NEW DEVELOPMENTS IN THE HIGH RESOLUTION WINDS PRODUCT (HRW), AT THE SATELLITE APPLICATION FACILITY ON SUPPORT TO NOWCASTING & VERY SHORT RANGE FORECASTING (NWCSAF)

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Abstract

The evolution of the NWCSAF High Resolution Winds product between 2008 and 2010 is to be explained. This product, which allows its users a detailed in coverage and time calculation of Atmospheric Motion Vectors, locally and in real time in the geographic area of their interest, has been greatly expanded for its version 2010.

Due to user requirements, wishing to have AMV data during all hours of the day, HRW algorithm has been adapted to calculate AMVs with both MSG/HRVIS and MSG/IR108 channels, and is prepared to calculate AMVs with other MSG/SEVIRI channels in future versions. With both channels and an important optimization of the algorithm, HRW product can now calculate more than double number of AMVs in a similar running time, with similar or better validation parameters, and can now provide users with a continuous set of AMV data during both daytime and nighttime.

Besides, NWCSAF/HRW product has been adapted to run in "Rapid Scan mode". A study has been made to define the best time difference between the initial tracer and the final tracking image for the AMV calculation, considering the amount of calculated winds and the validation errors. A 10 minute time difference has been defined for both channels (HRVIS & IR108), with the ability to be run with every SEVIRI Rapid Scan slot.

MAIN CHARACTERISTICS OF NWCSAF/HRW v3.0 PRODUCT

The Satellite Application Facility on support to Nowcasting and Very short range forecasting, was established between Eumetsat and the Spanish National Weather Service (AEMET, Agencia Estatal de Meteorología), to enhance this area of prediction with MSG and Polar Satellite data. To achieve this goal, the NWCSAF develops and maintains a software package which calculates several meteorological products with these satellites, and distributes it to its users supporting them on its handling.

An Atmospheric Motion Vector (AMV) product is included in the NWCSAF software: the "High Resolution Winds" (HRW). Its objective is to provide detailed sets of AMVs for near real time applications in the region defined by the user. Since HRW version 3.0, which will be available to the users since the spring of 2010, the product is capable to calculate winds from both MSG/HRVIS and MSG/IR108 channels, with the satellite working in both "Nominal scan mode" and "Rapid scan mode". Considering that the previous version HRW v2.2 was only available for MSG/HRVIS channel in "Nominal scan mode", there has been a visible increase in the capabilities of the product.

The real time running of HRW product with "Nominal scan mode" configuration is possible for National areas (f.ex. the Iberian Peninsula) and Continental areas (f.ex. Europe and Mediterranean Sea). The real time running with "Rapid scan mode" configuration is possible for National areas only. An

optimization included in HRW v3.0 algorithm permits to calculate AMVs with both channels (HRVIS & IR108) in less than two minutes in National areas and less than six minutes in Continental areas.

The main steps of NWCSAF/HRW algorithm are:

1. *Tracer calculation*: two methods are used one after the other: Gradient (which searches for well defined cloud edges) and Tracer characteristics (which fills the holes in the coverage).

2. *Tracer height assignment*: one of two different height levels is used, dependent on the cloud type related to the tracer (obtained from NWCSAF/Cloud type product):
   - Cloud top: IR108 brightness temperature of the coldest class in the tracer smoothed temperature histogram, with at least three pixels. Used with high semitransparent thick and meanly thick clouds.
   - Cloud base: calculated through formula $T_{Base}=T_{Mean}+K\cdot\sigma_{Temp}$, with "K" fitted through the validation and different for HRVIS and IR108 winds. Used with all other valid cloud types.

3. *Tracer tracking and wind calculation*: up to three correlation centres are selected for each tracer using one of two different methods: Euclidean difference or Cross correlation.

4. *Quality Control*: HRW product adapts the Quality Indicator Method developed by Eumetsat, including temporal, spatial and forecast consistency tests.

5. *Orographic Flag test*: tracers affected by land influence are rejected.

