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SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING

Operational use and examples of NWCSAF/HRW-High Resolution Winds AMV Software for Geostationary and Polar satellites

2 March 2022

EUMeTrain Wind Event Week

Javier García-Pereda (NWCSAF/AEMET)

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Description of NWCSAF/High Resolution Winds software

➔ AMVs/Trajectories calculated through the displacement of features in successive satellite images.

Use of NWCSAF/High Resolution Winds

➔ Use in meteorological applications:

- Assimilation in NWP models.
- Definition of the displacement of meteorological structures.

➔ Wind watch and monitoring in forecasting tasks.

NWCSAF/HRW-High Resolution Winds

In weather forecasting,
conventional observations in different tropospheric levels
are limited, while satellite observations
provide an almost global coverage in regular time intervals.

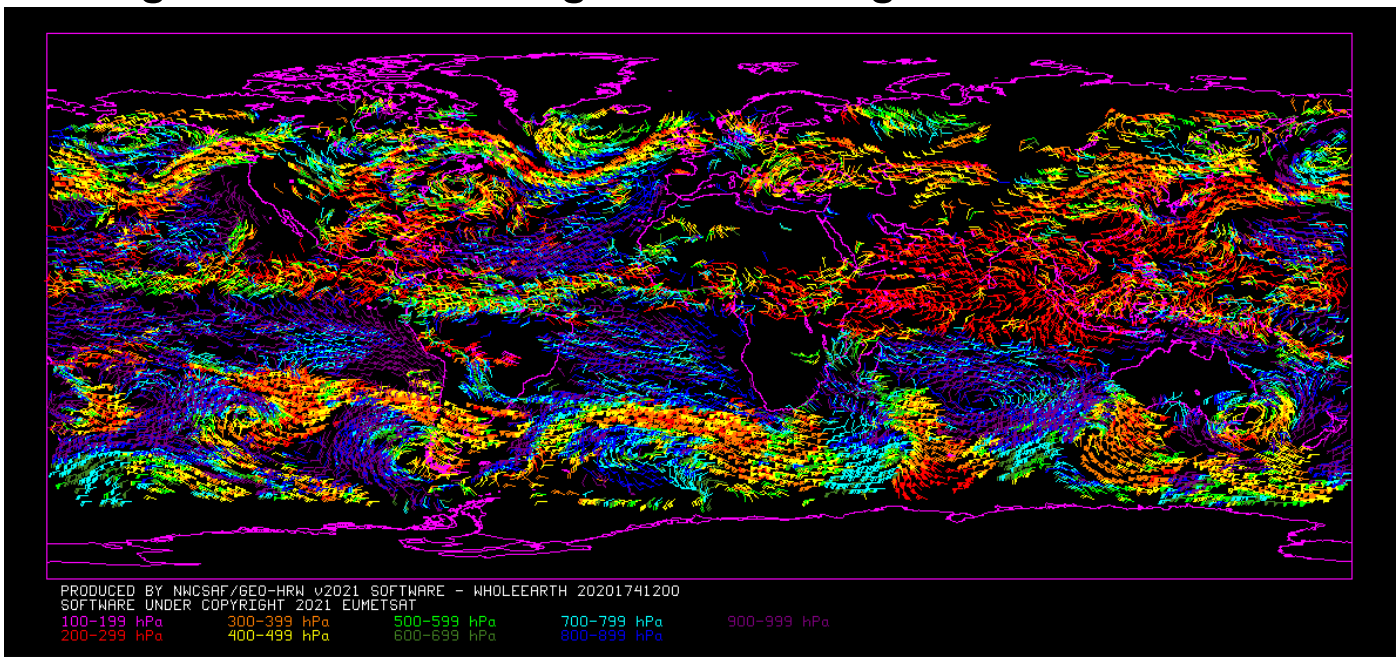
Among these satellite observations
Atmospheric Motion Vectors (AMVs)

➔ Winds calculated through the displacement of cloud and moisture features in successive satellite images,

are an important source of wind observations,
especially over oceans and remote areas.

NWCSAF/HRW-High Resolution Winds

In March 2022 the latest version of NWCSAF/High Resolution Winds is released (NWC/GEO-HRW v2021), calculating AMVs and Trajectories with five geostationary satellites all around the globe (MSG, MSG/IODC, Himawari-8/9, GOES-13/17), so providing for the first time global coverage.



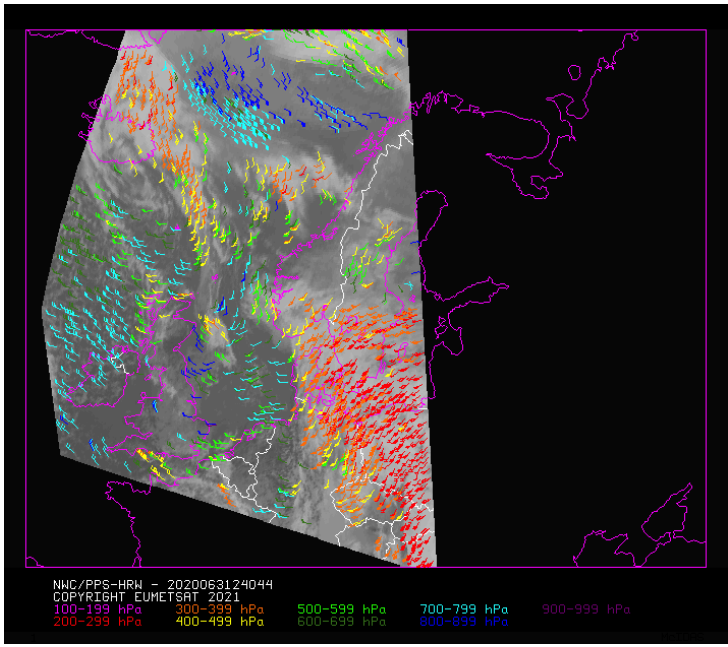
Example of NWC/GEO-HRW throughout the world with GOES-17, GOES-16, MSG, MSG/IODC, Himawari-8 satellites for 22 June 2020, 12:00Z

NWCSAF/HRW-High Resolution Winds

As you can see in previous slide, coverage with NWC/GEO-HRW v2021 geostationary software is limited up to latitude ≈ 65º N/S, not being able to provide information in polar areas.

Due to this, the decision was taken to extend HRW software to polar satellites (12 polar satellites with EOS, AVHRR/3 and VIIRS radiometers), so providing coverage also in polar areas.

This is available as NWC/PPS-HRW v2021, included in NWC/PPS v2021 polar software, released to users in November 2021.



Example of NWC/PPS-HRW in the Scandinavian region, for 3 March 2020, 12:40:44Z (coverage changes from slot to slot)

NWCSAF/HRW-High Resolution Winds

Two slides summarizing the process of AMV/Trajectory calculation in NWCSAF/HRW software:

1. Reading and preprocessing of satellite data

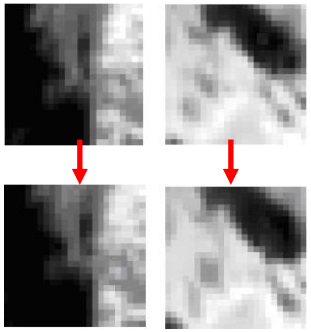
F.ex.: Normalizing visible images to homogenize illumination conditions.

2. Definition of square shaped “tracers” in an initial image

➔ In NWC/GEO-HRW, using visible, infrared, water vapour channels.

➔ In NWC/PPS-HRW, using only visible and infrared channels.

➔ Defined by cloud features and clear air moisture features in water vapour images.



3. “Tracking of tracers” in a later image

- Tracers can change their shape and even disappear, but a sufficient number of tracers persists between both images to produce an irregular distribution of AMVs.

NWCSAF/HRW-High Resolution Winds

4. Height assignment to localize the AMVs/Trajectories in a tropospheric level.

➔ This is the process in which the largest errors can occur.

5. Calculation of the AMVs/Trajectories, considering the displacement of the tracers between the images.

6. Quality control to keep only the best AMVs:

- Based on consistency checks:
  - ➔ Temporal consistency with near AMVs in the previous image.
  - ➔ Spatial consistency with near AMVs in the same image.
  - ➔ Consistency with NWP winds.
- And the Orographic flag, which removes AMVs affected by orographic influence (blocked by the ground, orographic waves,…)

NWCSAF/HRW-High Resolution Winds

Some elements to notice:

➔ **The AMV/Trajectory outputs are available in ≈ 5 minutes after the reception of the satellite images, which eases the use in real time applications.**

➔ **The software is run locally, with many configurable parameters. Due to this, the running conditions can be specified in many ways.**

F.ex.: ➔ Defining up to two scales for the AMV calculation ("basic scale" and "detailed scale"),

➔ Defining the size of the tracers used, etc.

NWCSAF/HRW-High Resolution Winds

But also some limitations:

➔ AMVs are horizontal mean winds

- They provide no info on wind gusts or vertical wind.

➔ There is a variability in the amount of available observations
(with the possibility that sometimes
there are no AMVs in a given location)

- It depends on the existence in the area of cloud/moisture tracers.

➔ There is a limitation in the number of AMVs
in different levels of the same location

- There is a limit of two/three AMVs in the same vertical profile,
based on several levels of cloudiness/moisture.

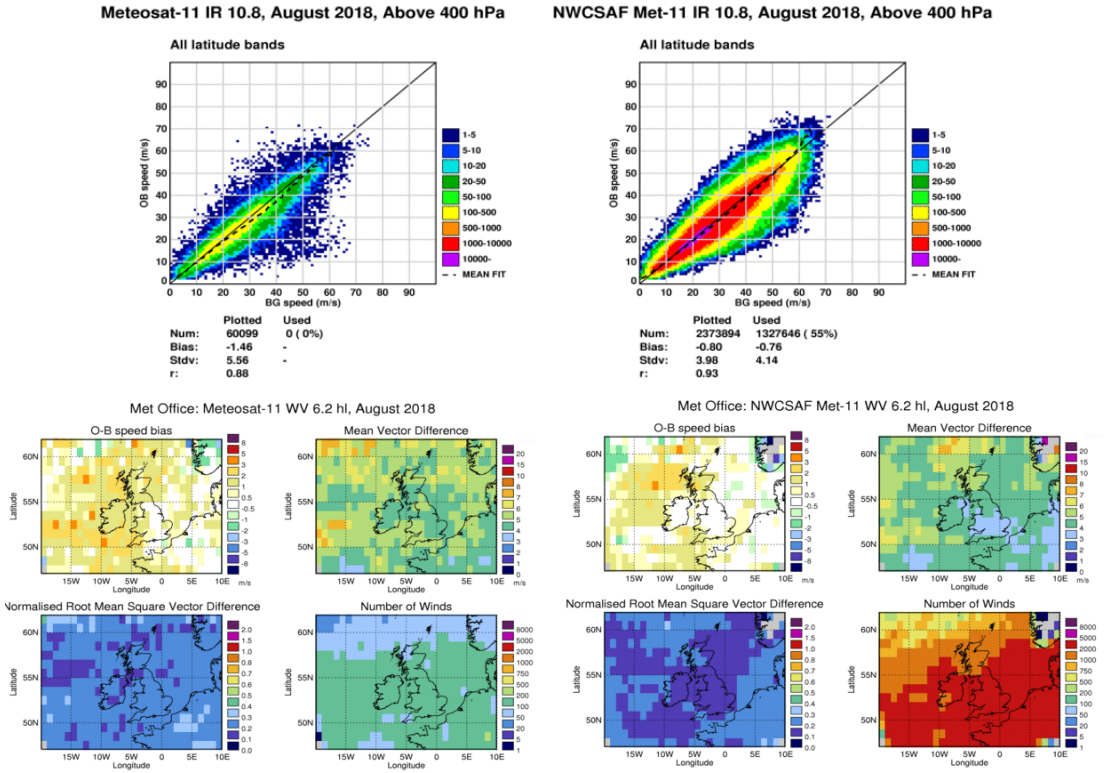
NWCSAF/HRW-High Resolution Winds

The Met Office (UK) is validating the NWC/GEO-HRW AMVs since 2014 in the webpages of the NWPSAF:

www.nwpsaf.eu/monitoring/amv/22_01/density_ukv.html

www.nwpsaf.eu/monitoring/amv/22_01/map_ukv.html

comparing its AMVs with those calculated by EUMETSAT:



NWC/GEO-HRW AMVs in general show:

- **A larger density of AMVs.**
- **Smaller BIAS, MVD, NRMSVD errors.**

NWCSAF/HRW-High Resolution Winds

In 2018, an "AMV intercomparison study" was made,
in which 6 institutions from all around the world took part.
NWCSAF/HRW AMVs were in second position:

** More info:

"2018 Atmospheric Motion Vector (AMV) Intercomparison Study", D.Santek et al.
(Remote Sensing Journal, www.mdpi.com/2072-4292/11/19/2240/pdf)

	N	Pre Bias	Pre RMS	Spd Bias	Spd RMS	Dir Bias	Vec RMS
BRZ	619	1.16	13.44	-0.40	7.36	-14.65	9.80
EUM	366	-0.66	14.74	-2.20	6.15	8.43	8.56
JMA	270	-3.43	18.67	-1.40	4.64	-0.83	5.93
KMA	628	-0.84	14.30	-1.21	7.39	-2.66	8.97
NOA	599	-1.69	13.98	-0.88	5.25	0.39	7.52
NWC	2063	-1.19	16.19	-2.11	5.99	0.79	6.94

	N	VD	RMS
BRZ	56515	5.73	8.35
EUM	56515	4.00	5.17
JMA	56515	2.27	2.80
KMA	56515	3.92	5.25
NOA	56515	3.53	4.42
NWC	56515	3.55	4.24

Verification of AMV algorithms against Radiosonde winds (up) and NWP wind analysis (down)

BRZ: Brazil **KMA: South Korea**
EUM: Eumetsat **NOA: NOAA**
JMA: Japan **NWC: NWCSAF/HRW**

Use of NWCSAF/HRW-High Resolution Winds

How can NWCSAF/HRW AMVs/Trajectories be used operationally?

Considering applications:

> 1. AMV assimilation in NWP models (f.ex.: UK Met.Office)

> 2. With the option to use now in Global and Climate applications

The extension with NWC/GEO+PPS v2021 to the whole geostationary ring and to polar areas, allows now even the use in Global NWP models and Global climate applications (with all AMVs calculated with the same AMV algorithm!)

> 3. Inclusion of the real displacement of meteorological structures in Nowcasting applications.

f.ex.: "NWCSAF/EXIM-Extrapolated Imagery" software.

Considering direct use:

> 4. Wind watch and monitoring in operational forecasting.

Use of NWCSAF/HRW: NWP assimilation

The UK Met.Office started in 2014 to assimilate operationally the NWCSAF/HRW AMVs in its "Unified model"
(in the highest resolution region around the British isles)

More details about how AMVs are assimilated in the Met.Office will be shown tomorrow by Mary Forsythe
in the presentation "Impact of satellite-derived winds in NWP".

Use of NWCSAF/HRW: Use in other applications

One of the main characteristics of NWCSAF/HRW:

➔ **It detects the real displacement of meteorological structures.**

➔ **This is done without any dependence on the NWP model wind in the geostationary version of NWCSAF/HRW.**

➔ **The inclusion of this real displacement of meteorological structures in other meteorological applications can have a very positive effect.**

One example of this is the NWCSAF/EXIM software for "Extrapolation of satellite images and NWCSAF products"

which will be presented just later by

Alexander Jann and Polly Schmederer (ZAMG)

Use of NWCSAF/HRW: Operational forecasting

NWCSAF/HRW software can be used in operational forecasting for:

* Watch and warning of dangerous wind situations.

* Monitoring of the general atmospheric flow.

* Monitoring of small scale circulation and wind singularities.

* Evaluation of low level convergence
  (when and where cumulus start to develop)
  and high level divergence.

Use of NWCSAF/HRW: Operational forecasting

Considering "Watch and warning of dangerous wind situations"
the procedure is based on:

1. **Assessing the vertical distribution of NWCSAF/HRW AMVs considering all layers (100 – 1000 hPa) and low level layers (700 – 1000 hPa).**
   - **The opacity of the clouds often avoids that we can observe low level clouds and displacements, so causing observations gaps in the low level AMVs.**
   - **We can try to extrapolate information from higher levels.**

Operationally, we must remember that NWCSAF/HRW AMVs represent mean winds between two satellite images (f.ex. 15 min. in MSG Nominal mode).

Use of NWCSAF/HRW: Operational forecasting

2. Checking if the wind speed is near or over the "warning thresholds".

Operational examples for AEMET/Spain are here provided:

➔ **In the sea, thresholds defined considering the mean wind:**

> **Moderate gale (F7, 50 km/h wind): yellow warning**

> **Storm (F10, 90 km/h wind): red warning**

➔ **Over land, thresholds defined considering the wind gusts:**

> **70-80-90 km/h gust: yellow warning**

> **130-140 km/h gust: red warning**

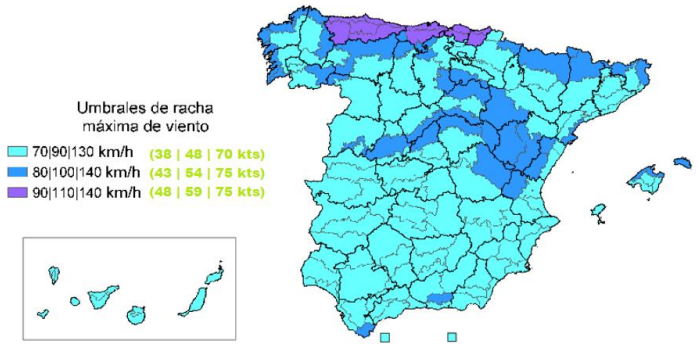
FENÓMENOS COSTEROS F7 = 52km/h, 28kts F8 = 63km/h, 34kts F10 = 89 km/h, 48kts

Zonas	Amarillo	Naranja	Rojo
CANTÁBRICAS ATLÁNTICAS	F7, mar combinada o compuesta que provoque oleaje de 4 a 6 metros	F8 y F9, mar combinada o compuesta que provoque oleaje de 5 a 8 metros	A partir de F10, mar combinada o compuesta que provoque oleaje de más de 8 metros
MEDITERRÁNEAS	F7, mar combinada o compuesta que provoque oleaje de 3 a 4 metros	F8 y F9, mar combinada o compuesta que provoque oleaje de 4 a 7 metros	A partir de F10, mar combinada o compuesta que provoque oleaje de más de 7 metros

GALERNAS

GALICIA ASTURIAS CANTABRIA PAÍS VASCO	AMARILLO	Mar: Cambio brusco del viento, arreciando y rolando al Noroeste con fuerza 7. Tierra: Giro brusco del viento al noroeste, aumentando repentinamente con rachas fuertes, superiores a 60 km/h en el litoral.
	NARANJA	Mar: Cambio brusco del viento, arreciando y rolando al Noroeste con fuerza 8 a 9. Tierra: Giro brusco del viento al noroeste, aumentando repentinamente con rachas muy fuertes de 90 a 120 km/h en el litoral.
	ROJO	Mar: Cambio brusco del viento, arreciando y rolando al Noroeste con fuerza 10 o superior. Tierra: Giro brusco del viento al noroeste, aumentando repentinamente con rachas huracanadas, superiores a 130 km/h en el litoral.

UMBRALES DE RACHA MÁXIMA DE VIENTO (km/h) POR ZONAS PROVINCIALES SEGÚN LOS COLORES ASIGNADOS EN EL MAPA, NIVELES AMARILLO | NARANJA | ROJO



Use of NWCSAF/HRW: Operational forecasting

3. With values like these,
   the threshold 50 km/h = 28 kts
   in NWCSAF/HRW AMVs can be used
   as first option for the warning.

   ➔ Here, AMVs in the layer 850-1000 hPa
   define a good representativity
   of the ground conditions.

   ➔ If not available,
   AMVs in the layer 700-1000 hPa
   provide additional data,
   although remembering that
   winds are stronger at higher levels.

FENÓMENOS COSTEROS F7 = 52km/h, 28kts F8 = 63km/h, 34kts F10 = 89 km/h, 48kts

Zonas	Amarillo	Naranja	Rojo
CANTÁBRICAS ATLÁNTICAS	F7, mar combinada o compuesta que provoque oleaje de 4 a 6 metros	F8 y F9, mar combinada o compuesta que provoque oleaje de 5 a 8 metros	A partir de F10, mar combinada o compuesta que provoque oleaje de más de 8 metros
MEDITERRÁNEAS	F7, mar combinada o compuesta que provoque oleaje de 3 a 4 metros	F8 y F9, mar combinada o compuesta que provoque oleaje de 4 a 7 metros	A partir de F10, mar combinada o compuesta que provoque oleaje de más de 7 metros

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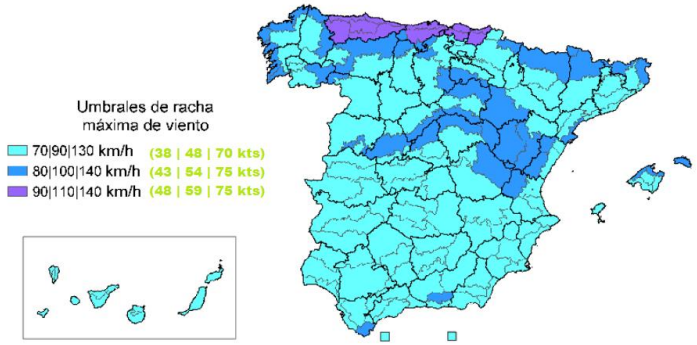
UMBRALES DE RACHA MÁXIMA DE VIENTO (km/h) POR ZONAS PROVINCIALES SEGÚN LOS COLORES ASIGNADOS EN EL MAPA, NIVELES AMARILLO | NARANJA | ROJO



Use of NWCSAF/HRW: Operational forecasting

Considering
"the monitoring of small scale circulation and wind singularities":

1. There can be interest to check
the behaviour of the wind in a specific location of interest
F.ex.: for the operations of a port, an airport,…

➔ **Sometimes operations have to be cancelled**
if the wind blows from a specific direction,
or the wind force is higher than a given threshold.

