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NWP SAF AMV monitoring: the 8th Analysis Report (AR8)

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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 29 June 2011, 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	26/2/18	F Warrick, J Cotton	First draft.
0.2	05/3/18	F Warrick, J Cotton	Second draft following comments by M Forsythe
1.0	08/3/18	F Warrick	Final draft following comments by R Saunders

Contents

1 Introduction

The NWP SAF (Satellite Application Facility for Numerical Weather Prediction) Atmospheric Motion Vector (AMV) monitoring (http://nwpsaf.eu/site/monitoring/winds-quality-evaluation/amv) has as its aim the detection and investigation of AMV errors so that their NWP impact can be improved via improvements to the product derivation, to the data assimilation strategy, or both. The NWP SAF maintains an archive of observation-minus-background (O-B) statistics which are the difference between AMVs and short-range NWP model fields. O-Bs are calculated against Met Office and ECMWF global models, to give insight into whether features in the monitoring are related to problems with NWP models or with the AMVs.

The biennial NWP SAF Analysis Reports identify and investigate features from the website's monitoring statistics and assess whether they have become more or less severe since the previous report. If new features have appeared, or changes are seen in test versions of existing AMV products, these are also investigated. Various data can be used to study a feature including extra O-B statistics, comparisons with model fields, imagery products, and cloud-top height products. This document marks the eighth in the series of analysis reports (AR8). Previous analysis reports are hereafter referred to as AR7 (2016), AR6 (2014), AR5 (2012), AR4 (2010), AR3 (2008), AR2 (2005) and AR1 (2001) and are available to download from the website.

The datasets included in the AMV monitoring as of January 2018 are listed in Table 1. A list of datasets added or removed since AR7 is show in Table 2. Significant changes to AMV products since AR7 include:

1. **Nested Tracking**. A new tracking and height assignment scheme has been developed for the new generation of GOES satellites. It aims to reduce negative O-B biases by tracking only the dominant cloud motion of a scene, avoiding averaging with other slower motions [3]. The height assignment is based on the cloud-top heights of pixels involved in the tracked motion. The new derivation no longer has the 'auto-editor' used for the heritage algorithm. AMVs derived using nested tracking on GOES 13 and 15 imagery were made available to allow early assessment of the impact on AMV quality of the new algorithm. Many significant changes were found.

2. **OCA heights for MSG**. Alternative height Meteosat Second Generation (MSG) assignments using the Optimal Cloud Analysis (OCA) [1] were made available for all MSG AMVs from November 2016. A useful feature of the OCA product is that it can identify multi-layer cloud situations and in these cases AMVs are assigned to the higher layer. The operational MSG height assignment scheme can struggle in these situations as it is influenced by the radiance of the lower layer and

Geostationary AMVs	Channels
Meteosat-10	IR 10.8, WV 6.2, WV 7.3, VIS 0.8, HRVIS
Meteosat-9	IR 10.8, WV 6.2, WV 7.3, VIS 0.8, HRVIS
Meteosat-8	IR 10.8, WV 6.2, WV 7.3, VIS 0.8, HRVIS
GOES-13 (+unedited)	IR 10.7, IR 3.8, WV, VIS
GOES-15 (+unedited)	IR 10.7, IR 3.8, WV, VIS
Himawari-8	IR, WV 6.2, WV 6.7, WV 7.3, VIS
INSAT-3D	IR, IR 3.8, WV, VIS
FY-2E	IR, WV
FY-2G	IR ,WV
COMS-1	IR, IR 3.8, WV, VIS
Polar AMVs	**Channels**
Aqua MODIS (from NESDIS & DB)	IR,WV,CSWV
Terra MODIS (from NESDIS & DB)	IR,WV,CSWV
Terra MISR (NASA-JPL)	VIS 0.6
NOAA-15 (CIMSS)	IR
NOAA-18/19 (CIMSS & DB)	IR
Metop-A (EUMETSAT, CIMSS)	IR
Metop-B (EUMETSAT, CIMSS)	IR
Suomi-NPP (NESDIS & DB)	IR
Mixed AMVs	**Channels**
LeoGeo (CIMSS)	IR
Dual-Metop (EUMETSAT)	IR

Table 1: AMV datasets monitored by the NWP SAF (January 2018). DB = direct broadcast, IR = infrared, VIS = visible, HRVIS = high resolution VIS, WV = cloudy water vapour, CSWV = clear sky water vapour.

the height is often assigned too low. O-Bs were different in some areas when calculated using the OCA heights.

The report structure is as follows. Section 2 gives an overview of current features identified in the monitoring statistics. Sections 3, 4 and 5 present updates on these features separated by low level (below 700 hPa), mid level (400-700 hPa) and high level (above 400 hPa) respectively. Updates on polar AMV features are described in Section 6. Section 7 is a report summary.

Change	Type	Date	Description
Meteosat-7	Removed	4/17	Satellite retired.
Meteosat-8	Added	11/16	Replaced Meteosat-7 for Indian ocean coverage, though further west at 41.5°E instead of 58°E.
Kalpana	Removed	6/16	Satellite retired.

Table 2: Changes to monitoring since AR7.

2 Index of Features

Features are referenced in the format X.Y, where X is the number of the analysis report where the feature was first described and Y is the example number from that report. In this report the tropics refer to the area within 20°N/S. Table 3 gives the status of new features and those previously documented, and states for each feature whether an update is given in this report.

Ref.	Feature	AR	Resolved?	Update?
Low Level (below 700 hPa)				
2.3	GOES winter negative bias over NE America	2,3,6	No	N
2.6	MSG positive bias over N Africa	2,3,4,6	No	Y
2.7	Spuriously fast Meteosat and MTSAT winds	2,3,4,6,7	No	N
4.1	Model differences in the Pacific	4,5	No	N
5.1	Patagonia negative bias	5	No	N
5.2	MSG negative bias during Somali jet	5,6	No	N
6.1	Bias in tropical E Atlantic	6	No	N
6.2	MTSAT and FY-2E bias during NE winter monsoon	6	No	N
8.1	Meteosat-8 (IODC) positive speed difference in the tropics	New	New	Y
Mid Level (400-700 hPa)				
2.8	Positive bias in the tropics	2,3,4,5,6,7	No	Y
2.9	Negative bias in the extra-tropics	2,3,4,5,6,7	No	Y
High Level (above 400 hPa)				
2.10	Jet region negative speed bias	2,3,4,5,6	No	Y
2.13	Tropics positive speed bias	2,3,4,5,6,7	No	Y
2.14	High troposphere positive bias	2,3,6	No	Y
2.15	Differences between channels	2,3,5	No	N
3.2	Negative Speed bias in TEJ	3,6	No	N
4.2	GOES negative bias in tropical Pacific	4,5,6	No	N
5.3	MTSAT tropical cyclone speed bias	5,6,7	No	N
6.3	Very high FY-2E WV winds	6,7	No	N
Polar AMVs				
2.19	High level positive speed bias	2,3,4,5	No	N
2.20	Low level negative speed bias	2,3,4	No	N
4.3	Near-pole mid level negative bias	4,5	No	N
6.4	EUMETSAT Metop near the poles	6	No	N
7.1	Dual-Metop high level positive bias in tropics	7	No	N
7.2	EUMETSAT Metop high level negative bias in mid-latitudes	7	No	N
7.3	MISR fast bias over ice and desert	7	No	N
7.4	LeoGeo coverage gaps at particular longitudes	7	No	Y
7.5	MISR bad orbits	7	No	N
7.6	VIIRS square distribution	7	No	Y

Table 3: Status of the current features identified in the NWP SAF AMV monitoring. Green shading indicates a new feature, blue indicates a feature that has been fixed or otherwise closed.

3 Low Level Updates

Feature: 2.6 MSG Positive Bias over North Africa

Feature Background:

A large, positive O-B speed bias is observed in the MSG IR and visible channels over North Africa and the Arabian Peninsula during winter. The difference is largest in magnitude for the IR channel, and more marked in the HRVIS than the 0.8μ channel. It follows the location of faster mid-upper level winds at different times of the year and although mainly observed over land, does extend over sea in some months. Previously the bias has been linked to large height assignment errors when tracking cirrus or semi-transparent clouds (AR4) leading to fast winds being assigned too low. A diurnal component has also been noted in the bias.

Update:

The characteristics of this large scale bias have remained unchanged since the last report. In this first section we try to further understand the cause of the diurnal signal that has been observed in previous investigations. Hovmoeller plots for the IR channel show a positive speed bias for AMVs extracted between the hours of 1600 UTC and 0500 UTC and for heights between 600-800 hPa (Figure 1). Below 800 hPa there is a particularly large bias between the hours of 1600 UTC and 0000 UTC which coincides with an increase in AMV speed whilst the model background speed remains rather constant (not shown). Hovmoeller plots by time of day in UTC time coordinates are less useful when the region of interest spans 80° longitude since this doesn't reflect the local or solar time. Instead we can use local mean time (LMT) which is the mean solar time for a specific location and found by adding or subtracting 4 mins for each degree of longitude. With LMT the bias is better constrained since we take account of the local time differences (Figure 2). The bias onset is around 1700 LMT and the largest signal ends around 0000 LMT, but continues through to 0500 LMT at very low heights.

The HRVIS channel shows a smaller signal in the last couple of hours of UTC, but nothing according to LMT

To understand why such a large bias only appears at certain times of the day we use AMVs extracted on 6 December 2016 as a case study. Over the central portion of North Africa between 0-40°E we can observe that AMVs assigned lower heights, e.g. below 350 hPa, have a positive bias compared to surrounding data. Within the 18 UTC cycle a cluster of data appear that are assigned heights

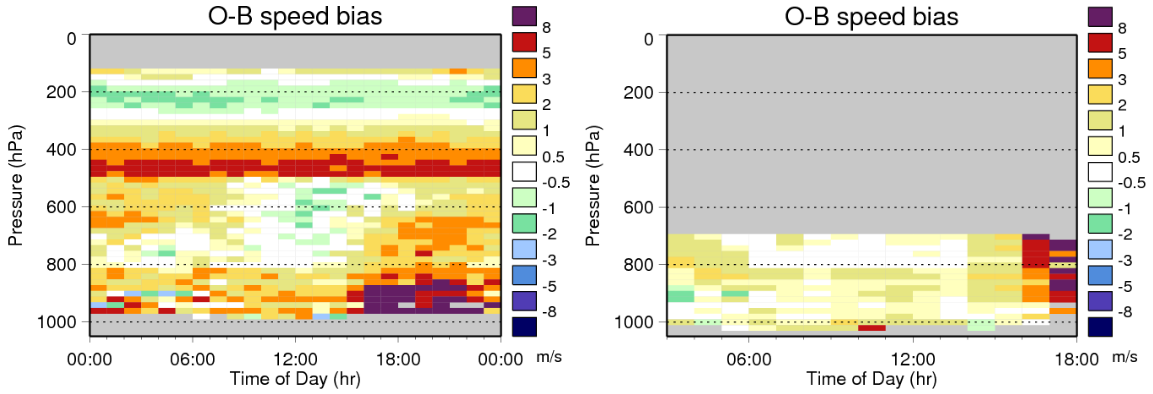


Figure 1: O-B speed bias for Meteosat-10 IR10.8μ (left) and HRVIS (right) AMVs as a function of the time of day and pressure. Data filtered for QI2 $>$ 80, latitude 0°-40°N, longitude 20°W-60°E, over land, during December 2016.

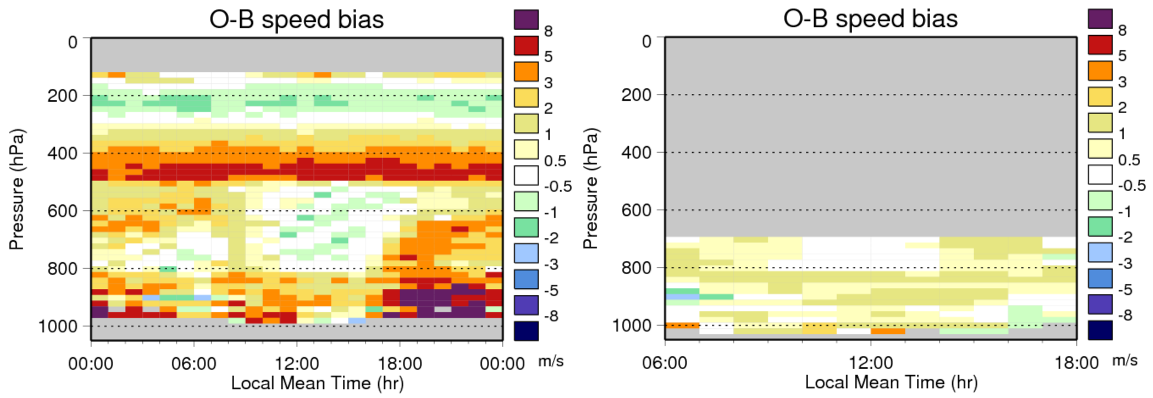


Figure 2: As Figure 1 but with time coordinate as the local mean time instead of UTC.

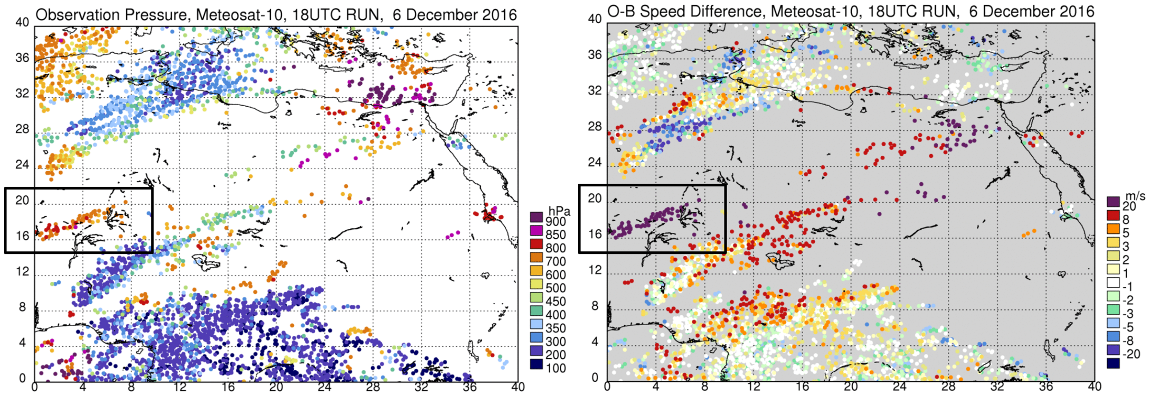


Figure 3: AMV assigned pressures (left) and O-B speed bias (right) for AMVs extracted between 1500 UTC to 2100 UTC on 6 December 2016. Data filtered for QI2 $>$ 80.

below 700 hPa and have a huge speed bias (over +20 m/s) compared to the model (Figure 3, outlined in black). AMV speeds are greater than 35 m/s from a southwesterly direction and model best-fit pressure is well constrained at higher than 300 hPa height. An example model profile for an AMV located in the problem area (Figure 4) shows a very dry atmosphere until a single moist layer at around 170-260 hPa. The AMV is assigned down at 808 hPa whilst best-fit pressure is well-constrained at 190 hPa, near the top of the model's moist layer. This suggests an error in height assignment of around 600 hPa.

