IMPROVEMENTS TO EUMETSAT AMVS

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Abstract

At IWW9 Borde and Oyama (2008) showed the importance of the pixel selection process applied to isolate the pixels used to set the AMV altitude. They described a new method that keeps a closer link between the tracking and the height assignment step in the AMV extraction algorithm proposing to use the individual pixel contribution to the cross correlation coefficient, CCij, to select the pixels that contribute the most to the tracking, which then offers a suitable subset of image pixels for the height assignment. Since IWW9 this method has been tested on a parallel chain at EUMETSAT for two separated periods of one month.

This paper summarizes the main results of these operational tests, which show large improvements of the new scheme on the AMV product for both the Vis0.8, HRVis and IR10.8 channels, increasing the total amount of AMVs (QI>80) and also the amount of good AMV/radiosonde collocations. Speed biases against radiosonde observations are generally a bit larger, especially the known slow biase observed at high levels for IR10.8 AMVs.

INTRODUCTION

At EUMETSAT, AMVs are derived e.g. from tracking clouds in the 10.8 µm IR channel of Meteosat, using a target box size of 24x24 pixels (72x72 km^2 at the sub-satellite point). Various types of clouds can be detected in such a target box, potentially moving at different speeds and altitudes. One of the critical issues is then to select the pixels within in the target box that should be used for the HA calculation. The EUMETSAT cross correlation scheme used for tracking the clouds is mainly based on the maximum contrast criterion, which intrinsically tends to favour the coldest cloudy pixels in the infrared channels. The EUMETSAT height assignment scheme uses a sub-group of the cloudy pixels for the height assignment, considering the coldest peak of the 1-D histogram of cloud top pressures calculated on a pixel basis in the target box. However, this set of pixels selected does not necessarily always correspond to those that mostly contribute to the tracking.

At IWW9 Borde and Oyama (2008) showed the importance of the pixel selection process applied to isolate the pixels used to set the AMV altitude. They described a new method that keeps a closer link between the tracking and the height assignment (HA) step in the AMV extraction algorithm proposing to use the Individual pixel contribution to the cross correlation coefficient, CCij, defined by Büche et al. (2006) to select the pixels that contribute the most to the tracking, which then offers a suitable subset of image pixels for the height assignment. Since IWW9 this method has been tested on a parallel chain at EUMETSAT for two separated periods of one month. This paper summarizes the main results of these operational tests.

Description of Validation Environment

Three different configurations have been tested operationally:

1) the current OPE algorithm (referred as OPE);

2) the current OPE algorithm without image enhancement (referred as OPE_noIE);

3) the new scheme that uses the CCij information to set the AMV height (referred as New).

The operational AMV height assignment is using the pressure from the CLA pixel height assignment (CLA-CTH) as input to the dynamic clustering, the operational CLA pressure is dominated by the EBBT height method for low levels and a water vapour slicing method for high/medium levels. If the dynamic clustering is returning more than one cloud cluster the one with the coldest average EBBT temperature is selected, the AMV height is then recalculated within the AMV process using the EBBT method for low levels as before but a CO2 height method for high/medium level clusters.

The new AMV height method (CCC-method) is directly using the pixel CLA-CTH for the AMV height assignment.

Two periods have been studied, the first one from 24 December 2008 00:00 UTC to 21 January 2009 00:00 UTC, and the second one from 22 January 2009 00:00 UTC to 18 February 2009 00:00 UTC. During the first period all the configurations used the CLA-CTH calculated operationally at EUMETSAT. During the second period another CLA-CTH parameter has been calculated using CO2 slicing method, and used to feed the tested configurations (OPE_noIE and New).

Table 1 summarizes the main differences of these configuration tests.

Hence, the pure impact of the new pixel selection scheme can be seen by comparing the New version with OPE_noIE. This has the advantage that the effects of the Image Enhancement are eliminated, see section 2.3 below.

Table1: Configuration tests

Test	Image Enhancement	Pixel selection scheme	CLA-CTH Parameter	
			Period 1	Period 2
OPE	On	Current	Current OPE	Current OPE
OPE_noIE	Off	Current	Current OPE	CO2 slicing
New	Off	New	Current OPE	CO2 slicing

PRODUCT VALIDATION

Technical performances.

