EVOLUTION OF HIGH RESOLUTION WINDS PRODUCT (HRW), AT THE SATELLITE APPLICATION FACILITY ON SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING (SAFNWC)

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Abstract

Among the products developed by the Eumetsat Satellite Application Facility on support to Nowcasting and Very short range forecasting (SAFNWC), to be used locally and in real time by its users, the High Resolution Winds Product (HRW) allows a detailed calculation in coverage and time of Atmospheric Motion Vectors during daytime, from MSG/HRVIS channel in the geographical area of their interest.

The evolution and main improvements of this product during the last two years are explained. One year of validation data with HRW version 2.1 is presented, with significant improvements in all verification parameters respect to the previous versions. The effect of the orographic flag (filtering out about a 8% of low levels winds with a lesser quality), and the geographical dispersion of the results (showing that the validation results are homogeneous throughout all the European area up to a satellite zenith angle of about 75º), are to be emphasized as noteworthy results.

A study about the effect of the cloud type in the height assignment process is also shown. It tries to discover which of the three different levels calculated for each tracer, from the cloud base to the cloud top, is best for the height assignment considering the different types of cloud. The cloud type is calculated in real time and in parallel to the HRW with another SAFNWC product (CT). The results, applied to the algorithm, involve a non negligible validation improvement.

REMINDER OF MAIN CHARACTERISTICS OF SAFNWC/HRW PRODUCT

The Nowcasting Satellite Application Facility was established between Eumetsat and the Spanish National Weather Service (INM, now evolved into the Agency Aemet), to enhance Nowcasting and Very Short Range Weather Forecasting with MSG and Polar Satellite data. To achieve this goal, the SAFNWC develops and maintains a software package calculating several meteorological products, and supports on the usage of the software.

Among the SAFNWC products, the High Resolution Winds (HRW) provide detailed sets of Atmospheric Motion Vectors for near real time applications, from MSG/HRVIS channel data in the region defined by the user. Results are calculated locally in less than 5 minutes, for observational cycles of 15 minutes. Current version is HRW v2.1, available since spring 2008. Its main steps are:

1. *Image preprocessing*: MSG/HRVIS reflectances are normalized with the sun zenith angle.

2. *Tracer calculation*: two methods are used: gradient (searching well defined cloud edges), and tracer characteristics (to fill holes in the coverage).

3. *Tracer height assignment*: three different height levels are calculated for each tracer:
   - Interpolation level of IR10.8 brightness temperature to a NWP vertical profile.
   - Cloud top: the coldest non isolated class in the smoothed temperature histogram.
   - Cloud base: calculated through formula $T_{Base} = T_{Mean} + \sqrt{2}\sigma_{Temp}$ (J.Schmetz et al., 1996).

4. *Tracking*: up to three correlation centres are selected using one of two different methods: euclidean difference and cross correlation.

5. *Quality Control*: HRW product adapts Eumetsat Quality Indicator Method. It includes temporal, spatial and forecast consistency tests, with double contribution from the spatial test.

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

Full Resolution MSG/HRVIS & MSG/IR10.8 data, and several NWP parameters for the working region (temperature and wind profiles, geopotential profile and surface temperature also if the orographic flag is being calculated) are used as input data. NWP is not mandatory but recommended; if it is not available a rough climatological profile is used.

Two BUFR bulletins are obtained as output data, with AMVs corresponding to two different scales of tracers: basic winds (tracer size of about 24 pixels), and detailed winds (tracer size of about 12 pixels).