The data outlined in Figure 3 are not present in the three preceding cycles at 00/06/12 UTC so either a new area of cloud has formed, been advected into the area, or the cloud exists throughout but could not be tracked at these times. IR imagery for 6 December shows a line of thin cloud streaming north eastward. In the hours around 12 UTC the warm surface temperatures appear darker in the image and the thin cloud is harder to detect (Figure 5, outlined in red). Assuming the height of the cloud remains constant then we can attribute the change in measured cloud radiance to a larger contribution from the surface. If the IR AMVs cannot be extracted in the hours surrounding local midday this could explain why the bias has a diurnal signal.

In this second section we further investigate the height assignment problem which appears to be the cause of this bias. First we can compare the AMV assigned heights from the EUMETSAT Cloud Analysis (CLA) to other SEVIRI cloud products from EUMETSAT and the Met Office (Figure 6). The EUMETSAT Optimal Cloud Analysis (OCA) cloud top pressures for the cloud of interest are generally below 750 hPa and so are similarly low in height as CLA. The Met Office cloud products (Figure 6, right) only allow us to view cloud top temperature/height, rather than pressure, but it is clear in this case the Met Office clouds are very cold (below -73°C) and high (above 12 km).

Secondly we can compare AMV heights with lidar observations from the CALIOP instrument on

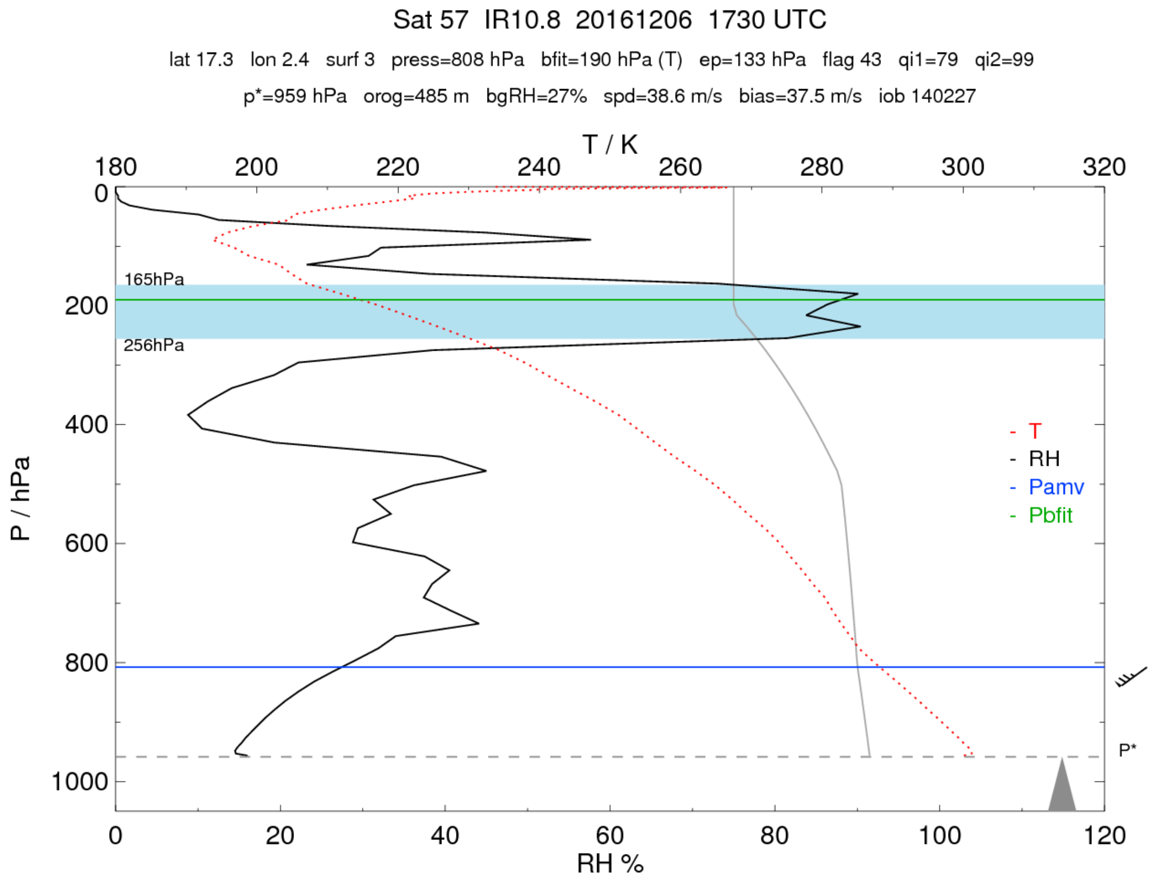


Figure 4: Model profile information for a single AMV extracted at 1730 UTC on 6 December 2016. Model relative humidity (RH, black line), temperature (red dashed line) and surface pressure (grey dashed). AMV pressure (blue line) and best-fit pressure (green line). Blue shading indicates a moist layer where the model RH has exceeded a height-dependent threshold (grey solid line).

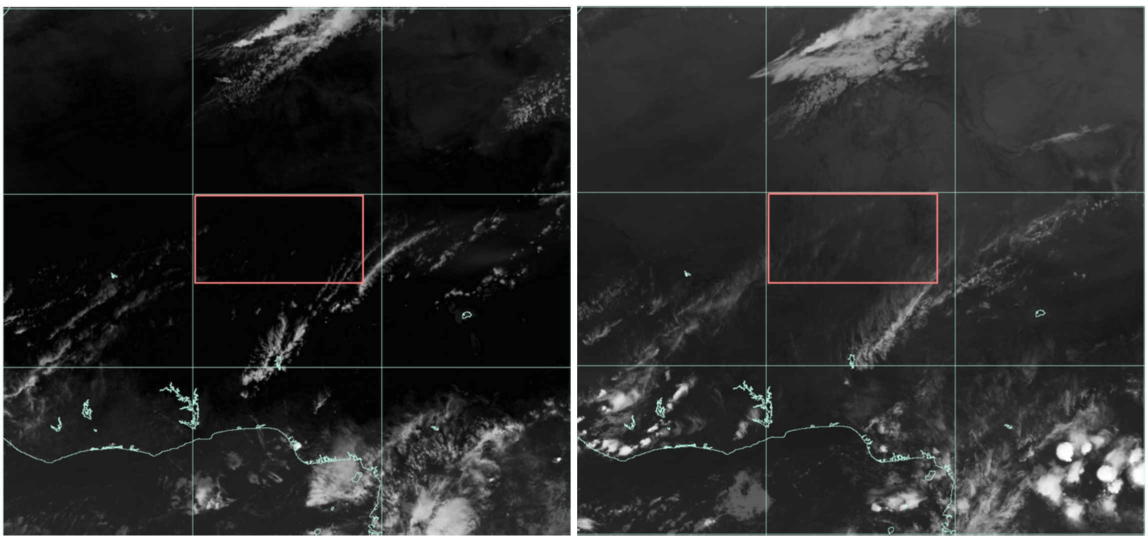


Figure 5: SEVIRI IR 10.8μ images for 1230 UTC (left) and 1830 UTC (right) on 6 December 2016. The red outline shows approximately the same latitude and longitude as the area outlined on Figure 3. Image credit Met Office/EUMETSAT.

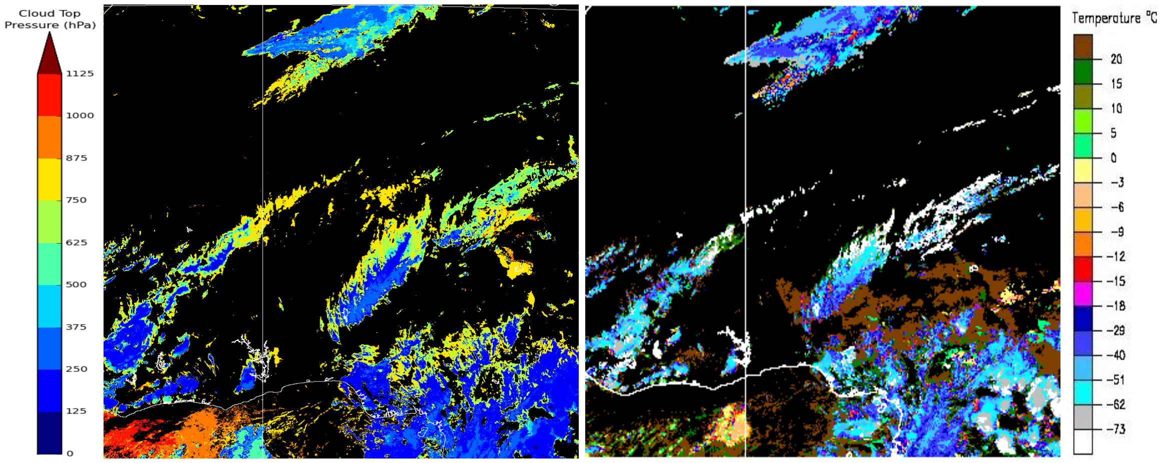


Figure 6: Comparison of cloud top products at 1730 UTC on 6 December 2016. EUMETSAT OCA cloud top pressure (left) and Met Office cloud top temperatures (right). Cloud top products courtesy of Pete Francis (Met Office).

Calipso. Results are courtesy of Alexander Cress at DWD using the method developed by Folger and Weissmann (2013) [4]. AMVs and lidar heights are matched up if they occur within 50 km and 30 minutes of each other. There are relatively few AMV-lidar collocations over North Africa in December 2016 so results are presented for the whole month rather than as a case study. For the limited collocations available it is found that on average AMV heights are lower than lidar heights for AMVs assigned below 700 hPa height (Figure 7, left). In particular, large discrepancies in height are found for visible channel winds at around 850 hPa.

In summary, we have shown that the diurnal variation of the bias in the IR channel is because the thin clouds associated with the error in height assigment are not detected/tracked in the hours either side of local midday. In a case study, CLA and OCA heights for a problematic area of cloud were found to be much lower in height compared to Met Office cloud products. AMV-lidar matchups are rather limited over North Africa but also indicate the AMVs are assigned heights that are too low. It would be good to further understand the differences between the cloud products over North Africa and why in this example the Met Office cloud heights appear to be better than OCA. In NWP assimilation the low levels winds in this problem area are dealt with through a spatial blacklist to reject the observations. However if these winds genuinely are upper level winds then potentially useful observations are being thrown away in an area where other sources of wind information are sparse.

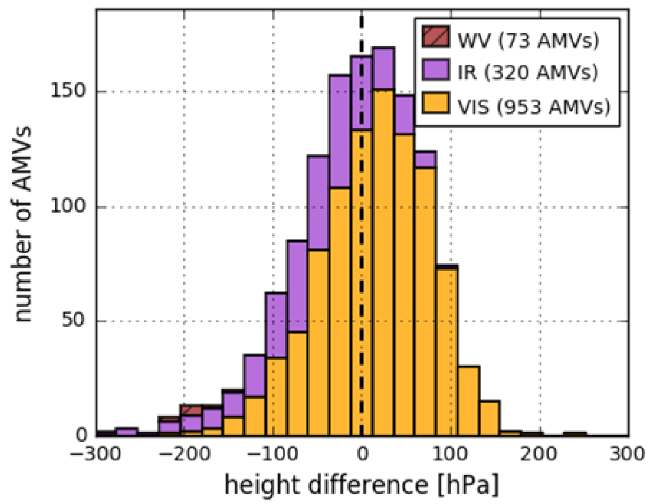


Figure 7: AMV minus lidar height frequency distribution for AMV heights below 700 hPa. Meteosat-10 IR, visible (HRVIS and 0.8μ), and WV channel winds in December 2016 with QI1 $>$ 60 and located 20-40N, 0-40E. AMV-lidar matchups are within 50 km in the horizontal and 30 minutes in time..

Feature: 8.1 Meteosat-8 (IODC) Positive Speed Difference in the Tropics

Meteosat-8 low level AMVs show a positive speed difference and increased RMSVD versus Met Office and ECMWF model background winds over the tropical Indian Ocean, south of the equator (Figure 8). In the Met Office plots the difference is largest for the visible 0.8μ channel, exceeding +3 m/s in August 2017, but appears less prominently in maps for the HRVIS channel. The difference is present for most of the first year of Meteosat-8 operation over the Indian Ocean (since Nov 2016) and peaks in magnitude around June-August.

Profiles of O-B speed show the AMVs are slower than the model for assigned heights below 880 hPa but are substantially faster than the model above that height (Figure 9). The IR and visible channels have an O-B speed bias of around +4 m/s at 700 hPa height. Observed minus model best-fit pressure differences at this height exceed -100 hPa indicating the AMVs are assigned too high according to the model.