Table2 shows the relative increase of AMVs monitored using the new scheme comparing to the current OPE product and AMVs extracted on OPE_noIE. Differences between New and OPE may come from the tracking (impact of image enhancement) or HA steps. Differences between New and OPE_noIE come only from HA because the tracking is similar for both the two schemes.

The current operational scheme sometimes fails technically to retrieve a pressure for each AMV. Various reasons can lead to such failure, like having not enough contrast within the target box, or no intersection point with the theoretical RTM curve…Etc. The new scheme does not fail to set a pressure to all AMVs extracted by the algorithm, and then it increases the total amount of AMVs monitored by the system for all the channels (IR-10.8, VIS-0.8 and HRV). However it should be noted that does not give any information about the quality and the accuracy of the retrieved pressure.

The vertical distribution of IR-10.8 AMVs is very different for period1 and period2. The use of the current operational CLA-CTH tends to give more AMVs at midlevels and less at high levels than the use of the CLA-CTH based on CO2slicing method.

Table 2: Relative increase (in %) of the amount of all the IR-10.8, Vis and HRV AMVs for the two periods. Results of the new scheme are presented against OPE and OPE_noIE

Relative increase of all AMVs monitored (in %)		(New – OPE) / OPE		(New - OPE_noIE) / OPE_noIE	
		Period 1	Period 2	Period 1	Period 2
IR-10.8	All levels	12	11	4	8
	High levels	-7	18	-12	17
	Mid Levels	106	46	88	25
	Low levels	9	-2	2	-5
	VIS-0.8	13	6		
	HRV	21	9		

Performance of the New scheme against the operational scheme OPE

AMVs with high Quality Index (QI > 80).

Like the new scheme increases the total amount of AMV monitored, the amount of IR-10.8 AMVs that have a Quality Index QI > 80, is increased by nearly 10% on average for the first period and 17% for the second period considering all pressure levels together. More detailed statistics are listed in Table 3. The calculation of the QI considered in this section is based on the use of spatial consistency, temporal consistency tests and forecast consistency test. However, the current QI does not indicate whether this estimated altitude is correct or not.

Comparing the results of the two periods shows the overall importance of the actual cloud top height assignment method.

Table 3: Relative increase (in %) of the amount of good IR-10.8, VIS-0.8 and HRV AMVs (QI with FC-consistency > 80) for the two periods.

Relative increase of AMVs with QI with FC-cons. > 80) (New – OPE) / OPE (in %)		Period 1	Period 2
IR-10.8	All levels	10	17
	High levels	-3	23
	Mid Levels	102	48
	Low levels	11	8
	VIS-0.8	4	4
	HRV	5	3

Comparison against Radiosonde observations.

The quality of the AMV product involves direct comparison of collocated computed AMVs and radiosonde (RS) observations. The following criteria are generally applied to filter only the "good collocations" in the statistic: Horizontal distance AMV / RS < 150 km; Vertical distance AMV / RS < 25 hPa ; AMV Quality Index (without forecast consistency test) >= 80 ; Speed difference AMV / RS < 30 m/s ; Direction difference AMV / RS < 60 deg ; AMV speed > 2.5 m/s, but it should be noted that the filter requirements speed/direction difference are very large, 30 m/s and 60°. It should be noted that the AMV QI considered for collocation against RS observation does not include Forecast Consistency test, and then the good AMVs considered for AMV/RS collocations are slightly different to those presented in section 2.2.1.

Tables 4 and 5 present the AMVs / RS speed biases (in m/s) and RMS (in m/s) for the two periods. The upper number corresponds to the result of the New scheme when the number in brackets corresponds to the corresponding OPE result. Results are given for low-levels VIS-0.8 and HRV AMVs, and split in three different altitude levels for IR-10.8 AMVs. Unfortunately, the geographical distribution of the statistics is not homogeneous, as the global statistics are mainly dominated by the northern hemisphere (more than 60% of the total amount for IR channels) where most radiosondes are launched. Therefore the results are also given according to geographical areas, i.e. global, Northern Hemisphere (NH), Southern Hemisphere (SH) and TRopics (TR).

Table 4: AMV / RS speed biases (in m/s) for the two periods.

