Validation Report for "High Resolution Winds" (HRW – PGE09 v4.0)

SAF/NWC/CDOP2/INM/SCI/VR/13, Issue 1, Rev. 0

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Applicable to SAFNWC/MSG version 2013

Prepared by AEMET

REPORT SIGNATURE TABLE

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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 by National Meteorological Services. More information about the project can be found at the NWC SAF webpage, http://www.nwcsaf.org.

This document is applicable to the NWC SAF processing package for Meteosat Second Generation satellites, SAFNWC/MSG.

1.1 SCOPE OF THE DOCUMENT

The purpose of this document is to present the Scientific Validation Results for version v4.0 of the HRW product ("High Resolution Winds", belonging to SAFNWC/MSG software version 2013). This validation has been based on the comparison of the HRW Atmospheric Motion Vectors with winds obtained from Radiosounding bulletins available from the GTS.

The statistical indicators established in the "Report from the Working Group on Verification Statistics of the 3rd International Winds Workshop" [RD.12], with some amendments in the "Report from the Working Group on Verification & Quality Indices of the 4th International Winds Workshop" [RD.15]), are calculated to achieve this. These indicators have been thoroughly used throughout the world for the Validation of Satellite winds through the comparison with Radiosoundings.

This report specially considers the similarities and differences found in the AMVs (Atmospheric Motion Vectors) calculated by HRW algorithm v4.0, with the seven different MSG/SEVIRI channels it is now able to process: HRVIS (High Resolution Visible), VIS06 and VIS08 (Visible 0.6 µm and 0.8 µm), WV062 and WV073 (Water vapour 6.2 µm and 7.3 µm), IR108 and IR120 (Infrared 10.8 µm and 12.0 µm). In the case of the water vapour channels, the AMVs calculated with cloudiness patterns (Cloudy AMVs) and humidity patterns in cloudless areas (Clear air AMVs) are considered separately.

The explanation of how the Validation procedure works is explained first. Later, the effect of several parameters on the Validation statistics will be shown for the AMVs calculated from all different SEVIRI channels: the two "Quality Indices" included in HRW v4.0 algorithm (using and not using the forecast), the "Height assignment method" used in the AMV calculation (CCC method or Brightness temperature interpolation method), the "Tracking method" used in the AMV calculation (Cross correlation or Euclidean distance), the "Tracer scale" used in the AMV calculation (Basic or Detailed, in which the side of the tracer is half the size used in the Basic scale), the "Pressure level" related to the AMVs and the "Season of the year".

With all of this, the Validation Report will be able to decide the conditions and circumstances in which the AMVs calculated with each SEVIRI channel are most useful, so that NWC SAF users can have a clear idea of their advantages and inconveniencies. A default configuration for HRW v4.0 (with "Cross correlation tracking" and "CCC height assignment method") is additionally defined, and its corresponding validation statistics are compared with those related to the previous version of HRW algorithm (HRW v3.2), to verify the evolution of results between versions.

1.2 SOFTWARE VERSION IDENTIFICATION

The validation results presented in this document apply to the High Resolution Winds algorithm implemented in the release 2013 of the SAFNWC/MSG package (HRW v4.0).

1.3 GLOSSARY

Please refer to the “Nowcasting SAF Glossary” [AD.13] for a glossary and a complete list of acronyms for the NWC SAF project.

1.4 REFERENCES

1.4.1 SAFNWC Applicable Documents

Ref.	*Title*	*Code*	*Version*
[AD.1]	Software User Manual for the SAFNWC/MSG Application: Software Part	SAF/NWC/CDOP2/INM/SW/SUM/2	7.0
[AD.2]	Product User Manual for “High Resolution Winds” (HRW – PGE09 v4.0)	SAF/NWC/CDOP2/INM/SCI/PUM/09	4.0
[AD.3]	Interface Control Document for the External and Internal Interfaces of the SAF NWC/MSG	SAF/NWC/CDOP2/INM/SW/ICD/1	7.0
[AD.4]	SAFNWC/MSG Output Products format definition	SAF/NWC/CDOP2/INM/SW/ICD/3	7.0
[AD.5]	Architectural Design Document for the INM related PGEs of the SAFNWC/MSG	SAF/NWC/CDOP2/INM/SW/AD/4	7.0
[AD.6]	Software Version Description Document for the SAFNWC/MSG Application	SAF/NWC/CDOP2/INM/SW/SVD/5	7.0
[AD.7]	Validation Report for “High Resolution Winds” (HRW – PGE09 v2.2)	SAF/NWC/CDOP/INM/SCI/VR/05	1.0
[AD.8]	Validation Report for “High Resolution Winds” (HRW – PGE09 v3.0)	SAF/NWC/CDOP/INM/SCI/VR/07	1.0
[AD.9]	Validation Report for “High Resolution Winds” (HRW – PGE09 v3.1)	SAF/NWC/CDOP/INM/SCI/VR/09	1.0
[AD.10]	Validation Report for “High Resolution Winds” (HRW – PGE09 v3.2)	SAF/NWC/CDOP/INM/SCI/VR/10	1.0
[AD.11]	NWC SAF Product Requirements Document	SAF/NWC/CDOP2/INM/MGT/PRD	1.2
[AD.12]	Estimation of computer environment needs to run NWC SAF products operatively in ‘Rapid scan mode’	SAF/NWC/CDOP/INM/SW/RP/01	1.0
[AD.13]	Algorithm Theoretical Basis Document for “High Resolution Winds” (HRW – PGE09 v4.0)	SAF/NWC/CDOP2/INM/SCI/ATBD/09	4.0

Table 1. List of SAFNWC Reference Documents

1.4.2 External Reference Documents

Ref.	Title
[RD.1]	J.Schmetz, K.Holmlund, J.Hoffman, B.Strauss, B.Mason, V.Gärtner, A.Koch, L. van de Berg, 1993: Operational Cloud-Motion Winds from Meteosat Infrared Images (Journal of Applied Meteorology, Num. 32, pp. 1206-1225).
[RD.2]	S.Nieman, J.Schmetz, W.P.Menzel, 1993: A comparison of several techniques to assign heights to cloud tracers (Journal of Applied Meteorology, Num. 32, pp. 1559-1568).
[RD.3]	C.M.Hayden & R.J.Purser, 1995: Recursive filter objective analysis of meteorological fields, and application to NESDIS operational processing (Journal of Applied Meteorology, Num. 34, pp. 3-15).
[RD.4]	K.Holmlund, 1998: The utilisation of statistical properties of satellite derived Atmospheric Motion Vectors to derive Quality Indicators (Weather and Forecasting, Num. 13, pp. 1093-1104).
[RD.5]	J.M.Fernández, 1998: A future product on HRVIS Winds from the Meteosat Second Generation for nowcasting and other applications. (Proceedings 4th International Wind Workshop, EUMETSAT Pub.24, pp.281-288).
[RD.6]	J.M.Fernández, 2000: Developments for a High Resolution Wind product from the HRVIS channel of the Meteosat Second Generation. (Proceedings 5th International Wind Workshop, EUMETSAT Pub.28, pp.209-214).
[RD.7]	J.M.Fernández, 2003: Enhancement of algorithms for satellite derived winds: the High Resolution and Quality Control aspects. (Proceedings 2003 Meteorological Satellite Conference, EUMETSAT Pub.39, pp.176-182).
[RD.8]	J.García-Pereda & J.M.Fernández, 2006: Description and validation results of the high resolution wind product from HRVIS MSG channel at the EUMETSAT Nowcasting SAF (Proceedings 8th International Wind Workshop, EUMETSAT Pub.47).
[RD.9]	J.García-Pereda, 2008: Evolution of High Resolution Winds Product (HRW), at the Satellite Application Facility on support to Nowcasting and Very short range forecasting (Proceedings 9th International Wind Workshop, EUMETSAT Pub.51).
[RD.10]	J.García-Pereda, 2010: New developments in the High Resolution Winds product (HRW), at the Satellite Application Facility on support to Nowcasting and Very short range forecasting (Proceedings 10th International Wind Workshop, EUMETSAT Pub.56).
[RD.11]	C.M.Hayden & R.T.Merrill, 1988: Recent NESDIS research in wind estimation from geostationary satellite images (ECMWF Seminar Proceedings: Data assimilation and use of satellite data, Vol. II, pp.273-293).
[RD.12]	W.P.Menzel, 1996: Report on the Working Group on verification statistics. (Proceedings 3rd International Wind Workshop, EUMETSAT Pub.18, pp.17-19).
[RD.13]	J.Schmetz, K.Holmlund, A.Ottenbacher, 1996: Low level winds from high resolution visible imagery. (Proceedings 3rd international winds workshop, EUMETSAT Pub.18, pp.71-79).
[RD.14]	Xu J. & Zhang Q., 1996: Calculation of Cloud motion wind with GMS-5 images in China. (Proceedings 3rd international winds workshop, EUMETSAT Pub.18, pp.45-52).
[RD.15]	K.Holmlund & C.S.Velden, 1998: Objective determination of the reliability of satellite derived Atmospheric Motion Vectors (Proceedings 4th International Wind Workshop, EUMETSAT Pub.24, pp.215-224).
[RD.16]	K.Holmlund, C.S.Velden & M.Rohn, 2000: Improved quality estimates of Atmospheric Motion Vectors utilising the EUMETSAT Quality Indicators and the UW/CIMSS Autoeditor (Proceedings 5th International Wind Workshop, EUMETSAT Pub.28, pp.72-80).
[RD.17]	R.Borde & R.Oyama, 2008: A direct link between feature tracking and height assignment of operational Atmospheric Motion Vectors (Proceedings 9th International Wind Workshop, EUMETSAT Pub.51).
[RD.18]	J.García-Pereda, R.Borde & R.Randriamampianina, 2012: Latest developments in "NWC SAF High Resolution Winds" product (Proceedings 11th International Wind Workshop, EUMETSAT Pub.60).
[RD.19]	WMO Common Code Table C-1 (WMO Publication, available at http://www.wmo.int/pages/prog/www/WMOCodes/WMO306_vI2/LatestVERSION/WMO306_vI2_CommonTable_en.pdf)
[RD.20]	M.Dragosavac, 2008: BUFR Reference Manual (ECMWF Operations Department Publication., available at http://www.ecmwf.int/products/data/software/bufr.html)

