DESCRIPTION AND VALIDATION RESULTS OF THE HIGH RESOLUTION WIND PRODUCT FROM HRVIS MSG CHANNEL, AT EUMETSAT NOWCASTING SAF (SAFNWC)

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ABSTRACT

One of the main objectives of the Eumetsat Satellite Application Facility in support to Nowcasting and Very short range forecasting (SAFNWC), has been the development of a software package permitting users to generate locally and in near real time, a series of products from MSG data every updating cycle. Among them, the High Resolution Winds Product (HRW) allows users a detailed calculation, in coverage and time, of Atmospheric Motion Vectors (AMV) during daytime, from the MSG HRVIS channel in the geographical area of their interest.

The main characteristics of the HRW algorithm have been shown at the Workshop. Basically, it considers two tracer scales (basic and detailed: 24 and 12 pixels) and two methods (sharp edge or gradient, tracer characteristics) for tracer determination. Tracer tracking is based on euclidean difference and cross correlation methods. Quality Indicator Method developed by Eumetsat and implemented at MPEF has been adapted for quality control and wind selection, where a Quality Index is calculated through the weighted sum of five individual tests: direction, speed and vector difference related to temporal consistency; vector difference related to spatial consistency; vector difference related to a forecast model.

SAFNWC software package has been available for users since 2004. One year of product validation with radiosounding data in a region centred in the Iberian Peninsula is presented. As main result of this verification procedure, it will be seen that with an adequate filtering of data, users are able to calculate locally and in near real time Atmospheric Motion Vectors from the MSG HRVIS channel, whose validation parameters are similar or only a bit worse than those of other AMVs calculated by other Centres, and with a very significant spatial density of data.

THE EUMETSAT NOWCASTING SATELLITE APPLICATION FACILITY (SAFNWC)

The Nowcasting Satellite Application Facility was established in 1996 between Eumetsat and the Spanish National Wather Service (Instituto Nacional de Meteorología). It is defined as a Consortium of Instituto Nacional de Meteorología, Météo France, Sveriges Meteorologiska och Hydrologiska Institut (Sweden), Zentralamstalt für Meteorologie und Geodinamik (Austria).

Its objectives are to provide operational services to enhance Nowcasting and Very Short Range Weather Forecasting from MSG and METOP data. To achieve this goal, the SAFNWC is responsible for the development and maintenance of appropriate software packages, and the user support on the software. Nowcasting tasks require fast data processing and delivery; due to this, SAFNWC does not produce stand-alone products, but delivers them to users so they can quickly process satellite data following their own premises.

SAFNWC has developed four products for both MSG and Polar (METOP, NOAA) satellites: Cloud mask (CMa), Cloud type (CT), Cloud top temperature and height (CTTH), Precipitating clouds (PC). It has also developed eight more products for MSG satellites: Convective rainfall rate (CRR), Total precipitable water (TPW), Layer precipitable water (LPW), Stability analysis imagery (SAI), Automatic satellite image interpretation (ASII), Rapidly developing thunderstorms (RDT), Air mass analysis (AMA), and High resolution winds (HRW). More information on the project and the products is available at SAFNWC website: http://nwcsaf.inm.es

HIGH RESOLUTION WINDS PRODUCT DESCRIPTION

The objective of the High resolution winds product (HRW) is to provide users detailed sets of Atmospheric Motion Vectors for near real-time applications, from MSG HRVIS channel data. Results can be obtained locally in less than 5 minutes, for observational cycles of 15 minutes. This may be useful for nowcasting tasks, and assimilation in mesoscale analysis and short range forecasting applications.

It includes a two scale procedure: 24 pixel (Basic winds) and 12 pixel (Detailed winds). Detailed tracers are searched in areas where no basic tracers are found, or these are large suggesting the possibility of a more detailed search. Both datasets are stored separately in different BUFR bulletins.

Full Resolution MSG HRVIS & IR10.8 Seviri data for the working region are the only necessary input for HRW running. Anyhow, temperature and wind forecast profiles from NWP data for the working region (which are not mandatory) are also fairly recommended; in case the temperature profile is not available a very rough climatological profile is used.

Six different steps take part in HRW algorithm, which are described next:

1. *Image preprocessing*: HRVIS Seviri data are previously normalized with the sun zenith angle; data values range from 0 to 255 (8 bit data, to avoid too low reflectance contrasts).