AMV / RS speed Bias New (OPE) (in m/s)		Period 1				Period 2			
		Global	NH	SH	TR	Global	NH	SH	TR
IR-10.8	All levels	-1.3 (-1.2)	-1.6 (-1.8)	-1.7 (-1.5)	-0.4 (-0.1)	-2.6 (-1.5)	-2.8 (-1.8)	-1.8 (-1.)	-2.0 (-0.7)
	High levels	-1.9 (-1.2)	-2.9 (-2.1)	-2.1 (-1.5)	-0.6 (0)	-3.3 (-1.7)	-3.9 (-2.3)	-2 (-0.9)	-2.3 (-0.7)
	Mid Levels	-1 (-2.2)	-1.4 (-2.4)	-0.9 (-1.5)	2.2 (-0.7)	-2.7 (-1.8)	-3 -1.9)	-1.7 (-1.1)	-0.4 (-0.3)
	Low levels	0.1 (-0.4)	0.5 (-0.2)	-0.5 (-1.2)	-0.9 (-0.8)	1. (0.)	1.6 (0.38)	-0.1 (-0.7)	-0.9 (-0.7)
VIS 0.8		-0.1 (-0.5)	-0.2 (-0.3)	-0.5 (-1.3)	-0.8 (-0.7)	0.4 (-0.3)	1. (0.1)	-0.2 (-0.5)	-0.8 (-0.8)
HRV		0.7 (0.1)	0.8 (0.1)	0.2 (0.5)	-0.8 (-0.9)	1.3 (0.3)	1.4 (0.4)	-0.9 (-1.5)	-0.6 (-1.1)

Table 5: AMV / RS RMS (in m/s) for the two periods.

AMV / RS RMS New (OPE) (in m/s)		Period 1				Period 2			
		Global	NH	SH	TR	Global	NH	SH	TR
IR-10.8	All levels	7.75 (7.58)	7.99 (7.87)	8.05 (7.44)	7.13 (7.09)	8.31 (7.74)	8.90 (8.33)	7.23 (6.61)	6.61 (6.31)
	High levels	8.47 (8.12)	9.16 (8.57)	8.52 (7.89)	7.52 (7.61)	8.75 (8.16)	9.55 (8.91)	7.36 (6.89)	6.86 (6.83)
	Mid Levels	7.83 (7.80)	7.76 (8.03)	7.41 (6.03)	8.68 (4.47)	8.44 (7.96)	8.44 (8.12)	8.34 (5.50)	8.43 (5.71)
	Low levels	4.99 (4.57)	5.36 (4.97)	5.49 (4.52)	3.36 (3.42)	5.49 (4.92)	5.93 (5.47)	5.49 (4.89)	3.21 (3.37)
VIS 0.8		4.65 (4.21)	5.22 (4.64)	3.84 (3.98)	3.40 (3.43)	5.13 (4.40)	5.80 (5.02)	4.67 (3.98)	3.29 (3.44)
HRV		5.12 (4.58)	5.20 (4.68)	4.74 (3.39)	3.29 (-3.12)	5.54 (5.00)	5.65 (5.10)	4.69 (5.44)	2.56 (2.89)

Tables 6 presents the relative increase of the amount of good AMVs / RS collocations (in %) between New and OPE for the two periods. A positive number in the Table 6 means that AMVs having QI without FC-consistency > 80 provided by new scheme give more frequently a collocation with the neighbouring radiosonde observations. The speed biases and RMS presented in Tables 4 and 5 were then calculated using a larger set of AMV / RS collocations, including certainly more difficult situations for which the OPE scheme simply failed to give a result. This information should also be considered when comparing the results of speed biases and RMS between OPE and the New scheme.

Table 6: Relative increase (in %) of the amount of AMVs with QI without FC-consistency > 80 / RS collocations for the two periods.

