The EUMETSAT Network of Satellite Application Facilities

NWC SAF

Support to Nowcasting and Very Short Range Forecasting

Scientific and Validation Report for the Wind product processors of the NWC/GEO

NWC/CDOP2/GEO/AEMET/SCI/VR/Wind, Issue 1, Rev. 0

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Applicable to GEO-HRW v5.0 (NWC-037)

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DOCUMENT CHANGE RECORD

Version	Date	Pages	Changes
1.0	*15 October 2016*	37	Initial version for the NWC/GEO v2016; updated after NWC/GEO v2016 STRR/DRR including: • Changes proposed at NWC/GEO v2016 STRR/DRR • An updated list of “Model configuration files” • An updated validation with the latest changes since November 2015 in NWC/GEO libraries, Cloud and HRW algorithms • A table with the list of possible errors caused by GEO-HRW-v5.0 algorithm

TABLE OF CONTENTS

List of Tables

List of Figures

1. INTRODUCTION

The EUMETSAT Satellite Application Facilities (SAF) are dedicated centres of excellence for the processing of satellite data, and form an integral part of the distributed EUMETSAT Application Ground Segment.

This documentation is provided by the SAF on support to Nowcasting and Very short range forecasting (NWC SAF). The main objective of the NWC SAF is to provide, develop and maintain software packages to be used with operational meteorological satellite data for Nowcasting applications. More information about the project can be found at the NWC SAF webpage, http://www.nwcsaf.org.

This document is applicable to the NWC SAF processing package for Geostationary Meteorological satellites, NWC/GEO.

1.1 SCOPE OF THE DOCUMENT

The purpose of this document is to present the Scientific Validation Results for the Wind Product Processor of the NWC/GEO software package (GEO-HRW, High Resolution Winds), which calculates Atmospheric Motion Vectors considering:

- Up to seven channels from MSG series SEVIRI imager: the 3 km Low Resolution Visible channels (VIS06 0.6 µm and VIS08 0.8 µm), Water Vapour channels (WV62 6.2 µm and WV73 7.3 µm), Infrared channels (IR108 10.8 µm and IR120 12.0 µm), and the 1 km High Resolution Visible channel (HRVIS 0.7 µm).
- Up to three channels from GOES-N series Imager: the 4 km Low Resolution Water Vapour channel (WV65, 6.5 µm) and Infrared channel (IR107, 10.7 µm), and the 1 km High Resolution Visible channel (VIS07, 0.7 µm).

This validation has been based on the comparison of the GEO-HRW-v50 Atmospheric Motion Vectors with winds obtained from Radiosounding bulletins available from the GTS. The statistical indicators established in the "Report from the Working Group on Verification Statistics of the 3rd International Winds Workshop" [RD.12], with some amendments in the "Report from the Working Group on Verification & Quality Indices of the 4th International Winds Workshop" [RD.15]), are calculated to achieve this. These indicators have been thoroughly used throughout the world for the Validation of Satellite winds through the comparison with Radiosoundings.

This report specifically takes into account the similarities and differences found in the AMVs (Atmospheric Motion Vectors) calculated with MSG satellite series and GOES-N satellite series, which for the first time can be processed by NWC/GEO-HRW software. Two main configurations have been considered for both satellite series: using NWC/GEO cloud products (and so using "CCC height assignment method") and not using NWC/GEO Cloud products (and so using "Brightness temperature interpolation height assignment method without cloud products").

A small difference occurs between the "CCC method" version used with MSG satellites (which due to the availability of NWC/GEO Cloud microphysics product includes a Microphysics correction), and the version used with GOES-N satellites (which due to the lack of the corresponding NWC/GEO Cloud microphysics product does not include this Microphysics correction).

A comparison between the default configurations of GEO-HRW v2013 and v2016 is also verified, to show the improvements of NWC/GEO-HRW algorithm since the previous version.

Finally, the differences between daytime AMVs and nighttime AMVs are also for the first time considered, considering the validation against Radiosounding data related to different synoptic hours of the day.

1.2 SOFTWARE VERSION IDENTIFICATION

This document describes the algorithm implemented in the GEO-HRW-v5.0 (Product Id NWC-037) of the NWC/GEO v2016 software package release.

1.3 REFERENCES

1.3.1 Applicable Documents

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X]

For versioned references, subsequent amendments to, or revisions of, any of these publications do not apply. For unversioned references, the current edition of the document referred applies.

Current documentation can be found at the NWC SAF Helpdesk web: http://www.nwcsaf.org.

Ref.	***Title***	***Code***	***Version***
[AD.1]	Proposal for the Second Continuous Development and Operations Phase (CDOP2)	NWC/CDOP2/MGT/AEMET/PRO	1.0
[AD.2]	NWC SAF CDOP-2 Project Plan	NWC/CDOP2/SAGF/AEMET/MGT/PP	1.9
[AD.3]	Configuration Management Plan for NWCSAF	NWC/CDOP2/SAF/AEMET/MGT/CMP	1.4
[AD.4]	NWC SAF Product Requirements Document	NWC/CDOP2/SAF/AEMET/MGT/PRD	1.9
[AD.5]	Interface Control Document for Internal and External Interfaces of the NWC/GEO	NWC/CDOP2/AEMET/SW/ICD/1	1.1
[AD.6]	Data Output Format for the NWC/GEO	NWC/CDOP2/AEMET/SW/DOF	1.1
[AD.7]	System Version Document for the NWC/GEO	NWC/CDOP2/AEMET/SW/SCVD	1.1
[AD.8]	Estimation of computer environment needs to run NWC SAF products operatively in ‘Rapid scan mode’	NWC/CDOP/INM/SW/RP/01	1.0
[AD.9]	Validation Report for “High Resolution Winds” (HRW – PGE09 v2.2)	NWC/CDOP/INM/SCI/VR/05	1.0
[AD.10]	Validation Report for “High Resolution Winds” (HRW – PGE09 v3.0)	NWC/CDOP/INM/SCI/VR/07	1.0
[AD.11]	Validation Report for “High Resolution Winds” (HRW – PGE09 v3.1)	NWC/CDOP/INM/SCI/VR/09	1.0
[AD.12]	Validation Report for “High Resolution Winds” (HRW – PGE09 v3.2)	NWC/CDOP/INM/SCI/VR/10	1.0
[AD.13]	Validation Report for “High Resolution Winds” (HRW – PGE09 v4.0)	NWC/CDOP2/INM/SCI/VR/13	1.0
[AD.14]	Algorithm Theoretical Basis Document for the Wind product processors of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SCI/ATBD/Wind	1.1
[AD.15]	User Manual for the Wind product processors of the NWC/GEO: Software part	NWC/CDOP2/GEO/AEMET/SCI/ATBD/Wind	1.0
[AD.16]	User Manual of the GOES2NC tool	NWC/CDOP2/GEO/AEMET/SW/UM/GOES2NC	1.0

Table 1. List of Applicable Documents

1.3.2 Reference Documents

The reference documents contain useful information related to the subject of the project. These reference documents complement the applicable ones, and can be looked up to enhance the information included in this document if it is desired. They are referenced in this document in the form [RD.X].

For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the current edition of the document referred applies.

Ref.	Title
[RD.1]	J.Schmetz, K.Holmlund, J.Hoffman, B.Strauss, B.Mason, V.Gärtner, A.Koch, L. van de Berg, 1993: Operational Cloud-Motion Winds from Meteosat Infrared Images (Journal of Applied Meteorology, Num. 32, pp. 1206-1225).
[RD.2]	S.Nieman, J.Schmetz, W.P.Menzel, 1993: A comparison of several techniques to assign heights to cloud tracers (Journal of Applied Meteorology, Num. 32, pp. 1559-1568).
[RD.3]	C.M.Hayden & R.J.Purser, 1995: Recursive filter objective analysis of meteorological fields, and application to NESDIS operational processing (Journal of Applied Meteorology, Num. 34, pp. 3-15).
[RD.4]	K.Holmlund, 1998: The utilisation of statistical properties of satellite derived Atmospheric Motion Vectors to derive Quality Indicators (Weather and Forecasting, Num. 13, pp. 1093-1104).
[RD.5]	J.M.Fernández, 1998: A future product on HRVIS Winds from the Meteosat Second Generation for nowcasting and other applications. (Proceedings 4th International Wind Workshop, EUMETSAT Pub.24, pp.281-288).
[RD.6]	J.M.Fernández, 2000: Developments for a High Resolution Wind product from the HRVIS channel of the Meteosat Second Generation. (Proceedings 5th International Wind Workshop, EUMETSAT Pub.28, pp.209-214).
[RD.7]	J.M.Fernández, 2003: Enhancement of algorithms for satellite derived winds: the High Resolution and Quality Control aspects. (Proceedings 2003 Meteorological Satellite Conference, EUMETSAT Pub.39, pp.176-182).
[RD.8]	J.García-Pereda & J.M.Fernández, 2006: Description and validation results of the high resolution wind product from HRVIS MSG channel at the EUMETSAT Nowcasting SAF (Proceedings 8th International Wind Workshop, EUMETSAT Pub.47).
[RD.9]	J.García-Pereda, 2008: Evolution of High Resolution Winds Product (HRW), at the Satellite Application Facility on support to Nowcasting and Very short range forecasting (Proceedings 9th International Wind Workshop, EUMETSAT Pub.51).
[RD.10]	J.García-Pereda, 2010: New developments in the High Resolution Winds product (HRW), at the Satellite Application Facility on support to Nowcasting and Very short range forecasting (Proceedings 10th International Wind Workshop, EUMETSAT Pub.56).
[RD.11]	C.M.Hayden & R.T.Merrill, 1988: Recent NESDIS research in wind estimation from geostationary satellite images (ECMWF Seminar Proceedings: Data assimilation and use of satellite data, Vol. II, pp.273-293).
[RD.12]	W.P.Menzel, 1996: Report on the Working Group on verification statistics. (Proceedings 3rd International Wind Workshop, EUMETSAT Pub.18, pp.17-19).
[RD.13]	J.Schmetz, K.Holmlund, A.Ottenbacher, 1996: Low level winds from high resolution visible imagery. (Proceedings 3rd international winds workshop, EUMETSAT Pub.18, pp.71-79).
[RD.14]	Xu J. & Zhang Q., 1996: Calculation of Cloud motion wind with GMS-5 images in China. (Proceedings 3rd international winds workshop, EUMETSAT Pub.18, pp.45-52).
[RD.15]	K.Holmlund & C.S.Velden, 1998: Objective determination of the reliability of satellite derived Atmospheric Motion Vectors (Proceedings 4th International Wind Workshop, EUMETSAT Pub.24, pp.215-224).
[RD.16]	K.Holmlund, C.S.Velden & M.Rohn, 2000: Improved quality estimates of Atmospheric Motion Vectors utilising the EUMETSAT Quality Indicators and the UW/CIMSS Autoeditor (Proceedings 5th International Wind Workshop, EUMETSAT Pub.28, pp.72-80).
[RD.17]	R.Borde & R.Oyama, 2008: A direct link between feature tracking and height assignment of operational Atmospheric Motion Vectors (Proceedings 9th International Wind Workshop, EUMETSAT Pub.51).
[RD.18]	J.García-Pereda, R.Borde & R.Randriamampianina, 2012: Latest developments in “NWC SAF High Resolution Winds” product (Proceedings 11th International Wind Workshop, EUMETSAT Pub.60).
[RD.19]	WMO Common Code Table C-1 (WMO Publication, available at http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/WMO306_vI2_CommonTable_en.pdf)
[RD.20]	M.Dragosavac, 2007: BUFR Reference Manual (ECMWF Operations Department Publication, available at https://www.wmo.int/pages/prog/gcos/documents/gruanmanuals/ECMWF/bufr_reference_manual.pdf)
[RD.21]	P.Lean, G.Kelly & S.Migliorini, 2014: Characterizing AMV height assignment errors in a simulation study (Proceedings 12th International Wind Workshop, EUMETSAT Pub.63).
[RD.22]	Á.Hernández-Carrascal & N.Bormann, 2014: Cloud top, Cloud centre, Cloud layer – Where to place AMVs? (Proceedings 12th International Wind Workshop, EUMETSAT Pub.63).
[RD.23]	K.Salonen & N.Bormann, 2014: Investigations of alternative interpretations of AMVs (Proceedings 12th International Wind Workshop, EUMETSAT Pub.63).
[RD.24]	D.Santek, J.García-Pereda, C.Velden, I.Genkova, S.Wanzong, D.Stettner & M.Mindock, 2014: 2014 AMV Intercomparison Study Report - Comparison of NWC SAF/HRW AMVs with AMVs from other producers (NWC SAF Visiting Scientist Report, available at http://www.nwcsaf.org/HD/files/vsadoc/CIMSS_AMV_Comparison_FinalReport_04July2014.pdf)
[RD.25]	D.J.Seidel, B.Sun, M.Pettey & A.Reale, 2011: Global radiosonde balloon drift statistics (Journal of Geophysical Research, Num. 116).

