NWCSAF/MSG Winds Product: High Resolution Winds (HRW, PGE09)

NWC SAF

Support to Nowcasting and Very Short Range Forecasting

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Characteristics & Improvements at HRW v3.0

- NWCSAF/MSG package includes High Resolution Winds product (HRW, PGE09), which provides detailed sets of MSG Satellite winds (Atmospheric Motion Vectors, AMVs) for near realtime applications:
  - Watch & warning of dangerous strong wind situations.
  - Monitoring of low level convergences/high level divergences, related to convective cloud formation.
  - Monitoring of small scale circulation and other wind singularities.
  - HRW data assimilation in Regional/Mesoscale NWPs.
  - HRW data assimilation (considering wind vectors or derived wind fields) in other Nowcasting and Short range forecasting applications.

Characteristics & Improvements at HRW v3.0

- **Main steps of HRW algorithm:**
  - Tracer calculation with two different methods: Gradient, Tracer characteristics.
  - Height assignment with one of two different levels: Cloud top, Cloud base (dependent on the SAFNWC/Cloud Type).
  - Tracer tracking/Wind calculation with selection of up to three correlation centres through Euclidean differences or Cross correlation methods.
  - Quality control: using Eumetsat Quality Indicator method.
  - Orographic flag test: tracers affected by land influence are rejected.

- MSG/HRVIS & MSG/IR108 winds calculated consecutively, if requested by the user.

- Output: Up to two BUFR bulletins, with AMVs related to two different tracer scales:
  -"Basic winds": Tracer size: 24 pixels. -"Detailed winds": Tracer size: 12 pixels.

  (HRVIS & IR108 winds included in the same BUFR bulletin, differentiable by parameter WCH: Wind channel).

Characteristics & Improvements at HRW v3.0

- The new version HRW v3.0 (included in NWCSAF v2010) is a very important step forward in the product:
  - AMVs are calculated 24h a day from both MSG/HRVIS & MSG/IR108 channels
    > Possibility of monitoring winds/fluxes without night intermittencies (as required by the users in previous meetings/surveys).
  - HRW v3.0 has been optimized
    > Calculation of AMVs in both channels (HRVIS & IR108) in ~2 min. in National & Continental areas (under linux environment) increasing the number of AMVs by a factor ~2.5 respect to HRW v2.2.
  - HRW v3.0 has also been adapted to work in 'Rapid scan mode'.
    > Possibility of calculation of new AMVs every five minutes with every MSG 'Rapid scan slot' in 'National areas', increasing the number of AMVs by a factor ~3 respect to 'Nominal mode' with a similar quality.

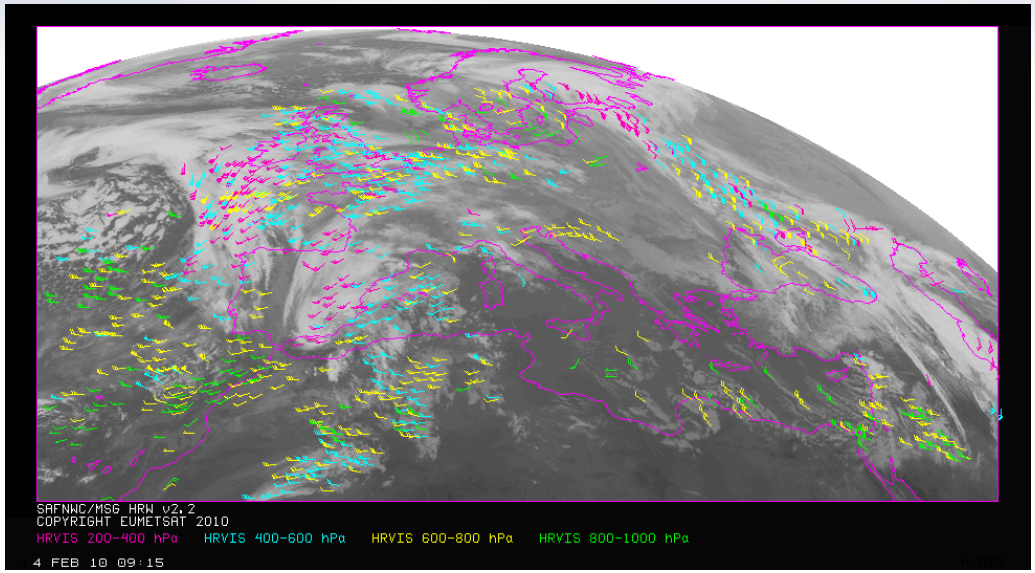
Characteristics & Improvements at HRW v3.0

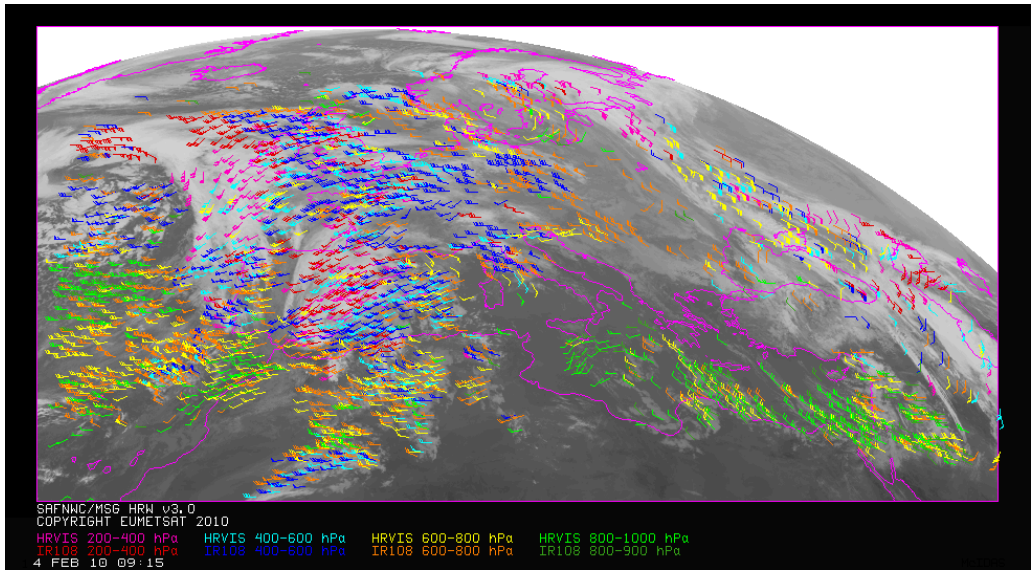
Example of evolution between HRW v2.2 & v3.0 (Nominal mode, European & Mediterranean area)

1. The increase in the number of available AMVs (~2.5 times respect to HRW v2.2) is clearly visible in the images.

2. The most important difference is during nighttime, where AMVs are available with the new IR108 winds and discontinuities dissapear.

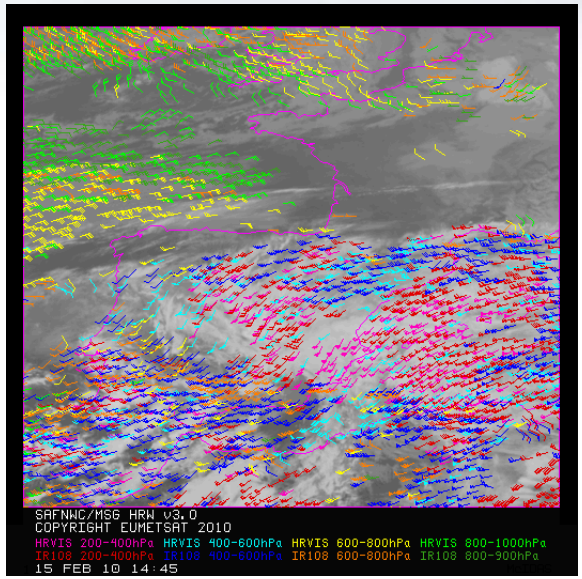
3. HRVIS & IR108 AMVs complement each other, giving information about different cloud patterns:
> Because of this, the frequency of AMV holes in cloudy areas of the images is smaller.

