EUMETSAT NWC SAF

SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING

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

NWC/CDOP3/PPS/AEMET/SCI/VR/Wind, Issue 0, Rev.2.0

07 November 2022

Applicable to NWC/PPS-HRW v7.Q

Applicable to SAFNWC/PPS version 2021.3

Applicable to the following PGEs:

Acronym	Product ID	Product name	Version number
HRW	*(demonstrational)*	High Resolution Winds	7.Q (demonstrational release)

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REPORT SIGNATURE TABLE

Function	Name	Signature	Date
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DOCUMENT CHANGE RECORD

Version	Date	Pages	Changes
0.1d	*30 September 2020*	28	Version for NWC/PPS-HRW v7.P
0.1e	*1 September 2021*	28	Updates due to results of PPS v2021 RR: Change the status of HRW to ‘demonstrational’.
0.1	*12 October 2021*	28	Updates after PPS v2021 DRR: Just updated document references.
0.2.0	*07 November 2022*	29	Initial version for NWC/PPS-HRW v7.Q

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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 (NWCSAF)". The main objective of the NWCSAF 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 NWCSAF webpage, http://www.nwcsaf.org.

This document is applicable to the NWC/PPS software package for polar satellites.

1.1 SCOPE OF THE DOCUMENT

This document is the Scientific and Validation Report for the second version of the Wind Product Processor of the NWC/PPS software package (NWC/PPS-HRW v7.Q, High Resolution Winds), which calculates Atmospheric Motion Vectors and Trajectories considering images reprojected to a static region, coming from any of the following polar satellites, radiometers and channels:

- AVHRR-3 radiometer inside NOAA-15, NOAA-16, NOAA-17, NOAA-18, NOAA-19, Metop-A, Metop-B or Metop-C polar satellites, using 0.630 μm VIS06 visible channel and/or 10.800 μm IR108 infrared channel.
- VIIRS radiometer inside SNPP, NOAA-20 or NOAA-21 polar satellites, using 0.640 μm VIS06 visible channel and/or 10.763 μm IR108 infrared channel.
- MODIS radiometer inside EOS-1 (Terra) or EOS-2 (Aqua) polar satellites, using 0.645 μm VIS06 visible channel, 11.030 μm IR110 infrared channel, 6.715 μm WV067 water vapour channel, and/or 7.325 μm WV073 water vapour channel.
- METimage radiometer inside Metop-SG-A1, Metop-SG-A2 or Metop-SG-A3 polar satellites (when they become available), using 0.668 μm VIS06 visible channel, 10.690 μm IR108 infrared channel, 6.725 μm WV067 water vapour channel, and/or 7.325 μm WV073 water vapour channel.
- MERSI-2 radiometer inside FY3-D polar satellite, using 0.650 μm VIS06 visible channel, 10.800 μm IR108 infrared channel, and/or 7.200 μm WV072 water vapour channel.
- SLSTR radiometer inside Sentinel-3A or Sentinel-3B polar satellites (and Sentinel-3C or Sentinel-3D when they become available), using 0.659 μm VIS06 visible channel and/or 10.850 μm IR108 infrared channel.

There is a commitment so that the adaptation of NWC/PPS-HRW software to these polar satellite series is validated. The corresponding validation results are shown in this document.

As for the all versions of NWC/GEO-HRW, the validation has been based on the comparison of the NWC/PPS-HRW v7.Q 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.

As for the latest versions of NWC/GEO-HRW, NWC/PPS-HRW v7.Q is also validated using ECMWF model analysis winds as additional reference. This permits to evaluate differences in the behaviour and scale of NWC/PPS-HRW AMVs with respect to both reference winds used.

A comparison with the previous version of NWC/PPS-HRW (v7.P inside NWC/PPS v2021 software package) is also verified, to show the similarities and differences in the AMVs obtained with both.

1.2 SOFTWARE VERSION IDENTIFICATION

This document corresponds to the software implemented in the second version of NWC/PPS-HRW, NWC/PPS-HRW v7.Q (with demonstrational status), included in NWC/PPS v2021.3 software package release.

1.3 IMPROVEMENTS FROM PREVIOUS VERSIONS

This is the second implementation of NWC/PPS-HRW software, for use with up to 19 polar satellites with AVHRR-3, VIIRS, MODIS, METimage, MERSI-2 and SLSTR radiometers.

Of all these, seven different additional polar satellites and three different additional radiometers have been added in the processing in this second version.

Additionally, the AMV calculation process has been extended to MODIS and METimage WV067 water vapour cloudy and clear air AMVs, and to MODIS, METimage and MERSI-2 WV072/WV073 water vapour cloudy and clear air AMVs, in a similar way water vapour AMVs are calculated in NWC/GEO-HRW geostationary software.

Additionally, NWC/PPS-CMIC product has been included in the processing, for the calculation of the "Cloud Microphysics height assignment correction", considering the value of the "Cloud phase", "Ice water path" and "Liquid water path", in a similar way it is done in NWC/GEO-HRW geostationary software.

Additionally, several improvements included in NWC/GEO-HRW software between versions v6.1 (used as basis for NWC/PPS-HRW v7.P in 2020) and v7.0 (which is the latest version developed for NWC/GEO-HRW in 2022, and which will be released after the launch of MTG-I1 satellite), have also been included in NWC/PPS-HRW v7.Q. These improvements include: an optimization of the running time of HRW, a better distribution of AMVs in high, medium and low levels, a change in the structure of the HRW netCDF output to be CF compliant and easier to process, and the correction of up to seven SPRs occurring between these versions.

Finally, many running parameters of NWC/PPS-HRW have been retuned in v7.Q, so defining better AMV densities and fewer holes in the AMV coverage.

With all this, there are even more similarities between both geostationary NWC/GEO-HRW and polar NWC/PPS-HRW AMV softwares, because for example both include now "Water vapour AMVs" and the "Cloud microphysics CCC height assignment correction". This way, NWC/GEO-HRW AMVs and NWC/PPS-HRW AMVs are more homogeneous throughout all the world, and users should find even easier the processing of both types of AMVs together, for example in NWP or climatic applications.

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 referred document applies.

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

Ref.	*Title*	*Code*	*Ver.*
[AD.1]	Proposal for the Fourth Continuous Development and Operations Phase (CDOP4)	NWC/SAF/AEMET/MGT/CDOP4Proposal	1.0
[AD.2]	Interface Control Document for Internal and External Interfaces of the NWC/PPS	NWC/CDOP3/PPS/SMHI/SW/ICD/1	3.2.0
[AD.3]	User Manual for the NWC/PPS application: Software Part, 2.Operation	NWC/CDOP3/PPS/SMHI/SW/UM/OPER	3.3.0
[AD.4]	System and Component Requirements Document for the NWC/PPS	NWC/CDOP3/PPS/SMHI/SW/SCRD	2.3
[AD.5]	Algorithm Theoretical Basis Document for the Wind product processor of the NWC/PPS	NWC/CDOP3/PPS/AEMET/SCI/ATBD/Wind	0.2.0
[AD.6]	User Manual for the Wind product processor of the NWC/PPS: Software part	NWC/CDOP3/PPS/AEMET/SCI/UM/Wind	0.2.0

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 referred document 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 "NWCSAF 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://library.wmo.int/doc_num.php?explnum_id=10722#page=956)
[RD.20]	WMO Code Tables and Flag Tables associated with BUFR/CREX table B, version 31 (WMO Publication, available at https://library.wmo.int/doc_num.php?explnum_id=10722#page=252)
[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 NWCSAF/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/PPS-HRW v7.Q is exactly equivalent to the one for the latest versions of the High Resolution Winds geostationary software (NWC/GEO-HRW v6.2) and polar software (NWC/PPS-HRW v7.P). It incorporates for each AMV both reference winds used in the validation: Radiosounding winds and ECMWF model analysis winds.

For each AMV, the corresponding ECMWF model analysis reference wind is defined by the autovalidation process inside NWC/PPS-HRW software, and incorporated in the HRW BUFR output with “NWCSAF specific format” (configured with OUTPUT_FORMAT = NWC). The corresponding Radiosounding reference wind for each AMV is extracted from Radiosounding wind profiles obtained from the GTS through an intermediate McIDAS process. All these validation data are then included in McIDAS MD files following a scheme called WDMR. A different WDMR MD file is generated for each day, scale (“Basic AMVs” or “Detailed AMVs”) and region (“EURON1 – Scandinavia” and “EUROPA”) used in the validation process.