2. *Tracer determination*: two methods are used, with the objective of finding as many tracers as possible all throughout the image.
   - Gradient or sharp edge: it searches fast and efficiently for well defined cloud edges.
   - Tracer characteristics: it is used to fill holes in coverage, with a longer but still reasonable computing time. Each location, selected through configurable parameters, is checked to find a brightness threshold (separating the cloudiness in front from the background), small scattering of IR channel temperatures in the target (to avoid multilevel cloudiness), and a well defined shape of the target bright pixels (to avoid too linear cloudy elements).

3. *Tracer level assignation*: the basic input is the average IR10.8 channel temperature for bright pixels. Level assignation is made through a linear vertical and horizontal interpolation to the centre of each tracer of NWP forecast or climatological temperature profiles. Next adaptations are then made considering the clouds at the different layers:
   - For high levels (<400hPa): AMVs are considered to be at the cloud top. Level assignation is made through the coldest non isolated class of the smoothed temperature histogram.
   - For medium levels (400–700hPa): AMVs are considered to be at the corresponding interpolation pressure level.
   - For low levels (>700hPa): AMVs are considered to be at the cloud base. An extrapolation of temperature is made to calculate pressure level through $T_{BASE} = T_{MEAN} + \sqrt{2}\, \sigma_{TEMP}$ (J.Schmetz et al. 1996).

4. *Tracking*: given a set of tracers for a HRVIS region at "t-Δt slot", tracking areas of the same size are defined at "t slot" to match tracking candidates. To reduce the tracking area, it is defined through the extrapolation of linearly interpolated NWP forecast wind profiles, up to a configurable distance.
   Two well known methods are used for this process: pixel euclidean difference (for big tracers) and cross correlation (for small tracers at a finer scale). The best three (configurable) tracking centres are kept, to perform a final selection step at the Quality Control process.

5. *Quality Control*: the Quality Indicator Method, developed at Eumetsat for AMV calculation at MPEF (K.Holmlund 1998), has been adapted for HRW product. Several consistency tests are if possible computed, considering:
    - Vector/direction/speed consistency with AMVs in the previous slot (Temporal test).
    - Vector consistency with neighbour AMVs (Spatial test).
    - Vector consistency with NWP forecast winds (Guess test).
    - Vector consistency with simultaneous Basic winds (Two scale test, only Detailed winds).

   An individual Quality Index (QI) is calculated for each Quality test, with the normalized statistical fitting functions described by the method. An overall Quality Index is calculated as the average sum of partial QI. A double contribution of spatial test is included: as it is shown later, it is the most significant test.

6. *AMV Selection*: a Comparison Flag is assigned to AMVs, when more than an AMV is available per tracer. These flags are used for final AMV Selection, where only one AMV per tracer can be kept. Five different flags are calculated:
    - From AMV calculation process: Tracking correlation flag.
    - From Quality control process: Temporal, Spatial, Guess flags.
      Two scale flag also for Detailed winds.

   Possible flag values are:
    - 3: when the AMV is the best of all for the corresponding tracer and criterion.
    - 2: when the AMV is slightly worse than others for the corresponding tracer and criterion.
    - 1: when the AMV is rather worse than others for the corresponding tracer and criterion.
    - 0: when the comparison flag could not be calculated for the AMV.

   The selection criterion is based on the AMV with best overall Comparison Flags. In case of draw, the AMV with best Guess Flag is selected, or else the AMV with best Tracking Correlation Flag.

HIGH RESOLUTION WINDS PRODUCT EVOLUTION

After a Product Development Phase (1997 – 2002), SAFNWC Initial Operations Phase was defined for the period 2002 – 2007. Few months after the first operational MSG1 data were available in January 2004, the first official HRW Product version was released (Spring 2004). The current operative version is v1.2, available since Spring 2005. Scientific validation and definition of new requirements by the users are based on this version.

Next version will be HRW v2.0, to be released in Summer 2006. It will include a thorough optimization of the software, that will allow to run HRW in big geographical areas. Comparing running times, HRW v2.0 process lasts 3-4 minutes over a region covering all Europe and the Mediterranean, while HRW v1.2 process lasts 3-4 minutes over a region of only 20x20 degrees of latitude and longitude (running times for a Sunblade 1500 MHz platform). Examples of both versions are shown in Figures 1 and 2 in the next page.