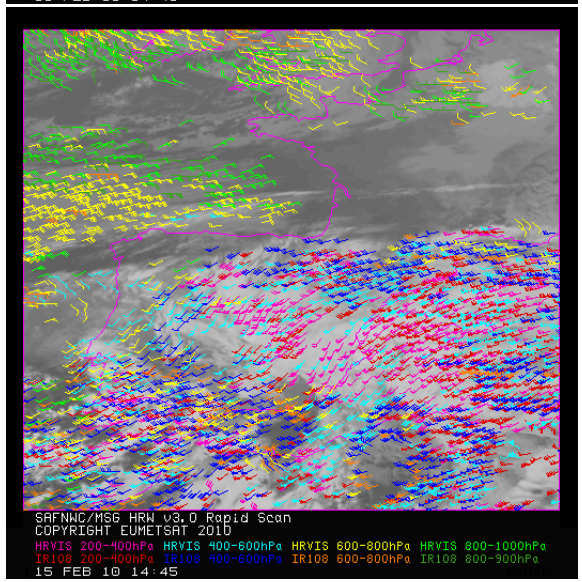




Characteristics & Improvements at HRW v3.0

Example of HRW v3.0 outputs in "Nominal mode" and "Rapid scan mode" (Spanish National area)





Conditions defined for "Rapid scan mode" (later shown):

- A 10 minute time difference between the initial tracer image and the later tracking image.
- The possibility to rerun HRW algorithm with every new MSG slot every five minutes in 'National areas'.

Main differences between "Nominal mode" and "Rapid scan mode" configurations:

- The amount of winds every 15 minutes is:
  - Multiplied by 3.5 (for HRVIS case)
  - Multiplied by 2.5 (for IR108 case), with a similar quality.
- Considering each image, there is an increase in the amount of HRVIS winds and a slight decrease in the amount of IR108 winds respect to "Nominal scan".

Effect of the time difference between tracer and tracking images in 'Rapid scan mode'

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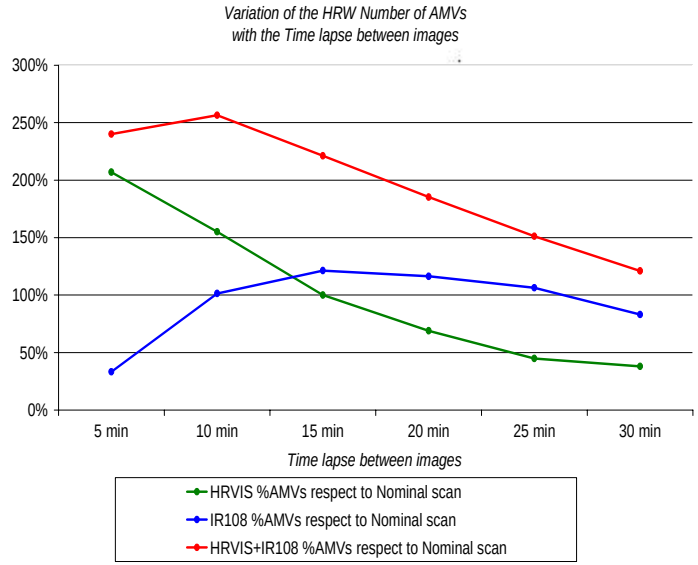
Considering the number of calculated winds:

- In the HRVIS case (green line), there is a progressive increase in the amount of winds with smaller time differences between tracer & tracking images.

- In the IR108 case (blue line), the maximum amount of winds occurs with a time difference of 15 minutes, with reductions over and below this value.

  > Necessarily related to the different pixel resolution of both channels: HRVIS resolution good enough to detect the displacement of slow moving structures in 5 minutes; IR108 resolution not so much.



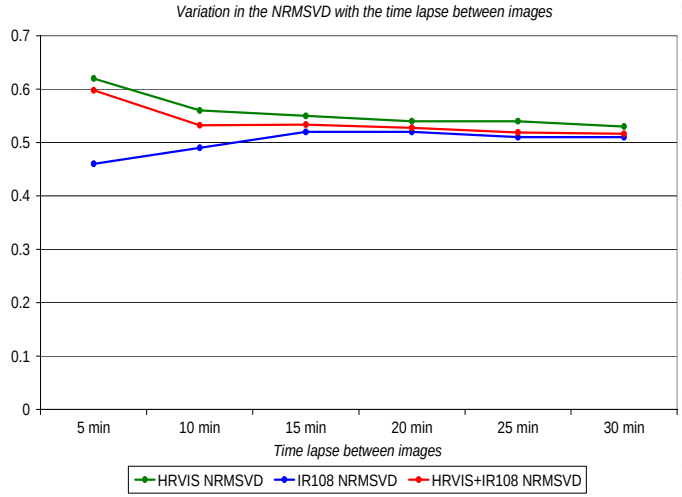
Considering together both datasets (HRVIS & IR108, red line), the maximum amount of calculated winds occurs with a time difference of 10 minutes.

Effect of the time difference between tracer and tracking images in 'Rapid scan mode'

Considering the RMSVD, there are small variations with the time difference between tracer and tracking images:

- Between 10 and 30 minutes the variations are minimal: smaller than a 4% in the composite dataset.

- For a 5 minute value, the variation is more visible, with an increase in the HRVIS RMSVD and a decrease in the IR108 RMSVD.
  > Due to the higher proportion of the HRVIS winds in the composite, their effect is more important and the RMSVD is a 12% bigger in the composite population.



Considering these two behaviours in the composite population: the time difference of 10 minutes between initial tracer and final tracking image is considered the best for the calculation of AMVs in 'Rapid scan mode'.

Validation of HRW v3.0 algorithm

- A validation procedure during the period April-December 2009 in the 'Europe & Mediterranean region' (950x1850 pixels centered in 39ºN/12ºE), has been done for a parallel comparison of:
  - HRVIS & IR108 "Nominal mode" winds.
  - HRVIS & IR108 "Rapid scan mode" winds.

- The effect of several parameters in the validation has been included in the study:
  - Atmospheric Level.
  - Orographic Flag.
  - Cloud type.

Effect of the Atmospheric level on validation

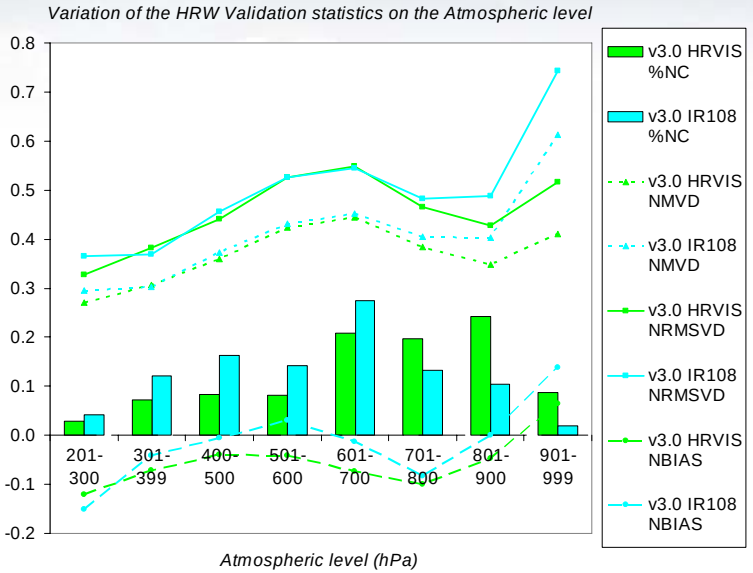
Behaviour of 'Nominal mode' and 'Rapid scan' HRVIS & IR108 winds, considering the Atmospheric level:

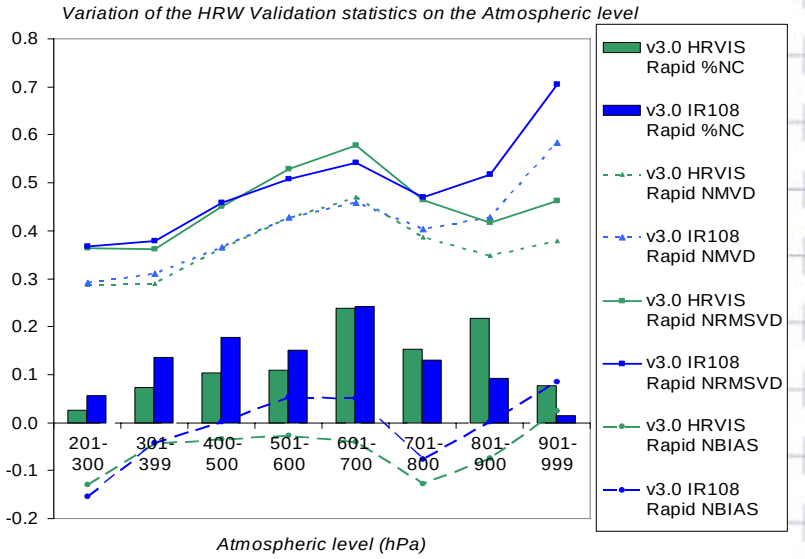
> Bigger proportion of IR108 winds in high/medium layer, and bigger proportion of HRVIS winds in low layer.
  - They tend to give information about different levels and complement each other, as shown in the images.

> Better BIAS in general for IR108 winds (blue lines).

> Few differences in MVD/RMSVD between 200-800 hPa, and better behaviour of HRVIS winds (green lines) in the other layers.
  - IR108 winds in the lowest layer (>900 hPa) so bad and so few, that are recommended to be eliminated.

Few differences between 'Nominal mode' and 'Rapid scan mode' winds.





Effect of the Orographic flag on validation

Different filterings have been defined on 'HRW orographic flag' for 'Nominal scan' and 'Rapid scan' winds:

> In 'Nominal scan', all HRVIS & IR108 winds without geographical obstacles in their vicinity (Orogr.flag≠1,2) are recommended to be kept.

> In 'Rapid scan', only HRVIS & IR108 winds without geographical obstacles in their vicinity and trajectory (Orogr.flag≠0,1,2,3) are recommended to be kept.

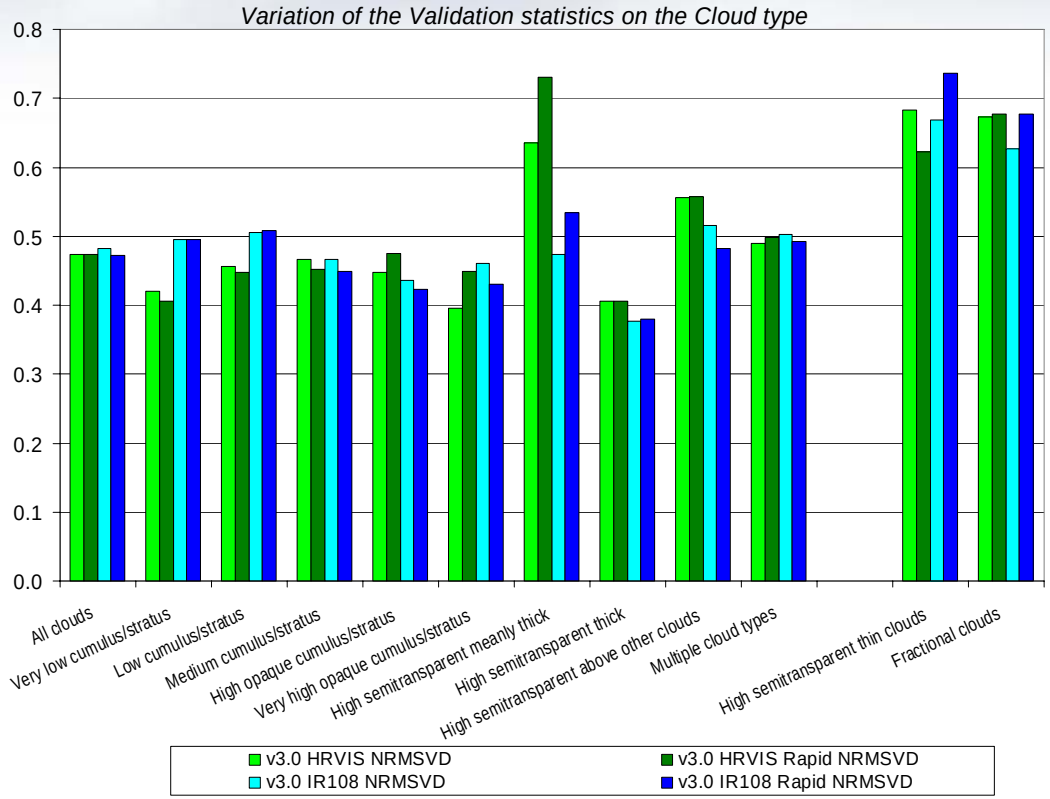
> Eliminated data conform less than a 4% of the total with much worse validation parameters (MVD and RMSVD 50%-100% higher).

Orographic parameter is a powerful tool to eliminate bad winds in all cases.

PGE09 v3.0 (Nominal scan mode winds) Apr-Dec 2009, European & Mediterranean area	Orogr. Flag = 1,2	Orogr. Flag = 0,3,4,5
Number of collocations - HRVIS winds	1000	36858
Mean Speed - HRVIS winds	7.40	13.85
Normalized Bias - HRVIS winds	0.32	-0.07
Normalized Mean Vector Difference - HRVIS winds	0.78	0.37
Normalized Root Mean Square Vector Difference - HRVIS winds	0.95	0.47
Number of collocations - IR108 winds	381	44705
Mean Speed - IR108 winds	7.55	15.84
Normalized Bias - IR108 winds	0.13	-0.02
Normalized Mean Vector Difference - IR108 winds	0.74	0.39
Normalized Root Mean Square Vector Difference - IR108 winds	0.88	0.48

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	1631	42874
Mean Speed - HRVIS winds	8.43	14.01
Normalized Bias - HRVIS winds	0.05	-0.07
Normalized Mean Vector Difference - HRVIS winds	0.57	0.38
Normalized Root Mean Square Vector Difference - HRVIS winds	0.72	0.47
Number of collocations - IR108 winds	706	36669
Mean Speed - HRVIS winds	10.38	17.19
Normalized Bias - IR108 winds	0.14	-0.01
Normalized Mean Vector Difference - IR108 winds	0.69	0.39
Normalized Root Mean Square Vector Difference - IR108 winds	0.82	0.47