The vertical distribution of IR and visible 0.8μ channel winds is similar and has a peak in numbers at 800 hPa, however the HRVIS channel has a lower secondary peak at around 1000 hPa (not shown). This may help explain why the positive speed difference is less prominent in the maps plots for the HRVIS, since there will be more weight toward the O-B at 1000 hPa where the speed bias is smaller

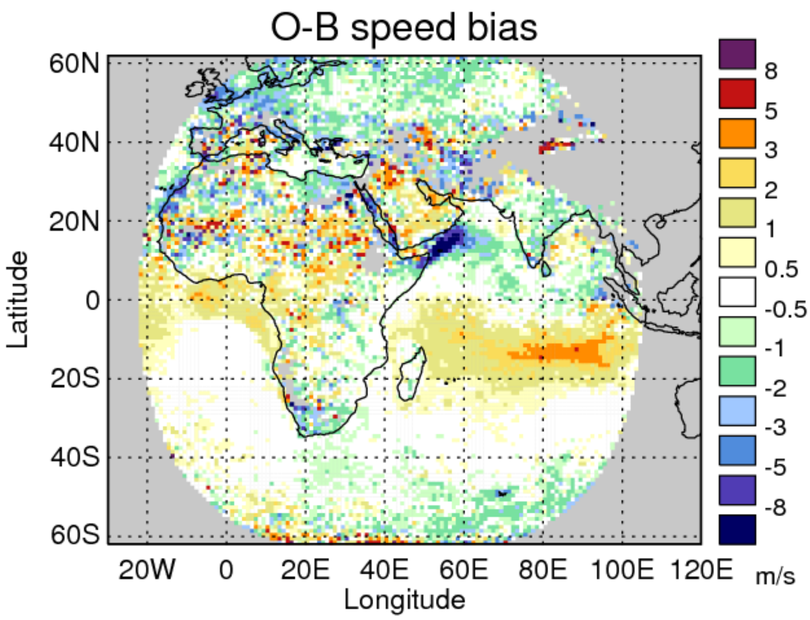


Figure 8: O-B speed bias for Meteosat-8 visible 0.8μ AMVs below 700 hPa. Data for August 2017 and filtered for QI2>80.

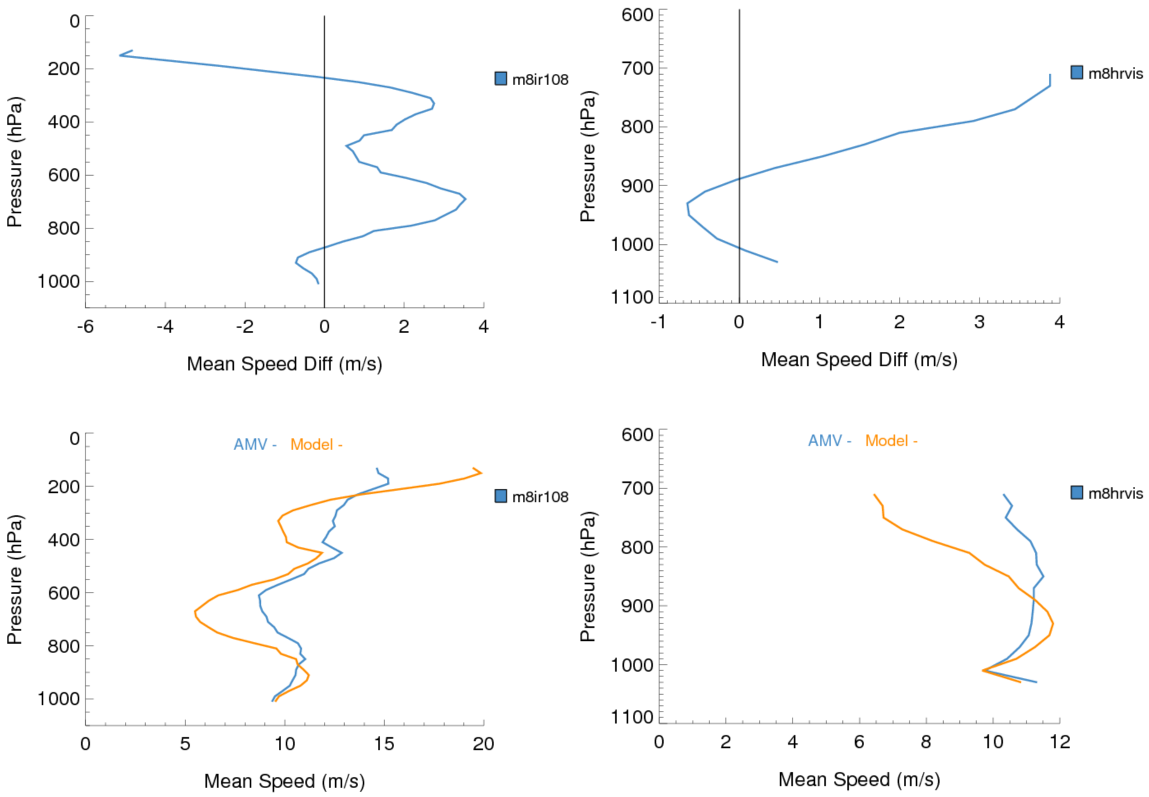


Figure 9: Profiles of mean O-B speed difference and mean model and AMV speed for IR10.8 (left) and HRVIS (right) channels winds. Data for August 2017 filtered for QI2>80 and located between latitude 25°S-5°S, longitude 50°E-100°E. Note the different vertical range used for the IR and visible.

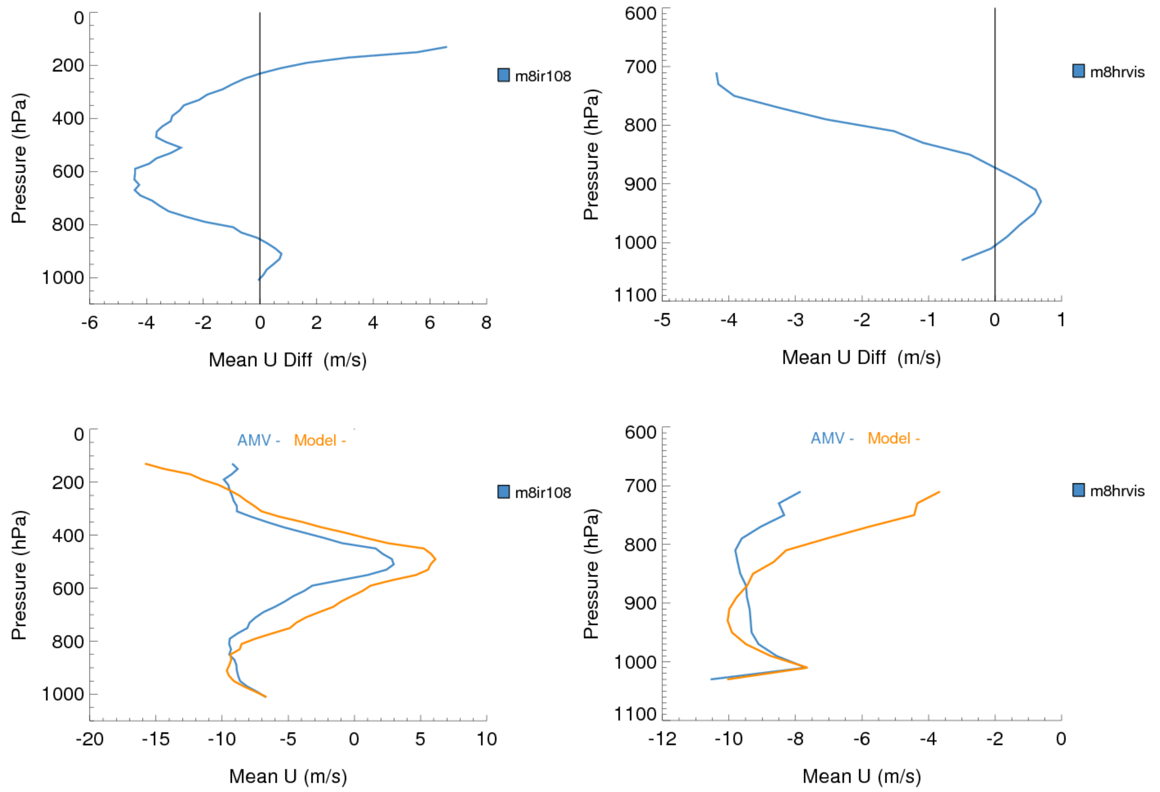


Figure 10: As Figure 9 but profiles for the zonal (U) wind component.

and negative.

Considering the zonal wind component we see that mean low level wind is an easterly (Figure 10) but whereas the model peaks below 900 hPa the AMVs peak much higher at 800 hPa. It is apparent that there is a lack of vertical wind shear in the AMV zonal wind profile for heights between 800-950 hPa (at higher heights the difference is more of an offset or scaling issue). The lack of shear is particularly clear for the HRVIS channel. Profiles against the ECMWF model background also confirm the same issue (K.Lean, Pers.Comms.).

Considering both zonal and meridional wind components, the mean AMV is stronger than the model in easterly and southerly components above 900 hPa and weaker below.

The Met Office inversion height correction scheme [5] has little effect on the heights of AMVs for data in August 2017, but has some impact at other times of the year. For data in December 2016 the inversion correction increases zonal shear in the observations above 770 hPa height (Figure 11), but in this case also has the effect of increasing shear in the collocated background (due to a change in sampling) resulting in little change to the overall bias. Typically only around 5% of MSG HRVIS channel AMVs have heights that are inversion corrected.

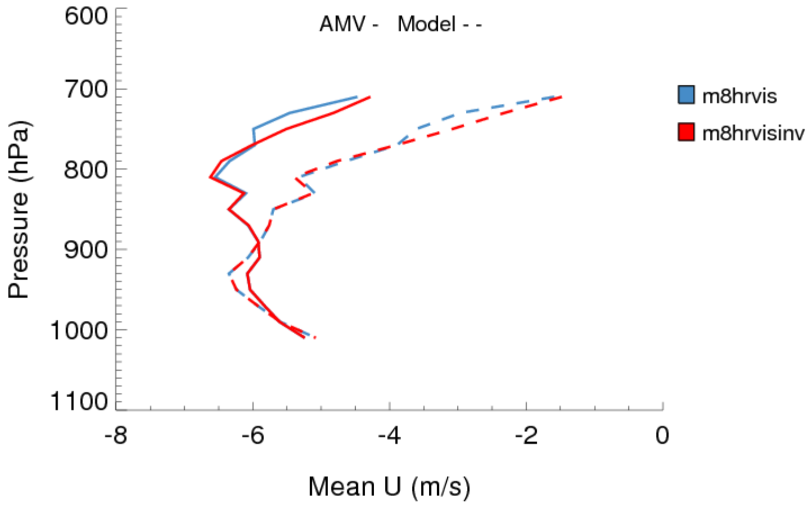


Figure 11: Profiles of mean model (dashed line) and AMV (solid line) zonal/U wind component for HRVIS channel winds. AMVs at the original assigned height are shown in blue and the inversion corrected height in red. Data for December 2016 filtered for QI2>80 and located between latitude 25°S-5°S, longitude 50°E-100°E.

To further investigate the potential lack of shear in the AMVs we can compare against radiosonde (RS) ascents. In the area of interest between 5°S-25°S and 50°E-100°E there are only two stations with profile data in the Met Office archive for August 2017: Cocos Islands (ID=96996, lat. -12.18°, lon. 96.83°) and Saint Denis (ID=61980, lat. -20.90°, lon. 55.53°). Note these stations are separated by 41° longitude, being at either end of the region of interest.

In Figure 12 we compare mean zonal wind profiles for the sonde and the sonde collocated model background, together with the Meteosat-8 AMVs and the AMV collocated model background. AMVs are those located within a 2x2 degree box centred on the RS station location. Differences between the model profiles from the sonde and AMV backgrounds is likely due to different sampling (sonde is vertical column at single location, AMV is mean profile constructed from points within 2x2° box).

The sonde and the sonde-background show good agreement for the Cocos Islands. For Saint Denis station there is some variation in the observed profile that is not captured by the model but still a fair level of agreement. In all cases the two model profiles match better than the AMV and sonde profiles. For the Cocos Islands we see that the AMV profile has a lack of shear and diverges from both the sonde and the model for heights above 800 hPa. For Saint Denis there is less agreement between the two model profiles above 900 hPa height but even less agreement for the sonde and AMV.

Therefore one RS station (Cocos Islands) appears to support the idea that the AMVs show a lack of shear in this region.

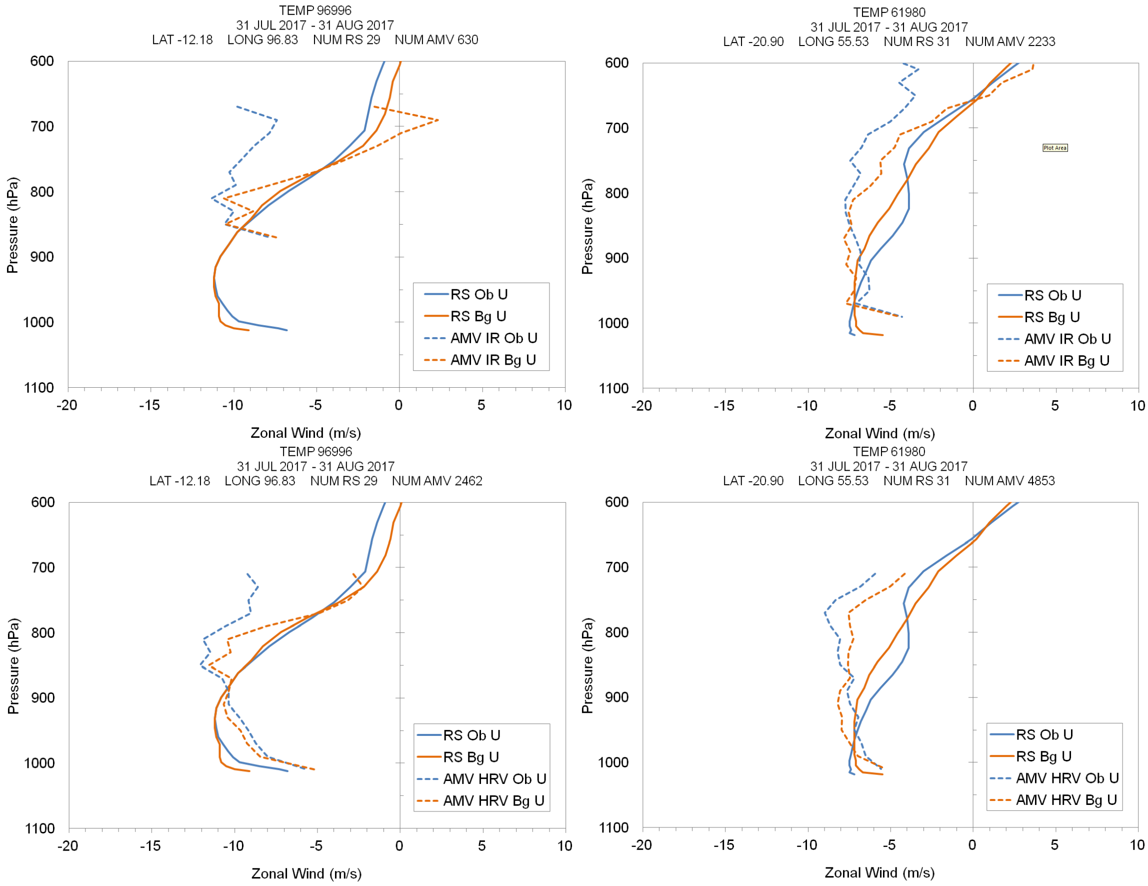


Figure 12: Profiles of mean model background (orange lines) and observed (blue) zonal/U wind component for WMO stations identifiers 96996 (left) and 61980 (right). Data for August 2017. Radiosonde (RS) and RS-background profiles are shown by solid lines, AMV and AMV-background are shown by dashed lines. Meteosat-8 IR10.8 AMVs (top) and high resolution visible (HRV) AMVs (bottom) located in a 2x2 degree box centred on the RS location.