An Orographic Flag will also be included in v2.0 for a better treatment of land influence at low layers. It will be related to the detection of land tracers, tracers blocked by orography and orographic waves. The algorithm will calculate for a geographical box of 1x1 degrees of latitude and longitude around each tracer its medium and maximum representative heights (50th and 97th centiles of the height histogram), and will do a barometric conversion to pressure with NWP data to calculate the medium and maximum representative pressures. With these data, the possible values of the Orographic Flag will be:

1: The tracer pressure is below the mean representative pressure of its geographical box (a very significant orography influence is expected, or a land tracer has been found).

2: The tracer pressure is below the level defined to be without orographic influence: maximum representative pressure plus 25 hPa (a less significant orography influence is expected).

Else, if vertical stability is found at the tracer location and speed is at least 5 m/s, previous positions of the tracer up to two hours are calculated with the AMV trying to find if it corresponds to an orographic wave. With these conditions, other possible Orographic Flag values are:

3: An obstacle has been found against the flux, when the tracer pressure is below the level defined to be without orographic influence at any of its previous positions (possible orographic wave).

4: No obstacle has been found, but stability condition is still present at all previous positions (the obstacle might be further).

In any other case, the value of Orographic Flag will be:

5: No orographic influence has been found.

After HRW version v2.0, a Continuous Development and Operations Phase is to be established for the period 2007 – 2012. Some hints on future work for later versions are:

- Reduction of the current dependence of HRW algorithm on model data. SAFNWC Cloud Type and Cloud Top Height products will be studied as input for height assignment.
- Adaptation of algorithm to MSG IR channels, permitting night-time AMV calculation. This is a user requirement, who consider this necessary for nowcasting tasks.
- Validation against datasets with a higher spatial density, as wind profiles from Doppler radar.

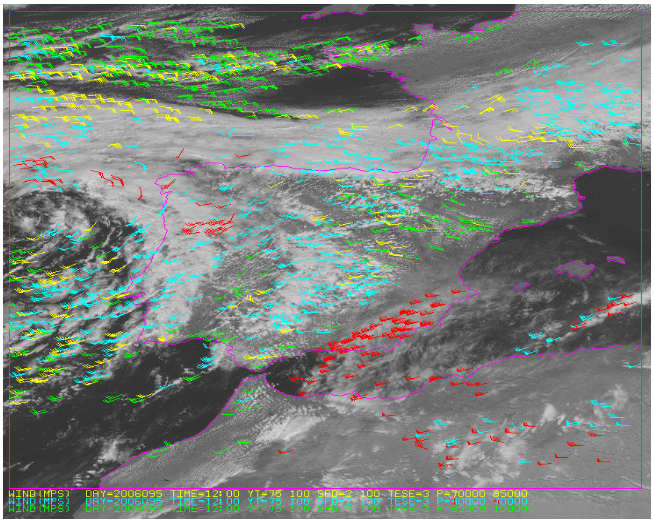

Figure 1: **HRW v1.2 / SAFNWC Helpdesk HRW Region (05 Apr 2006, 1200Z; QI≥75; Spatial test=3; Speed≥*2* m/s)**
Layer Colours: 100 – 400 hPa 400 – 700 hPa 700 – 850 hPa 850 – 1000 hPa
(Live examples available at SAFNWC Helpdesk Webpage: http://nwcsaf.inm.es)