➔ **In Spain, f.ex.:**
La Palma airport/SPC (in the Canary Islands)
has to close operations when the wind blows from the West
due to turbulence (frequently and for long periods of time).

Use of NWCSAF/HRW: Operational forecasting

Considering
"the monitoring of small scale circulation and wind singularities":

2. NWCSAF/HRW AMVs can be used for this,
verifying especially the differences with other forecast tools
(like NWP models).

> The wind direction is checked
considering directly NWCSAF/HRW AMVs.

> But to check the wind speed,
some knowledge about the relationship between
NWCSAF/HRW AMVs and the local winds/gusts might be needed.

Use of NWCSAF/HRW: Operational forecasting

Considering
"the monitoring of small scale circulation and wind singularities":

3. In longer time forecast periods (> 3 hours)
the forecast depends on other forecast tools like NWP model

However, NWCSAF/HRW AMVs can still be used
to check the validity of the NWP model outputs in each moment.

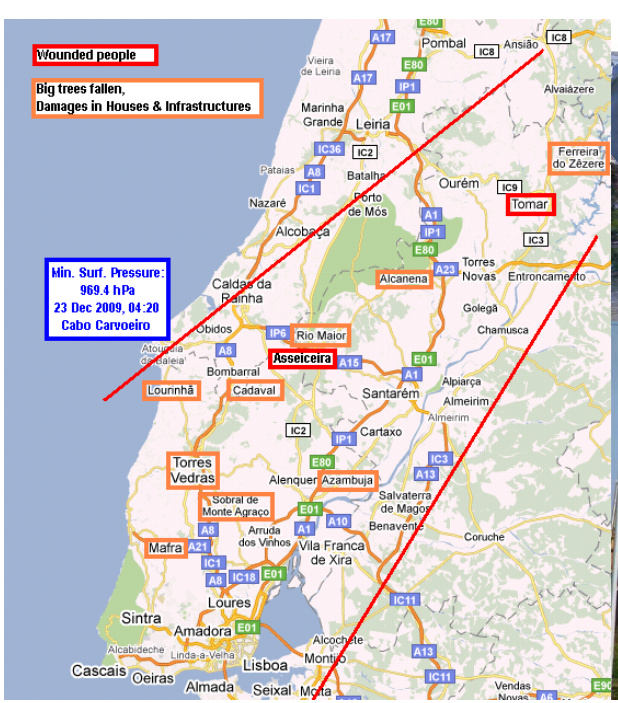
Use of NWCSAF/HRW: Example cases

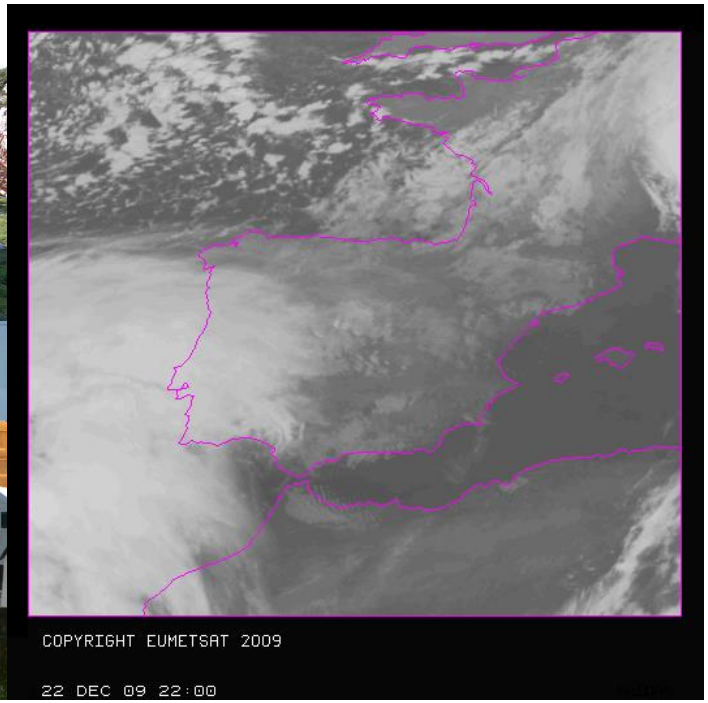
We are going to see now “4 reference examples”
(from years ago, but very good to be used as reference!)
to check the usefulness of NWCSAF/HRW AMVs
in “Wind watch and monitoring tasks”.

These examples show us how to use it
in any future forecast situation:

- ➔ A: Cyclogenesis in Portugal on 22-23 December 2009.
- ➔ B: Cyclogenesis in France on 27-28 February 2010.
- ➔ C: Wind forecast for a summer thermal low on 10 August 2016.
- ➔ D: Wind forecast for a low pressure area on 12 October 2016.

Use of NWCSAF/HRW: Example cases

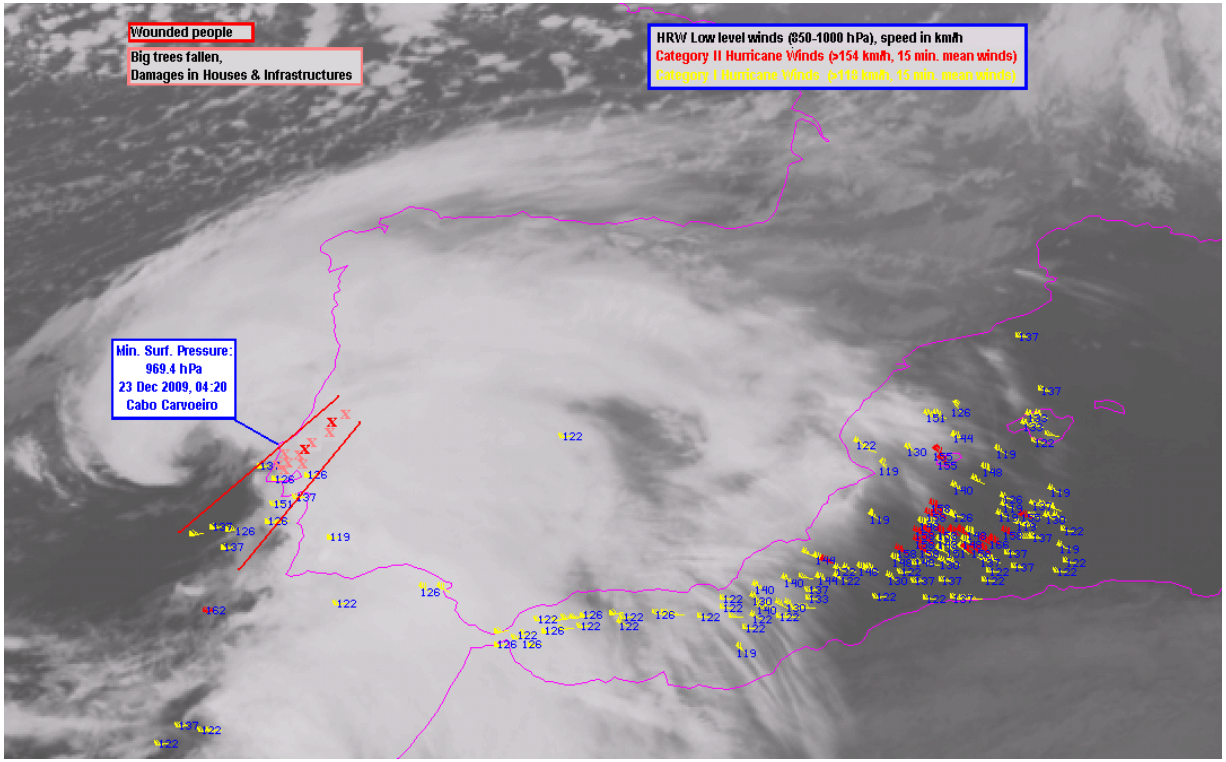




An explosive cyclogenesis moving from the Atlantic Ocean into Portugal in the night of 22-23 December 2009 (minimum pressure change higher than 20 hPa/24 h).

It caused important damages (wounded people, damages in houses/infrastructures) in a narrow region in the Southern flank of the low, moving NE from Lisbon into the inner parts of the country.

Use of NWCSAF/HRW: Example cases

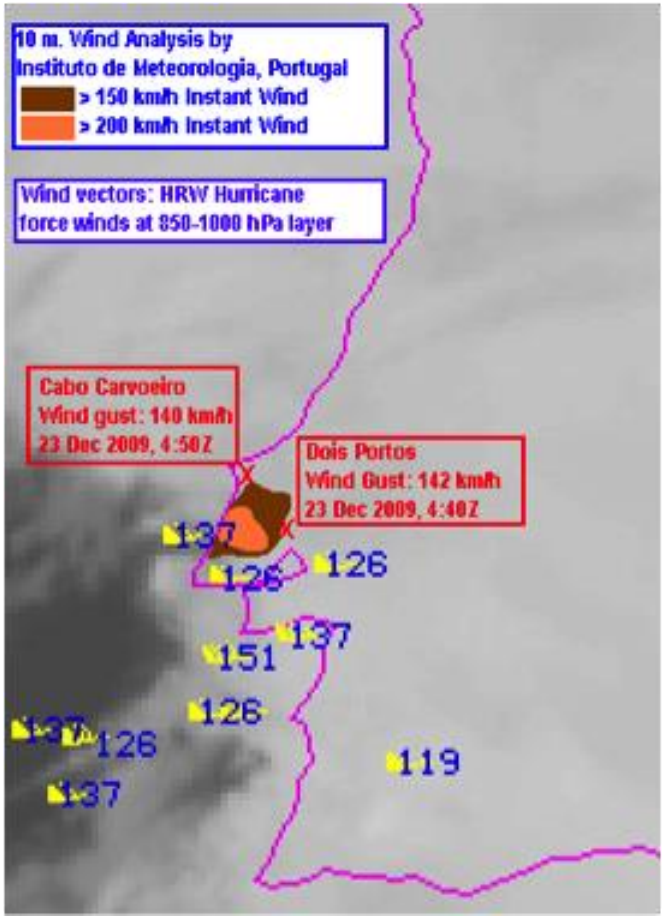


NWCSAF/HRW AMVs are able to identify in the layer 850-1000 hPa

a narrow band of hurricane winds (125-150 km/h)

which fit very well with the affected areas.