Table 2. List of Reference Documents

2. DESCRIPTION OF THE VALIDATION PROCEDURE

2.1 VALIDATION PROCEDURE

Relevant data for the validation, from the corresponding NWC/GEO-HRW output BUFR files, are converted into McIDAS MD files, following a scheme called HRW1. Structure of data in this scheme and its correspondence with BUFR parameters is shown in the following table:

ROW/ELEMENT	BUFR DESCRIPTOR	PARAMETER	HRW1 SCHEME DESCRIPTION
Row 01	001007	SS	Satellite Identifier
Row 02	004001/002/003	DAY	Day
Row 03	004004/005	TIME	Time
Row 04	004025	INTT	Time displacement
Row 05	031002	CMAX	Number of HRW winds at slot
Element 01	060100	IDN	Wind sequence number
Element 02	060102	TYPE	Characterization as Basic or Detailed tracer, and Type of Detailed tracer
Element 03	002028	SIZX	Segment size at nadir in X direction in kms
Element 04	002029	SIZY	Segment size at nadir in Y direction in kms
Element 05	060103	TYPL	Characterization as Cloudy or Clear air wind, and Height assignment method used
Element 06	002164	TYPT	Euclidean Distance or Cross Correlation
Element 07	005001	LAT	Initial latitude
Element 08	006001	LON	Initial longitude
Element 09	005011	DLAT	Latitude increment
Element 10	006011	DLON	Longitude increment
Element 11	012001	T	Wind Temperature
Element 12	007004	P	Wind Pressure
Element 13	011001	DIR	Wind Direction
Element 14	011002	SPD	Wind Speed
Element 15	033007	YT	Wind Quality index (using forecast)
Element 19	033007	YYT	Wind Quality index (not using forecast)
Element 23	060202	TES2	Two scale quality test flag
Element 24	060202	TEST	Temporal quality test flag
Element 25	060202	TESE	Spatial quality test flag
Element 26	060202	TESG	Forecast quality test flag
Element 27	060201	TESA	Correlation test flag
Element 28	060203	AVAT	Number of NWP levels used in HRW calculation
Element 29	060204	AVAW	Number of Predecessor winds in the trajectory
Element 30	060200	WREP	Number of Computed winds for the tracer
Element 31	060101	IDN0	Number of Predecessor wind in the previous slot
Element 32	060205	FLAT	Orographic flag
Element 33	060202	TESI	Orographic test flag
Element 36	060206	CT	Wind cloud type
Element 37	060207	WCH	Satellite channel (5:HRVIS, 2:VIS06/VIS07, 3:VIS08, 10:WV062/WV065, 12:WV073, 16:IR108/IR107, 17:IR120)
Element 38	060208	CORR	Correlation between tracer and tracking centre
Element 39	060209	PERR	Wind pressure error

Table 3. Description of McIDAS HRW1 Scheme and Correspondence with HRW BUFR file

Comparisons are elaborated through a procedure which uses on one side the given MD files, and on the other side Radiosoundings loaded from the GTS. Comparisons are available through MD files following a specific scheme called WCOH. The structure of data included in this WCOH scheme, and its correspondence with parameters in the HRW1 scheme, is shown also in the following table:

ROW/ELEMENT	WCOH PARAMETER	WCOH SCHEME DESCRIPTION	HRW1 CORRESPONDENCE
Row 01	DAY	Day	DAY
Element 01	COL	Number of Collocation	
Element 02	DIST	Maximum Distance admitted	
Element 03	DIFP	Maximum Pressure difference admitted	
Element 04	PMAX	Maximum Pressure admitted	
Element 05	TIME	Time	TIME
Element 06	LAT	HRW Wind Latitude	LAT
Element 07	LON	HRW Wind Longitude	LON
Element 08	DIR	HRW Wind Direction	DIR
Element 09	SPD	HRW Wind Speed	SPD
Element 10	PW	HRW Wind Pressure	P
Element 11	QI	HRW Wind Quality with forecast	YT
Element 12	TEST	HRW Wind Spatial Test, Wind channel, Number of winds for the tracer	200*TESE+10*WCH+WREP
Element 13	UQI	HRW Wind Quality without forecast	YYT
Element 14	TYPE	Characterization as Basic or Detailed tracer, and Type of Detailed tracer	TYPE
Element 15	CH	Characterization of Height assignment method used with/without correction, Calculation threshold, Cloud phase	TYPL
Element 16	WM	Euclidean Distance or Cross Correlation tracking	TYPT
Element 17	TIM1	Radiosounding Time	
Element 18	TYP1	Radiosounding Observational Type	
Element 19	IDN	Radiosounding Station Indicative	
Element 21	LAT1	Radiosounding Latitude	
Element 22	LON1	Radiosounding Longitude	
Element 23	DIR1	Radiosounding Direction	
Element 24	SPD1	Radiosounding Speed	
Element 25	P	Radiosounding Pressure	
Element 26	FLAG	HRW Wind AMV Orographic Flag	FLAI
Element 27	PS	HRW Wind Cloud phase	

Table 4. Description of McIDAS WCOH Scheme and Correspondence with HRW1 Scheme

The HRW Validation statistical parameters select data from the WCOH MD files considering the value of some specific parameters, and calculate the corresponding validation statistics.

2.2 STATISTICAL PARAMETERS

The statistical parameters for the comparison between NWC/GEO-HRW Atmospheric Motion Vectors (AMVs) and Radiosounding winds are the ones proposed at the Third International Winds Workshop (Ascona, Switzerland, 1996), afterwards recommended by the Coordination Group for Meteorological Satellites (CGMS) for the international comparison of satellite winds.

All winds are compared to the nearest Radiosounding wind, with a maximum distance of 150 km and a maximum pressure difference of 25 hPa (standard limits defined for the comparison of AMVs with Radiosounding winds). From now on, in this document, all AMV validation parameters shown are calculated with these collocated Radiosounding winds.

A description of these statistical parameters follows:

1. N: Number of collocations between Radiosounding wind vectors [Ur,Vr] and GEO-HRW AMV wind vectors [Ui,Vi].

2. SPD: Mean Radiosounding horizontal wind speed, considering all collocated Radiosounding winds in the whole validated vertical layer. For each Radiosounding, the nearest level to the corresponding collocated AMV level is considered only.

3. BIAS: Difference between the mean wind speed of the Radiosounding winds and the collocated GEO-HRW AMVs winds:

$$BIAS = \frac{1}{N}\sum_{i=1}^{N}\left(\sqrt{U_i^2 + V_i^2} - \sqrt{U_r^2 + V_r^2}\right)$$

   It shows an estimation of the systematic error related to the calculation of the wind speed modulus (over- or underestimation of the mean AMV wind speed with respect to the mean Radiosounding wind speed). The index “i” denotes each collocation and runs from 1 to the total number of collocations N.

4. MVD: Mean vector difference between the Radiosounding wind speeds and the GEO-HRW AMV wind speeds:

$$MVD = \frac{1}{N}\sum_{i=1}^{N} VD_i$$

   It shows an estimation of the systematic error related to the calculation of vectors, where

$$VD_i = \sqrt{(U_i - U_r)^2 + (V_i - V_r)^2}$$

5. RMSVD: Root mean square vector difference:

$$RMSVD = \sqrt{(MVD)^2 + (SD)^2}$$

   It shows an estimation of the systematic and random error related to the calculation of the wind vectors. It is calculated through the Mean vector difference (MVD), and the Standard deviation of each vector difference with respect to the mean, where

$$SD = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(VD_i - MVD)^2}$$

Due to the variable magnitude the defined statistical parameters can have in different samples, the mean Radiosounding horizontal wind speed SPD (parameter 2) is used for normalization. So, the relative parameters related to the ones before:

3a. NBIAS = BIAS / SPD,

4a. NMVD = MVD / SPD,

5a. NRMSVD = RMSVD / SPD,

which are independent of the magnitude of the winds and can more easily be compared in different samples of data, are going to be used and presented throughout this Validation report.

2.3 IMPACT OF THE REPRESENTATIVITY OF THE RADIOSOUNDING WINDS

No consideration is taken here on the impact in the AMV validation statistics, caused by the displacement of the Radiosounding during its ascent, or by differences between the nominal sounding time and the real data acquisition time.

Two studies are done here to evaluate this issue. In these studies, seven days of statistics for MSG AMVs with NWC/GEO-HRW-v5.0 algorithm are considered (03-09 March 2016). Although this sample is small, it is considered enough to show the trends caused by variations in the maximum distance and the time difference between the AMV and the reference Radiosounding wind.

In the first study, statistics are considered for maximum distances between the AMV and the reference Radiosounding wind between 20 and 300 km. The standard validation statistics defined previously are provided for these conditions. It can be seen that the impact of the distance in the validation parameters is around a 33% with distances up to 100 km, around a 50% with distances up to 150 km, and around a 100% with distances up to 300 km. The "150 km" value can be seen as a compromise value which maximizes the number of validated AMV data while keeping still the representativity of the statistics.

Maximum distance	N	SPD	NBIAS	NMVD	NRMSVD
20 km	222	17.986	-0.03	0.18	0.24
40 km	871	17.636	-0.05	0.21	0.26
70 km	2563	17.821	-0.07	0.23	0.28
100 km	4892	18.291	-0.08	0.25	0.31
150 km	10431	19.019	-0.08	0.28	0.35
200 km	17481	19.292	-0.06	0.31	0.39
250 km	24937	19.696	-0.07	0.34	0.42
300 km	30901	19.634	-0.06	0.37	0.46

Table 5: Validation parameters for a sample of GEO-HRW-v50 considering variations of the maximum distance with the reference Radiosounding winds (03-09 March 2016, MSG2 satellite, 12:00 UTC, European and Mediterranean area; Basic AMVs; Cross correlation tracking; CCC height assignment with Microphysics correction)

Related to this, studies have been published about the distance drift the Radiosounding balloon can have during its ascent and measurement (which includes an additional factor of distance error to be taken into account, in the comparison between the AMVs and the Radiosounding winds). A two year study is for example available at Seidel et al. [RD.25]. It shows that the distance drift of the Radiosounding balloon has medium/maximum values of 5/15 km at 700 hPa, 10/30 km at 500 hPa, 20/60 km at 300 hPa, and 40/130 km at 100 hPa.