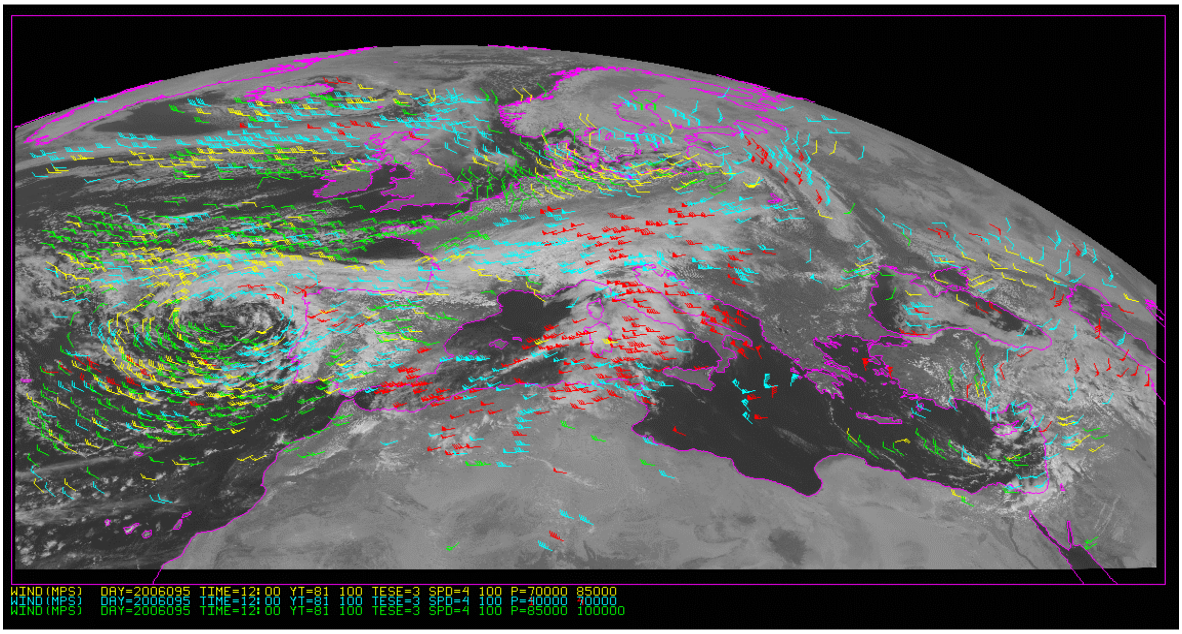

Figure 2: **HRW v2.0 / Europe and Mediterranean Region (05 Apr 2006, 1200Z; QI>80; Spatial test=3; Speed ≥ 4 m/s)**
Layer Colours: 100 – 400 hPa 400 – 700 hPa 700 – 850 hPa 850 – 1000 hPa

HIGH RESOLUTION WINDS PRODUCT VALIDATION

The Product Validation is based on the comparison of the 1200Z HRW v1.2 output with radiosounding winds. It has covered the SAFNWC Helpdesk HRW Region (an area centred in the Iberian Peninsula, shown in Figure 1) during one year (March 2005 - February 2006). Its objective has been to calculate the statistical indicators defined at International Winds Workshops for satellite wind validation.

Validation is made with the nearest radiosounding, considering only cases where distance is less than 150 km and pressure difference is less than 25 hPa). Results are computed for both Basic and Detailed winds, for three different atmospheric layers: High (< 400 hPa), Medium (400 – 700 hPa), Low (> 700 hPa).

The statistical parameters are the ones defined at IWW Ascona Meeting: NC (Number of collocations), SPD (Mean radiosounding speed), BIAS (Mean speed difference between AMVs and radiosoundings), MVD (Mean vector difference), RMSVD (Root mean square vector difference). Normalized parameters (BIAS/SPD, MVD/SPD, RMSVD/SPD: more easily comparable considering different samples) and Correlation between speeds have also been considered.

<u>General distribution of wind speeds.</u>

Scatter plots show an adequate data distribution. Correlation with radiosoundings is better for Detailed winds (0.80 against 0.76 for Basic winds with Quality Index > 80%), maybe due to the greater amount of data. Comparing layers, the best results are obtained at the High layer; the worst at the Low layer. In all cases, the effects of the negative BIAS (with population maxima at the left of diagonal) and of blocked/ground tracers (with part of the population concentrated on the vertical axis) are visible.

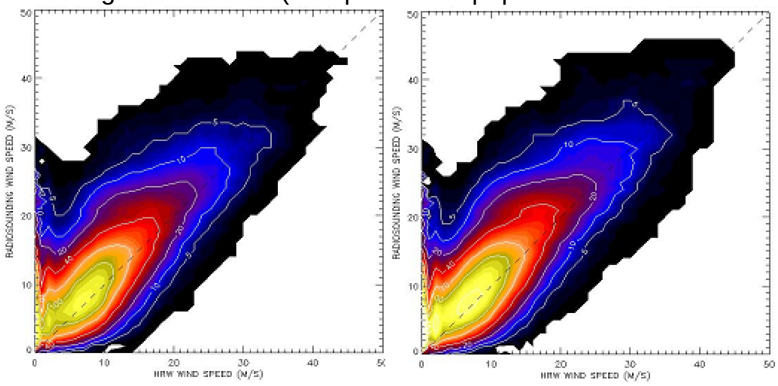

Figure 3: **Scatterplots of Basic and Detailed HRW speeds against Radiosounding speeds (Quality index > 80%)**