Use of NWCSAF/HRW: Example cases

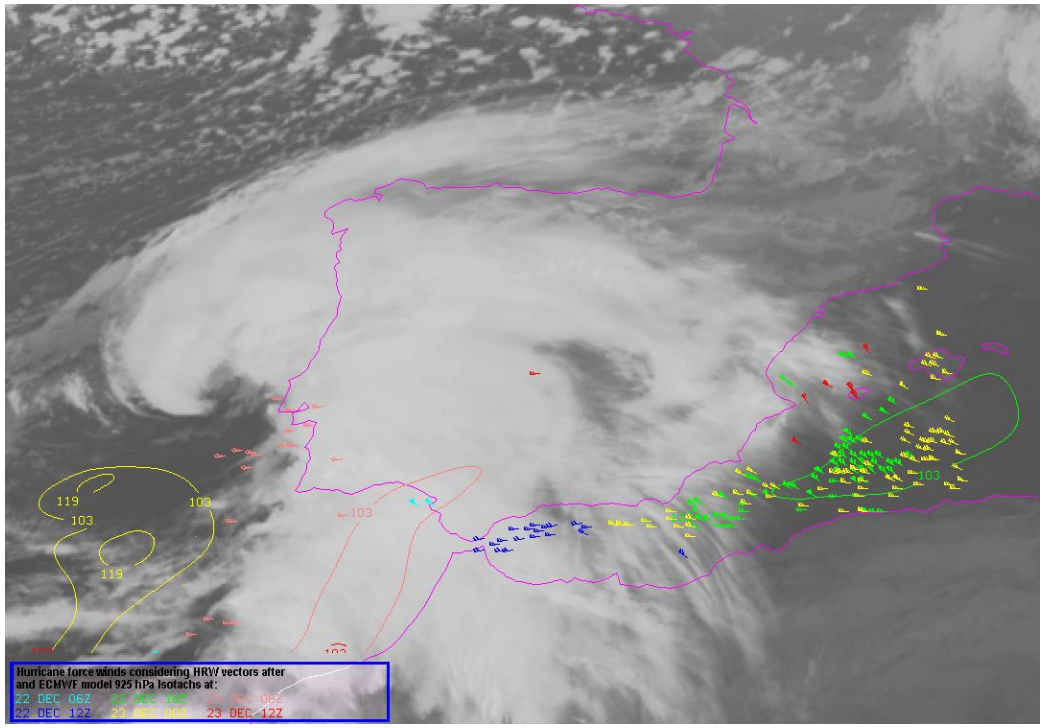


In this area, only two surface wind observations were registered with wind gusts of ≈ 140 km/h:

- Cabo Carvoeiro
- Dois Portos

However, a later analysis by the Portuguese Meteorological Service (IPMA) considering Doppler Radar wind extrapolation shows areas with 10 m. wind > 150 km/h in the affected regions around 04:30Z of 23 December

Use of NWCSAF/HRW: Example cases

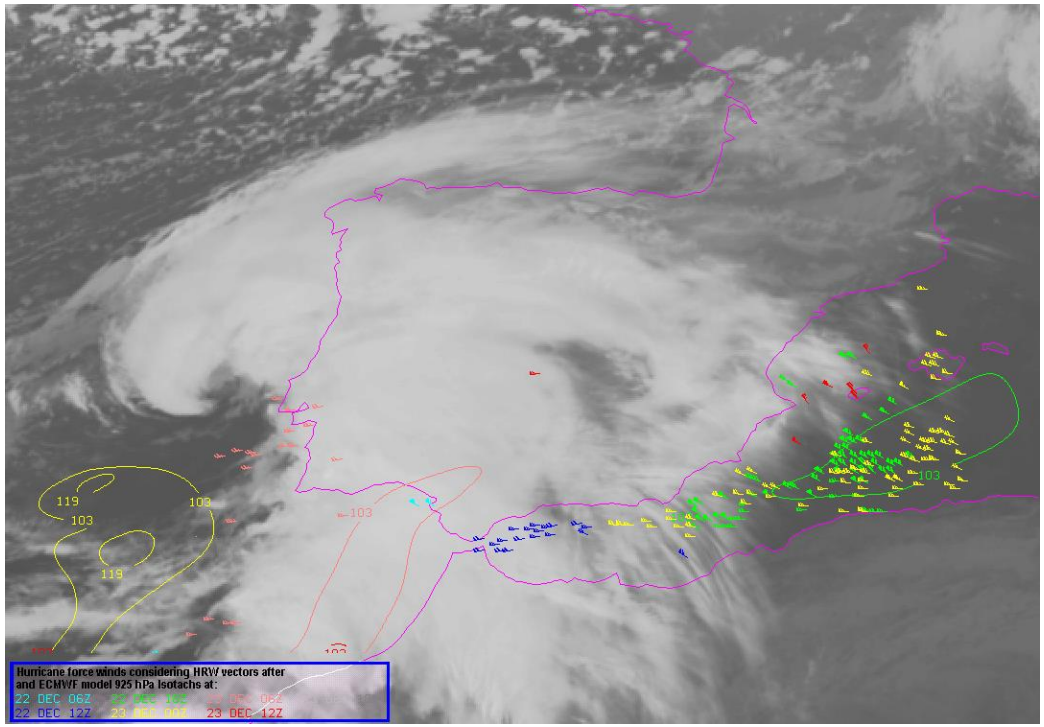


The areas in Portugal and the Spanish Mediterranean

where NWCSAF/HRW defines its 850-1000 hPa hurricane winds,

were not identified by the ECMWF NWP model forecast.

Use of NWCSAF/HRW: Example cases



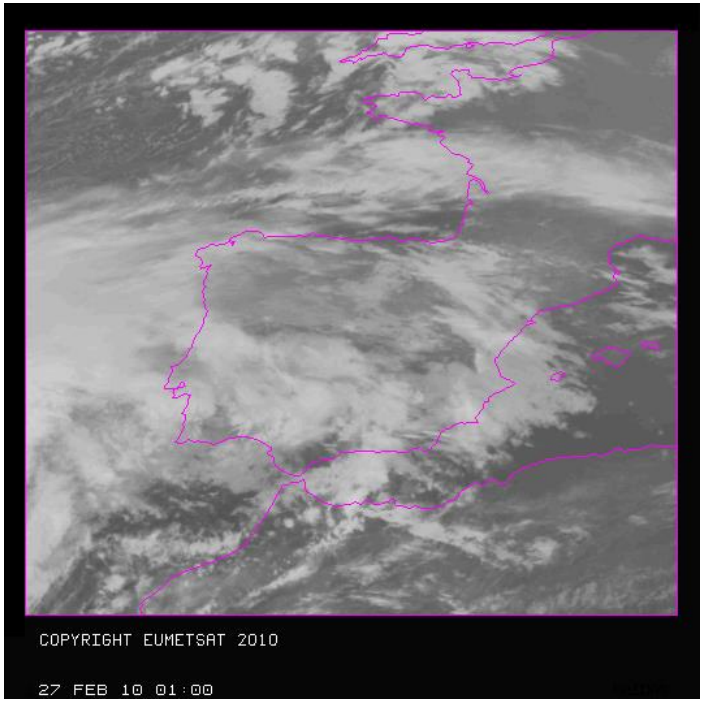
Due to this,

NWCSAF/HRW can be very useful in Wind watch and monitoring, perceiving weather elements not identified by the NWP model

Use of NWCSAF/HRW: Example cases

Explosive cyclogenesis 'Xynthia'

(deepening of ~ 20 hPa/24 h,
minimum surface pressure of ~ 968 hPa)
moves NE on 27-28 Feb. 2010
from the Bay of Biscay into Central France.



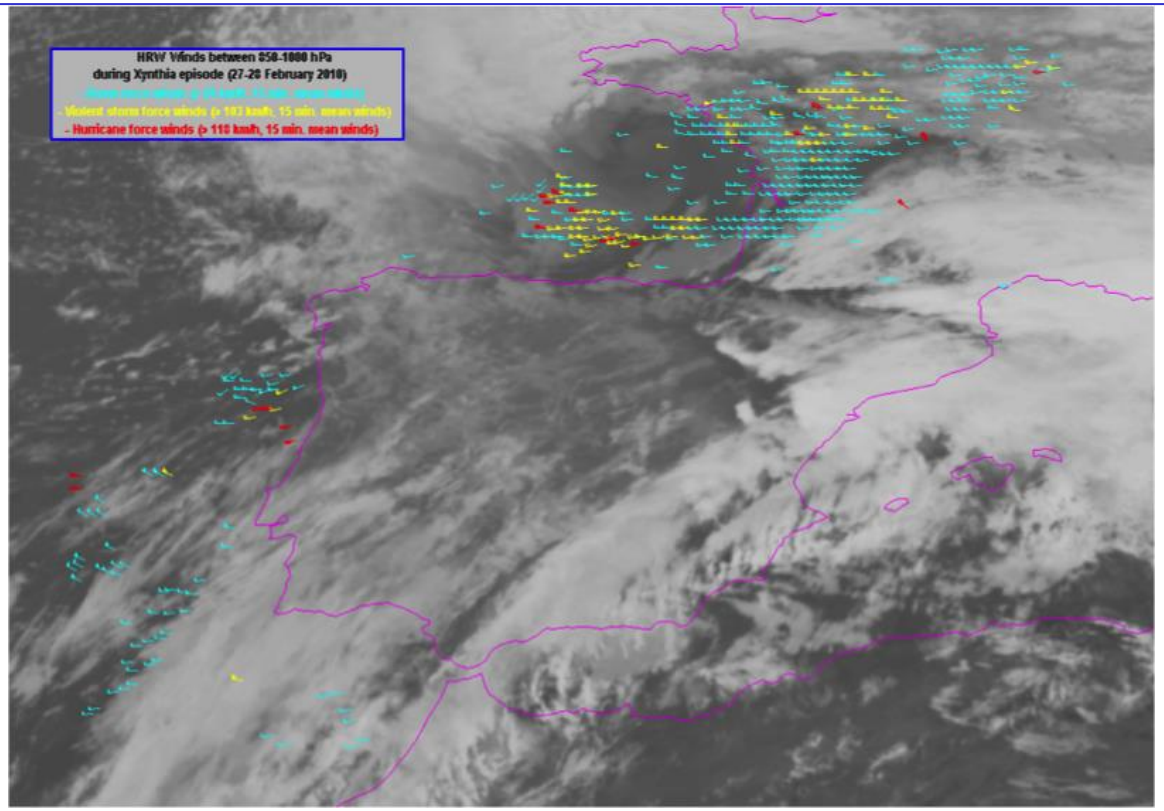
It caused many damages:

> 65 deaths in France, due to flooding caused by the union of the High tide and a 1.5 m Storm surge.

> Economic losses beyond 1 milliard Euros.

> One million homes without power.

