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

NWC/CDOP3/GEO/AEMET/SCI/VR/Wind, Issue 1, Rev. 0

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Applicable to GEO-HRW v6.0 (NWC-038)

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REPORT SIGNATURE TABLE

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DOCUMENT CHANGE RECORD

Version	Date	Pages	Changes
1.0	*21 January 2019*	46	Version for NWC/GEO-HRW v6.0 in NWC/GEO v2018, including changes proposed by the Developer and the Reviewers at the NWC/GEO v2018 DRR.

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1. INTRODUCTION

The “EUMETSAT Satellite Application Facilities (SAFs)” 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/GEO software package for geostationary satellites.

1.1 SCOPE OF THE DOCUMENT

This document is the “Scientific and Validation Report for the Wind Product Processor of the NWC/GEO” software package (GEO-HRW, High Resolution Winds), which calculates Atmospheric Motion Vectors (AMVs) and Trajectories considering:

- Up to seven channels from MSG/SEVIRI imager: six 3 km low resolution visible, water vapour and infrared channels (VIS06 0.635 µm, VIS08 0.810 µm, WV62 6.250 µm, WV73 7.350 µm, IR108 10.800 µm and IR120 12.000 µm), and the 1 km high resolution visible channel (HRVIS 0.750 µm).
- Up to three channels from GOES-N/IMAGER: two 4 km low resolution water vapour and infrared channels (WV65 6.550 µm and IR107 10.700 µm), and the 1 km high resolution visible channel (VIS07 0.650 µm).
- Up to six channels from Himawari-8/9/AHI imager: four 2 km low resolution water vapour and infrared channels (WV62 6.250 µm, WV70 6.950 µm, WV73 7.350 µm and IR112 11.200 µm), one 1 km high resolution visible channel (VIS08 0.860 µm), and the 0.5 km very high resolution visible channel (VIS06 0.645 µm).

There is a commitment so that the adaptation of NWC/GEO-HRW algorithm to the three geostationary satellite series (MSG, GOES-N and Himawari-8/9) in NWC/GEO v2018 software package is fully validated. The corresponding validation results are shown in this document.

The adaptation of NWC/GEO-HRW to GOES-R satellite series and the corresponding validation, not committed for this version, is under way and will be delivered as a patch for NWC/GEO v2018 software package throughout the year 2019.

As in previous versions of NWC/GEO-HRW, the validation has been based on the comparison of the NWC/GEO-HRW v6.0 AMVs 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.

Considering the new requirement for this version, NWC/GEO-HRW v6.0 is also validated for the first time using ECMWF model analysis winds as additional reference. This permits to evaluate differences in behaviour and scale of NWC/GEO-HRW AMVs with respect to both reference winds used.

A comparison with the default configuration of NWC/GEO-HRW v5.0 in NWC/GEO v2016 software package is also verified, to show the improvements of NWC/GEO-HRW algorithm since this previous version. The similarities and differences found in the validation of NWC/GEO-HRW AMVs for the three different satellite series for which the algorithm is available (MSG, GOES-N and Himawari-8/9), are also evaluated in this document.

1.2 SOFTWARE VERSION IDENTIFICATION

This document describes the algorithm implemented in the NWC/GEO-HRW v6.0 (Product Id NWC-038) of the NWC/GEO v2018 software package release.

1.3 IMPROVEMENTS FROM PREVIOUS VERSIONS

The main improvements related to NWC/GEO-HRW v6.0 algorithm are the following ones:

1. The extension of NWC/GEO-HRW algorithm for the processing of Himawari-8/9 satellite series.
2. The option to increase the spatial density of AMVs at low levels. This is done with a more detailed evaluation of the spatial density of low level tracers.
3. The implementation of a "Mixed calculation method", considering at the same time short and long time intervals, through which the tracking process is verified in short time intervals, but the AMVs are calculated considering displacements in long time intervals. This process is useful for the calculation of AMVs with high resolution images, and to improve the quality of the calculated AMVs.
4. The calculation of the "Common Quality Index without forecast", to be used by all AMV production centres, as defined by the "International Winds Working Group".
5. The autovalidation of NWC/GEO-HRW algorithm with respect to NWP model analysis or forecast winds, including the calculation of the NWP wind at "best fit pressure level" and the "difference with the NWP winds".

1.4 REFERENCES

1.4.1 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*	*Ver.*
[AD.1]	Proposal for the Third Continuous Development and Operations Phase (CDOP3)	NWC/CDOP3/SAF/AEMET/MGT/PRO	1.0
[AD.2]	Project Plan for the NWC SAF CDOP3 Phase	NWC/CDOP3/SAF/AEMET/MGT/PP	1.0
[AD.3]	Configuration Management Plan for the NWC SAF	NWC/CDOP3/SAF/AEMET/MGT/CMP	1.0
[AD.4]	NWC SAF Product Requirements Document	NWC/CDOP3/SAF/AEMET/MGT/PRD	1.0
[AD.5]	Interface Control Document for Internal and External Interfaces of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/ICD/1	1.0
[AD.6]	Data Output Format for the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/DOF	1.0
[AD.7]	System and Component Requirements Document for the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/SCRD	2.1
[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 processor of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SCI/ATBD/Wind	2.1
[AD.15]	User Manual for the Wind product processor of the NWC/GEO: Science Part	NWC/CDOP3/GEO/AEMET/SCI/UM/Wind	1.0

Table 1. List of Applicable Documents

1.4.2 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).
[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).
[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).
[RD.8]	J.García-Pereda & J.M.Fernández, 2006: Description and validation results of High Resolution Winds 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).
[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).
[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).
[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).
[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).
[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 https://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/WMO306_vI2_CommonTable_en.pdf)
[RD.20]	WMO Code Tables and Flag Tables associated with BUFR/CREX table B, version 29 (WMO Publication, available at http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/PrevVERSIONS/20171108/WMO306_vI2_BUFRCREX_CodeFlag_en.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 (available at http://www.nwcsaf.org/aemetRest/downloadAttachment/225)
[RD.25]	D.Santek, R.Dworak, S.Wanzong, K.Winiecki, S.Nebuda, J.García-Pereda, R.Borde & M.Carranza, 2018: 2018 AMV Intercomparison Study Report (available at http://www.nwcsaf.org/aemetRest/downloadAttachment/5092)
[RD.26]	K.Salonen, J.Cotton, N.Bormann & M.Forsythe, 2015: Characterizing AMV height-assignment error by comparing best-fit pressure statistics from the Met Office and ECMWF data assimilation systems (Journal of Applied Meteorology and Climatology, Vol.54, Num.1).

Table 2. List of Reference Documents

2. DESCRIPTION OF THE VALIDATION PROCEDURE

2.1 VALIDATION PROCEDURE

The validation process for NWC/GEO-HRW v6.0 has been simplified and extended to incorporate for each AMV both reference winds used in the validation: Radiosounding winds and ECMWF model analysis winds.

To do this, relevant data for the validation (AMVs and NWP analysis reference winds from NWC/GEO-HRW AMV "NWC" BUFR output on one side, and the corresponding Radiosounding reference wind for each AMV extracted from Radiosounding wind profiles obtained from the GTS on the other side), are converted into McIDAS MD files following a scheme called WDMR.

The NWP analysis reference winds have been extracted by the autovalidation process included for the first time in NWC/GEO-HRW algorithm; the Radiosounding wind profiles are obtained through an intermediate McIDAS process.

The structure of data in this WDMR scheme is shown in the following table. The NWC/GEO-HRW validation process selects AMV data from the WDMR McIDAS MD file, considering the value of some specific parameters, and calculates the corresponding validation statistics. For validation against Radiosounding winds, elements in green in the table are used. For validation against NWP analysis winds, elements in blue in the table are used.

ROW/COLUMN ELEMENT	"NWC" BUFR DESCRIPTOR	PARAMETER MD ID.	WDMR SCHEME DESCRIPTION
Row 01	001007	SS	Satellite Identifier
Column 01	004001/002/003	DAY	Date
Column 02	004004/005	TIME	Time
Column 03	004025	INTT	Temporal interval (tracer to tracking centre)
Column 04	031002	CMAX	Number of NWC/GEO-HRW AMVs per Row
Column 05	060000	TRAX	Segment size of tracer in X direction in pixel
Column 06	060001	TRAY	Segment size of tracer in Y direction in pixel
Column 07	060100	IDN	AMV sequence number in the Row
Column 08	060104	TYPE	Characterization as Basic or Detailed tracer, and Type of Detailed tracer
Column 09	002028	SIZX	Segment size of tracer in X direction in m
Column 10	002029	SIZY	Segment size of tracer in Y direction in m
Column 11	060103	TYPL	Characterization as Cloudy or Clear air wind, and Height assignment method used
Column 12	002164	TYPT	Euclidean Distance or Cross Correlation tracking
Column 13	005001	LAT	Initial latitude
Column 14	006001	LON	Initial longitude
Column 15	005011	DLAT	Latitude increment
Column 16	006011	DLON	Longitude increment
Column 17	012001	T	AMV Temperature
Column 18	007004	P	AMV Pressure
Column 19	011001	DIR	AMV wind Direction
Column 20	011002	SPD	AMV wind Speed
Column 21	033007	QI	AMV Quality index using forecast
Column 22	033007	QINF	AMV Quality index not using forecast
Column 23	033007	QIWG	AMV Common Quality index

ROW/COLUMN ELEMENT	"NWC" BUFR DESCRIPTOR	PARAMETER MD ID.	WDMR SCHEME DESCRIPTION
Column 24		QT	AMV Quality index threshold using forecast
Column 25		QTNF	AMV Quality index threshold not using forecast
Column 26		QTWG	AMV Common Quality index threshold
Column 27	060202	TES2	Two scale quality test flag
Column 28	060202	TEST	Temporal quality test flag
Column 29	060202	TESE	Spatial quality test flag
Column 30	060202	TESG	Forecast quality test flag
Column 31	060201	TESA	Correlation test flag
Column 32	060203	AVNW	Number of NWP levels used in HRW calculation
Column 33	060204	WPRE	Number of Predecessor AMVs in the trajectory
Column 34	060200	WREP	Number of Computed AMVs for the tracer
Column 35	060101	IDN0	Number of Predecessor AMV in the previous slot
Column 36	060205	FLAI	Orographic flag
Column 37	060202	TESI	Orographic test flag
Column 38	060206	CT	AMV NWC/GEO Cloud type
Column 39	060207	WCH	AMV NWC/GEO Satellite channel
Column 40	060208	CORR	Correlation between tracer and tracking centre
Column 41	060209	PERR	AMV Pressure error
Column 42	060210	PCORR	AMV Pressure correction (by Microphysics)
Column 43	060211	DIRN	NWP wind direction at AMV level
Column 44	060212	SPDN	NWP wind speed at AMV level
Column 45	060216	DIFN	Difference with NWP wind at AMV level
Column 46	060213	DRNN	NWP wind direction at AMV best fit level
Column 47	060214	SPNB	NWP wind speed at AMV best fit level
Column 48	060217	DFNB	Difference with NWP wind at AMV best fit level
Column 49	060215	PWNB	NWP pressure at AMV best fit level
Column 50		IDR	Radiosounding identifier
Column 51		LATR	Radiosounding latitude
Column 52		LONR	Radiosounding longitude
Column 53		DIRR	Radiosounding wind direction at AMV near level
Column 54		SPDR	Radiosounding wind speed at AMV near level
Column 55		DIFR	Difference with Radiosounding wind
Column 56		PWR	Radiosounsing pressure at AMV near level
Column 57		DRRN	Radiosounding wind direction at AMV best fit
Column 58		SPRB	Radiosounding wind speed at AMV best fit level
Column 59		DFRB	Difference with Radiosounding wind
Column 60		PWRB	Radiosounsing pressure at AMV best fit level

Table 3. Description of McIDAS WDMR Scheme
and Correspondence with NWC/GEO-HRW "NWC" BUFR output

2.2 STATISTICAL PARAMETERS

The statistical parameters for the validation of NWC/GEO-HRW Atmospheric Motion Vectors (AMVs) 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.

A description of these statistical parameters is shown here:

1. N: Number of collocations between the reference wind vectors (Radiosounding winds or NWP analysis winds) [Ur,Vr] and the NWC/GEO-HRW AMV wind vectors [Ui,Vi].
2. SPD: Mean horizontal wind speed in m/s for the reference winds (Radiosounding winds or NWP analysis winds).
3. BIAS: Difference between the mean horizontal wind speed of the reference winds (Radiosounding winds or NWP analysis winds), and the collocated NWC/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 reference wind speed). The index “i” here denotes each collocation and runs from 1 to the total number of collocations N.

4. MVD: Mean vector difference between the reference winds (Radiosounding winds or NWP analysis winds) and the collocated NWC/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, for which:

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

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 (SD) of each vector difference with respect to the mean, for which:

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

Due to the variable magnitude the defined statistical parameters can have in different samples, the mean horizontal wind speed for the reference winds (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.

Considering the validation against Radiosounding winds, AMVs 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). This way, only a part of the AMVs can be validated against Radiosounding winds.

Considering the validation against NWP analysis winds, the interpolation of the NWP wind to the AMV location and level is used. This way, formally all AMVs can be validated against NWP analysis winds.

To ease the comparison of the validation of AMVs against both reference datasets (Radiosounding winds and NWP analysis winds), throughout this Validation report only AMVs which could be validated against both reference datasets are considered. Although the size of the AMV sample is so smaller, the number of AMV data validated against both datasets is exactly the same in all cases this way, and differences in the validation can be better extracted because of using exactly the same AMVs in each case.

3. VALIDATION OF HRW V6.0 AMVS WITH MSG SATELLITES

3.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION

The validation of NWC/GEO-HRW v6.0 algorithm for MSG satellite series is considered first. It is based on the validation of AMVs calculated during 354 days of the yearly period July 2009 – June 2010 at 12:00 UTC, with MSG2 satellite images, in an area covering Europe and the Mediterranean Sea. This area is shown in *Figure 1*.

