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Third AMV Intercomparison Study

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Abstract

This study is a continuation and update of the previous "2014 AMV Intercomparison study", presented in the 12th International Winds Workshop in Copenhagen in 2014.

In this continuation, Atmospheric Motion Vectors (AMVs) calculated with Japan Meteorological Agency's Himawari-8 satellite data are compared, considering two different input datasets with two different image triplets for 21 July 2016. Image data are equivalent to those used by the "International Cloud Working Group (ICWG) Cloud Intercomparison study", to improve synergies between both studies. The different centers use a prescribed configuration and their own configuration for the AMV production with these datasets.

Six different institutions participated in the study (CPTEC/INPE, EUMETSAT, JMA, KMA, NOAA and NWCSAF). This paper is a summary of the full "AMV Intercomparison Technical Report", which can be found at: http://www.nwcsaf.org/aemetRest/downloadAttachment/5284. The study has been updated in November 2018 with two new datasets from EUMETSAT and KMA, which correct two issues related with the "Common Quality Index (QIC)" and the "Height assignment" respectively.

INTRODUCTION

Two "AMV Intercomparison studies" have taken place in the past up to now: Genkova et al. 2008 & 2010, and Santek et al. 2014. The evolution of the AMV algorithms and of the geostationary satellites since then defined the need for a "Third AMV Intercomparison study" in 2017-2018. Three main goals are considered for this new study:

1) To verify the advantages of the calculation of AMVs with the new generation of geostationary satellites, started with Himawari-8, with better spatial and temporal resolution and new spectral channels, with respect to those calculated with MSG series.
2) To extract conclusions about the best options for the calculation of AMVs with this new generation of geostationary satellites, considering the options taken by the different centers for their AMV calculation.
3) To compute a "Common Quality Index (QIC)" for all centers, to verify if there is a better agreement between the different AMV datasets.

The report analyzes the AMV algorithms provided by the following six AMV producers. The three-letter abbreviations are used as identifiers of the AMV datasets throughout the remainder of this report:

BRZ: Brazil Weather Forecast and Climatic Studies Center (CPTEC/INPE)
EUM: European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)
JMA: Japan Meteorological Agency
KMA: Korea Meteorological Administration
NOA: Unites States National Oceanic and Atmospheric Administration (NOAA)
NWC: Satellite Application Facility on Support to Nowcasting (NWCSAF)

China Meteorological Administration (CMA) participated in the previous intercomparison study but not in this one.

The AMV outputs were originated considering two triplets of Himawari-8/AHI infrared (10.4 µm) full–disk images for 21 July 2016 at 0530-0550 and 1200-1220 UTC, one of which is shown in *Figure 1*. Additionally, ECMWF ERA-INTERIM NWP analysis for the given day, for 37 vertical levels every 6 hours, and corresponding cloud products derived by NOAA/NESDIS for the given slots, were provided for the AMV calculation.

The AMV outputs provided by each AMV algorithm, are analyzed in three independent experiments, designed to measure differences related to specific aspects of the algorithms. Scripts used in the two previous intercomparison studies (Genkova et al. 2008 & 2010, and Santek et al. 2014) have been used again, so allowing for the comparison of the results in the different studies.

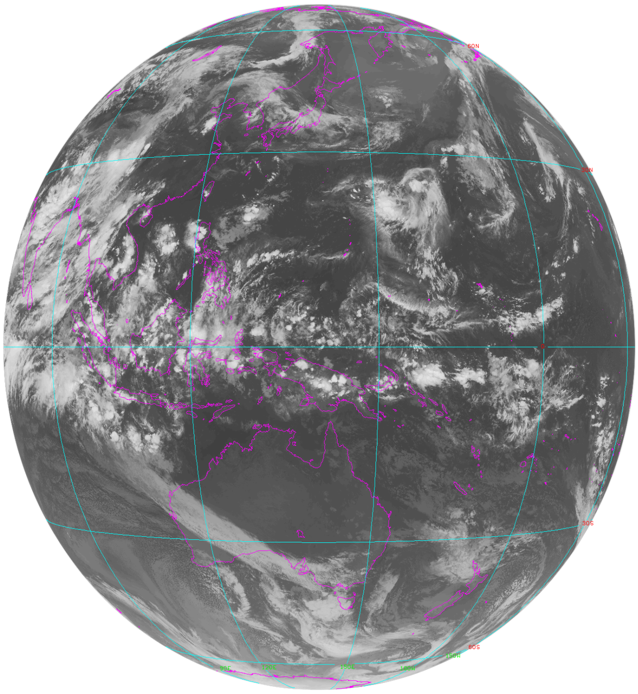


Figure 1: **Himawari-8 10.4 µm satellite image for 21 July 2016 at 1200 UTC**

Each center's output for the experiments included data for identical variables, as shown in *Table 1*, with the exception of BRZ, who did not report the "Quality Index with forecast (QIF)".