Relative increase of the amount AMV / RS collocations: (New-OPE)/OPE (in %)		Period 1				Period 2			
		Global	NH	SH	TR	Global	NH	SH	TR
IR-10.8	All levels	22	26	22	15	40	45	30	29
	High levels	7	6	14	8	48	59	31	33
	Mid Levels	58	47	109	205	41	65	19	-4
	Low levels	48	60	39	24	6	0	56	94
VIS 0.8		28	40	7	13	25	51	9	-7
HRV		32	34	30	6	44	47	25	-6

In summary the new method largely increases the number of good AMVs / RS collocations nearly everywhere for IR-10.8, VIS-0.8 and HRV AMVs. The AMVs / RS speed biases and RMS are a bit larger using the new method, especially the well known slow bias observed for high levels IR-10.8 AMVs. Results are slightly different for the two periods which again illustrates the importance of the method used to calculate the CLA-CTH parameter.

Impact of the Image Enhancement (IE) process against OPE and New scheme.

AMVs with high Quality Index (QI > 80).

A part of the effects noted above in 2.1 are due to the use of Image Enhancement procedure in the current operational AMV algorithm. As this procedure has been switched off in a parallel chain during the same test periods, we can also observe directly the impact of this procedure. Results are presented only for the IR-10.8 channel because the IE procedure is not used for other channels.
Table 7 shows the relative increase of good AMVs (QI with FC-consistency > 80) switching off the IE process. These results are presented for period 1 and period 2, against the operational code ((OPE_noIE – OPE) / OPE) and against the new scheme ((OPE_noIE - New) / New) respectively. The use of IE in OPE systematically decreases by several percents the amount of good AMVs. However, the results are more similar for the second period that uses CO2 slicing method to estimate the CLA-CTH.
Comparison against the new scheme shows that the results are different for period 1 and period 2. During period 1 which used the operational CLA-CTH, the OPE_noIE chain gave more good AMVs at high levels (above 400 hPa) than the new scheme, +18%, and less at mid levels, -38% During the period 2 the new scheme got more good AMVs at high levels (-13%) and mid levels (-12%). Results obtained at low level are not directly linked to IE procedure, and are not further commented here.
A first comment is that a part of the benefits of the new scheme described in section 2.1 are partly due to the use of IE procedure in the operational code OPE. However, a direct comparison OPE_noIE against New scheme shows that their relative performances are also linked to the method used to calculate the CLA-CTH.

Table 7: Relative increase (in %) of the amount of good IR-10.8 AMVs (QI with FC-consistency > 80) for the two periods. The OPE_noIE results have been compared against current OPE results, and against the new scheme results.

Relative increase of good AMVs (QI with FC-consistency > 80) using IE (in %)		(OPE_noIE – OPE) / OPE		(OPE_noIE - New) / New	
		Period 1	Period 2	Period 1	Period 2
IR-10.8	All levels	14	8	3	- 8
	High levels	15	6	18	-13
	Mid Levels	24	30	-38	-12
	Low levels	12	7	1	-1

Comparison against Radiosonde observations.

It is recalled that AMV QI considered for collocation against RS observation does not include Forecast Consistency test.
Table 8 and Table 9 present respectively the AMVs / RS speed biases (in m/s) and RMS (in m/s) for the two periods for the OPE_noIE results. These results must be compared to those presented in

Table 4 for New scheme, and OPE (number within brackets). The speed biases and RMS obtained with OPE_noIE at high levels are generally slightly smaller than those obtained using the new scheme, and slightly larger than the biases obtained using OPE. This is obviously a reason why the IE procedure has been implemented operationally. In parallel to high levels results, it should be noted that speed bias at mid-level is greatly reduced using the new scheme during the period 1, comparing to OPE or OPE_noIE results.

Table 8: AMV / RS speed biases (in m/s) for the two periods for OPE_noIE.

AMV / RS speed Bias OPE_noIE (in m/s)		Period 1				Period 2			
		Global	NH	SH	TR	Global	NH	SH	TR
IR-10.8	All levels	-1.6	-2.3	-1.9	-0.2	-1.8	-2.2	-1.4	-0.8
	High levels	-1.6	-2.6	-2.0	0.	-2.0	-2.7	-1.5	-0.9
	Mid Levels	-3.	-3.2	-1.9	-1.3	-2.3	-2.4	-1.6	-0.6
	Low levels	-0.7	-0.6	-1.3	-0.8	-0.2	-0.2	-0.9	-0.7

Table 9: AMV / RS RMS (in m/s) for the two periods for OPE_noIE.