The default conditions for NWC/GEO-HRW v6.0 for MSG satellites, considering "Nominal scan satellite mode", "Basic scale AMVs", "Cross correlation tracking", "CCC height assignment method with Microphysics correction", and a "higher density for tracers related to low and very low clouds", are considered first. These conditions are specified in the default model configuration file `$SAFNWC/config/safnwc_HRW_MSG.cfm`, but with validation of all possible satellite channels. Cloudy AMVs in the layer 100-1000 hPa and clear air AMVs in the layer 100-400 hPa, with a Quality index with forecast ≥ 70%, are considered for the validation. NWC/GEO Cloud product outputs (CMA, CT, CTTH and CMIC) in the processing region have to be available so that NWC/GEO-HRW can fully process the conditions defined in the model configuration file. The running of three consecutive slots for all Cloud and HRW products every day during the reference validation period (11:30 UTC, 11:45 UTC and 12:00 UTC), is needed for the validation. An example of this configuration is shown in Figure 1.

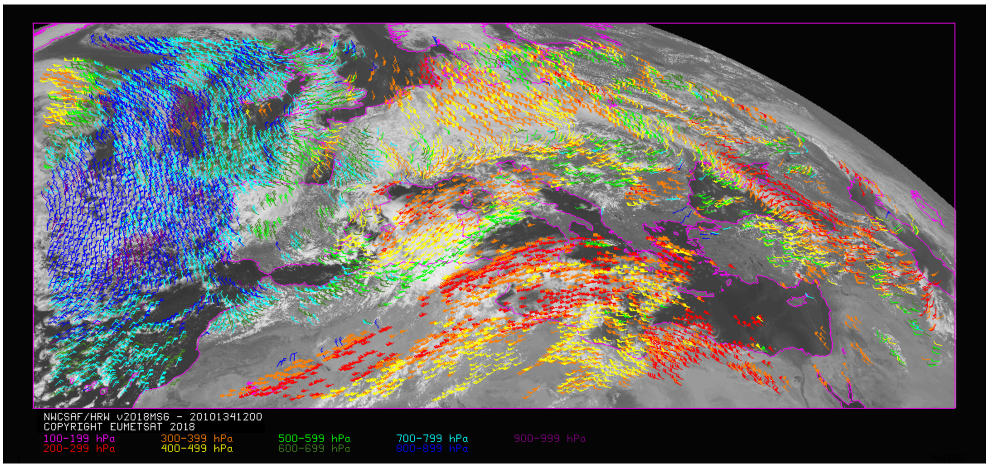

Figure 1: NWC/GEO-HRW v6.0 "Basic AMV" output example in the European and Mediterranean region (14 May 2010 12:00 UTC, MSG2 satellite), considering default conditions defined in `$SAFNWC/config/safnwc_HRW_MSG.cfm` model configuration file. Colour coding based on the AMV pressure level

Comparing the statistics against Radiosounding winds and ECMWF NWP analysis in *Table 4* (considering all layers together) and in *Table 5* (considering the three layers separately), the NBIAS, NMVD and NRMSVD parameters are significantly smaller (around a 30% smaller) against NWP analysis winds. A conclusion can be taken here, that the general scale and behaviour of AMV winds is more similar to that of NWP analysis winds than to that of Radiosounding winds.

Considering the different satellite channels, as for previous versions of NWC/GEO-HRW algorithm, the MVD and NRMSVD seem very different considering all layers together, with changes larger than the 50% between the best case (Cloudy WV62 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 the layers, differences of NMVD and NRMSVD are much smaller.

Considering the different layers, NWC/GEO-HRW Product Requirement Table "Optimal accuracy" (with a value of 0.35 against Radiosounding winds) is reached in the High layer, and the NWC/GEO-HRW Product Requirement Table "Target accuracy" (with values respectively of 0.50 and 0.56 against Radiosounding winds) is reached in the Medium and Low layer.

NWC/GEO-HRWv6.0 AMVs (Jul 2009-Jun 2010, MSG2)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	67288	98861	90082	226314	228664	139042	227273	20383	1097907
SPD [m/s]	12.87	10.28	10.25	17.50	17.72	22.78	20.14	17.42	17.23
NBIAS (ALL LAYERS)	-0.03	-0.13	-0.13	-0.08	-0.07	-0.02	-0.05	+0.01	-0.07
NMVD (100-1000 hPa)	0.35	0.41	0.42	0.30	0.30	0.26	0.29	0.30	0.32
NRMSVD	0.42	0.49	0.49	0.37	0.37	0.32	0.36	0.37	0.39
NC	67288	98861	90082	226314	228664	139042	227273	20383	1097907
SPD [m/s]	12.72	9.99	9.98	17.19	17.41	22.37	19.76	17.23	16.91
NBIAS (ALL LAYERS)	-0.02	-0.10	-0.11	-0.07	-0.06	-0.01	-0.03	+0.02	-0.05
NMVD (100-1000 hPa)	0.22	0.28	0.29	0.20	0.20	0.17	0.19	0.22	0.22
NRMSVD	0.28	0.35	0.35	0.25	0.25	0.21	0.24	0.28	0.27

Table 4: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs considering all layers together against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Nominal scan, European and Mediterranean region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v5.0 Basic AMVs

NWC/GEO-HRWv6.0 AMVs (Jul 2009-Jun 2010, MSG2)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	15919			119091	124905	128731	157689	20383	566718
SPD [m/s]	21.13			21.85	21.81	23.23	22.63	17.42	22.19
NBIAS (HIGH LAYER)	-0.03			-0.07	-0.06	-0.03	-0.06	+0.01	-0.05
NMVD (100-400 hPa)	0.25			0.26	0.26	0.26	0.26	0.30	0.26
NRMSVD	0.30			0.32	0.32	0.32	0.32	0.37	0.32
NC	15447	31346	29700	65544	64179	10311	60432		276959
SPD [m/s]	12.88	11.72	11.49	14.29	14.44	17.13	14.95		13.91
NBIAS (MEDIUM LAYER)	-0.05	-0.15	-0.16	-0.09	-0.08	+0.04	-0.02		-0.08
NMVD (400-700 hPa)	0.35	0.38	0.38	0.35	0.35	0.36	0.37		0.36
NRMSVD	0.42	0.45	0.46	0.43	0.43	0.44	0.46		0.44
NC	35922	67515	60382	41679	39580		9152		254230
SPD [m/s]	9.21	9.61	9.63	10.11	10.14		11.51		9.79
NBIAS (LOW LAYER)	-0.02	-0.11	-0.11	-0.11	-0.10		-0.02		-0.09
NMVD (700-1000 hPa)	0.45	0.43	0.44	0.40	0.40		0.41		0.42
NRMSVD	0.53	0.51	0.51	0.48	0.47		0.48		0.50
NC	15919			119091	124905	128731	157689	20383	566718
SPD [m/s]	20.87			21.54	21.50	22.81	22.22	17.23	21.83
NBIAS (HIGH LAYER)	-0.01			-0.06	-0.05	-0.01	-0.04	+0.02	-0.04
NMVD (100-400 hPa)	0.16			0.17	0.17	0.16	0.17	0.22	0.17
NRMSVD	0.19			0.22	0.21	0.20	0.21	0.28	0.21
NC	15447	31346	29700	65544	64179	10311	60432		276959
SPD [m/s]	12.58	11.33	11.11	13.95	14.09	16.83	14.65		13.56
NBIAS (MEDIUM LAYER)	-0.03	-0.12	-0.13	-0.07	-0.06	+0.06	-0.00		-0.05
NMVD (400-700 hPa)	0.25	0.28	0.28	0.25	0.25	0.26	0.28		0.26
NRMSVD	0.31	0.34	0.34	0.31	0.31	0.32	0.35		0.33
NC	35922	67515	60382	41679	39580		9152		254230
SPD [m/s]	9.17	9.37	9.42	9.86	9.91		11.21		9.58
NBIAS (LOW LAYER)	-0.01	-0.09	-0.10	-0.09	-0.08		+0.00		-0.07
NMVD (700-1000 hPa)	0.28	0.28	0.29	0.27	0.27		0.31		0.28
NRMSVD	0.34	0.35	0.35	0.33	0.33		0.38		0.34

Table 5: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs considering three separate layers against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Nominal scan, European and Mediterranean region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v5.0 Basic AMVs

3.2 COMPARISON WITH HRW V5.0 DEFAULT CONFIGURATION

The comparison of the statistics against Radiosounding winds of NWC/GEO-HRW v6.0 default configuration with those for the previous version of NWC/GEO-HRW algorithm (NWC/GEO-HRW v5.0 released in 2016), is considered here in *Tables 6 and 7* for MSG satellite series.

The main element is that the distribution of AMVs in the different layers has changed significantly, going from a value of 61%/25%/14% for the High/Medium/Low layer in the previous version, to a more homogeneous value in the new version of 52%/25%/23% (considering validated AMVs) and 45%/23%/32% (considering calculated AMVs). This helps to better characterize the behaviour of the wind in the different levels of the troposphere. The change is caused by the higher density of tracers related to low clouds, with both a relative and absolute increase of AMVs in the low layer. Considering the high and medium layer there is however a reduction in the number of AMVs, caused by the need to keep the running time of NWC/GEO-HRW algorithm while increasing the density of low level AMVs. The reduction is also seen in the total number of AMVs (26% less AMVs).

Comparing the validation parameters for the new and previous version of NWC/GEO-HRW, and considering all layers together, there is a small increase of the NMVD and NRMSVD values (up to a 10%), which is only caused by the larger proportion now of low layer AMVs, with worse validation parameters. Considering each layer separately, the NMVD and NRMSVD keep similar values in all of them, while the NBIAS reduces around a 20% with the new version in all layers.

NWC/GEO-HRWv5.0 AMVs (Jul 2009-Jun 2010, MSG2)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	31630	97221	87177	313072	317120	256951	331831	48509	1483511
SPD [m/s]	16.64	10.51	10.48	18.53	18.67	22.78	20.80	16.64	18.70
NBIAS (ALL LAYERS)	-0.04	-0.14	-0.15	-0.09	-0.08	-0.04	-0.07	-0.00	-0.08
NMVD (100-1000 hPa)	0.29	0.41	0.42	0.29	0.29	0.26	0.28	0.32	0.30
NRMSVD	0.35	0.49	0.49	0.35	0.35	0.32	0.35	0.39	0.36

Table 6: Validation parameters for the previous version of HRW algorithm: NWC/GEO-HRW v5.0 Basic AMVs considering all layers together against Radiosounding winds (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Nominal scan, European and Mediterranean region; Basic AMVs; Cross correlation; CCC height assignment with Microphysics)

NWC/GEO-HRWv5.0 AMVs (Jul 2009-Jun 2010, MSG2)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	14748			186143	193173	235550	238459	41261	909334
SPD [m/s]	21.77			22.16	22.11	23.31	23.15	17.19	22.48
NBIAS (HIGH LAYER)	-0.03			-0.08	-0.07	-0.04	-0.08	-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			0.32	0.31	0.31	0.32	0.38	0.32
NC	8532	37419	34188	86936	86010	21401	84678	7248	366412
SPD [m/s]	14.64	12.08	11.94	14.61	14.69	16.90	15.10	13.51	14.35
NBIAS (MEDIUM LAYER)	-0.05	-0.18	-0.18	-0.12	-0.11	+0.02	-0.05	+0.09	-0.10
NMVD (400-700 hPa)	0.31	0.38	0.38	0.35	0.35	0.37	0.37	0.40	0.36
NRMSVD	0.48	0.46	0.45	0.43	0.43	0.46	0.45	0.47	0.44
NC	8350	59802	52989	39993	37937		8694		207765
SPD [m/s]	9.64	9.52	9.54	10.14	10.18		12.09		9.88
NBIAS (LOW LAYER)	-0.02	-0.12	-0.12	-0.12	-0.12		-0.09		-0.11
NMVD (700-1000 hPa)	0.44	0.44	0.44	0.41	0.40		0.38		0.43
NRMSVD	0.52	0.51	0.52	0.48	0.48		0.46		0.50

Table 7: Validation parameters for the previous version of HRW algorithm: NWC/GEO-HRW v5.0 Basic AMVs considering three separate layers against Radiosounding winds (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Nominal scan, European and Mediterranean region; Basic AMVs; Cross correlation; CCC height assignment with Microphysics)

3.3 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION

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 configurable parameter CDET = 1 in the default model configuration file. These are provided as an additional dataset of AMVs together with the "Basic AMVs", which are always calculated.

The conditions for the validation of "Detailed AMVs" are exactly equivalent to those shown in chapter 3.1 for the MSG "Basic AMVs". An example of this configuration is shown in *Figure 2*. The validation statistics are presented in *Table 8* considering all layers together, and *Table 9* considering the three layers separately for the same validation period.