Parameter	Code	Description
1	IDN	Identification number
2	LAT[DEG]	Latitude
3	LON[DEG]	Longitude
4	TS[PIX]	Target box size
5	SS[PIX]	Search box size
6	SPD[MPS]	AMV speed
7	DIR[DEG]	AMV direction
8	PRES[HPA]	AMV pressure
9	L	Low level correction flag
10	NWPSPD[MPS]	Background guess wind speed
11	NWPDIR[DEG]	Background guess wind direction
12	ALB[%]	Albedo
13	CORR[%]	Correlation
14	T[K]	Brightness temperature
15	PRESERR[HPA]	AMV pressure error
16	H	Height assignment method flag
17	QINF[%]	Quality Index without forecast
18	QIF[%]	Quality Index with forecast
19	QIC[%]	Common Quality Index

Table 1: **Reported Variables**

EXPERIMENT 1

In this case, AMV producers extracted cloudy AMVs with the triplet 1200-1220UTC, using their best options for the AMV calculation, but considering a prescribed target box size, search scene size and target locations. All AMV extraction processes could be compared this way (tracer selection, tracer tracking, height assignment and quality control), comparing equivalent AMV datasets.

Figure 2 shows the distribution of parameters (Common Quality Index, speed, direction and pressure) for the different AMV datasets, with a QIC threshold of 50%:

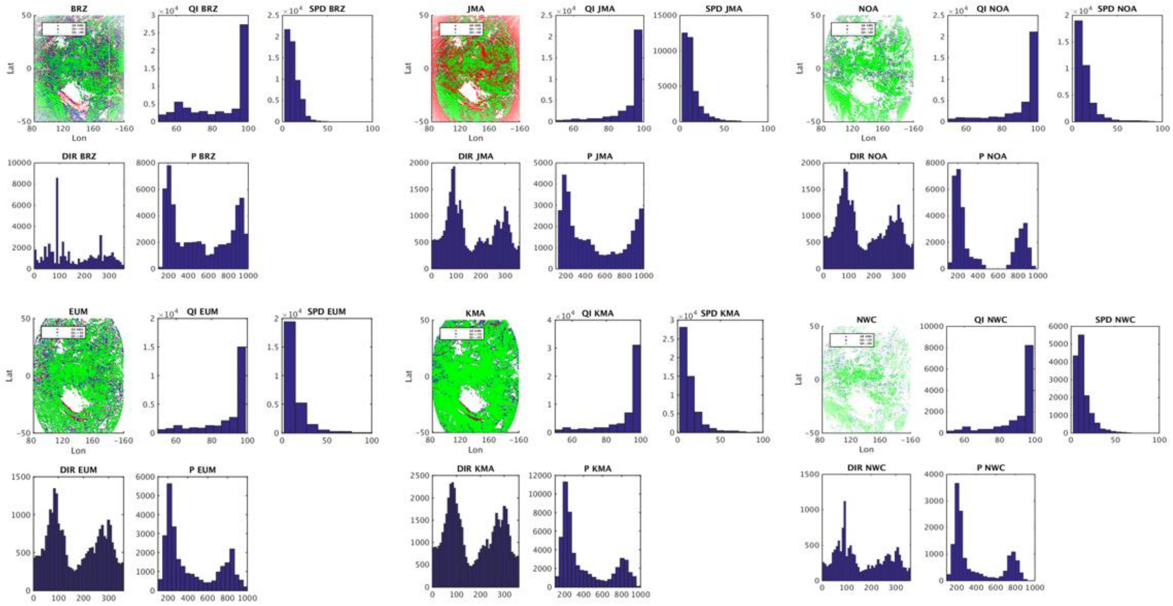
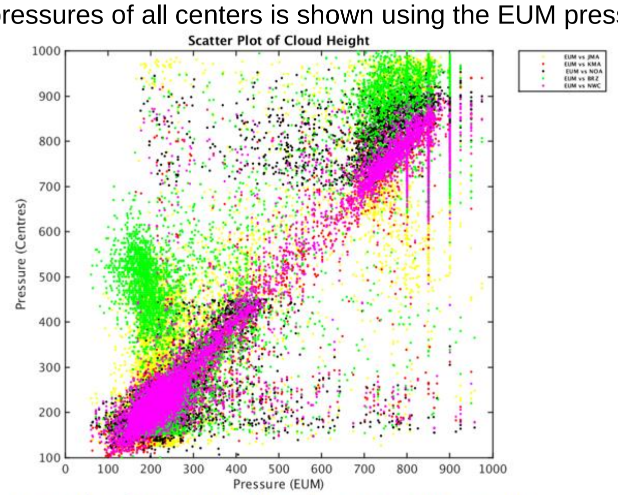