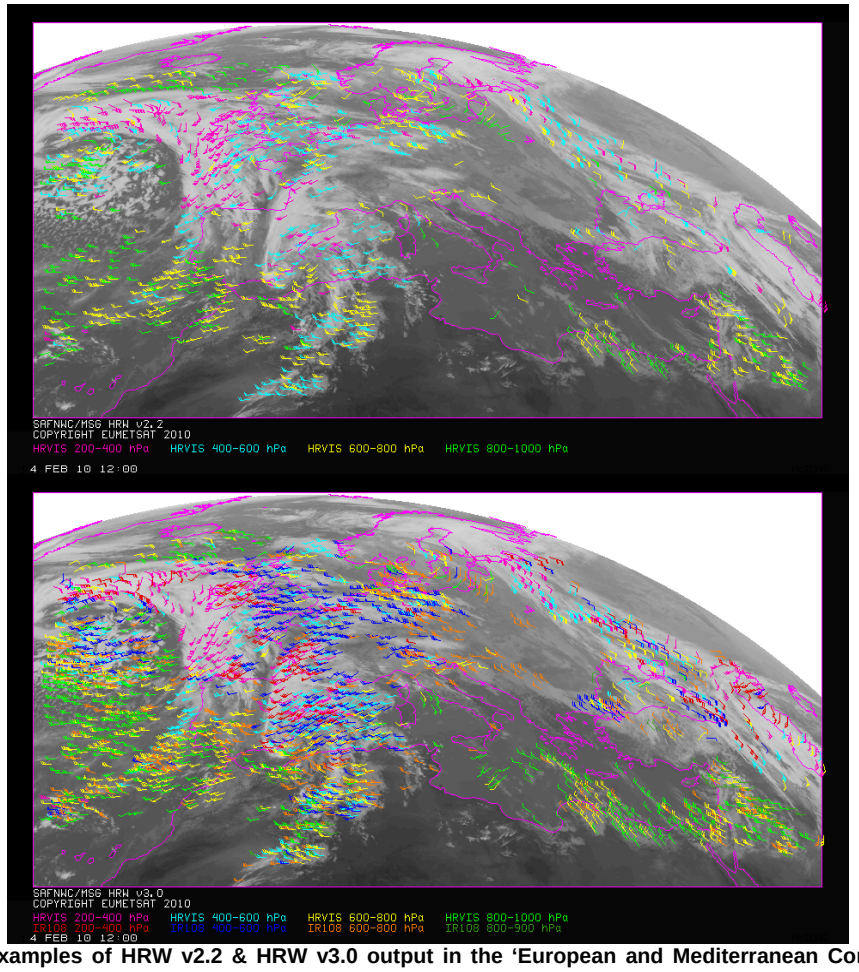
To run NWCSAF/HRW product it is necessary to download and install the software package in a computer/working station under Solaris/Linux/IBM AIX environment. Full Resolution MSG/HRVIS & MSG/IR108 data, and several NWP parameters for the working region (temperature and wind profiles, geopotential profile and surface temperature also if the orographic flag is to be calculated) are used as input data. NWP is not mandatory but recommended; if it is not available a rough climatological profile is used.

The running of HRW product is then very easy: algorithm parameters (including the region of computation, the running mode: "Nominal or Rapid scan" and the MSG channel with which AMVs are to be calculated: "HRVIS, IR108 or both") are defined by the user through the "Model configuration file" (*.cfm), the "Region configuration file" (*.cfg) and the "Satellite configuration file" (sat_conf_file). Up to two BUFR bulletins are obtained as output data, with AMVs corresponding to two different scales of tracers: basic winds (tracer size of 24 pixels), and detailed winds (tracer size of 12 pixels). The decision was taken to include HRVIS and IR108 AMVs in the same BUFR bulletin, differentiable by parameter WCH (Wind channel).