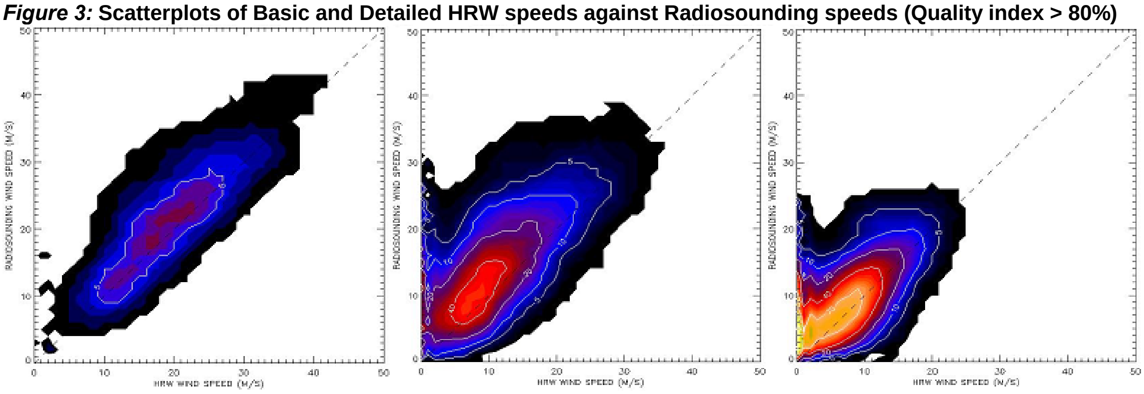

Figure 4: **Scatterplots of Basic HRW against Radiosounding (High, Medium and Low layers; Quality index > 80%)**

The influence of several parameters on validation results has also been studied, to define the filters that should be used operationally to get the best results with the product. The study about this influence was made for the NWCSAF Product Assessment Review Workshop in Autumn 2005, with HRW data up to September 2005. The parameters are:

Quality Index:

MVD, RMSVD and Correlation have clearly better values when the Quality index threshold (QIThr.) is higher. Reductions in RMSVD are about 2-3 m/s when QIThr. changes from 60% to 90%; about 1-2 m/s when it changes from 60% to 80%. BIAS improves only when QIThr. > 80%. Below this value, values are even a bit worse when QIThr. increases up to 80%.

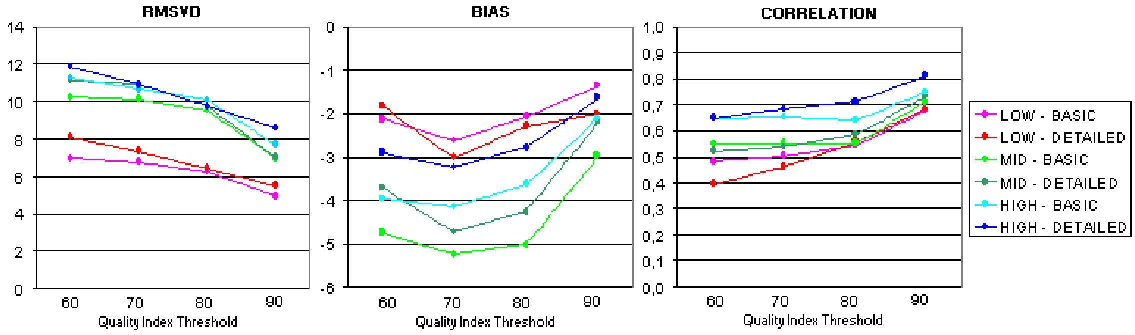

Figure 5: **Dependence of RMSVD, BIAS and Correlation on the Quality Index Threshold (High, Medium and Low Layers; Basic and Detailed Winds)**

With these results, the criterion to define an operative Quality index threshold would be the proportion of the AMV population that is kept. Comparing with QIThr. = 60, QIThr. = 90% keeps 1 out of 20 winds; QIThr. = 80% keeps 1 out of 3 winds; QIThr. = 75% keeps 1 out of 2 winds. Taking the value QIThr. = 80%, the reduction of population can be fairly compensated using both Basic and Detailed wind datasets.