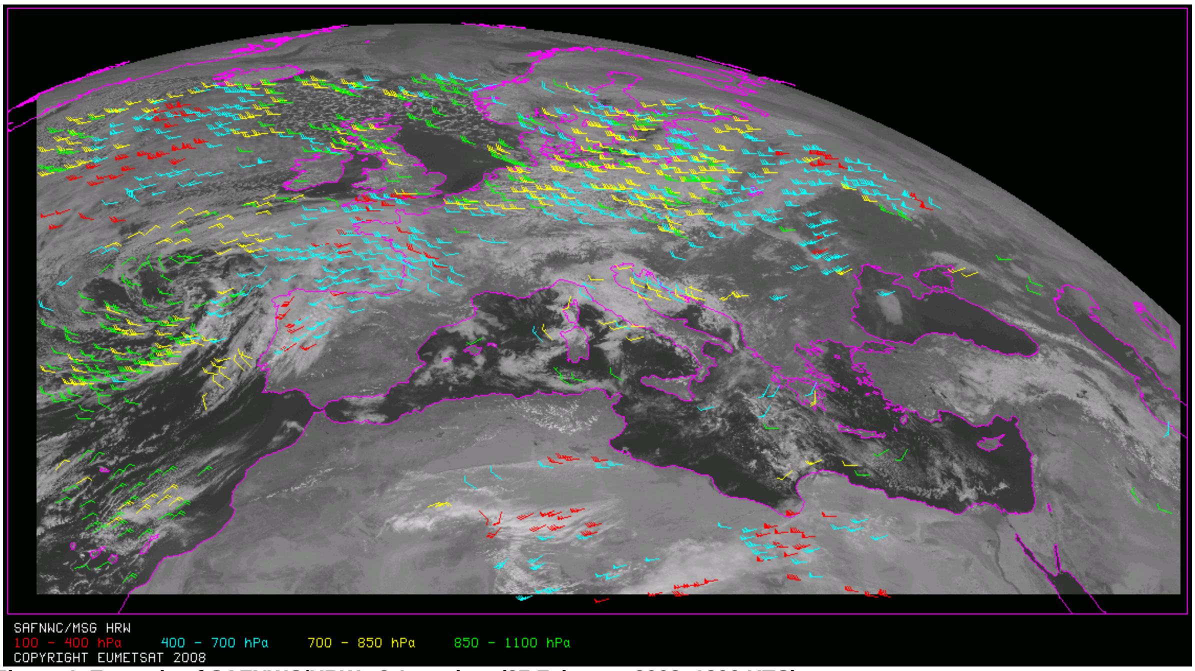


***Figure 1*: Example of SAFNWC/HRW v2.1 product (27 February 2008, 1200 UTC).**

SAFNWC CONTINUOUS DEVELOPMENT AND OPERATION PHASE

Considering the SAFNWC schedule, a new Working phase is now running: Continuous Development and Operation Phase (CDOP, 2007 – 2012). The objectives to be achieved during this phase are:

1. *To use cloud information from other SAFNWC products*: Cloud type (CT) and Cloud Top Height and Temperature (CTTH), to detect the cloud level that represents best the AMVs for each cloud type, and improve the height assignment.

2. *To adapt the algorithm to Rapid Scanning through two working procedures*: wind extraction at every slot, and tracer tracking at every slot but only calculating winds every several slots.

3. *To adapt the algorithm to infrared channels*: to provide data throughout the whole day, following the requirements of the product users.

4. *To develop new validation tools not considered previously*: e.g., to compare the AMVs against Doppler radar data for a more continuous validation in time and space.

EVOLUTION OF HRW PRODUCT BETWEEN VERSIONS v1.2 AND v2.1

A new validation procedure has been taken to evaluate the evolution of the HRW product during the last two years. The effect of several parameters in the validation results has also been studied: the quality index threshold, the atmospheric level, the orographic flag and the geographical distribution of errors.

The validation has been based on the comparison of the 1200Z HRW output with Radiosounding winds in the European and Mediterranean area, during the period September 2006 – August 2007. In general, comparing HRW v2.1 with HRW v1.2, there is a reduction of about a 50% in the normalized BIAS (NBIAS), and a reduction of about a 5% in the normalized MVD (NMVD) and normalized RMSVD (NRMSVD). The improvements are based basically on the optimisation of the algorithm configuration parameters, and in the low levels on the introduction of the orographic flag.