NWCSAF/HRW ALGORITHM EXAMPLES

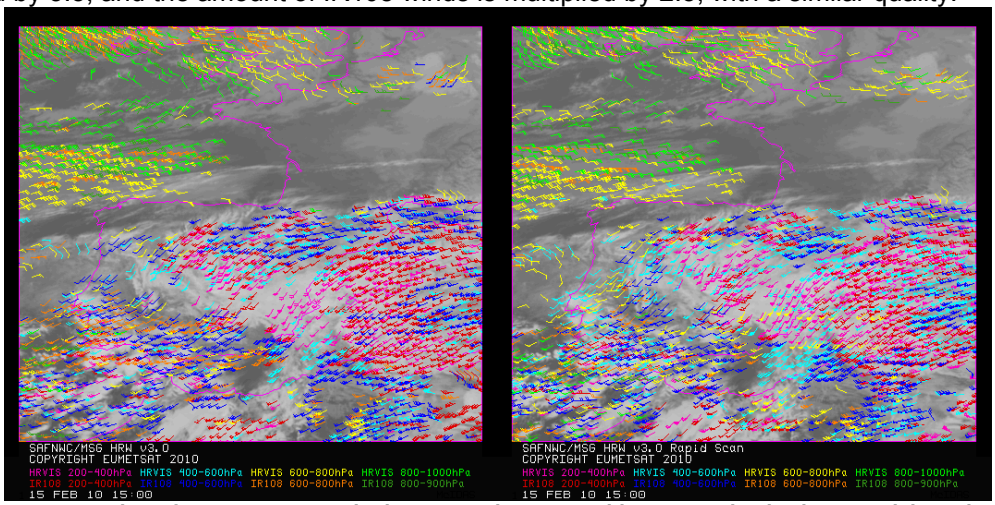
In the next two figures, the evolution of HRW algorithm between the last two versions is clearly seen, with an HRW example run in the "European and Mediterranean Continental region". The possibility to calculate AMVs with two MSG channels (HRVIS & IR108) in HRW v3.0, and the optimization included in its algorithm, expands greatly the amount of available winds. During daytime, the amount of winds defined by HRW v3.0 is about 2.5 times the amount calculated by HRW v2.2. During nighttime, HRW v2.2 suffered long discontinuities having to wait until sunrise for new data calculation, while HRW v3.0 can offer new output 24 hours a day with IR108 AMV data fields.

With the AMV contribution from both MSG channels, the spectrum of information gets also broader. HRVIS & IR108 data complement each other up to a certain point, and tend to give information about different levels of the troposphere: HRVIS winds are more common in the low layer, and IR108 winds are more common in the high and medium layers. Because of this, the frequency of AMV holes in cloudy areas of the images is smaller.



***Figures 1 & 2*: Examples of HRW v2.2 & HRW v3.0 output in the 'European and Mediterranean Continental Region' (4 February 2010, 1200Z, Nominal scan mode)**

The next two figures show an example of HRW output, running in "Nominal scan mode" and "Rapid scan mode" configuration in the "Spanish National region". As it is later seen, with the conditions defined (fundamentally a 10 minute time difference between the initial tracer image and the later tracking image, and the possibility to rerun HRW algorithm with every new MSG slot every five minutes in National regions), the main difference between both configurations can be seen: with three 'Rapid scan slots' for every 'Nominal scan slot', the amount of HRVIS winds every 15 minutes is multiplied by 3.5, and the amount of IR108 winds is multiplied by 2.5, with a similar quality.



***Figures 3 & 4*: Examples of HRW v3.0 "Nominal scan mode" & "Rapid scan mode" in the 'Spanish National Region' (15 February 2010, 1500Z)**

VALIDATION OF HRW v3.0 ALGORITHM

A validation procedure during the period April-December 2009 in the 'European and Mediterranean region' (950x1850 pixels centered in 39ºN/12ºE), has been evaluated for a parallel comparison of:

- HRVIS & IR108 "Nominal scan mode" winds.
- HRVIS & IR108 "Rapid scan mode" winds.

The effect of several parameters in the validation has been included in the study: the Atmospheric level where the AMVs are situated, and the Orographic flag and Cloud type related to them. A special evaluation has also been taken in the "Rapid scan mode", to define the best 'time difference' between the initial tracer image and the final tracking image for the calculation of AMVs.