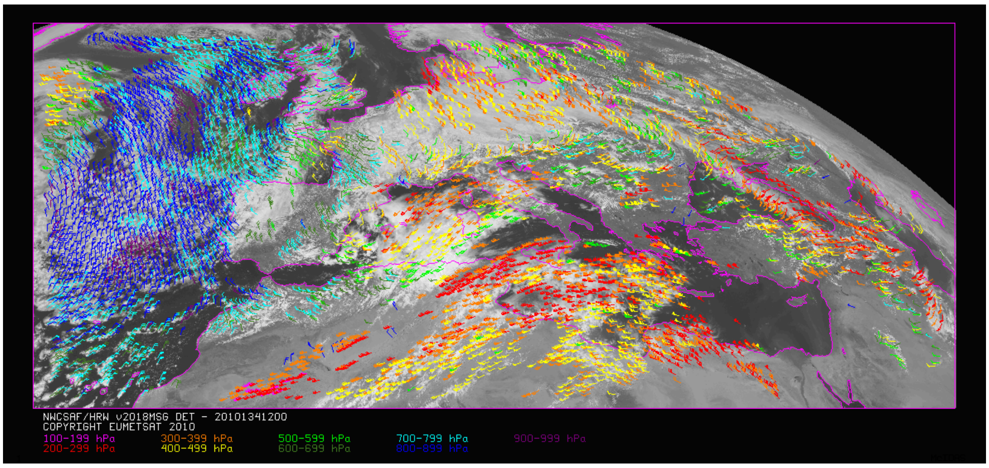

Figure 2: NWC/GEO-HRW v6.0 "Detailed AMV" output example in the European and Mediterranean region (14 May 2010 12:00 UTC, MSG2 satellite), considering default conditions defined in `$SAFNWC/config/safnwc_HRW_MSG.cfm` model configuration file but with configurable parameter CDET = 1. Colour coding based on the AMV pressure level

Comparing with the "Basic AMVs", a reduction in the number of AMVs of about a 25% is seen for the "Detailed AMVs". This can be explained through the smaller size of the tracers (affecting especially the water vapour channels, for which the image features are generally larger), the smaller persistence in time of the finest image features (affecting especially the High resolution visible AMVs, for which the size of the Detailed tracers is the smallest of all: up to 12x12 km), and especially the smaller contrast in the features using smaller tracer sizes.

However, the distribution of validated AMVs in the different layers has a value of 51%/23%/26% for the High/Medium/Low layer, and this is basically equivalent to that for "Basic AMVs", so helping to characterize the behaviour of the wind in the different levels of the troposphere. Considering the validation parameters, the NMVD and NRMSVD are similar or slightly better than for the "Basic AMVs", while the NBIAS shows general reductions up to a 50%.

Comparing the statistics against Radiosounding winds and ECMWF NWP analysis winds, all validation parameters are again significantly smaller (around a 30% smaller) against NWP analysis winds. Considering the different layers, NWC/GEO-HRW Product Requirement Table "Optimal accuracy" is reached in the High layer, and the NWC/GEO-HRW Product Requirement Table "Target accuracy" is reached in the Medium and Low layer.

In short, the behaviour of "Detailed AMVs" is very similar to that of "Basic AMVs" (with slightly better statistics), and so both datasets can be used together for the characterization of the wind in the different layers of the troposphere.

NWC/GEO-HRWv6.0 AMVs (Jul 2009-Jun 2010, MSG2)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	28829	102806	97852	180541	179209	73681	162405	2868	828191
SPD [m/s]	11.78	10.24	10.11	18.12	18.57	24.56	21.92	17.80	17.39
NBIAS (ALL LAYERS)	-0.01	-0.09	-0.10	-0.05	-0.04	-0.02	-0.03	+0.08	-0.05
NMVD (100-1000 hPa)	0.37	0.41	0.41	0.28	0.28	0.25	0.27	0.31	0.32
NRMSVD	0.44	0.48	0.49	0.35	0.34	0.31	0.33	0.39	0.38
NC	28829	102806	97852	180541	179209	73681	162405	2868	828191
SPD [m/s]	11.69	10.00	9.89	17.81	18.26	24.02	21.52	17.89	17.07
NBIAS (ALL LAYERS)	-0.00	-0.07	-0.08	-0.04	-0.03	-0.00	-0.01	+0.07	-0.03
NMVD (100-1000 hPa)	0.24	0.27	0.28	0.18	0.18	0.16	0.17	0.23	0.21
NRMSVD	0.30	0.33	0.34	0.23	0.22	0.20	0.22	0.29	0.26

Table 8: Validation parameters for NWC/GEO-HRW v6.0 Detailed AMVs considering all layers together against Radiosounding winds (light green) and ECMWF NWP analysis winds (light blue) (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Nominal scan, European and Mediterranean region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Basic AMVs

NWC/GEO-HRWv6.0 AMVs (Jul 2009-Jun 2010, MSG2)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	4750			101623	106457	71134	131661	2868	418493
SPD [m/s]	22.08			22.39	22.44	24.78	23.46	17.80	23.11
NBIAS (HIGH LAYER)	-0.02			-0.05	-0.04	-0.02	-0.04	+0.08	-0.04
NMVD (100-400 hPa)	0.25			0.25	0.25	0.25	0.25	0.31	0.25
NRMSVD	0.30			0.31	0.30	0.31	0.31	0.39	0.31
NC	4985	31548	30370	49089	46966	2547	28748		194253
SPD [m/s]	12.60	11.23	11.09	14.05	14.32	18.23	15.55		13.43
NBIAS (MEDIUM LAYER)	-0.04	-0.13	-0.13	-0.06	-0.05	+0.06	+0.01		-0.06
NMVD (400-700 hPa)	0.36	0.39	0.39	0.34	0.34	0.37	0.36		0.36
NRMSVD	0.44	0.46	0.47	0.42	0.41	0.45	0.45		0.44
NC	19094	71258	67482	29829	25786		1996		215445
SPD [m/s]	9.00	9.80	9.66	10.28	10.31		12.18		9.84
NBIAS (LOW LAYER)	+0.00	-0.08	-0.08	-0.08	-0.07		-0.02		-0.07
NMVD (700-1000 hPa)	0.44	0.42	0.43	0.38	0.37		0.38		0.41
NRMSVD	0.52	0.49	0.50	0.45	0.45		0.45		0.48
NC	4750			101623	106457	71134	131661	2868	418493
SPD [m/s]	21.77			22.06	22.12	24.24	23.04	17.89	22.72
NBIAS (HIGH LAYER)	-0.01			-0.03	-0.02	-0.00	-0.02	+0.07	-0.02
NMVD (100-400 hPa)	0.16			0.16	0.16	0.16	0.16	0.23	0.16
NRMSVD	0.20			0.20	0.20	0.19	0.20	0.29	0.20
NC	4985	31548	30370	49089	46966	2547	28748		194253
SPD [m/s]	12.42	10.85	10.71	13.72	13.97	18.06	15.21		13.09
NBIAS (MEDIUM LAYER)	-0.02	-0.10	-0.10	-0.03	-0.02	+0.07	+0.03		-0.03
NMVD (400-700 hPa)	0.27	0.28	0.28	0.23	0.23	0.25	0.26		0.25
NRMSVD	0.33	0.35	0.35	0.29	0.29	0.31	0.32		0.32
NC	19094	71258	67482	29829	25786		1996		215445
SPD [m/s]	8.99	9.63	9.52	10.07	10.16		11.80		9.68
NBIAS (LOW LAYER)	+0.00	-0.06	-0.06	-0.06	-0.06		+0.01		-0.05
NMVD (700-1000 hPa)	0.27	0.27	0.27	0.24	0.24		0.27		0.26
NRMSVD	0.33	0.32	0.33	0.29	0.29		0.34		0.32

Table 9: Validation parameters for NWC/GEO-HRW v6.0 Detailed AMVs considering three separate layers against Radiosounding winds (light green) and ECMWF NWP analysis winds (light blue) (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Nominal scan, European and Mediterranean region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Basic AMVs

3.4 VALIDATION FOR BASIC AMVS WITHOUT CLOUD PRODUCTS

The validation for the situation in which NWC/GEO Cloud products are not available for the running of HRW algorithm with MSG satellite series, and so the "Brightness temperature interpolation height assignment without Cloud products" is used, is presented here in *Table 10* (considering all layers together) and *Table 11* (considering the three layers separately) for the same validation period. So users are able to know what they can expect from NWC/GEO-HRW v6.0 algorithm when it is run independently. An example of this configuration is shown in *Figure 3*.

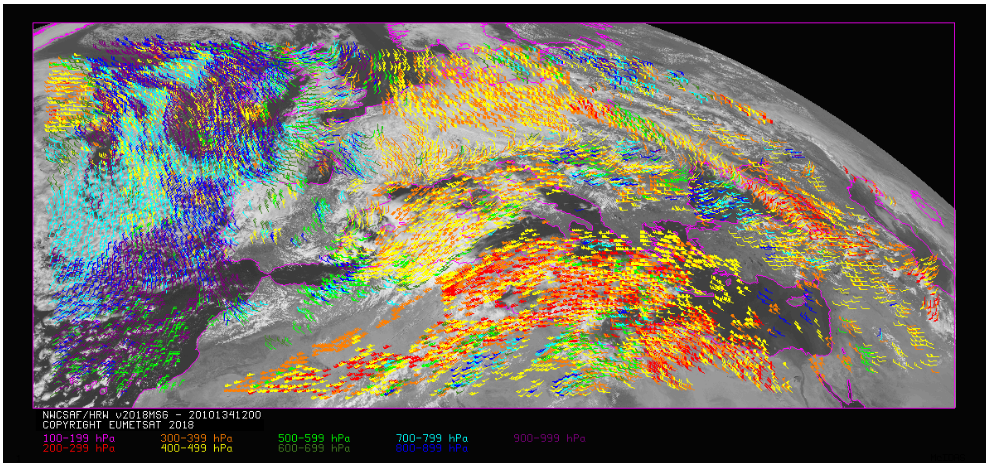

Figure 3: NWC/GEO-HRW v6.0 "Basic AMV" output example in the European and Mediterranean region (14 May 2010 12:00 UTC, MSG2 satellite), considering default conditions defined in `$SAFNWC/config/safnwc_HRW_MSG.cfm` model configuration file but without Clouds products. Colour coding based on the AMV pressure level

Comparing with *Tables 4 and 5* (using "CCC height assignment with Microphysics correction"), the first comment is that now all water vapour AMVs (Cloudy and Clear air) are presented together, due to the impossibility to differentiate them without the use of Cloud products. The main difference between both results is the reduction now of the number of AMVs to around a half, and an increase in the population of Medium level AMVs (with a distribution of validated AMVs in the different layers of 46%/34%/20% for the High/Medium/Low layer), which seems to be in less agreement with reality.

Considering however the validation parameters, there are very small differences in the NMVD and the NRMSVD (up to a 6% only) between both height assignment methods, and significantly better values of the NBIAS not using Cloud products, nearer to zero. Comparing the statistics against Radiosounding winds and ECMWF NWP analysis winds, the NMVD and NRMSVD parameters are also a 30% smaller using NWP analysis winds as reference.

Due to the small differences in the NRMSVD parameter with both height assignments, the situation respect to the NWC/GEO-HRW Product Requirement Table accuracies is exactly the same for both cases (with all layers complying with the "Target accuracy", and the high layer AMVs complying with the "Optimal accuracy").

So, NWC/GEO users can perfectly use NWC/GEO-HRW v6.0 operatively with MSG satellite series, even in the case in which NWC/GEO Clouds are not available. But for a better clarification for the users about which height assignment works better, a deeper analysis is going to be done in next chapter.

NWC/GEO-HRWv6.0 AMVs (Jul 2009-Jun 2010, MSG2)	**HRVIS**	**VIS06**	**VIS08**	**IR108**	**IR120**	**WV62**	**WV73**	**All AMVs**
NC	21426	32383	30888	76336	80855	142955	152160	537003
SPD [m/s]	14.82	11.76	11.74	15.89	15.99	22.05	17.94	17.59
NBIAS (ALL LAYERS)	+0.01	-0.01	-0.02	+0.05	+0.05	-0.01	+0.06	+0.02
NMVD (100-1000 hPa)	0.32	0.37	0.36	0.32	0.32	0.26	0.34	0.31
NRMSVD	0.39	0.44	0.44	0.39	0.40	0.32	0.42	0.38
NC	21426	32383	30888	76336	80855	142955	152160	537003
SPD [m/s]	14.79	11.64	11.59	15.84	15.94	21.81	17.88	17.48
NBIAS (ALL LAYERS)	+0.01	-0.00	-0.00	+0.05	+0.06	-0.00	+0.06	+0.03
NMVD (100-1000 hPa)	0.20	0.24	0.24	0.22	0.22	0.17	0.26	0.21
NRMSVD	0.25	0.30	0.30	0.28	0.28	0.21	0.32	0.27

Table 10: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs without Cloud products considering all layers together against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Nominal scan, European and Mediterranean region; Basic AMVs; Cross correlation; Brightness temperature height assignment without cloud products) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Basic AMVs with Cloud products

NWC/GEO-HRWv6.0 AMVs (Jul 2009-Jun 2010, MSG2)	**HRVIS**	**VIS06**	**VIS08**	**IR108**	**IR120**	**WV62**	**WV73**	**All AMVs**
NC	6204			18313	20787	139834	63707	248845
SPD [m/s]	22.53			24.76	24.53	22.12	21.01	22.24
NBIAS (HIGH LAYER)	+0.00			+0.01	+0.01	-0.01	+0.05	+0.00
NMVD (100-400 hPa)	0.24			0.24	0.25	0.26	0.28	0.26
NRMSVD	0.29			0.29	0.30	0.32	0.34	0.32
NC	6980	12473	12161	28987	30864	3121	88453	183039
SPD [m/s]	14.06	14.97	14.94	16.39	16.13	18.55	15.73	15.78
NBIAS (MEDIUM LAYER)	+0.00	-0.03	-0.03	+0.09	+0.10	-0.17	+0.07	+0.06
NMVD (400-700 hPa)	0.34	0.33	0.33	0.34	0.35	0.42	0.40	0.37
NRMSVD	0.42	0.39	0.39	0.41	0.42	0.52	0.49	0.45
NC	8242	19910	18727	29036	29204			105119
SPD [m/s]	9.66	9.74	9.65	9.80	9.76			9.74
NBIAS (LOW LAYER)	+0.03	+0.00	-0.01	+0.05	+0.04			+0.02
NMVD (700-1000 hPa)	0.44	0.41	0.40	0.41	0.41			0.41
NRMSVD	0.52	0.49	0.48	0.49	0.50			0.49
NC	6204			18313	20787	139834	63707	248845
SPD [m/s]	22.36			24.67	24.44	21.90	21.03	22.10
NBIAS (HIGH LAYER)	+0.01			+0.01	+0.02	-0.00	+0.05	+0.01
NMVD (100-400 hPa)	0.15			0.16	0.16	0.17	0.19	0.17
NRMSVD	0.18			0.19	0.20	0.21	0.24	0.21
NC	6980	12473	12161	28987	30864	3121	88453	183039
SPD [m/s]	13.80	14.71	14.69	16.20	15.96	17.73	15.62	15.61
NBIAS (MEDIUM LAYER)	+0.02	-0.02	-0.01	+0.11	+0.11	-0.13	+0.07	+0.07
NMVD (400-700 hPa)	0.25	0.24	0.23	0.26	0.27	0.28	0.32	0.29
NRMSVD	0.31	0.29	0.29	0.33	0.33	0.35	0.40	0.36
NC	8242	19910	18727	29036	29204			105119
SPD [m/s]	9.93	9.71	9.58	9.90	9.85			9.80
NBIAS (LOW LAYER)	+0.01	+0.00	-0.00	+0.04	+0.03			+0.02
NMVD (700-1000 hPa)	0.22	0.24	0.24	0.23	0.23			0.23
NRMSVD	0.28	0.30	0.29	0.30	0.29			0.29

Table 11: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs without Cloud products considering three separate layers against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Nominal scan, European and Mediterranean region; Basic AMVs; Cross correlation; Brightness temperature height assignment without cloud products) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Basic AMVs with Cloud products

3.5 COMPARISON BETWEEN HEIGHT ASSIGNMENT PROCEDURES

The fact that "CCC method height assignment with microphysics correction" is able to calculate around the double number of AMVs than "Brightness temperature interpolation height assignment without Cloud products" with similar NMVD/NRMSVD validation parameters, should be a cause to prefer this height assignment method in the AMV processing.