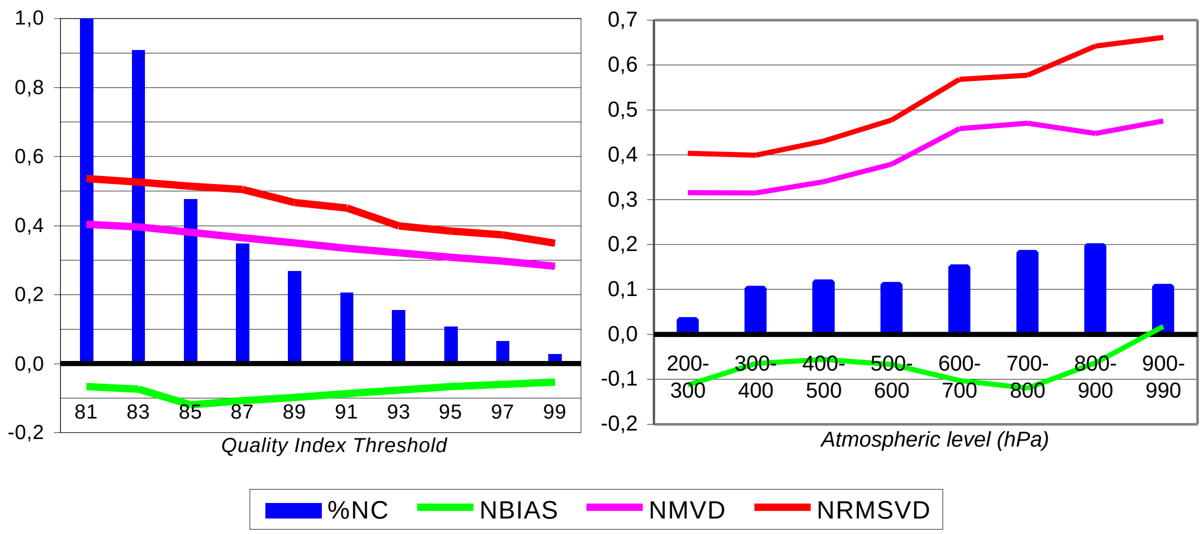
HRW v2.1 Validation (Sep. 06 – Aug. 07, European Area)	**All levels**	**High levels**	**Med. levels**	**Low levels**
Number of collocations (NC)	86144	11297	39130	35717
Mean radiosounding speed (SPD)	15.54	28.02	16.64	10.38
Normalized Bias (NBIAS)	-0.08	-0.08	-0.08	-0.05
Normalized Mean vector difference (NMVD)	0.40	0.32	0.40	0.46
Normalized Root mean square vector difference (NRMSVD)	0.53	0.41	0.51	0.59

***Figure 2*: Validation statistics for HRW v2.1 (Sep. 2006 – Aug. 2007; Quality Index = 83; Orographic flag = 0,3,4,5; Spatial flag = 3).**

<u>Effect of the Quality index threshold and the Atmospheric level</u>:

Considering the Quality Index, the NMVD and NRMSVD improve clearly if the threshold becomes higher; the NBIAS shows anyhow the same behaviour than in the previous HRW versions: it reduces only with the highest Quality Index thresholds (it is even worse when the threshold is 85 or 90 than when the threshold is lower). Considering the amount of available AMVs, a maximum Quality Index threshold = 83 is recommendable to keep the main part of the AMV population: there is an important reduction of elements (of about 50%) over this value.

Considering the different atmospheric levels, the best statistics are reached in the highest levels (with NRMSVD ~ 0.41), and the worst in the lowest levels (with NRMSVD ~ 0.66), improving anyhow the results with respect to HRW v1.2 throughout all the layers.



***Figures 3 & 4*: Dependence of the Validation statistics on the Quality Index Threshold and Atmospheric level.**

<u>Effect of the Orographic flag</u>:

The algorithm calculates since autumn 2006 the next data for geographical boxes of 1x1 degree of latitude and longitude:

- The "minimum and maximum representative heights" (3% and 97% percentiles of the height histogram for each geographical box).
- The barometric conversion of these heights to the "maximum and minimum representative pressures" for each geographical box.

With these data, an orographic flag is calculated to detect the tracers affected by any land influence:

- *Orographic flag = 1*: The tracer is located below the mean pressure level for the corresponding geographical box (Very important orographic influence).
- *Orographic flag = 2*: The tracer is located below the level without orographic influence, defined as the Minimum Representative Pressure - 25 hPa. (Less important orographic influence).

If these conditions do not apply, if there is stability at the tracer location and the speed is at least 5 m/s, the previous positions of the tracers are calculated with the corresponding AMV:

- *Orographic flag = 3*: The tracer is below the level without orographic influence, at any of its previous positions up to two hours (An obstacle is found; the cloudiness can be related to mountain waves).
- *Orographic flag = 4*: No obstacle has been found, but stability is still present at all its previous positions (The obstacle might be at a further place).
- *Orographic flag = 5*: No obstacle has been found, and stability disappears at any of its previous positions (No orographic influence is found).

If the orographic flag cannot be calculated:

- *Orographic flag = 0*: Fundamentally when the AMV comes from the edge of the working region (where the previous positions cannot be calculated).