Effect of the Cloud type on validation

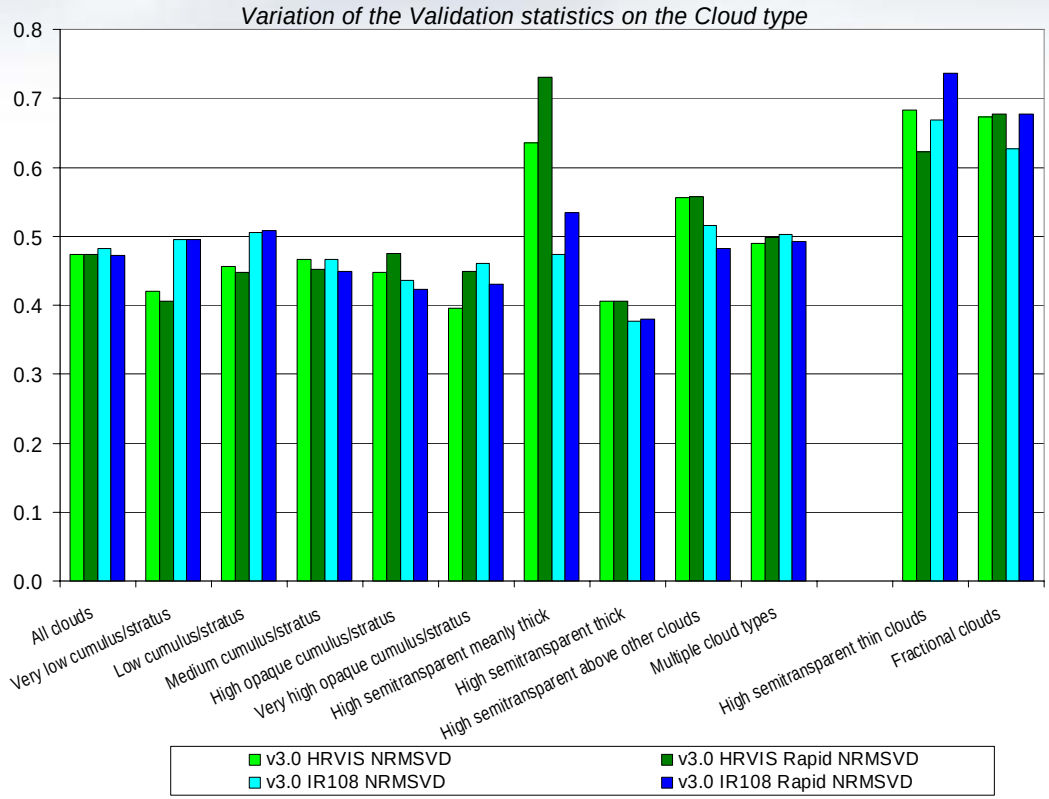


All SAFNWC/Cloud types admitted in HRW winds except:

- "Fractional clouds" and "High semitransparent thin clouds" for HRVIS and IR108 winds.
- "High semitransparent meanly thick clouds" for HRVIS winds.

Semitransparency corrections still not implemented (hopefully in the next HRW versions), but the algorithm is capable of identifying and eliminating AMVs related to problematic Cloud types.

Effect of the Cloud type on validation



Comparing results between HRVIS & IR108 winds:

> **Stat.parameters better for HRVIS winds with "Very low and low cumulus/stratus", better seen in the visible.**

> **Stat.parameters better for IR108 winds with "High semitransparent thick and meanly thick clouds, and over other clouds", more clearly seen in the infrared.**

Validation of HRW v3.0 algorithm (HRVIS winds)

Comparison of HRW v3.0 HRVIS AMVs ("Nominal mode" and "Rapid scan") with HRW v2.2 AMVs, considering the default configurations:

1. **Validation statistics (NBIAS, NMVD, NRMSVD) better for HRW v3.0 HRVIS winds than for HRW v2.2 winds, for both "Nominal mode" & "Rapid scan" (with few differences among them).**

2. **Improvements in NMVD / NRMSVD greater at the low level (~10%); smaller at the high/medium levels (up to a 5%).**

3. **Increases in the amount of HRVIS AMVs per slot, specially considering "Rapid scan mode".**

PGE09 v2.2: HRVIS Nominal scan mode winds (April – December 2009)	All levels	High levels	Med. levels	Low levels
Number of collocations (NC)	32730	3412	12311	17007
Mean radiosounding Speed (SPD)	13.49	25.57	14.55	10.30
Normalized Bias (NBIAS),	-0.09	-0.10	-0.10	-0.07
Normalized Mean Vector Difference (NMVD)	0.39	0.30	0.42	0.41
Normalized Root Mean Square Vector Difference (NRMSVD)	0.50	0.38	0.52	0.50

Validation for PGE09 v2.2 HRVIS Nominal scan mode winds
(QI>83; Pressure[hPa] ∈(200,1000); Orographic flag≠1,2; Cloud type≠1,2,3,4,15,19)

PGE09 v3.0: HRVIS Nominal scan mode winds (April – December 2009)	All levels	High levels	Med. 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 PGE09 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)

PGE09 v3.0: HRVIS Rapid scan mode winds (April – December 2009)	All levels	High levels	Med. 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 PGE09 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 lapse=10 min)

Validation of HRW v3.0 algorithm (IR108 winds)

Considering HRW v3.0 IR108 AMVs ("Nominal mode" and "Rapid scan"), with the default configurations:

1. **Validation statistics** (NBIAS, NMVD, NRMSVD) **for HRW v3.0 IR108 winds similar to HRW v2.2 winds, for both "Nominal mode" & "Rapid scan"** (with few differences among them), but slightly larger than for HRW v3.0 HRVIS winds.

2. The **amount of HRW v3.0 IR108 AMVs** is ~20% greater than HRVIS AMVs in "Nominal mode" and ~15% smaller in "Rapid scan mode".

3. The **differences in Validation between the four types of HRW v3.0 winds is so small**, that they can be considered data of similar quailiy.

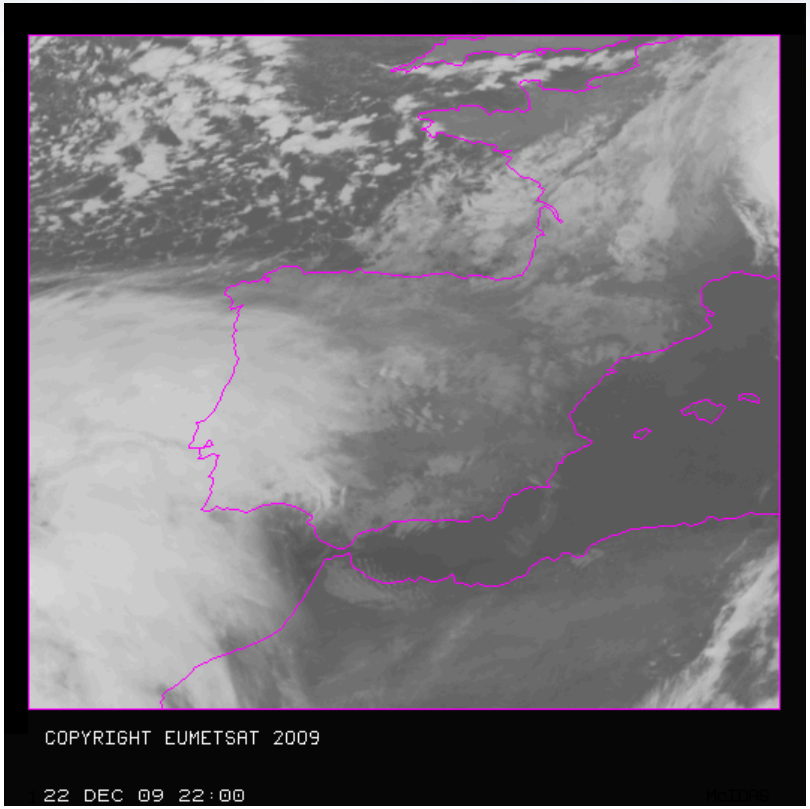
PGE09 v3.0: IR108 Nominal scan mode winds (April – December 2009)	All levels	High levels	Med. levels	Low levels
Number of collocations (NC)	44705	6807	24312	13586
Mean radiosounding Speed (SPD)	15.84	24.55	15.75	11.63
Normalized Bias (NBIAS),	-0.02	-0.07	-0.00	-0.03
Normalized Mean Vector Difference (NMVD)	0.39	0.30	0.42	0.43
Normalized Root Mean Square Vector Difference (NRMSVD)	0.48	0.37	0.51	0.51