Table 2. List of External Reference Documents

2. DESCRIPTION OF THE VALIDATION PROCEDURE

2.1 VALIDATION PROCEDURE

Relevant data for the validation, obtained from the corresponding HRW output BUFR files located in `$SAFNWC/export/PGE09` directory, are converted into McIDAS MD files through a procedure called `pge09tomd2013nwcsaf.k`, following a scheme specifically generated called HRW1.The structure of data used in this HRW1 scheme and its correspondence with parameters in the BUFR files is next:

ROW/ELEMENT	BUFR DESCRIPTOR	PARAMETER	HRW1 SCHEME DESCRIPTION
Row 01	001007	SS	Satellite Identifier
Row 02	004001/002/003	DAY	Day
Row 03	004004/005	TIME	Time
Row 04	004025	INTT	Time displacement
Row 05	031002	CMAX	Number of HRW winds at slot
Element 01	060100	IDN	Wind sequence number
Element 02	060102	TYPE	Characterization as Basic or Detailed tracer, and Type of Detailed tracer
Element 03	002028	SIZX	Segment size at nadir in X direction in kms
Element 04	002029	SIZY	Segment size at nadir in Y direction in kms
Element 05	060103	TYPL	Characterization as Cloudy or Clear air wind, and Height assignment method used
Element 06	002164	TYPT	Euclidean Distance or Cross Correlation
Element 07	005001	LAT	Initial latitude
Element 08	006001	LON	Initial longitude
Element 09	005011	DLAT	Latitude increment
Element 10	006011	DLON	Longitude increment
Element 11	012001	T	Wind Temperature
Element 12	007004	P	Wind Pressure
Element 13	011001	DIR	Wind Direction
Element 14	011002	SPD	Wind Speed
Element 15	033007	YT	Wind Quality index (using forecast)
Element 19	033007	YYT	Wind Quality index (not using forecast)
Element 23	060202	TES2	Two scale quality test flag
Element 24	060202	TEST	Temporal quality test flag
Element 25	060202	TESE	Spatial quality test flag
Element 26	060202	TESG	Forecast quality test flag
Element 27	060201	TESA	Correlation test flag
Element 28	060203	AVAT	Number of NWP levels used in HRW calculation
Element 29	060204	AVAW	Number of Predecessor winds in the trajectory
Element 30	060200	WREP	Number of Computed winds for the tracer
Element 31	060101	IDN0	Number of Predecessor wind in the previous slot
Element 32	060205	FLAI	Orographic flag
Element 33	060202	TESI	Orographic test flag
Element 36	060206	CT	Wind cloud type
Element 37	060207	WCH	Wind channel (0:HRVIS, 1:VIS06, 2:VIS08, 5:WV062, 6:WV073, 9:IR108, 10:IR120)
Element 38	060208	CORR	Correlation between tracer and tracking centre
Element 39	060209	PERR	Wind pressure error

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

Later, the comparisons are elaborated through a procedure called `ycomp2013.k`, using these MD files and the Radiosoundings loaded from the GTS into McIDAS. The comparisons are available through MD files following the scheme WCOH. The structure of data included in this WCOH scheme, and its correspondence with parameters included in the HRW1 scheme, is shown next.

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

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

The HRW Validation statistical parameters are calculated through two programs (`hrwstat.proc`, `hrwstatvalidate.proc`), which read the WCOH MD files and select data considering the value of their different parameters. The validation is based on the comparison of radiosoundings with HRW MSG-2 Satellite Nominal scan AMVs at 1200Z, in an area covering Europe and the Mediterranean (772x1856 VIS_IR pixels centered in 40.5ºN/11.1ºE) during 355 days of the whole year July 2009 – June 2010 (data were not available during 10 days of this period).

The MSG/SEVIRI, NWP data and Radiosounding observations for this whole year have been archived since the year 2010, and are used since then for all validations of HRW product, allowing the comparison of any new version of the product with the same data.

2.2 STATISTICAL PARAMETERS

The statistical parameters for the comparison between HRW Atmospheric Motion Vectors (AMVs) and Radiosoundings are the ones proposed at the Third International Winds Workshop (Ascona, Switzerland, 1996), afterwards recommended by the Coordination Group for Meteorological Satellites (CGMS) for the international comparison of satellite winds. All winds are compared to the nearest radiosounding, 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). No consideration is taken on the displacement that the radiosounding may suffer during its ascent or on differences between the nominal sounding time and the real data acquisition time.

A description of these statistical parameters is shown next:

1. NC: Number of collocations between radiosounding vectors [Ur,Vr] and AMV vectors [Ui,Vi].
2. SPD: Mean radiosounding speed.
3. BIAS: Difference between the mean velocity of the radiosoundings and the HRW AMVs.

   It shows an estimation of the systematic error related to the calculation of speed modulus (over- or underestimation of the mean AMV velocity with respect to the mean radiosounding velocity).

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

4. MVD: Mean vector difference between the radiosoundings and the HRW AMVs.

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

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

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

5. RMSVD: Root mean square vector difference.

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

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

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

Due to the variable magnitude the defined statistical parameters can have in different samples, SPD 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 the ones that are going to be presented throughout this Validation report.

3. INFLUENCE OF DIFFERENT FACTORS ON THE VALIDATION

The influence of different factors over the Validation statistics is going to be analyzed first, to define the conditions giving the best possible Validation statistics. This study is done separately for the seven MSG/SEVIRI channels from which HRW v4.0 is able to calculate Atmospheric Motion Vectors (AMVs). Some of these factors are new, and have not been verified before in previous HRW validation reports (or were only considered several years ago in initial versions of HRW product, so that an updated verification is much needed). The factors that are going to be evaluated here are:

1. The two Quality Indices used since HRW v4.0 for the filtering of the winds: QI with forecast and QI without forecast.
   A study is going to be done to verify the HRW validation statistics considering different thresholds for both Quality Indices. Additionally, because HRW v4.0 is the first version that offers two different Indices, a study is done to verify which of them works better for the filtering of the HRW winds.
   With all of this, some operative thresholds are going to be defined for the operative use of the HRW AMVs, and the difference of the validation statistics between the default configuration of the new HRW algorithm (v4.0) and the default configuration of the previous version of HRW algorithm (v3.2) is going to be seen.
2. The two Height assignment methods used in the calculation of the AMVs: "Brightness temperature interpolation method" or "CCC method".
3. The two Tracking methods used in the calculation of the AMVs: "Euclidean distance" or "Cross Correlation".
4. The scale of the tracers used: "Basic scale" or "Detailed scale".