Validating the impact of this parameter, the NMVD and NRMSVD are about a 70% worse when the orographic flag is 1 or 2. Eliminating AMVs with these orographic flag values, this parameter becomes good to filter out a 8% of low level AMVs with worse quality.

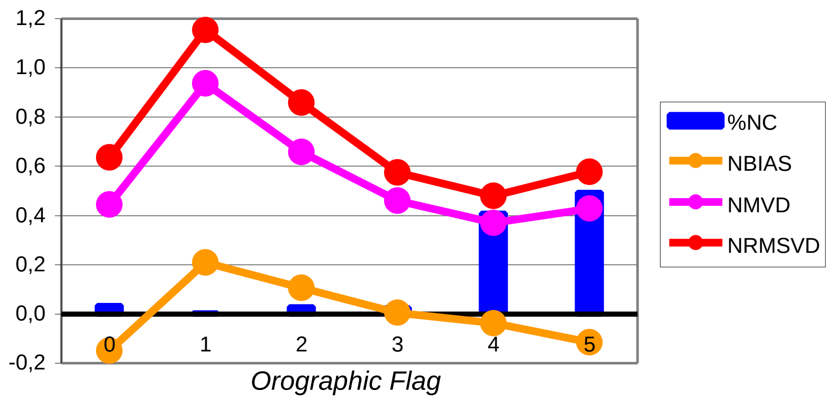


***Figure 5*: Dependence of the Validation statistics on the Orographic flag.**

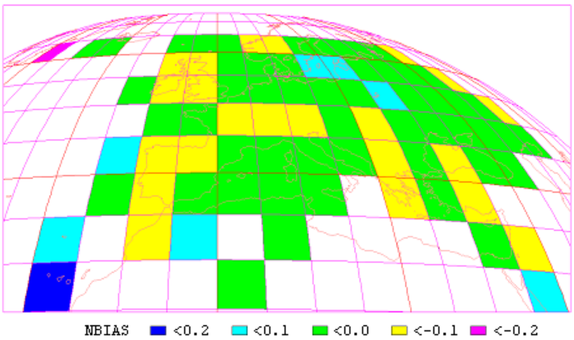
HRW v2.1 (Sep.06 – Aug.07, European Area)	**Orog.Flag=1,2**	**Orog.Flag=0,3,4,5**
Number of collocations (NC)	3177	86144
Mean radiosounding speed (SPD)	7.28	15.54
Normalized Bias (NBIAS)	0.12	-0.08
Normalized Mean vector difference (NMVD)	0.69	0.40
Normalized Root mean square vector difference (NRMSVD)	0.90	0.53

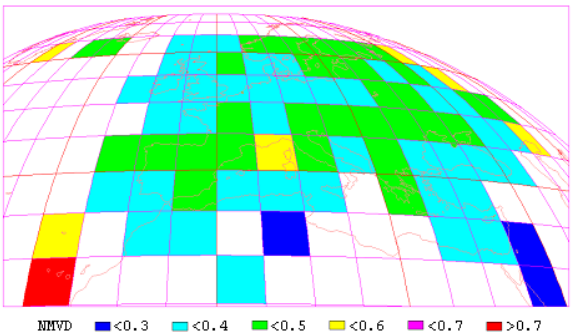
***Figure 6*: Comparison of the HRW Validation statistics in two samples of AMVs with different Orographic flag values: 1,2 and 0,3,4,5.**

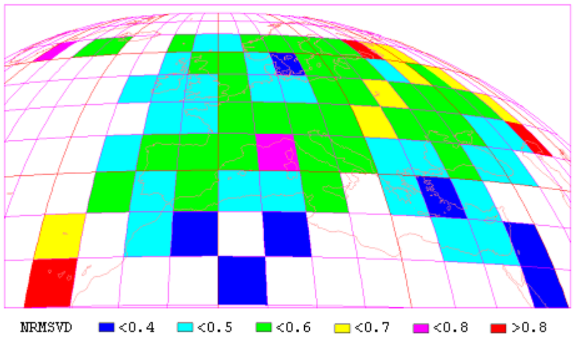
<u>Geographical distribution of errors</u>:

The geographical dispersion of the validation statistics is calculated to define the areas in which the atmospheric flux is best and worst represented by the AMVs. To achieve this, the NBIAS, NMVD and NRMSVD are calculated for 5x5 degree boxes with at least 40 collocations in the whole European and Mediterranean area.