The structure of data in this WDMR scheme is shown in the following table. The NWC/PPS-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 from initial to final image
Column 04	031002	CMAX	Number of NWC/PPS-HRW AMVs per slot
Column 05	060000	TRAX	Segment size of tracer in X direction in pixels
Column 06	060001	TRAY	Segment size of tracer in Y direction in pixels
Column 07	060100	IDN	AMV sequence number in the slot
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	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

ROW/COLUMN ELEMENT	"NWC" BUFR DESCRIPTOR	PARAMETER MD ID.	WDMR SCHEME DESCRIPTION
Column 21	033007	QI	AMV Quality index with forecast
Column 22	033007	QINF	AMV Quality index without forecast
Column 23	033007	QIWG	AMV Common Quality index without forecast
Column 24		QT	Threshold: Quality index with forecast
Column 25		QTNF	Threshold: Quality index without forecast
Column 26		QTWG	Threshold: Common Quality index without forecast
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/PPS Cloud type
Column 39	060207	WCH	AMV NWC/PPS 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 (not used in NWC/PPS-HRW)
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	Radiosounding 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	Radiosounding Pressure at AMV best fit level

Table 3. Description of McIDAS WDMR Scheme
and Correspondence with NWC/PPS-HRW BUFR output with "NWCSAF" specific format

2.2 STATISTICAL PARAMETERS

The statistical parameters for the validation of NWC/PPS-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/PPS-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/PPS-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/PPS-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.

The validation process has been based on Radiosounding winds at 12:00 UTC, and ECMWF NWP model analysis winds at 12:00 UTC, during 91 days inside the period April – June 2020.

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), and a maximum time difference of one hour between the Radiosounding time and the AMV time (the time of the "later image" used for the AMV calculation), This way, only AMVs for slots between 11:00 UTC and 13:00 UTC of this period complying with these characteristics have been considered valid for this validation.

Considering the validation against ECMWF NWP model analysis winds, with the same time restriction, all AMVs for slots between 11:00 UTC and 13:00 UTC can formally be validated against NWP analysis winds (considering an interpolation of the NWP wind to the AMV location and level). However, 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 at the same time against both reference datasets are considered. Although the size of the AMV sample is this way smaller, the number of AMV data validated against both datasets is exactly the same in all cases, and differences in the validation against both datasets can be better seen because of using exactly the same AMVs in each case.

3. VALIDATION OF NWC/PPS-HRW V7.Q AMVS

3.1 VALIDATION FOR BASIC AMVS WITH DEFAULT CONFIGURATION

The validation of NWC/PPS-HRW v7.Q software for polar satellite series is considered here. As already said, a validation period of three months has been defined (April – June 2020). Here, satellite scannings from ten different polar satellites (Metop-A, Metop-B, Metop-C, NOAA-18, NOAA-19, NOAA-20, SNPP, EOS-1, EOS-2, FY3-D) have been reprojected over two static regions ("EURON1 - Scandinavia", shown in *Figure 1*, and "EUROPA", shown in *Figure 2*), between 07:00 UTC and 13:00 UTC for the 91 days inside this validation period, and all AMVs for all related slots between 11:00 UTC and 13:00 UTC have been validated against both Radiosounding winds and NWP analysis winds at 12:00 UTC.

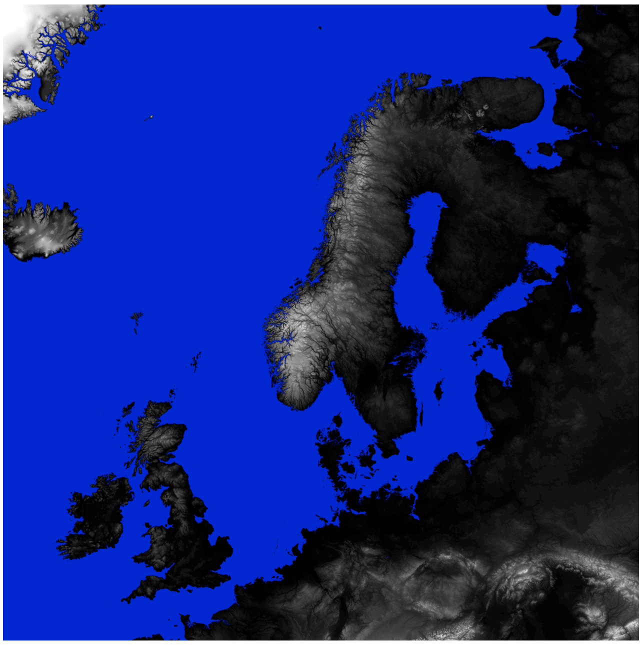


Figure 1: "EURON1 – Scandinavia" static region used for the validation of NWC/PPS-HRW v7.Q

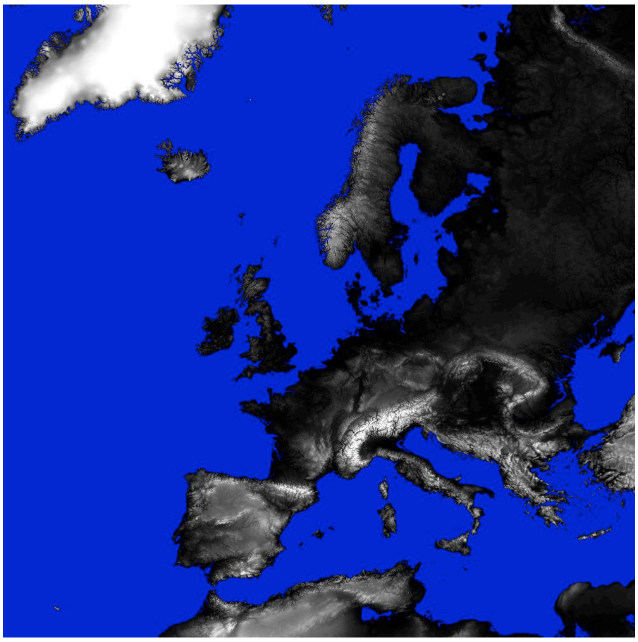


Figure 2: "EUROPA" static region used for the validation of NWC/PPS-HRW v7.Q

The configuration considers the conditions defined in the default "model configuration file" `$SM_CONFIG_DIR/safnwc_HRW_POLAR.cfm`. For this process, all NWC/PPS-Cloud products (CMA, CT, CTTH and CMIC) have to be produced in both reprojected validation regions before the running of NWC/PPS-HRW. Examples of AMVs calculated with NWC/PPS-HRW software for these two static regions are shown in *Figure 3* and *Figure 4*.

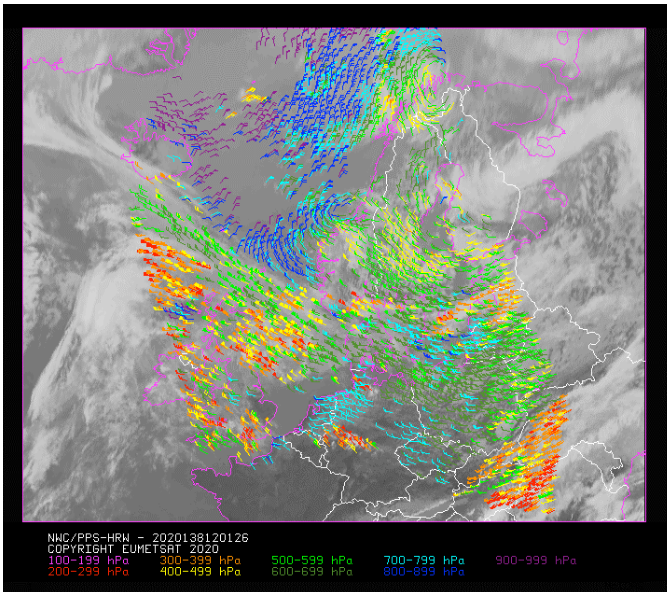


Figure 3: NWC/PPS-High Resolution Winds "Basic AMV" output example in the region "EURON1 - Scandinavia" (17 May 2020 12:01:26 UTC for EOS-2 satellite, with tracers calculated at 11:44:19 UTC for NOAA-20 satellite), considering conditions defined in $SM_CONFIG_DIR/safnwc_HRW_POLAR.cfm model configuration file. Colour coding based on the AMV pressure level