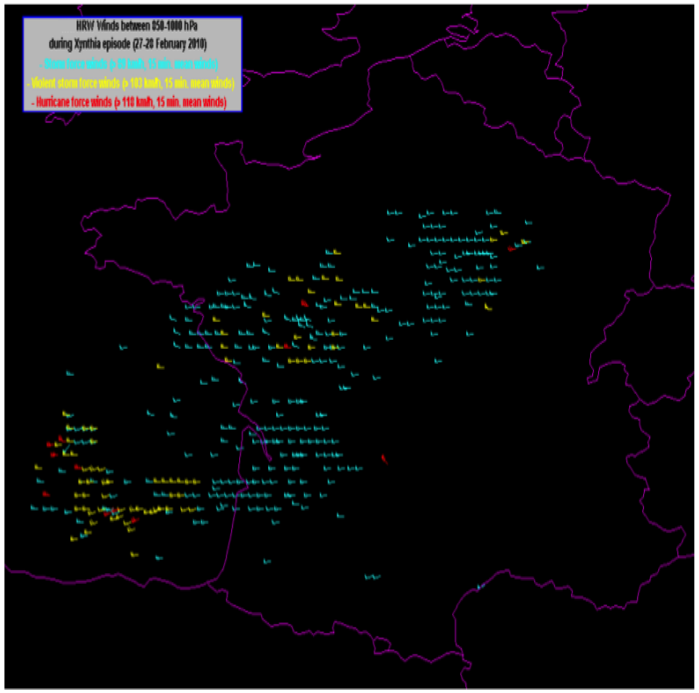
Use of NWCSAF/HRW: Example cases

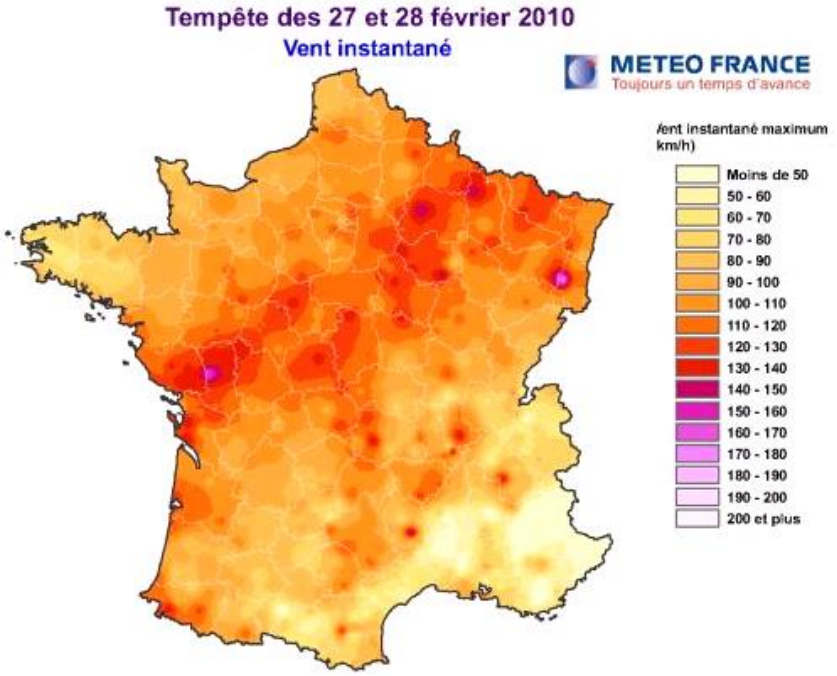


NWCSAF/HRW AMVs in 850-1000 hPa layer define clearly the areas with strongest winds:

- **Wind in France is much stronger than in the Iberian Peninsula.**
- **Hurricane force winds (>118 km/h, in red) are limited.**
- **But Storm force winds (>89 km/h, in blue and yellow) are detected in wide areas, moving from the Western Coast into the NE of France.**

Use of NWCSAF/HRW: Example cases



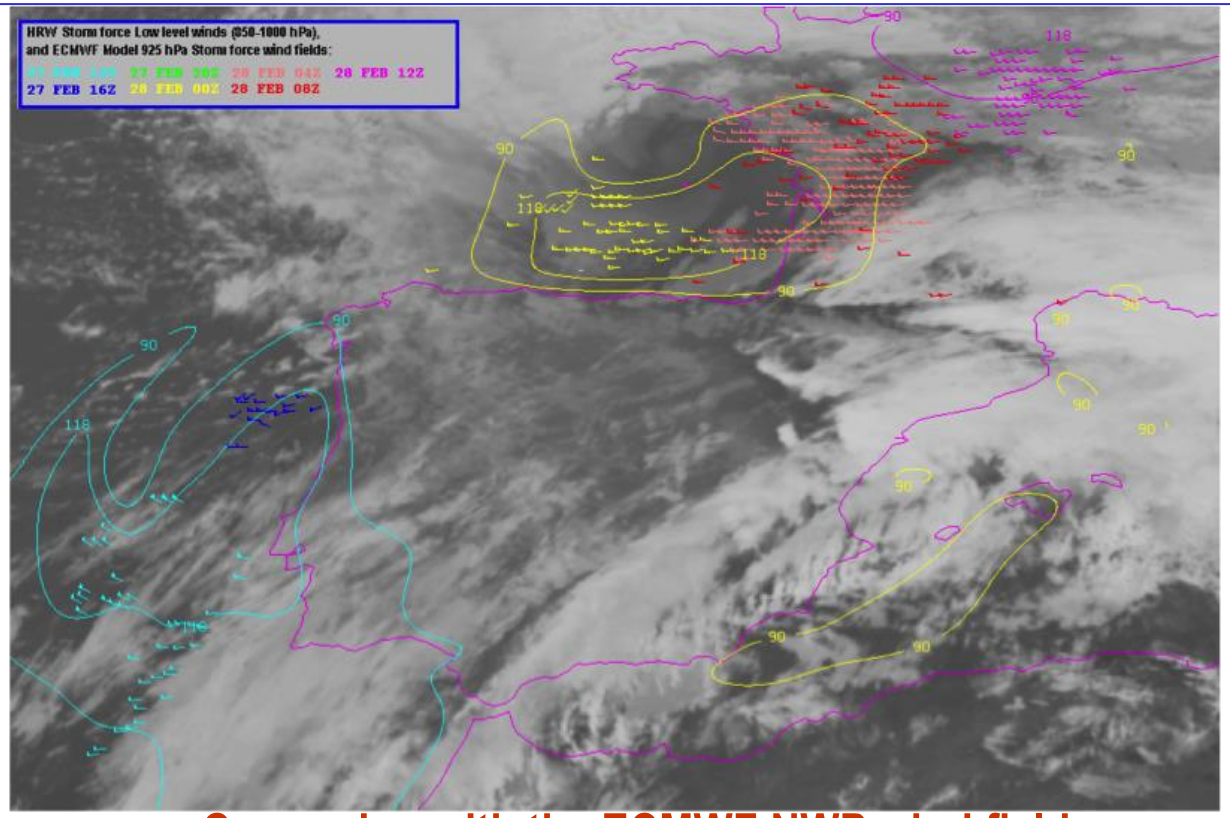


Comparing NWCSAF/HRW AMVs

with Surface wind observations collected by Météo-France,

the track defined by the strongest winds fits very well in both datasets.

Use of NWCSAF/HRW: Example cases



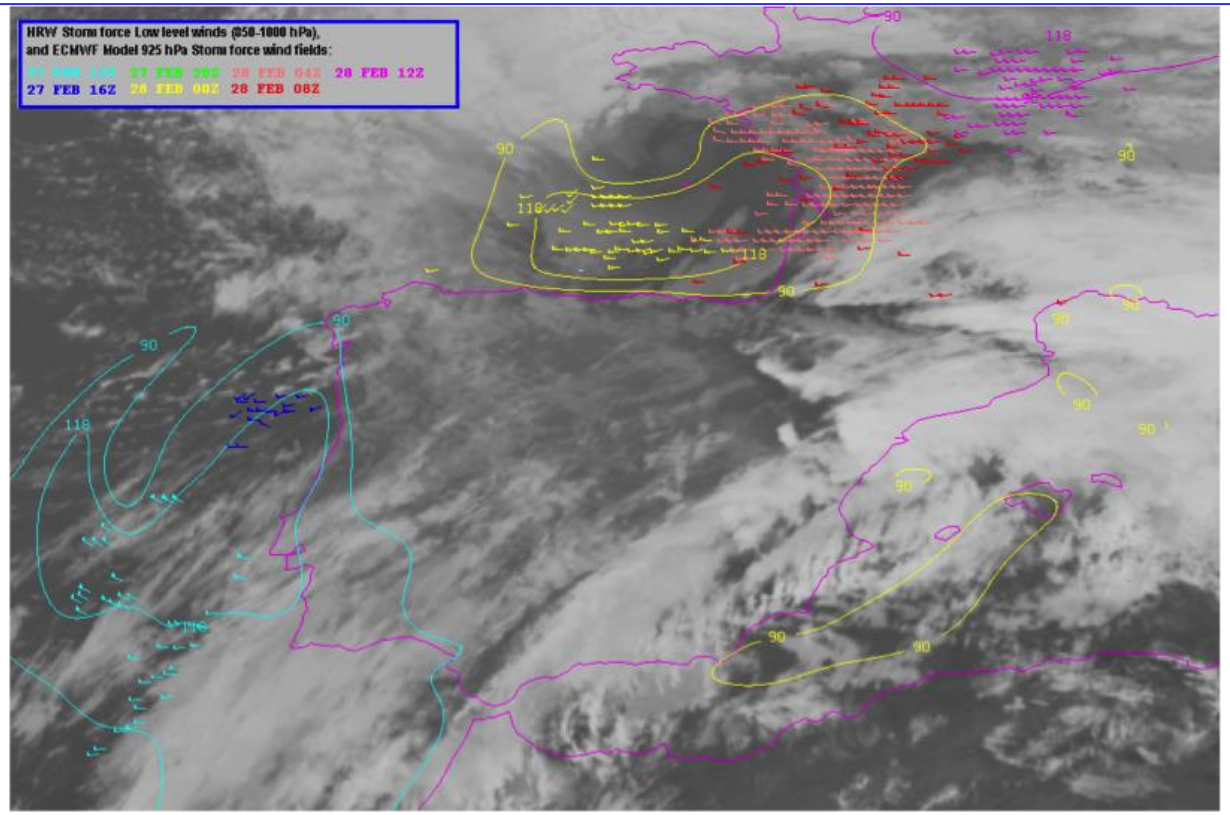
Comparing with the ECMWF NWP wind fields,