Figure 2: **Distribution of parameters for Experiment 1 considering QIC >= 50% (AMV distribution, Common Quality Index, Speed, Direction, Pressure) for the different AMV datasets (BRZ: upper left; EUM: lower left; JMA: upper center; KMA: lower center; NOA: upper right; NWC: lower right).**

The distributions look similar for all centers, with the following items to be taken into account:

1) The distribution of direction values for BRZ shows some directions more frequent than other ones;
2) The distribution of the QIC values looks basically similar for all centers;
3) The distribution of AMV pressures is instead very different for the different centers due to the very different calculation methods - only EUM & NWC being similar because of both using “CCC method” for the height assignment. This last result is even more evident looking to *Figure 3*, in which the scatter plot of AMV pressures of all centers is shown using the EUM pressure as reference.



Scatter plot of AMV pressure for each center vs. EUM pressure
(considering a QIC threshold of 50%)

Figure 3: **Scatterplot of collocated AMV pressures for Experiment 1 considering QIC >= 50%, for each center versus EUM AMV pressures (BRZ in green; JMA in yellow; NOA in black; KMA in red; NWC in pink).**

When the AMVs are compared to radiosonde winds (in *Table 2* using the threshold of 50%, and in *Table 3* using the threshold of 80% for the QIC, the best results are for JMA (with a vector RMS of 5 m/s), and then for NWC and NOA (with a vector RMS of 6-8 m/s). BRZ and EUM show bad results for the low quality threshold, while much better for the high quality threshold, for which there is more homogeneity between centers. In addition, there are important differences in the number of AMVs for the different centers with the prescribed configuration (although in all cases the number of AMVs is larger than in the previous study with MSG satellite).

	N	Pre Bias	Pre RMS	Spd Bias	Spd RMS	Dir Bias	Vec RMS
BRZ	774	0.90	14.68	.1,28	10.00	-13.13	12.61
EUM	473	-1.63	16.52	-1.74	7.86	8.69	12.67
JMA	400	0.50	13.81	-0.91	3.95	1.30	5.74
KMA	859	-0.55	15.16	-1.88	7.61	5.46	10.10
NOA	512	-1.05	14.15	-0.86	6.29	1.10	8.16
NWC	163	-0.69	15.11	-1.14	4.99	-1.47	6.80

Table 2: **Experiment 1: Comparison of AMVs (with QIC >= 50%) to radiosonde winds within 150 km. N = number of matches; Pre Bias = pressure bias; Pre RMS = pressure RMS; Spd Bias = wind speed bias; Spd RMS = wind speed RMS; Dir Bias = wind direction bias; Vec RMS = vector RMS. The extreme for each category is highlighted: Yellow = worst value; cyan = best value**

	N	Pre Bias	Pre RMS	Spd Bias	Spd RMS	Dir Bias	Vec RMS
BRZ	448	0.02	13.97	0.31	6.07	-14.61	8.62
EUM	312	-0.83	16.54	-1.79	6.54	8.31	8.56
JMA	344	0.78	13.77	-1.07	4.07	1.09	5.93
KMA	666	-0.79	15.51	-1.56	6.42	2.78	8.97
NOA	427	-1.49	13.96	-0.89	5.42	0.45	7.52
NWC	132	-0.41	15.08	-0.97	5.01	-5.98	6.94

Table 3: **Experiment 1: Comparison of AMVs (with QIC>= 80%) to radiosonde winds within 150 km. N = number of matches; Pre Bias = pressure bias; Pre RMS = pressure RMS; Spd Bias = wind speed bias; Spd RMS = wind speed RMS; Dir Bias = wind direction bias; Vec RMS = vector RMS. The extreme for each category is highlighted: Yellow = worst value; cyan = best value**

Considering the comparison of collocated AMVs against the NWP analysis winds, in *Table 4* using the threshold of 80% for the QINF, and in *Table 5* using the threshold of 80% for the QIC, the differences between centers are smaller (with only BRZ really over), and even smaller using the QIC for the filtering.

