/NESDIS. The hourly data is due to become operational in April 2012.

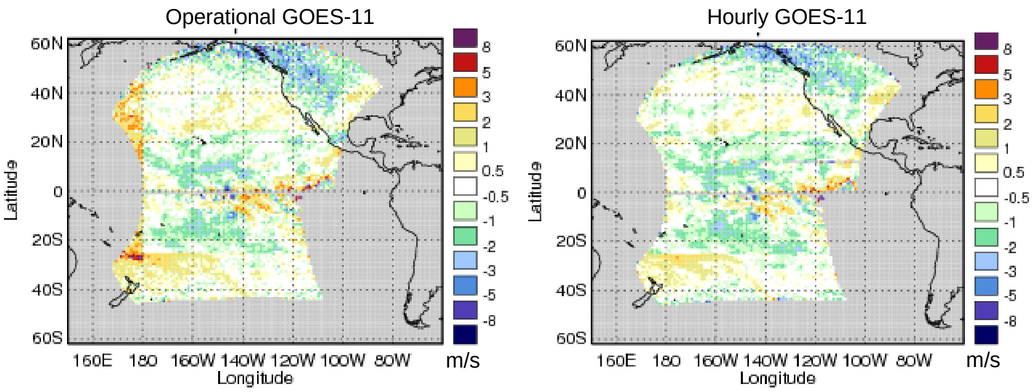

Figure 42: O-B speed bias for high level GOES-11IR AMVs in November 2011: operational (left) and hourly (right) data. Statistics versus the Met Office model background.

5.4. Polar winds

The NWP SAF monitoring covers a range of polar AMV datasets. These include data from CIMSS, direct broadcast stations and NESDIS with the latter split to show O-B monitoring for both the unedited and edited winds. Generally the statistics are similar for all datasets, but some differences are noted below.

Update on Features 2.19 and 3.6. High level fast speed bias and NESDIS-CIMSS polar AMV differences

A fast bias is still present at high levels for polar winds derived from IR and cloudy WV channels. As shown by the example in Figure 43 the distribution of the fast bias is quite variable but usually located at the lower latitudes near the edge of the polar coverage. In this case the bias is associated with a small area near the tip of Greenland. Previous work has concluded that these features are probably linked to the position of the polar front jets, e.g. see update in third analysis.

For the MODIS winds the fast bias appears slightly worse for Terra compared to Aqua and is more prominent in the WV channel compared to the IR. It is also noticeable that for the example in Figure 43 the bias seen in the NESDIS MODIS product is not present in the CIMSS product, though largely due to there being fewer winds derived near the problem area.

For the AVHRR winds, the fast bias is slightly more visible following the processing update at CIMSS in June 2011 which has increased the geographical coverage of the data down to lower latitudes (Figure 44).

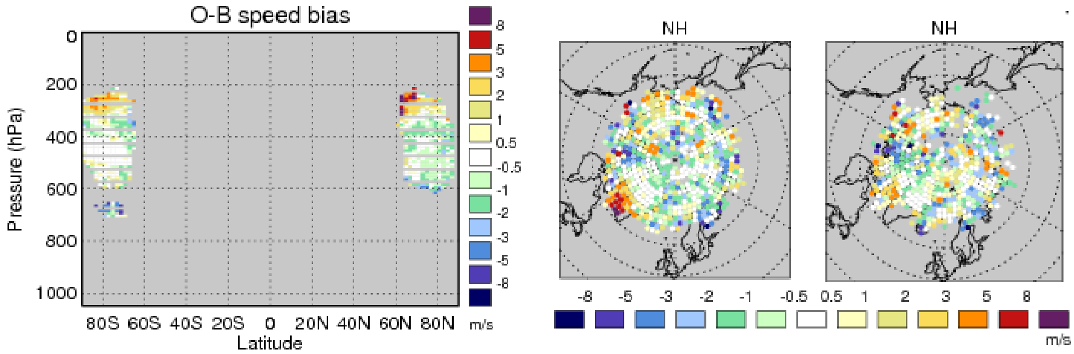

Figure 43: (left) Zonal plot of O-B speed bias for NESDIS Terra WV data in November 2010. Also shown for the same month are the equivalent NH map plots for the NESDIS (middle) and CIMSS (right) Terra products.

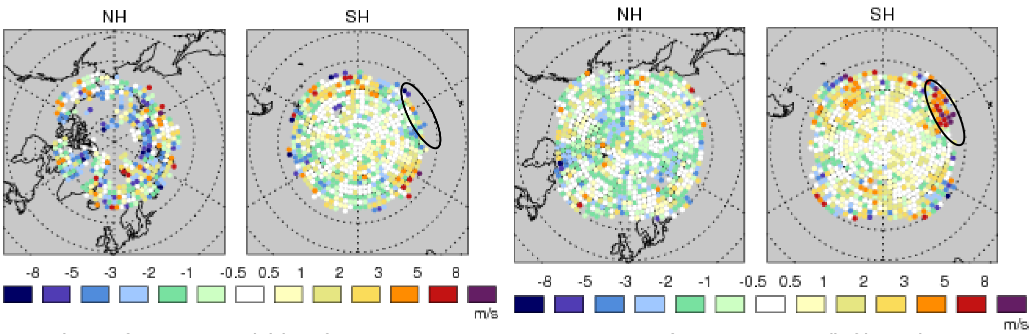

Figure 44: Map plots of O-B speed bias for CIMSS NOAA-16 IR AMVs for May 2011 (left) and August 2011 (right). Notice the change in geographical coverage.