Comparison Flags:

BIAS and RMSVD reduce significantly when the Spatial Flag is higher. BIAS reduces also when the Two Scale Flag is higher. No significant influence on validation has been found in other flags.
One recommendation can be extracted for operational purposes reducing only slightly the population: to use only HRW AMVs with Spatial Flag = 3.

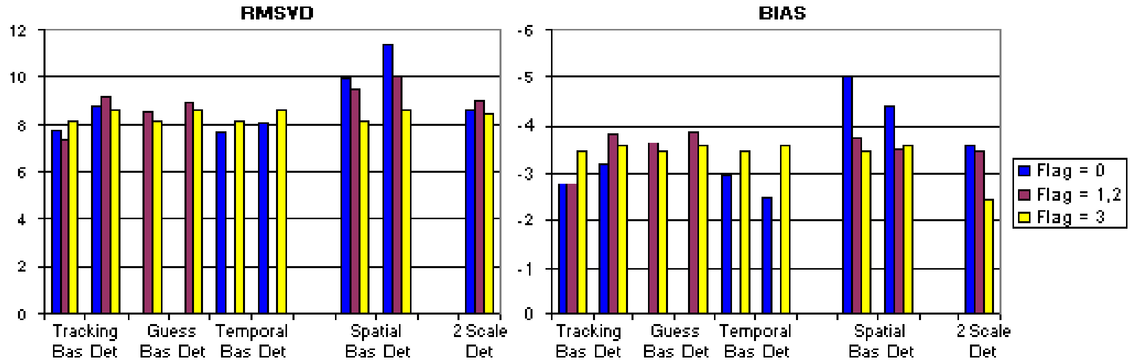

Figure 6: **Dependence of RMSVD and BIAS on the different Comparison Flag values (Tracking Correlation, Guess, Temporal, Spatial, Two Scale Flags; Basic and Detailed Winds)**

Atmospheric Levels:

The variation of statistical parameters with height has been studied to know where level assignation may be having problems. Comparison has been made with the normalized parameters due to the differences in speed magnitude.
The high layer is the best one, with the best values in Correlation, RMSVD/SPD and BIAS/SPD. The worst results occur between 550-750 hPa (where the worst values of BIAS/SPD, and relatively worse values of Correlation and RMSVD/SPD occur), and below 925 hPa (where the worst values of Correlation and RMSVD/SPD occur, although in this case BIAS/SPD tends to zero). The first layer is the objective one for the height assignment improvement. Errors in the second one are related to land effects: the Orographic Flag is expected to improve these results.

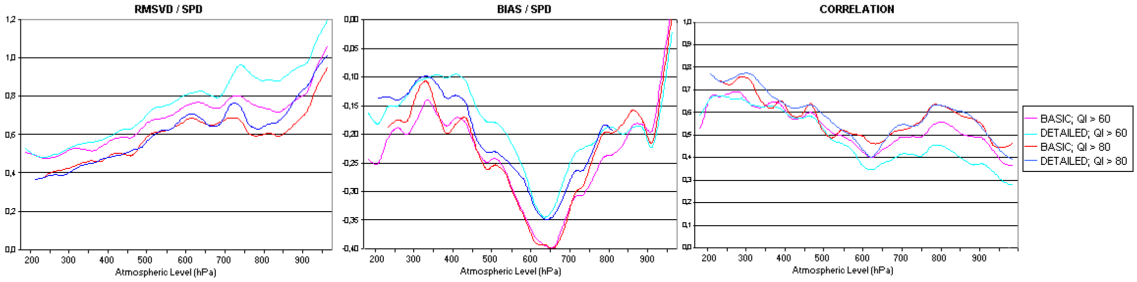

Figure 7: **Dependence of RMSVD/SPD, BIAS/SPD and Correlation on the Atmospheric levels (Quality index thresholds 60% and 80%; Basic and Detailed Winds)**

Speed Modulus:

Statistical parameters are best for speed values 4-29 m/s. Below these values, RMSVD doubles and BIAS doubles or triples when speed tends to zero (effect of blocked tracers); RMSVD doubles but BIAS becomes positive for speeds over 30-40 m/s (an effect that might be related to fast winds corresponding to thin cirrus, but incorrectly assigned to lower levels).
A 4 m/s speed threshold is recommended to avoid blocked tracers; a 2 m/s speed threshold avoids a great proportion of them without reducing excessively data population.