For AMVs at low and medium levels this distance drift causes negligible effects in the validation statistics (causing errors up to a 10%-15% only). Only for a small part of AMVs near 100 hPa, level at which there are besides very few AMVs, can this impact be more significant.

Considering the time drift in the Radiosounding balloon, the same study estimates it reaches 700 hPa in less than 10 minutes, 400 hPa in less than 25 minutes, and 100 hPa in less than 55 minutes. So, AMV validation statistics are affected by a time drift in the radiosounding measurement of up to an hour, especially at the high levels.

Validation statistics for the same sample of GEO-HRW-v5.0 AMVs, considering time drifts between the AMV and the Radiosounding wind nominal time between 0 and 12 hours, are shown next. The standard validation statistics defined here are also provided for these conditions. It can be seen that with differences smaller than three hours, the errors in the validation statistics are smaller than 10%. Only with three hours and longer intervals, the errors increase more noticeably.

Time difference	N	SPD	NBIAS	NMVD	NRMSVD
0 minutes	10431	19.019	-0.08	0.28	0.35
15 minutes	10303	19.127	-0.08	0.28	0.35
30 minutes	9568	19.184	-0.08	0.27	0.34
45 minutes	9578	19.372	-0.08	0.28	0.34
1.0 hour	11076	18.548	-0.09	0.28	0.35
1.5 hours	11327	18.834	-0.09	0.29	0.35
2.0 hours	10897	18.832	-0.09	0.30	0.36
2.5 hours	10549	18.901	-0.09	0.30	0.36
3.0 hours	10329	18.539	-0.09	0.32	0.39
4.5 hours	8384	18.273	-0.06	0.35	0.44
6.0 hours	8209	20.501	-0.09	0.38	0.47
9.0 hours	9205	20.495	-0.11	0.52	0.66
12.0 hours	9937	18.924	-0.05	0.69	0.93

Table 6: Validation parameters for a sample of GEO-HRW-v50 considering variations of the time difference with the reference Radiosounding winds (03-09 March 2016, MSG2 satellite, 12:00 UTC, European and Mediterranean area; Basic AMVs; Cross correlation tracking; CCC height assignment with Microphysics correction)

Considering all this, it can be concluded that the distance drift caused by the Radiosounding balloon during its ascension has only an impact in the validation statistics of a small part of AMVs near the level of 100 hPa. It can also be concluded that the time drift caused by the Radiosounding balloon during its ascension (less than an hour up to 100 hPa), and any differences between the nominal and real start of the Radiosounding measurement (which in normal conditions should never be worse than 1.5 hours), have a very limited impact in the AMV statistics, and can in general be discarded.

If a modification should be considered for the validation of AMVs, the most convenient one could be to reduce the maximum distance between the AMV and the reference wind to a value around "100 km" (which would directly reduce errors by at least a 10%), and maybe to take into account the distance drift of the Radiosounding balloon in the validation of AMVs at high levels.

But, due to the fact that this validation procedure is standard for all AMV producers in the world, it should be considered by all of them at the same time, so that the validation statistics produced by all of them would still be homogeneous.

3. VALIDATION OF GEO-HRW-V50 MSG BASIC AMVS

The validation of GEO-HRW-v50 algorithm for MSG satellite series is considered first. It is based on the validation of GEO-HRW AMVs calculated during the whole year July 2009 – June 2010 with MSG2 satellite images in Nominal scan mode (every 15 minutes) in an area covering Europe and the Mediterranean Sea. This area is shown in *Figure 1*.

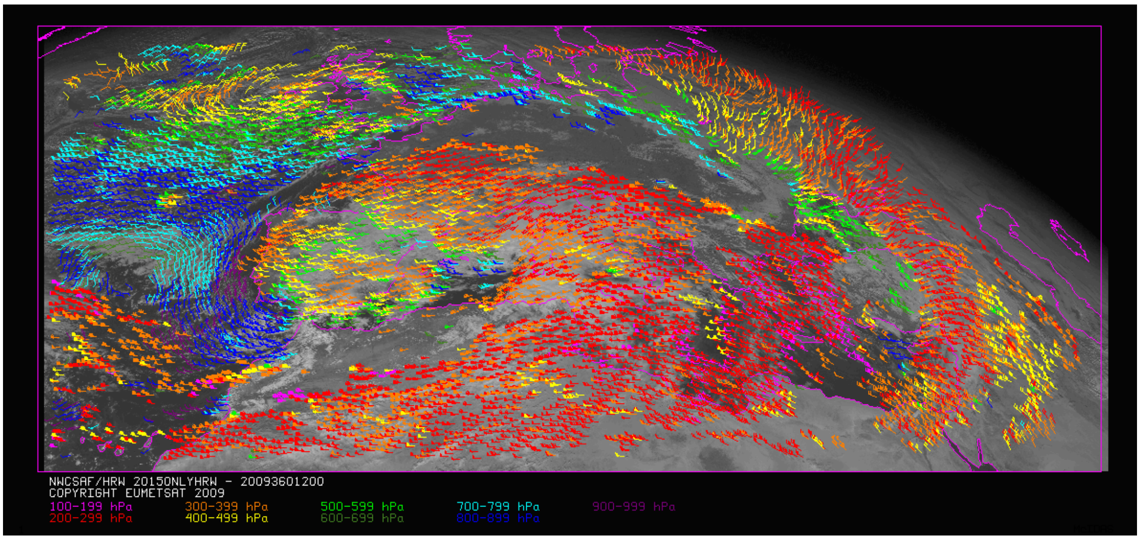

Figure 1: NWC/GEO High Resolution Winds v2016 Basic AMV output example in the European and Mediterranean region (26 December 2009 1200Z, Nominal scan mode, MSG2 satellite), considering default conditions defined in $SAFNWC/config/safnwc_HRW.cfm.MSG15MIN model configuration file. Colour coding based on the AMV pressure level

The default conditions for GEO-HRW-v50 for MSG satellites, considering “Basic scale AMVs” with “Cross correlation tracking” and “CCC height assignment method with Microphysics correction” are used first. These conditions are specified in `$SAFNWC/config/safnwc_HRW.cfm.MSG15MIN` model configuration file, with all satellite channels being validated. Cloudy AMVs in the layer 100-1000 hPa and clear air AMVs in the layer 100-425 hPa, with a Quality index with forecast ≥ 70 in the High and Medium layer and a Quality index with forecast ≥ 75 in the Low layer, are considered for this validation.

NWC/GEO Cloud product outputs (CMA, CT, CTTH and CMIC) in the processing region have to be available so that GEO-HRW-v50 can fully process the conditions defined in the given model configuration file.

Comparing validation results with those required by the GEO-HRW Product Requirement Table, the “Target accuracy” (with values respectively of 0.44, 0.50 and 0.56) is reached in all layers (High, Medium and Low) by the MSG AMVs during both daytime and nighttime.

The “Optimal accuracy” (with a value of 0.35) is even reached in the High layer by the MSG AMVs during daytime (not during nighttime, due to the smaller contrasts in brightness temperatures occurring at this moment, so still giving room for improvement in the AMVs calculated with this satellite series at all layers).

3.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION (DAY)

Validation for midday (1200Z) AMVs, calculated running NWC/GEO Cloud products (CMA, CT, CTTH and CMIC) and GEO-HRW-v50 product for three consecutive slots (1130Z, 1145Z and 1200Z) every day during the reference validation period, are considered first and shown in *Table 7*.

Statistics have been provided considering each satellite channel separately and altogether, and each layer separately and altogether (High layer between 100 and 400 hPa, Medium layer between 400 and 700 hPa, and Low layer between 700 and 1000 hPa). Cloudy AMVs and Clear air AMVs are also considered separately (cloudy AMVs based on the tracking of a tracer related to a cloud feature; clear air AMVs based on the tracking of a tracer related to a humidity feature in the water vapour channels).

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV62	Cloudy WV73	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
N	31630	97221	87177	256951	331831	313072	317120	48509	1483511
SPD [m/s]	16.64	10.51	10.48	22.78	20.80	18.53	18.67	16.64	18.70
NBIAS (ALL LAYERS)	-0.04	-0.14	-0.15	-0.04	-0.07	-0.09	-0.08	-0.00	-0.08
NMVD (100-1000 hPa)	0.29	0.41	0.42	0.26	0.28	0.29	0.29	0.32	0.30
NRMSVD	0.35	0.49	0.49	0.32	0.35	0.35	0.35	0.39	0.36
N	14748			235550	238459	186143	193173	41261	909334
SPD [m/s]	21.77			23.31	23.15	22.16	22.11	17.19	22.48
NBIAS (HIGH LAYER)	-0.03			-0.04	-0.08	-0.08	-0.07	-0.01	-0.07
NMVD (100-400 hPa)	0.24			0.26	0.26	0.26	0.26	0.31	0.26
NRMSVD	0.29			0.31	0.32	0.32	0.31	0.38	0.32
N	8532	37419	34188	21401	84678	86936	86010	7248	366412
SPD [m/s]	14.64	12.08	11.94	16.90	15.10	14.61	14.69	13.51	14.35
NBIAS (MEDIUM LAYER)	-0.05	-0.18	-0.18	0.02	-0.05	-0.12	-0.11	0.09	-0.10
NMVD (400-700 hPa)	0.31	0.38	0.38	0.37	0.37	0.35	0.35	0.40	0.36
NRMSVD	0.48	0.46	0.45	0.46	0.45	0.43	0.43	0.47	0.44
N	8350	59802	52989		8694	39993	37937		207765
SPD [m/s]	9.64	9.52	9.54		12.09	10.14	10.18		9.88
NBIAS (LOW LAYER)	-0.02	-0.12	-0.12		-0.09	-0.12	-0.12		-0.11
NMVD (700-1000 hPa)	0.44	0.44	0.44		0.38	0.41	0.40		0.43
NRMSVD	0.52	0.51	0.52		0.46	0.48	0.48		0.50

Table 7: Validation parameters for GEO-HRW-v50
(Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean area;
Basic AMVs; Cross correlation tracking; CCC height assignment with Microphysics correction)

In common with all AMV procedures, statistics are better for the High layer and degrade progressively for the Medium and Low layer.

Comparing the statistics for the different satellite channels, the MVD and NRMSVD seem very different considering all layers together, with changes larger than the 50% between the best case (Cloudy WV062 AMVs) and the worst case (Cloudy VIS08 AMVs). Nevertheless, this is only caused by the different proportion of AMVs in the different layers for each channel. Inside each one of them, differences of NMVD and NRMSVD for the different channels are much smaller.

3.2 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION (NIGHT)

Validation for midnight (0000Z) AMVs, calculated running NWC/GEO Cloud products (CMA, CT, CTTH and CMIC) and GEO-HRW-v50 product for three consecutive slots (2330Z, 2345Z and 0000Z) every night during the reference validation period, using equivalent conditions to those defined previously for midday AMVs, are shown in *Table 8*. These statistics are provided for the first time in GEO-HRW validation to evaluate differences between day and night AMVs.