	N	BFN	VD	RMS	VDABF	RMSABF
BRZ	4930	1191	5.90	8.47	5.27	8.16
EUM	4930	1625	3.96	4.93	3.19	4.28
JMA	4930	1793	2.48	2.96	2.24	2.77
KMA	4930	1732	3.69	4.61	2.85	3.79
NOA	4930	1757	3.45	4.30	2.76	3.73
NWC	4930	1763	3.95	4.70	3.09	3.95

Table 4: **Experiment 1: Comparison of collocated AMVs (with QINF >= 80%) to NWP analysis winds. N = number of AMVs; BFN = number of AMVs with Best fit pressure; VD = Vector difference for all AMVs; RMS = Root mean square error for all AMVs; VDABF = Vector difference for AMVs with Best fit pressure; RMSABF = Root mean square error for AMVs with Best fit pressure. The extreme for each category is highlighted: Yellow = worst value; cyan = best value**

	N	BFN	VD	RMS	VDABF	RMSABF
BRZ	8076	2122	5.54	7.53	4.85	7.13
EUM	8076	2655	4.04	4.97	3.24	4.28
JMA	8076	2860	2.59	3.10	2.33	2.89
KMA	8076	2802	3.80	4.73	2.97	3.94
NOA	8076	2854	3.54	4.36	2.82	3.74
NWC	8076	2791	3.99	4.74	3.17	4.03

Table 5: **Experiment 1: Comparison of collocated AMVs (with QIC >= 80%) to NWP analysis winds. N = number of AMVs; BFN = number of AMVs with Best fit pressure; VD = Vector difference for all AMVs; RMS = Root mean square error for all AMVs; VDABF = Vector difference for AMVs with Best fit pressure; RMSABF = Root mean square error for AMVs with Best fit pressure. The extreme for each category is highlighted: Yellow = worst value; cyan = best value**

Considering in *Figure 4* the AMV level against the AMV best fit level, it is also clear that JMA AMVs are near the best fit level; much more than for all other datasets. The maps in the lower panels of *Figure 4* depict the best fit displacements above (red) and below (blue) the AMV level, which tend to be in similar locations for all centers for collocated AMVs.

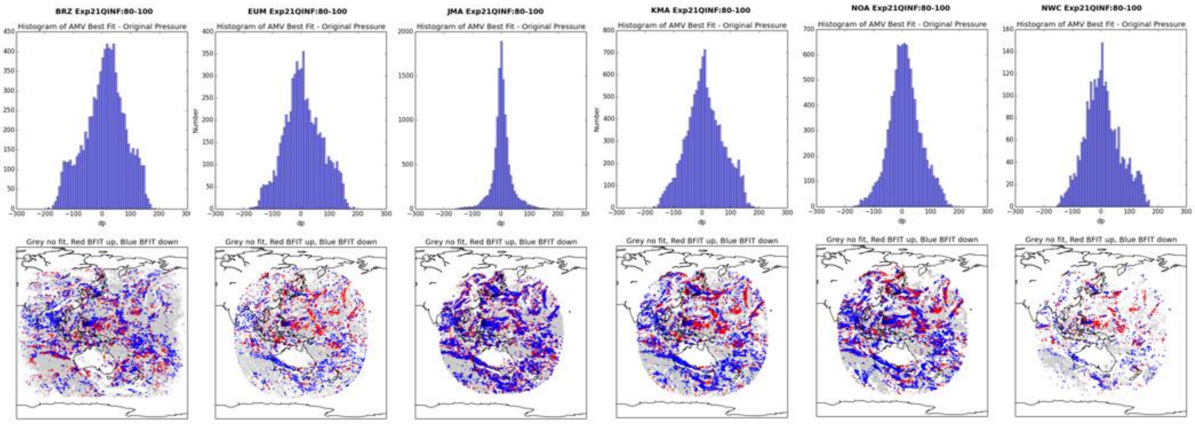


Figure 4: **Experiment 1: Histogram and maps of "AMV best fit pressure – original AMV pressure" for BRZ, EUM, JMA, KMA, NOA, NWC (from left to right). In the maps, red shows the best fit level is at a higher level; blue shows the best fit level is at a lower level**

EXPERIMENT 2

In this case, AMV producers extracted cloudy AMVs with the triplet 1200-1220UTC, using their best options for the AMV calculation, and considering their own configuration for target box size, search scene size and target locations. The differences of each AMV extraction process (with respect to the previous prescribed configuration) can be compared this way.