Additionally, the influence in the validation statistics of some specific parameters which accompany the HRW AMV output data is also going to be studied:

5. The Pressure level of the AMVs, to evaluate the differences in behaviour of the AMVs calculated with the different SEVIRI channels considering the Pressure level they are associated to.
6. The Season of the year, to evaluate differences in behaviour of the HRW AMVs considering the different times of the year, throughout the whole year validation period used (July 2009 – June 2010).

With all these verifications, the Validation report is going to decide the conditions and circumstances in which the AMVs calculated with each SEVIRI channel are most useful, so that NWC SAF users can have a clear idea of their advantages and inconveniencies.

3.1 VALIDATION CONSIDERING THE QUALITY INDICES

First of all, a study on the changes of the HRW Validation statistics with the Quality indices is going to be done. Both Quality indices included in HRW v4.0 (using and not using forecast) are going to be studied, considering all AMVs together and separately HRVIS, VIS06, VIS08, IR108, IR120, WV062 and WV073 cloudy AMVs, and Water vapour clear air AMVs. Their corresponding definition is available in Chapter 3.1.2.2.8 of the "Algorithm Theoretical Basis Document for "High Resolution Winds" (HRW – PGE09 v4.0)" [AD.13].

Next figures show the behaviour against the Quality index with forecast and the Quality index without forecast, of the main validation parameters: NRMSVD (Normalized root mean square vector difference) and NBIAS (Normalized bias), for each one of these categories, considering different Quality index thresholds between 0% and 90%. Some configuration aspects already defined as default ones in the previous version of HRW algorithm (v3.2) are also considered: Basic winds, Cross correlation tracking, CCC height assignment method.

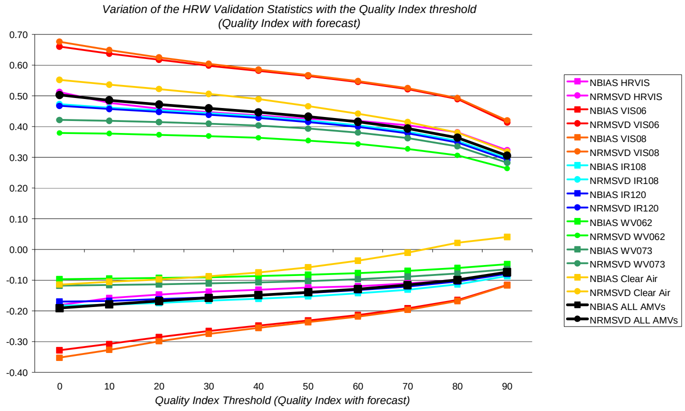

Figure 1: Variation of the NBIAS and the NRMSVD with the Quality Index threshold (using the Quality index with forecast) for all types of HRW v4.0 AMVs (Jul 2009 – Jun 2010, European & Mediterranean area) Basic winds with Cross correlation tracking and CCC height assignment method; Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs

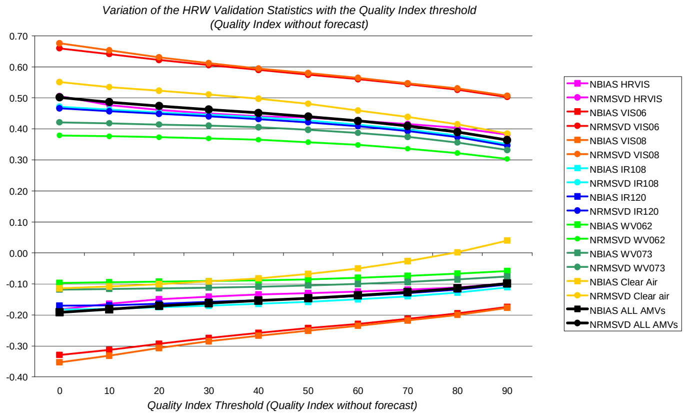

Figure 2: Variation of the NBIAS and the NRMSVD with the Quality Index threshold (not using the Quality index with forecast) for all types of HRW v4.0 AMVs (Jul 2009 – Jun 2010, European & Mediterranean area) Basic winds with Cross correlation tracking and CCC height assignment method; Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs

For both cases, it can be seen that the NRMSVD reduces significantly with higher Quality index thresholds, falling from mean values around 0.50 with QI > 0% to values around 0.30 with QI >90%. Comparing the different channels, the lowest NRMSVD is seen in the cloudy water vapour AMVs for all thresholds of both Quality indices. The parameter grows progressively to higher values in the cloudy infrared AMVs, cloudy HRVIS AMVs, clear air water vapour AMVs and cloudy low resolution visible AMVs. The difference in NRMSVD between all these groups of data can be large with low Quality index thresholds (up to a 78% between the WV062 cloudy AMVs and the VIS08 cloudy AMVs), although it reduces with higher Quality index thresholds (nevertheless, as it later will be seen in Chapter 3.6, the difference is mainly caused by the different contribution of the High, Medium and Low layer to the amount of AMVs related to each MSG/SEVIRI channel).

Considering the NBIAS, its value also reduces significantly to less negative values with higher Quality index thresholds, passing from mean values around -0.20 with QI > 0% to values around -0.08 with QI > 90%. Comparing the different channels, the NBIAS nearest to zero is seen in the clear air water vapour AMVs for all thresholds of both Quality indices, becoming even positive for the highest thresholds. The parameter grows progressively to more negative values in the cloudy water vapour AMVs, cloudy HRVIS AMVs, cloudy infrared AMVs and cloudy low resolution visible AMVs. The difference in NBIAS between all these groups of data can be large for any Quality index threshold (more than three times between the value for the water vapour clear air AMVs and the VIS08 cloudy AMVs).

Considering the amount of AMVs (not shown in the figures), and comparing it with the less restrictive case with QI > 0%, it reduces approximately to around the 60% of the data with a QI > 60% and around the 20% of the data with a QI > 90% when the Quality index with forecast has been used in the AMV filtering. The use of the Quality index without forecast is less restrictive in the AMV filtering, keeping approximately around the 60% of the data with a QI > 70% and around the 20% of the data with a QI > 95%.

Comparing the validation statistics using similar thresholds of the Quality index with forecast or the Quality index without forecast, the differences in the NRMSVD are small for low thresholds (smaller than the 6% for thresholds up to the 70%), but become bigger for the high thresholds (20% and over for a threshold of 90%), in all cases having a smaller NRMSVD using the Quality index with forecast in the AMV filtering. The situation is similar for the NBIAS, with values nearer to zero using the Quality index with forecast and increasing differences respect to using the Quality index without forecast when the threshold is higher. Here it is necessary again to take into account the more important restrictions in the AMV filtering caused by the Quality index with forecast, with small differences in the amount of data up to the 12% for low thresholds up to the 70%, and bigger differences for the high thresholds, of around half of AMV data for a threshold of 90%.

But considering that for equivalent amounts of AMV data the NRMSVD and NBIAS using the Quality index with forecast are still nearer to zero, it is generally recommended to keep the use of the forecast test in the Quality index for the AMV filtering (with configurable parameter QI_THRESHOLD_USEFORECAST = 1), in the general use of HRW algorithm. If nevertheless it is preferred to avoid as much as possible the dependence from NWP data of the calculated AMVs (for example, when they are going to be assimilated by NWP models), users can opt to avoid the use of the forecast test in the Quality index changing the value of this parameter to zero.

It can also be seen that even with the lowest Quality index threshold (QI > 0%), the NRMSVD keeps a nice mean value of 0.50 compliant with the "Target accuracy" defined in the HRW Product Requirement Table. This result (which has been obtained for the first time in any HRW version, and which is implemented through configurable parameter QI_THRESHOLD = 1), shows that AMVs with a Quality index higher than 0% can formally be used by the NWCSAF users, increasing very effectively the density of useful AMV data (taking into account that their Quality worsens with smaller Quality index values, although complying with the "Target accuracy").

AMVs with Quality index = 0% (which are only possible with QI_THRESHOLD = 0) should instead never be used because this QI value is formally reserved for invalid AMV data.

The validation statistics for all AMVs, altogether and considering separately the different MSG/SEVIRI channels, with this Quality index threshold with forecast > 0% are shown in Table 5.