Statistics are provided again considering each satellite channel separately and altogether, and each layer separately and altogether (high, medium and low layer). Cloudy AMVs and Clear air AMVs are also considered separately.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV62	Cloudy WV73	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
N				220908	306730	291064	294753	51382	1164837
SPD [m/s]				23.72	21.36	19.20	19.29	16.50	20.53
NBIAS (ALL LAYERS)				-0.07	-0.10	-0.11	-0.10	-0.05	-0.10
NMVD (100-1000 hPa)				0.28	0.30	0.30	0.30	0.33	0.30
NRMSVD				0.38	0.39	0.41	0.42	0.42	0.40
N				202087	222193	169895	174532	41314	810021
SPD [m/s]				24.35	23.81	23.00	22.95	17.22	23.25
NBIAS (HIGH LAYER)				-0.08	-0.11	-0.11	-0.10	-0.06	-0.09
NMVD (100-400 hPa)				0.28	0.28	0.28	0.28	0.32	0.28
NRMSVD				0.37	0.37	0.39	0.39	0.41	0.38
N				18821	81000	96920	96368	10068	303177
SPD [m/s]				16.98	15.06	14.75	14.87	13.53	14.97
NBIAS (MEDIUM LAYER)				0.01	-0.08	-0.13	-0.12	-0.02	-0.10
NMVD (400-700 hPa)				0.36	0.36	0.35	0.35	0.37	0.36
NRMSVD				0.46	0.48	0.45	0.46	0.45	0.46
N					3537	24249	23853		51639
SPD [m/s]					11.91	10.36	10.38		10.48
NBIAS (LOW LAYER)					-0.01	-0.12	-0.11		-0.10
NMVD (700-1000 hPa)					0.40	0.40	0.40		0.40
NRMSVD					0.47	0.47	0.47		0.47

Table 8: Validation parameters for GEO-HRW-v50
(Jul 2009-Jun 2010, MSG2 satellite, 00:00 UTC, European and Mediterranean area;
Basic AMVs; Cross correlation tracking; CCC height assignment with Microphysics correction)

Although some visible AMVs could be formally calculated at this validation moment (00:00Z) in the weeks around the summer solstice, sun angle thresholds in GEO-HRW algorithm remove these AMV data. So, only statistics for infrared and water vapour channels are provided.

Comparing with 12:00Z statistics, there is a reduction of about 20% in the amount of infrared and water vapour data, and a degradation of between 10% and 20% in the NBIAS and NRMSVD considering all layers altogether. This was expected, and understandable due to the smaller contrasts in brightness temperature which can be seen during the nighttime respect to the daytime.

3.3 COMPARISON WITH GEO-HRW-V40 DEFAULT CONFIGURATION

The default conditions defined in chapter 3.1 are equivalent to those defined in the Validation statistics for the previous version of GEO-HRW algorithm (GEO-HRW-v40 or GEO-HRW v2013), which are shown in *Table 9.* So a comparison between both versions can be made.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV62	Cloudy WV73	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
N	47280	100836	91677	189804	262992	251524	252375	43004	1239492
SPD [m/s]	16.14	11.04	11.04	23.51	21.28	19.58	19.74	16.52	19.01
NBIAS (ALL LAYERS)	-0.10	-0.18	-0.18	-0.06	-0.08	-0.12	-0.11	0.00	-0.10
NMVD (100-1000 hPa)	0.31	0.42	0.42	0.26	0.28	0.30	0.29	0.33	0.31
NRMSVD	0.38	0.50	0.50	0.32	0.35	0.37	0.36	0.40	0.38
N	20317			181417	198792	167513	171248	37454	776741
SPD [m/s]	23.22			23.76	23.24	22.85	22.83	16.98	22.88
NBIAS (HIGH LAYER)	-0.10			-0.06	-0.09	-0.12	-0.11	-0.01	-0.09
NMVD (100-400 hPa)	0.26			0.25	0.26	0.27	0.27	0.32	0.27
NRMSVD	0.31			0.31	0.32	0.34	0.33	0.39	0.33
N	12774	51714	48729	8387	57466	50698	49329	5550	284647
SPD [m/s]	12.84	12.68	12.54	17.96	15.62	15.27	15.34	13.45	14.35
NBIAS (MEDIUM LAYER)	-0.13	-0.20	-0.21	0.00	-0.03	-0.11	-0.09	0.10	-0.12
NMVD (400-700 hPa)	0.37	0.40	0.40	0.34	0.37	0.35	0.36	0.40	0.37
NRMSVD	0.45	0.47	0.48	0.42	0.45	0.43	0.44	0.47	0.45
N	14189	49122	42948		6734	33313	30699		177005
SPD [m/s]	8.96	9.31	9.32		11.90	9.73	9.83		9.55
NBIAS (LOW LAYER)	-0.06	-0.13	-0.13		-0.03	-0.09	-0.10		-0.11
NMVD (700-1000 hPa)	0.46	0.45	0.46		0.42	0.42	0.42		0.44
NRMSVD	0.54	0.53	0.54		0.50	0.50	0.50		0.52

Table 9: Validation parameters for GEO-HRW-v40 (HRW v2013)
(Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean area;
Basic AMVs; Cross correlation tracking; CCC height assignment without Microphysics correction)

It can be seen that all Validation parameters improve for GEO-HRW-v50, with:

- An increase in the amount of compared AMVs of about a 20% (from 1239492 to 1483511),
- A reduction in the NBIAS of about a 20% (from -0.10 to -0.08),
- Smaller reductions in the NMVD (from 0.31 to 0.30) and NRMSVD (from 0.38 to 0.36).

This improvements can be seen considering all layers altogether, and also each layer separately. So, the evolution of GEO-HRW-v50 respect to previous versions of the algorithm is positive, for each layer and altogether, providing more AMV data with a better quality.

3.4 VALIDATION FOR BASIC AMVS WITHOUT MICROPHYSICS CORRECTION

Validation for midday (1200Z) AMVs using "CCC method height assignment" but without the Microphysics correction, is also presented to specifically verify the impact the Microphysics correction might be having in the calculated AMVs. These results are presented in *Table 10*.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV62	Cloudy WV73	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
N	32082	96208	87359	251575	318869	314333	317890	48781	1467097
SPD [m/s]	17.43	10.88	10.86	22.46	20.72	19.33	19.47	16.66	19.01
NBIAS (ALL LAYERS)	-0.07	-0.16	-0.16	-0.03	-0.07	-0.12	-0.11	-0.00	-0.09
NMVD (100-1000 hPa)	0.29	0.41	0.42	0.27	0.28	0.30	0.29	0.32	0.30
NRMSVD	0.35	0.49	0.50	0.33	0.35	0.36	0.36	0.39	0.37
N	17434			232951	235317	205011	211469	41450	943632
SPD [m/s]	22.31			22.90	22.78	22.65	22.61	17.21	22.49
NBIAS (HIGH LAYER)	-0.07			-0.04	-0.07	-0.11	-0.10	-0.01	-0.08
NMVD (100-400 hPa)	0.25			0.26	0.26	0.27	0.27	0.31	0.27
NRMSVD	0.30			0.32	0.32	0.33	0.33	0.38	0.33
N	7225	45328	42477	18624	74709	74235	72961	7331	342890
SPD [m/s]	13.78	12.41	12.23	17.01	15.29	14.56	14.65	13.53	14.26
NBIAS (MEDIUM LAYER)	-0.08	-0.19	-0.19	0.03	-0.05	-0.14	-0.13	0.09	-0.12
NMVD (400-700 hPa)	0.34	0.39	0.39	0.37	0.36	0.36	0.36	0.40	0.37
NRMSVD	0.41	0.46	0.47	0.45	0.44	0.44	0.44	0.47	0.45
N	7423	50880	44882		8843	35087	33460		180575
SPD [m/s]	9.51	9.52	9.55		11.86	10.06	10.11		9.86
NBIAS (LOW LAYER)	-0.03	-0.12	-0.13		-0.09	-0.12	-0.12		-0.12
NMVD (700-1000 hPa)	0.44	0.44	0.45		0.39	0.42	0.42		0.43
NRMSVD	0.51	0.52	0.53		0.46	0.49	0.49		0.51

Table 10: Validation parameters for GEO-HRW-v50
(Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean area;
Basic AMVs; Cross correlation tracking; CCC height assignment without Microphysics correction)

Comparing with the statistics for GEO-HRW-v40 in *Table 9*, and the statistics for GEO-HRW-v50 with Microphysics correction in *Table 7*, it can be seen that around half of the improvement in the AMVs is caused by the Microphysics correction, and the other half is caused by other changes included in GEO-HRW-v2016 (basically, changes caused by the new NWCLIB library, the inclusion of a new and better version of NWC/GEO Clouds, and other changes included in the processing of NWC/GEO-HRW algorithm).

More information about all these changes in GEO-HRW-v50 algorithm can be found in the "Algorithm Theoretical Basis Document for the Wind product processors of the NWC/GEO" [AD.14].

3.5 VALIDATION FOR BASIC AMVS WITHOUT CLOUD PRODUCTS

Validation for midday (1200Z) and midnight (0000Z) AMVs for the situation in which NWC/GEO Cloud are not available, and so "Brightness temperature interpolation height assignment without Cloud products" has to be used, are presented now in *Tables 11 and 12*. So users are able to know what they can expect from GEO-HRW-v50 algorithm when they cannot run NWC/GEO Clouds.

Results can be compared with those results in *Tables 7 and 8* for daytime and nighttime respectively, in which NWC/GEO Cloud products were available and all options of GEO-HRW-v50 algorithm could be implemented. Water vapour AMVs (Cloudy and Clear air) are presented together, due to the impossibility to differentiate them due to the lack of Cloud products.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	HRVIS	VIS06	VIS08	WV62	WV73	IR108	IR120	All AMVs
N	23855	74554	69975	317904	321140	149190	162831	1119449
SPD [m/s]	16.08	11.59	11.63	22.11	18.04	16.84	16.78	17.98
NBIAS (ALL LAYERS)	-0.01	-0.06	-0.06	-0.04	0.02	0.02	0.02	-0.00
NMVD (100-1000 hPa)	0.31	0.38	0.38	0.27	0.34	0.31	0.32	0.32
NRMSVD	0.38	0.46	0.45	0.33	0.42	0.38	0.39	0.39
N	8417			310650	132497	40419	45913	537896
SPD [m/s]	22.48			22.19	21.24	24.78	24.57	22.36
NBIAS (HIGH LAYER)	-0.02			-0.03	0.02	-0.00	-0.00	-0.01
NMVD (100-400 hPa)	0.24			0.27	0.29	0.25	0.25	0.27
NRMSVD	0.29			0.33	0.34	0.30	0.30	0.33
N	9037	30312	29333	7254	191643	65549	70573	403701
SPD [m/s]	14.35	14.65	14.62	18.80	15.83	16.22	15.96	15.76
NBIAS (MEDIUM LAYER)	-0.00	-0.07	-0.07	-0.19	0.02	0.06	0.07	0.02
NMVD (400-700 hPa)	0.35	0.34	0.34	0.43	0.40	0.34	0.35	0.37
NRMSVD	0.43	0.41	0.40	0.53	0.49	0.42	0.43	0.45
N	6401	44242	40642			43222	46345	180852
SPD [m/s]	10.11	9.49	9.47			10.35	10.31	9.92
NBIAS (LOW LAYER)	-0.00	-0.04	-0.05			-0.03	-0.04	-0.04
NMVD (700-1000 hPa)	0.43	0.42	0.42			0.38	0.38	0.40
NRMSVD	0.51	0.50	0.50			0.45	0.45	0.48

Table 11: Validation parameters for GEO-HRW-v50
(Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean area;
Basic AMVs; Cross correlation tracking;
Brightness temperature interpolation height assignment without cloud products)

The general results obtained in all previous versions of GEO-HRW algorithm since 2011 (in which "CCC method" was implemented for the first time) are seen again.