Figure 5 shows the distribution of parameters (Common Quality Index, speed, direction and pressure) for the different AMV datasets, with a QIC threshold of 50%:

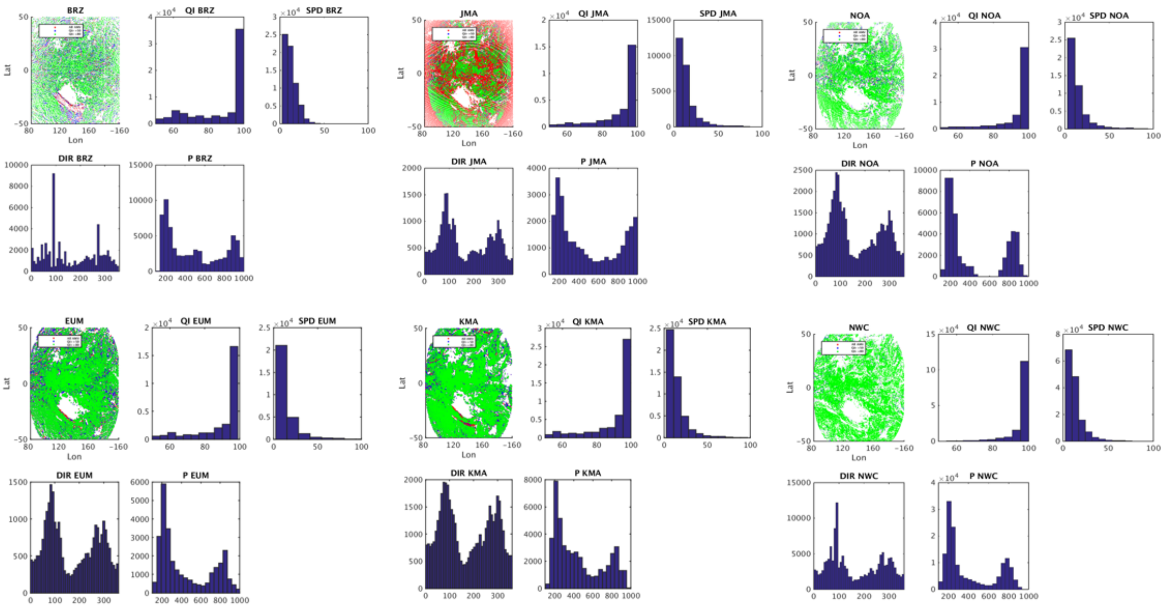


Figure 5: **Distribution of parameters for Experiment 1 considering QIC >= 50% (AMV distribution, Common quality index, Speed, Direction, Pressure) for the different AMV datasets (BRZ: upper left; EUM: lower left; JMA: upper center; KMA: lower center; NOA: upper right; NWC: lower right).**

The parameter distributions are very similar to those in Experiment 1. With this, the differences in the height assignment process drive the majority of differences observed. Again, the distribution of the QIC values looks similar for all centers.

The scatter plot of AMV pressures of all centers using the EUM pressure as reference is shown again in *Figure 6*, with equivalent results to those in Experiment 1 (as expected).

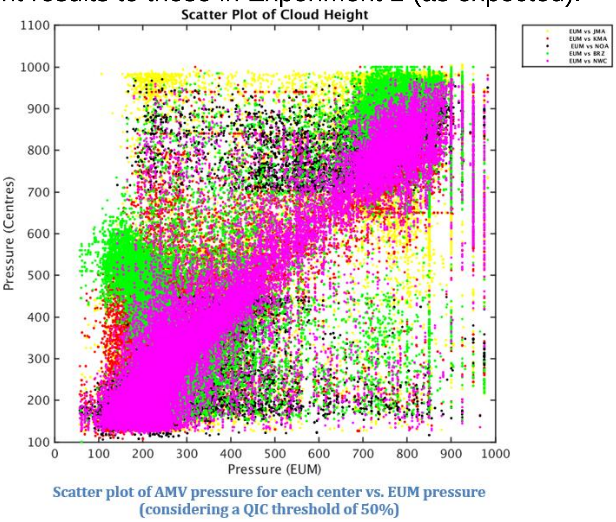


Figure 6: **Scatterplot of collocated AMV pressures for Experiment 2 considering QIC >= 50%, for each center versus EUM AMV pressures (BRZ in green; JMA in yellow; NOA in black; KMA in red; NWC in pink).**

When the AMVs are compared to radiosonde winds (in *Table 6* using the threshold of 50%, and in *Table 7* using the threshold of 80% for the QIC, the best results are again for JMA (with a vector RMS of 6 m/s), and then for NOA and NWC (with a vector RMS of 7 m/s). EUM results are much better in Experiment 2, using their own configuration. The number of AMVs in Experiment 2 with respect to Experiment 1 changes only significantly for NWC, for which there is an increase of around 15 times.