The results show small variations in the statistical parameters with the geographical coordinates: similar results are obtained in Northern Europe and the Mediterranean Sea. The worst results for NMVD and NRMSVD parameters are obtained at the edge of the working region (far northwest and northeast, where a reduction of the satellite zenith angle threshold from 80º to 75º can improve results), and in some maritime boxes (Canaries, Madeira, Corsica, Sardinia), where maritime AMVs may have been compared to land radiosoundings, and local effects can reduce the correlation between land and sea winds.







***Figures 7, 8 & 9*: Geographic distribution of normalized BIAS, normalized MVD and normalized RMSVD in the European and Mediterranean area.**

INCLUSION OF SAFNWC/CLOUD TYPE PRODUCT IN THE HEIGHT ASSIGNMENT

HRW can run in parallel to other SAFNWC products. The product Cloud type (CT) classifies pixels in different categories considering information from the MSG/SEVIRI channels VIS0.6, VIS0.8, IR1.6, IR3.9, IR8.7, IR10.8 and IR12.0. Although CT product is still not fully developed (the separation between cumulus and stratus is not available) next categories are already defined in the classification:

1	Cloud free land	12	High opaque cumulus/stratus
2	Cloud free sea	14	Very high opaque cumulus/stratus
3	Ice contaminated land	15	High semitransparent thin clouds
4	Ice contaminated sea	16	High semitransparent meanly thick clouds
6	Very low cumulus/stratus	17	High semitransparent thick clouds
8	Low cumulus/stratus	18	High semitransparent above other clouds
10	Medium cumulus/stratus	19	Fractional clouds

A preliminary study (still not included in the official SAFNWC/HRW version) has been run to define which of the different height levels defined for each tracer:

- *IR10.8 brightness temperature interpolation level to NWP or climatology*.
- *Cloud top*: coldest non isolated class in the smoothed temperature histogram.
- *Cloud base*: calculated through formula $T_{Base} = T_{Mean} + \sqrt{2}\sigma_{Temp.}$

is best for the height assignment, considering the different types of clouds.

Several procedures were tried to define the "tracer cloud type". The clearest information was obtained when the most common cloud type for the tracer was at least 1.5 times the second most common type. When this does not occur, an "undefined cloud type" is assigned. Statistically, the best fit is reached with the *Cloud top* for High semitransparent thick and meanly thick clouds, and the *Cloud base* for all other types.

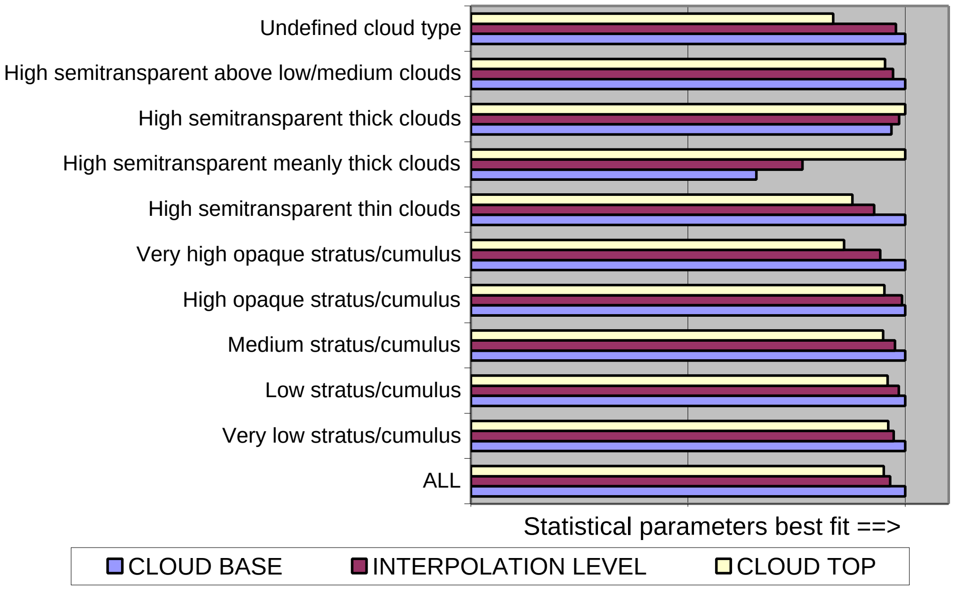


***Figure 10*: Validation statistics comparison for all cloud types considering the three different height assignment levels: Cloud top, IR interpolation level, Cloud base.**