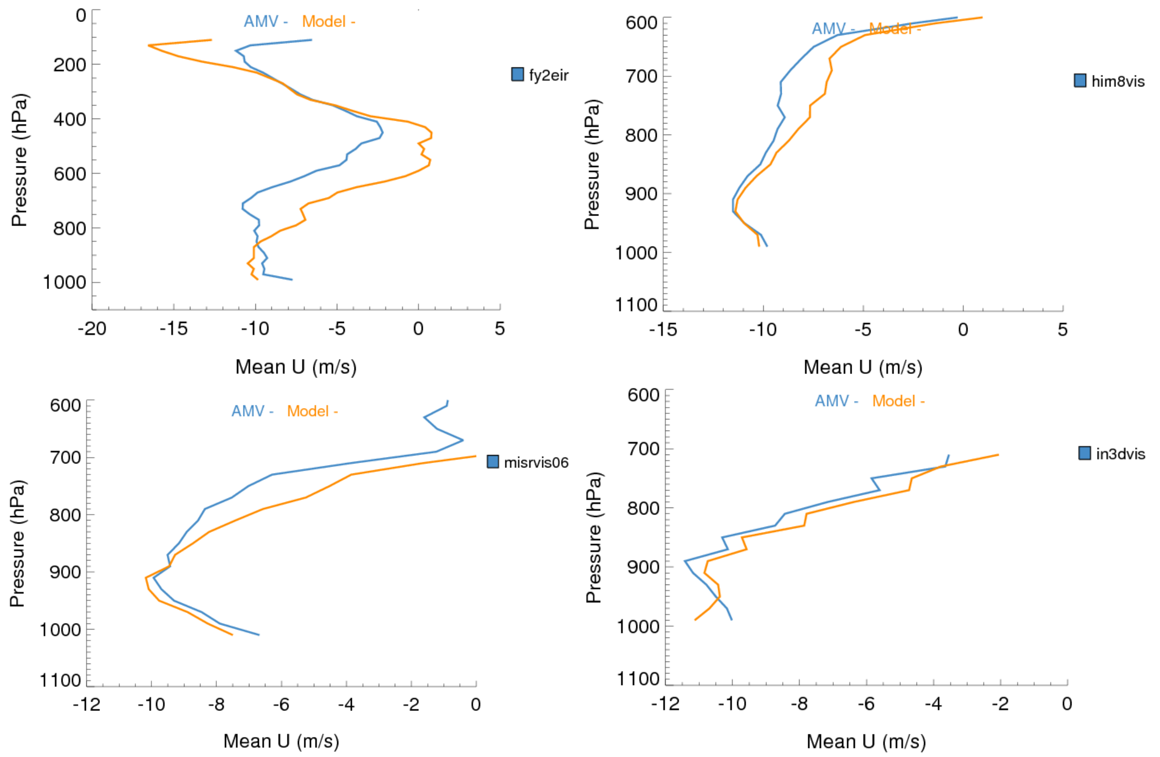


Figure 13: Profiles of mean model and AMV zonal/U wind for FY-2E IR (top left), Himawari-8 visible (top right), MISR (bottom left), and INSAT-3D (bottom right) channels winds. Data for August 2017 filtered for QI2>80 (FY-2E and Himawari) or QI2>60 (MISR and INSAT) and located between latitude 25° S-5° S, longitude 50° E-100° E.

Over the same area of the Indian Ocean, FY-2E AMVs also show a similar lack of shear in the vertical but Himawari, MISR and INSAT-3D match closer to the model profile (Figure 13). Looking at other areas of the tropics (over sea) for the same period, neither GOES-13/15 nor Himawari-8 AMVs show an issue with lack of shear. For Meteosat-10 the IR10.8 channel has less shear than the model at upper levels, whilst the HRVIS channel diverges from the model profile altogether above 900 hPa.

In summary, Meteosat-8 low level winds show a positive speed O-B and high RMSVD over the southern tropics of the Indian Ocean. Model and radiosonde profiles provide evidence for a lack of shear in the AMVs which leads to a positive speed bias above 900 hPa height. Best-fit pressure indicates this could be due to AMVs being assigned too high. Experiments at the Met Office and ECMWF have both shown that the assimilation of Meteosat-8 increases the westerly component of the winds at 850 hPa in the Indian Ocean and leads to an apparent increase in forecast RMS error. It could be that both models share the same deficiencies and more work is needed to understand whether these increments are the result of a model bias or whether the error is in the AMV heights.

4 Mid Level Updates

Features 2.8 and 2.9: Positive Bias in the Tropics, Negative Bias in the Extra-Tropics

Feature Background:

At mid-level, AMV products generally have an O-B speed bias that is positive in the tropics and negative in the extra-tropics.

Update:

MSG

The large O-B speed biases seen in the MSG AMVs assigned to CLA heights are somewhat reduced in many areas when assigning to the OCA heights (Figure 14).

GOES

In the nested tracking test data, the extra-tropical negative O-B speed bias is substantially reduced (Figure 15).

Others

The mid-level infra-red AMVs from CMA, JMA, KMA and IMD that are displayed on the NWP SAF website appear not to have undergone derivation updates since AR7 and their O-Bs show no long-term trend.

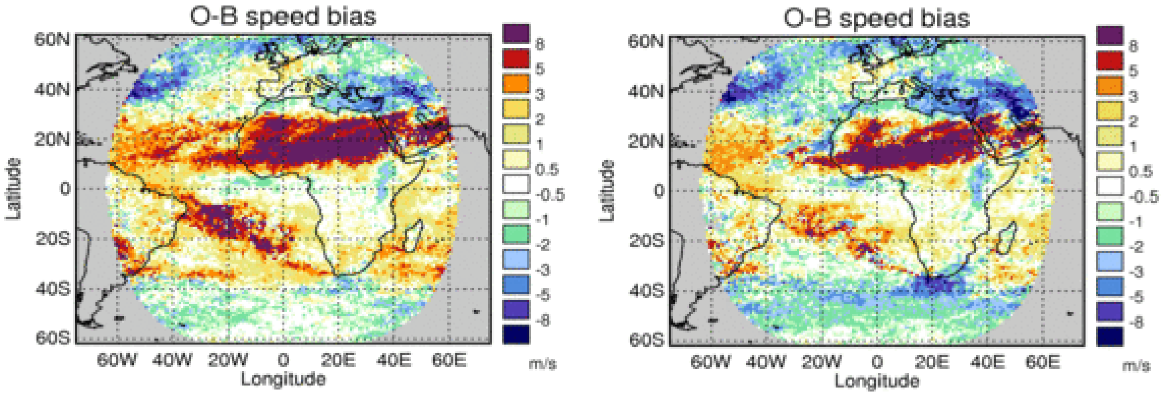


Figure 14: O-B speed bias for Meteosat-10 infra-red AMVs, December 2016, 400-700 hPa. Left: CLA, right: OCA.

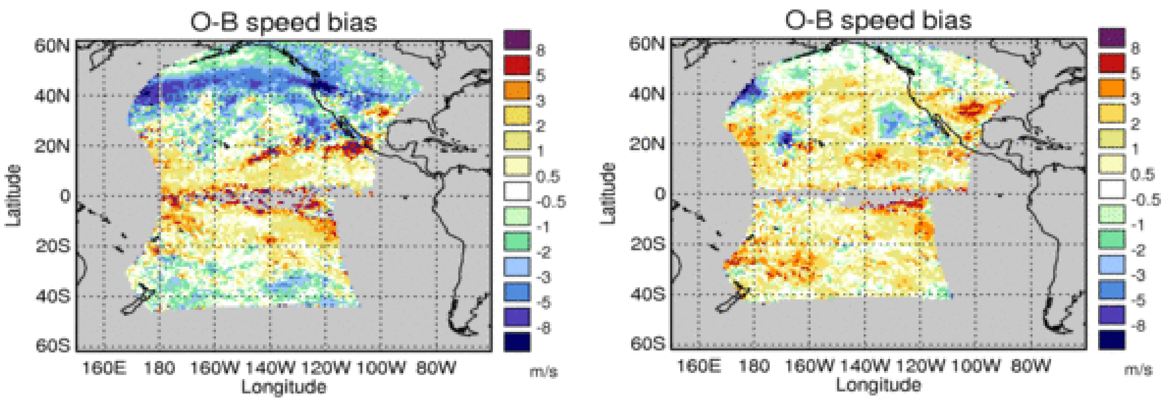


Figure 15: O-B speed bias for GOES-15 infra-red AMVs, December 2016, 400-700 hPa. Left: un-edited heritage AMVs, right: nested tracking AMVs.

5 High Level Updates

Feature 2.10 Jet Region Negative Speed Bias

Feature Background:

Most AMV products show a negative O-B speed bias at high level in the extratropics which has a seasonal variation in intensity linked to the position of the jet streams. Previous analyses have pointed to problems tracking smooth cloud features, and height assignment problems where wind shear is high, as possible causes.

Update:

GOES

The nested tracking algorithm, designed for deriving AMVs using the next-generation GOES-16 satellite, aims to reduce the slow bias common with high level AMVs. A cluster-based approach is used, deriving a field of local vectors from multiple small targets, identifying the dominant cloud motion, and assigning a height using the cloud-top heights of vectors from the dominant motion. It is thought that the slow bias in the heritage algorithm, and other AMV products, is partly due to averaging the motions of the whole scene [3].

Test data using the new nested tracking algorithm on GOES 13 and 15 imagery was made available, allowing a like-for-like comparison of its performance against the heritage algorithm. The operational heritage product uses an 'auto-editor' to change the AMV speeds and heights, making them more closely match NWP wind fields (AR3). Since this step is not included in the nested tracking algorithm, the comparison shown here is against the 'un-edited' heritage winds.

Compared to the unedited heritage AMVs, the nested tracking data is generally improved at high level. Looking at the high level AMVs for March 2017 (Figure 16), a clear reduction can be seen in the northern hemisphere slow bias. The O-B spread (mean vector difference) is also greatly reduced. A similar difference was seen for other months for which the nested tracking test data was available.

Looking at the Hovmoeller plots for the North Atlantic (Figure 17), again for March 2017, we can see

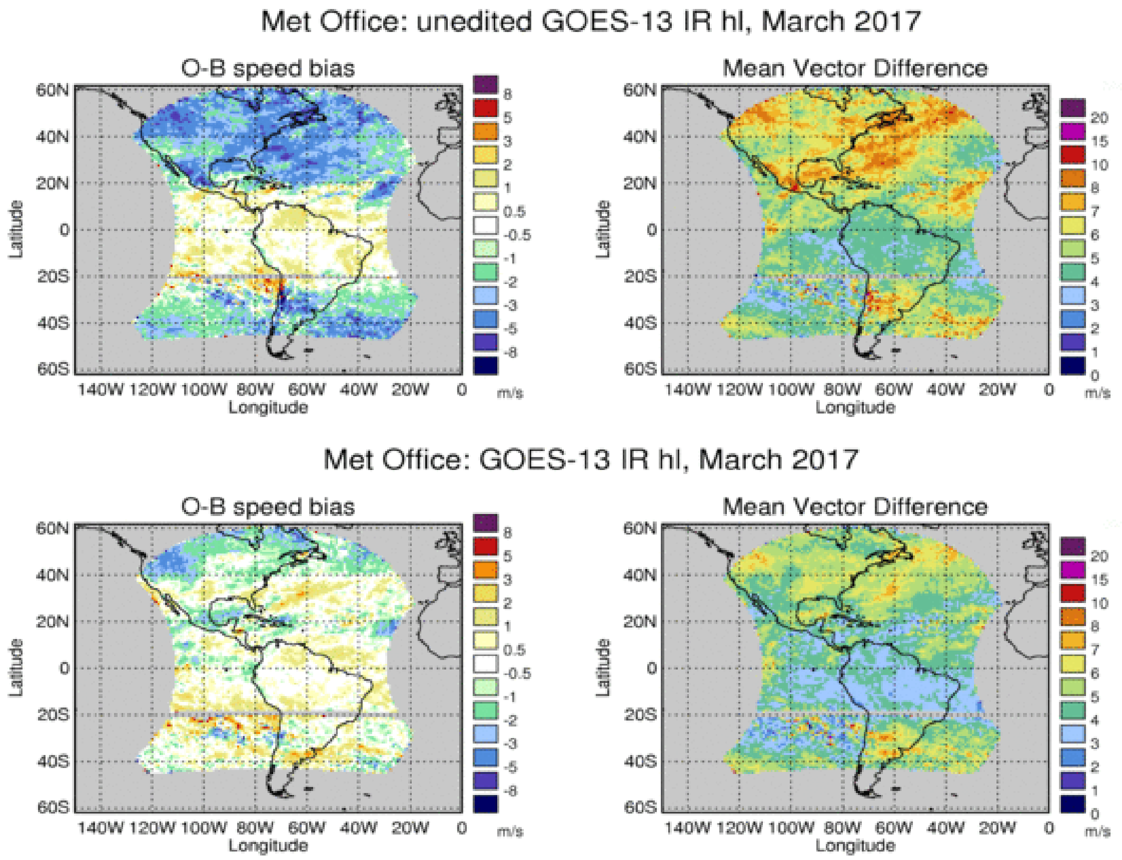


Figure 16: O-B speed bias and mean vector difference for un-edited heritage AMVs (top row) and nested tracking AMVs (bottom row). AMVs above 400 hPa.