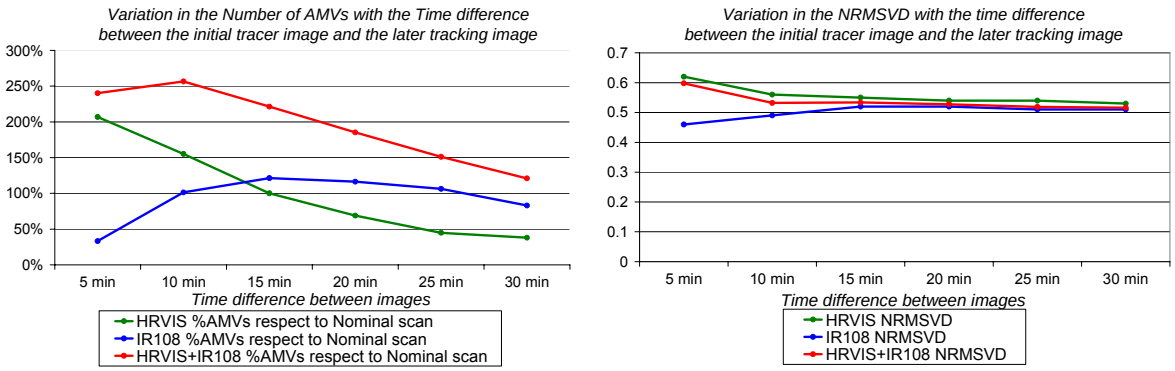
Effect of the 'time difference' between images in the "Rapid scan mode"

Prior to the validation during March 2009, a procedure was run on MSG-1 satellite in "Rapid scan mode", to identify the variations in the amount of calculated AMVs and their corresponding validation parameters, considering different 'time differences' between the initial tracer image and the later tracking image. Time differences between 5 and 30 minutes were considered (slot gap between 1 and 6), in all cases with the latter tracking image at 1200Z.

As Figure 5 shows, in the HRVIS case there is a progressive increase in the amount of calculated winds with smaller time differences between images up to 5 minutes; in the IR108 case, the maximum amount of winds occurs with a time difference of 15 minutes with reductions over and below this value (the difference is necessarily related to the different pixel resolution of both channels: HRVIS resolution is good enough to detect the displacement of slow moving structures in 5 minutes; IR108 resolution not so much). Considering together both datasets (HRVIS and IR108), the maximum amount of calculated winds occurs with a time difference of 10 minutes.

As Figure 6 shows, considering the normalized RMSVD there are small variations with the time difference. Between 10 and 30 minutes these are negligible (smaller than a 4% if the composite HRVIS & IR108 dataset is considered). With a time difference of 5 minutes there is a more visible variation in the RMSVD: an increase in the HRVIS winds and a decrease in the IR108 winds. Due to the higher proportion of the HRVIS in the wind population their effect is more important, and the RMSVD is a 12% bigger in the composite population.

Considering these two behaviours in the composite wind population, the 'time difference' of 10 minutes between initial tracer and final tracking image has been defined the best for the calculation of Atmospheric Motion Vectors in the "Rapid scan mode", and has been considered for both MSG channels during all the validation process.

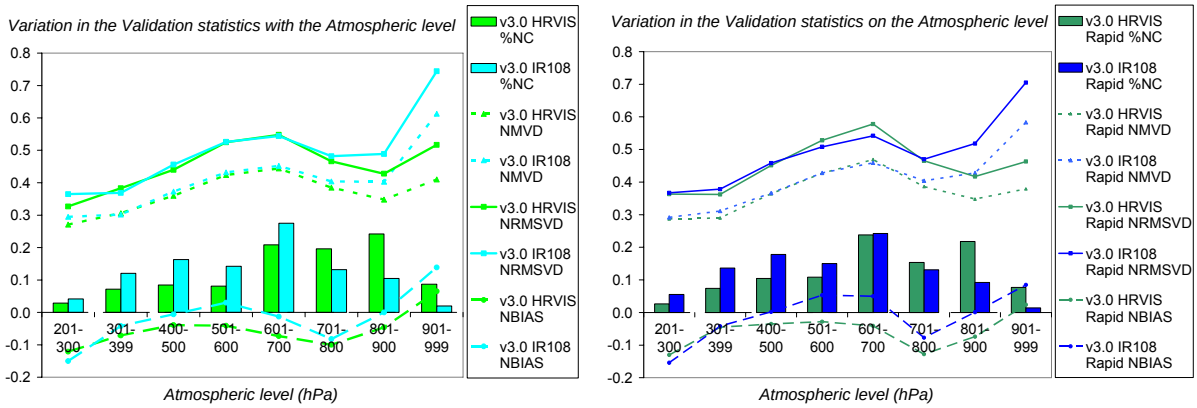


***Figures 5 & 6*: Variation in the Amount of calculated AMVs and the Normalized RMSVD, with the 'Time difference' between the initial tracer image and the final tracking image in the "Rapid scan mode" (March 2009, HRVIS & IR108 AMVs in the European and Mediterranean region).**