Using "Brightness temperature interpolation height assignment without Cloud products", the quality of daytime AMVs degrades a bit, but not too significantly (NMVD and NRMSVD parameters are up to a 10% larger in all layers except the low layer, for which these parameters are slightly better). The number of calculated AMVs is around a 25% smaller, with the reduction related to the high and low layer. Nevertheless, the NBIAS is shown to be significantly better.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	HRVIS	VIS06	VIS08	WV62	WV73	IR108	IR120	All AMVs
N				266124	314701	154226	163095	898146
SPD [m/s]				22.71	18.29	17.19	17.26	19.22
NBIAS (ALL LAYERS)				-0.06	-0.01	-0.00	-0.00	-0.02
NMVD (100-1000 hPa)				0.28	0.34	0.32	0.32	0.31
NRMSVD				0.38	0.43	0.439	0.39	0.40
N				260361	125203	40102	44187	469853
SPD [m/s]				22.79	21.96	25.54	25.471	23.06
NBIAS (HIGH LAYER)				-0.06	-0.02	-0.04	-0.04	-0.04
NMVD (100-400 hPa)				0.28	0.28	0.26	0.26	0.27
NRMSVD				0.38	0.36	0.33	0.32	0.36
N				5763	189498	77657	81528	354446
SPD [m/s]				18.76	15.86	15.97	15.85	15.93
NBIAS (MEDIUM LAYER)				-0.17	-0.00	0.02	0.02	0.00
NMVD (400-700 hPa)				0.43	0.39	0.34	0.34	0.37
NRMSVD				0.55	0.49	0.41	0.41	0.46
N						36467	37380	73847
SPD [m/s]						10.58	10.64	10.61
NBIAS (LOW LAYER)						-0.01	-0.01	-0.01
NMVD (700-1000 hPa)						0.40	0.40	0.40
NRMSVD						0.48	0.47	0.47

Table 12: Validation parameters for GEO-HRW-v50
(Jul 2009-Jun 2010, MSG2 satellite, 00:00 UTC, European and Mediterranean area;
Basic AMVs; Cross correlation tracking;
Brightness temperature interpolation height assignment without cloud products)

In nighttime AMVs, the effect of “CCC height assignment with Microphysics correction” in the NMSVD and NRMSVD is shown to be smaller (so showing that the NWC/GEO Cloud products are calculated during the nighttime using less satellite channels).

Due to the small differences existing in the NRMSVD parameter with both height assignments, the situation respect to the GEO-HRW Product Requirement Table accuracies is exactly the same (with all layers for both height assignments complying with the “Target accuracy”; high layer AMVs during daytime for both height assignments also complying with the “Optimal accuracy”).

So, NWC/GEO users can perfectly use GEO-HRW-v50 operatively with MSG satellite series, even in the case in which NWC/GEO Clouds are not available.

For clarification for the users, a deeper analysis of the question "Which and in which cases each height assignment method works better?" is going to be done next.

3.6 COMPARISON BETWEEN HEIGHT ASSIGNMENT PROCEDURES

On one side, the fact that "CCC method height assignment with microphysics correction" is able to calculate around a 25% more of AMVs than "Brightness temperature interpolation height assignment without Cloud products" with similar quality thresholds and NMVD/NRMSVD validation parameters, should be a cause to prefer this height assignment method in the AMV processing.

On the other side, calculating statistics respect to the "Radiosounding best fit level", which means the best possible statistics only through changes in the height assignment, both height assignment procedures show NBIAS values of 0.00, NMVD values of 0.20, and NRMSVD values of 0.33. So, it can be seen that any additional impact of the height assignment in the validation statistics is small. The NBIAS can be reduced to zero, but the NMVD and NRMSVD can only be reduced slightly.

One additional question can be raised from this: How both height assignment methods behave considering the "difference between the AMV level and the AMV best fit level respect to Radiosounding data".

Next table shows the mean value of this "difference" and the "absolute difference" between the "AMV best fit level" and the "AMV level", for all layers and both height assignment methods:

	Brightness Temp. Interpolation without Clouds Height Assignment		CCC Method with Microphysics correction Height Assignment	
	Mean $P_{Bestfit} - P_{AMV}$	Mean $\lvert P_{Bestfit} - P_{AMV} \rvert$	Mean $P_{Bestfit} - P_{AMV}$	Mean $\lvert P_{Bestfit} - P_{AMV} \rvert$
100 – 999 hPa (ALL LEVELS)	-41 hPa	120 hPa	-2 hPa	103 hPa
100 – 399 hPa (HIGH LEVEL)	-23 hPa	90 hPa	-2 hPa	85 hPa
400 – 699 hPa (MEDIUM LEVELS)	-67 hPa	165 hPa	-11 hPa	160 hPa
700 – 999 hPa (LOW LEVELS)	-51 hPa	136 hPa	11 hPa	124 hPa

Table 13: "Mean difference" and "Mean absolute difference"
between the "AMV best fit level" and the "AMV level" in the different layers
(Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean area;
Basic AMVs; Cross correlation tracking;
"Brightness temperature interpolation height assignment without cloud products"
compared to "CCC method height assignment with microphysics correction")

"CCC method height assignment with microphysics correction" behaves clearly much better, with a mean "difference" of only 2 hPa with the "AMV best fit level" as a whole, and less than 12 hPa at all three layers (high, medium and low). The dispersion respect to the "AMV best fit level" can nevertheless be important, with a mean value of the "absolute difference" of 103 hPa.

"Brightness temperature interpolation height assignment without Cloud products" behaves much worse, with the "AMV best fit level" located 41 hPa higher in the atmosphere as a whole. This issue (to systematically locate the AMVs at a lower level than the optimal one) can contribute to artificially reduce the NBIAS to 0, when this height assignment is used. So, no worries should occur with the fact of obtaining smaller NBIAS values with this method, because this does not directly mean that the corresponding AMVs are better. On the other side, the "absolute difference" is also higher, with a mean value of 120 hPa.

Next table shows the "difference" and "absolute difference" values between the "AMV best fit level" and the "AMV level", for AMVs related to the different cloud types when "CCC method height assignment with microphysics correction" is used.

	CCC Method with Microphysics correction Height Assignment	
	Mean $P_{Bestfit} – P_{AMV}$	**Mean $\| P_{Bestfit} – P_{AMV} \|$**
Clear air	-66 hPa	124 hPa
Very low cumulus/stratus	4 hPa	116 hPa
Low cumulus/stratus	20 hPa	146 hPa
Medium cumulus/stratus	6 hPa	166 hPa
High cumulus/stratus	7 hPa	103 hPa
Very high cumulus/stratus	26 hPa	89 hPa
High semitransparent thin	-21 hPa	72 hPa
High semitransparent meanly thick	-9 hPa	71 hPa
High semitransparent thick	-7 hPa	84 hPa
High semitransparent above other clouds	-37 hPa	100 hPa

Table 14: “Mean difference” and “Mean absolute difference”
between the “AMV best fit level” and the “AMV level” for the different cloud types
(Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean area;
Basic AMVs; Cross correlation tracking;
“CCC method height assignment with microphysics correction”)

In general, considering the “mean difference” between the “AMV best fit level” and the “AMV level”, all cloud types behave well. Only "clear air AMVs" (which are not affected by the Microphysics correction) and "AMVs related to high semitransparent clouds above other clouds" have differences with respect to the best fit level larger than 26 hPa.

The different behaviour between cumulus/stratus on one side (with a higher dispersion with respect to the best fit level, and a best fit level tending to be at a level nearer to the ground than the AMV level) and cirrus on the other side (with a smaller dispersion with respect to the best fit level, and a best fit tending to be at a level higher in the atmosphere than the AMV level) is also remarkable. These results give a hint about how the "Microphysics correction" could be retuned considering the different cloud types (separating cirrus from cumulus/stratus).

In any case, the results in these two tables give enough confidence to say that “CCC method with microphysics correction” works better as AMV height assignment method, and that it works well for all atmospheric layers and cloud types (being clear air AMVs the ones with a worse behaviour).

4. VALIDATION OF GEO-HRW-V50 MSG DETAILED AMVS

The validation of Detailed AMVs (with a default tracer size of 12x12 pixels instead of the 24x24 pixels considered by the Basic AMVs) for MSG satellite series is considered now. The calculation of Detailed AMVs is activated changing CDET parameter in the GEO-HRW-v5.0 Model configuration file to value ALL or RANGE. They are provided as an additional dataset of AMVs together with the Basic AMVs, which are always calculated.

The conditions for this validation are exactly equivalent to the one shown in chapter 3 for the MSG Basic AMVs. An output example of GEO-HRW Detailed AMVs in the European and Mediterranean region for the same moment shown in *Figure 1* is shown here in *Figure 2*.

A smaller amount of Detailed AMVs is seen comparing both images, which can be explained through the smaller size of the tracers (which affects especially the water vapour channels, in which the image features are generally larger) and the smaller persistence in time of the finest image features (which affects especially the High resolution visible channel, in which the size of the Detailed tracers is the smallest of all: 12x12 km at subsatellite point).

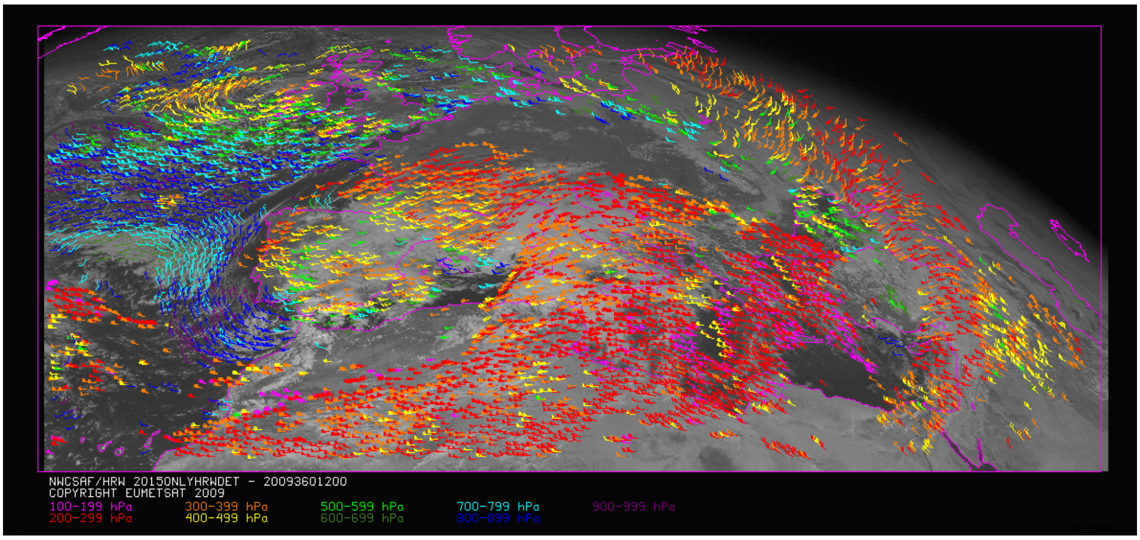

Figure 2: NWC/GEO High Resolution Winds v2016 Detailed AMV output example in the European and Mediterranean region (26 December 2009 1200Z, Nominal scan mode, MSG2 satellite), considering default conditions defined in $SAFNWC/config/safnwc_HRW.cfm.MSG15MIN model configuration file. Colour coding based on the AMV pressure level