AMV / RS RMS OPE_noIE (in m/s)		Period 1				Period 2			
		Global	NH	SH	TR	Global	NH	SH	TR
IR-10.8	All levels	7.82	8.20	7.79	7.03	8.03	8.57	7.02	6.68
	High levels	8.36	8.98	8.19	7.55	8.52	9.26	7.34	7.21
	Mid Levels	8.34	8.54	7.27	4.90	8.27	8.43	6.21	6.50
	Low levels	4.61	4.94	4.92	3.45	4.98	5.47	4.75	3.37

Figure 1 shows the relative increase of AMV with QI without FC-consistency > 80 / RS collocation between OPE and OPE_noIE for periode 1 (left) and periode 2 (right). A positive value means that OPE_noIE chains generated more good AMV / RS collocations, which is the case for both the two periods at high and mid levels. The speed biases and RMS presented in Tables 8 and 9 were then calculated using a larger set of AMV / RS collocations than those referred to OPE.

Figure 2 represents the same than Figure 1 for comparisons between OPE_noIE and New scheme. Positive values on the graphs means that the new scheme got more good AMV / RS collocations than OPE_noIE. The speed biases and RMS presented in Tables 8 and 9 were then calculated using a smaller set of AMV / RS collocations than those referred to the New scheme.

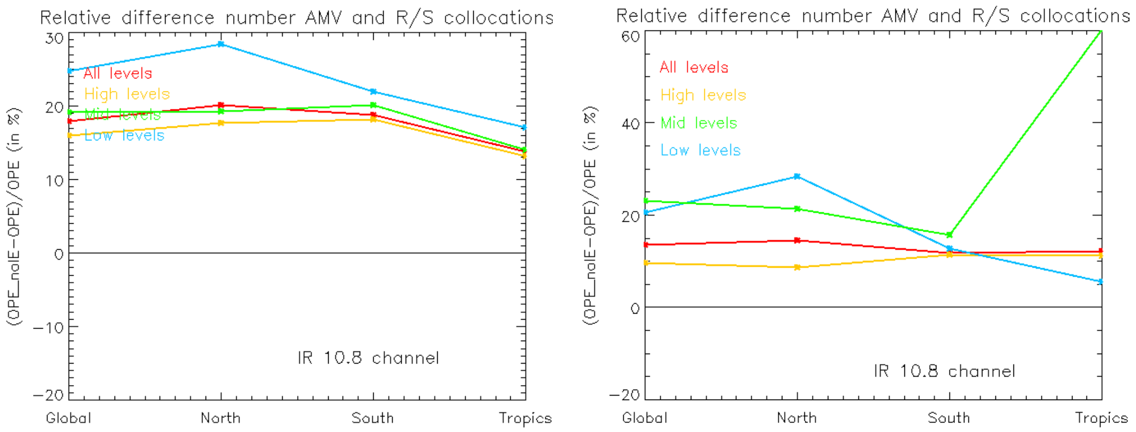

Figure 1: relative increase of AMV with QI without FC-consistency > 80 / RS collocation between OPE and OPE_noIE for periode 1 (left) and periode 2 (right).