Validation considering the 'Atmospheric level'

If a comparison is studied between "Nominal scan mode" and "Rapid scan mode" HRVIS & IR108 winds, considering differences related to the 'atmospheric level' where the AMVs are located, a bigger proportion of IR108 winds is detected in the high and medium layer, and a bigger proportion of HRVIS winds is detected in the low layer. Because of this, HRVIS & IR108 tend to give information about different levels in the troposphere, and complement each other up to a certain point.

Considering validation parameters, a better BIAS is observed for IR108 winds in all layers. Similar MVD and RMSVD are detected for HRVIS and IR108 winds between 300-800 hPa, with a better behaviour of HRVIS winds in the other layers. IR108 winds in the lowest layer (>900 hPa) are so bad and so few, that are recommended to be eliminated. Few differences are seen between "Nominal scan mode" and "Rapid scan mode" AMVs, although HRVIS winds have validation statistics a bit worse comparatively in the "Rapid scan mode".



***Figures 7 & 8*: Variation in the HRVIS & IR108 AMV Validation parameters with the 'Atmospheric level', in "Nominal scan mode" and "Rapid scan mode" (April-December 2009, European and Mediterranean region).**

Validation considering the 'Orographic flag'

Different filterings have been defined on the 'HRW orographic flag' for "Nominal scan mode" winds and "Rapid scan mode" winds. In "Nominal scan mode", all HRVIS and IR108 AMVs without geographical obstacles in their vicinity (Orographic flag ≠ 1,2) are recommended to be kept. In "Rapid scan mode", only HRVIS and IR108 AMVs without geographical obstacles in their vicinity and trajectory (Orographic flag ≠ 0,1,2,3) are recommended to be kept. The eliminated data conform less than a 4% of the total, with much worse validation parameters (MVD and RMSVD values are between a 50% and a 100% higher).

PGE09 v3.0 - Nominal scan mode winds Apr-Dec 2009, European & Mediterranean area	Orogr. Flag = 1,2	Orogr. Flag = 0,3,4,5	PGE09 v3.0 - Rapid scan mode winds Apr-Dec 2009, European & Mediterranean area	Orogr. Flag = 0,1,2,3	Orogr. Flag = 4,5
Number of collocations - HRVIS winds	1000	36858	Number of collocations - HRVIS winds	1631	42874
Mean radiosounding Speed - HRVIS winds	7.40	13.85	Mean radiosounding Speed - HRVIS winds	8.43	14.01
Normalized Bias - HRVIS winds	0.32	-0.07	Normalized Bias - HRVIS winds	0.05	-0.07
Normalized Mean Vector Difference - HRVIS winds	0.78	0.37	Normalized Mean Vector Difference - HRVIS winds	0.57	0.38
Normalized Root Mean Square Vector Difference - HRVIS winds	0.95	0.47	Normalized Root Mean Square Vector Difference - HRVIS winds	0.72	0.47
Number of collocations - IR108 winds	381	44705	Number of collocations - IR108 winds	706	36669
Mean radiosounding Speed - IR108 winds	7.55	15.84	Mean radiosounding Speed - IR108 winds	10.38	17.19
Normalized Bias - IR108 winds	0.13	-0.02	Normalized Bias - IR108 winds	0.14	-0.01
Normalized Mean Vector Difference - IR108 winds	0.74	0.39	Normalized Mean Vector Difference - IR108 winds	0.69	0.39
Normalized Root Mean Square Vector Difference - IR108 winds	0.88	0.48	Normalized Root Mean Square Vector Difference - IR108 winds	0.82	0.47

***Figures 9 & 10*: Variation in the HRVIS & IR108 AMV validation parameters with the 'Orographic flag', in "Nominal scan mode" and "Rapid scan mode" (April-December 2009, European and Mediterranean region), considering in each case the two data groups considered as valid and invalid.**

Validation considering the 'Cloud type'

A study has been done to identify the cloud types whose AMVs show a better and worse behaviour. The study shows that "Fractional clouds" and "High semitransparent thin clouds" are recommended to be filtered out for both HRVIS & IR108 AMVs, due to their worse validation statistics. HRVIS "High semitransparent meanly thick clouds" show also a worse behaviour than in the IR108, and are also recommended to be eliminated. With this procedure, although semitransparency corrections are not implemented, the algorithm is nevertheless capable of identifying and eliminating AMVs related to problematic cloud types.