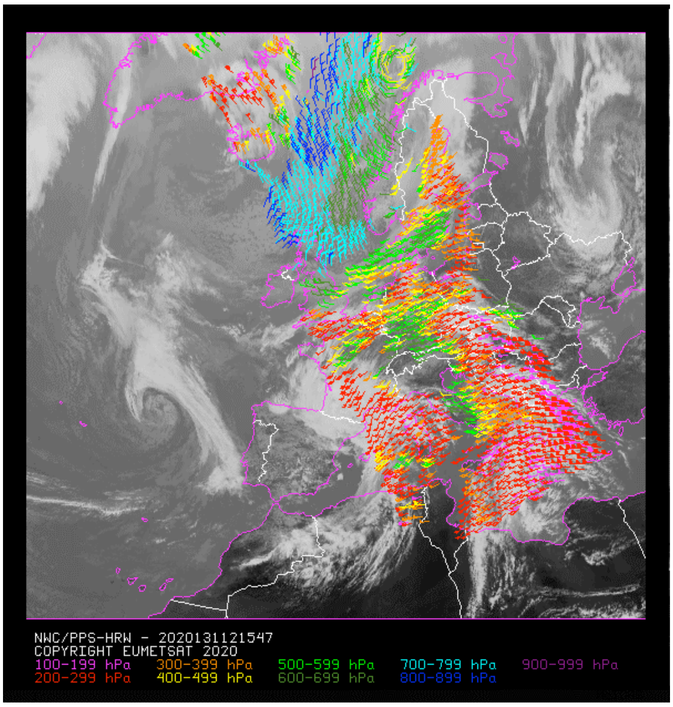


Figure 4: NWC/PPS-High Resolution Winds "Basic AMV" output example in the region "EUROPA" (10 May 2020 12:15:47 UTC for NOAA-20 satellite, with tracers calculated at 11:55:19 UTC for EOS-2 satellite), considering conditions defined in $SM_CONFIG_DIR/safnwc_HRW_POLAR.cfm model configuration file. Colour coding based on the AMV pressure level

Comparing the statistics for NWC/PPS-HRW v7.Q against Radiosounding winds and ECMWF NWP analysis winds in *Table 4* (considering all layers together) and in *Table 5* (considering three layers separately), NMVD and NRMSVD are around a 30% smaller against NWP analysis winds. The general trend in the validation of other versions of NWCSAF/High Resolution Winds in seen again, showing that the general scale and the behaviour of AMV winds is more similar to the one for NWP analysis winds than to the one for Radiosounding winds.

Considering the statistics for the new satellite channels for which AMV can be calculated with NWC/PPS-HRW v7.Q (cloudy and clear air water vapour AMVs), the main element is that the proportion of these cloudy and clear air Water vapour AMVs is very small (between 0.5% and 1.5%), basically because only three out of the ten validated satellites include water vapour channels in their options, and so the probability that both initial and final image include water vapour channels is less than a 10%. With this, the importance of Water vapour AMVs will be in general smaller in polar AMVs than in geostationary AMVs. Considering corresponding statistics, NMVD and NRMSVD parameters are also worse for water vapour AMVs than those for visible and infrared AMVs (up to a 15% against Radiosounding winds and up to a 35% against NWP winds), which can also be caused by the small amount of water vapour AMVs and their fewer references in the Quality control process.

Considering the differences in the AMVs for regions "EUROPA" and "EURON1", with pixels of 5 km size and 1 km size, AMVs for region "EUROPA" have slightly smaller validation parameters (up to a 5% smaller), which can be related to the fact of using tracers of larger size which are more persistent in time. It can also be seen that NBIAS values have different sign in both regions, being positive in "EURON1" region and negative in "EUROPA" region. This can also be related to the fact of using tracers of larger size in "EUROPA" region. Comparing the statistics for the different layers, the highest values of the validation statistics are for the medium layer, while the lowest values are for the high layer against Radiosounding winds and for the low layer against NWP analysis winds. This result is different to the one for all versions of NWC/GEO-HRW software, for which the highest values are related to the low layer and the lowest values are related to the high layer.

The "Target accuracy" value defined for all NWCSAF/High Resolution Winds versions up to now is reached in both validation regions in the high and medium layer (with values respectively up to 0.44 and 0.50 against Radiosounding winds), and the "Optimal accuracy" is reached in both validation regions for the low layer (with a value up to 0.45 against Radiosounding winds).

	"EURON1-Scandinavia" region					"EUROPA" region				
NWC/PPS-HRWv7.Q AMVs (Apr 2020-Jun 2020)	VIS	IR	cloudy WV	clear air WV	all AMVs	VIS	IR	cloudy WV	clear air WV	all AMVs
NC	99279	106702	914	35	206930	160274	247727	4886	591	413478
SPD [m/s]	15.87	20.02	36.77	21.60	18.10	15.68	18.79	24.36	16.31	17.64
NBIAS (ALL LAYERS)	+0.03	+0.03	+0.09	-0.01	+0.03	-0.04	-0.02	+0.05	+0.00	-0.02
NMVD (100-1000 hPa)	0.36	0.34	0.39	0.35	0.35	0.34	0.34	0.35	0.40	0.34
NRMSVD	0.46	0.41	0.47	0.50	0.43	0.41	0.41	0.44	0.53	0.41
NC	99279	106702	914	35	206930	160274	247727	4886	591	413478
SPD [m/s]	16.20	20.12	37.23	21.24	18.31	15.76	18.67	25.21	15.86	17.61
NBIAS (ALL LAYERS)	+0.01	+0.03	+0.08	+0.00	+0.02	-0.05	-0.02	+0.02	+0.02	-0.03
NMVD (100-1000 hPa)	0.25	0.25	0.34	0.31	0.25	0.24	0.23	0.28	0.31	0.23
NRMSVD	0.34	0.32	0.42	0.41	0.33	0.29	0.29	0.37	0.39	0.29

Table 4: Validation parameters for NWC/PPS-HRW v7.Q AMVs, considering all layers together, against Radiosounding winds in light green and against ECMWF NWP analysis winds in dark green. (Basic AMVs in nominal configuration; Apr-Jun 2020 between 11:00 and 13:00 UTC; Polar satellites with AVHRR-3, VIIRS, MODIS and MERSI-2 radiometers). Statistics for region "EURON1 - Scandinavia" on the left side; region "EUROPA" on the right side.

	“EURON1-Scandinavia” region					“EUROPA” region				
NWC/PPS-HRWv7.Q AMVs (Apr 2020-Jun 2020)	**VIS**	**IR**	**cloudy WV**	**clear air WV**	**All AMVs**	**VIS**	**IR**	**cloudy WV**	**clear air WV**	**All AMVs**
NC	25504	50740	740	0	76984	50091	137702	3450	0	191243
SPD [m/s]	26.79	26.78	39.24		26.90	22.73	23.39	27.34		23.28
NBIAS (HIGH LAYER)	+0.03	+0.03	+0.08		+0.03	-0.05	-0.03	+0.04		-0.03
NMVD (100-400 hPa)	0.33	0.31	0.39		0.31	0.33	0.33	0.34		0.33
NRMSVD	0.40	0.37	0.47		0.38	0.38	0.38	0.42		0.38
NC	24669	29087	174	35	53965	55400	67479	1436	591	124906
SPD [m/s]	15.70	19.24	26.23	21.60	17.64	13.79	13.98	17.19	16.31	13.94
NBIAS (MEDIUM LAYER)	+0.01	+0.04	+0.17	-0.01	+0.02	-0.04	-0.02	+0.11	+0.00	-0.02
NMVD (400-700 hPa)	0.37	0.37	0.38	0.35	0.37	0.36	0.37	0.39	0.40	0.36
NRMSVD	0.45	0.45	0.44	0.50	0.45	0.43	0.44	0.49	0.53	0.43
NC	49106	26875	0	0	75981	54783	42546	0	0	97329
SPD [m/s]	10.27	11.35			10.65	11.16	11.56			11.33
NBIAS (LOW LAYER)	+0.05	+0.03			+0.04	-0.02	-0.02			-0.02
NMVD (700-1000 hPa)	0.39	0.38			0.38	0.34	0.34			0.34
NRMSVD	0.46	0.45			0.45	0.39	0.40			0.40
NC	25504	50740	740	0	76984	50091	137702	3450	0	191243
SPD [m/s]	26.78	26.69	39.84		26.84	22.41	22.95	28.40		22.90
NBIAS (HIGH LAYER)	+0.03	+0.04	+0.07		+0.03	-0.04	-0.01	+0.00		-0.01
NMVD (100-400 hPa)	0.26	0.24	0.34		0.24	0.24	0.23	0.28		0.23
NRMSVD	0.32	0.29	0.42		0.30	0.28	0.27	0.37		0.27
NC	24669	29087	174	35	53965	55400	67479	1436	591	124906
SPD [m/s]	15.83	16.32	26.12	21.24	16.13	14.03	14.14	17.55	15.86	14.13
NBIAS (MEDIUM LAYER)	+0.00	+0.04	+0.18	+0.00	+0.02	-0.06	-0.04	+0.09	+0.02	-0.04
NMVD (400-700 hPa)	0.27	0.27	0.34	0.31	0.27	0.24	0.25	0.30	0.31	0.24
NRMSVD	0.34	0.34	0.40	0.41	0.34	0.29	0.30	0.38	0.39	0.29
NC	49106	26875	0	0	75981	54783	42546	0	0	97329
SPD [m/s]	10.89	11.85			11.23	11.44	12.01			11.69
NBIAS (LOW LAYER)	-0.00	-0.01			-0.00	-0.05	-0.06			-0.05
NMVD (700-1000 hPa)	0.23	0.24			0.24	0.22	0.22			0.22
NRMSVD	0.28	0.28			0.28	0.26	0.25			0.26