However, the calculation of the AMV statistics considering the "Radiosounding wind best fit level" as reference (which means the best possible AMV statistics through changes in the height assignment only), shows for both height assignment procedures NBIAS values of 0.00 and NRMSVD values of 0.09. So, it can be seen that there is still a lot of possible room for improvement in the AMV statistics, considering the height assignment procedure.

One question can be defined here related to this: What is the difference for both height assignment methods between the "AMV level" and the "Radiosounding wind best fit level", considering different layers and cloud types.

Table 12 shows the mean value of the "difference" and the "absolute difference" (between the "Radiosounding wind best fit level" and the "AMV level"), for both height assignment methods for all layers. It can be seen that "CCC method height assignment with microphysics correction" behaves much better, with a mean "difference" of only 2 hPa considering all AMVs together, and less than 7 hPa for all layers (high, medium and low). The dispersion respect to the "Radiosounding wind best fit level" is nevertheless important, with a mean value of the "absolute difference" of 107 hPa.

"Brightness temperature interpolation height assignment without Cloud products" behaves worse, with the mean "Radiosounding best fit level" located 50 hPa higher in the atmosphere as a whole, and at least 29 hPa for each one of the individual layers. This issue (systematically locating the AMVs at a lower level than the optimal one) can contribute to the artificial reduction of the negative NBIAS with this height assignment. So, the fact of obtaining smaller NBIAS values with this method does not mean that the corresponding AMVs are better. On the other side, the "absolute difference" is also a bit higher, with a mean value of 118 hPa.

Comparing with the equivalent table for the previous version of NWC/GEO-HRW algorithm, there are very small differences only; the most significant change is that the mean "difference" for the medium and low layer with "CCC method height assignment with microphysics correction" is smaller, possibly caused by improvements in the new version of NWC/GEO-Cloud Microphysics product.

	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)	-50 hPa	118 hPa	-2 hPa	107 hPa
100 - 399 hPa (HIGH LEVEL)	-29 hPa	76 hPa	-2 hPa	83 hPa
400 - 699 hPa (MEDIUM LEVELS)	-79 hPa	163 hPa	-6 hPa	162 hPa
700 - 999 hPa (LOW LEVELS)	-69 hPa	135 hPa	5 hPa	126 hPa

Table 12: "Mean difference" and "Mean absolute difference" between the "AMV best fit level calculated with Radiosounding winds" and the "AMV level" in the different layers (Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean region; Basic AMVs; Cross correlation; "Brightness temperature interpolation height assignment without cloud products" compared to "CCC method height assignment with Microphysics") Green figures show improvements of at least 10 hPa for "CCC method height assignment with Microphysics"

Table 13 shows the mean "difference" and mean "absolute difference" between the "Radiosounding wind 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.

In general, considering the mean "difference", 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 "difference" values larger than 25 hPa. Considering the mean "absolute difference", a divergent behaviour between cumulus/stratus clouds on one side (with a higher dispersion with respect to the best fit level) and cirrus clouds on the other side (with a smaller dispersion with respect to the best fit level) is to be remarked.

Comparing with the equivalent table for the previous version of NWC/GEO-HRW algorithm, slight improvements in the mean "difference" and the mean "absolute difference" are to be seen for the large part of cloud types, possibly again caused by improvements in the new version of NWC/GEO-Cloud Microphysics product.

	CCC Method with Microphysics correction Height Assignment	
	Mean $P_{Bestfit} - P_{AMV}$	**Mean $\mid P_{Bestfit} - P_{AMV} \mid$**
Clear air	-43 hPa	91 hPa
Very low cumulus/stratus	-1 hPa	124 hPa
Low cumulus/stratus	15 hPa	146 hPa
Medium cumulus/stratus	-1 hPa	164 hPa
High cumulus/stratus	2 hPa	102 hPa
Very high cumulus/stratus	21 hPa	87 hPa
High semitransparent thin	-9 hPa	74 hPa
High semitransparent meanly thick	-3 hPa	70 hPa
High semitransparent thick	-6 hPa	81 hPa
High semitransparent above other clouds	-38 hPa	100 hPa

Table 13: "Mean difference" and "Mean absolute difference" between the "AMV best fit level calculated wind Radiosounding winds" and the "AMV level" for the different cloud types (Jul 2009-Jun 2010, MSG2 satellite, 12:00 UTC, European and Mediterranean region; Basic AMVs; Cross correlation; "CCC method height assignment with Microphysics")

With all of this, the results in *Tables 12 and 13* give enough confidence to say that "CCC method with microphysics correction" works better as AMV height assignment method, and so it does for all atmospheric layers and cloud types.

3.6 VALIDATION FOR BASIC AMVS WITH MIXED CALCULATION METHOD IN NOMINAL SCAN MODE

A specific validation of AMVs calculated with "Mixed calculation method", available for the first time in this version of NWC/GEO-HRW algorithm, is shown here to see the differences with the previous configurations. This validation is specified for both "Nominal scan mode" (in this chapter), and "Rapid scan mode" (in next chapter), so that the different effect with both scanning modes is shown.

As explained in the "Algorithm Theoretical Basis Document for the Wind product processor of the NWC/GEO" [AD.14], the "Mixed calculation method" considers at the same time short and long time intervals for the AMV calculation, through which the tracking process is verified in shorter time intervals but the AMVs are calculated considering displacements in longer time intervals.

The validation of "Mixed calculation method" with "Nominal scan mode" is presented in *Table 14* (considering all layers together) and *Table 15* (considering the three layers separately). It considers AMVs calculated with MSG2 satellite images, during the same validation period of July 2009–June 2010 at 12:00 UTC, with configurable parameters MIXED_SCANNING = 2 and SLOT_GAP = 2. This way, tracers are tracked every 15 minutes but AMVs are calculated after 30 minutes, with two consecutive displacements of each tracer, such as defined in *Figure 4*. An AMV example of this configuration is shown in *Figure 5*. The rest of conditions is equivalent to those used for the default configuration, using all possible satellite channels, so that the results in this chapter can be directly compared to those in Chapter 3.1 for the default configuration.

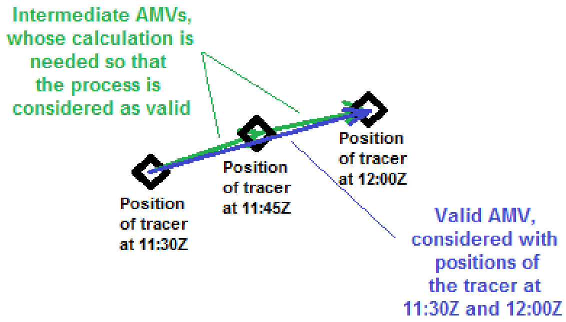

Figure 4: Example of processing with the "Mixed calculation method" for MSG satellite series "Nominal scan mode", in which the tracers are tracked every 15 minutes (so providing two intermediate AMVs) but the valid AMVs are calculated every 30 minutes (considering the initial and final position of the tracer only)

The "Mixed calculation method" in "Nominal scan mode" can be useful to reduce errors caused by the resolution of the satellite images (because longer distances are used for the calculation of the AMV displacements), and to reduce errors caused by the tracking process (because all AMVs have to be related to the calculation of at least two intermediate AMVs in a same trajectory). This implies an AMV calculation process more similar to that defined in general by other AMV calculation centres, in which all AMVs are related to the calculation of several intermediate AMVs. When the "Mixed calculation method" is not activated in NWC-GEO/HRW algorithm, not all AMVs are related to the calculation of several intermediate AMVs.

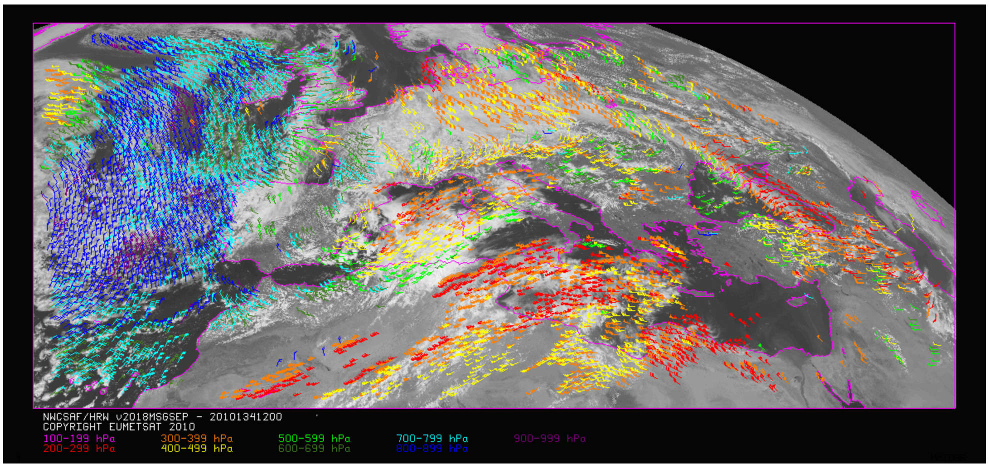

Figure 5: NWC/GEO-HRW v6.0 "Basic AMV" output example in the European and Mediterranean region (14 May 2010 12:00 UTC, MSG2 satellite, Nominal scan mode), considering default conditions defined in `$SAFNWC/config/safnwc_HRW_MSG.cfm` model configuration file but with Mixed calculation method (with configurable parameters MIXED_SCANNING = 2 and SLOT_GAP = 2). Colour coding based on the AMV pressure level

Comparing these validation statistics with those in *Tables 4 and 5* (not using "Mixed calculation method"), several conclusions can be taken. On one side, a reduction in the number of AMVs of about a 35% is seen for the "Mixed scanning calculation", which can be explained through the need that all AMVs have to be related to the calculation of two intermediate AMVs in a same trajectory.

The distribution of validated AMVs in the different layers keeps on being very similar (54%/23%/23% for the High/Medium/Low layer, with a similar characterization of the behaviour of the wind in the different levels of the troposphere). Considering the validation parameters, the NMVD and NRMSVD are similar or slightly better, while the NBIAS shows general reductions up to a 25%.

Comparing the statistics against Radiosounding winds and ECMWF NWP analysis winds the result is similar (with validation parameters around a 30% smaller against NWP analysis winds). Considering the accuracies in the NWC/GEO-HRW Product Requirement Table, the results are equivalent also (with the "Optimal accuracy" reached in the High layer, and the "Target accuracy" reached in the Medium and Low layer).

For operational use, the NWC SAF user has to decide if the reduction in the amount of AMVs is compensated positively by the reductions in the validation parameters.