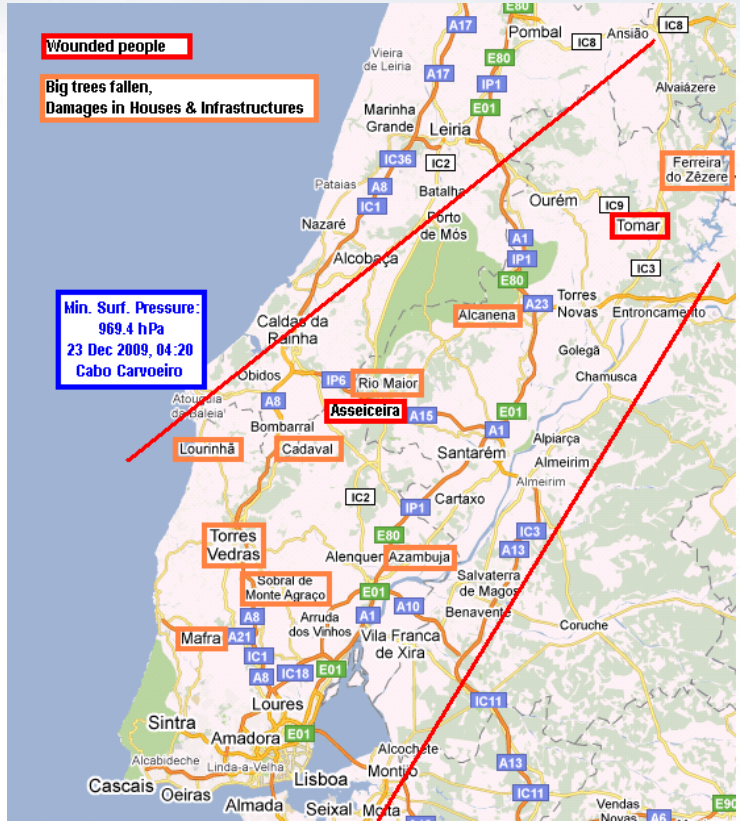
Validation for PGE09 v3.0 IR108 Nominal scan mode winds
(QI>83; Pressure[hPa] ∈(200,900]; Orographic flag≠1,2; Cloud type≠1,2,3,4,15,19)

PGE09 v3.0: IR108 Rapid Scan mode winds (April – December 2009)	All levels	High levels	Med. 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 PGE09 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 lapse=10min)

22-23 Dec. 2009 Rapid Cyclogenesis in Portugal

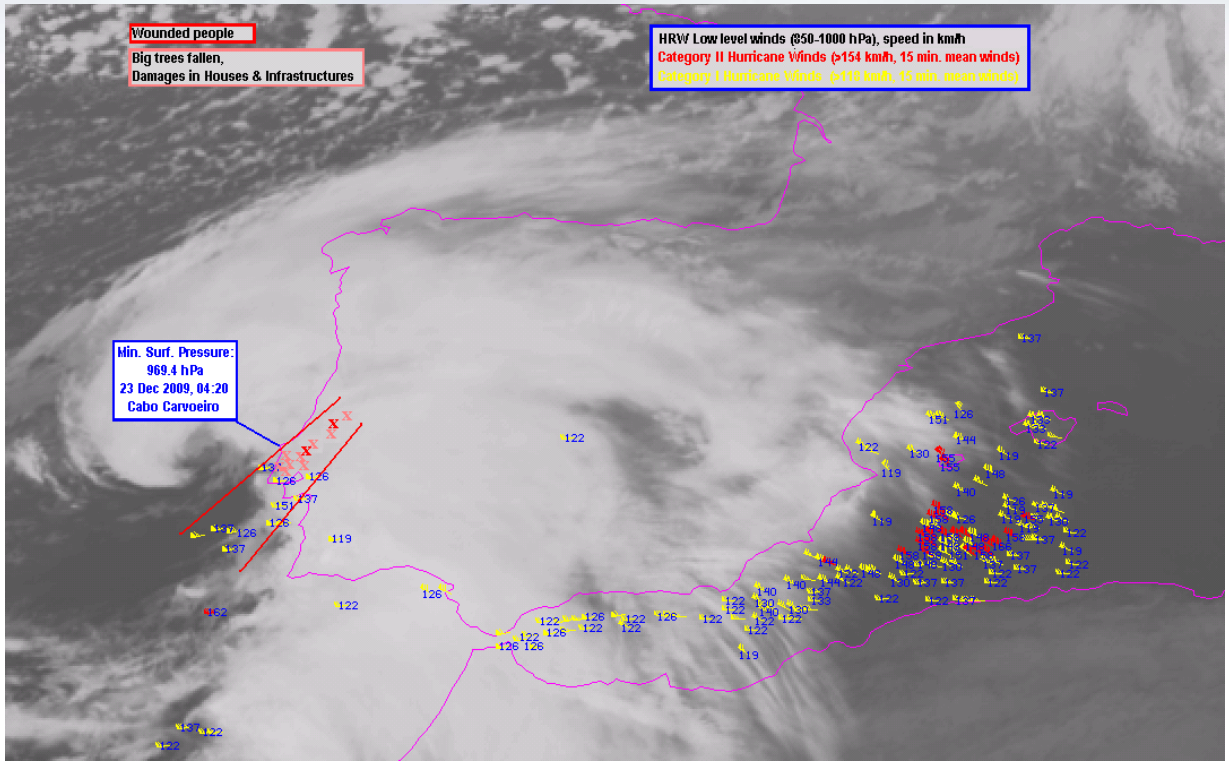




A rapid cyclogenesis coming from the Atlantic and entering Portugal during the night 22-23 December 2010 (with deepening stronger than 20 hPa/24 h),

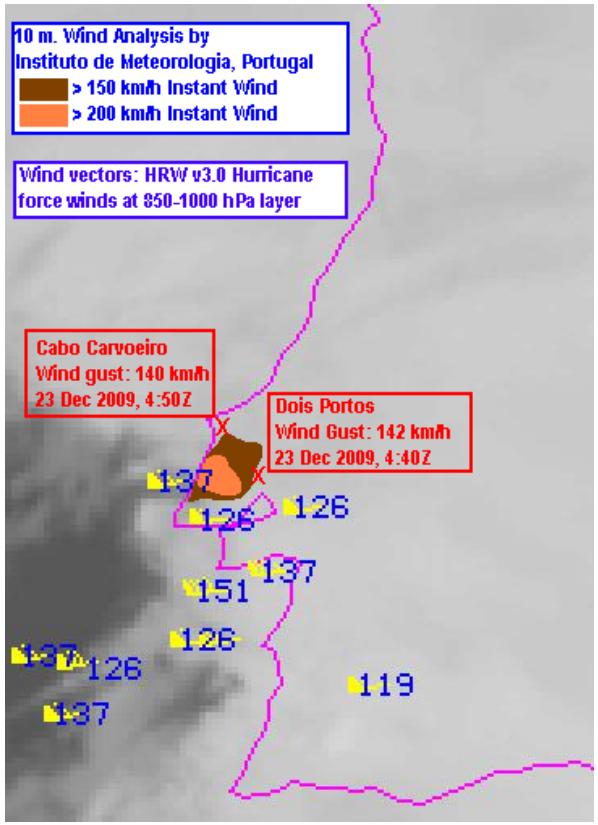
caused important damages (several people wounded, damages in houses and infrastructures, big trees fallen) along a narrow area moving Northeast from the Tagus mouth to the inner country (areas located south of the low centre, with 969.4 hPa at Cabo Carvoeiro).

22-23 Dec. 2009 Rapid Cyclogenesis in Portugal



HRW v3.0 product is able to identify a narrow area of Hurricane force low level winds coming from the ocean (15 min. mean winds between 125-150 km/h in the layer 850-1000 hPa), related to the area where the main damages occurred.