	N	Pre Bias	Pre RMS	Spd Bias	Spd RMS	Dir Bias	Vec RMS
BRZ	942	1.46	14.44	-2.69	11.65	-9.48	15.22
EUM	508	-0.62	15.92	-2.17	7.03	10.08	8.87
JMA	313	-2.94	18.33	-1.36	4.64	-0.83	6.34
KMA	797	-0.64	14.80	-1.55	7.78	-1.41	10.03
NOA	691	-1.58	13.93	-0.90	5.44	1.89	7.62
NWC	2204	-1.02	16.30	-2.17	6.03	0.40	7.85

Table 6: **Experiment 2: Comparison of AMVs (with QIC >= 50%) to radiosonde winds within 150 km. N = number of matches; Pre Bias = pressure bias; Pre RMS = pressure RMS; Spd Bias = wind speed bias; Spd RMS = wind speed RMS; Dir Bias = wind direction bias; Vec RMS = vector RMS. The extreme for each category is highlighted: Yellow = worst value; cyan = best value**

	N	Pre Bias	Pre RMS	Spd Bias	Spd RMS	Dir Bias	Vec RMS
BRZ	619	1.16	13.44	-0.40	7.36	-14.65	9.80
EUM	366	-0.66	14.74	-2.20	6.15	8.43	8.05
JMA	270	-3.43	18.67	-1.40	4.64	-0.83	6.42
KMA	628	-0.84	14.30	-1.21	7.39	-2.66	9.49
NOA	599	-1.69	13.98	-0.88	5.25	0.39	7.48
NWC	2063	-1.19	16.19	-2.11	5.99	0.79	7.85

Table 7: **Experiment 2: Comparison of AMVs (with QIC >= 80%) to radiosonde winds within 150 km. N = number of matches; Pre Bias = pressure bias; Pre RMS = pressure RMS; Spd Bias = wind speed bias; Spd RMS = wind speed RMS; Dir Bias = wind direction bias; Vec RMS = vector RMS. The extreme for each category is highlighted: Yellow = worst value; cyan = best value**

Considering the comparison of collocated AMVs against the NWP analysis winds, in *Table 8* using the threshold of 80% for the QINF, and in *Table 9* using the threshold of 80% for the QIC, the differences between centers are smaller for collocated AMVs.

	N	BFN	VD	RMS	VDABF	RMSABF
BRZ	43281	9814	5.60	8.20	5.01	7.90
EUM	43281	13270	3.84	4.96	3.05	4.24
JMA	43281	14572	2.20	2.71	1.99	2.52
KMA	43281	12709	3.75	5.05	3.08	4.51
NOA	43281	13765	3.41	4.26	2.74	3.64
NWC	43281	13588	3.45	4.13	2.79	3.54

Table 8: **Experiment 2: Comparison of collocated AMVs (with QINF >= 80%) to NWP analysis winds. N = number of AMVs; BFN = number of AMVs with Best fit pressure; VD = Vector difference for all AMVs; RMS = Root mean square error for all AMVs; VDABF = Vector difference for AMVs with Best fit pressure; RMSABF = Root mean square error for AMVs with Best fit pressure. The extreme for each category is highlighted: Yellow = worst value; cyan = best value**

	N	BFN	VD	RMS	VDABF	RMSABF
BRZ	56515	13075	5.73	8.35	5.11	8.02
EUM	56515	17533	4.00	5.17	3.17	4.43
JMA	56515	19208	2.27	2.80	2.06	2.62
KMA	56515	16635	3.92	5.25	3.23	4.72
NOA	56515	18163	3.53	4.42	2.84	3.80
NWC	56515	17860	3.55	4.24	2.87	3.65

Table 9: **Experiment 2: Comparison of collocated AMVs (with QIC >= 80%) to NWP analysis winds. N = number of AMVs; BFN = number of AMVs with Best fit pressure; VD = Vector difference for all AMVs; RMS = Root mean square error for all AMVs; VDABF = Vector difference for AMVs with Best fit pressure; RMSABF = Root mean square error for AMVs with Best fit pressure. The extreme for each category is highlighted: Yellow = worst value; cyan = best value**

Considering in *Figure 7* the AMV level against the AMV best fit level, it is again clear that JMA AMVs are near the best fit level; much more than for all other datasets. Best fit displacements above and below, tend to be again in similar locations for all centers for collocated AMVs.