NWCSAF/HRW AMVs confirm the NWP model forecast in France

(Xynthia trajectory, and regions suffering the strongest winds),

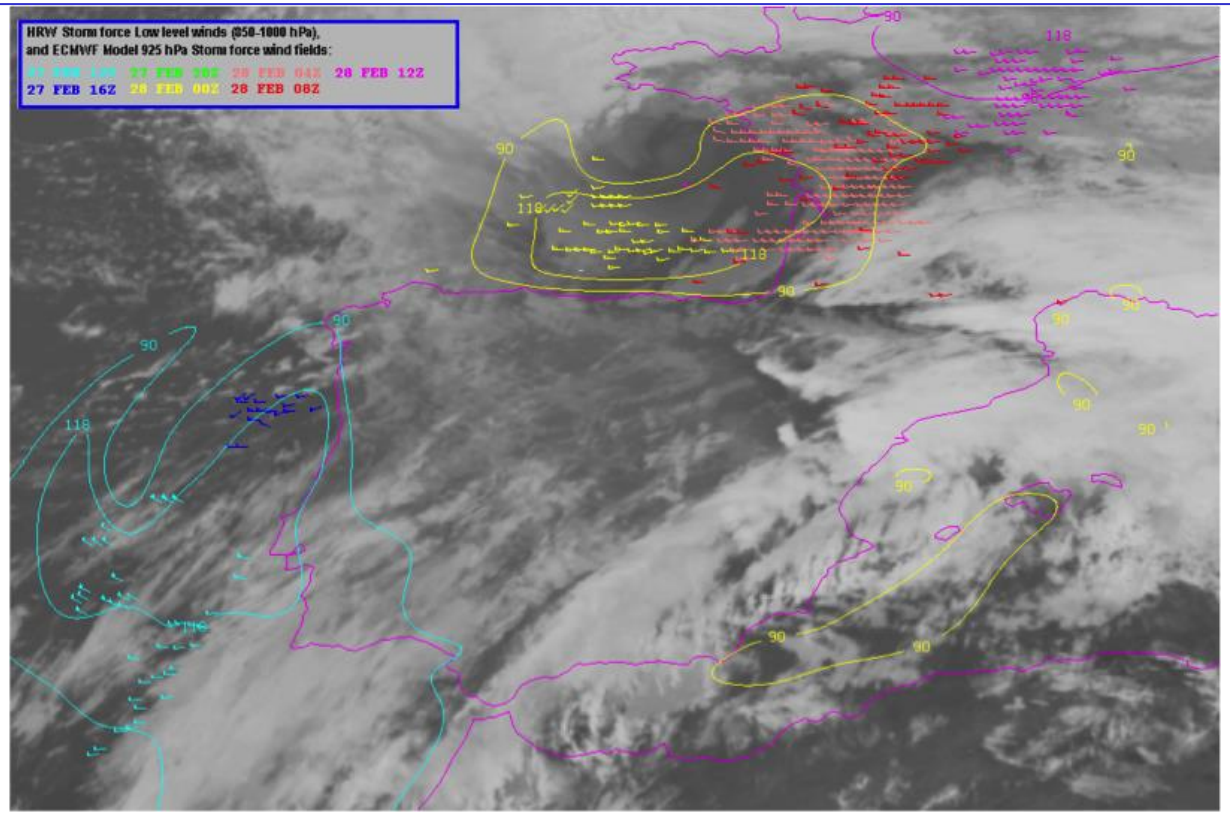
which also is useful in Operational forecasting.

Use of NWCSAF/HRW: Example cases



The temporal evolution of NWCSAF/HRW AMVs also helps to identify where the strongest winds are occurring in each moment.

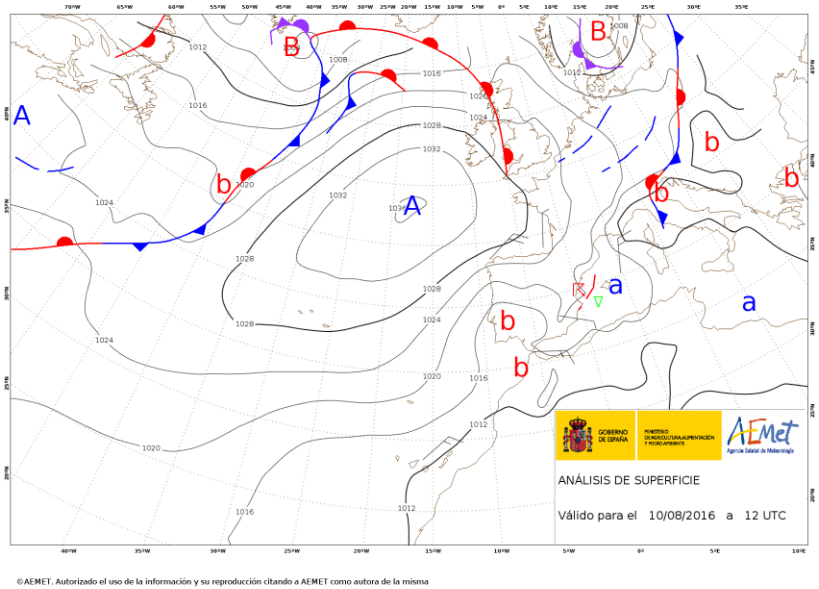
Use of NWCSAF/HRW: Example cases



NWCSAF/HRW high density AMVs help us in this case:

- **To identify the spatial/temporal location of the strongest winds in every moment.**
- **To verify the NWP model weather forecast.**

Use of NWCSAF/HRW: Example cases

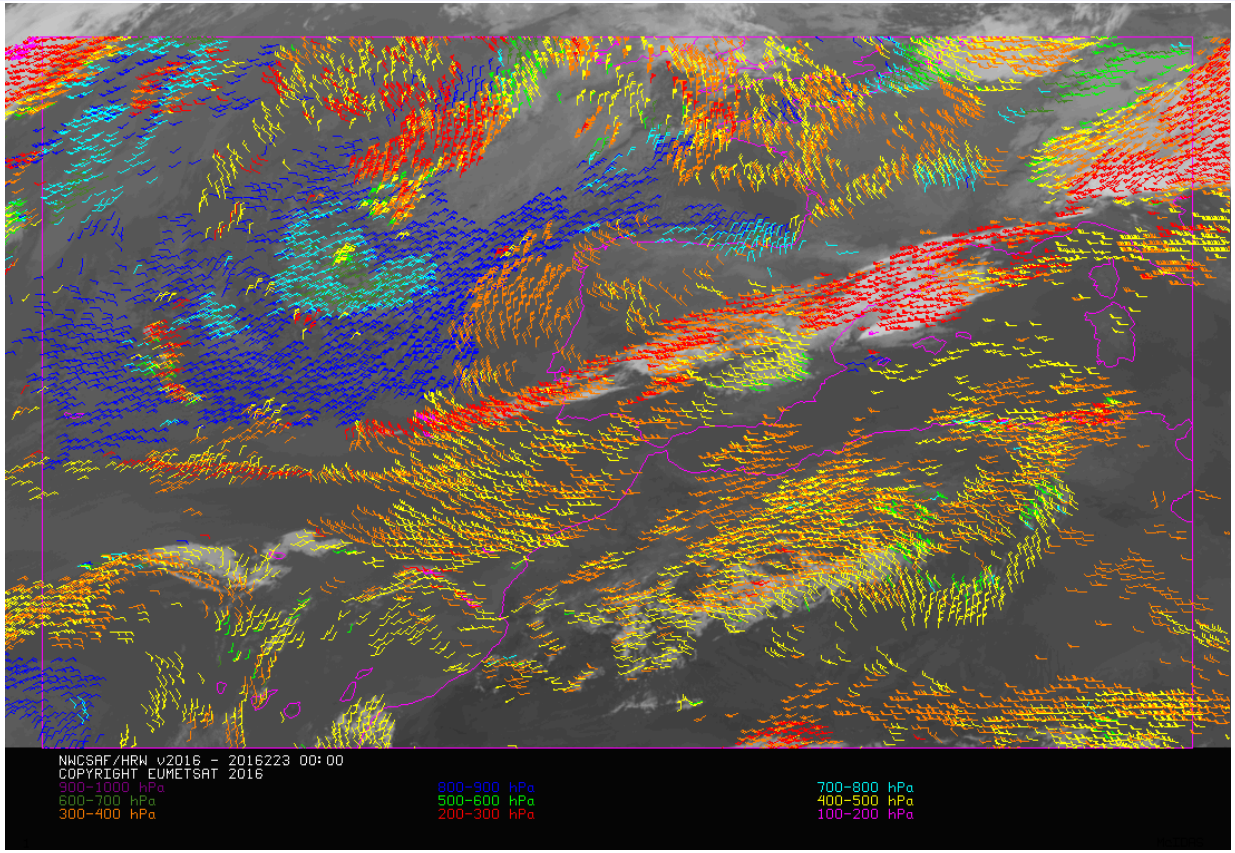


Operational forecasting in Spain. Analysis for the day:

- **High pressure area in the NE Atlantic, extending up to the W Mediterranean.**
- **Summer thermal low in the SW of the Iberian Peninsula,**
  which will cause storms, locally strong, in the E of Spain.

A "wind warning" was defined in the official forecast for
the NW corner of Spain, NE corner of Spain and in the Strait of Gibraltar.