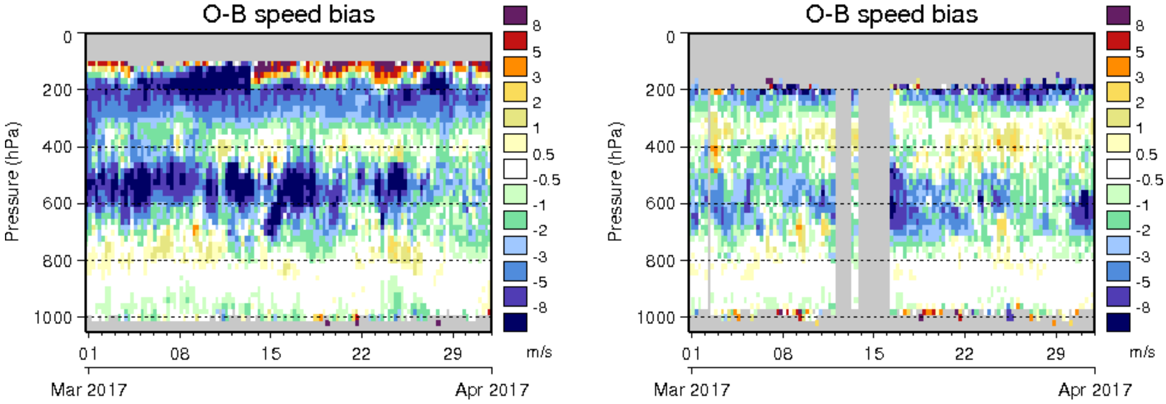


Figure 17: Hovmoeller plots for GOES-13 infra-red AMVs, March 2017, northward of 20°N. Left: un-edited heritage AMVs, right: nested tracking AMVs.

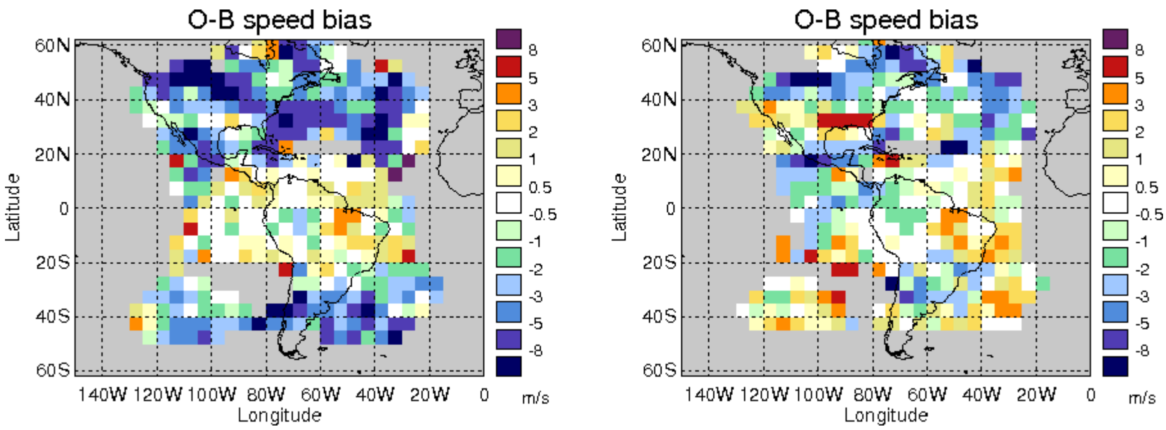


Figure 18: Map of GOES-13 infra-red O-B speed bias for unedited heritage (left) and nested tracking (right). Filtered for heights above 400 hPa, 9th March 2017.

a period from around the 8th-12th March when the slow bias is much more severe in the un-edited heritage AMVs than the nested tracking AMVs. Within this date range, a large reduction in O-B speed bias can be seen over the North Atlantic on the 9th March (Figure 18).

The O-B speed differences of some of these AMVs can be seen in Figure 19. Although some of the nested tracking AMVs are in different places due to the different tracking scheme, it can be seen that in regions of severe slow bias in the un-edited heritage data (over 10 m/s), the nested tracking AMVs generally show a reduced slow bias, though in a few cases a fast bias appears.

Figure 20 shows that the reduced biases in the nested tracking AMVs tend to coincide with them having lower height assignments than the unedited heritage AMVs. Figure 21 shows that in this case the AMV speed and direction are in good agreement and it is the height assignments that are different. This suggests that rather than the new tracking approach, it is the new height assignment scheme that causes the improvement in this case. Improvements to AMV quality in this area have

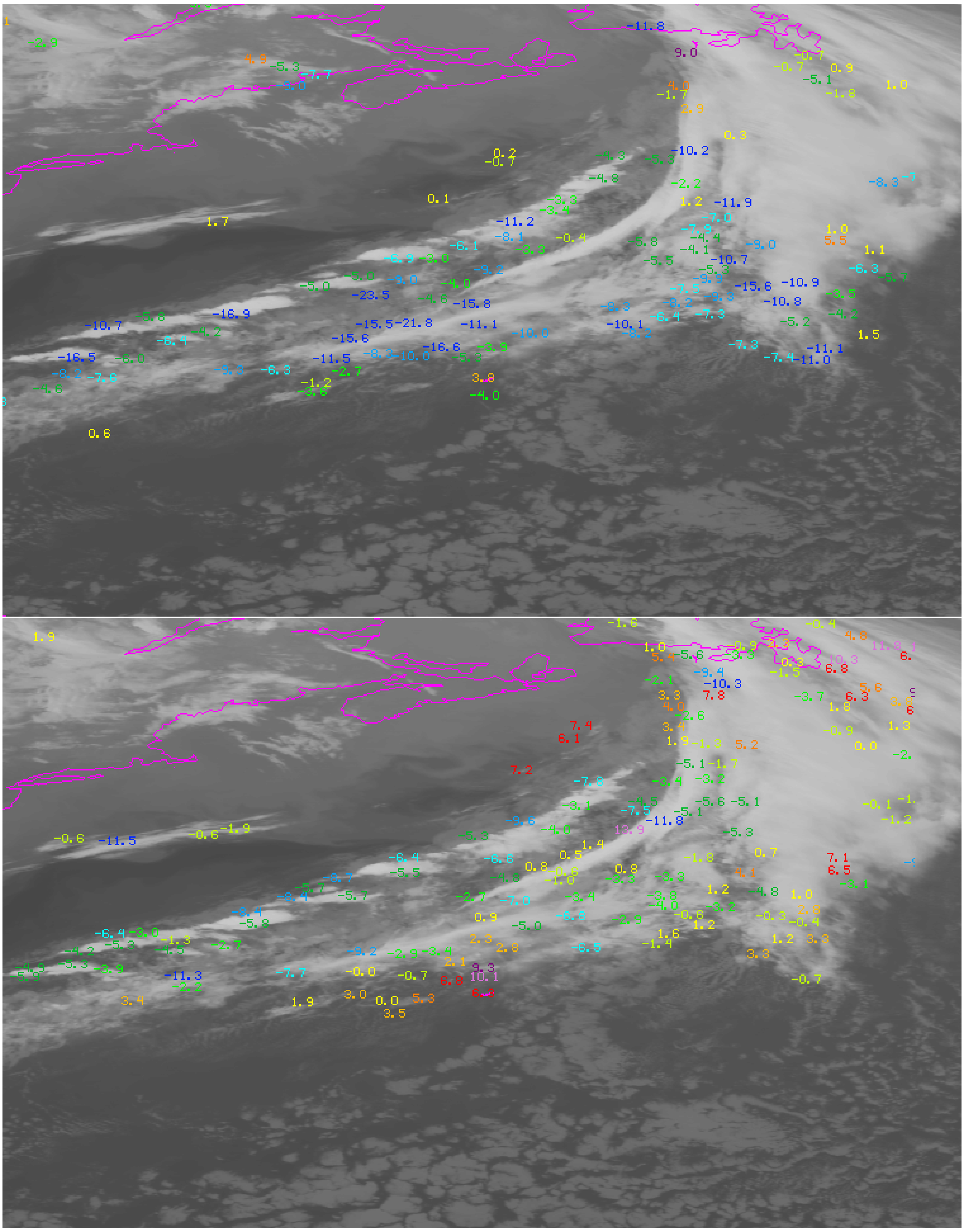


Figure 19: O-B speed differences (m/s) of unedited heritage (top) and nested tracking (bottom) AMVs. Image shown is GOES-13 IR channel, at 0545 on 09/03/2017.

the potential to improve NWP forecasts as previous AMV assimilation experiments have shown a slowing of the model wind fields in jet regions.

Feature 2.13. Tropics Positive Speed Bias

Feature Background:

A positive bias is prevalent in most satellite-channel combinations in the tropics at high level. In the past this has been partially explained by difficulties deriving winds from linear tracers, and the sensitivity of height assignment in the presence of wind shear.

Update: **MSG**

Operationally, the heights of MSG AMVs are assigned by the CLA scheme. Starting in November 2016, MSG winds with alternative height assignments provided by the OCA scheme have been made available. For AMVs, the main advantage of the OCA scheme is that it identifies multi-layer cloud situations and assigns the AMV to the top layer. Meanwhile the CLA assigned height is often an average of the cloud layers in these cases [1].

At high level, the O-B speed bias is reduced in the tropics when using the OCA height assignments (Figure 22). This was also the case in other months and in the water vapour 7.3 micron channel. Figure 23 shows that while there is consistently a reduction in O-B speed bias in December 2016, there are several periods of a few days when the positive O-B bias in the CLA data is particularly large. Focussing on the period from 24th-27th December, Figure 24 shows much of this positive bias is in the Southern Atlantic, near Brazil.

Image sequences for the evening of 26th December 2016 show clouds at high level moving to the south-east, and below them a lower cloud layer moves to the south-west. In Figure 25 some large O-B biases of over 10 m/s can be seen in the CLA data. Many of these are greatly reduced in the OCA data.

The only difference between the two datasets is the height assignment. From Figure 26 we can see that many of the AMVs that showed large positive biases in Figure 25 were assigned heights in the range 250-350 hPa. OCA places many AMVs higher, within 200-250 hPa. The model profiles in Figure 27, which were typical for the AMVs in Figures 25 and 26, show a two-layer situation. The

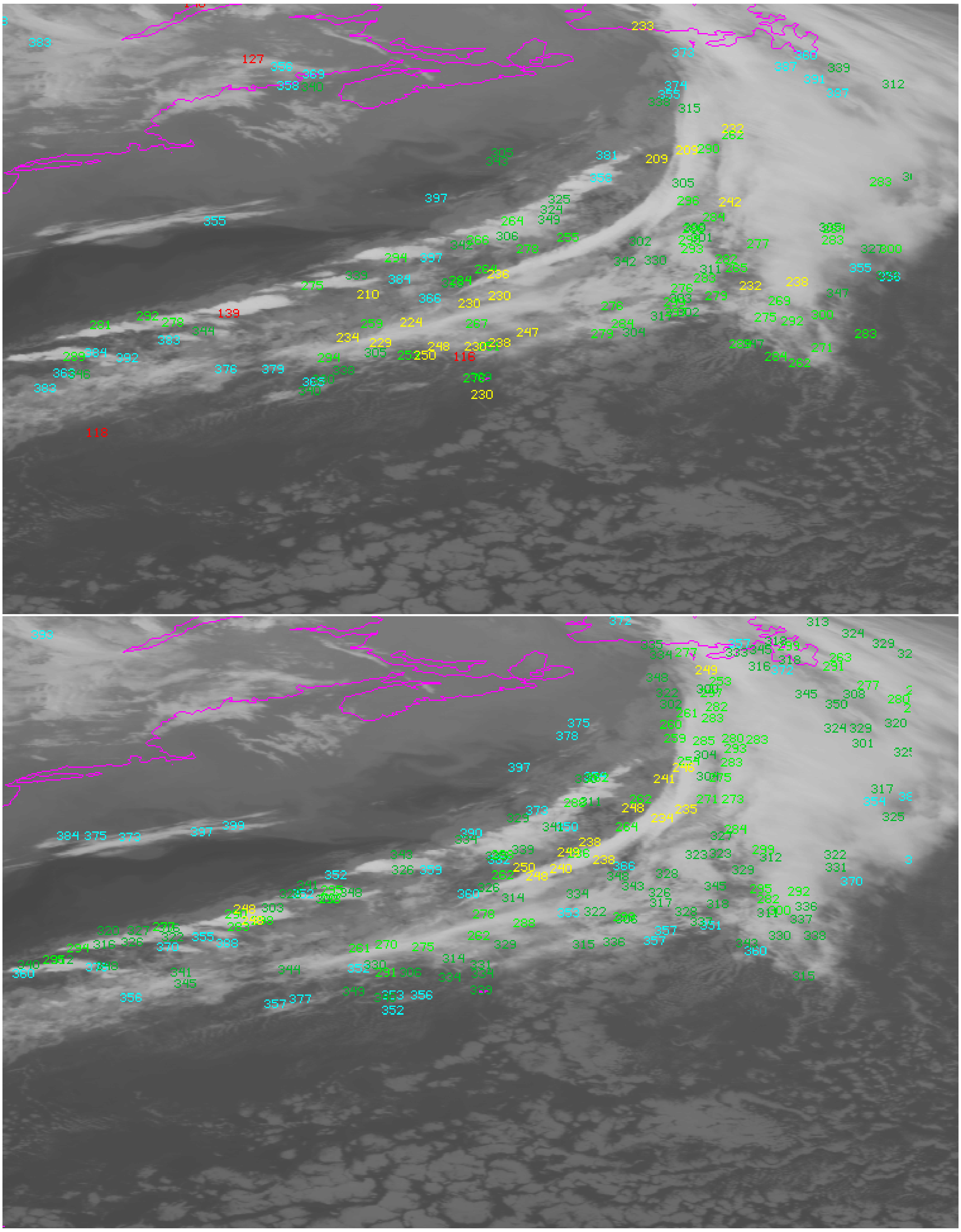


Figure 20: AMV pressures (hPa) of unedited heritage (top) and nested tracking (bottom) AMVs. Image shown is GOES-13 IR channel, at 0545 on 09/03/2017.