4.1 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION

The validation statistics for GEO-HRW-v50 MSG Detailed AMVs using "CCC method height assignment without microphysics correction" at 12:00 UTC, in conditions exactly equivalent to those for Basic AMVs in *Table 7* are presented in next table. Statistics have been provided considering each satellite channel separately and altogether, and each layer separately and altogether.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV62	Cloudy WV73	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
N	12463	89803	86660	114603	211814	256654	257092	7332	1036331
SPD [m/s]	16.16	10.65	10.51	24.46	22.64	19.32	19.54	16.39	19.08
NBIAS (ALL LAYERS)	-0.02	-0.12	-0.12	-0.03	-0.05	-0.06	-0.05	0.07	-0.06
NMVD (100-1000 hPa)	0.29	0.40	0.41	0.25	0.26	0.27	0.27	0.34	0.29
NRMSVD	0.35	0.47	0.48	0.30	0.32	0.33	0.33	0.42	0.35
N	5302			109748	175335	165105	171739	5398	632627
SPD [m/s]	22.34			24.77	24.05	22.50	22.41	17.24	23.25
NBIAS (HIGH LAYER)	-0.02			-0.03	-0.06	-0.06	-0.05	0.05	-0.05
NMVD (100-400 hPa)	0.24			0.25	0.25	0.25	0.25	0.33	0.25
NRMSVD	0.29			0.30	0.31	0.30	0.30	0.41	0.30
N	2984	36235	34603	4855	34998	67629	64668	1934	247926
SPD [m/s]	14.78	11.70	11.53	17.57	16.05	14.61	14.76	14.02	14.05
NBIAS (MEDIUM LAYER)	-0.02	-0.16	-0.16	0.03	-0.02	-0.08	-0.07	0.12	-0.08
NMVD (400-700 hPa)	0.31	0.38	0.39	0.37	0.35	0.34	0.34	0.38	0.35
NRMSVD	0.38	0.46	0.46	0.46	0.44	0.41	0.42	0.46	0.43
N	4177	53568	52057		1481	23830	20665		155778
SPD [m/s]	9.29	9.93	9.83		12.50	10.64	10.67		10.11
NBIAS (LOW LAYER)	-0.00	-0.09	-0.09		-0.05	-0.10	-0.09		-0.09
NMVD (700-1000 hPa)	0.43	0.41	0.42		0.37	0.37	0.37		0.40
NRMSVD	0.50	0.49	0.50		0.44	0.44	0.43		0.47

Table 15: Validation parameters for GEO-HRW-v50
(Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean area;
Detailed AMVs; Cross correlation tracking; CCC height assignment with Microphysics correction)

4.2 VALIDATION FOR DETAILED AMVS WITHOUT CLOUD PRODUCTS

The validation of GEO-HRW-v5.0 MSG Detailed AMVs using "Brightness temperature interpolation height assignment without cloud products" (used when the Cloud products are not available) at 12:00 UTC is also presented in next table to show differences with the case before in which the NWC/GEO Clouds are available.

The conditions are exactly equivalent to those for Basic AMVs in *Table 11*. Statistics have been provided considering each satellite channel separately and altogether, and each layer separately and altogether.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	HRVIS	VIS06	VIS08	WV62	WV73	IR108	IR120	All AMVs
N	11658	76828	75560	123366	199016	135528	142857	764813
SPD [m/s]	16.20	11.52	11.54	23.77	20.00	17.95	18.07	18.14
NBIAS (ALL LAYERS)	0.00	-0.04	-0.04	-0.01	0.05	0.04	0.04	0.02
NMVD (100-1000 hPa)	0.31	0.37	0.37	0.25	0.32	0.30	0.30	0.31
NRMSVD	0.38	0.45	0.45	0.31	0.38	0.37	0.37	0.38
N	4395			121953	114849	44444	50110	335751
SPD [m/s]	22.91			23.82	22.13	24.58	24.31	23.40
NBIAS (HIGH LAYER)	-0.01			-0.01	0.03	0.01	0.02	0.01
NMVD (100-400 hPa)	0.25			0.25	0.28	0.25	0.26	0.26
NRMSVD	0.30			0.31	0.34	0.30	0.31	0.32
N	3942	29538	29751	1413	84167	60665	63259	403701
SPD [m/s]	14.00	14.39	14.43	19.15	17.12	16.85	16.61	15.76
NBIAS (MEDIUM LAYER)	0.03	-0.05	-0.05	-0.12	0.09	0.09	0.09	0.02
NMVD (400-700 hPa)	0.36	0.35	0.34	0.41	0.38	0.34	0.35	0.37
NRMSVD	0.43	0.42	0.41	0.51	0.47	0.42	0.42	0.45
N	3321	47290	45803			30219	29488	156327
SPD [m/s]	9.95	9.72	9.67			10.48	10.58	10.02
NBIAS (LOW LAYER)	-0.01	-0.02	-0.03			-0.01	-0.02	-0.02
NMVD (700-1000 hPa)	0.41	0.40	0.40			0.35	0.35	0.38
NRMSVD	0.49	0.48	0.48			0.41	0.41	0.45

Table 16: Validation parameters for GEO-HRW-v50
(Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean area;
Detailed AMVs; Cross correlation tracking;
Brightness temperature interpolation height assignment without cloud products)

It can be seen that using both height assignments in *Table 15* and *Table 16*, and comparing with the Basic AMVs in *Table 7* and *Table 11*, the amount of Detailed AMVs is around a 30% smaller, but at the same time all the validation parameters (NBIAS, NMVD, NRMSVD) are better considering each layer and all layers together (except the NBIAS using "Brightness temperature interpolation").

Apart from the better validation parameters, considering the GEO-HRW Product Requirement Table, the situation is basically equivalent for the MSG Basic AMVs and the MSG Detailed AMVs for both height assignments. Considering this, NWC/GEO users can perfectly use the detailed dataset of AMVs as an additional element of NWC/GEO-HRW-v5.0 algorithm for MSG series with a very good quality.

5. VALIDATION OF GEO-HRW-V50 GOES-N BASIC AMVS

The validation of GEO-HRW-v50 algorithm for GOES-N satellite series is considered now. It is based on the validation of GEO-HRW AMVs calculated during the whole year July 2010 – June 2011 with GOES13 satellite images extracted every 15 minutes, in an area covering the Continental United States. The area is shown in *Figure 3*.

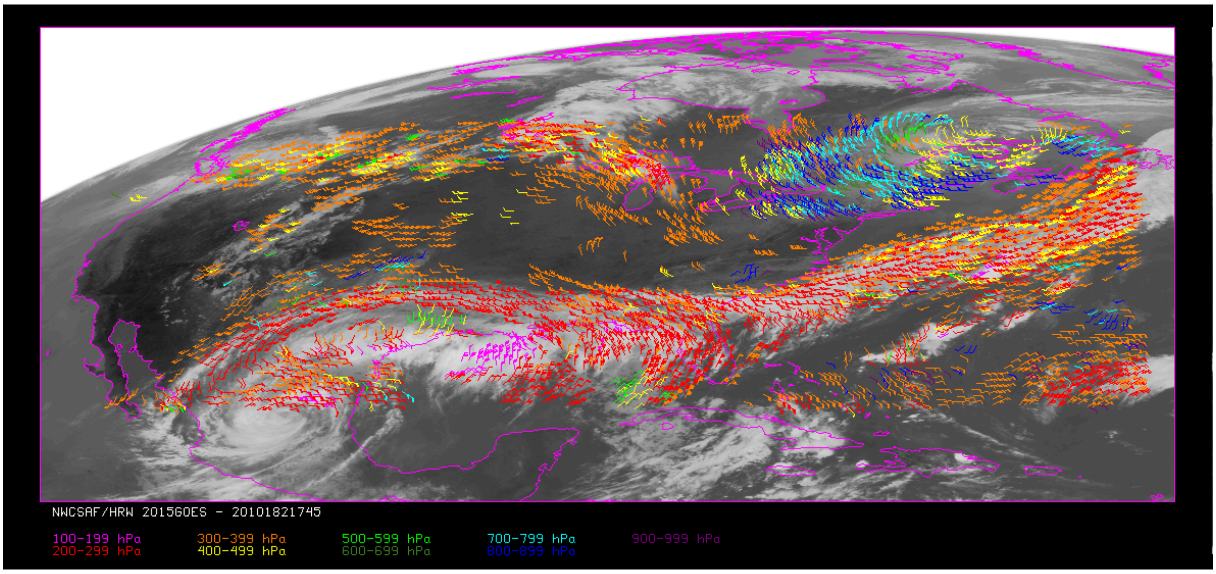

Figure 3: NWC/GEO High Resolution Winds v2016 Basic AMV output example in the Continental United States region (1 July 2010 1745Z, GOES13 satellite), considering the default conditions defined in $SAFNWC/config/safnwc_HRW.cfm.GOES15MIN model configuration file. Colour coding based on the AMV pressure level

Next triplets of images for GEO-HRW-v50 algorithm processing, and next Radiosounding data have been considered for the GOES-N validation:

- Images at 23:15Z, 23:30Z and 23:45Z; 23:45Z AMVs validated against 00:00Z Radiosoundings.
- Images at 05:15Z, 05:30Z and 05:45Z; 05:45Z AMVs validated against 06:00Z Radiosoundings.
- Images at 11:15Z, 11:30Z and 11:45Z; 11:45Z AMVs validated against 12:00Z Radiosoundings.
- Images at 17:15Z, 17:30Z and 17:45Z; 17:45Z AMVs validated against 18:00Z Radiosoundings.

No AMVs could be processed at 00:00Z, 06:00Z, 12:00Z and 18:00Z because GOES13 images are not available at these main synoptic hours.

This process every six hours has been used in the statistics to increase the amount of comparisons, especially for visible AMVs. Dawn or dusk occurs at the main synoptic hours 00:00 and 12:00, because of which the number of visible AMVs is much smaller at these moments; at the same time, the number of Radiosoundings at midday time, i.e. 18:00Z, is very limited. Despite of all this, the number of collocations for visible AMVs is still small.

5.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION

Default conditions for GEO-HRW-v50 for GOES-N satellites, considering "Basic scale AMVs" with "Cross correlation tracking" and "CCC method height assignment without microphysics correction" (due to the lack of NWC/GEO-CMIC product with this satellite series), are considered first.

These conditions are specified in `$SAFNWC/config/safnwc_HRW.cfm.GOES15MIN` model configuration file, with all satellite channels being validated. Cloudy AMVs in the layer 100-1000 hPa and clear air AMVs in the layer 100-425 hPa, with a Quality index with forecast ≥ 70 for High and Medium layer and a Quality index with forecast ≥ 75 for Low layer, are considered for this validation.

NWC/GEO Cloud product outputs for GOES (CMA, CT and CTTH) have to be available so that GEO-HRW-v50 can fully process the conditions defined in the given model configuration file.