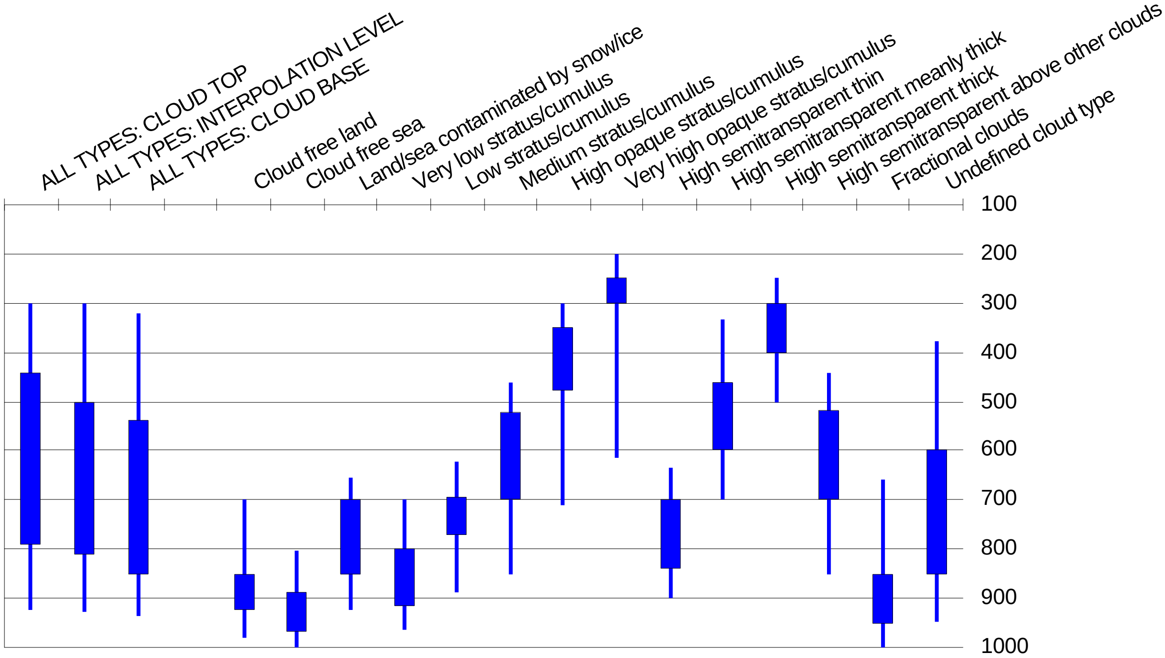


***Figure 11*: Vertical distribution of AMVs related to the Cloud type, plotted against pressure (hPa). Representation of 5%, 25%, 75%, 95% population centiles.**

Considering the vertical distribution of the tracers and the different cloud types, some conclusions can be obtained for the height assignment. In general, the best statistics are obtained with the high stratus/cumulus and the high semitransparent thick clouds; the worst statistics with the low stratus/cumulus and other high semitransparent types. More specifically:

- Incorrect *cloud free and ice/snow tracers* (a 3% of the total), which are related to land features and characterized as low level cloudiness (below 700 hPa), should be excluded.
- *High semitransparent thin tracers* (a 1% of the total), which are contaminated by the layers below the cloud and incorrectly considered as low level cloudiness, should also be excluded.
- Partial low level contamination also occurs with *High semitransparent meanly thick* tracers, where the tracers are located between 300 and 700 hPa.
- *High semitransparent tracers above other clouds* represent actually the cloud below, through the cloud base.
- *Fractional cloud type tracers* (a 4% of the total) are related to low level cloudiness (below 650 hPa). Anyhow they should be excluded because of their bad validation statistics.