Table 5: Validation parameters for NWC/PPS-HRW v7.Q AMVs, considering respectively the high, medium and low layer, against Radiosounding winds in light green and against ECMWF NWP analysis winds in dark green. (Basic AMVs in nominal configuration; Apr-Jun 2020 between 11:00 and 13:00 UTC; Polar satellites with AVHRR-3, VIIRS, MODIS and MERSI-2 radiometers). Statistics for region “EURON1 - Scandinavia” on the left side; region “EUROPA” on the right side.

3.2 COMPARISON WITH NWC/PPS-HRW V7.P DEFAULT CONFIGURATION

The comparison of the statistics for NWC/PPS-HRW v7.Q default configuration, with those for the previous polar version NWC/PPS-HRW v7.P, is considered here. The main differences are that the older version NWC/PPS-HRW v7.P is not able to process MERSI-2 radiometer (so not processing the FY3-D satellite used in the validation), and that it only calculates visible and infrared AMVs (because it does not calculate cloudy nor clear water vapour AMVs). Statistics for NWC/PPS-HRW v7.P are shown in *Table 6* considering all layers together and in *Table 7* considering three layers separately (high, medium and low).

Considering the evolution in the number of AMVs between NWC/PPS-HRW v7.P and v7.Q, there are increases in the number of AMVs of 2.6 times in "EURON1" region and 3.7 times in "EUROPA" region. This is a very important improvement, caused by the retuning of many running parameters in NWC/PPS-HRW software mentioned in Chapter 1.3 (Improvements from previous versions), which defines better AMV densities and fewer holes in the AMV coverage. Additionally, with the increase in the number of AMVs there is at least a 7% reduction of NMVD and NRMSVD validation parameters considering all layers together, which is also very positive.

Considering the different layers separately, the main difference between NWC/PPS-HRW v7.P and v7.Q is the better distribution of AMVs in the high/medium/low layer for v7.Q. In v7.P, the distribution was 43%/22%/35% for "EURON1" region and 60%/24%/16% for "EUROPA" region. In v7.Q, the distribution is 37%/26%/37% for "EURON1" region and 43%/22%/35% for "EUROPA" region, with increases in the number of AMVs in the three layers. Additionally, the NMVD and the NRMSVD reduce in general in each layer for both validation regions; in some case up to a 27%. All this causes a better representation of atmospheric winds in all tropospheric levels with NWC/PPS-HRW v7.Q algorithm,

Taking into account all these elements, it can be concluded that the behaviour of NWC/PPS-HRW v7.Q is significantly better than the one for v7.P, with the general recommendation to all users of updating the version of NWC/PPS-HRW as soon as they have a chance for this.

NWC/PPS-HRWv7.P AMVs (Apr 2020-Jun 2020)	"EURON1-Scandinavia" region VIS	IR	All AMVs	"EUROPA" region VIS	IR	All AMVs
NC	38628	39990	78618	34105	75800	109905
SPD [m/s]	14.75	20.67	17.76	15.89	20.51	19.08
NBIAS (ALL LAYERS)	+0.03	+0.03	+0.03	-0.07	-0.04	-0.05
NMVD (100-1000 hPa)	0.38	0.35	0.36	0.37	0.36	0.36
NRMSVD	0.50	0.43	0.46	0.45	0.43	0.44
NC	38628	39990	78618	34105	75800	109905
SPD [m/s]	15.11	20.68	17.94	15.98	20.23	18.91
NBIAS (ALL LAYERS)	+0.01	+0.03	+0.02	-0.07	-0.03	-0.04
NMVD (100-1000 hPa)	0.28	0.27	0.27	0.27	0.26	0.26
NRMSVD	0.38	0.34	0.36	0.34	0.31	0.32

Table 6: Validation parameters for NWC/PPS-HRW v7.P AMVs, considering all layers together, against Radiosounding winds in light blue and against ECMWF NWP analysis winds in dark blue. (Basic AMVs in nominal configuration; Apr-Jun 2020 between 11:00 and 13:00 UTC; Polar satellites with AVHRR-3, VIIRS and MODIS radiometers). Statistics for region "EURON1 - Scandinavia" on the left side; region "EUROPA" on the right side.

	"EURON1-Scandinavia" region			"EUROPA" region		
NWC/PPS-HRWv7.P AMVs (Feb 2020-Apr 2020)	VIS06	IR108/ IR110	All AMVs	VIS06	IR108/ IR110	All AMVs
NC	10581	23220	33801	13621	52438	66059
SPD [m/s]	25.89	25.54	25.65	24.01	24.36	24.29
NBIAS (HIGH LAYER)	+0.01	+0.03	+0.02	-0.09	-0.05	-0.06
NMVD (100-400 hPa)	0.36	0.34	0.35	0.34	0.35	0.34
NRMSVD	0.43	0.40	0.41	0.39	0.40	0.40
NC	6808	10242	17050	10316	15669	25985
SPD [m/s]	14.79	15.72	15.35	12.57	13.12	12.90
NBIAS (MEDIUM LAYER)	+0.01	+0.05	+0.03	-0.06	-0.01	-0.03
NMVD (400-700 hPa)	0.40	0.39	0.39	0.40	0.39	0.40
NRMSVD	0.52	0.47	0.49	0.48	0.48	0.48
NC	21239	6528	27767	10168	7693	17861
SPD [m/s]	9.19	11.10	9.64	8.38	9.33	8.79
NBIAS (LOW LAYER)	+0.07	+0.03	+0.06	-0.02	-0.02	-0.02
NMVD (700-1000 hPa)	0.40	0.37	0.40	0.48	0.47	0.48
NRMSVD	0.47	0.44	0.46	0.54	0.55	0.55
NC [m/s]	10581	23220	33801	13621	52438	66059
NBIAS (HIGH LAYER)	25.69	25.41	25.50	23.67	23.80	23.77
NMVD (100-400 hPa)	+0.02	+0.04	+0.03	-0.07	-0.07	-0.04
NRMSVD	0.28	0.26	0.27	0.26	0.25	0.25
	0.35	0.32	0.33	0.31	0.30	0.30
NC	6808	10242	17050	10316	15669	25985
SPD [m/s]	14.89	15.76	15.41	12.83	13.40	13.17
NBIAS (MEDIUM LAYER)	+0.01	+0.04	+0.03	-0.08	-0.03	-0.05
NMVD (400-700 hPa)	0.31	0.30	0.30	0.28	0.27	0.28
NRMSVD	0.39	0.37	0.38	0.33	0.33	0.33
NC	21239	6528	27767	10168	7693	17861
SPD [m/s]	9.91	11.54	10.29	8.88	9.86	9.30
NBIAS (LOW LAYER)	+0.00	-0.00	-0.00	-0.07	-0.07	-0.07
NMVD (700-1000 hPa)	0.26	0.25	0.26	0.31	0.27	0.29
NRMSVD	0.30	0.30	0.30	0.36	0.32	0.34

Table 7: Validation parameters for NWC/PPS-HRW v7.P AMVs,
considering respectively the high, medium and low layer,
against Radiosounding winds in light blue and against ECMWF NWP analysis winds in dark blue.
(Basic AMVs in nominal configuration; Apr-Jun 2020 between 11:00 and 13:00 UTC;
Polar satellites with AVHRR-3, VIIRS and MODIS radiometers).
Statistics for region "EURON1 - Scandinavia" on the left side; region "EUROPA" on the right side.