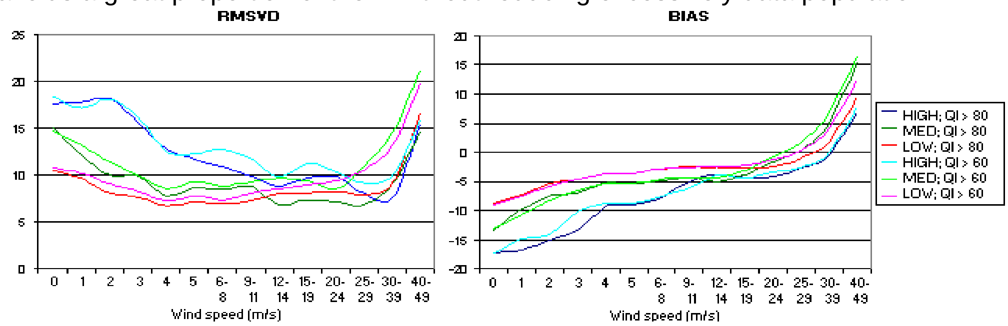

Figure 8: **Dependence of RMSVD and BIAS on the Speed Modulus (Quality index thresholds 60% and 80%; High, Medium and Low Layers; Basic and Detailed Winds)**

Orography:

The best values of RMSVD, BIAS and Correlation are reached in sea and low plain areas. The worst values in mountain areas, specially at low levels. Differences between both regions are at least 3 m/s for RMSVD and BIAS. Values in Correlation range from 0.2-0.4 in the Alps, Pyrenees and Northern Spain mountains to 0.6-0.9 in most of remaining areas. With these results, there is another hint showing that the Orographic Flag can have a positive impact on statistical results.

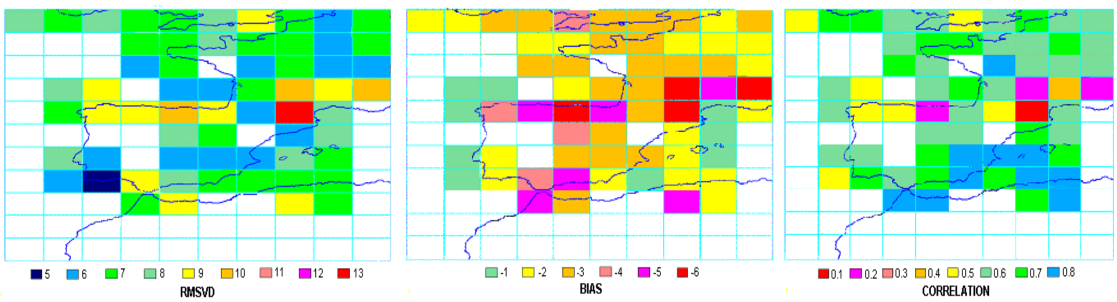

Figure 9: **Dependence of RMSVD, BIAS and Correlation on Orography (Basic Winds, All layers, QI > 60%) Only geographical boxes with a significant amount of data are represented (at least 30 collocations). A lower Quality Index Threshold has been taken to increase the number of significant values.**

Validation results.

Three different recommendations have been taken for the operational product validation from the parameter influence study: Quality index > 80%, Speed > 2 m/s, Spatial flag = 3. They have been applied to validation tables, computed on a seasonal and yearly basis for the whole validation period.