Considering the different cloud types and the two MSG channels used for AMV extraction, the validation parameters are in general better in the HRVIS channel for "Very low and low cumulus/stratus", better seen in the visible. They are better in the IR108 channel for "High semitransparent clouds: thick, meanly thick and above other clouds", more clearly seen in the infrared channel.

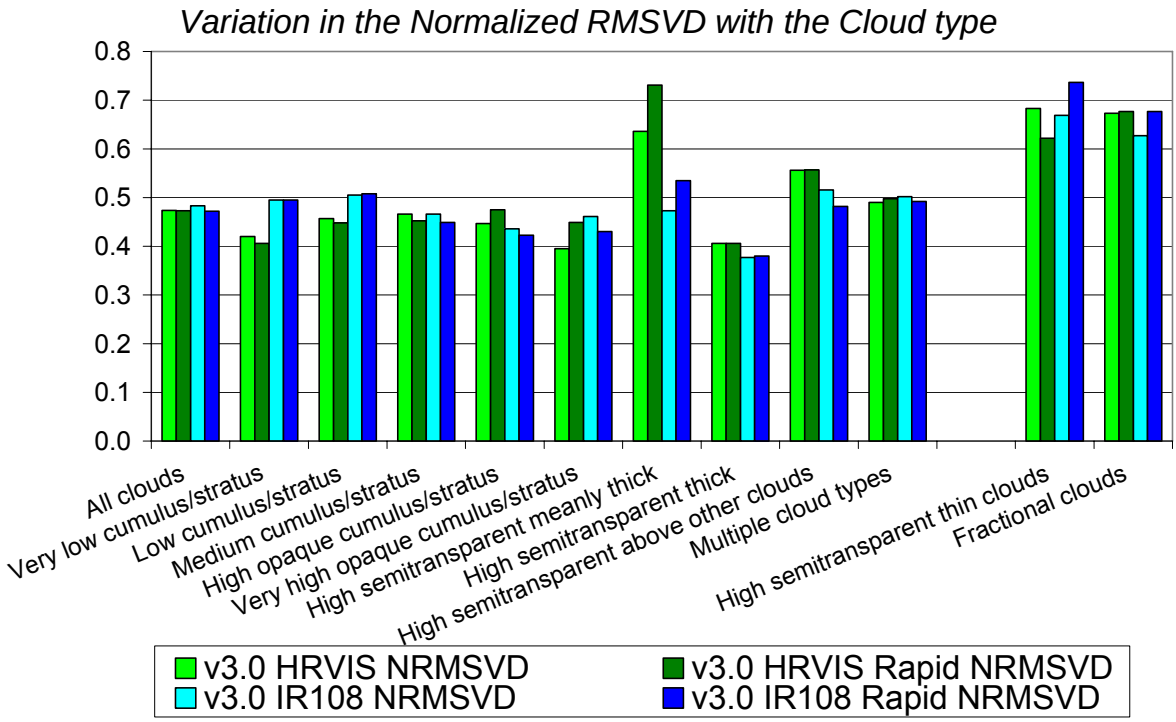


***Figure 11*: Variation in the HRVIS & IR108 AMV Normalized RMSVD with the 'Cloud type', in the "Nominal scan mode" and "Rapid scan mode" (April-December 2009, European and Mediterranean region).**

HRW v3.0 Validation statistics for 'Nominal scan mode' and 'Rapid scan mode'

After all the previous studies, where the best filterings have been discovered for HRW v3.0 validation, the statistical parameters for HRVIS & IR108 AMVs are shown in both 'Nominal scan mode' and 'Rapid scan mode' with the conditions defined, for the period April-December 2009.

The most important results in the HRW v3.0 validation is that the optimization included in its algorithm permits to calculate AMVs in both HRVIS & IR108 channels, in a running time similar to that for HRW v2.2 (2 minutes in "National areas" and 6 minutes in "Continental areas"), with a big increase in the number of total winds (about 2.5 times).