AMVs throughout all atmospheric layers are considered for the Cloudy AMVs, but only AMVs over the level of 425 hPa are considered in the Clear air AMVs because of the degradation their statistics are seen to suffer at lower levels. The channels which are showing better statistics in Figure 1 (cloudy infrared and water vapour AMVs) comply with the "Target accuracy" for any Quality index threshold with forecast > 0%, so causing that the whole AMV dataset altogether also complies with the "Target accuracy". The rest of MSG/SEVIRI channels need nevertheless a higher Quality index threshold to comply with this "Target accuracy": QI > 5% for HRVIS AMVs, QI > 75% for low resolution visible AMVs and QI > 30% for Water vapour clear air AMVs. If it is requested that all MSG/SEVIRI channels comply by themselves with the target accuracy, these other threshold values should then be considered in the AMV processing for these MSG/SEVIRI channels.

HRW v4.0 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	116737	293256	279776	290907	427707	488159	486724	136309	2519575
SPD [m/s]	14.28	9.76	9.62	21.32	18.86	16.46	16.59	14.72	15.72
NBIAS	-0.18	-0.32	-0.35	-0.09	-0.11	-0.18	-0.17	-0.11	-0.19
NMVD	0.41	0.55	0.56	0.30	0.34	0.38	0.37	0.44	0.41
NRMSVD	0.51	0.66	0.67	0.37	0.42	0.47	0.46	0.55	0.50

Table 5: Validation parameters for HRW v4.0 AMVs
Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Basic winds with Cross correlation tracking and CCC height assignment method;
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs;
Quality index with forecast >0

The results in Figure 1 also show that a mean NRMSVD of 0.40 is obtained with a Quality index threshold using forecast of 65% (complying with the HRW "Optimal accuracy" and improving the validation results for the default configuration of the previous HRW v3.2 algorithm, shown in next chapter of this document).

In this situation, whose statistics are shown in Table 6, the amount of AMV data increases additionally around a 75% respect to HRW v3.2 default configuration if all seven MSG/SEVIRI channels are considered, and around a 60% if the default configuration with five MSG/SEVIRI channels (HRVIS, VIS08, IR120, WV062, WV073) is considered. Nevertheless, part of this result can be related to the nominal change in the density of tracers inferred by the changes in TRACER_SEARCH_STEP_HRV, TRACER_SEARCH_STEP_OTHER configurable parameters, which nominally consider now a more dense distribution of tracers in the low resolution images and a less dense distribution of tracers in the HRVIS high resolution image.

HRW v4.0 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	59562	129295	117194	220154	312808	305840	306124	53730	1504707
SPD [m/s]	15.47	10.71	10.72	22.66	20.38	18.64	18.79	15.99	18.10
NBIAS	-0.11	-0.20	-0.20	-0.07	-0.09	-0.13	-0.12	-0.02	-0.12
NMVD	0.33	0.44	0.45	0.27	0.30	0.32	0.31	0.34	0.33
NRMSVD	0.41	0.53	0.53	0.35	0.37	0.39	0.39	0.42	0.40

Table 6: Validation parameters for HRW v4.0 AMVs
Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Basic winds with Cross correlation tracking and CCC height assignment method;
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs;
Quality index with forecast >65

3.2 VALIDATION RESPECT TO THE PREVIOUS VERSION OF HRW ALGORITHM

Apart from the facts considered in the previous chapter, the definition of an operative Quality index threshold for the use of HRW v4.0 algorithm is going to be based on:

- The improvement of the NRMSVD for the whole dataset of AMVs by at least a 10% respect to the validation statistics of HRW v3.2.
- The improvement of the NRMSVD for each one of the atmospheric layers (High, medium and low), and for each one of the MSG/SEVIRI channels used for the AMV extraction, respect to the validation statistics for HRW v3.2.

The Quality index with forecast is considered, as suggested by the previous chapter for the AMV filtering. A threshold of 70% for the High layer and Medium layer and a threshold of 75% for the Low layer comply with these conditions, and are suggested for the operative use of HRW v4.0 algorithm. This option is then defined as default configuration for HRW 4.0, and the `safnwc_pge09.cfm` model configuration file is based on it. This configuration is additionally going to be considered in all other studies later in this document. The corresponding validation statistics for the whole validation period, considering all AMVs and those related to each MSG/SEVIRI channel separately, are shown next:

HRW v4.0 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	47280	100836	91677	189804	262992	251524	252375	43004	1239492
SPD [m/s]	16.14	11.04	11.04	23.51	21.28	19.58	19.74	16.52	19.01
NBIAS	-0.10	-0.18	-0.18	-0.06	-0.08	-0.12	-0.11	-0.00	-0.10
NMVD	0.31	0.42	0.42	0.26	0.28	0.30	0.29	0.33	0.31
NRMSVD	0.38	0.50	0.50	0.32	0.35	0.37	0.36	0.40	0.38

Table 7: Validation parameters for HRW v4.0 AMVs default configuration
Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Basic winds with Cross correlation tracking and CCC height assignment method;
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs;
Quality index with forecast: ≥ 70 for High and Medium layer; ≥ 75 for Low layer)

Comparing in Table 8 with the validation statistics for HRW v3.2 its default configuration, considering all AMVs altogether and those related to each MSG/SEVIRI channel separately, just as extracted from the previous Validation Report for HRW algorithm ("Validation Report for High Resolution Winds (HRW – PGE09 v3.2)" – [AD.10]):

HRW v3.2 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	138633	71213	64022	133011	176648	112833	115171	48178	859709
SPD [m/s]	18.03	11.75	11.71	23.63	21.96	19.68	19.89	16.32	19.08
NBIAS	-0.11	-0.16	-0.16	-0.06	-0.08	-0.11	-0.10	-0.04	-0.09
NMVD	0.32	0.44	0.44	0.29	0.31	0.32	0.32	0.35	0.33
NRMSVD	0.40	0.52	0.52	0.36	0.39	0.41	0.40	0.43	0.41

Table 8: Validation parameters for HRW v3.2 AMVs default configuration
(Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Basic winds with Cross correlation tracking and CCC height assignment method;
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-500) for Clear Air AMVs;
Quality index with forecast: ≥ 83 for High and Medium layer; ≥ 85 for Low layer)

It can be seen that the default configuration of HRW v4.0 algorithm increases the amount of available AMV data respect to those provided by HRW v3.2 algorithm by around a 45% if all seven MSG/SEVIRI channels are considered (by around a 30% if the five default MSG/SEVIRI channels are considered: HRVIS, VIS08, IR120, WV062, WV073), while reducing the mean NMVD and NRMSVD for all MSG/SEVIRI channels (especially the infrared and water vapour AMVs, for which the difference is larger than the 10%) and keeping the NBIAS basically similar (with slight increases and decreases in the values depending on the channel, although with a significant decrease for the clear air AMVs).

Considering the different MSG/SEVIRI channels, there are increases in the amount of AMVs for all channels except for HRVIS AMVs (for which the density of data in HRW v4.0 has been reduced to keep the HRW algorithm running time under limits, because of the higher relative time cost the calculation of AMVs has with this channel due to the larger tracking area it needs when the wind guess is not used) and for the Clear air AMVs (where the amount of data reduces also slightly).

Nevertheless, it is important to take here into account that with the changes in the Quality control included in HRW v4.0 the density of AMV data can be now denser in some areas and less dense in other areas respect to the HRW v3.2 output, so that the amount of AMV data available in some locations can change visibly (an issue that has to be taken into account by the NWCSAF users). In this case, as shown in the previous chapter of this document, the use of HRW v4.0 algorithm with a smaller Quality Index threshold using forecast of 65% provides a mean NRMSVD (0.40) still complying with the HRW "Optimal accuracy" and better than the NRMSVD for the previous version of the algorithm (HRW v3.2), with an additional increase in the amount of data over the 20%, which can be useful for NWCSAF users in some occasions.

With all of this, it can be seen that HRW v4.0 algorithm provides larger amounts of AMVs with smaller NMVD and NRMSVD values, and unspecific changes in the NBIAS. Considering additionally the conceptual differences between both HRW versions:

- The fact in HRW v4.0 of not using the wind guess operationally as default option for the definition of the tracking area, reducing the dependence of the calculated AMVs from the NWP model,
- The inclusion of the "Subpixel tracking" in the calculation of the AMVs avoiding discontinuities in the field of wind speeds and directions caused by the resolution of the image pixels,
- The additional information provided now in the Quality control with two different Quality Indices (with and without forecast),

it is formally recommended to NWC SAF users to update their HRW algorithm to HRW v4.0 included in SAFNWC/MSG v2013.

3.3 VALIDATION CONSIDERING THE HEIGHT ASSIGNMENT

A study on the changes of the HRW Validation statistics with both Height Assignment Methods available in HRW v4.0 algorithm ("Brightness temperature interpolation" and "CCC method") is here done, to show that both of them (not only "CCC method") are good enough to be used operatively.