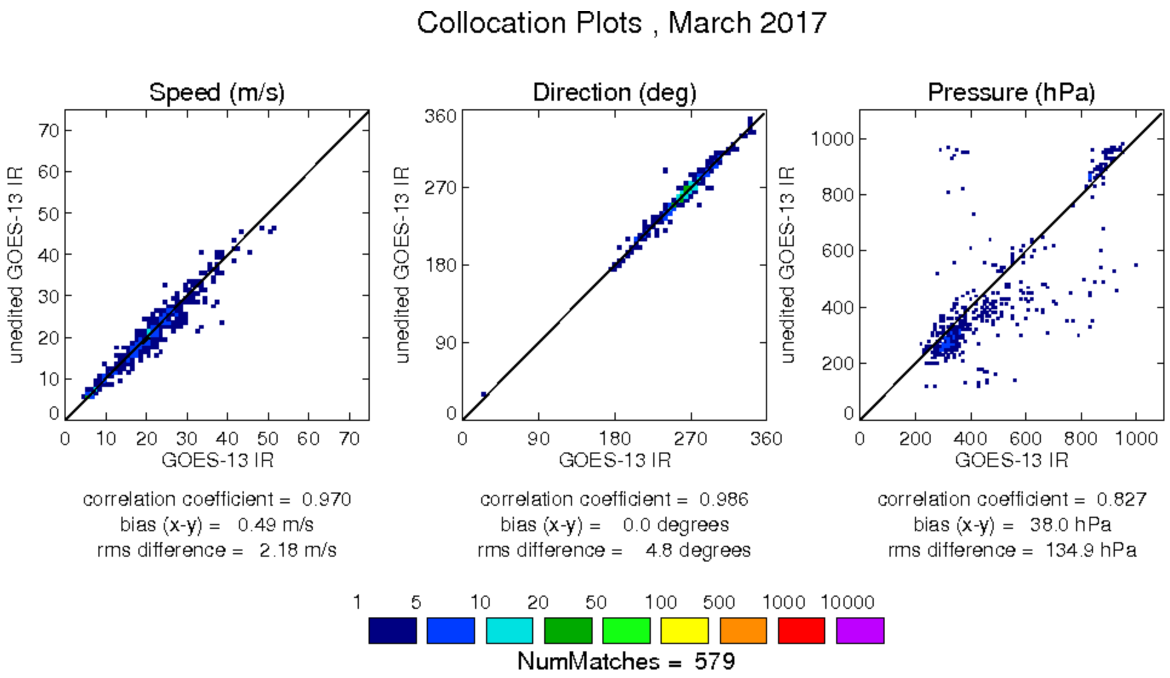


Figure 21: Speed, direction and pressure histograms for unedited heritage vs nested tracking GOES-13 infra-red AMVs. 9/3/17, 06Z cycle, co-located within 10km and 10 minutes, within a box 30-50° N, 50-75° W.

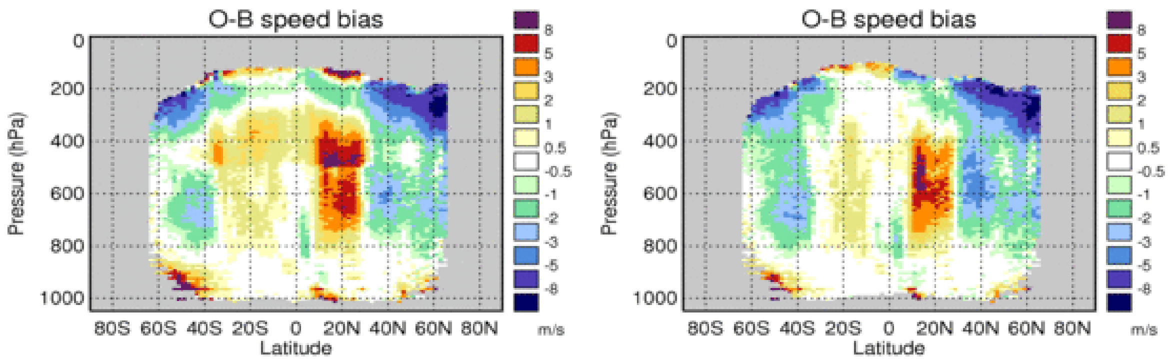


Figure 22: Zonal plot of O-B speed bias for Meteosat-10 infra-red AMVs, December 2016. Left: CLA, right: OCA.

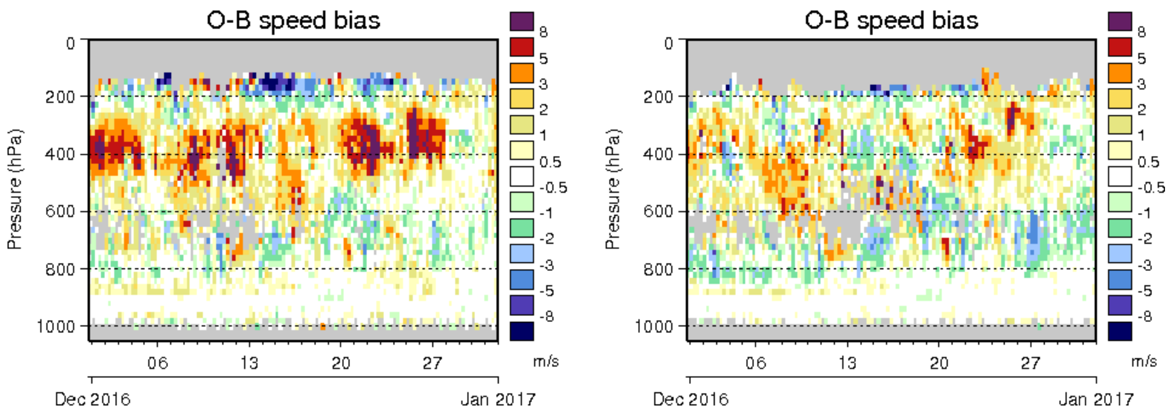


Figure 23: Hovmoeller plot of O-B speed bias for Meteosat-10 infra-red AMVs, December 2016, South Atlantic. Left: CLA, right: OCA.

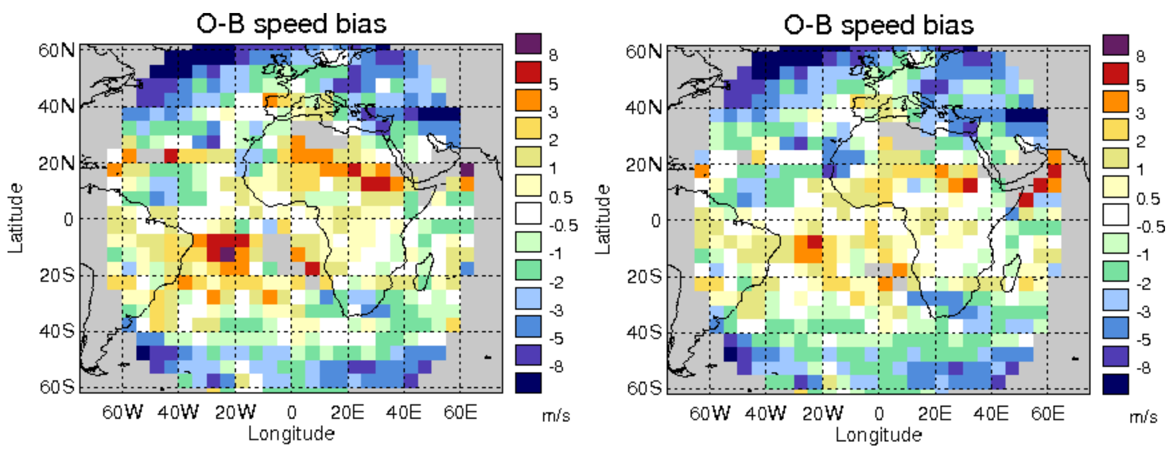


Figure 24: Map of O-B speed bias for Meteosat-10 infra-red AMVs - left: CLA, right: OCA. Filtered for heights above 400 hPa in the date range 24-27th December 2016.

OCA scheme, which can detect multiple cloud layers and assigns AMVs to the upper layer in these cases, places the AMV much closer to its model best-fit pressure[1] than the CLA scheme for the AMVs in this case study.

This case study shows the benefit of the OCA height assignments. While the CLA height assignment can handle situations with semi-transparent or sub-pixel cloud, in multi-layer cloud situations the information from the lower layer can lower the height assignment when it is the higher layer being tracked. The OCA scheme detects the two cloud layers and assigns a more appropriate height.

Feature 2.14. High-Troposphere Positive Bias

Feature Background:

A positive O-B speed bias is often seen for MSG and un-edited heritage GOES AMVs with height assignments at around 150 hPa. In the un-edited GOES AMVs the bias is always present; in the MSG AMVs the bias is seasonal, mostly appearing in the winter hemisphere.

Update:

GOES

The un-edited heritage GOES infra-red AMVs consistently had a fast bias in the high-troposphere. This is removed in the nested tracking test data - Figure 28 is typical in this regard of all the months for which the nested tracking test data was available. The nested tracking data no longer has AMVs at the heights where this positive bias was seen in the un-edited heritage AMVs.

Figure 29 shows that in cases where there is an AMV above 180 hPa in the unedited heritage product, the co-located AMV in the nested tracking data is lower by up to 250 hPa, with some assigned down at low level, below 700 hPa.

MSG

The feature is less severe in the MSG product than the unedited GOES product. Using the OCA heights reduced the bias in the winter hemisphere - Figure 30 shows an example.

[1] Height that minimises vector difference between AMV and model wind.

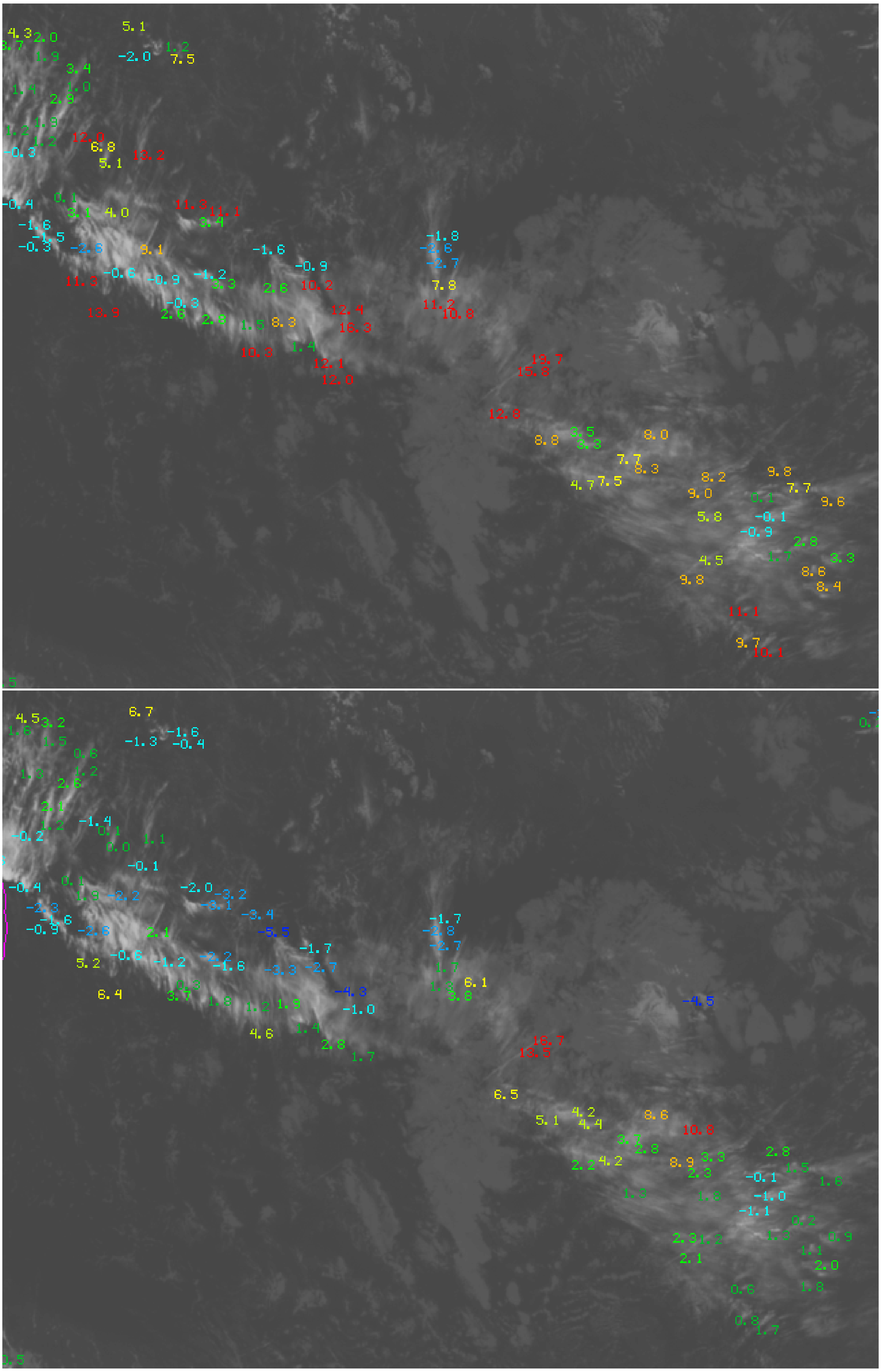


Figure 25: O-B speed differences of CLA (top) and OCA (bottom) AMVs. Image shown is Meteosat-10 IR 10.8 channel, at 1815 on 26/12/2016.