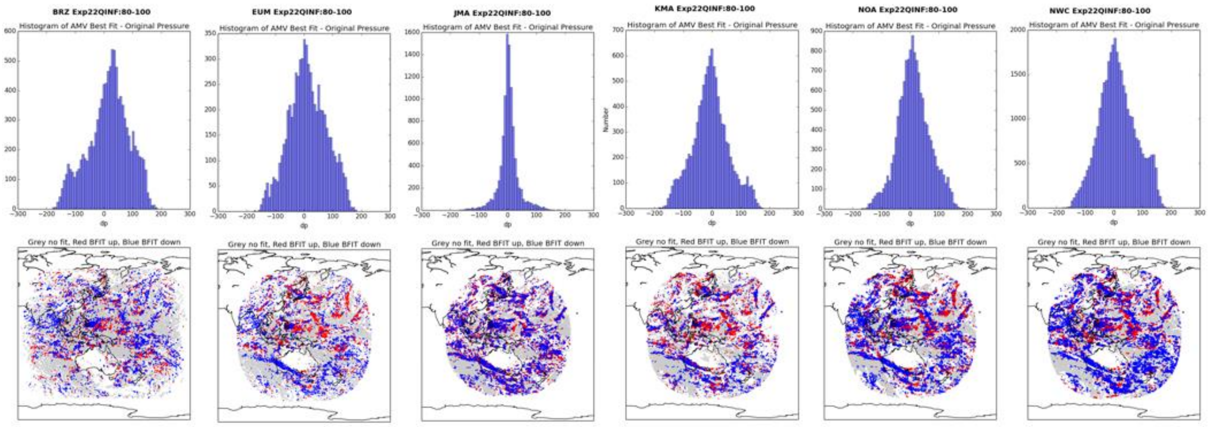
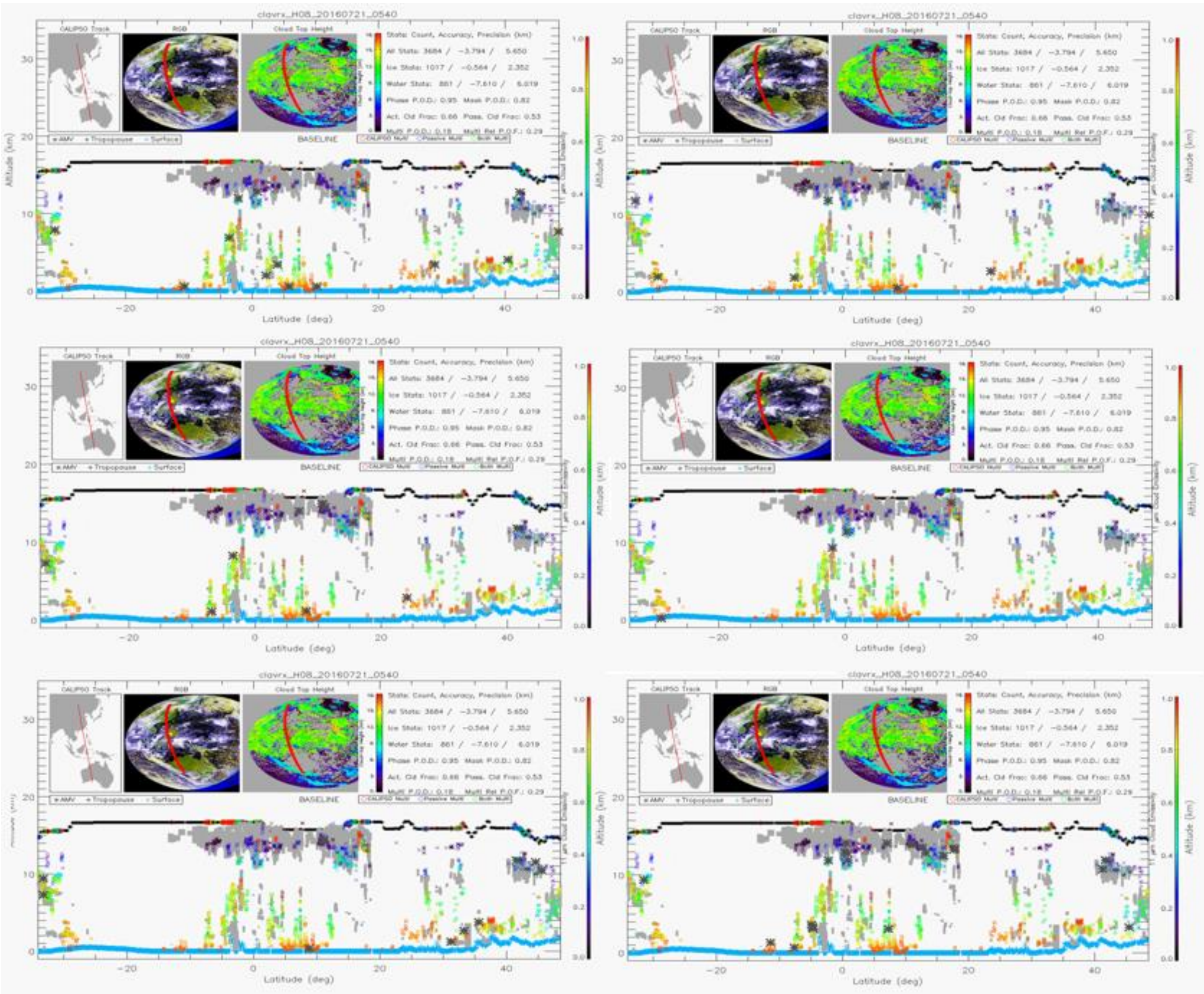