The validation statistics for the AMVs using the "Brightness temperature interpolation method" are shown next for the different MSG/SEVIRI channels separately and as a whole, with the options defined through the default configuration file `safnwc_pge09.cfm`, except next changes: DEFINEWITHCONTRIBUTIONS = 0 and DEFPOSWITHCONTRIBUTIONS = 0.

HRW v4.0 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	34795	35656	32991	194018	258856	161839	171493	2075	891723
SPD [m/s]	14.77	10.08	10.15	23.62	18.89	17.08	17.21	14.38	18.42
NBIAS	-0.02	-0.09	-0.10	-0.05	+0.00	+0.00	+0.00	-0.10	-0.01
NMVD	0.33	0.41	0.41	0.25	0.33	0.31	0.31	0.35	0.31
NRMSVD	0.40	0.49	0.48	0.31	0.40	0.38	0.38	0.43	0.38

Table 9: Validation parameters for HRW v4.0 AMVs
(Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Basic winds with Cross correlation tracking, Brightness temperature interpolation height assignment
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs;
Quality index with forecast: ≥ 70 for High and Medium layer; ≥ 75 for Low layer)

It can be seen (comparing with the data shown at Table 7 for the default configuration) that similar NMVD and NRMSVD values with a smaller negative NBIAS are obtained using the "Brightness temperature interpolation method", so that the quality of the AMV data is at least similar.

But the amount of AMV data for similar mean NMVD and NRMSVD values is much larger (around a 38% larger) using "CCC height assignment method". This fact occurs for all MSG/SEVIRI channels, but specially considering the low resolution visible channels (for which it is more than the double) and the Clear air water vapour AMVs (for which the amount of AMVs with the "Brightness temperature interpolation method" is very small, and with "CCC method" it is at least comparable to the amount for HRVIS AMVs, showing additionally better values in the validation statistics).

Considering a similar amount of AMVs for both Height assignments, for example through a higher Quality Index threshold of 82% for the AMVs using "CCC method", next statistics are obtained:

HRW v4.0 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	35116	71697	65108	142943	194194	181802	182626	25844	899330
SPD [m/s]	16.70	11.26	11.23	24.85	22.59	20.65	20.84	17.54	20.10
NBIAS	-0.09	-0.15	-0.16	-0.05	-0.07	-0.10	-0.10	+0.02	-0.09
NMVD	0.30	0.40	0.40	0.24	0.26	0.28	0.27	0.30	0.29
NRMSVD	0.36	0.47	0.48	0.30	0.32	0.34	0.34	0.37	0.35

Table 10: Validation parameters for HRW v4.0 AMVs
(Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Basic winds with Cross correlation tracking and CCC height assignment method;
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs;
Quality index with forecast: ≥ 82)

Comparing the results of Tables 9 and 10, better NMVD and NRMSVD values are obtained (0.35 against 0.38) using "CCC method", in spite of still keeping a more negative NBIAS. With all of this:

- Because for a similar amount of AMVs "CCC method" gives a better NMVD and NRMSVD,
- Because for a larger amount of AMVs "CCC method" gives a similar NMVD and NRMSVD,
- Because "CCC method" specifically provides a larger amount of Clear air AMVs,
- And because "CCC method" generally provides a better spatial distribution of AMVs,

"Cross correlation tracking with CCC height assignment method" is the option preferred for the AMV calculation (as it was in the two previous versions HRW v3.1 and v3.2).

But the statistics for the "Brightness temperature interpolation height assignment" are also good (with a similar NMVD and NRMSVD value and a smaller negative NBIAS for the default configuration, although with a much smaller amount of AMV data), so that this method can be used by the NWC SAF users.

3.4 VALIDATION CONSIDERING THE TRACKING METHOD

A study on the changes of the HRW Validation statistics with both Tracking Methods available in HRW v4.0 algorithm ("Euclidean distance" and "Cross correlation") is here done, not only to show which of them is working better but also to show that both of them are good enough to be used operatively. To compare the Validation results of both Tracking methods, the "Brightness temperature interpolation height assignment" has to be used because this is the only "height assignment method" available with the "Euclidean distance" tracking.

The options through the default configuration file `safnwc_pge09.cfm`, except next changes: DEFINEWITHCONTRIBUTIONS = 0, DEFPOSWITHCONTRIBUTIONS = 0 and TRACKING = LP, are used to implement the "Euclidean distance tracking". Table 11 shows the corresponding validation statistics for this configuration for the different MSG/SEVIRI channels separately and as a whole:

HRW v4.0 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	43980	38968	37260	162206	232056	166233	176263	1336	858302
SPD [m/s]	14.40	10.51	10.62	24.59	19.62	17.29	17.41	16.63	18.58
NBIAS	-0.03	-0.09	-0.10	-0.05	+0.00	+0.00	+0.00	-0.01	-0.01
NMVD	0.33	0.40	0.39	0.25	0.32	0.31	0.31	0.38	0.31
NRMSVD	0.41	0.47	0.47	0.31	0.39	0.38	0.38	0.47	0.38

Table 11: Validation parameters for HRW v4.0 AMVs
(Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Basic winds with Euclidean distance tracking, Brightness temperature interpolation height assignment
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs;
Quality index with forecast: ≥ 70 for High and Medium layer; ≥ 75 for Low layer)

Comparing with the case using "Cross correlation tracking" and the "Brightness temperature interpolation method" shown in Table 9, the amount of AMVs is slightly larger (around a 3%) for the configuration using "Cross correlation". The Validation parameters (NBIAS, NMVD and NRMSVD) are similar. There are small differences when the MSG/SEVIRI channels are considered separately, with a slightly better behaviour of the "Euclidean distance" case for low resolution visible channels (with a larger amount of AMVs with better statistics) and a slightly better behaviour of the "Cross correlation" case for water vapour channels (with a larger amount of AMVs with better statistics for the clear air AMVs).

With all of this, due to the very similar validation results obtained for both configurations using Cross correlation/Euclidean distance tracking with the Brightness temperature interpolation method, and because the first one has already been seen to be good enough to be used by the NWC SAF users, the configuration with "Euclidean distance tracking" is also good enough to be used by the NWC SAF users.

But for the same reasons explained in the previous chapter, the option using "Cross correlation tracking with CCC method" is preferred to be used operationally as default option.

3.5 VALIDATION CONSIDERING THE TRACER SCALE

A study on the changes of the HRW Validation statistics with the scale of the tracers is here done, to show that both scales of tracers offered by HRW v4.0 algorithm ("Basic scale" and "Detailed scale") work well and can be used operatively. This study is going to be done for the algorithm default configuration (with "Cross correlation tracking" and "CCC height assignment method").

The validation statistics for the "Basic scale" have already been shown previously in Table 7. The validation statistics for the "Detailed scale" are offered in Table 12. To configure this option, NWC SAF users have to change in the default configuration file `safnwc_pge09.cfm` parameter CDET to value ALL.

HRW v4.0 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	23453	106066	100123	157088	220841	258347	255583	11623	1133124
SPD [m/s]	15.32	11.22	10.89	24.56	22.72	20.22	20.47	16.89	19.56
NBIAS	-0.09	-0.16	-0.16	-0.05	-0.06	-0.09	-0.08	+0.06	-0.09
NMVD	0.32	0.41	0.42	0.25	0.26	0.28	0.27	0.33	0.29
NRMSVD	0.40	0.49	0.50	0.30	0.32	0.34	0.34	0.41	0.36

Table 12: Validation parameters for HRW v4.0 AMVs
(Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Detailed winds with Cross correlation tracking and CCC height assignment method;
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs;
Quality index with forecast: ≥ 70 for High and Medium layer; ≥ 75 for Low layer)

Comparing to the "Basic scale" in Table 7 with the default Quality index threshold, the amount of winds in the "Detailed scale" is around a 9% smaller, but all validations statistics are at least a 6% better (NBIAS, NMVD, NRMSVD) considering all AMVs together. Considering the different MSG/SEVIRI channels, the "Detailed scale winds" statistics are better for the infrared and water vapour cloudy AMVs; not so for the visible and clear air AMVs.

With all of this, although calculation of "Detailed scale winds" is not included in the default configuration of HRW v4.0 algorithm (mainly because of running time reasons, because the calculation of the "Detailed scale winds" basically duplicates the amount of needed time, and in large region like whole Europe the procedure can be excessively time consuming), the calculation of the "Detailed scale winds" is formally recommended to NWC SAF users because its validation statistics are good (in fact better than for the "Basic scale winds") and in regions as big as national areas if a high density of AMVs is demanded, the "Detailed scale winds" provide good additional data for the operative use.