NWC/GEO-HRWv6.0 AMVs (Jul 2009-Jun 2010, MSG2)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	33117	62033	55865	142547	143865	95179	145697	10354	688657
SPD [m/s]	12.48	10.31	10.28	18.03	18.29	23.36	20.88	17.45	17.82
NBIAS (ALL LAYERS)	-0.02	-0.10	-0.10	-0.07	-0.07	-0.02	-0.05	+0.03	-0.06
NMVD (100-1000 hPa)	0.35	0.41	0.42	0.29	0.29	0.26	0.28	0.29	0.29
NRMSVD	0.42	0.48	0.49	0.35	0.35	0.31	0.34	0.35	0.36
NC	33117	62033	55865	142547	143865	95179	145697	10354	688657
SPD [m/s]	12.35	10.10	10.08	17.70	17.96	22.95	20.48	17.29	17.50
NBIAS (ALL LAYERS)	-0.01	-0.08	-0.09	-0.06	-0.05	-0.01	-0.03	+0.04	-0.04
NMVD (100-1000 hPa)	0.22	0.28	0.28	0.19	0.19	0.16	0.18	0.21	0.19
NRMSVD	0.27	0.33	0.34	0.24	0.23	0.20	0.23	0.26	0.24

Table 14: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs considering all layers together against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Nominal scan, European and Mediterranean region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics; Mixed calculation method). Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Basic AMVs without Mixed calculation method

NWC/GEO-HRWv6.0 AMVs (Jul 2009-Jun 2010, MSG2)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	7736			78360	82578	89647	106352	10354	375027
SPD [m/s]	20.67			22.21	22.13	23.72	23.10	17.45	22.64
NBIAS (HIGH LAYER)	-0.03			-0.07	-0.06	-0.03	-0.06	+0.03	-0.05
NMVD (100-400 hPa)	0.25			0.26	0.26	0.25	0.26	0.29	0.26
NRMSVD	0.30			0.31	0.31	0.31	0.32	0.35	0.31
NC	6475	17999	16849	38351	36911	5532	34816		156933
SPD [m/s]	12.62	11.67	11.50	14.64	14.83	17.55	15.30		14.17
NBIAS (MEDIUM LAYER)	-0.05	-0.14	-0.14	-0.08	-0.07	+0.03	-0.02		-0.07
NMVD (400-700 hPa)	0.34	0.38	0.38	0.34	0.34	0.35	0.36		0.35
NRMSVD	0.41	0.45	0.45	0.42	0.42	0.43	0.44		0.43
NC	18906	44034	39016	25836	24376		4529		156697
SPD [m/s]	9.08	9.76	9.75	10.40	10.51		11.85		9.96
NBIAS (LOW LAYER)	-0.01	-0.08	-0.09	-0.09	-0.09		-0.04		-0.08
NMVD (700-1000 hPa)	0.46	0.43	0.43	0.39	0.39		0.37		0.42
NRMSVD	0.53	0.50	0.51	0.46	0.46		0.44		0.49
NC	7736			78360	82578	89647	106352	10354	375027
SPD [m/s]	20.37			21.85	21.78	23.30	22.66	17.29	22.26
NBIAS (HIGH LAYER)	-0.01			-0.05	-0.04	-0.01	-0.04	+0.04	-0.03
NMVD (100-400 hPa)	0.15			0.17	0.16	0.16	0.17	0.21	0.16
NRMSVD	0.18			0.21	0.20	0.20	0.21	0.26	0.20
NC	6475	17999	16849	38351	36911	5532	34816		156933
SPD [m/s]	12.33	11.29	11.12	14.27	14.48	17.23	14.98		13.82
NBIAS (MEDIUM LAYER)	-0.03	-0.11	-0.11	-0.06	-0.05	+0.05	-0.00		-0.05
NMVD (400-700 hPa)	0.24	0.28	0.28	0.24	0.24	0.24	0.26		0.25
NRMSVD	0.29	0.34	0.33	0.29	0.30	0.30	0.33		0.31
NC	18906	44034	39016	25836	24376		4529		156697
SPD [m/s]	9.08	9.61	9.63	10.20	10.30		11.59		9.81
NBIAS (LOW LAYER)	-0.01	-0.07	-0.07	-0.07	-0.07		-0.02		-0.06
NMVD (700-1000 hPa)	0.28	0.28	0.28	0.26	0.25		0.27		0.27
NRMSVD	0.34	0.33	0.34	0.31	0.31		0.34		0.33

Table 15: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs considering three separate layers against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Nominal scan, European and Mediterranean region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics; Mixed calculation method). Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Basic AMVs without Mixed calculation method

3.7 Validation for Basic AMVs with Mixed calculation method in Rapid Scan mode

The validation of "Mixed calculation method" in "Rapid scan mode" is presented in *Table 16* (considering all layers together) and *Table 17* (considering the three layers separately).

The validation presented here considers AMVs calculated with MSG1 satellite images in "Rapid scan mode", during the same validation period of July 2009 – June 2010 at 12:00 UTC. Tracers are tracked every 5 minutes, but AMVs are calculated every 15 minutes with three consecutive displacements of each tracer, such as defined in *Figure 6*. An example of this configuration is shown in *Figure 7*. The rest of conditions is equivalent to those used for the previous case with "Nominal scan mode", so that the results in this chapter can be directly compared to those shown previously.

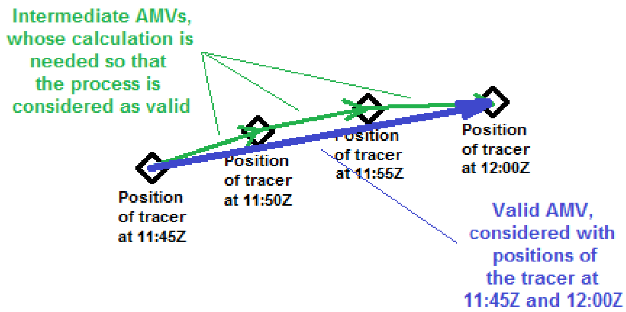

Figure 6: Example of processing with the "Mixed calculation method" for MSG satellite series "Rapid scan mode", in which the tracers are tracked every 5 minutes (so providing three intermediate AMVs) but the valid AMVs are calculated every 15 minutes (considering the initial and final position of the tracer only)

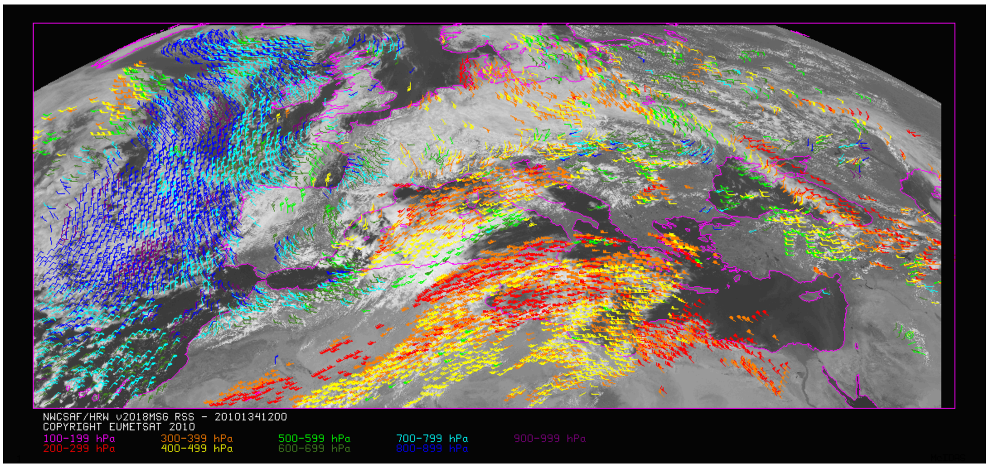

Figure 7: NWC/GEO-HRW v6.0 "Basic AMV" output example in the European and Mediterranean region (14 May 2010 12:00 UTC, MSG2 satellite, Rapid scan mode), considering default conditions defined in `$SAFNWC/config/safnwc_HRW_MSG.cfm` model configuration file but with Mixed calculation method (with configurable parameters MIXED_SCANNING = 2 and SLOT_GAP = 2). Colour coding based on the AMV pressure level

NWC/GEO-HRWv6.0 AMVs (Jul 2009-Jun 2010, MSG1)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	103036	40507	39470	100302	101375	75171	108076	4262	572199
SPD [m/s]	13.96	11.20	11.23	21.06	21.48	26.95	24.33	22.98	19.89
NBIAS (ALL LAYERS)	-0.03	-0.12	-0.14	-0.06	-0.05	-0.00	-0.02	+0.03	-0.04
NMVD (100-1000 hPa)	0.32	0.50	0.51	0.31	0.31	0.27	0.28	0.28	0.31
NRMSVD	0.39	0.57	0.58	0.37	0.36	0.32	0.34	0.34	0.37
NC	103036	40507	39470	100302	101375	75171	108076	4262	572199
SPD [m/s]	13.86	11.16	9.98	20.89	21.32	26.65	24.07	22.48	19.71
NBIAS (ALL LAYERS)	-0.03	-0.12	-0.14	-0.05	-0.04	+0.00	-0.01	+0.05	+0.03
NMVD (100-1000 hPa)	0.21	0.41	0.42	0.24	0.24	0.19	0.21	0.22	0.23
NRMSVD	0.25	0.46	0.47	0.28	0.27	0.22	0.25	0.27	0.28

Table 16: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs considering all layers together against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Rapid scan, European and Mediterranean region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics; Mixed calculation method). Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Basic AMVs without Mixed calculation method

NWC/GEO-HRWv6.0 AMVs (Jul 2009-Jun 2010, MSG1)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy IR108	Cloudy IR120	Cloudy WV62	Cloudy WV73	Clear Air	All AMVs
NC	21340			58775	62125	71062	83499	4262	301063
SPD [m/s]	24.75			25.77	25.76	27.31	26.35	22.98	26.18
NBIAS (HIGH LAYER)	-0.03			-0.05	-0.04	-0.01	-0.03	+0.03	-0.03
NMVD (100-400 hPa)	0.23			0.27	0.27	0.26	0.27	0.28	0.26
NRMSVD	0.27			0.32	0.32	0.31	0.32	0.34	0.32
NC	24680	13831	14776	28217	27459	4109	23788		136860
SPD [m/s]	14.67	12.61	12.42	16.01	16.27	20.81	17.62		15.51
NBIAS (MEDIUM LAYER)	-0.04	-0.15	-0.17	-0.08	-0.07	+0.08	-0.01		-0.06
NMVD (400-700 hPa)	0.32	0.46	0.48	0.39	0.38	0.37	0.38		0.39
NRMSVD	0.38	0.53	0.54	0.45	0.44	0.43	0.44		0.45
NC	57016	26676	24694	13310	11791		789		134276
SPD [m/s]	9.62	10.46	10.53	11.00	11.07		13.01		10.24
NBIAS (LOW LAYER)	-0.04	-0.11	-0.12	-0.09	-0.09		-0.06		-0.08
NMVD (700-1000 hPa)	0.42	0.52	0.53	0.48	0.48		0.43		0.47
NRMSVD	0.49	0.60	0.61	0.55	0.56		0.51		0.55
NC	21340			58775	62125	71062	83499	4262	301063
SPD [m/s]	24.36			25.57	25.57	26.99	26.07	22.48	25.92
NBIAS (HIGH LAYER)	-0.01			-0.04	-0.03	+0.00	-0.02	+0.05	-0.02
NMVD (100-400 hPa)	0.15			0.20	0.20	0.19	0.20	0.22	0.19
NRMSVD	0.18			0.24	0.24	0.22	0.23	0.27	0.23
NC	24680	13831	14776	28217	27459	4109	23788		136860
SPD [m/s]	14.37	12.34	12.08	15.70	16.02	20.71	17.40		15.24
NBIAS (MEDIUM LAYER)	-0.01	-0.13	-0.15	-0.06	-0.06	+0.08	-0.00		-0.05
NMVD (400-700 hPa)	0.22	0.39	0.40	0.32	0.32	0.28	0.31		0.31
NRMSVD	0.28	0.44	0.45	0.37	0.36	0.33	0.36		0.37
NC	57016	26676	24694	13310	11791		789		134276
SPD [m/s]	9.71	10.55	10.66	11.21	11.27		12.79		10.36
NBIAS (LOW LAYER)	-0.05	-0.11	-0.13	-0.11	-0.10		-0.05		-0.09
NMVD (700-1000 hPa)	0.25	0.43	0.43	0.39	0.39		0.38		0.35
NRMSVD	0.30	.48	0.48	0.44	0.44		0.44		0.41

Table 17: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs considering three separate layers against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Jul 2009-Jun 2010 12:00 UTC, MSG2 satellite, Rapid scan, European and Mediterranean region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics; Mixed calculation method). Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Basic AMVs without Mixed calculation method

As the validation in *Tables 16 and 17* show (compared with those in *Tables 4 and 5* not using "Mixed calculation method"):

- For AMVs related to HRVIS high resolution channel, the number of AMVs increases more than a 50% and NMVD/NRMSVD validation parameters reduce between a 5% and a 15%.
- For AMV related to low resolution channels, the number of AMV reduces however around a 50% and NMVD/NRMSVD validation parameters increase up to a 25%.

The "Mixed calculation method" in "Rapid scan mode" shows then to be useful for the calculation of AMVs with high resolution images. This is caused by the smaller changes in the features evaluating the tracking in shorter time intervals.

With MSG satellite series (which has an only high resolution channel), the impact is not good considering all channels altogether, but considering its future use with new satellite series Himawari-8/9, GOES-R and MTG-I, the impact will be much better, due to the more important weight of high and very high resolution visible channels in these satellite series. The fact that extracting good densities of AMVs with higher resolution channels is more difficult (due to the smaller size of the features in kilometres and their shorter persistence), can be partially solved by using this method for the extraction of AMVs.

4. VALIDATION OF HRW V6.0 AMVS WITH GOESN SATELLITES

4.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION

The validation of NWC/GEO-HRW v6.0 algorithm for GOES-N satellite series is considered now. It is based on the validation of NWC/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. Next triplets of images for NWC/GEO-HRW algorithm processing, and next Radiosounding data have been considered for this GOES-N validation:

- Images at 23:15, 23:30, 23:45 UTC; 23:45 UTC AMVs validated against 00:00 UTC Radiosounding winds.
- Images at 05:15, 05:30, 05:45 UTC; 05:45 UTC AMVs validated against 06:00 UTC Radiosounding winds.
- Images at 11:15, 11:30, 11:45 UTC; 11:45 UTC AMVs validated against 12:00 UTC Radiosounding winds.
- Images at 17:15, 17:30, 17:45 UTC; 17:45 UTC AMVs validated against 18:00 UTC Radiosounding winds.

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 UTC, because of which the number of visible AMVs in these moments is very small. The number of Radiosoundings available at midday time, i.e. around 18:00 UTC, is however also very limited. Because of all this, the number of collocations for visible AMVs is small.