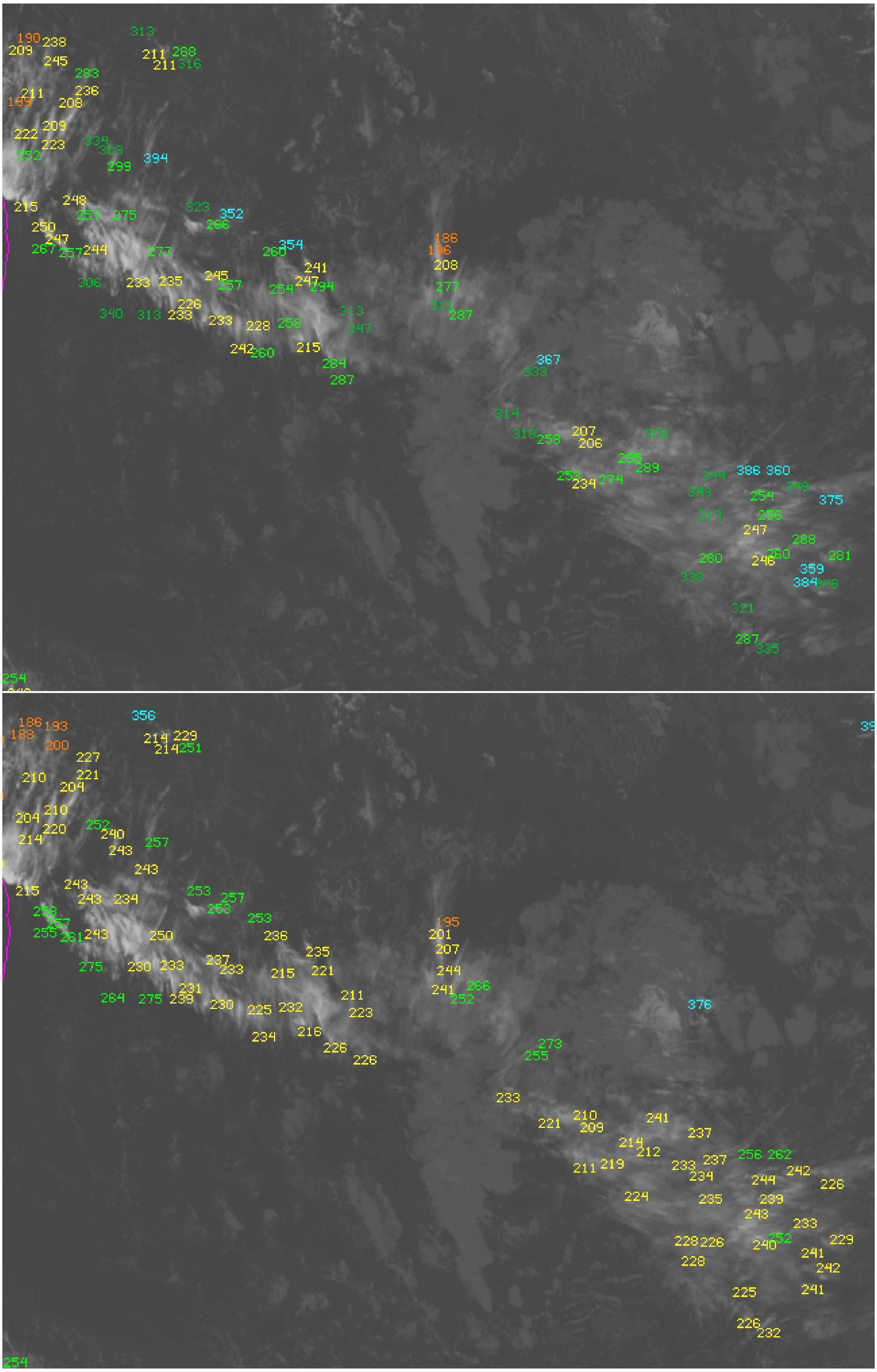


Figure 26: AMV pressures of CLA (top) and OCA (bottom) AMVs. Image shown is Meteosat-10 IR 10.8 channel, at 1815 on 26/12/2016.

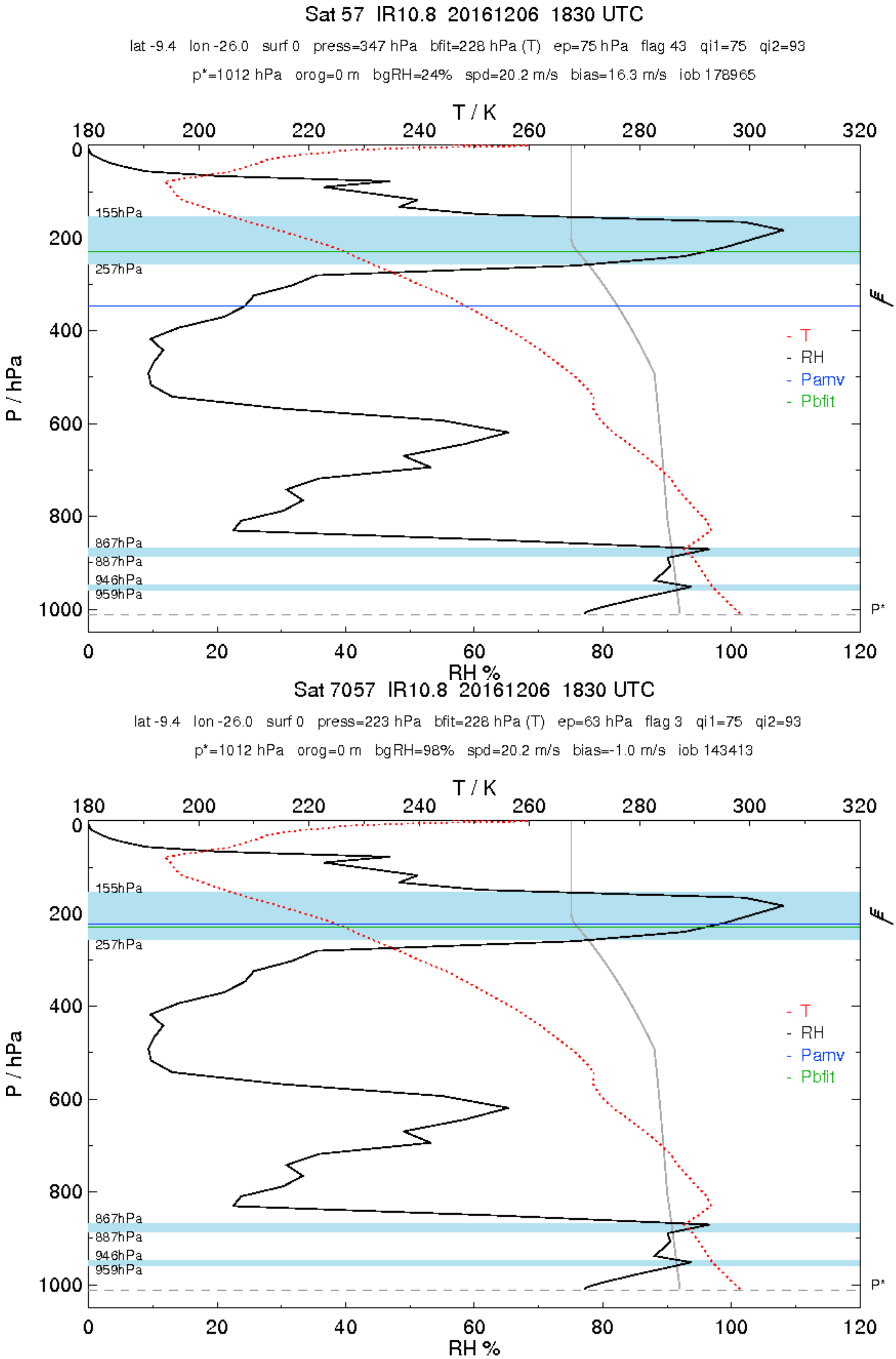


Figure 27: Met Office global model humidity profiles at AMV locations. The top plot shows the AMV's CLA height assignment (blue) and the lower plot shows the OCA height assignment for the same AMV. The model best-fit pressure at this location is shown by the green line. Moist layers (definition from Zhang et al 2010 [2]) are defined by the blue-shaded regions.

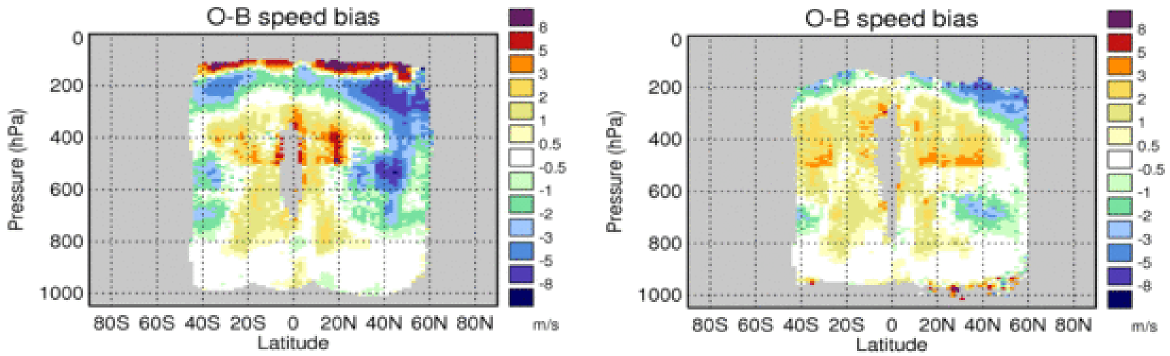


Figure 28: Zonal plot of O-B speed bias for GOES-15 infra-red AMVs, December 2016. Left: unedited heritage, right: nested tracking.

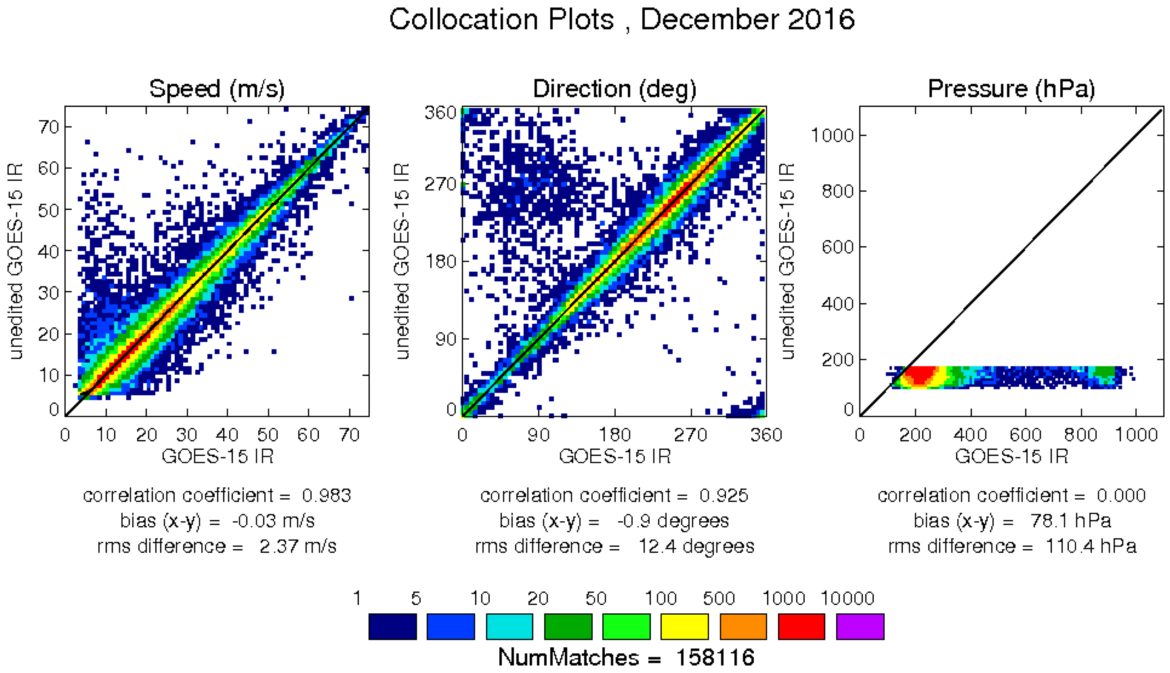


Figure 29: Speed, direction and pressure histograms for unedited heritage vs nested tracking GOES-15 infra-red AMVs. December 2016, co-located within 10km and 10 minutes, unedited heritage AMVs only shown above 180 hPa.

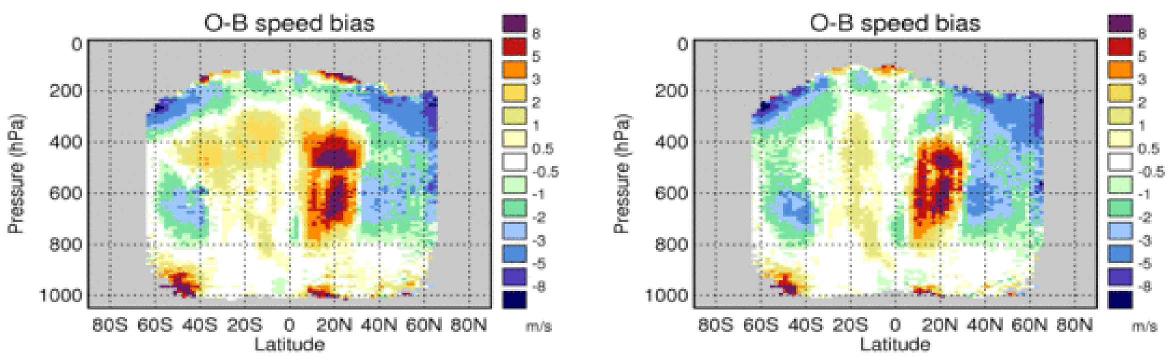


Figure 30: Zonal plot of O-B speed bias for Meteosat-10 infra-red AMVs, January 2017. Left: CLA, right: OCA.

6 Polar Wind Updates

Feature 7.4. LeoGeo Coverage Gaps at Particular Longitudes

Update:

Gaps remain in the spatial coverage of the LeoGeo mixed-satellite AMV product which do not correspond to gaps in coverage between geostationary imagers. Figure 31 shows that these longitudes are approximately 90°W, and 90°E (both hemispheres), and 170°W, 105°W, 35°W (northern hemisphere only).