3.3 COMPARISON WITH NWC/GEO-HRW V6.2 DEFAULT CONFIGURATION

The comparison of the statistics for NWC/PPS-HRW v7.Q, with those for NWC/GEO-HRW v6.2 (the latest version of NWC/GEO-HRW software for geostationary satellites, released in April 2022), is considered here. Statistics for NWC/GEO-HRW are shown here for MSG satellites, in *Table 8* considering all layers together, and in *Table 9* considering the three layers separately (high, medium and low). Statistics are shown for MSG/HRVIS cloudy AMVs (the only visible channel for which statistics are calculated at all layers), MSG/IR108 cloudy AMVs (corresponding infrared channel), MSG/WV062+WV073 cloudy and clear air AMVs (with AMVs for both water vapour channels together, to give a hint on the different proportion of water vapour AMVs with NWC/PPS-HRW software). Statistics are also shown for all AMVs with all applicable MSG channels together.

Considering all layers together, validation parameters are very similar for the geostationary v6.2 AMVs and the polar v7.Q AMVs (with NBIAS being smaller for the polar AMVs, and the NMVD and NRMSVD being smaller for the geostationary AMVs; the difference is in general smaller than 7%; only for “EURON1” region is the NRMSVD up to a 20% higher). Considering the different satellite channels, statistics are similar or a bit better for polar visible AMVs, a bit worse for polar infrared AMVs, and visibly worse for polar water vapour AMVs. The reasons provided before (the small amount of polar water vapour AMVs and their fewer references in the Quality control) explain this. The distribution of AMVs in the high/medium/low layer for NWC/GEO-HRW v6.2 shows a value of 35%/32%/33% considering all AMVs for all possible channels, while for NWC/PPS-HRW v7.Q the distribution is as already said 37%/26%/37% for “EURON1” region and 43%/22%/35% for “EUROPA” region. The differences are relatively small, of up to a 10% only in the worst case, related to a smaller proportion of medium level AMVs in the polar implementation.

Considering the validation in the different layers, NMVD and NRMSVD parameters are around a 20% better for the polar AMVs in the low layer, similar in the medium layer, and around a 20% worse in the high layer. Taking this into account, the “Target accuracy” value defined for all NWCSAF/High Resolution Winds versions up to now is reached for NWC/GEO-HRW v6.2 in the medium and low layer, while the “Optimal accuracy” is reached in the high layer. In comparison, as already said, NWC/PPS-HRW v7.Q reaches in both validation regions the “Target accuracy” in the high and medium layer, while it reaches the “Optimal accuracy” in the low layer. In spite of these small differences, the behaviour of NWC/GEO-HRW v6.2 and NWC/PPS-HRW v7.Q AMVs is similar, and the polar AMVs can perfectly be used by the NWCSAF users the same way they are using the geostationary AMVs, in spite of the definition of NWC/PPS-HRW as a demonstrational product only.

European/Mediterranean region					
NWC/GEO-HRW v6.2 AMVs (Jul 2010-Jun 2020, MSG sat.)	**Cloudy HRVIS**	**Cloudy IR108**	**Cloudy WV**	**Clear air WV**	**All AMVs**
NC	87205	223076	317051	19460	1164357
SPD [m/s]	11.03	16.18	20.37	18.01	15.54
NBIAS (ALL LAYERS)	-0.05	-0.08	-0.02	+0.00	-0.07
NMVD (100-1000 hPa)	0.39	0.31	0.29	0.30	0.33
NRMSVD	0.46	0.38	0.35	0.37	0.40
NC	87205	223076	317051	19460	1164357
SPD [m/s]	10.80	15.89	20.02	17.98	15.24
NBIAS (ALL LAYERS)	-0.03	-0.06	-0.01	+0.00	-0.05
NMVD (100-1000 hPa)	0.25	0.21	0.19	0.23	0.22
NRMSVD	0.31	0.26	0.24	0.29	0.27

Table 8: Validation parameters for NWC/GEO-HRW v6.2 AMVs (latest NWC/GEO-HRW version), considering all layers together, against Radiosounding winds in light yellow and against ECMWF NWP analysis winds in dark yellow. (Basic AMVs in nominal configuration; Jul 2009-Jun 2010 at 12:00 UTC; MSG-2 satellite; “European and Mediterranean” region).

European/Mediterranean region					
NWC/GEO-HRW v6.2 AMVs (Jul 2010-Jun 2020, MSG sat.)	Cloudy HRVIS	Cloudy IR108	Cloudy WV	Clear air WV	All AMVs
NC	7221	82709	209820	19460	407408
SPD [m/s]	22.17	21.86	23,03	18.01	22.28
NBIAS (HIGH LAYER)	-0.02	-0.06	-0.03	+0.00	-0.04
NMVD (100-400 hPa)	0.23	0.26	0.26	0.30	0.26
NRMSVD	0.28	0.31	0.32	0.37	0.32
NC	24251	85498	95350		377043
SPD [m/s]	12.05	14.36	15.63		13.99
NBIAS (MEDIUM LAYER)	-0.08	-0.08	-0.00		-0.07
NMVD (400-700 hPa)	0.37	0.35	0.37		0.36
NRMSVD	0.44	0.43	0.45		0.44
NC	55733	54869	11881		379906
SPD [m/s]	9.14	10.43	11.50		9.86
NBIAS (LOW LAYER)	-0.05	-0.12	-0.00		-0.10
NMVD (700-1000 hPa)	0.46	0.39	0.39		0.42
NRMSVD	0.54	0.46	0.47		0.49
NC	7221	82709	209820	19460	407408
SPD [m/s]	21.90	21.61	2.66	17.98	21.98
NBIAS (HIGH LAYER)	-0.01	-0.05	-0.02	+0.00	-0.03
NMVD (100-400 hPa)	0.14	0.16	0.16	0.23	0.16
NRMSVD	0.17	0.21	0.20	0.29	0.20
NC	24251	85498	95350		377043
SPD [m/s]	11.76	14.04	15.32		13.66
NBIAS (MEDIUM LAYER)	-0.06	-0.06	+0.02		-0.05
NMVD (400-700 hPa)	0.26	0.25	0.28		0.26
NRMSVD	0.32	0.31	0.34		0.33
NC	55733	54869	11881		379906
SPD [m/s]	8.94	10.13	11,21		9.59
NBIAS (LOW LAYER)	-0.03	-0.09	+0.02		-0.08
NMVD (700-1000 hPa)	0.29	0.26	0.31		0.28
NRMSVD	0.35	0.32	0.38		0.34

Table 9: Validation parameters for NWC/GEO-HRW v6.2 AMVs (latest NWC/GEO-HRW version), considering respectively the high, medium and low layer, against Radiosounding winds in light yellow and against ECMWF NWP analysis winds in dark yellow. (Basic AMVs in nominal configuration; Jul 2009-Jun 2010 at 12:00 UTC; MSG-2 satellite; "European and Mediterranean" region).

3.4 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”) with NWC/PPS-HRW v7.Q software is considered now. The calculation of “Detailed AMVs” is activated with configurable parameter CDET = 1 in the NWC/PPS-HRW “model configuration file”. They are provided as an additional dataset of AMVs, together with the “Basic AMVs” which are always calculated. The conditions for the validation are exactly equivalent to those in chapter 3.1 for the “Basic AMVs”. Examples of “Detailed AMVs” calculated for the same two static regions “EURON1” and “EUROPA” are shown in *Figure 5* and *Figure 6*. Corresponding validation statistics are presented in *Table 10* (considering all layers together), and *Table 11 (*considering the three layers separately).