22-23 Dec. 2009 Rapid Cyclogenesis in Portugal



Only **two Surface wind observations were available** in the affected area, with **Wind gusts ~140 km/h**:

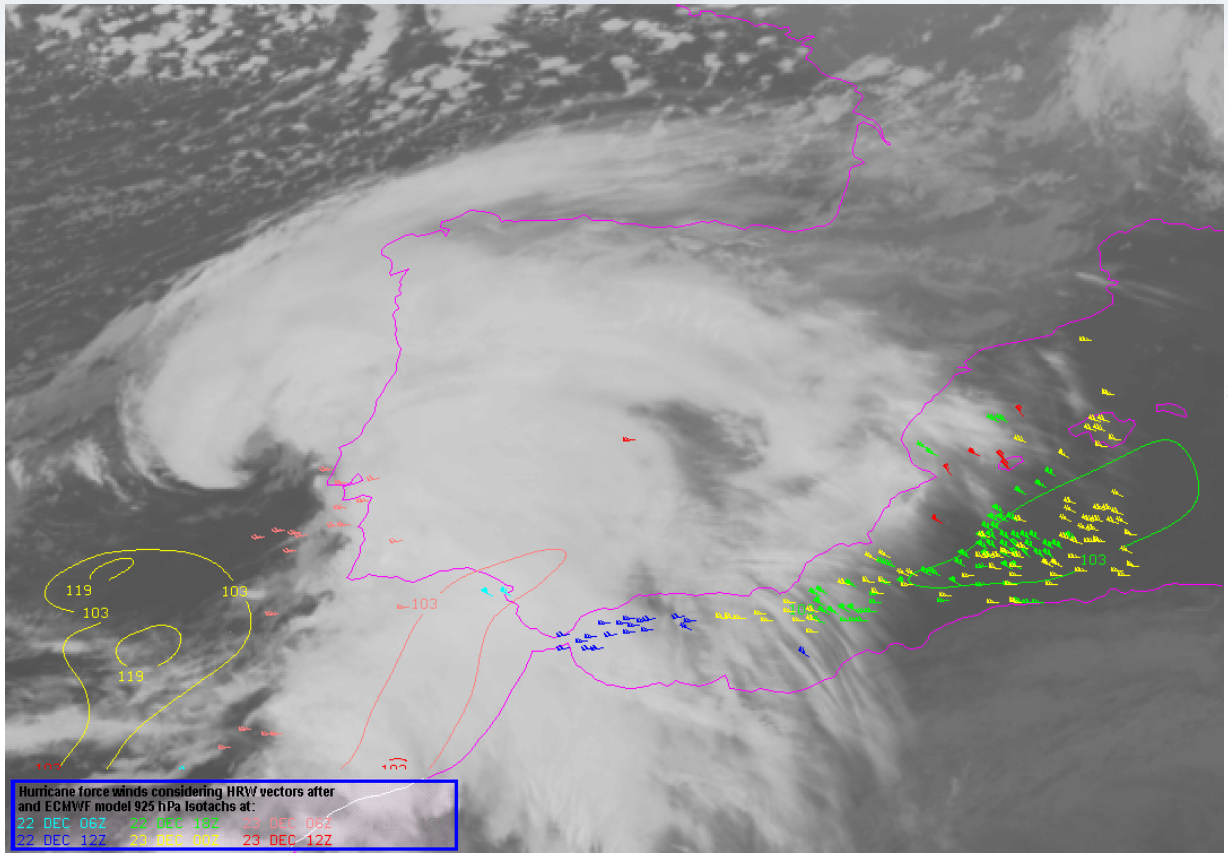
- Cabo Carvoeiro
- Dois Portos

A later **Analysis of Surface winds** considering **extrapolation of Doppler Radar Winds** by the Portuguese Instituto de Meteorologia:

www.meteo.pt/resources.www/docs_pontuais/ocorrencias2009/RelVentoOeste.pdf

shows Areas with **10 m. Maximum winds >150 km/h and >200 km/h** in the affected regions around 23 Dec 2009, 04:30Z.

22-23 Dec. 2009 Rapid Cyclogenesis in Portugal



The areas of Portugal worst affected by the cyclogenesis and all the Spanish Mediterranean, where HRW product defines its 850-1000 hPa Hurricane force winds were not identified by the ECMWF model forecast used for HRW calculation.

HRW can be very helpful in the Nowcasting of areas affected by dangerous winds, beyond the possibilities of the NWP model used for the HRW calculation

27-28 Feb. 2010 Rapid Cyclogenesis 'Xynthia'

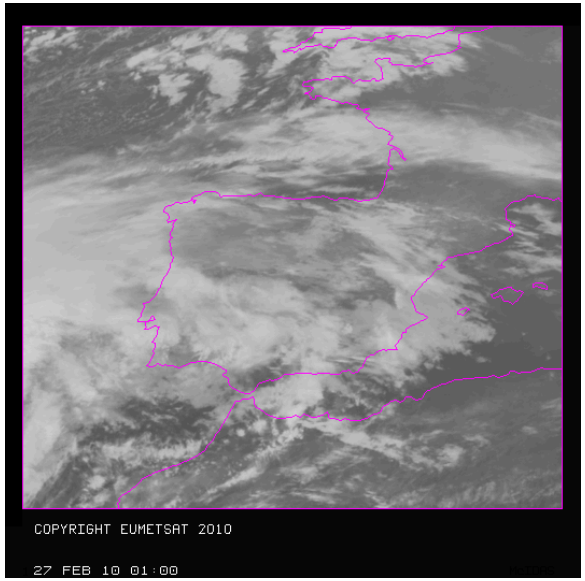
During 27-28 February 2010, Rapid Cyclogenesis 'Xynthia' coming from Subtropical Atlantic (Deepening ~20 hPa/24 h & Minimum surface pressure ~ 968 hPa) crosses the NW Iberian Peninsula and Bay of Biscay into France.

Although not as strong as other Cyclogenesis before (Lothar 1999; Klaus 2009), it was very damaging:

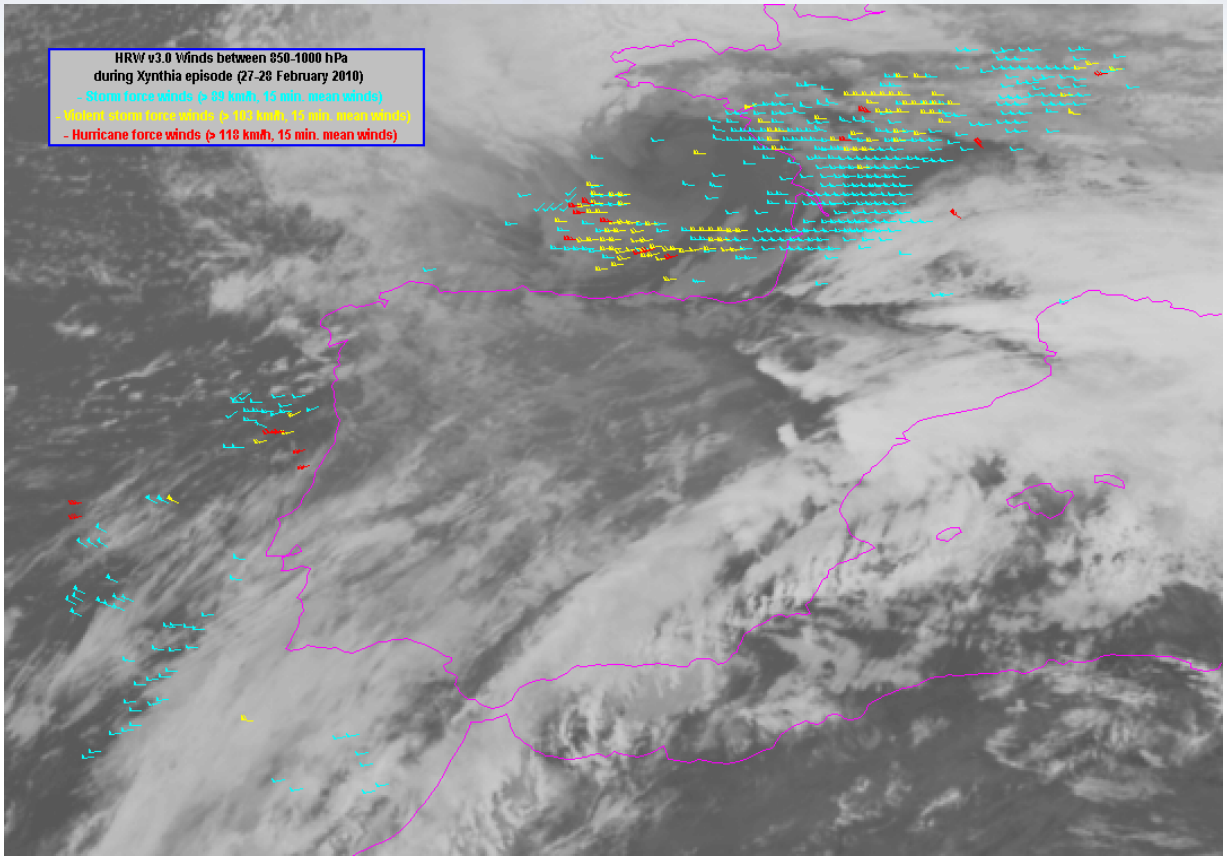
> 65 deaths in several European countries (Specially in France, through floodings in Vendée and Charente-Maritime departments, caused together by the spring high tide and a 1.5 m storm surge).