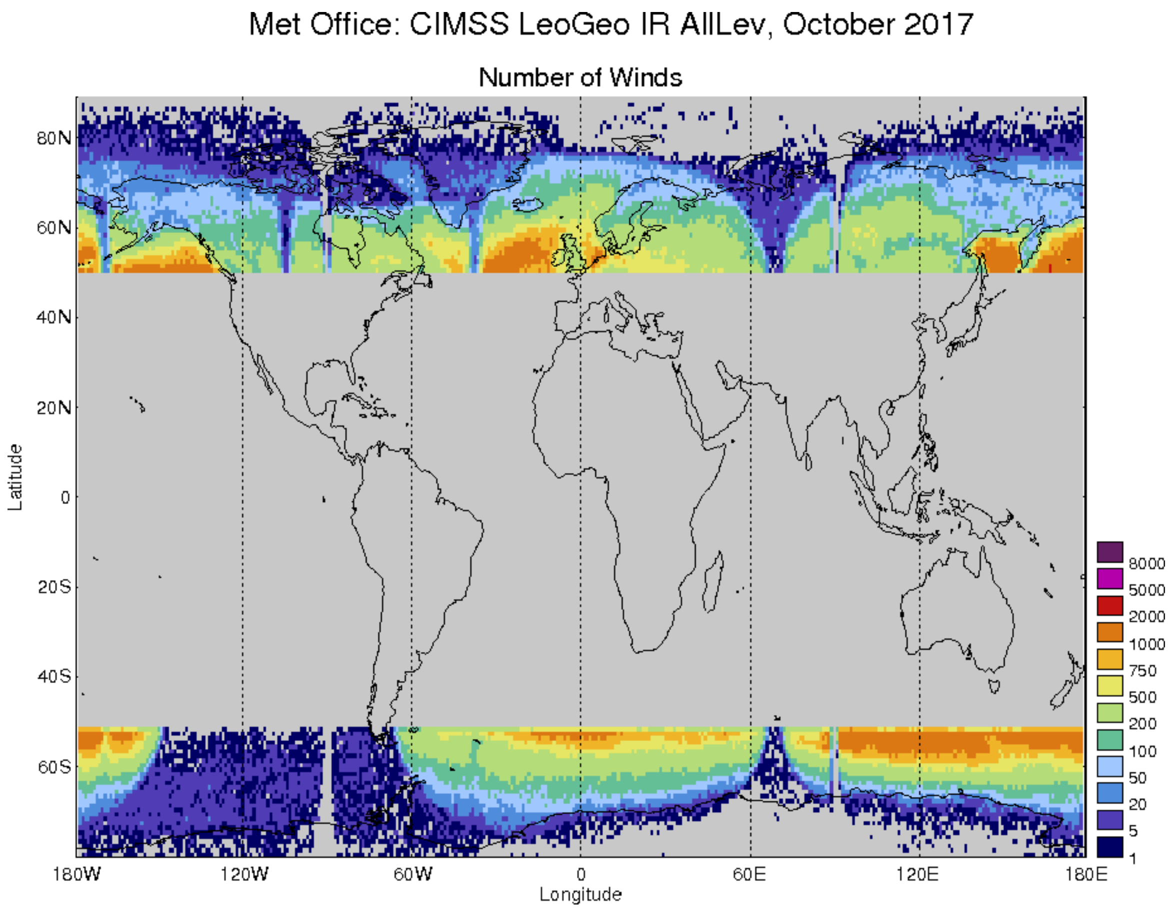


Figure 31: spatial distribution of LeoGeo AMVs, October 2017, all heights.

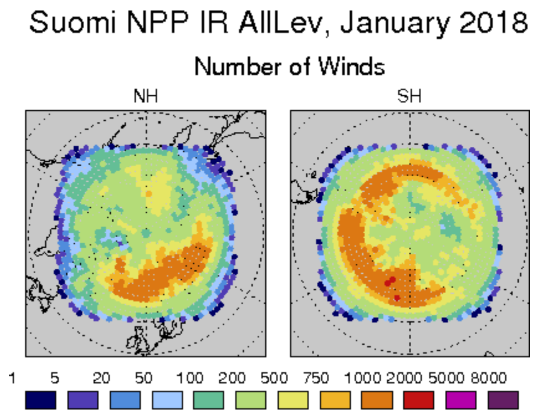
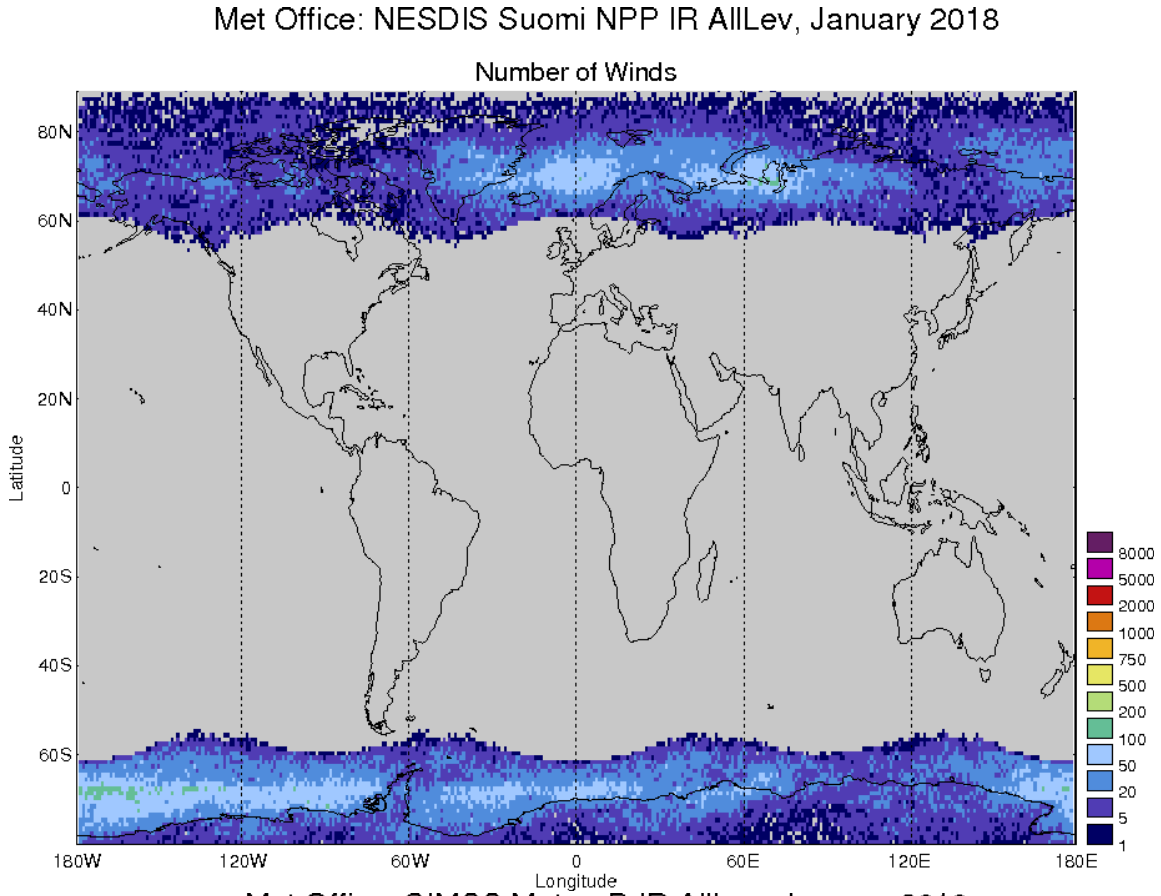


Figure 32: Spatial distribution of NESDIS NPP AMVs, January 2018, all heights.

Feature 7.6. Square-Shaped Spatial Distribution of NPP Winds

Update:

This feature remains unchanged from AR7. The square distribution (Figures 32 and 33) is also seen to a lesser extent (due to narrower swath width) in other US polar AMV products such as AVHRR winds, for example Metop-B in Figure 33. The feature is known to be caused by the limited size of a box used during the U.S. polar winds algorithm.



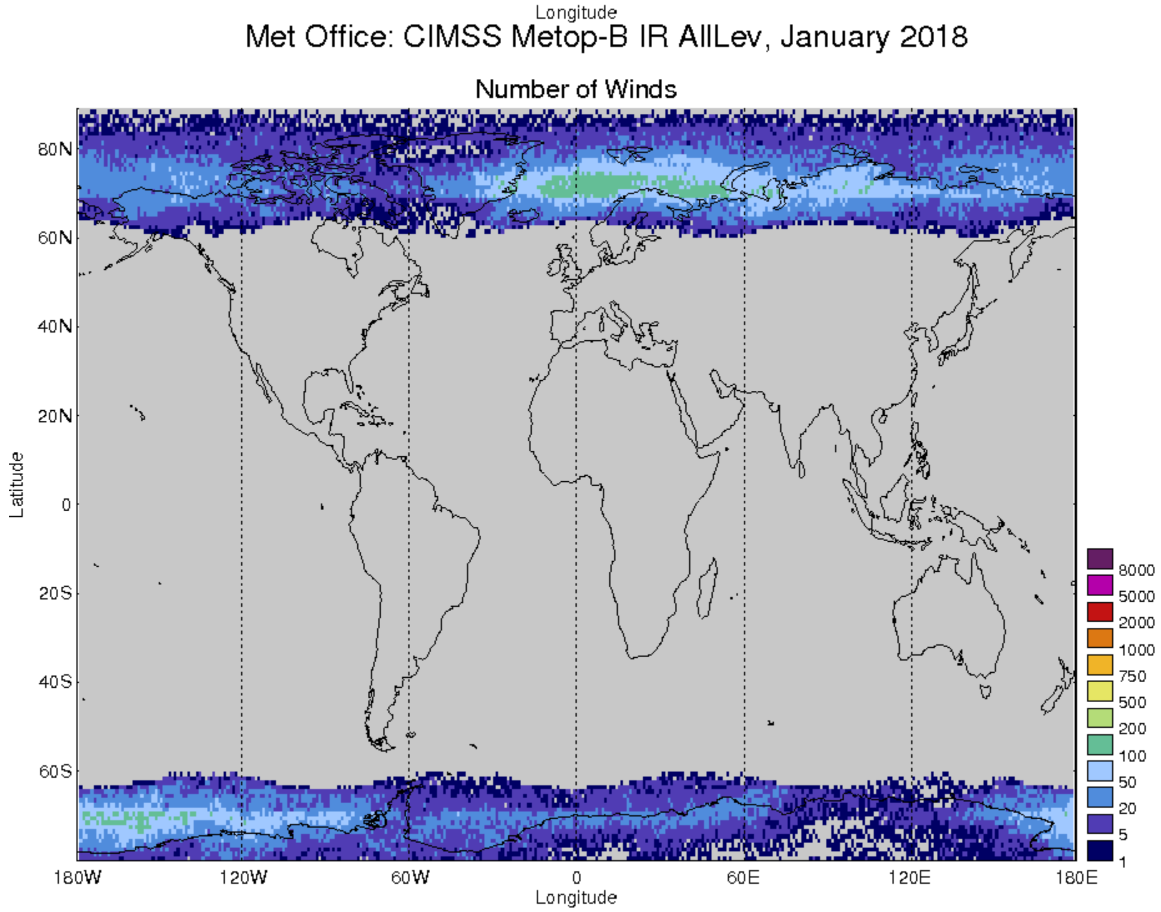


Figure 33: Spatial distribution of NESDIS NPP AMVs (top) and CIMSS Metop-B AMVs (bottom), January 2018, all heights.

7 Summary

The NWP SAF AMV monitoring can be a useful tool for investigating the causes of errors in AMV products. Since AR7 Meteosat-8 has replaced Meteosat-7 in the monitoring, with GOES-16 and Meteosat-11 soon to be added. Test data has also been made available using nested tracking for GOES AMVs, and OCA height assignments for MSG AMVs. Following the switch from MTSAT-2 to Himawari-8 which was covered extensively in AR7, no significant changes have been seen since then in the Himawari-8 O-Bs.

Overall MSG O-Bs are improved when using the OCA instead of CLA heights. At high-level, the case study in the Mid-Atlantic showed the benefit of OCA's multi-layer cloud detection. In that case OCA produced a height assignment much closer to model best-fit pressure which in turn led to big reductions in O-B speed bias.

GOES-13 and 15 AMVs derived with the nested tracking algorithm show improved O-Bs compared to the unedited heritage product, though O-Bs were larger than those of the auto-edited heritage product. In the case study looked at over the North Atlantic, an O-B slow bias was greatly reduced in the nested tracking data compared to the unedited heritage AMVs. In this case results suggest the reduced bias is primarily due to the new height assignment scheme than the new tracking scheme.

The large bias for MSG observed over North Africa has been further investigated. The diurnal component of the signal seen in the IR channel is believed to be due to the lack of detection of thin clouds in the hours surrounding local midday. The bias itself is caused by large height assignment errors. In a case study, CLA and OCA heights for a problematic area of cloud were found to be much lower in height compared to Met Office cloud products. AMV-lidar matchups are rather limited over North Africa but also indicate the AMVs are assigned heights that are too low.

Meteosat-8 low level winds show a positive speed O-B bias and high RMSVD over the southern tropics of the Indian Ocean. Model and radiosonde profiles provide evidence for a lack of shear in the AMVs which leads to a positive speed bias above 900 hPa height. Best-fit pressure indicates this could be due to AMVs being assigned too high. FY-2E data also show a similar problem in this area but other AMV products seem unaffected.

References

[1] Optimal Cloud Analysis: Product Guide, EUM/TSS/MAN/14/770106, 2016

[2] Zhang, J., H. Chen, Z. Li, X. Fan, L. Peng, Y. Yu, Cribb, M., Analysis of cloud layer structure in Shouxian, China using RS92 radiosonde aided by 95 GHz cloud radar, 2010, J. Geophys. Res., 115

[3] Bresky, W.C., Daniels, J.M., Bailey, A.A., Wanzong, S.T., New Methods toward Minimizing the Slow Speed Bias Associated with Atmospheric Motion Vectors, 2012, Journal of Applied Meteorology and Climatology, Volume 51, pp 2137-2151

[4] Folger, K., and M. Weissmann, Height Correction of Atmospheric Motion Vectors Using Satellite Lidar Observations from CALIPSO, 2014, J. Appl. Meteor. Climatol., 53, 1809-1819, https://doi.org/10.1175/JAMC-D-13-0337.1

[5] Cotton, J., Forsythe, M., and F. Warrick, Towards improved height assignment and quality control of AMVs in Met Office NWP, Proceedings for the 13th International Winds Workshop, Monterey, California, USA, 27 June - 1 July 2016.