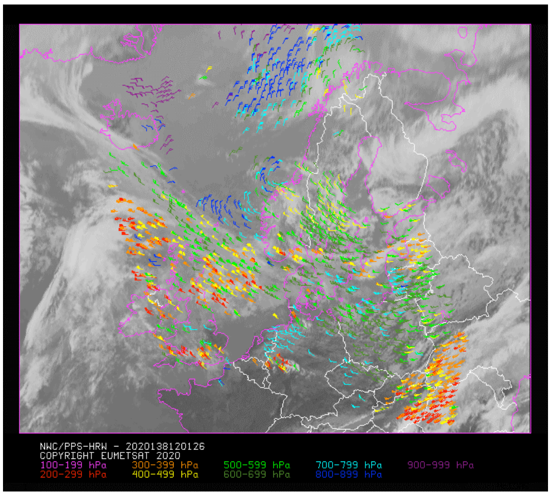


Figure 5: NWC/PPS-High Resolution Winds “Detailed AMV” output example in the region “EURON1 - Scandinavia” (17 May 2020 12:01:26 UTC for EOS-2 satellite, with tracers calculated at 11:44:19 UTC for NOAA-20 satellite), considering conditions defined in $SM_CONFIG_DIR/safnwc_HRW_POLAR.cfm model configuration file and configurable parameter CDET = 1. Colour coding based on the AMV pressure level

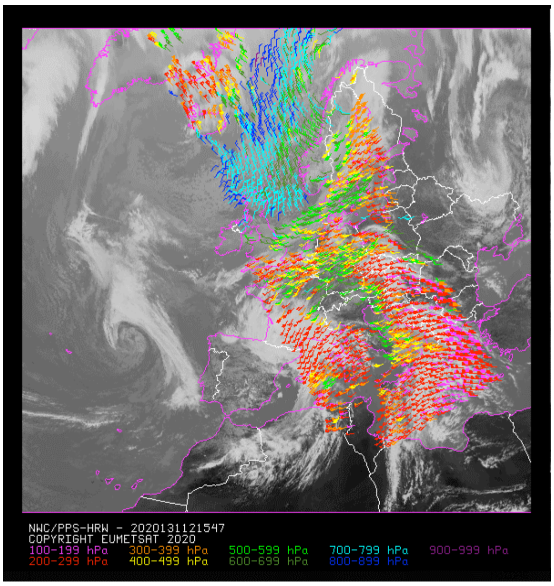


Figure 6: NWC/PPS-High Resolution Winds “Detailed AMV” output example in the region “EUROPA” (10 May 2020 12:15:47 UTC for NOAA-20 satellite, with tracers calculated at 11:55:19 UTC for EOS-2 satellite), considering conditions defined in $SM_CONFIG_DIR/safnwc_HRW_POLAR.cfm model configuration file and configurable parameter CDET = 1. Colour coding based on the AMV pressure level

Comparing with the "Basic AMVs", the number of "Detailed AMVs" is smaller (with a reduction of 76% in "EURON1" region and 37% in "EUROPA" region). The different scale of the pixels in both regions (5 km and 1 km respectively) explains this different behaviour. In "EUROPA" region, "Basic AMVs" are related to tracer sizes around 120 km while "Detailed AMVs" are related to tracer sizes around 60 km. In "EURON1" region, "Basic AMVs" are related to tracer sizes around 24 km while "Detailed AMVs" are related to tracer sizes around 12 km. The smaller size of the tracer in pixels is favourable in "EUROPA" region for the calculation of more AMVs, while in "EURON1" region it is less convenient.

In any case the "Detailed AMVs" define an additional dataset of valid AMVs, and considering both datasets together ("Basic AMVs" + "Detailed AMVs") there is an increase in the total number of AMVs with respect to those calculated for NWC/PPS-HRW v7.P software version of 2.2 times for "EURON1" region and 3.0 for "EUROPA" region.

Comparing the validation statistics against Radiosounding winds and ECMWF NWP analysis winds, NMVD and NRMSVD parameters are again for "Detailed AMVs" significantly smaller (up to a 30% smaller) against NWP analysis winds, showing the similar behaviour than with "Basic AMVs".

Considering all layers and each layer separately, the NBIAS becomes more positive for "Detailed AMVs" in "EURON1" region and less negative in "EUROPA" region. Meanwhile, the NMVD and NRMSVD parameters are similar to those for "Basic AMVs" in both regions, with variations up to a 15% in some case only. Considering these small differences, "Detailed AMVs" are inside the "Target accuracy" value defined for all NWCSAF/High Resolution Winds versions up to now in both regions in the high and medium layer, and inside the "Optimal accuracy" in both regions in the low layer. This is exactly the same situation occurring for "Basic AMVs".

Considering the distribution of AMVs in the different layers, the "Detailed AMVs" show a value of 50%/24%/26% for the High/Medium/Low layer in "EUROPA" region and a value of 42%/29%/29% in "EURON1" region. This means a higher proportion of high level AMVs and lower proportion of low level AMVs in "EUROPA", and a higher proportion of medium level AMVs and lower proportion of low level AMVs in "EURON1" region, although the three layers are still well represented in the distribution of AMVs.

In short, the behaviour of "Detailed AMVs" is very similar to the one for "Basic AMVs" (with small differences in the validation statistics and the distribution of AMVs in the different layers), and this way both datasets can be used together for the characterization of the wind in the different layers of the troposphere.

	"EURON1-Scandinavia" region					"EUROPA" region				
NWC/PPS-HRWv7.Q AMVs (Apr 2020-Jun 2020)	VIS	IR	cloudy WV	clear air WV	All AMVs	VIS	IR	cloudy WV	clear air WV	All AMVs
NC	27329	20755	284	2	48370	112394	144892	1952	175	259413
SPD [m/s]	20.58	25.16	39.73	17.50	22.65	15.26	19.83	27.13	15.09	17.90
NBIAS (ALL LAYERS)	+0.08	+0.06	+0.08	+0.08	+0.07	-0.00	+0.00	+0.10	+0.03	+0.00
NMVD (100-1000 hPa)	0.36	0.33	0.35	0.34	0.34	0.34	0.33	0.39	0.38	0.33
NRMSVD	0.46	0.39	0.43	0.41	0.43	0.43	0.41	0.47	0.55	0.41
NC	27329	20755	284	2	48370	112394	144892	1952	175	259413
SPD [m/s]	20.94	25.23	39.93	16.15	22.89	15.49	19.73	28.14	12595.24	17.95
NBIAS (ALL LAYERS)	+0.06	+0.06	+0.07	+0.17	+0.06	-0.02	+0.00	+0.06	+0.02	-0.00
NMVD (100-1000 hPa)	0.28	0.26	0.31	0.23	0.27	0.24	0.24	0.31	0.27	0.24
NRMSVD	0.37	0.32	0.39	0.28	0.34	0.31	0.29	0.40	0.38	0.30

Table 10: Validation parameters for NWC/PPS-HRW v7.Q AMVs, considering all layers together, against Radiosounding winds in light green and against ECMWF NWP analysis winds in dark green. ("Detailed AMVs" in nominal configuration; Apr-Jun 2020 between 11:00 and 13:00 UTC; Polar satellites with AVHRR-3, VIIRS, MODIS and MERSI-2 radiometers). Statistics for region "EURON1 - Scandinavia" on the left side; region "EUROPA" on the right side.