Considering now that three different kinds of "Detailed scale winds" exist ("Related to wide basic tracers", "Related to narrow basic tracers" and "Unrelated to basic tracers"), specific statistics for each one of these groups are shown in Table 13 to verify the differences. Comparing them all, small differences in the validation parameters appear among the three groups of data (with the "Detailed winds unrelated to Basic tracers" working best and the "Detailed winds related to narrow basic tracers" working worst), but in any case the statistics for all three groups are at least as good than for the "Basic scale winds", so that all of them can be used operationally.

The main difference among the three groups is related to the amount of data in each group, with a 54% of the total, a 5% of the total and a 41% of the total related respectively to "Detailed winds related to wide basic tracers", "Detailed winds related to narrow basic tracers" and "Detailed winds unrelated to basic tracers".

HRW v4.0 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
Related to Wide Basic tracers									
NC	15071	52430	49263	80671	119958	142362	141609	5206	606570
SPD [m/s]	15.58	11.41	11.06	24.30	22.66	20.29	20.49	17.45	19.68
NBIAS	-0.09	-0.17	-0.17	-0.05	-0.06	-0.10	-0.09	+0.06	-0.09
NMVD	0.32	0.41	0.42	0.25	0.27	0.28	0.28	0.32	0.30
NRMSVD	0.40	0.49	0.50	0.31	0.33	0.35	0.35	0.41	0.37
Related to Narrow Basic tracers									
NC	2014	6679	6855	5777	8933	13112	12765	682	56817
SPD [m/s]	15.11	11.50	10.99	24.28	22.25	19.02	19.44	17.34	18.15
NBIAS	-0.10	-0.19	-0.18	-0.05	-0.06	-0.11	-0.10	+0.03	-0.11
NMVD	0.33	0.43	0.42	0.25	0.27	0.29	0.29	0.32	0.32
NRMSVD	0.40	0.51	0.50	0.30	0.33	0.36	0.35	0.39	0.38
Unrelated to Basic tracers									
NC	6368	46957	44005	70640	91950	102873	101209	5735	469737
SPD [m/s]	14.78	10.96	10.68	24.87	22.84	20.27	20.58	16.33	19.58
NBIAS	-0.10	-0.14	-0.14	-0.04	-0.05	-0.09	-0.08	+0.06	-0.08
NMVD	0.32	0.40	0.41	0.24	0.25	0.27	0.26	0.33	0.29
NRMSVD	0.39	0.48	0.49	0.30	0.31	0.33	0.32	0.41	0.35

Table 13: Validation parameters for HRW v4.0 AMVs
(Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Each group of Detailed winds with Cross correlation tracking and CCC height assignment method;
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs;
Quality index with forecast: ≥ 70 for High and Medium layer; ≥ 75 for Low layer)

3.6 VALIDATION CONSIDERING THE PRESSURE LEVEL

Comparing again the statistics for the different MSG/SEVIRI channels with the default HRW v4.0 configuration (shown in Table 7 for the Basic winds and in Table 12 for the Detailed winds), the NRMSVD seems very different for the different channels, with changes larger than the 50% between the best case (Cloudy WV062 AMVs, with 0.32/0.30) and the worst case (Cloudy VIS08 AMVs, with 0.50). Nevertheless this is only caused by the different proportion of AMVs in the different pressure layers for each channel. As it can be seen in Tables 15 and 16 (where the validation statistics are extracted for the Basic and Detailed winds separately for the three different layers: High at 100-400 hPa, Medium at 400-700 hPa and Low at 700-1000 hPa), inside each one of the layers the differences of NMVD and NRMSVD for the different MSG/SEVIRI channels are much smaller: up to a 25% in the High layer, and up to a 15% in the Medium and Low layer between the best and worst case.

Comparing additionally the statistics given for the three pressure layers for the default configuration of the current algorithm (HRW v4.0) respect to the previous algorithm (HRW v3.2 Basic winds, in Table 14), increases in the amount of data over the 30%, 10% and 40% are observed respectively for the High, Medium and Low layer for both Basic and Detailed winds. Visible decreases in the NMVD and NRMSVD are additionally observed for all layers and channels (except only the Clear air AMVs in the medium layer and the Basic AMVs in the low layer, for which small variations are seen in the NMVD and NRMSVD of the different MSG/SEVIRI channels which compensate considering all of them together to obtain similar mean values). Considering the NBIAS, there are small variations between HRW v4.0 and HRW v3.2 which are only significant for the Basic winds at the medium layer for which a more negative value is generally seen (except in the Clear air AMVs for which the value turns to positive).

HRW v3.2 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	74986			126993	141182	69778	73646	35489	522074
SPD [m/s]	23.49			23.89	23.35	23.12	23.05	17.34	23.02
NBIAS (HIGH LAYER)	-0.10			-0.06	-0.09	-0.12	-0.11	-0.04	-0.09
NMVD (100-400 hPa)	0.28			0.29	0.30	0.30	0.29	0.34	0.30
NRMSVD	0.35			0.36	0.37	0.37	0.37	0.42	0.37
NC	33356	41595	37728	6018	34416	32724	32364	12689	230890
SPD [m/s]	13.47	13.11	12.97	18.18	16.52	15.06	15.19	13.45	14.37
NBIAS (MEDIUM LAYER)	-0.12	-0.17	-0.17	+0.00	-0.03	-0.08	-0.06	-0.03	-0.10
NMVD (400-700 hPa)	0.38	0.42	0.42	0.38	0.39	0.39	0.39	0.39	0.40
NRMSVD	0.47	0.51	0.51	0.48	0.49	0.48	0.48	0.47	0.49
NC	30291	29618	26294		1050	10331	9161		106745
SPD [m/s]	9.52	9.84	9.89		13.13	11.10	11.09		10.02
NBIAS (LOW LAYER)	-0.09	-0.13	-0.14		-0.02	-0.09	-0.08		-0.11
NMVD (700-1000 hPa)	0.44	0.46	0.46		0.40	0.41	0.41		0.44
NRMSVD	0.52	0.54	0.54		0.48	0.49	0.48		0.52

Table 14: Validation parameters for HRW v3.2 AMVs with the default configuration and High, Medium and Low layers considered separately (Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area; Basic winds with Cross correlation tracking and CCC height assignment method; Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-500) for Clear Air AMVs; Quality index with forecast: ≥ 83 for High and Medium layer; ≥ 85 for Low layer)

HRW v4.0 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	20317			181417	198792	167513	171633	37454	777126
SPD [m/s]	23.22			23.76	23.24	22.85	22.82	16.98	22.88
NBIAS (HIGH LAYER)	-0.10			-0.06	-0.09	-0.12	-0.11	-0.01	-0.09
NMVD (100-400 hPa)	0.26			0.25	0.26	0.27	0.27	0.32	0.27
NRMSVD	0.31			0.31	0.32	0.34	0.33	0.39	0.33
NC	12774	51714	48729	8387	57466	50698	49413	5550	284731
SPD [m/s]	12.84	12.68	12.54	17.96	15.62	15.27	15.34	13.45	14.35
NBIAS (MEDIUM LAYER)	-0.13	-0.20	-0.21	+0.00	-0.03	-0.11	-0.09	+0.10	-0.12
NMVD (400-700 hPa)	0.37	0.40	0.40	0.34	0.37	0.35	0.36	0.40	0.37
NRMSVD	0.45	0.47	0.48	0.42	0.45	0.43	0.44	0.47	0.45
NC	14189	49122	42948		6734	33313	31329		177635
SPD [m/s]	8.96	9.31	9.32		11.90	9.73	9.77		9.54
NBIAS (LOW LAYER)	-0.06	-0.13	-0.13		-0.03	-0.09	-0.09		-0.11
NMVD (700-1000 hPa)	0.46	0.45	0.46		0.42	0.42	0.42		0.44
NRMSVD	0.54	0.53	0.54		0.50	0.50	0.50		0.52

Table 15: Validation parameters for HRW v4.0
and High, Medium and Low layers considered separately
(Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Basic winds with Cross correlation tracking and CCC height assignment method;
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs;
Quality index with forecast: ≥ 70 for High and Medium layer; ≥ 75 for Low layer)