Figure 7: **Experiment 2: Histogram and maps of "AMV best fit pressure – original AMV pressure" for BRZ, EUM, JMA, KMA, NOA, NWC (from left to right). In the maps, red shows the best fit level is at a higher level; blue shows the best fit level is at a lower level**

EXPERIMENT 3

In this case, AMV producers extract IR10.4 µm cloudy AMVs with the triplet 0530-0550UTC, using their best options for AMV calculation, and considering their own configurations for target box size, search scene size and target location (as in Experiment 2). This dataset is used for validation against NASA's CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation), which provides an independent measurement of cloud top heights.

CALIPSO is a line-of-site measurement, so there are few collocations with AMVs (tens of matches only). Therefore, this evaluation is qualitative as illustrated in the following *Figure 8*. AMVs are generally near the cloud base for high-level and semitransparent clouds, and near the cloud top for low- and mid-level clouds. AMV heights for the different centers are in good agreement in this specific example, in apparent disagreement with the previous AMV pressure scatter plots.



Figures 8: **Experiment 3: Collocation of AMVs (defined as black asterisks *), with CALIPSO cloud measurements for BRZ (upper row left), JMA (upper row right), NOA (center row left), EUM (center row right), KMA (lower row left) and NWC (lower row right).**

CONCLUSIONS

In general, the differences in AMV datasets for each centre between Experiment 1 and 2 are basically related to the number of AMVs. In addition, the differences in AMV datasets for different centres are much more related to the height assignment process than to the use of a prescribed or a specific configuration.

Another important conclusion is that the distribution of the Common Quality Index values is very similar for all centers, and the use of the QIC has a real skill in filtering collocated AMVs for an improved statistical agreement.

Considering also specific conclusions for the different centers:

BRZ - Brazil Weather Forecast and Climatic Studies Center (CPTEC/INPE)

The performance of BRZ algorithm has improved with respect to the previous AMV intercomparison, with better agreement with other centers (especially, for high Quality index thresholds and collocated AMV data). Anyhow, there still exists room for improvement: large differences in the AMV pressures, and the need to verify the direction histograms, with some directions much more frequent than other ones.

KMA - Korea Meteorological Administration

The KMA algorithm performed similarly to the results from the previous AMV intercomparison. Overall, the comparisons to rawinsondes and model background were in the middle of the distributions. KMA algorithm is reasonably good, but it needs still to define its final stable version.

NOA – United States National Oceanic and Atmospheric Administration (NOAA)

NOAA agreement compared to other centers improves over the previous study. NOAA algorithm has now the second best statistics, along with NWCSAF. An element for analysis is the vertical distribution of AMVs, with no AMVs present between 450-700 hPa (in contrast to other algorithms).

NWC – Satellite application facility on support to Nowcasting (NWCSAF)

NWCSAF algorithm has the second best statistics, along with NOAA. The algorithm is basically similar to the one in the previous study, and due to this stability, the performance is similar to the one found then. An element for analysis is that some directions for Himawari AMVs are more frequent than other ones in the vicinity of 90 degrees.

EUM - European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)

The behavior of EUMETSAT algorithm is much better when the Quality index threshold is high (80%) and the specific configuration is used. In these circumstances, the performance is basically similar to that of other centers. The similarity in the height assignment with NWC center is also to be noticed, due to both using “CCC method”.

JMA - Japan Meteorological Agency

JMA algorithm has the best overall performance considering all validation and checking elements, most likely due to its updated height assignment procedure: “optimal estimation method using observed radiance and NWP vertical profile”. This is the most important change in all AMV algorithms since the previous AMV intercomparison. However, it is to be studied if the small difference between the AMVs and the background NWP has a good impact in later applications, like NWP assimilation.

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