	BASIC WINDS	SPRING 2005	SUMMER 2005	AUTUMN 2005	WINTER 2005-06	MAR 05-FEB 06
HIGH LEVELS	NC	421	352	595	488	1856
	SPD	22.17	24.33	24.73	28.26	25.00
	MVD	7.71	7.79	8.92	8.53	8.33
	RMSVD	9.88	9.33	11.36	11.30	10.66
	RMSVD/SPD	0.45	0.38	0.46	0.40	0.43
	BIAS	-3.82	-3.69	-2.47	-2.70	-3.07
MID LEVELS	NC	1891	1253	1432	2094	6670
	SPD	15.71	15.31	15.77	16.56	15.91
	MVD	6.57	6.53	7.68	7.39	7.06
	RMSVD	8.08	7.88	9.65	9.11	8.73
	RMSVD/SPD	0.51	0.52	0.61	0.55	0.55
	BIAS	-3.79	-3.50	-2.65	-2.59	-3.12
LOW LEVELS	NC	1203	1026	1140	1725	5094
	SPD	9.77	9.18	9.51	11.30	10.11
	MVD	4.41	4.55	5.26	5.03	4.84
	RMSVD	5.40	5.65	6.63	6.32	6.06
	RMSVD/SPD	0.55	0.62	0.70	0.56	0.60
	BIAS	-0.87	-1.28	-1.30	-1.41	-1.23
ALL LEVELS	NC	3515	2631	3167	4307	13620
	SPD	14.45	14.12	15.20	15.77	14.98
	MVD	5.96	5.93	7.05	6.57	6.40
	RMSVD	7.53	7.33	9.07	8.42	8.16
	RMSVD/SPD	0.52	0.52	0.60	0.53	0.54
	BIAS	-2.80	-2.66	-2.13	-2.13	-2.41

	DETAILED WINDS	SPRING 2005	SUMMER 2005	AUTUMN 2005	WINTER 2005-06	MAR 05-FEB 06
HIGH LEVELS	NC	572	465	542	576	2155
	SPD	24.70	24.02	24.83	28.37	25.57
	MVD	8.13	8.26	8.76	8.74	8.48
	RMSVD	10.21	10.48	10.99	11.23	10.75
	RMSVD/SPD	0.41	0.44	0.44	0.40	0.42
	BIAS	-3.63	-2.80	-2.54	-2.45	-2.86
MID LEVELS	NC	1879	1189	1285	2013	6366
	SPD	15.97	15.22	15.82	16.89	16.09
	MVD	6.73	6.71	7.71	7.64	7.21
	RMSVD	8.31	8.19	9.67	9.51	8.97
	RMSVD/SPD	0.52	0.54	0.61	0.56	0.56
	BIAS	-3.50	-2.89	-2.76	-2.44	-2.90
LOW LEVELS	NC	1217	1009	1023	1577	4826
	SPD	9.77	8.74	9.67	11.36	10.05
	MVD	4.72	4.83	5.22	5.18	5.00
	RMSVD	5.87	6.08	6.58	6.49	6.27
	RMSVD/SPD	0.60	0.70	0.68	0.57	0.62
	BIAS	-1.08	-0.99	-1.41	-1.25	-1.19
ALL LEVELS	NC	3668	2663	2850	4166	12247
	SPD	15.27	14.30	15.33	16.38	15.44
	MVD	6.28	6.27	7.01	6.86	6.62
	RMSVD	7.94	7.94	8.98	8.78	8.44
	RMSVD/SPD	0.52	0.56	0.59	0.54	0.55
	BIAS	-2.72	-2.15	-2.24	-1.99	-2.28

Figure 10: **Validation tables for HRW Product (Quality Index > 80%; Speed > 2 m/s; Spatial flag = 3) Results for Basic and Detailed Winds, March 2005 to February 2006.**

In general, RMSVD/SPD values range from 0.60 at the low layer to 0.42 at the high layer. BIAS values range from –1 m/s at the low layer to –3 m/s at the medium and high layers. There are no significant differences between Basic and Detailed winds. Comparing HRW v1.2 Validation Statistics with Eumetsat HRVIS Wind Statistics, results are similar at the high layer, or worse but anyhow of the same order at the medium and low layers. The main reason for these differences may be that the HRW geographical validation area has an important proportion over land with various mountain systems (orography has been seen to play an important role in validation results). HRW v2.0 will allow to run the product over all Europe, which in whole is less affected by orography (permitting a more direct comparison of results).

In spite of the differences, it is important to recall HRW advantages: AMVs are calculated locally by the users few minutes after MSG data are received (in the area and conditions they need), every 15 minutes with a bigger density of data. Considering a more exigent data filtering, validation results are even better with a still very significant amount of data. With these results, HRW Product can be very useful for nowcasting and assimilation tasks.

SAFNWC SOFTWARE DISTRIBUTION POLICY

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

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García Pereda J., 2005: Validation Report for the PGE09 of the SAFNWC/MSG (SAFNWC Document SAF/NWC/IOP/INM/SCI/VAL/05).

(Both documents are available at SAFNWC Website User Area; they can be requested to the authors in case of need).