Update on Features 4.3 and 3.6: High latitude mid level slow speed bias and NESDIS-CIMSS polar AMV differences

In the previous analysis it was noted that a slow speed bias was present for mid level IR AMVs located towards the higher latitudes, mainly during the winter months. This feature was most prominent for the CIMSS-derived MODIS winds but this no longer appears to be the case. It is noticeable in the zonal plots that from September 2010 onwards, the MODIS winds from CIMSS now have mid level bias characteristics more similar to those generated at NESDIS i.e. the slow bias is improved. This can most likely be attributed to a change made to the CIMSS processing on 23 August 2010 which implemented a fix to some of the autoeditor reassigned heights. The MODIS processing at NESDIS was not affected by this problem (different code base) hence this might explain why the winds now appear more similar.

Comparing the NESDIS MODIS plots between the Met Office and ECMWF shows that the slow bias is most prominent when compared against the ECMWF model (Figure 45) and at times can also be seen at high level. A recent comparison of model best-fit pressure statistics (Salonen and Bormann, 2011) reveals that the ECMWF statistics showed a more pronounced height bias for the MODIS data e.g. Figure 46. Although both models suggest the AMVs at mid level have been assigned slightly too low (positive pressure difference) the bias is greater in the ECMWF system.

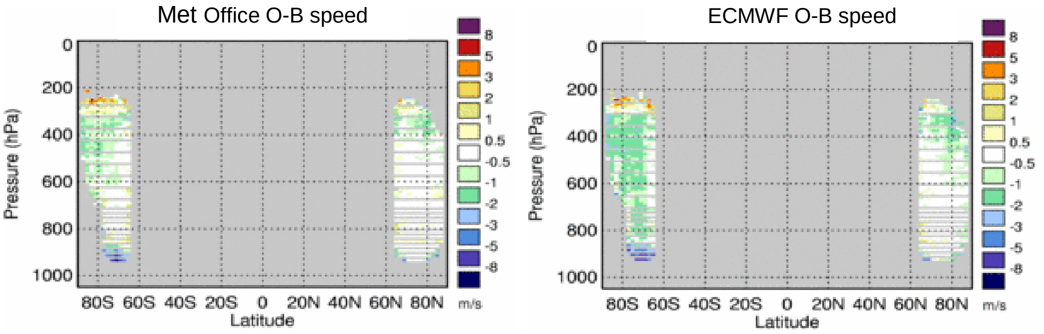

Figure 45: Zonal O-B speed bias plots for NESDIS Aqua MODIS IR winds for September 2011. Observations versus the Met Office (left) and ECMWF (right) global model backgrounds.

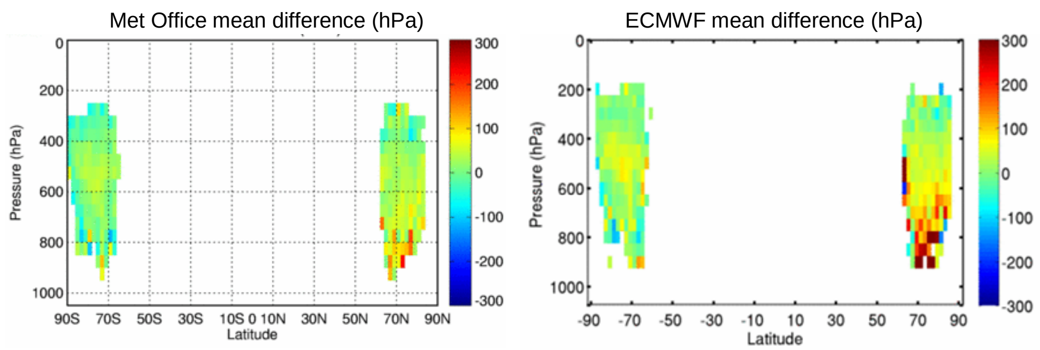

Figure 46: Zonal plots of the mean difference between assigned AMV height and the model best-fit pressure height estimate: Met Office (left) and ECMWF (right) models. Statistics are for NESDIS MODIS Aqua IR winds assigned using the EBBT method, over land in February and March 2010.