			“EURON1-Scandinavia” region							“EUROPA” region
NWC/PPS-HRWv7.Q AMVs (Apr 2020-Jun 2020)	VIS	IR	cloudy WV	clear air WV	All AMVs	VIS	IR	cloudy WV	clear air WV	All AMVs
NC	10226	13646	252	0	24124	25607	80660	1487	0	107754
SPD [m/s]	32.37	29.38	40.95		30.76	25.29	24.64	29.60		24.86
NBIAS (HIGH LAYER)	+0.07	+0.05	+0.08		+0.05	-0.02	+0.00	+0.10		-0.00
NMVD (100-400 hPa)	0.34	0.31	0.35		0.32	0.32	0.32	0.38		0.32
NRMSVD	0.39	0.37	0.43		0.37	0.39	0.38	0.46		0.38
NC	6595	5068	32	2	11697	35301	39949	465	175	75890
SPD [m/s]	18.60	19.01	30.12	17.50	18.80	14.05	14.84	19.25	15.09	14.50
NBIAS (MEDIUM LAYER)	+0.08	+0.09	+0.13	+0.08	+0.08	-0.01	+0.00	+0.12	+0.03	-0.00
NMVD (400-700 hPa)	0.38	0.37	0.34	0.34	0.37	0.36	0.36	0.41	0.38	0.36
NRMSVD	0.46	0.44	0.40	0.41	0.45	0.44	0.44	0.48	0.55	0.44
NC	10508	2041	0	0	12549	51486	24283	0	0	75769
SPD [m/s]	10.35	12.22			10.66	11.10	12.06			11.41
NBIAS (LOW LAYER)	+0.12	+0.09			+0.11	+0.01	-0.00			+0.00
NMVD (700-1000 hPa)	0.43	0.41			0.43	0.35	0.34			0.35
NRMSVD	0.51	0.48			0.51	0.41	0.41			0.41
NC	10226	13646	252	0	24124	25607	80660	1487	0	107754
SPD [m/s]	32.50	29.38	41.24		30.82	24.96	24.27	30.97		24.52
NBIAS (HIGH LAYER)	+0.07	+0.05	+0.07		+0.05	-0.01	+0.02	+0.05		+0.01
NMVD (100-400 hPa)	0.28	0.25	0.31		0.26	0.25	0.24	0.31		0.24
NRMSVD	0.33	0.30	0.39		0.31	0.30	0.28	0.39		0.28
NC	6595	5068	32	2	11697	35301	39949	465	175	75890
SPD [m/s]	18.57	19.07	29.58	16.15	18.81	14.34	15.01	19.08	15.24	14.72
NBIAS (MEDIUM LAYER)	+0.08	+0.08	+0.15	+0.17	+0.08	-0.03	-0.01	+0.13	+0.02	-0.01
NMVD (400-700 hPa)	0.29	0.29	0.32	0.23	0.29	0.25	0.25	0.33	0.27	0.25
NRMSVD	0.36	0.35	0.38	0.28	0.35	0.31	0.31	0.41	0.38	0.31
NC	10508	2041	0	0	12549	51486	24283	0	0	75769
SPD [m/s]	11.19	12.76			11.45	11.58	12.42			11.85
NBIAS (LOW LAYER)	+0.04	+0.04			+0.04	-0.02	-0.03			-0.02
NMVD (700-1000 hPa)	0.26	0.27			0.26	0.22	0.23			0.22
NRMSVD	0.32	0.32			0.32	0.25	0.26			0.26

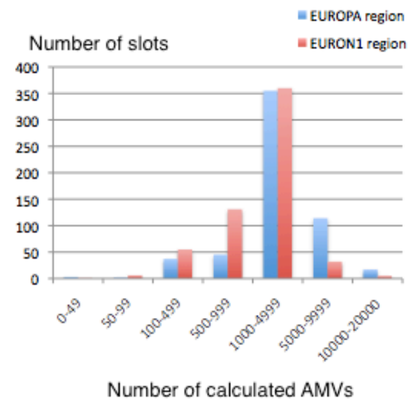
Table 11: Validation parameters for NWC/PPS-HRW v7.Q AMVs,
considering respectively the high, medium and low layer,
against Radiosounding winds in light green and against ECMWF NWP analysis winds in dark green.
(“Detailed AMV”s in nominal configuration; Apr-Jun 2020 between 11:00 and 13:00 UTC;
Polar satellites with AVHRR-3, VIIRS, MODIS and MERSI-2 radiometers).
Statistics for region “EURON1 - Scandinavia” on the left side; region “EUROPA” on the right side.

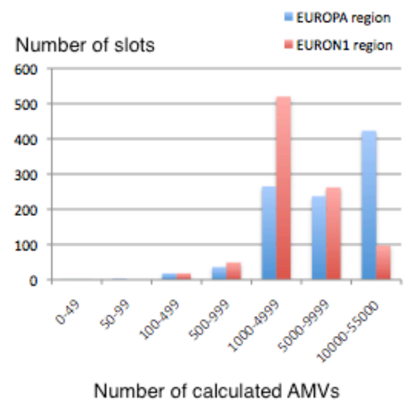
4. ABOUT THE VARIABILITY IN THE NUMBER OF AMVS

The variability in the number of AMVs calculated by NWC/PPS-HRW in different slots is much higher than the one for NWC/GEO-HRW, for which the time separation between the images used for the AMV calculation and the resolution of the images is always constant (and so the number of AMVs is more similar in different slots).
Instead, in NWC/PPS-HRW the separation between the images used for the AMV calculation can vary from minutes up to two hours, and the product is run in different regions with different satellite resolutions (for example the 5 km resolution used in "EUROPA" and the 1 km resolution used in "EURON1 – Scandinavia"), caused by the image reprojection process that takes place before the AMV calculation.

Additionally, in NWC/PPS-HRW the part of region covered by both images used for the AMV calculation at the same time is also very variable, going from a minimum of 10% to a maximum of 100%. There is a process inside NWC/PPS-HRW which optimizes for each "later image" the "initial image" which best fits for the image calculation (considering the time separation between images, the common region scanned by both images, and the number of satellite channels available for AMV calculation in both images), but with this procedure in many cases the common region scanned by both images is still much smaller than 100%. This is normal considering how different polar satellites can scan the same Earth region.

The graph and table in *Figure 7* show the distribution of the "Number of calculated AMVs for each slot" throughout the whole validation process for the "Basic AMVs", using the default configuration for both versions NWC/PPS-HRW v7.P and v7.Q (Apr-Jun 2020) in both validation regions ("EUROPA" with 5 km resolution and "EURON1 – Scandinavia" with 1 km resolution).





	EUROPA region	EURON1 region
0-49	3	1
50-99	2	6
100-499	37	55
500-999	45	131
1000-4999	355	360
5000-9999	114	32
10000-20000	17	5
TOTAL NUMBER OF PROCESSED SLOTS	573	590

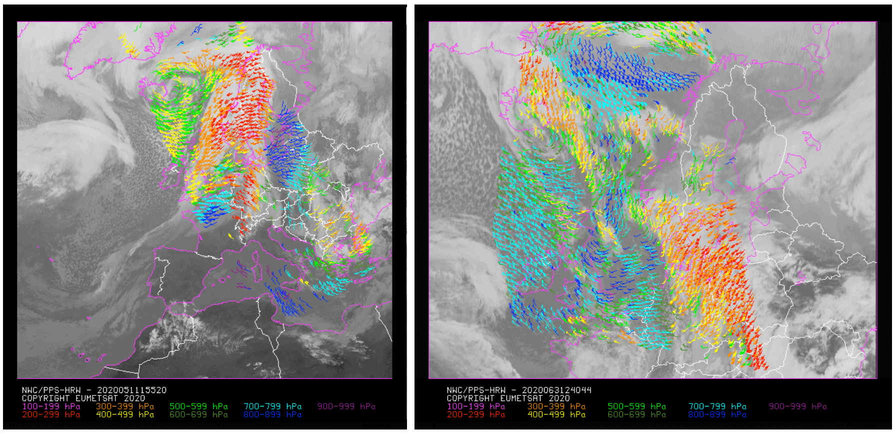
	EUROPA region	EURON1 region
0-49	1	1
50-99	3	0
100-499	18	18
500-999	36	49
1000-4999	265	520
5000-9999	237	262
10000-55000	423	97
TOTAL NUMBER OF PROCESSED SLOTS	983	947

Figure 7: Distribution of the "Number of calculated AMVs for each slot" for both versions NWC/PPS-HRW v7.P (left) and v7.Q (right), in both validation regions "EUROPA" and "EURON1 – Scandinavia", throughout the whole validation period Apr-Jun 2020