> Property losses higher than 1000 million euros.

> Around one million homes without electricity in Western and Central France.



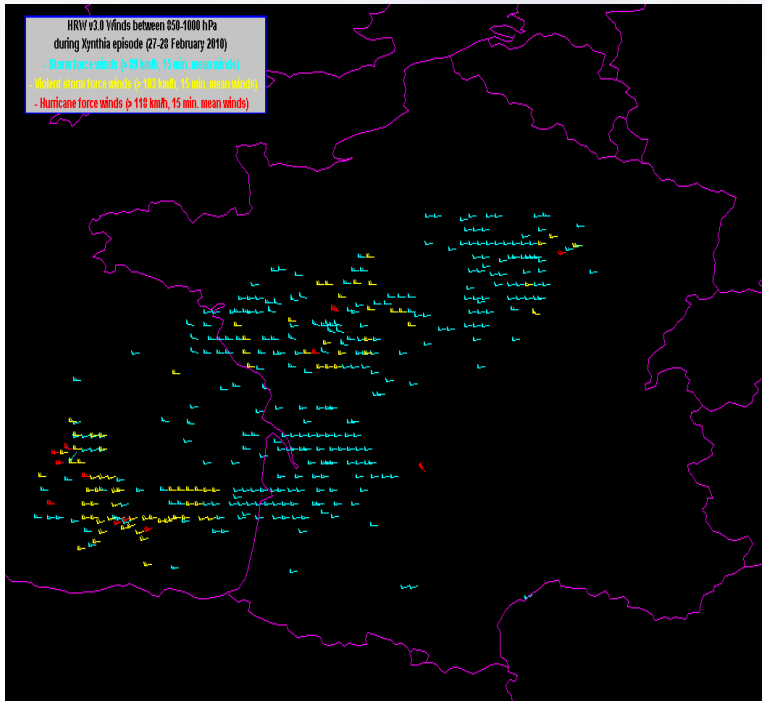
27-28 Feb. 2010 Rapid Cyclogenesis 'Xynthia'

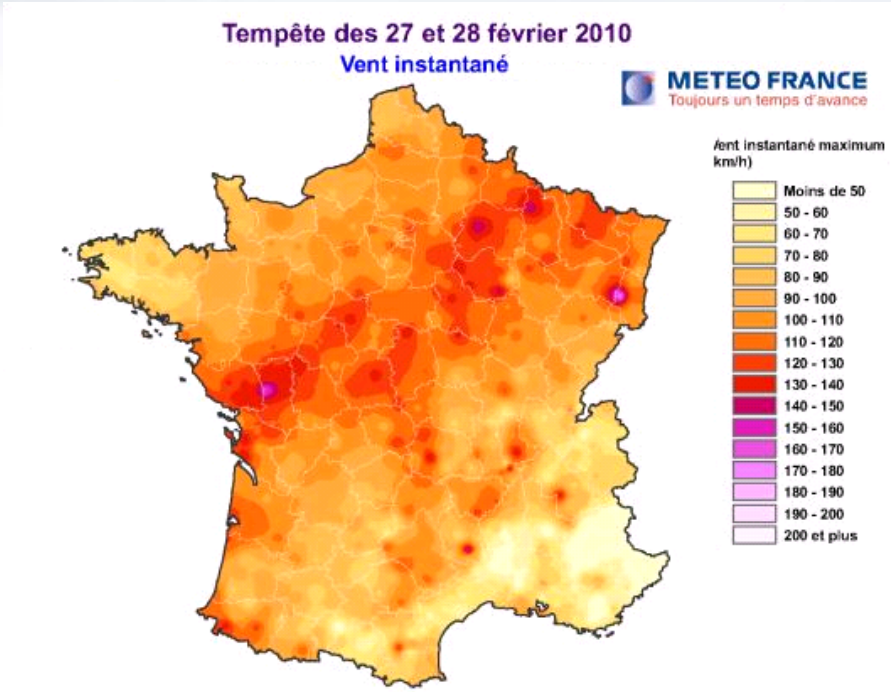


HRW v3.0 winds define very clearly the areas with strongest winds:

- **Wind strength over France more important than over the Iberian Peninsula.**
- **Anyhow, Hurricane force winds less widespread than in the December Cyclogenesis.**
- **Sustained Storm force winds in France from Coastal Areas (Departments of Loire Atlantique, Vendée, Charente Maritime, Gironde) into the Inner country following a NE trajectory.**

27-28 Feb. 2010 Rapid Cyclogenesis 'Xynthia'

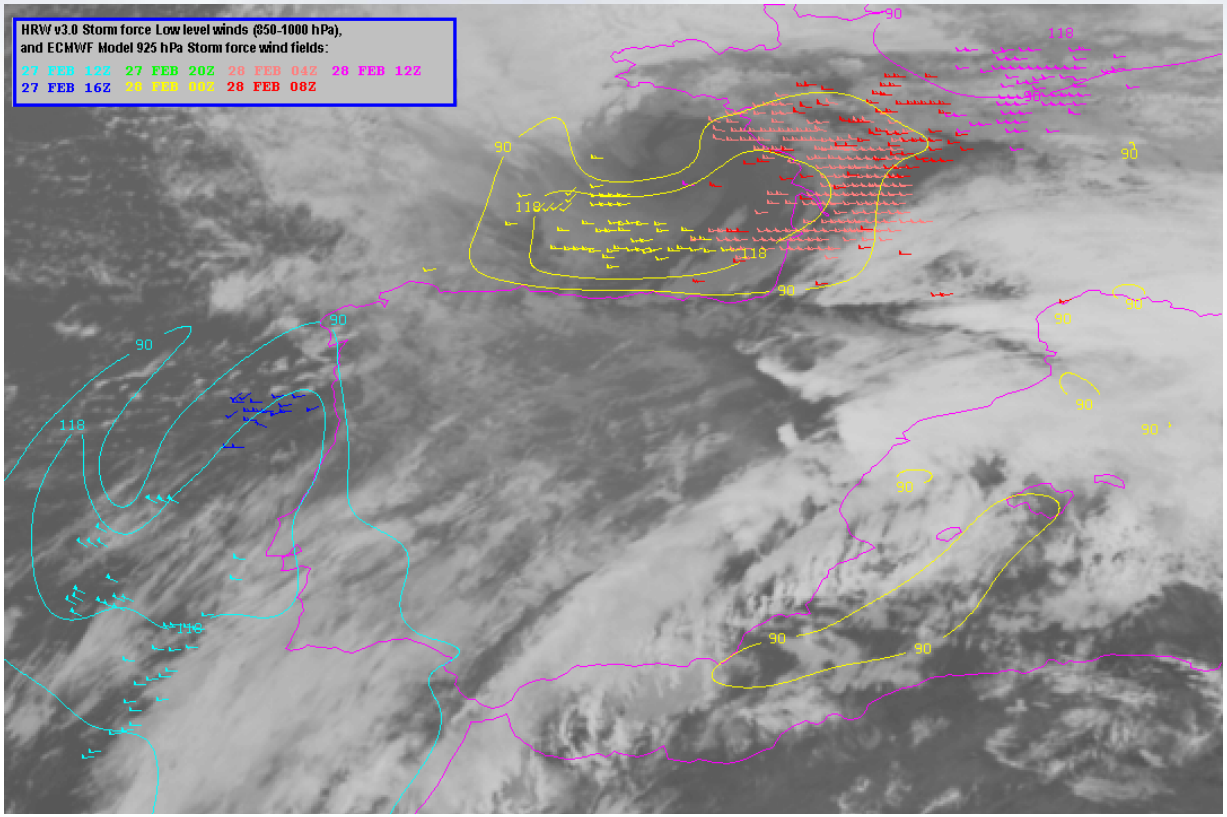




Comparing HRW output in France (Storm force low level winds) with Surface Wind observations, the diagonal path followed by the strongest winds (from Charente-Maritime to Ardennes) is seen.