HRW v4.0 AMV Validation (Jul 2009-Jun 2010)	Cloudy HRVIS	Cloudy VIS06	Cloudy VIS08	Cloudy WV062	Cloudy WV073	Cloudy IR108	Cloudy IR120	Clear Air	All AMVs
NC	8546			153216	180404	180427	183843	9756	716192
SPD [m/s]	24.46			24.72	24.20	23.18	23.16	17.50	23.70
NBIAS (HIGH LAYER)	-0.09			-0.05	-0.07	-0.10	-0.09	+0.04	-0.07
NMVD (100-400 hPa)	0.26			0.24	0.25	0.26	0.25	0.32	0.25
NRMSVD	0.31			0.30	0.30	0.31	0.31	0.40	0.31
NC	5717	60064	55521	3872	38607	51162	48641	1867	265451
SPD [m/s]	12.00	12.17	11.86	18.19	16.30	15.02	15.24	13.75	13.91
NBIAS (MEDIUM LAYER)	-0.12	-0.18	-0.19	+0.05	+0.02	-0.08	-0.06	+0.16	-0.10
NMVD (400-700 hPa)	0.39	0.40	0.41	0.36	0.36	0.34	0.34	0.40	0.37
NRMSVD	0.47	0.48	0.49	0.44	0.44	0.42	0.42	0.48	0.45
NC	9190	46002	44602		1830	26758	23099		151481
SPD [m/s]	8.89	9.97	9.67		12.54	10.15	10.15		9.91
NBIAS (LOW LAYER)	-0.08	-0.12	-0.12		+0.02	-0.07	-0.06		-0.10
NMVD (700-1000 hPa)	0.44	0.42	0.43		0.42	0.39	0.40		0.41
NRMSVD	0.51	0.49	0.50		0.51	0.47	0.47		0.49

Table 16: Validation parameters for HRW v4.0
and High, Medium and Low layers considered separately
(Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area;
Detailed winds with Cross correlation tracking and CCC height assignment method;
Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs;
Quality index with forecast: ≥ 70 for High and Medium layer; ≥ 75 for Low layer)

A procedure has also been run to verify the variation of the Validation statistics with the pressure level. In Figure 3 the distribution in the different Pressure levels between 100 and 1000 hPa of the HRW v4.0 AMVs, considering separately each one of the MSG/SEVIRI channels they have been calculated with, is shown. In Figure 4 the behaviour of the NBIAS and the NRMSVD in these Pressure levels is also shown. In both figures, the default configuration used for the calculation of the AMVs (Basic winds with Cross correlation tracking and CCC height assignment method) has been considered.

In these graphs it is important to take into account that the "Pressure level" and "Cloud type" filterings that were defined in the previous validation report ("Validation Report for High Resolution Winds (HRW – PGE09 v3.2)" – [AD.10]) have been kept, so that the AMVs coming from the different MSG/SEVIRI channels are not contributing to all pressure layers due to these filterings (which nevertheless affect a small percentage of the total AMV data).

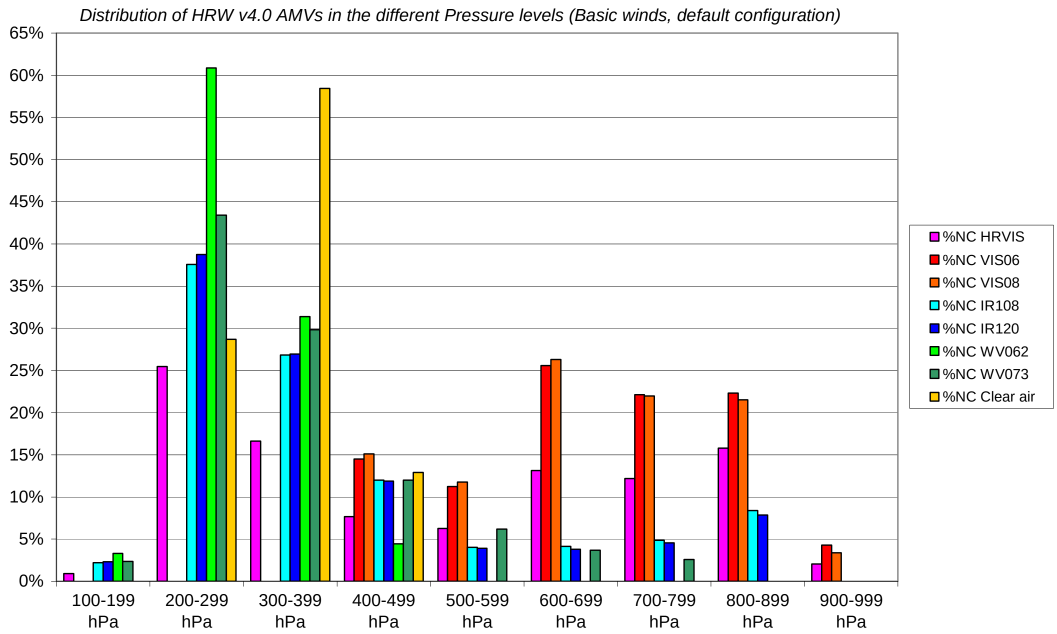

Figure 3. Distribution of HRW v4.0 AMVs in the different Pressure levels (Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area; Basic winds with Cross correlation tracking and CCC height assignment method; Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs; Quality index with forecast: ≥ 70 for High and Medium layer; ≥ 75 for Low layer)

The first conclusion is the different contribution of the AMVs from the different MSG/SEVIRI channels to the different pressure levels. The relative weight of the low resolution visible AMVs is comparatively largest in the medium and low levels (especially between 600 and 900 hPa), and the relative weight of the infrared and the water vapour AMVs is comparatively largest in the high levels (especially between 200 and 400 hPa). The HRVIS distribution throughout the pressure levels is more uniform with a maximum also between 200 and 400 hPa.

Looking at the NRMSVD for the different AMVs in Figure 4, with the defined filterings there are relatively small differences in the NRMSVD values for the different channels in the different pressure levels. Comparing the situation for the different MSG/SEVIRI channels, there are clear minimum NRMSVD values for the HRVIS AMVs in the upper half of the troposphere and for the infrared AMVs in the lower half of the troposphere. Clear maximum NRMSVD values only occur for the clear air AMVs in the layers they have been used and for VIS08 AMVs in the lowest layer. The NRMSVD values grow additionally from around 0.30 in the highest levels to values over 0.70 in the lowest levels.

The behaviour in the NBIAS is more variable, with largest negative values for the low resolution visible AMVs (in cases larger than -0.20), and progressively smaller values for the infrared AMVs, HRVIS AMVs and the water vapour AMVs (with values near zero or even positive for the Clear air water vapour AMVs). The largest negative NBIAS is shown around 500-700 hPa, reducing at lower levels (even becoming positive at the lowest level), and with relatively stable small negative values in the rest of levels (up to -0.12).

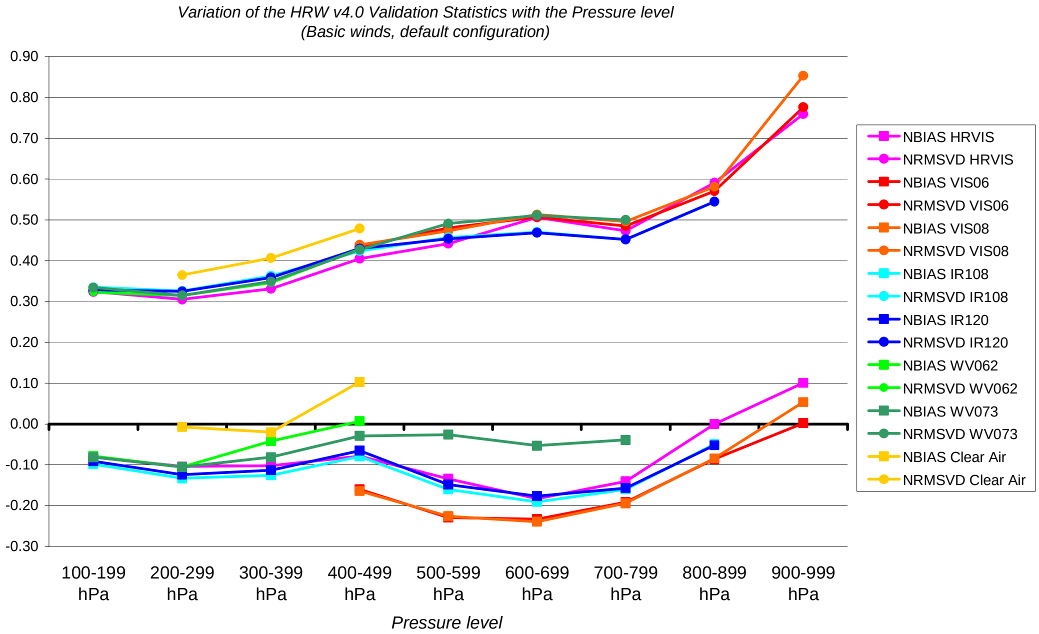

Figure 4. Variation of the Validation statistics with the Pressure level for HRW v4.0 AMVs (Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area; Basic winds with Cross correlation tracking and CCC height assignment method; Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs; Quality index with forecast: ≥ 70 for High and Medium layer; ≥ 75 for Low layer)

3.7 VALIDATION CONSIDERING THE SEASON OF THE YEAR

Because of the fact of having a whole year of data in the Reference validation dataset (July 2009 – June 2010), a study has been done to evaluate the seasonal variation of the HRW validation statistics. Next graph shows the NBIAS and the NRMSVD for the AMVs calculated with the different MSG/SEVIRI channels, considering each month of the Validation period.