No AMVs could be processed at 00:00, 06:00, 12:00 and 18:00 UTC because GOES13 images are not available at these main synoptic hours. Because of this, statistics against NWP analysis winds are not provided for this satellite series here (compared to MSG series), due to the lack of GOES13 satellite images at the ECMWF analysis hours.

The validation takes into account the default conditions for NWC/GEO-HRW v6.0 for GOES-N satellites, considering "Basic scale AMVs" with "Cross correlation tracking" and "CCC method height assignment without microphysics correction". Comparing with MSG satellite series, no microphysics correction is implemented in the height assignment due to the lack of NWC/GEO-CMIC product with this satellite series. An example of this configuration is shown in *Figure 8*.

These conditions are specified in `$SAFNWC/config/safnwc_HRW_GOESN.cfm` model configuration file, with all satellite channels being validated. Cloudy AMVs in the layer 100-1000 hPa and clear air AMVs in the layer 100-400 hPa, with a Quality index with forecast ≥ 70 are considered for this validation. An example of this configuration is shown in *Figure 8*. NWC/GEO Cloud product outputs for GOES-N (CMA, CT and CTTH) have to be available so that NWC/GEO-HRW v6.0 can fully process the conditions defined in the given model configuration file.

The validation statistics are presented in *Table 18* (considering all layers together) and *Table 19* (considering the three layers separately). All moments of the day have been considered together.

Considering the different satellite channels, the main difference is related to the Clear air AMVs, for which MVD and NRMSVD parameters are around a 50% larger. However, their contribution to the characterization of the wind in cloudless areas is important to keep them inside the processing.

Considering the different layers, as in MSG case, NMVD and NRMSVD parameters are progressively larger for the High, Medium and Low layer. NWC/GEO-HRW Product Requirement Table "Optimal accuracy" (with a value of 0.35 against Radiosounding winds) is also reached in the High layer, and the NWC/GEO-HRW Product Requirement Table "Target accuracies" (with values respectively of 0.50 and 0.56 against Radiosounding winds) are also reached in the Medium and Low layer. These results mean that NWC/GEO-HRW algorithm can perfectly be used operatively with GOES-N satellites series.

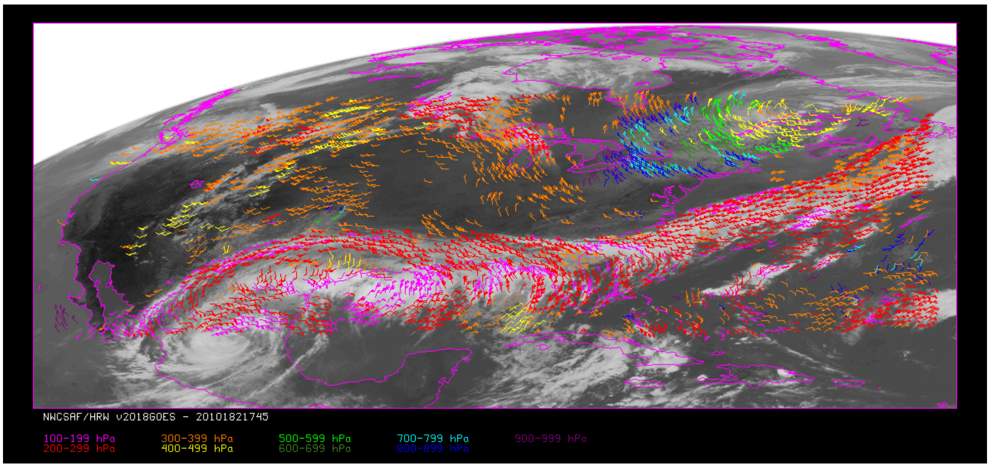

Figure 8: NWC/GEO-HRW v6.0 "Basic AMV" output example in the Continental United States region (1 July 2010 17:45 UTC, GOES13 satellite), considering default conditions defined in `$SAFNWC/config/safnwc_HRW_GOESN.cfm` *model configuration file. Colour coding based on the AMV pressure level*

NWC/GEO-HRWv6.0 AMVs (Jul 2010-Jun 2011, GOES13)	Cloudy VIS07	Cloudy IR107	Cloudy WV65	Clear Air	All AMVs
NC	9282	287572	247350	64486	608690
SPD [m/s]	21.33	21.82	25.22	14.64	22.43
NBIAS (ALL LAYERS)	-0.01	-0.08	-0.04	+0.04	-0.05
NMVD (100-1000 hPa)	0.24	0.29	0.26	0.37	0.28
NRMSVD	0.31	0.37	0.33	0.49	0.36

Table 18: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs considering all layers together against Radiosounding winds (Jul 2010-Jun 2011 05:45/11:45/17:45/23:45 UTC, GOES13 satellite, Continental United States; Basic AMVs; Cross correlation; CCC height assignment without Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v5.0 Basic AMVs

NWC/GEO-HRWv6.0 AMVs (Jul 2010-Jun 2011, GOES13)	Cloudy VIS07	Cloudy IR107	Cloudy WV65	Clear Air	All AMVs
NC	6828	215848	235439	64486	522601
SPD [m/s]	25.28	24.74	25.44	14.64	23.82
NBIAS (HIGH LAYER)	-0.01	-0.09	-0.04	+0.04	-0.05
NMVD (100-400 hPa)	0.23	0.28	0.26	0.37	0.28
NRMSVD	0.28	0.35	0.33	0.49	0.35
NC	243	33933	11911		46087
SPD [m/s]	18.29	17.04	20.84		18.03
NBIAS (MEDIUM LAYER)	-0.11	-0.05	+0.00		-0.03
NMVD (400-700 hPa)	0.34	0.35	0.29		0.33
NRMSVD	0.45	0.43	0.37		0.41
NC	2211	37791			40002
SPD [m/s]	9.46	9.44			9.44
NBIAS (LOW LAYER)	-0.02	-0.09			-0.09
NMVD (700-1000 hPa)	0.35	0.40			0.39
NRMSVD	0.43	0.49			0.49

Table 19: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs considering three separate layers against Radiosounding winds (Jul 2010-Jun 2011 05:45/11:45/17:45/23:45 UTC, GOES13 satellite, Continental United States; Basic AMVs; Cross correlation; CCC height assignment without Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v5.0 Basic AMVs

4.2 COMPARISON WITH HRW V5.0 DEFAULT CONFIGURATION

The comparison of the statistics against Radiosounding winds of NWC/GEO-HRW v6.0 default configuration with those for the previous version of NWC/GEO-HRW algorithm (NWC/GEO-HRW v5.0 released in 2016), is considered here in *Tables 20 and 21* for GOES-N satellite series.

NWC/GEO-HRWv6.0 AMVs (Jul 2010-Jun 2011, GOES13)	Cloudy VIS07	Cloudy IR107	Cloudy WV65	Clear Air	All AMVs
NC	5849	208726	205757	47253	467585
SPD [m/s]	22.34	22.98	24.46	15.31	23.00
NBIAS (ALL LAYERS)	+0.00	-0.08	-0.03	-0.00	-0.05
NMVD (100-1000 hPa)	0.25	0.29	0.27	0.35	0.28
NRMSVD	0.31	0.36	0.33	0.48	0.36

Table 20: Validation parameters for the previous version of HRW algorithm: NWC/GEO-HRW v5.0 Basic AMVs considering all layers together against Radiosounding winds (Jul 2010-Jun 2011 05:45/11:45/17:45/23:45 UTC, GOES13 satellite, Continental United States; Basic AMVs; Cross correlation; CCC height assignment without Microphysics)

NWC/GEO-HRWv6.0 AMVs (Jul 2010-Jun 2011, GOES13)	Cloudy VIS07	Cloudy IR107	Cloudy WV65	Clear Air	All AMVs
NC	4694	173848	191878	47253	417673
SPD [m/s]	24.71	24.33	24.68	15.31	23.47
NBIAS (HIGH LAYER)	+0.00	-0.09	-0.03	-0.00	-0.05
NMVD (100-400 hPa)	0.24	0.28	0.27	0.35	0.28
NRMSVD	0.29	0.35	0.33	0.47	0.36
NC	460	25067	13879		39406
SPD [m/s]	18.10	18.60	21.43		19.59
NBIAS (MEDIUM LAYER)	-0.03	-0.06	-0.00		-0.04
NMVD (400-700 hPa)	0.28	0.32	0.29		0.31
NRMSVD	0.36	0.40	0.36		0.38
NC	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 21: Validation parameters for the previous version of HRW algorithm: NWC/GEO-HRW v5.0 Basic AMVs considering three separate layers against Radiosounding winds (Jul 2010-Jun 2011 05:45/11:45/17:45/23:45 UTC, GOES13 satellite, Continental United States; Basic AMVs; Cross correlation; CCC height assignment without Microphysics)

The main elements to be taken into account are: on one side the larger population of AMVs, with increments between 20% and 30% in total and for the High and Medium layer, and more significantly up to 380% in the Low layer (which is directly related to the "higher density for tracers related to low and very low clouds"). On the other side, because of these changes in the population of AMVs the distribution of AMVs in the different layers has also changed, going from a value of 89%/9%/2% for the High/Medium/Low layer in the previous version, to a more homogeneous value in the new version of 86%/7%/7% (considering validated AMVs) and 69%/12%/19% (considering calculated AMVs). The distribution between different layers has improved, although less significantly than in the MSG case.

Comparing validation parameters for the new and previous version of NWC/GEO-HRW, considering all layers together in *Tables 18 and 20*, the validation statistics are exactly equivalent. So, the fact that more AMVs are calculated with similar statistics is a positive evolution of the GOES-N series AMVs with this version. Considering each layer separately in *Tables 19 and 21*, the variations in the validation parameters are smaller than a 10%.

4.3 COMPARISON WITH MSG SATELLITE SERIES

The comparison of the statistics of NWC/GEO-HRW v6.0 default configuration for GOES-N satellite series with those for MSG satellites series is considered here. Comparing with the equivalent statistics for MSG (shown in *Tables 4 and 5*), validation statistics for GOES-N AMVs are similar (with differences up to a 15% only), and in many cases better (considering all AMVs together, or the Medium and Low layer).

Considering the different GOES-N channels, the statistics for VIS07 AMVs are better than for the equivalent MSG HRVIS channel (although this could be caused by the small sample of AMVs used for the GOES-N VIS07 AMV validation), while the GOES-N Clear air AMVs have worse statistics than for the MSG case. However, as already said, their contribution to the characterization of the wind in cloudless areas is important to keep them inside the processing.

The main difference between both satellite series is related to the distribution of AMVs in the different layers, with a smaller proportion of Medium and Low layer AMVs for GOES-N satellite series. This occurs with both satellite series implementing the “Higher density of tracers related to low and very low clouds”. The result can be related to the fact that the only GOES-N visible channel is a high resolution one (for which the number of AMVs tends to be smaller), and the fact that only one infrared channel is used for the AMV calculation.

4.4 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION

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. The calculation of "Detailed AMVs" is activated changing configurable parameter CDET = 1 in the default model configuration file. These AMVs are provided as an additional dataset of AMVs together with the "Basic AMVs", which are always calculated.

The conditions for the validation of "Detailed AMVs" are exactly equivalent to those shown in chapter 4.1 for the GOES-N "Basic AMVs". An example of this configuration is shown in *Figure 9*. The validation statistics are presented in *Table 22* (considering all layers together) and *Table 23* (considering the three layers separately) for the same validation period.

Comparing with the "Basic AMVs", a reduction in the number of AMVs of about a 33% is seen for the "Detailed AMVs". This result is similar to that obtained for MSG satellite series. Again, this can be explained through the smaller size of the tracers (affecting especially the water vapour channel, for which the image features are generally larger), the smaller persistence in time of the finest image features (affecting especially the VIS07 AMVs, for which the size of the "Detailed tracers" is the smallest of all: up to 12x12 km), and especially the smaller contrast in the features using smaller tracer sizes. The distribution of validated AMVs in the different layers has a value of 93%/6%/1% for the High/Medium/Low layer, concentrating the AMVs in the High layer more than for the "Basic scale". Considering the validation parameters, the NMVD and NRMSVD are up to a 15% better than for the "Basic AMVs", while the NBIAS shows general reductions up to a 40%.

Considering the different layers, NWC/GEO-HRW Product Requirement Table "Optimal accuracy" is also reached in the High layer, and the NWC/GEO-HRW Product Requirement Table "Target accuracy" is also reached in the Medium and Low layer.

In short, the behaviour of "Detailed AMVs" is very similar to that of "Basic AMVs" (with slightly better statistics), and so both datasets can be used together for the characterization of the wind in the different layers of the troposphere. However, the low number of Low level GOES-N AMVs is to be taken into account in operational use, even using both datasets together with a "higher density for tracers related to low and very low clouds".