Comparing the AMVs related to both MSG channels, IR108 winds show a much lower BIAS than HRVIS winds, similar MVD & RMSVD in the high & medium layers, and a bit worse MVD & RMSVD in the low layer. Nevertheless, validation statistics are in all cases similar or smaller (specially the BIAS) to those shown by HRW v2.2 winds.

Considering ‘Rapid scan mode winds’ validation parameters, there are few differences with the filterings defined by the HRW operative thresholds to those shown by ‘Nominal scan winds’ (the differences in the MVD and the RMSVD are always smaller than a 5%). The most important distinction is related to the number of winds per slot, with the behaviour described before: in ‘Rapid scan mode’, with a time difference between initial tracer image and final tracking image of 10 minutes and all the conditions defined for validation filtering, the number of HRVIS winds increases about a 17% per slot and the number of IR108 winds decreases about a 17% per slot (related to the better spatial resolution of HRVIS channel, with more possibilities to distinguish speed differences with short tracer displacements).

Considering a 15 minute period, the main advantage of ‘Rapid scan mode’ can be seen: with three ‘Rapid scan slots’ for every ‘Nominal scan slot’, the amount of HRVIS winds every 15 minutes is multiplied by 3.5, and the amount of IR108 winds is multiplied by 2.5, with a similar quality.

HRW v3.0, April – December 2009 HRVIS Nominal scan mode winds	All levels	High levels	Medium levels	Low levels
Number of collocations (NC)	36858	3641	13577	19640
Mean radiosounding Speed (SPD)	13.85	25.70	14.57	11.16
Normalized Bias (NBIAS)	-0.07	-0.09	-0.07	-0.05
Normalized Mean Vector Difference (NMVD)	0.37	0.29	0.41	0.37
Normalized Root Mean Square Vector Difference (NRMSVD)	0.47	0.36	0.51	0.46

Validation for HRW v3.0 HRVIS Nominal scan mode winds
(QI>83; Pressure[hPa] ∈(200,1000); Orographic flag≠1,2; Cloud type≠1,2,3,4,15,16,19)

HRW v3.0, April – December 2009 HRVIS Rapid scan mode winds	All levels	High levels	Medium levels	Low levels
Number of collocations (NC)	42874	4713	18812	19349
Mean radiosounding Speed (SPD)	14.01	25.91	14.34	10.80
Normalized Bias (NBIAS)	-0.07	-0.08	-0.05	-0.08
Normalized Mean Vector Difference (NMVD)	0.38	0.30	0.42	0.36
Normalized Root Mean Square Vector Difference (NRMSVD)	0.47	0.37	0.52	0.44

Validation for HRW v3.0 HRVIS Rapid scan winds
(QI{High,Medium}>83; QI{Low}>84; Pressure[hPa] ∈(200,1000); Orographic flag≠0,1,2,3; Cloud type≠1,2,3,4,15,16,19; Speed(High)>10 m/s; Image time difference=10 min)

HRW v3.0, April – December 2009 IR108 Nominal scan mode winds	All levels	High levels	Medium levels	Low levels
Number of collocations (NC)	44705	6807	24312	13586
Mean radiosounding Speed (SPD)	15.84	24.55	15.75	11.63
Normalized Bias (NBIAS)	-0.02	-0.07	-0.00	-0.03
Normalized Mean Vector Difference (NMVD)	0.39	0.30	0.42	0.43
Normalized Root Mean Square Vector Difference (NRMSVD)	0.48	0.37	0.51	0.51

Validation for HRW v3.0 IR108 Nominal scan mode winds
(QI>83; Pressure[hPa] ∈(200,900]; Orographic flag≠1,2; Cloud type≠1,2,3,4,15,19)

HRW v3.0, April – December 2009 IR108 Rapid Scan mode winds	All levels	High levels	Medium levels	Low levels
Number of collocations (NC)	36669	6809	19836	10024
Mean radiosounding Speed (SPD)	17.19	25.57	16.67	12.53
Normalized Bias (NBIAS)	-0.01	-0.08	0.04	-0.02
Normalized Mean Vector Difference (NMVD)	0.39	0.30	0.42	0.43
Normalized Root Mean Square Vector Difference (NRMSVD)	0.47	0.38	0.50	0.50