Considering the NRMSVD there are differences up to 0.18 between months, especially in the Water vapour and Infrared channels, with lowest errors in the winter and largest errors in the summer. This aspect is not observed in the visible channels, more related to the low layer, where a seasonal variation in the wind can be smaller. At the same time, seasonal variations in the NBIAS are not so clear and tend to change more randomly.

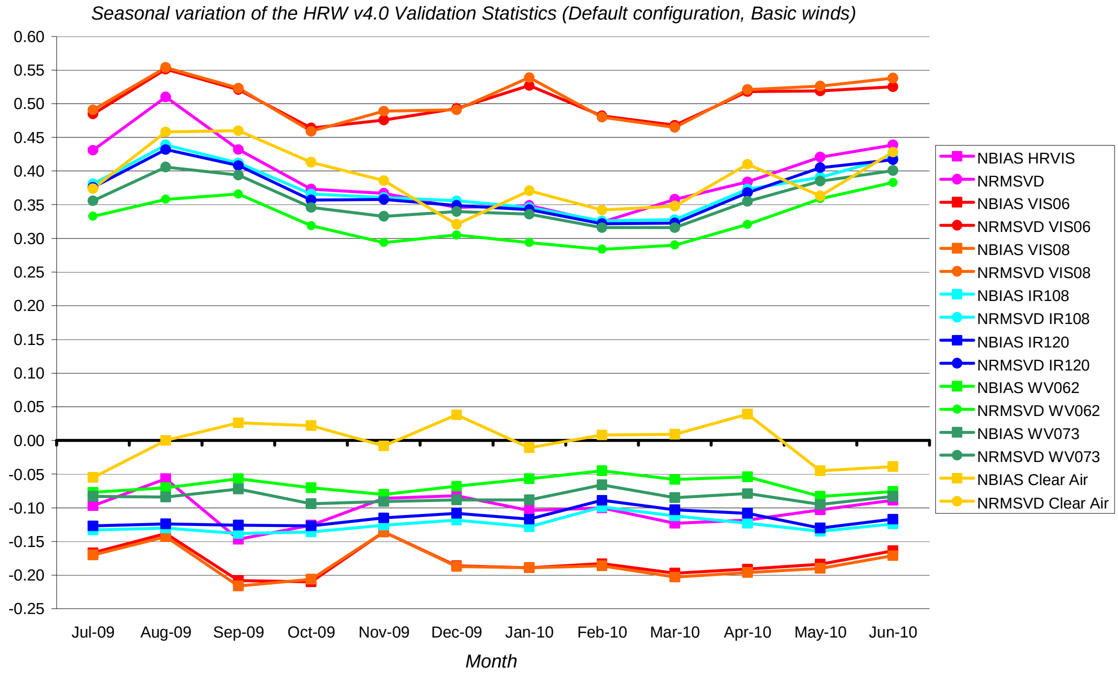

Figure 5: Seasonal variation of the HRW NBIAS and NRMSVD for HRW v4.0 AMVs (Jul 2009-Jun 2010, MSG2 satellite, European and Mediterranean area; Basic winds with Cross correlation tracking and CCC height assignment method; Pressure range [hPa]: [100-999) for Cloudy AMVs, [100-425) for Clear Air AMVs; Quality index with forecast: ≥ 70 for High and Medium layer; ≥ 75 for Low layer)

4. CONCLUSIONS

Some conclusions can be extracted from this "Validation report for HRW 4.0". Considering Table 17, where the accuracies defined in the Product Requirement Table (PRT) for HRW product are compared with the default implementations of HRW version considered and recommended in this Validation report (HRW v4.0, Basic and Detailed winds) and the previous one (HRW v3.2, Basic winds), in both cases with "Cross correlation tracking" and "CCC height assignment method":

Evolution of the Validation statistics between HRW versions, related to the Operative thresholds defined in the HRW Product Requirement Table	All Layers NRMSVD	High Layer NRMSVD	Medium Layer NRMSVD	Low Layer NRMSVD
HRW v3.2, Basic winds, Default configuration	0.41	0.37	0.49	0.52
HRW v4.0, Basic winds, Default configuration (With an increase in the Amount of AMV data of +44% respect to HRW v3.2 Basic winds)	0.38	0.33	0.45	0.52
HRW v4.0, Detailed winds, Default configuration (With an increase in the Amount of AMV data of +32% respect to HRW v3.2 Basic winds)	0.36	0.31	0.45	0.49
HRW Product Requirement Table "Optimal Accuracy"	0.40	0.35	0.40	0.45
HRW Product Requirement Table "Target Accuracy"	0.50	0.44	0.50	0.56
HRW Product Requirement Table "Threshold Accuracy"	0.60	0.53	0.60	0.67

Table 17: Evolution of Validation statistics between HRW v3.2 and HRW v4.0 versions, related to the Operative thresholds defined in the HRW Product Requirement Table.

It can be seen that both Basic and Detailed HRW v4.0 wind datasets show a smaller mean NRMSVD ("Normalized root mean square vector difference") with a larger amount of AMVs than the ones provided by the default HRW v3.2 configuration. The HRW v4.0 Detailed winds are additionally seen to behave better for a similar configuration than the HRW v4.0 Basic winds, with a smaller NRMSVD (although also with a slightly lower amount of AMVs).

With all of this, as already mentioned previously, both "Basic and Detailed HRW 4.0 winds" can be used operationally. If both datasets are considered together, the increase in the amount of AMVs is very important and can operationally be very useful, especially when very high density AMV datasets are needed by the NWC SAF users.

Additionally, the "Optimal accuracy" defined for the HRW AMVs at the Product Requirement Table is reached for the first time when the high layer or all layers together are considered (while the medium and the low layer AMV accuracy stays between the "Target accuracy" and the "Optimal accuracy" defined in the PRT).

As already commented previously, if also the conceptual differences between HRW v3.2 and v4.0 are taken into account:

- The fact in HRW v4.0 of not using the wind guess operationally as default option for the definition of the tracking area, reducing the dependence of the calculated AMVs from the NWP model.
- The inclusion of the "Subpixel tracking" in the calculation of the AMVs avoiding discontinuities in the field of wind speeds and directions caused by the resolution of the image pixels.
- The additional information provided now in the Quality control with two different Quality Indices (with and without forecast),

it is formally recommended to NWC SAF users to update their HRW algorithm to HRW v4.0 included in SAFNWC/MSG v2013.

Considering finally the two other HRW algorithm options shown previously in this document (“Cross correlation tracking with Brightness temperature interpolation height assignment” in Table 9 and “Euclidean distance tracking with Brightness temperature interpolation height assignment” in Table 11), it can be seen that in both cases the amount of AMVs is similar or larger than the one provided by the default configuration of HRW v3.2, and that their mean NRMSVD for all layers (0.38) also reaches the “Optimal accuracy” defined in the HRW Product Requirement Table.

Because of this reason these other HRW options can also be used operationally by the NWC SAF users (taking only into account that they can show some problems with the spatial distribution of the AMV data, especially when Clear Air AMVs are considered). This options can be useful for example in the cases in which all of the SAFNWC/MSG Cloud products of any of them (Cloud mask, Cloud type and Cloud top temperature and height) cannot be calculated, which obliges to use SAFNWC/MSG HRW product with the “Brightness temperature interpolation method”, for which this Validation report shows that the calculated AMVs are still useful operationally.