The validation statistics are presented in *Table 17*, considering all moments of the day together. Statistics have been provided considering each satellite channel (VIS07, WV065, IR107) separately and altogether, and each layer (High, Medium and Low) separately and altogether.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	Cloudy VIS07	Cloudy WV65	Cloudy IR107	Clear Air	All AMVs
N	5849	205757	208726	47253	467585
SPD [m/s]	22.34	24.46	22.98	15.31	23.00
NBIAS (ALL LAYERS)	0.00	-0.03	-0.08	-0.00	-0.05
NMVD (100-1000 hPa)	0.25	0.27	0.29	0.35	0.28
NRMSVD	0.31	0.33	0.36	0.48	0.36
N	4694	191878	173848	47253	417673
SPD [m/s]	24.71	24.68	24.33	15.31	23.47
NBIAS (HIGH LAYER)	0.00	-0.03	-0.09	-0.00	-0.05
NMVD (100-400 hPa)	0.24	0.27	0.28	0.35	0.28
NRMSVD	0.29	0.33	0.35	0.47	0.36
N	460	13879	25067		39406
SPD [m/s]	18.10	21.43	18.60		19.59
NBIAS (MEDIUM LAYER)	-0.03	-0.00	-0.06		-0.04
NMVD (400-700 hPa)	0.28	0.29	0.32		0.31
NRMSVD	0.36	0.36	0.40		0.38
N	695		9811		10506
SPD [m/s]	9.17		10.24		10.17
NBIAS (LOW LAYER)	-0.06		-0.10		-0.10
NMVD (700-1000 hPa)	0.35		0.39		0.38
NRMSVD	0.43		0.48		0.48

Table 17: Validation parameters for GEO-HRW-v50
(Jul 2010-Jun 2011, GOES13 satellite, 00/06/12/18:00 UTC, Continental United States area;
Basic AMVs; Cross correlation tracking;
CCC height assignment without Microphysics correction)

5.2 VALIDATION FOR BASIC AMVS WITHOUT CLOUD PRODUCTS

The validation using "Brightness temperature interpolation height assignment without cloud products" (used when the Cloud products are not available) is also presented to show differences with the case before in which the NWC/GEO Clouds for GOES were available.

The validation statistics are presented in *Table 18*, considering all moments of the day together. Statistics have been provided considering each satellite channel (VIS07, WV065, IR107) separately and altogether, and each layer (High, Medium and Low) separately and altogether. All other conditions are equivalent to the ones used in the previous case.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	VIS07	WV65	IR107	All AMVs
N	8176	281224	77701	367101
SPD [m/s]	18.61	21.91	21.87	21.83
NBIAS (ALL LAYERS)	0.05	-0.00	0.02	0.00
NMVD (100-1000 hPa)	0.30	0.29	0.29	0.29
NRMSVD	0.38	0.36	0.35	0.36
N	3834	252275	36889	292998
SPD [m/s]	23.37	22.05	26.92	22.68
NBIAS (HIGH LAYER)	0.06	0.00	0.00	0.00
NMVD (100-400 hPa)	0.28	0.28	0.26	0.28
NRMSVD	0.35	0.35	0.32	0.35
N	2530	28949	28624	60103
SPD [m/s]	17.94	20.65	19.91	20.18
NBIAS (MEDIUM LAYER)	0.07	-0.07	0.06	-0.00
NMVD (400-700 hPa)	0.32	0.32	0.32	0.32
NRMSVD	0.40	0.41	0.39	0.40
N	1812		12188	14000
SPD [m/s]	9.49		11.19	10.97
NBIAS (LOW LAYER)	-0.02		-0.03	-0.03
NMVD (700-1000 hPa)	0.35		0.35	0.35
NRMSVD	0.44		0.42	0.42

Table 18: Validation parameters for GEO-HRW-v50
(Jul 2010-Jun 2011, GOES13 satellite, 00/06/12/18:00 UTC, Continental United States area;
Basic AMVs; Cross correlation tracking;
Brightness temperature interpolation height assignment without Cloud products;
No distinction between Cloudy and Clear air Water vapour AMVs due to the lack of Cloud products)

Comparing with the equivalent statistics for MSG in *Table 7* and *Table 11*, statistics for GOES-N AMVs (NBIAS, NMVD, NRMSVD) are as a whole better for all parameters in all layers (NBIAS, NMVD, NRMSVD), with the only exception of the NMVD and NRMSVD at the High layer.

Considering the GEO-HRW Product Requirement Table, the "Optimal accuracies" (respectively 0.35, 0.40 and 0.45 for the High, Medium and Low layer) are reached in all layers when the "Brightness temperature interpolation height assignment without Cloud products" is used, and in the Medium layer also when "CCC height assignment without Microphysics correction" is used. The "Target accuracies" are also widely reached in all cases.

This results means that NWC/GEO users can perfectly use GEO-HRW-v50 operatively with GOES-N satellite series, even in the case in which NWC/GEO Clouds are not available.

All this also proves the validity of exporting NWC/GEO-HRW algorithm to other geostationary satellite series, being the adaptation to GOES-N series an initial valid step for a later adaptation in later versions to other geostationary series (Himawari, GOES-R, MTG,…).

Considering the height assignment recommended to be used by NWC/GEO-HRW algorithm with GOES-N series, and taking into account the results obtained for MSG in chapter 3.6, a similar analysis is going to be done next for GOES-N AMVs, to clarify the question "Which and in which cases each height assignment method works better?".

5.3 COMPARISON BETWEEN HEIGHT ASSIGNMENT PROCEDURES

As in the case with MSG satellite series, the fact that "CCC method height assignment without microphysics correction" is able to calculate around a 25% more of AMVs than "Brightness temperature interpolation height assignment without Cloud products" for similar quality thresholds and similar mean NMVD/NRMSVD validation parameters (although with differences existing in these parameters when the different layers are considered separately), should be a cause to prefer this height assignment method in the AMV processing.

Again, calculating the validation statistics respect to the "Radiosounding best fit level", which means the best possible statistics only through changes in the height assignment, both height assignment procedures show NBIAS values of 0.00, NMVD values of 0.19, and NRMSVD values of 0.31. So, it can be seen that any additional impact of the height assignment in the validation statistics is small. The NBIAS can be reduced to zero, but the NMVD and NRMSVD can only be reduced slightly.

Considering the "difference" and the "absolute difference" between the AMV level and the AMV best fit level respect to Radiosounding data, next table shows the mean value of these parameters for all layers for both height assignment methods:

	Brightness Temp. Interpolation without Clouds Height Assignment		**CCC Method with Microphysics correction Height Assignment**	
	Mean $P_{Bestfit} – P_{AMV}$	**Mean $\mid P_{Bestfit} – P_{AMV}\mid$**	**Mean $P_{Bestfit} – P_{AMV}$**	**Mean $\mid P_{Bestfit} – P_{AMV}\mid$**
100 – 999 hPa (ALL LEVELS)	-18 hPa	92 hPa	20 hPa	89 hPa
100 – 399 hPa (HIGH LEVEL)	-11 hPa	82 hPa	23 hPa	85 hPa
400 – 699 hPa (MEDIUM LEVELS)	-41 hPa	131 hPa	-14 hPa	133 hPa
700 – 999 hPa (LOW LEVELS)	-62 hPa	124 hPa	17 hPa	101 hPa

Table 19: "Mean difference" and "Mean absolute difference"
between the "AMV best fit level" and the "AMV level" in the different layers
(Jul 2010-Jun 2011, GOES13 satellite, 00/06/12/18:00 UTC, Continental United States area,
Basic AMVs; Cross correlation tracking;
"Brightness temperature interpolation height assignment without cloud products"
compared to "CCC method height assignment without microphysics correction")

The differences between both height assignment procedures are very small if all layers are considered together (-18 hPa against +20 hPa). It is also seen that "CCC method height assignment" tends to locate the AMVs slightly over the best fit level, while the "Brightness temperature interpolation height assignment without Cloud products" tends to locate them slightly below the best fit level.

Considering the three layers separately, "Brightness temperature interpolation height assignment without Cloud products" tends to behave slightly better at the high layer, and "CCC method height assignment" behaves clearly better at the medium and low layer. This last circumstance should be enough to consider "CCC method height assignment" as the default height assignment for GOES-N satellite series. Nevertheless, to take a decision, the user should have to verify if there is a preference to locate the AMV over or below the best fit level commented in the paragraph before.

The fact of "Brightness temperature interpolation height assignment without Cloud products" systematically locating the AMVs at a lower level than the optimal one can again (as in with MSG satellite series) contribute to artificially reduce the NBIAS to 0, when this height assignment is used. So, no worries should occur again with the fact of obtaining smaller NBIAS values with this method, because this does not directly mean that the corresponding AMVs are better.

With all this, it is also verified that the difference between both height assignments for GOES-N satellite series is much smaller than for MSG satellite series, due to the fact that the NWC/GEO Clouds for GOES-N series had to be calculated with less satellite channels, and that no microphysics correction could be applied (so having an impact in the results for "CCC method height assignment" method).

Next table shows now the "difference" and "absolute difference" values between the "AMV best fit level" and the "AMV level", for AMVs related to the different cloud types when "CCC method height assignment without microphysics correction" is used.

	CCC Method with Microphysics correction Height Assignment	
	Mean $P_{Bestfit} - P_{AMV}$	**Mean | $P_{Bestfit} - P_{AMV}$ |**
Clear air	-19 hPa	102 hPa
Very low cumulus/stratus	28 hPa	93 hPa
Low cumulus/stratus	26 hPa	141 hPa
Medium cumulus/stratus	-50 hPa	146 hPa
High cumulus/stratus	19 hPa	86 hPa
Very high cumulus/stratus	72 hPa	94 hPa
High semitransparent thin	27 hPa	86 hPa
High semitransparent meanly thick & thick	5 hPa	71 hPa
High semitransparent above other clouds	23 hPa	85 hPa

Table 20: "Mean difference" and "Mean absolute difference"
between the "AMV best fit level" and the "AMV level" for the different cloud types
(Jul 2010-Jun 2011, GOES13 satellite, 00/06/12/18:00 UTC, Continental United States area,
Basic AMVs; Cross correlation tracking;
"Brightness temperature interpolation height assignment without cloud products"
compared to "CCC method height assignment without microphysics correction")

Considering the "mean difference" between the "AMV best fit level" and the "AMV level", the worst behaviour occurs in medium to very high cumulus/stratus, with differences over 50 hPa. In the rest of cases, the difference is smaller than 28 hPa.

The different behaviour between AMVs related to cumulus/stratus and cirrus clouds seen in *Table 14* for MSG series in now here less clear, maybe showing the more important difficulties found by NWC/GEO cloud products to define the different cloud types with GOES-N series and its five satellite channels.

6. VALIDATION OF GEO-HRW-V50 GOES-N DETAILED AMVS

The validation of Detailed AMVs (with a default tracer size of 12x12 pixels instead of the 24x24 pixels considered by the Basic AMVs) for GOES-N satellite series is considered now. As already commented, the calculation of Detailed AMVs is activated changing CDET parameter in the GEO-HRW-v5.0 Model configuration file to value ALL or RANGE.

The conditions for this validation are exactly equivalent to the one shown in chapter 5 for the GOES-N Basic AMVs. An output example of GEO-HRW Detailed AMVs in the Continental United States for the same moment shown in *Figure 3* is shown here in *Figure 4*. A smaller amount of Detailed AMVs is seen comparing both images, as also seen previously for the MSG Detailed AMVs.