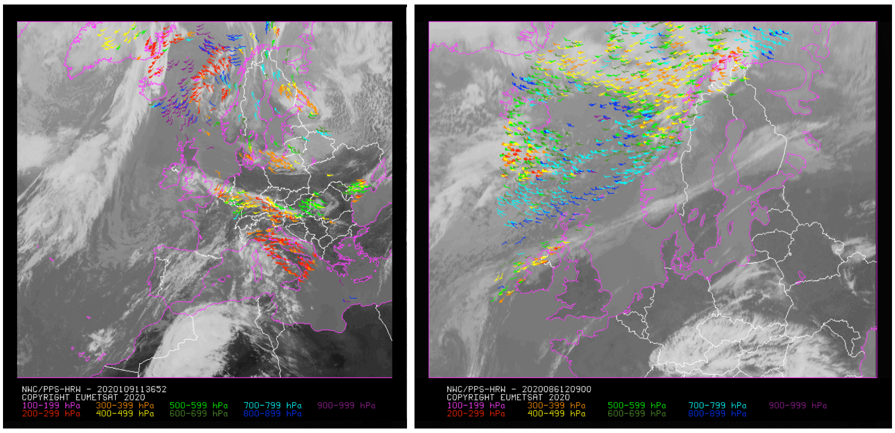
The evolution between both versions can be seen: on one side, the larger amount of usable satellites in v7.Q (seven additional satellites with three additional radiometers) permits the calculation of AMVs for more slots, going from around 500 slots in v7.P to around 900 slots in v7.Q in the same validation period, which is positive by itself.
The "Number of calculated AMVs" for each slot increases also to higher values in v7.Q. The

maximum "Number of calculated AMVs" grows from around 20000 in v7.P to around 55000 in v7.Q. The proportion of cases with more than 10000 AMVs grows from less than 3% in v7.P to 10% in "EURON1" region and 43% in "EUROPA" region in v7.Q. All this is also positive for a better characterization of the wind with polar AMVs. The minimum "Number of calculated AMVs" keeps on however being smaller than 100 for a very small number of slots in both versions (related to a low common scanning of the working region by both satellite images).

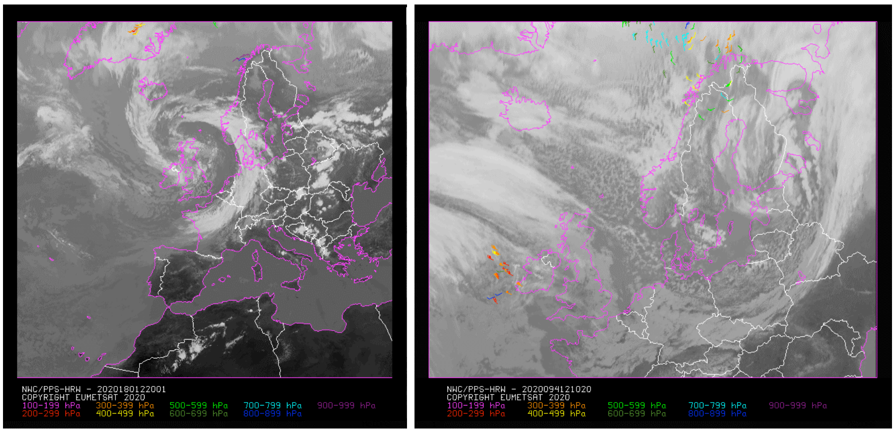
To better see the differences in the "Number of calculated AMVs", some examples of NWC/PPS-HRW v7.Q AMV outputs are shown for several ranges of calculated AMVs in both regions:



Figures 8 and 9: Example of NWC/PPS-HRW v7.Q output for both "EUROPA" and "EURON1 – Scandinavia" regions, with around 10000 AMVs.



Figures 10 and 11: Example of NWC/PPS-HRW v7.Q output for both "EUROPA" and "EURON1 – Scandinavia" regions, with around 1000 AMVs.



Figures 12 and 13: Example of NWC/PPS-HRW v7.Q output for both "EUROPA" and "EURON1 – Scandinavia" regions, with around 100 AMVs.

Finally, it is also to be remarked that "numbers of calculated AMVs" of the same order of magnitude are obtained for "EURON1 – Scandinavia" region with 1 km resolution, and for "EUROPA" region with 5 km resolution (in spite of the much larger region). Some difference occurs anyhow for values higher than 10000, for which the frequency is higher for "EUROPA" region with NWC/PPS-HRW v7.Q (not for v7.P).
With this, it is checked that the resolution of the region used has an important impact in the "number of calculated AMVs".
It has also been checked that regions with 5 km resolution are optimal for AMV calculation with NWC/PPS-HRW in "Continental areas", like the "EUROPA" region used in the validation process, and regions with 1 km resolution are optimal for AMV calculation in "National areas", like the "EURON1 – Scandinavia" region also used in the validation process.

With all this, two recommendations are given for the operational use of NWC/PPS-HRW v7.Q:

- To check if the working region better fits a "Continental region" (for which a 5 km resolution region like the "EUROPA" region shown here is recommended), or a "National region" (for which a 1 km resolution region like the "EURON1 - Scandinavia" region shown here is recommended. About the way to define a specific region for NWC/PPS-HRW processing, the "User Manual for the NWC/PPS application: Software Part, 2.Operation" ([AD.3]) is to be checked.
- To run NWC/PPS-HRW for several slots, to start to see the variability in the "Number of calculated AMVs" shown in this document.

5. CONCLUSIONS

Several conclusions can be extracted from this "Validation report", in which NWC/PPS-HRW v7.Q AMVs have been validated against both Radiosounding winds and NWP model analysis winds, and have been compared with the results for the latest version of geostationary AMV software (NWC/GEO-HRW v6.2) and the previous version of polar AMV software (NWC/PPS-HRW v7.P).

Comparing the behaviour of NWC/PPS-HRW v7.Q with the one for NWC/PPS-HRW v7.P, there has been a significant improvement: the number of AMVs is at least 2.6 times higher in both validation regions using the default configuration, defining better AMV densities and fewer holes in the AMV coverage. Additionally, there is a better distribution of AMVs in the three layers (high/medium/low), so defining a better characterization of the wind in the different layers of the troposphere. Considering the validation parameters, there is at least a 7% reduction of the NMVD (normalized mean vector difference) and the NRMSVD (normalized root mean square vector difference) considering all layers together in both validation regions, which is also positive.

Comparing the behaviour of NWC/PPS-HRW v7.Q with the one for NWC/GEO-HRW v6.2 (latest geostationary version), the distribution of AMVs in the different layers is very similar (37%/26%/37% for "EURON1" region and 43%/22%/35% for "EUROPA" region for the polar AMVs, while it is 35%/32%/33% for the geostationary AMVs), with a bit smaller proportion of medium level AMVs in the polar implementation. Considering the validation parameters, while for NWC/GEO-HRW v6.2 software the "Optimal accuracy" is reached in the high layer and the "Target accuracy" is reached in the medium and low layer, for NWC/PPS-HRWv7.Q software the "Target accuracy" is reached for both validation regions in the high and medium layer and the "Optimal accuracy" is reached in the low layer.

Considering all this, NWC/PPS-HRW v7.Q AMV outputs can be perfectly used by NWCSAF users the same way they are using NWC/GEO-HRW AMV outputs, in spite of being defined only as a "demonstrational product". The results of NWC/PPS-HRW v7.Q additionally improve vwith respect to those for the previous polar version, because of which NWCSAF users of polar AMVs are recommended to update the software to this latest version as soon as possible

Evolution of the Validation statistics between HRW versions, related to the operational thresholds defined for NWC/GEO-HRW (against Radiosounding winds)	**High Layer NRMSVD**	**Medium Layer NRMSVD**	**Low Layer NRMSVD**
NWC/PPS-HRW v7.Q, "EURON1 region" (with 2.6x more AMVs)	**0.38**	**0.45**	**0.45**
NWC/PPS-HRW v7.Q, "EUROPA region" (with 3.7x more AMVs)	**0.38**	**0.43**	**0.40**
NWC/PPS-HRW v7.P, "EURON1 region"	**0.41**	**0.49**	**0.46**
NWC/PPS-HRW v7.P, "EUROPA region"	**0.40**	**0.48**	**0.55**
NWC/GEO-HRW v6.2, MSG satellites	**0.32**	**0.44**	**0.49**
NWC/GEO-HRW "Optimal Accuracy" (all versions up to now)	**0.35**	**0.40**	**0.45**
NWC/GEO-HRW "Target Accuracy" (all versions up to now)	**0.44**	**0.50**	**0.56**
NWC/GEO-HRW "Threshold Accuracy" (all versions up to now)	**0.53**	**0.60**	**0.67**

Table 12: Validation statistics for NWC/PPS-HRW v7.Q and v7.P, and NWC/GEO-HRW v6.2, related to the operational thresholds defined for NWC/GEO-HRW