The capabilities of HRW product are clearly shown
for Watch & warning of areas affected by dangerous winds,
due to its high density wind fields.

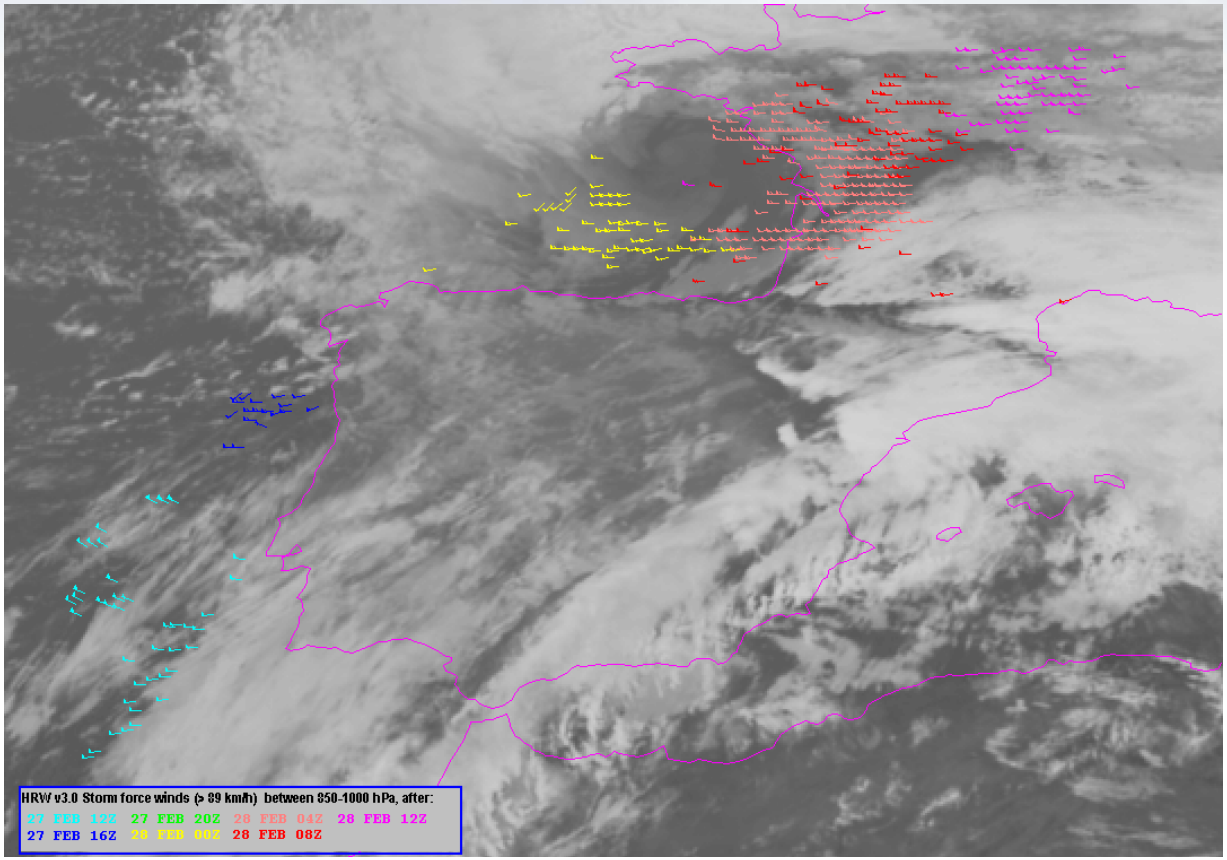
27-28 Feb. 2010 Rapid Cyclogenesis 'Xynthia'



Comparing against ECMWF Model wind fields, HRW v3.0 confirms the trajectory of Xynthia and the areas with strong winds defined by the model, although winds are weaker than expected by the model.

> Confirmation of the model by HRW winds can also be useful for operative forecasting.

27-28 Feb. 2010 Rapid Cyclogenesis 'Xynthia'



The temporal evolution of the HRW v3.0 winds permits also to know at every moment which regions can be suffering the hardest winds.

- This can also be very helpful for watch and warnings tasks.

Future developments in HRW product

Developments during the Continuous Development and Operations Phase (until 2012)

> Changes in the Quality Control, permitting local variations in the QI threshold.
  - To avoid the total elimination of all AMVs with the Quality filterings in some areas, as sometimes occurs with the current configuration.

> Possibility to define which Cloud types are Basic/Detailed winds calculated for.
  - Users have shown the interest to calculate Detailed winds considering specifically some Cloud types (like fractional clouds).

> Changes in HRW algorithm through external collaborations.
  - A collaboration with EUMETSAT Central Facility is planned to implement and test in HRW algorithm several procedures developed for MPEF AMV algorithm (Related to Pixel selection techniques & Height assignment).

> Configuration of HRW product to calculate AMVs with other MSG channels.
  - For the moment, the calculation of Water Vapour AMVs is expected.

Future developments in HRW product

Other possible developments for CDOP-2 Phase (after 2012):

- Calculation of divergence and vorticity fields with AMV data.
  - Several applications possible, f.ex. Humidity convergence.
- Application to calculate extrapolated images, through the displacement of image elements with AMV data.
- Application to calculate displacements/trajectories.
- And any other procedure defined by the users at this "NWCSAF Users Workshop".

Conclusions

- Optimized HRW v3.0 algorithm permits to calculate HRVIS & IR108 winds:
  => In a running time similar to the time used by previous versions to calculate only HRVIS winds.
  => With a big increase in the number of available winds (~2.5 times if winds from both channels are considered together).

- Operationally, the main consequences of the new HRW algorithm are:
  => The possibility to use HRW product 24 hours a day, with 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 only to use operationally this configuration in national areas, but this can be useful in regional studies.
    * 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).

Conclusions

- The small variations in the validation statistics for all HRW algorithm outputs ('Nominal mode' and 'Rapid scan mode' HRVIS & IR108 winds), permit to consider them as similar quality wind datasets.

  => They can then be used jointly as an only dataset for later applications (as calculation of divergence/vorticity fields or regular wind grids).

- Anyhow, 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

  => IR108 winds are more common in the High and Medium layers (The spectrum of information gets broader).

Conclusions

- **The utility of "High Resolution Winds product" has increased significantly with these improvements, and is now more in accordance with the needs of NWCSAF users.**

  => An important increase in the use of HRW product among NWCSAF users is expected with the new version of the algorithm.

- **The users collaboration is expected (including you!) to evaluate the impact of HRW data assimilation in NWP Mesoscale or Regional models.**

  => We have still no experience with this application of HRW data!

- **This work could be even economically awarded through a NWCSAF Visiting Scientist Activity, with the elaboration of a Report on the impact of HRW data assimilation in NWP models.**

Do not hesitate to contact me about this or any other matter through email
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or at any moment during this "Users Workshop".