6. Conclusions

The NWP SAF AMV monitoring site hosts a collection of resources aimed at better understanding the error characteristics of this important source of tropospheric wind information. The monitoring has continued to develop over the past two years with a new investigation comparing model best-fit pressure statistics between the Met Office and ECMWF systems. Another useful resource is the information from various NWP centres detailing how AMVs are assimilated in their models and this continues to be reviewed and updated regularly in order to reflect the latest developments, but could benefit from the inclusion of other NWP centres such as NRL/BoM (see A2.14 in the action list). However, the largest and most significant part of the website is the archive of monthly monitoring plots that display AMV departure statistics against both the Met Office and ECMWF global NWP models. Two new data sets have been added to the archive: the Metop-A polar wind products from EUMETSAT and CIMSS. Although derived from the same AVHRR instrument, the wind retrieval algorithms vary significantly in their approach to extracting winds over Polar Regions and as such there are interesting differences to note when comparing the quality of the winds. The routine production of monthly plots within the NWP SAF has proven to be especially useful when tracking the impact of derivation changes made to the EUMETSAT Metop winds during 2011.

The NWP SAF monitoring archive also allows various features to be identified in the statistics and this analysis report is part of an ongoing effort to diagnose where significant biases are occurring in the AMV data and what the likely causes are. Three new features have been identified in this report: a low level slow bias in GOES visible data near Patagonia (5.1), a slow bias in the MSG visible winds during the low level Somali Jet (5.2) and a fast bias in high level MTSAT data associated with the passage of a Typhoon (5.3). It is encouraging to see that two long standing features of the GOES AMVs (2.1, 3.3) appear to have been resolved by updates due to be implemented operationally by NOAA early in 2012. Several other features, although still present, appear to have improved since the previous analysis report. This has resulted from derivation changes (2.13, 4.3) by the wind producers but also from improvements to the model winds. Perhaps the largest improvement has been for the GOES-West winds at mid level when compared against the Met Office model. A significant reduction in speed bias and vector difference can be observed in both the tropics (2.9) and extra-tropics (2.8) which is likely a result of improvements made to the model winds in this region of the Pacific.

At low level the magnitude of the speed biases is generally smaller, reflecting the lower wind speeds found here. The largest departures from the model are the result of large height assignment errors which can lead to spuriously fast AMVs assigned too low. Other more localised biases appear to be caused by orographic influences, sometimes in combination with seasonal enhancements in the strength of the low level flow e.g. low level jet. Despite some improvements at mid level there is still scope for improving on some known height assignment issues e.g. use of forecast data at higher temporal resolutions (Sahara fast bias). Departures at high level are dominated by the slow bias associated with the sub-tropical/polar jets, particularly for the EUMETSAT and JMA winds. It is slightly concerning that in the case of the MSG winds this bias appears to have deteriorated since the last analysis. For the polar winds the difference between the CIMSS and NESDIS MODIS winds continues to decrease and some model error contribution can also be identified (4.3).

Appendix: Revised Action List

The NWP SAF AMV action list can be viewed at:
http://research.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. Feedback is welcome, including any additional suggestions for follow-up work.

A1.1. Discrepancies between contributors

Action	Details	Centre(s)	Status
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	Not yet resolved

A1.2. Improvements to site design

Action	Details	Centre(s)	Status
Add real-time monitoring	Currently provide links to other sites - could add some basic plots for the Met Office (ECMWF covered elsewhere).	MetO	No current plans
Display examples of plot output	The AMV monitoring/analysis system has been developed over a number of years to help with the biennial analysis and other investigations. We could add a new tab to highlight the range of plots that can be produced.	MetO	No current plans
Assimilation information	Try to expand information to include other NWP centres e.g. NRL and BoM.	MetO	In progress
Review and update all web pages		MetO	Ongoing

A1.3. Development of plots

Action	Details	Centre(s)	Status
Add Hovmöller plots	These can be produced at the Met Office (by latitude or pressure) and can be useful for investigating day-to-day variability in O-B stats.	MetO, ECMWF	Not yet added due to the large number of plots already displayed.
Develop plots comparing AMVs to other observations	Lower priority unless strong demand	MetO, ECMWF	No current plans

A1.4. Analysis of results

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

A1.5. Follow up investigations

Action	Details	Centre(s)	Status
Height assignment investigations	Continue investigations into differences between channels and satellites in regions of overlap and comparisons with model best-fit pressure.	MetO, ECMWF	Ongoing

Acknowledgements
Thanks go to Antonio Garcia-Mendez for providing the ECMWF monthly statistics, Robert Tubbs for managing the NWP SAF website and Mary Forsythe and Roger Saunders for suggestions to improve this document. The work has also benefited from discussions with data providers, in particular EUMETSAT and NOAA/NESDIS.

Visualisations plotted using McIDAS-X 2007. MSG imagery sourced from the EUMETSAT Data Centre and GOES imagery from NOAA's Comprehensive Large Array-data Stewardship System (CLASS). MTSAT imagery courtesy of Jerrold Robaidek and Douglas Ratcliff, SSEC Data Center, University of Wisconsin.

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