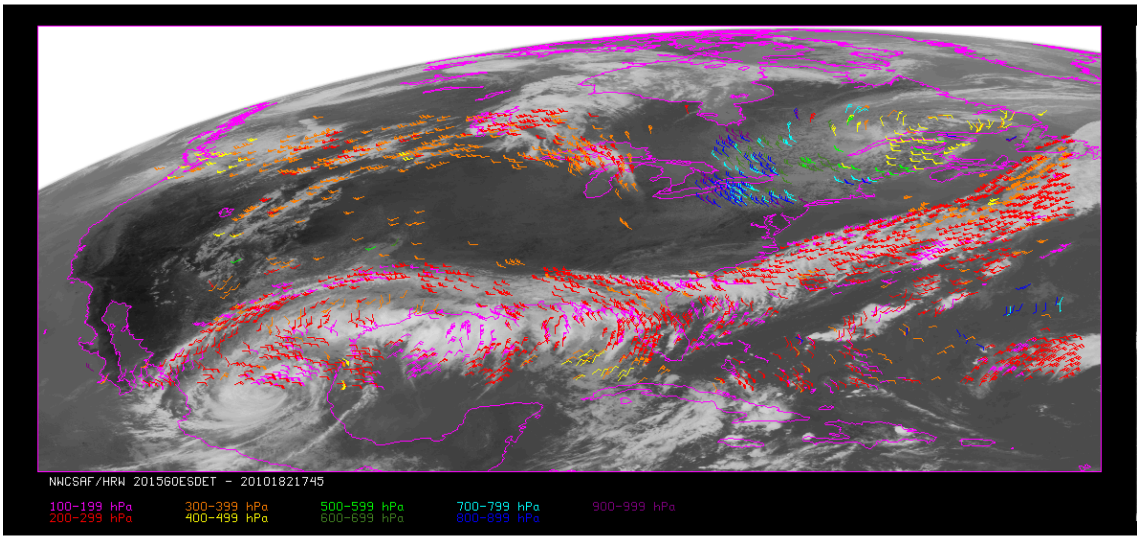

Figure 4: NWC/GEO High Resolution Winds v2016 Detailed AMV output example in the Continental United States region (1 July 2010 1745Z, GOES13 satellite), considering the default conditions defined in $SAFNWC/config/safnwc_HRW.cfm.GOES15MIN model configuration file. Colour coding based on the AMV pressure level

6.1 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION

The validation statistics for GEO-HRW-v50 GOES-N Detailed AMVs using "CCC method height assignment without microphysics correction", in conditions exactly equivalent to those for Basic AMVs in *Table 17* are presented in *Table 21*.

All moments of the day have been considered together (00:00, 06:00, 12:00, 18:00). Statistics have been provided considering each satellite channel (VIS07, WV065, IR107) separately and altogether, and each layer (High, Medium and Low) separately and altogether.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	Cloudy VIS07	Cloudy WV65	Cloudy IR107	Clear Air	All AMVs
N	1296	142084	147971	8122	299473
SPD [m/s]	24.23	25.76	24.58	16.20	24.93
NBIAS (ALL LAYERS)	0.01	-0.01	-0.05	0.05	-0.03
NMVD (100-1000 hPa)	0.25	0.25	0.26	0.34	0.26
NRMSVD	0.32	0.31	0.33	0.48	0.32
N	1084	135154	128864	8122	273224
SPD [m/s]	26.19	25.92	25.45	16.20	25.41
NBIAS (HIGH LAYER)	0.02	-0.01	-0.05	0.05	-0.03
NMVD (100-400 hPa)	0.23	0.25	0.26	0.34	0.26
NRMSVD	0.29	0.31	0.32	0.48	0.32
N	98	6930	16676		23704
SPD [m/s]	19.91	22.56	19.96		20.72
NBIAS (MEDIUM LAYER)	-0.03	0.04	-0.01		0.00
NMVD (400-700 hPa)	0.36	0.28	0.30		0.30
NRMSVD	0.49	0.35	0.38		0.37
N	114		2431		2545
SPD [m/s]	9.34		10.17		10.13
NBIAS (LOW LAYER)	-0.05		-0.07		-0.07
NMVD (700-1000 hPa)	0.37		0.35		0.36
NRMSVD	0.47		0.43		0.43

Table 21: Validation parameters for GEO-HRW-v50
(Jul 2010-Jun 2011, GOES13 satellite, 00/06/12/18:00 UTC, Continental United States area;
Detailed AMVs; Cross correlation tracking;
CCC height assignment without Microphysics correction)

6.2 VALIDATION FOR DETAILED AMVS WITHOUT CLOUD PRODUCTS

The validation statistics of GEO-HRW-v5.0 GOES-N Detailed AMVs using “Brightness temperature interpolation height assignment without cloud products” (used when Cloud products are not available) is presented to show differences with the case before in which the NWC/GEO Clouds are available.

The validation statistics are presented in *Table 22*, considering all moments of the day together. Statistics have been provided considering each satellite channel (VIS07, WV065, IR107) separately and altogether, and each layer (High, Medium and Low) separately and altogether. Conditions are equivalent to the ones used in the cases for Basic AMVs in *Table 18*.

GEO-HRW-v50 AMVs (Jul 2009-Jun 2010)	VIS07	WV65	IR107	All AMVs
N	1925	173141	71874	246940
SPD [m/s]	21.22	24.69	23.79	24.40
NBIAS (ALL LAYERS)	0.06	0.01	0.04	0.02
NMVD (100-1000 hPa)	0.29	0.26	0.28	0.27
NRMSVD	0.36	0.32	0.34	0.33
N	1000	166384	42060	292998
SPD [m/s]	25.49	24.73	26.70	22.68
NBIAS (HIGH LAYER)	0.05	0.01	0.02	0.00
NMVD (100-400 hPa)	0.24	0.26	0.26	0.28
NRMSVD	0.29	0.32	0.32	0.35
N	658	6757	25703	33118
SPD [m/s]	17.68	23.59	21.02	21.48
NBIAS (MEDIUM LAYER)	0.10	-0.01	0.09	0.06
NMVD (400-700 hPa)	0.35	0.30	0.31	0.31
NRMSVD	0.44	0.39	0.38	0.38
N	267		4111	4378
SPD [m/s]	10.20		1.28	11.21
NBIAS (LOW LAYER)	-0.00		-0.01	-0.01
NMVD (700-1000 hPa)	0.39		0.34	0.34
NRMSVD	0.50		0.41	0.41

Table 22: Validation parameters for GEO-HRW-v50
(Jul 2010-Jun 2011, GOES13 satellite, 00/06/12/18:00 UTC, Continental United States area;
Detailed AMVs; Cross correlation tracking;
Brightness temperature interpolation height assignment without Cloud products;
No distinction between Cloudy and Clear air Water vapour AMVs due to the lack of Cloud products)

It can be seen that using both height assignments in *Table 21* and *Table 22*, and comparing with the Basic AMVs in *Table 17* and *Table 18*, the amount of Detailed AMVs is around a 35% smaller, but at the same time all the validation parameters (NBIAS, NMVD, NRMSVD) are better considering each layer and all layers together (except the NBIAS using “Brightness temperature interpolation”).

Considering the GEO-HRW Product Requirement Table, the “Optimal accuracies” (respectively 0.35, 0.40 and 0.45 for the High, Medium and Low layer) are even reached at all layers for both height assignments. Considering this, NWC/GEO users can perfectly use the detailed dataset of AMVs as an additional element of NWC/GEO-HRW-v5.0 algorithm for GOES-N series with a very good quality.

7. CONCLUSIONS

Some conclusions can be extracted from this Validation report for GEO-HRW-v50. Considering the following table, where the accuracies in the Product Requirement Table (PRT) for GEO-HRW product (defined in [AD.4]) are compared for the default implementation of current and previous GEO-HRW versions:

Evolution of the Validation statistics between HRW versions, related to the Operative thresholds defined in the HRW Product Requirement Table	All Layers NRMSVD	High Layer NRMSVD	Medium Layer NRMSVD	Low Layer NRMSVD
GEO-HRW-v40, Default configuration, MSG satellites	0.38	0.33	0.45	0.52
GEO-HRW-v50, Default configuration, MSG satellites (With an increase in the Amount of AMV data of +20%)	0.36	0.32	0.44	0.50
GEO-HRW-v50, Default configuration, GOES-N satellites	0.36	0.36	0.38	0.48
HRW Product Requirement Table “Optimal Accuracy”	0.40	0.35	0.40	0.45
HRW Product Requirement Table “Target Accuracy”	0.50	0.44	0.50	0.56
HRW Product Requirement Table “Threshold Accuracy”	0.60	0.53	0.60	0.67

Table 23: Evolution of Validation statistics between GEO-HRW-v40 and GEO-HRW-v50 versions, related to the Operative thresholds defined in the GEO-HRW Product Requirement Table.

It can be seen that GEO-HRW-v50 AMVs for MSG satellites show a smaller mean NRMSVD (“Normalized root mean square vector difference”) and a larger amount of AMVs, respect to the ones provided by GEO-HRW-v40. So, AMVs for current version are better than those provided by previous version. The “Optimal accuracy” defined for GEO-HRW AMVs at the Product Requirement Table is reached in the High layer AMVs during daytime, and the “Target accuracy” is reached in all other cases (although here there are no differences respect to the behaviour of previous GEO-HRW version).

For GOES-N satellites, the NRMSVD considering all layers as a whole is exactly the same than the one obtained for MSG satellites. The “Optimal accuracy” is reached in the Medium layer AMVs, and the “Target accuracy” is reached in all other cases, so proving the validity of exporting NWC/GEO-HRW algorithm to GOES-N satellite series.

If Detailed AMVs are considered, the situation respect to the Product Requirement Table is the same for MSG satellite series and better for GOES-N satellite series, for which all layers reach the “Optimal accuracy” (although the differences between GEO-HRW validation for MSG and GOES-N can in part be explained by the general variability of using two different validation datasets).

With all of this, and as already mentioned previously, GEO-HRW-v50 AMVs and Trajectories for both MSG and GOES-N satellite series, considering both scales of data (Basic and Detailed), can be used operationally.

Considering additionally the conceptual differences between GEO-HRW-v40 and GEO-HRW-v50 algorithms in the following:

- The use of the new NWC/GEO NWCLIB library, which better homogenizes processes between the different NWC/GEO products, and permits the extension of NWC/GEO software to other geostationary satellites,
- The fact of using a new version of NWC/GEO Cloud products,
- The inclusion of the “Microphysics correction”, which improves the height assignment for MSG satellites when “CCC method” is being used, by taking into account the depth of the clouds,

it is formally recommended that NWC SAF users update their NWC/GEO High Resolution Winds algorithm to NWC/GEO-HRW-v50 included in NWC/GEO v2016 software package.

The results of the 2014 AMV Intercomparison Study Report (Comparison of NWC SAF/HRW AMVs with AMVs from other producers [RD.24]) are also important here to be taken into account. In this study, the AMVs calculated with NWC/GEO-HRW were compared to the AMVs calculated by six other institutions (EUMETSAT/MPEF, NOAA, Japan Meteorological Agency - JMA, China Meteorological Administration - CMA, Korea Meteorological Administration - KMA and the Weather Forecast and Climatic Studies Centre from the Brazilian National Spatial Research Institute – CPTEC/INPE) using the same MSG satellite and ECMWF NWP model data.

The report shows that NWC/GEO-HRW AMVs together with the EUMETSAT/MPEF AMVs have the two best validation statistics in the AMV intercomparison, using “CCC method” for the AMV height assignment.