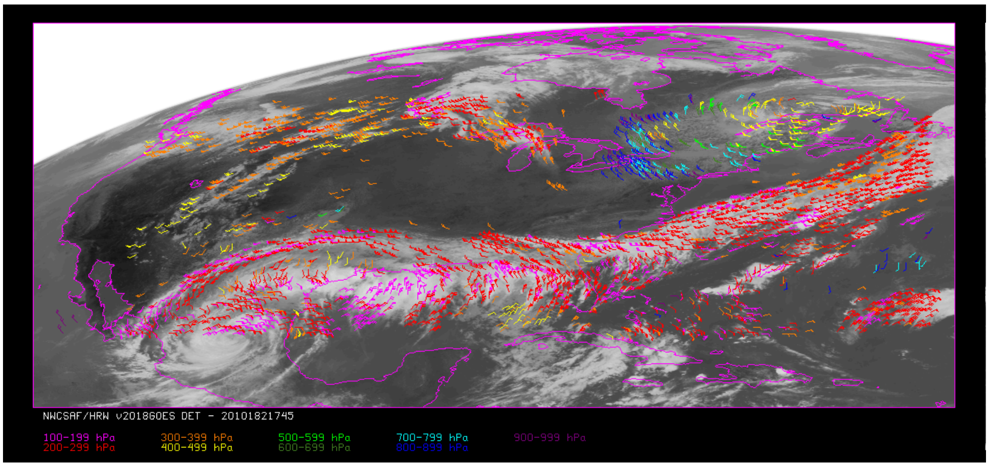

Figure 9: NWC/GEO-HRW v6.0 "Detailed AMV" output example in the Continental United States region (1 July 2010 17:45 UTC, GOES13 satellite), considering default conditions defined in `$SAFNWC/config/safnwc_HRW_GOESN.cfm` *model configuration file but with configurable parameter CDET = 1. Colour coding based on the AMV pressure level*

NWC/GEO-HRWv6.0 AMVs (Jul 2010-Jun 2011, GOES13)	Cloudy VIS07	Cloudy IR107	Cloudy WV65	Clear Air	All AMVs
NC	1533	205435	191379	7341	405688
SPD [m/s]	23.59	24.69	26.52	16.23	25.40
NBIAS (ALL LAYERS)	+0.00	-0.04	-0.02	+0.09	-0.03
NMVD (100-1000 hPa)	0.23	0.26	0.24	0.35	0.25
NRMSVD	0.30	0.32	0.30	0.44	0.31

Table 22: Validation parameters for NWC/GEO-HRW v6.0 Detailed AMVs considering all layers together against Radiosounding winds (Jul 2010-Jun 2011 05:45/11:45/17:45/23:45 UTC, GOES13 satellite, Continental United States; Basic AMVs; Cross correlation; CCC height assignment without Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Basic AMVs

NWC/GEO-HRWv6.0 AMVs (Jul 2010-Jun 2011, GOES13)	Cloudy VIS07	Cloudy IR107	Cloudy WV65	Clear Air	All AMVs
NC	1174	179457	186679	7341	374651
SPD [m/s]	27.57	25.83	26.62	16.23	26.04
NBIAS (HIGH LAYER)	+0.00	-0.05	-0.02	+0.09	-0.03
NMVD (100-400 hPa)	0.22	0.25	0.24	0.35	0.25
NRMSVD	0.27	0.31	0.30	0.44	0.31
NC	29	20920	4700		25649
SPD [m/s]	17.17	18.45	22.54		19.20
NBIAS (MEDIUM LAYER)	-0.09	+0.04	+0.04		+0.01
NMVD (400-700 hPa)	0.44	0.32	0.30		0.32
NRMSVD	0.56	0.40	0.37		0.40
NC	330	5058			5388
SPD [m/s]	10.01	10.19			10.18
NBIAS (LOW LAYER)	-0.04	-0.05			-0.05
NMVD (700-1000 hPa)	0.36	0.39			0.39
NRMSVD	0.44	0.49			0.48

Table 23: Validation parameters for NWC/GEO-HRW v6.0 Detailed AMVs considering three separate layers against Radiosounding winds (Jul 2010-Jun 2011 05:45/11:45/17:45/23:45 UTC, GOES13 satellite, Continental United States; Basic AMVs; Cross correlation; CCC height assignment without Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Basic AMVs

5. VALIDATION OF HRW V6.0 AMVS WITH HIMAWARI-8/9 SATELLITES

5.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION

The validation of NWC/GEO-HRW-v60 algorithm for Himawari-8/9 satellite series is based on the validation of AMVs calculated during 166 days of the half-yearly period March – August 2018 at 00:00 UTC, with Himawari-8 satellite images, in a region covering China, Korea, Japan and the adjacent parts of the Pacific Ocean. This region is shown in the example in *Figure 10*.

The default conditions for NWC/GEO-HRW v6.0 for Himawari-8/9 satellites, considering "Nominal scan satellite mode", "Basic scale AMVs", "Cross correlation tracking", "CCC height assignment method with Microphysics correction", and a "higher density for tracers related to low and very low clouds", are considered for the validation. These conditions are specified in the default model configuration file `$SAFNWC/config/safnwc_HRW_HIMA.cfm`, but with validation of all possible satellite channels. Infrared and visible cloudy AMVs in the layer 100-1000 hPa, water vapour cloudy AMVs in the layer 100-700 hPa, and water vapour clear air AMVs in the layer 100-400 hPa, with a Quality index with forecast ≥ 70%, are considered for the validation.

NWC/GEO Cloud product outputs (CMA, CT, CTTH and CMIC) in the processing region have to be available so that NWC/GEO-HRW can fully process the conditions defined in the model configuration file. The running of three consecutive slots for all Cloud and HRW products every day during the reference validation period (23:40 UTC, 23:50 UTC and 00:00 UTC), is needed for the validation.

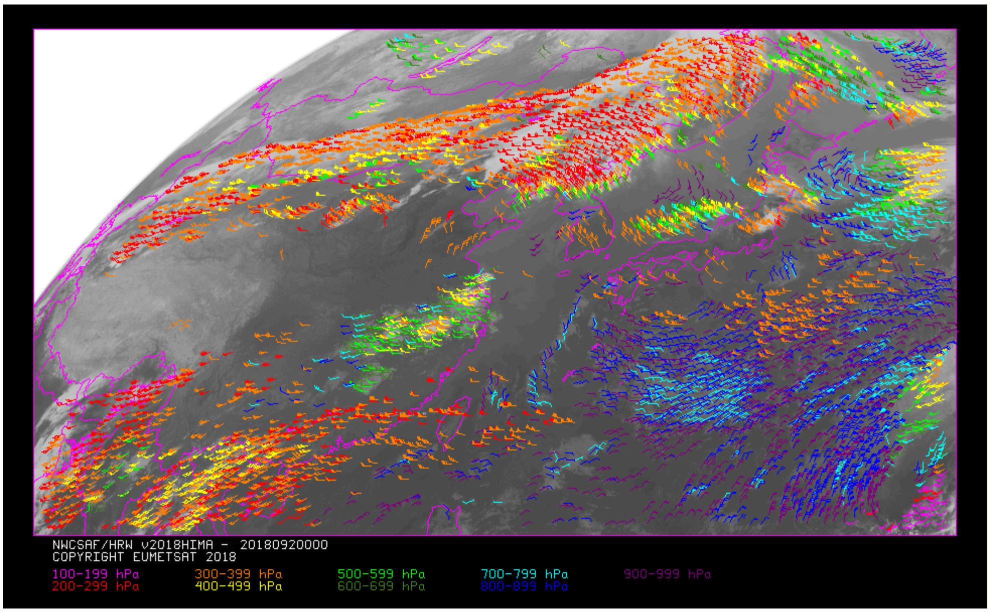

Figure 10: NWC/GEO-HRW v6.0 "Basic AMV" output example in the China/Korea/Japan region (2 April 2018 00:00 UTC, Himawari-8 satellite), considering default conditions defined in `$SAFNWC/config/safnwc_HRW_HIMA.cfm` model configuration file. Colour coding based on the AMV pressure level

Comparing the statistics against Radiosounding winds and ECMWF NWP analysis in *Table 24* (considering all layers together) and in *Table 25* (considering the three layers separately), the NBIAS, NMVD and NRMSVD parameters are once again around a 25% smaller against NWP analysis winds.

Considering the different layers, as in previous cases the validation parameters are progressively higher for the high layer, medium layer and low layer. The NWC/GEO-HRW Product Requirement Table "Optimal accuracy" (with a value of 0.35 against Radiosounding winds) is reached in the High layer, and the NWC/GEO-HRW Product Requirement Table "Target accuracy" (with values respectively of 0.50 and 0.56 against Radiosounding winds) is reached in the Medium and Low layer.

NWC/GEO-HRWv6.0 AMVs (Mar-Aug 2018, Himawari-8)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV73	Clear Air	All AMVs
NC	36841	71618	287147	189457	246356	280899	85148	1197466
SPD [m/s]	21.70	19.95	19.58	23.60	22.58	21.94	19.32	21.46
NBIAS (ALL LAYERS)	+0.00	-0.00	+0.04	+0.06	+0.06	+0.04	+0.06	+0.05
NMVD (100-1000 hPa)	0.24	0.26	0.27	0.26	0.27	0.26	0.30	0.28
NRMSVD	0.29	0.31	0.35	0.32	0.33	0.33	0.38	0.35
NC	36841	71618	287147	189457	246356	280899	85148	1197466
SPD [m/s]	21.72	19.97	19.60	23.65	22.62	21.96	19.56	21.50
NBIAS (ALL LAYERS)	-0.00	-0.00	+0.04	+0.06	+0.06	+0.04	+0.05	+0.05
NMVD (100-1000 hPa)	0.17	0.18	0.20	0.19	0.21	0.20	0.23	0.21
NRMSVD	0.21	0.23	0.25	0.24	0.25	0.25	0.30	0.26

Table 24: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs considering all layers together against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Mar-Aug 2018 00:00 UTC, Himawari-8 satellite, China/Korea/Japan region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to equivalent NWC/GEO-HRW v6.0 MSG2 Basic AMVs

NWC/GEO-HRWv6.0 AMVs (Mar-Aug 2018, Himawari-8)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV73	Clear Air	All AMVs
NC	26769	48276	196718	183124	214714	229291	85148	984040
SPD [m/s]	25.83	24.52	22.61	23.73	23.44	23.31	19.32	23.06
NBIAS (HIGH LAYER)	-0.01	-0.01	+0.04	+0.06	+0.05	+0.03	+0.06	+0.04
NMVD (100-400 hPa)	0.22	0.23	0.25	0.26	0.26	0.25	0.30	0.25
NRMSVD	0.26	0.27	0.31	0.31	0.31	0.30	0.38	0.31
NC	4200	9507	65466	6333	31642	51608		168756
SPD [m/s]	14.67	14.18	14.68	20.08	16.72	15.85		15.60
NBIAS (MEDIUM LAYER)	+0.10	+0.09	+0.05	+0.17	+0.21	+0.11		+0.11
NMVD (400-700 hPa)	0.32	0.33	0.35	0.36	0.43	0.38		0.37
NRMSVD	0.40	0.42	0.49	0.47	0.54	0.50		0.50
NC	5872	13835	24963					44670
SPD [m/s]	7.90	7.97	8.53					8.27
NBIAS (LOW LAYER)	-0.03	+0.03	-0.01					+0.00
NMVD (700-1000 hPa)	0.44	0.47	0.43					0.45
NRMSVD	0.54	0.58	0.53					0.55
NC	26769	48276	196718	183124	214714	229291	85148	984040
SPD [m/s]	25.81	24.51	22.73	23.77	23.51	23.39	19.56	23.14
NBIAS (HIGH LAYER)	-0.01	-0.01	+0.04	+0.06	+0.05	+0.03	+0.05	+0.04
NMVD (100-400 hPa)	0.16	0.16	0.18	0.19	0.19	0.18	0.23	0.19
NRMSVD	0.19	0.20	0.23	0.24	0.23	0.22	0.30	0.23
NC	4200	9507	65466	6333	31642	51608		168756
SPD [m/s]	14.75	14.15	14.44	20.11	16.57	15.60		15.40
NBIAS (MEDIUM LAYER)	+0.09	+0.09	+0.07	+0.17	+0.22	+0.13		+0.12
NMVD (400-700 hPa)	0.23	0.24	0.26	0.29	0.36	0.30		0.29
NRMSVD	0.30	0.31	0.33	0.36	0.44	0.38		0.38
NC	5872	13835	24963					44670
SPD [m/s]	8.08	8.13	8.48					8.32
NBIAS (LOW LAYER)	+0.01	+0.01	-0.00					+0.00
NMVD (700-1000 hPa)	0.25	0.29	0.30					0.29
NRMSVD	0.33	0.36	0.39					0.37

Table 25: Validation parameters for NWC/GEO-HRW v6.0 Basic AMVs considering three separate layers against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Mar-Aug 2018 00:00 UTC, Himawari-8 satellite, China/Korea/Japan region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to equivalent NWC/GEO-HRW v6.0 MSG2 Basic AMVs

5.2 COMPARISON WITH MSG SATELLITE SERIES

Comparing the statistics of NWC/GEO-HRW v6.0 default configuration for Himawari-8/9 satellites with those for MSG satellites, an equivalent number of AMVs is calculated for both satellites for regions of similar sizes. So the density of AMV data is similar for both satellites.

Considering the distribution of AMVs in the different layers, for Himawari satellites it has a value of 82%/14%/4% for the High/Medium/Low layer (considering validated AMVs) and 78%/14%/8% (considering calculated AMVs). The concentration of AMVs in the High layer is only caused by the China/Korea/Japan region used for the validation (with large high altitude and desert areas, and so less frequent low clouds). Considering for example AMVs calculated in the Himawari Full Disk for IR112 channel in the same validation period, the distribution in the High/Medium/Low layer is 52%/15%/33%, which is similar to that obtained by other AMV algorithms.

Comparing the validation parameters for both satellites, considering all layers together Himawari satellite show better NMVD and NRMSVD values (up to a 10% smaller), which is only caused by its larger proportion of High layer AMVs, with better validation parameters. It is remarkable to see that NBIAS parameter shows similar values but with an opposite sign.

Considering each layer separately, validation parameters are more or less similar for MSG and Himawari satellites in the High layer. NMVD and NRMSVD parameters are however up to a 15% worse for the Medium and Low layer for Himawari. NBIAS parameter is higher in the Medium layer and smaller in the Low layer for Himawari.

In spite of the differences of NWC/GEO-HRW algorithm for MSG and Himawari, the operability of NWC/GEO-HRW algorithm for both satellites is equivalent. As already said, for both satellites the "Optimal accuracy" is reached in the High layer, and the "Target accuracy" is reached in the Medium and Low layer.