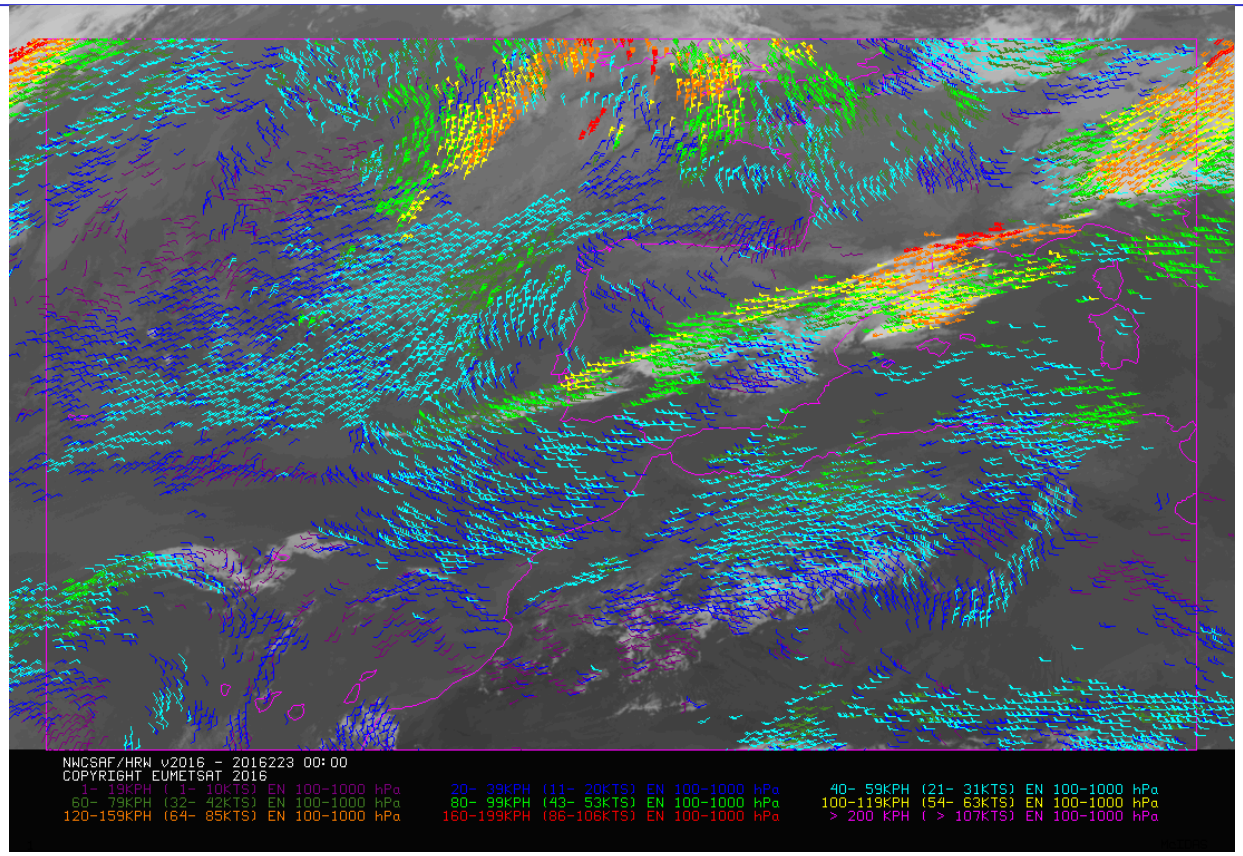
Use of NWCSAF/HRW: Example cases



- The evaluation of wind at the different levels
- The evaluation of convergence/divergence/wind shear related to convection
- The forecast of other meteorological variables related to the behaviour of the wind

is defined by the evolution throughout the day of NWCSAF/HRW AMVs considering the pressure level.

Use of NWCSAF/HRW: Example cases

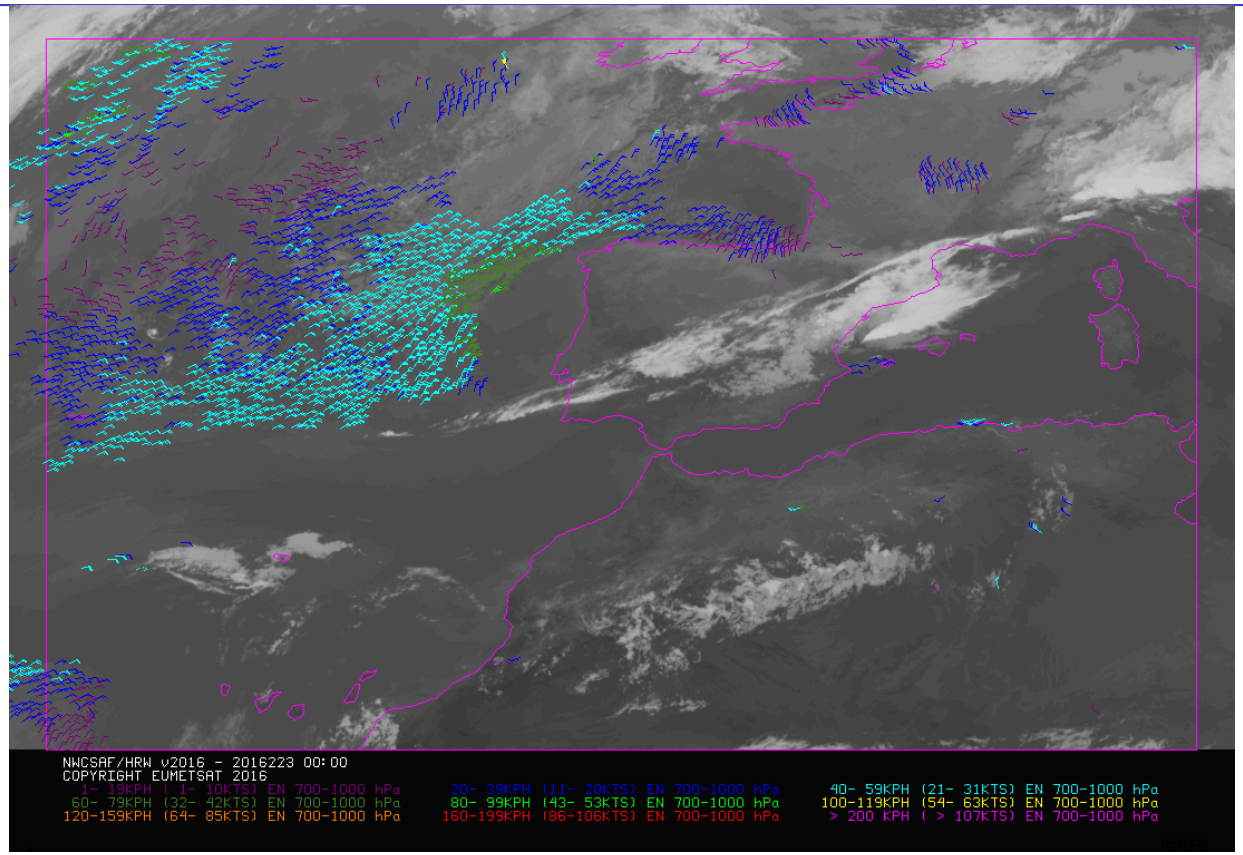


The evolution throughout the day of

NWCSAF/HRW AMVs considering the wind speed at all levels

Is also helpful for this

Use of NWCSAF/HRW: Example cases



The evolution throughout the day of

NWCSAF/HRW AMVs considering the wind speed at low levels is helpful for:

- **Evaluation of wind at low levels**

Use of NWCSAF/HRW: Example cases

NWCSAF/HRW AMVs are able to identify:

- Strong NE winds in low levels in the NW Coast all day
  (Strongest winds 60-80 km/h between 03Z and 15Z)
  ➔ The wind warning has to be extended in time,
  and increased in category to "orange warning".

- NW wind in low levels in the Mediterranean Sea
  between Catalonia and Balearic Islands (40-60 km/h)
  ➔ The wind warning has to be extended to these areas.

- However, there are few AMV data in low levels in the Strait of Gibraltar
  which could be used to check the warning in this area
  ➔ NWCSAF/HRW does not always define relevant data for what we need.

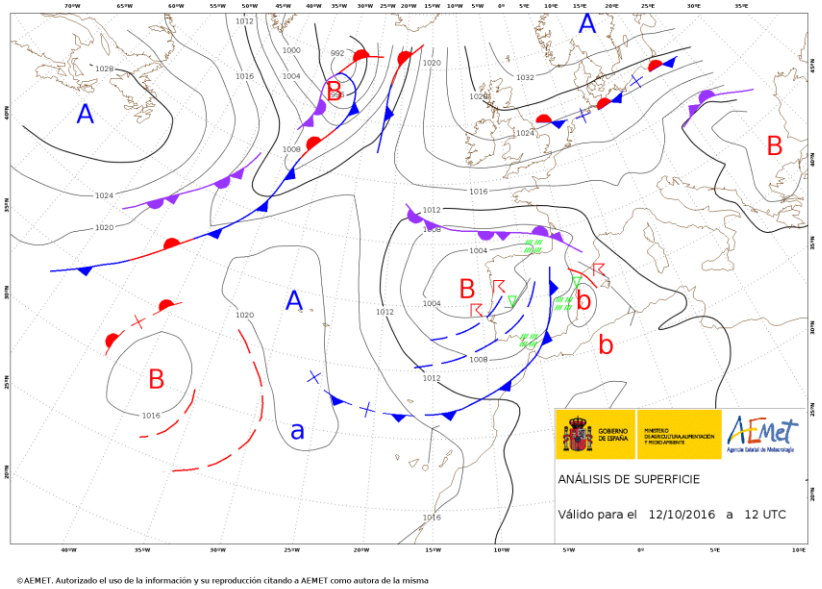
Use of NWCSAF/HRW: Example cases

NWCSAF/HRW is also able to identify:

- **Some winds in the Mediterranean Sea and Spain contributing to convergence and convection:**
  - **> A clear wind shear (E wind in low levels; W wind in high/medium levels)**
  - **> Moisture coming inland from the Mediterranean Sea.**

- **E/SE wind in all levels from Africa into the Canary Islands confirming high temperatures there**
  - **> Verified with Maximum temperatures of 40º in Tenerife and 38º in Lanzarote.**

Use of NWCSAF/HRW: Example cases

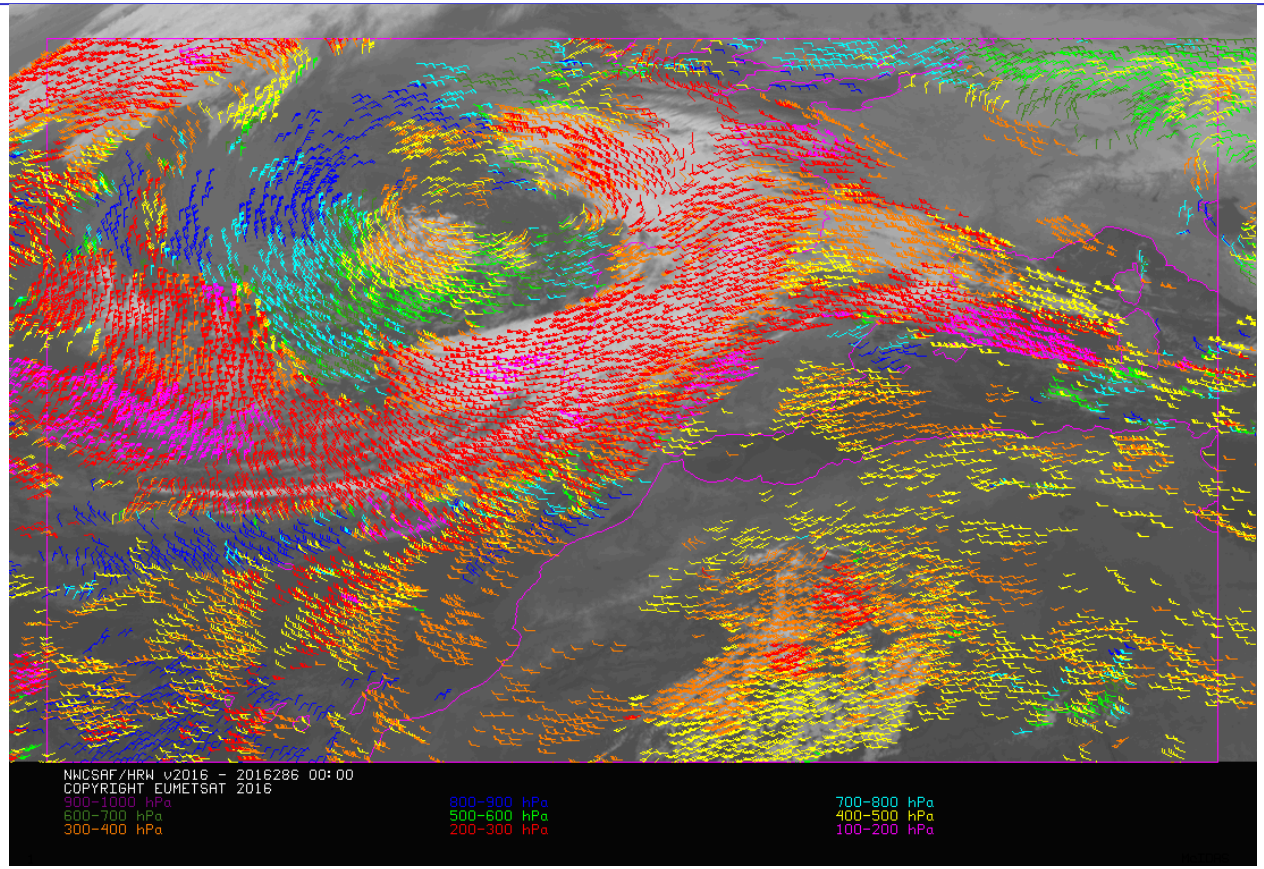


Operational forecasting for Spain. An area of low pressure moves from the NW into the Iberian Peninsula, affecting it throughout the day.