Validation for HRW v3.0 IR108 Rapid scan winds
(QI>83; Pressure[hPa] ∈(200,900]; Orographic flag≠0,1,2,3; Cloud type≠1,2,3,4,15,19; Image time difference=10min)

***Figures 12, 13, 14 & 15*: Validation parameters for HRVIS & IR108 ‘Nominal scan’ and ‘Rapid scan’ HRW v3.0 AMVs (April-December 2009, European and Mediterranean region).**

FUTURE DEVELOPMENTS IN NWCSAF/HRW PRODUCT

During the NWCSAF Continuous Development and Operations Phase (CDOP, lasting until 2012), the next developments are planned:

- A change in the Quality Control procedure, permitting small local variations in the Quality Index threshold, to avoid the total elimination of all AMVs with the Quality filterings in some areas, as sometimes occurs with the current configuration.
- Changes in the Height assignment procedure, to consider only the pixels related to the Cloud type defined for the tracer and the corresponding NWCSAF/Cloud top height value.
- The reconfiguration of HRW product to calculate AMVs with other MSG channels, based on suggestions from the NWCSAF users at the next “NWCSAF Users Workshop” (for the moment, the calculation of AMVs in a Water vapour channel is foreseen). The “NWCSAF Users Workshop”, to be celebrated in Madrid during the days 26-28 April 2010, is free to all NWCSAF Users and all scientists interested in its products developed for Nowcasting and Very short range forecasting. The attendance to the Workshop of users pretending to adapt NWCSAF products to other geostationary satellites is even expected.

Possible developments to be started after the CDOP Phase (after 2012) are the calculation with AMV data of divergence and vorticity fields, and a new application to calculate extrapolated images through the displacement of image elements with AMV data.

CONCLUSIONS

The optimized HRW v3.0 algorithm permits users to calculate HRVIS & IR108 winds, in a running time similar to the time used by previous versions of HW algorithm to calculate only HRVIS winds, with a big increase in the number of available winds (about 2.5 times if winds from both channels are considered together). Operationally the main consequences of the new HRW algorithm are:

- The spectrum of information gets broader: HRVIS & IR108 data complement each other and tend to give information about different levels of the troposphere: HRVIS winds are more common in the low layer, and IR108 winds are more common in the high and medium layers.
- The possibility to use HRW product 24 hours a day, for a monitoring of winds and fluxes without intermittencies.
- The possibility of a quicker update of the wind data fields with the 'Rapid scan mode' configuration. Time limitations allow using this configuration only in National areas, but this can be useful in regional studies. Besides, the calculation of new wind data every 5 minutes causes also an important increase in the number of available winds (multiplied by a factor of about 3).
- The small variations in the validation statistics for all HRW algorithm outputs ('Nominal scan mode' and 'Rapid scan mode' HRVIS & IR108 winds), permit to consider them as similar quality datasets. Because of this, they can then be used jointly as an only dataset for later applications, as the calculation of divergence and vorticity fields, or regular wind grids.

With these improvements, the utility of "High Resolution Winds product" has increased significantly and is now more in accordance with the needs of NWCSAF users. An important growth in the use of HRW product with the new version of the algorithm is then expected. The collaboration from the users is also expected to evaluate the impact of HRW winds in NWP assimilation in mesoscale or regional models. This work could be even economically awarded, after the elaboration of a Report on the impact of HRW data in NWP assimilation, through an NWCSAF Visiting Scientist Activity.

NWCSAF SOFTWARE DELIVERY PROCEDURE

In case of interest on using the HRW product, all National Meteorological Services within Eumetsat Member/Cooperating States are automatically considered potential users of NWCSAF Software. Any other Organisation may apply to become user of NWCSAF Software through the Leading Entity (Pilar Fernández, NWCSAF CDOP Manager, pif@inm.es).

The software delivery will be authorized to users according to their Licence Agreement, signed by Eumetsat (represented by the Leading Entity) and the applicant user. Once the Licence Agreement is signed, access credentials to the NWCSAF Help Desk Restricted Area are provided, where the NWCSAF software can be downloaded: http://www.nwcsaf.org.

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