NUMBER OF TRACERS / CLOUD TYPE	SPD	NBIAS	NMVD	NRMSVD	HEIGHT LEV.
597 Cloud free sea	7.91	0.10	0.74	0.95	**Eliminated**
734 Cloud free land	8.72	-0.03	0.59	0.77	**Eliminated**
14 Land/sea with snow/ice	10.64	-0.08	0.57	0.67	**Eliminated**
1722 Fractional clouds	9.90	0.05	0.51	0.66	**Eliminated**
8681 Low stratus/cumulus	11.74	-0.11	0.48	0.60	**Cloud base**
489 High semitransparent thin	10.57	-0.08	0.48	0.59	**Eliminated**
587 High semitransparent meanly thick	15.27	0.16	0.48	0.58	**Cloud top**
2396 High semitransparent above clouds	14.75	-0.04	0.47	0.57	**Cloud base**
7619 Very low stratus/cumulus	10.51	-0.11	0.44	0.54	**Cloud base**
5096 Medium stratus/cumulus	14.48	-0.03	0.42	0.53	**Cloud base**
8153 Undefined cloud type	13.71	-0.03	0.41	0.52	**Cloud base**
2327 High semitransparent thick	26.31	-0.00	0.35	0.45	**Cloud top**
5650 High opaque stratus/cumulus	23.54	-0.01	0.33	0.42	**Cloud base**
615 Very high opaque stratus/cumulus	31.52	-0.03	0.30	0.37	**Cloud base**

***Figure 12*: Validation statistics for the different cloud types (Jun 2007 – Jan 2008, European & Mediterranean area).**

Considering the validation statistics with the inclusion of the SAFNWC/CT product in the height assignment process the impact is positive, taking advantage of the cloud identification process considered in its algorithm.

There are additional improvements in the normalized RMSVD of up to a 10% in the low levels, and up to a 5% in the high levels with it. No impact is seen in the medium levels. The changes are very significant in the low levels: the elimination of wrong cloud free tracers, ice/snow tracers and fractional cloud tracers, make the low level statistics become better than the medium level ones.

HRW without SAFNWC/CT in the Height assignment (Jan. 08 – Mar.08, European Area)	**All levels**	**High levels**	**Med. levels**	**Low levels**
Number of collocations (NC)	14687	2323	6304	6060
Mean radiosounding speed (SPD)	18.20	35.60	18.01	11.74
Normalized Bias (NBIAS)	-0.09	-0.09	-0.11	-0.06
Normalized Mean vector difference (NMVD)	0.37	0.31	0.39	0.40
Normalized Root mean square vector difference (NRMSVD)	0.49	0.40	0.50	0.51

HRW with SAFNWC/CT in the Height assignment (Jan.08 – Mar.08, European Area)	**All levels**	**High levels**	**Med. Levels**	**Low levels**
Number of collocations (NC)	12221	1400	5761	5060
Mean radiosounding speed (SPD)	17.45	35.04	17.81	12.18
Normalized Bias (NBIAS)	-0.10	-0.10	-0.11	-0.08
Normalized Mean vector difference (NMVD)	0.37	0.30	0.39	0.38
Normalized Root mean square vector difference (NRMSVD)	0.48	0.38	0.50	0.47

***Figures 13 & 14:* Comparison of validation statistics for HRW product, without and with SAFNWC/CT product in the Height assignment.**

CONCLUSIONS

The validation is homogeneous and good enough throughout the European and Mediterranean area:

- The product is perfectly usable up to a satellite zenith angle of about 75º.
- The quality in northern areas like Scandinavia is similar to the quality in Southern Europe.

The orographic flag is valuable in the filtering of data to get a better validation:

- The orographic flag values = 1,2 detect a small proportion of AMVs in the low levels (about a 8%) with a much lesser quality.

The evolution is positive since HRW v1.2:

- There is a reduction of about a 50% in the NBIAS.
- There is a reduction of about a 5% in the NMVD and NRMSVD.

Effects of SAFNWC/CT product in the Height assignment:

- The AMVs represent better the cloud base displacement for all cloud types, except for High semitransparent thick and meanly thick clouds (better related to the cloud top displacement).
- Some "cloud type categories" can be eliminated to improve statistics: cloud free and ice contaminated tracers, fractional clouds, high semitransparent thin clouds.
- As a consequence, the inclusion of this input in the algorithm causes an additional reduction of up to a 10% in the normalized RMSVD in the low levels, and up to a 5% in the high levels.

SAFNWC SOFTWARE DELIVERY PROCEDURE

In case of interest on using the HRW product, all National Meteorological Services within Eumetsat Member and Cooperating States are automatically considered potential users of the SAFNWC software. Any other organization may also apply to become user of it through the leading entity (Luis Fernando López Cotín, SAFNWC Manager, l.cotin@inm.es).

Software delivery is authorized through the signing of a Licence Agreement by Eumetsat (represented by the Leading Entity) and the applicant user. After this, access credentials to the SAFNWC Helpdesk User Area are given, where the software can be downloaded. More information is available at the SAFNWC website: http://nwcsaf.inm.es.

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