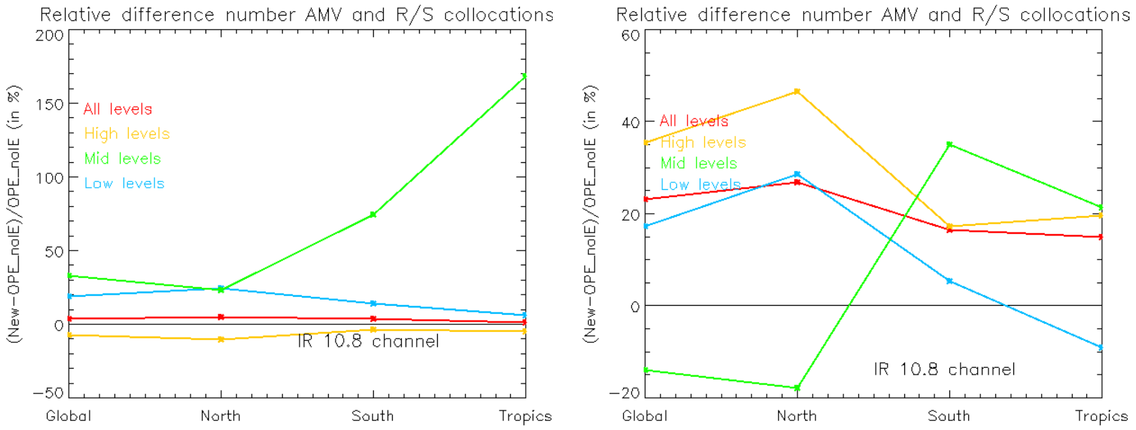

Figure 2: relative increase of good AMV / RS collocation between OPE_noIE and the New scheme for periode 1 (left) and periode 2 (right).

Direct comparison OPE_NoIE and New method

To simplify the evaluation of the new pixel selection method as such, the following tables directly compares the operational AMV metod without Image Enhancement (OPE_NoIE) with the new CCC-method.

AMVs with high Quality Index (QI > 80).

Table 10: Relative increase (in %) of the amount of IR-10.8 AMVs / RS collocations (QI without FC-consistency > 80) for the two periods. The OPE_noIE results have been compared directly against the new scheme results. This is the same data shown in figure 2 above.

In summary, looking at the total for all levels, the new CCC-method increases the number of AMV's with QI with FC-consistency > 80% / RS collocations for IR channel 10.8, at least when using the new CLA. But the vertical redistribution is substantial, again emphasizing the importance of the CLA quality.

Table 10: Amount of good AMVs / RS collocations for the two periods.

Relative increase of the amount AMV / RS collocations: (New-OPE_noIE)/OPE_noIE (in %)		Period 1				Period 2			
		Global	NH	SH	TR	Global	NH	SH	TR
IR-10.8	All levels	4	5	4	1	23	27	17	15
	High levels	-7	-10	-4	-5	35	47	17	20
	Mid Levels	33	23	74	168	-14	-18	35	21
	Low levels	19	24	14	6	17	28	5	-9

Table 11 presents the relative increase (in %) of the RMS error normalized with the average radiosonde speed in each group. In spite of the large increase of good AMV / RS collocations at high levels when using the new CLA, the NRMS is not degraded. At low levels the impact on NRMS is generally negative. Like the differences at low levels are not due to CCC method they are not further discussed here. For medium levels the impact of the new scheme is also mainly negative. However medium levels AMVs are mainly located in the Tropics and in the SH dominated by CB-activities, which generally correspond to difficult situations for both AMV's and Radiosondes.

Table 11: Relative increase (in %) of the amount of NRMS vs RS collocations for the two periods.

Relative improvement of the NRMS AMV / RS collocations: -1*(New-OPE_noIE)/OPE_noIE (in %)		Period 1				Period 2			
		Global	NH	SH	TR	Global	NH	SH	TR
IR-10.8	All levels	-3	-3	-5	-2	3	3	0	10
	High levels	0	0	-5	0	3	-3	3	13
	Mid Levels	0	4	-14	-73	-6	-2	-53	-29
	Low levels	-15	-20	-18	3	-23	-27	-20	9

CONCLUSIONS

This paper summarizes the main results of the operational tests done at EUMETSAT using the new pixel selection method proposed by Borde and Oyama (2008). This new scheme provides a clearer and better physical relationship between the displacement vector and the radiances that are used to set the AMV height. Comparisons against operational product show some improvements of the new scheme on the AMV product for the VIS-0.8, HRV and IR-10.8 channels, increasing the total amount of AMVs monitored and the amount of AMVs with QI > 80, if using a new CLA. Speed biases and RMS against RS are generally a bit larger using the new scheme, especially the known slow bias at high levels for IR-10.8 AMVs. However, it should be considered that these values have been estimated on a larger set of data because the new scheme also increases largely the amount of AMVs / RS collocations.

These two period datasets have been tested in assimilation at ECMWF, preliminary results showing a generally neutral or even slightly positive impact on the forecast for the second period.

Based on a better physical concept, the new pixel selection method is also very simple and provides a high potential to easily integrate future improvements, like a better estimation of the cloud top heights using the future OCA product (Watts et al., 1998) for example.

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