Comparatively, there is however room for improvement for the AMVs with Himawari, trying to reduce its errors in the Medium and Low layer, and trying to increase the proportion of AMVs in the Low layer for a better characterization of the wind throughout all the troposphere. As GOES-R and MTG-I satellite series are very similar to Himawari, any improvement in these aspects will be positive for the three new generation satellite series.

5.3 VALIDATION FOR DETAILED AMVS WITH DEFAULT CONFIGURATION

The validation of "Detailed AMVs" (with a default tracer size of 12x12 pixels instead of the 24x24 pixels considered by the "Basic AMVs") for Himawari-8/9 satellite series is considered now. The calculation of "Detailed AMVs" is activated again changing configurable parameter CDET = 1 in the default model configuration file. These are provided as an additional dataset of AMVs together with the "Basic AMVs", which are always calculated.

The conditions for the validation of "Detailed AMVs" are exactly equivalent to those shown in chapter 5.1 for the Himawari "Basic AMVs". An example of this configuration is shown in *Figure 11*. The validation statistics are presented in *Table 26* (considering all layers together) and *Table 27* (considering the three layers separately) for the same validation period.

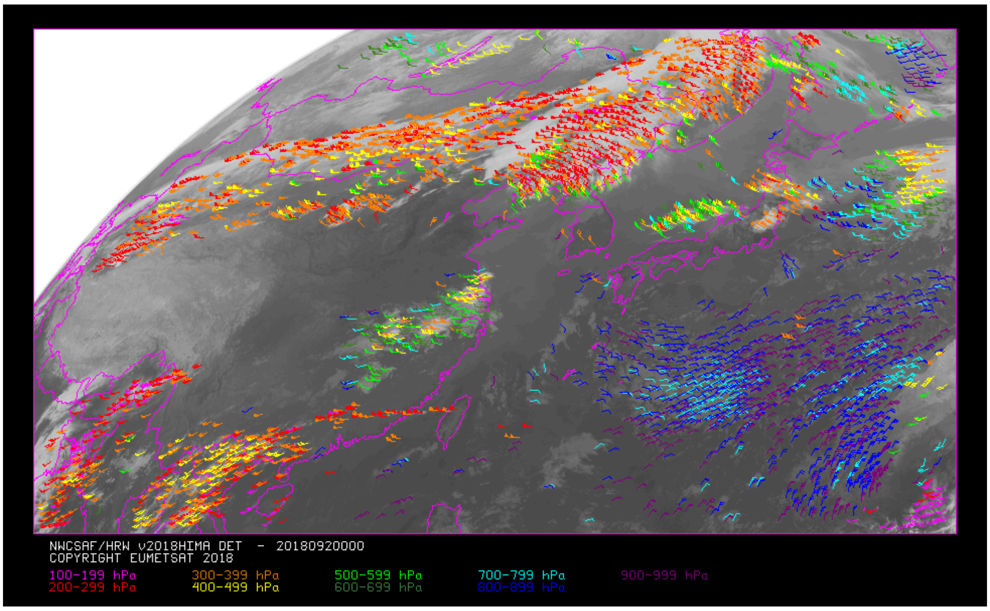

Figure 11: NWC/GEO-HRW v6.0 "Detailed AMV" output example in the China/Korea/Japan region (2 April 2018 00:00 UTC, Himawari-8 satellite), considering default conditions defined in `$SAFNWC/config/safnwc_HRW_HIMA.cfm` model configuration file with configurable parameter CDET = 1. Colour coding based on the AMV pressure level

Comparing with the "Basic AMVs", a reduction in the number of AMVs of about a 40% is seen for the "Detailed AMVs". Again, this can be explained through the smaller size and persistence of the tracers, and especially the smaller contrast in the features using smaller tracer sizes. The distribution of validated AMVs in the different layers has a value of 88%/10%/2% for the High/Medium/Low layer, concentrating more the AMVs at the High layer.

Considering the validation, NMVD and NRMSVD parameters are around a 15% smaller than for the "Basic AMVs", while the NBIAS shows a very little difference. Considering the accuracies of the NWC/GEO-HRW Product Requirement Table, the situation is similar for "Basic AMVs" and "Detailed AMVs".

With all of this, the behaviour of "Detailed AMVs" is very similar to that of "Basic AMVs" (with slightly better statistics), and so both datasets can be used together operationally. However, the low number of Low level AMVs is to be taken into account in operational use, even using both datasets together with a "higher density for tracers related to low and very low clouds".

NWC/GEO-HRWv6.0 AMVs (Mar-Aug 2018, Himawari-8)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV73	Clear Air	All AMVs
NC	6002	37393	207718	96056	151000	198745	13567	710481
SPD [m/s]	20.64	22.10	21.50	24.53	24.26	23.72	21.44	23.14
NBIAS (ALL LAYERS)	+0.01	+0.00	+0.05	+0.05	+0.05	+0.04	+0.13	0.05
NMVD (100-1000 hPa)	0.25	0.24	0.26	0.25	0.25	0.25	0.31	0.25
NRMSVD	0.31	0.29	0.32	0.30	0.30	0.30	0.39	0.31
NC	6002	37393	207718	96056	151000	198745	13567	710481
SPD [m/s]	20.71	22.12	21.55	24.54	24.31	23.75	21.72	23.18
NBIAS (ALL LAYERS)	+0.00	+0.00	+0.05	+0.05	+0.05	+0.04	+0.11	0.04
NMVD (100-1000 hPa)	0.17	0.17	0.19	0.18	0.18	0.18	0.24	0.18
NRMSVD	0.22	0.21	0.23	0.22	0.23	0.22	0.31	0.23

Table 26: Validation parameters for NWC/GEO-HRW v6.0 Detailed AMVs considering all layers together against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Mar-Aug 2018 00:00 UTC, Himawari-8 satellite, China/Korea/Japan region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Himawari-8 Basic AMVs

NWC/GEO-HRWv6.0 AMVs (Mar-Aug 2018, Himawari-8)	Cloudy VIS06	Cloudy VIS08	Cloudy IR112	Cloudy WV62	Cloudy WV70	Cloudy WV73	Clear Air	All AMVs
NC	3772	26678	161951	94839	142229	179612	13567	622648
SPD [m/s]	27.18	26.45	23.41	24.55	24.64	24.39	21.44	24.26
NBIAS (HIGH LAYER)	-0.00	-0.00	+0.05	+0.05	+0.04	+0.03	+0.13	+0.04
NMVD (100-400 hPa)	0.21	0.22	0.24	0.25	0.24	0.24	0.31	0.24
NRMSVD	0.26	0.26	0.29	0.30	0.29	0.29	0.39	0.29
NC	643	3750	38462	1217	8771	19133		71976
SPD [m/s]	13.58	15.60	15.62	22.67	18.10	17.46		16.51
NBIAS (MEDIUM LAYER)	+0.16	+0.10	+0.09	+0.18	+0.23	+0.17		+0.13
NMVD (400-700 hPa)	0.36	0.32	0.34	0.36	0.45	0.38		0.37
NRMSVD	0.45	0.40	0.48	0.44	0.51	0.48		0.48
NC	1587	6965	7305					15857
SPD [m/s]	7.94	8.95	9.96					9.32
NBIAS (LOW LAYER)	+0.05	+0.03	-0.02					+0.00
NMVD (700-1000 hPa)	0.48	0.44	0.39					0.42
NRMSVD	0.58	0.52	0.47					0.50
NC	3772	26678	161951	94839	142229	179612	13567	622648
SPD [m/s]	27.15	26.42	23.50	24.56	24.69	24.42	21.72	24.31
NBIAS (HIGH LAYER)	-0.00	-0.00	+0.04	+0.04	+0.04	+0.03	+0.11	+0.04
NMVD (100-400 hPa)	0.15	0.16	0.18	0.18	0.18	0.17	0.24	0.18
NRMSVD	0.19	0.19	0.22	0.22	0.22	0.21	0.1	0.22
NC	643	3750	38462	1217	8771	19133		71976
SPD [m/s]	13.95	15.55	15.52	22.69	18.07	17.40		16.44
NBIAS (MEDIUM LAYER)	+0.13	+0.10	+0.10	+0.18	+0.23	+0.17		+0.14
NMVD (400-700 hPa)	0.26	0.23	0.26	0.29	0.36	0.31		0.28
NRMSVD	0.34	0.30	0.33	0.36	0.44	0.39		0.37
NC	1587	6965	7305					15857
SPD [m/s]	8.12	9.18	9.92					9.41
NBIAS (LOW LAYER)	+0.03	+0.01	-0.02					-0.00
NMVD (700-1000 hPa)	0.26	0.25	0.27					0.26
NRMSVD	0.34	0.32	0.34					0.34

Table 27: Validation parameters for NWC/GEO-HRW v6.0 Detailed AMVs considering three separate layers against Radiosounding winds (in light green) and ECMWF NWP analysis winds (in light blue) (Mar-Aug 2018 00:00 UTC, Himawari-8 satellite, China/Korea/Japan region; Basic AMVs; Cross correlation; Higher density related to low and very low clouds; CCC height assignment with Microphysics) Green figures show improvements of at least 10%, and red figures show worsenings of at least 10%, with respect to NWC/GEO-HRW v6.0 Himawari-8 Basic AMVs

6. CONCLUSIONS

Some conclusions can be extracted from this "Validation report" for NWC/GEO-HRW v6.0. Taking into account next main objectives for this version of NWC/GEO-HRW algorithm:

- NWC/GEO-HRW algorithm has been validated for the first time against both Radiosounding winds and NWP model analysis winds. Considering this, in general it has been seen that NBIAS, NMVD and NRMSVD validation parameters are significantly smaller (around a 30% smaller) against NWP analysis winds. As general conclusion, the general scale and behaviour of AMV winds is more similar to that of NWP analysis winds than to that of Radiosounding winds.
- The "Mixed calculation method" has been implemented, considering at the same time short and long time intervals, through which the tracking process is verified in short time intervals, but the AMVs are calculated considering displacements in long time intervals. It has been verified that this process is useful to calculate AMVs with high resolution images (as shown in chapter 3.7 of this document for "Rapid scan mode"), and to improve the quality of the calculated AMVs (as shown in chapter 3.6 of this document for "Nominal scan mode").
- NWC/GEO-HRW algorithm has been extended for the processing of Himawari-8/9 satellite series, and the population of AMVs at low levels has been increased for MSG and GOES-N satellite series. Both objectives have been reached, as shown in chapters 3.2, 4.2 and 5 of this document.

Besides, looking at the following table, it can be seen that the "Optimal accuracy" defined by the NWC/GEO-HRW Product Requirement Table is reached for the High layer AMVs for the three satellite series, and the "Target accuracy" is reached for the Medium and Low layer AMVs for the three satellite series. This way, NWC/GEO-HRW v6.0 can be used operationally with equivalent options for the three satellite series: MSG, GOES-N and Himawari-8/9.

Evolution of the Validation statistics between HRW versions, related to the Operative thresholds defined in the HRW Product Requirement Table (against Radiosounding winds)	High Layer NRMSVD	Medium Layer NRMSVD	Low Layer NRMSVD
NWC/GEO-HRW v5.0, Default configuration, MSG satellites	0.32	0.44	0.50
NWC/GEO-HRW v5.0, Default configuration, GOES-N satellites	0.36	0.38	0.48
NWC/GEO-HRW v6.0, Default configuration, MSG satellites (With an increase in the amount of low level AMVs of +22%)	0.32	0.44	0.50
NWC/GEO-HRW v6.0, Default configuration, GOES-N satellites (With an increase in the amount of low level AMVs of +380%)	0.35	0.41	0.49
NWC/GEO-HRW v6.0, Default configuration, Himawari satellites	0.31	0.50	0.55
NWC/GEO-HRW Product Requirement Table Optimal Accuracy	0.35	0.40	0.45
NWC/GEO-HRW Product Requirement Table Target Accuracy	0.44	0.50	0.56
NWC/GEO-HRW Product Requirement Table Threshold Accuracy	0.53	0.60	0.67

Table 28: Evolution of Validation statistics between NWC/GEO-HRW v5.0 and NWC/GEO-HRW v6.0, related to the Operative thresholds defined in the NWC/GEO-HRW Product Requirement Table, and comparison for the different satellite series

Comparing the validation parameters for MSG and GOES-N satellite series with those for the previous version of HRW algorithm, they are basically similar (because the AMV algorithm is basically similar for them), but there is an important difference to be taken into account. The vertical distribution of AMV data is now more homogeneous in the different layers, and this can help for a better characterization of the wind in all layers of the troposphere. With this, it is formally recommended that NWC SAF users update their NWC/GEO High Resolution Winds algorithm to NWC/GEO-HRW v6.0 included in NWC/GEO v2018 software package.

Considering the validation for Himawari satellite series, usable for the first time with this version of HRW algorithm, it has been seen that there is still room for improvement, trying to reduce the errors in the Medium and Low layer, and trying to increase the proportion of AMVs in the Low layer. As already said, as GOES-R and MTG-I satellite series are very similar to Himawari, any improvement in these aspects will be positive for the three new generation satellite series.

Considering the validation for Himawari satellite series, the results of the "2018 AMV Intercomparison Study" [RD.25] can also be taken into account. In this study, the AMVs calculated with a triplet of Himawari-8 images with NWC/GEO-HRW algorithm, were compared to those AMVs calculated by five other institutions (EUMETSAT/MPEF, NOAA, Japan Meteorological Agency - JMA, Korea Meteorological Administration - KMA and the Weather Forecast and Climatic Studies Centre from the Brazilian National Spatial Research Institute – CPTEC/INPE). The report shows that NWC/GEO-HRW AMVs are tied with NOAA in the second position of the AMV intercomparison, both after JMA AMVs and their new height assignment: "Optimal estimation method using observed radiance and NWP vertical profile".

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