The official forecast defined for this day:

- **Rainfall, including convection, especially in the Western half of Spain and Catalonia.**
- **Windy in mountain areas, and coastal areas in the Mediterranean and Atlantic SW.**
  Strong wind in coastal areas of the South and the Balearic Islands.

Use of NWCSAF/HRW: Example cases

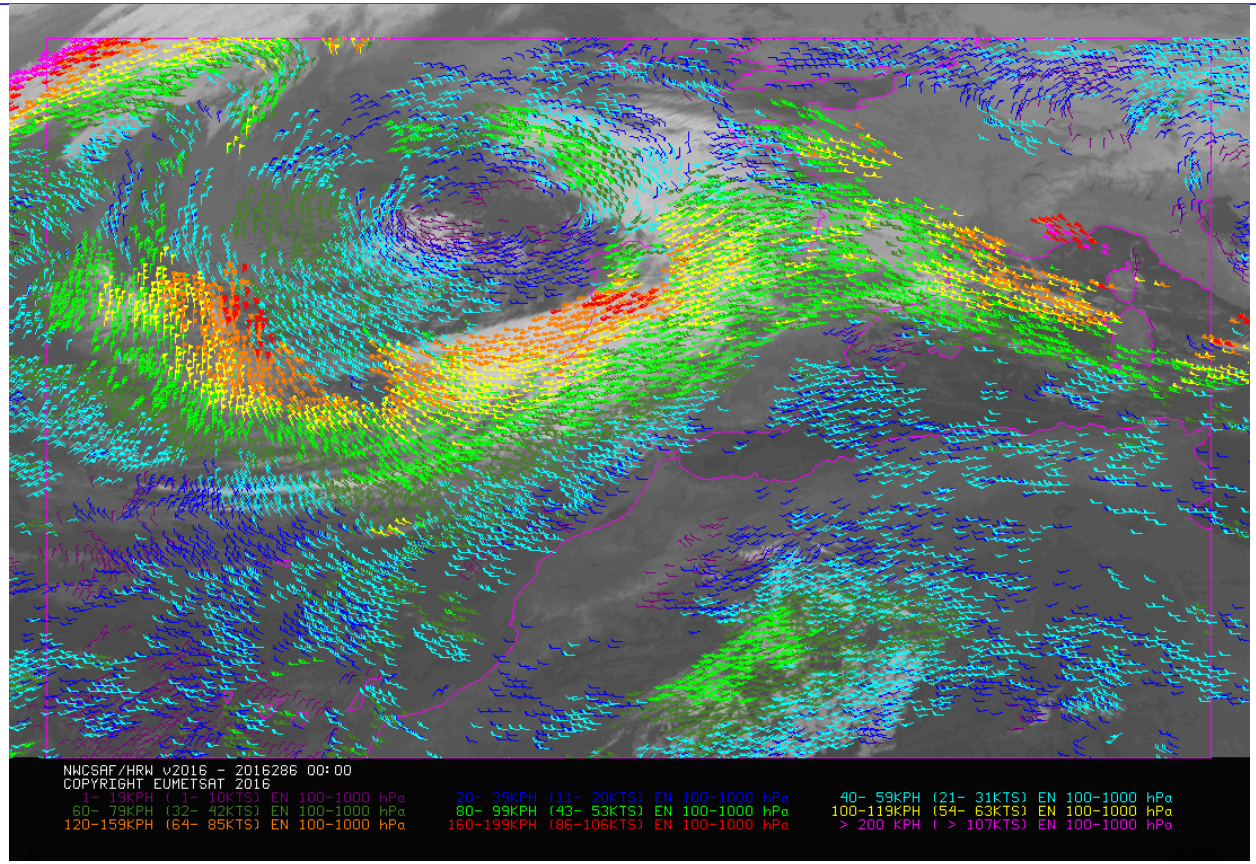


The evolution throughout the day of

NWCSAF/HRW AMVs considering the pressure level

Is helpful to see the evolution of the low pressure area circulation and related fronts

Use of NWCSAF/HRW: Example cases

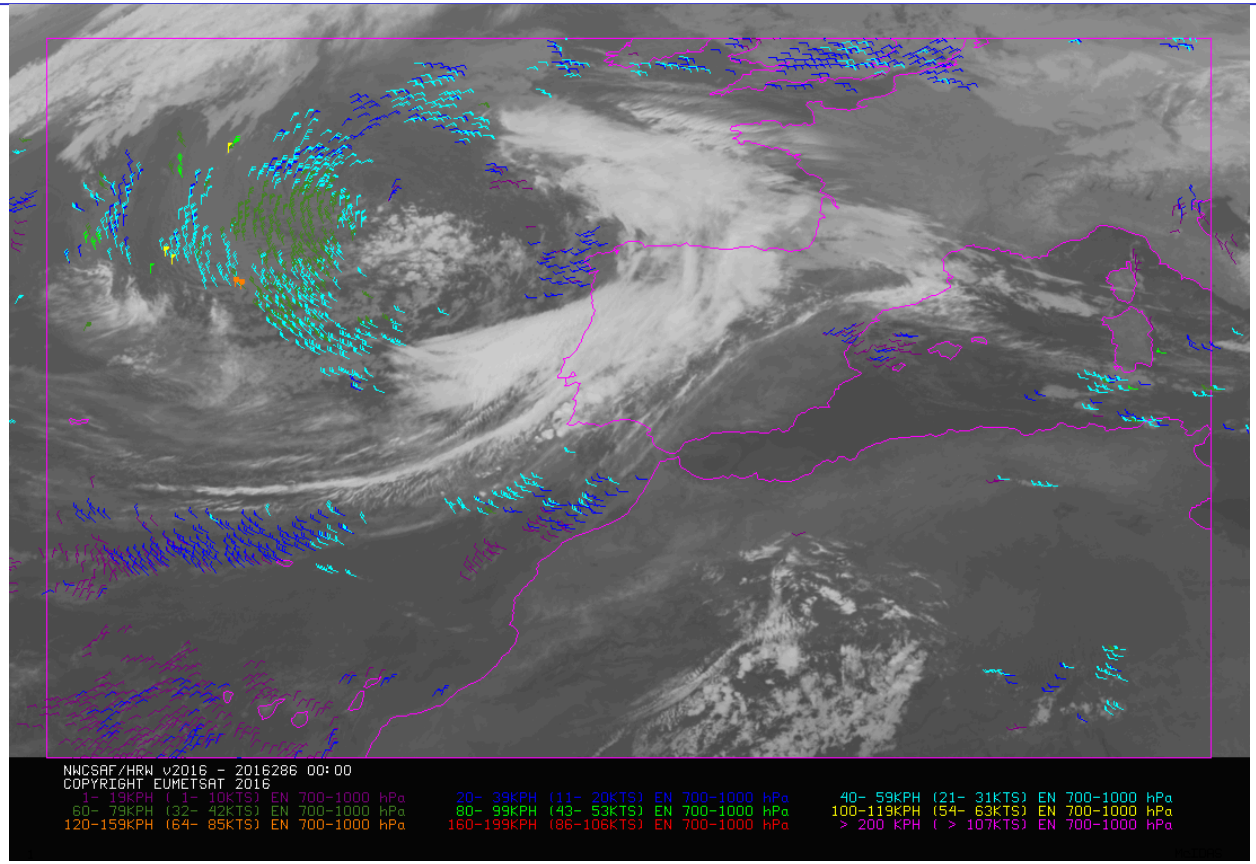


The evolution throughout the day of

NWCSAF/HRW AMVs considering wind speed at all levels

is also helpful to see the evolution of the low pressure area circulation and related fronts

Use of NWCSAF/HRW: Example cases



The evolution throughout the day of

NWCSAF/HRW AMVs considering wind speed at 700-1000 hPa levels

Is helpful to check the evolution of the wind at low levels

Use of NWCSAF/HRW: Example cases

Considering NWCSAF/HRW observations:

We can see the strongest low level winds (maximum values of 40-60 km/h) are located:

- **> In the Mediterranean Sea, before the pass of the front (included in the forecast).**
- **> In the Gulf of Cádiz and SW areas of Spain, before and after the pass of the front (included in the forecast).**
- **> In the Canary Islands in the evening, before the pass of the front (not included in the forecast).**

The AMV observations fit very well with those shown later by METAR reports in airports.

Use of NWCSAF/HRW: Example cases

Other conclusions:

We can see a high density of wind data in all layers

➔ We can do a quick analysis of the circulation and dynamics of the low pressure area in all levels (useful for example in aeronautics forecasting).

➔ There are cases with two different circulations in different levels in the same location:

- F.ex. in the Balearic Islands:

  with S wind in low levels and W wind in high/medium levels in the morning.

  in the Canary Islands:

  with NE winds in low levels and NW wind high/medium levels in the morning.

But with the compact structure of the front

we cannot analyse the low level winds just in the moment the front is passing.

➔ The analysis is easier before the pass of the front, and especially in the cold advection after the pass of the front.

➔ In these cases, NWCSAF/HRW shows a larger amount of low level AMVs.

How to reach NWCSAF/HRW-High Resolution Winds

All National Meteorological Services within EUMETSAT

can be users of NWCSAF & NWCSAF/HRW software.

Any other Organisation may also apply, considering conditions defined in

www.nwcsaf.org/web/guest/software-delivery-conditions

All applicants have become users up to now without restrictions:

around 400 institutions from all around the world.

The software delivery is authorized according to the Licence Agreement,

signed by EUMETSAT (represented by AEMET) and the applicant user.

After this, access credentials to NWCSAF Helpdesk Restricted Area are provided,

where NWCSAF software can be downloaded:

nwc-saf.eumetsat.int

How to reach NWCSAF/HRW-High Resolution Winds

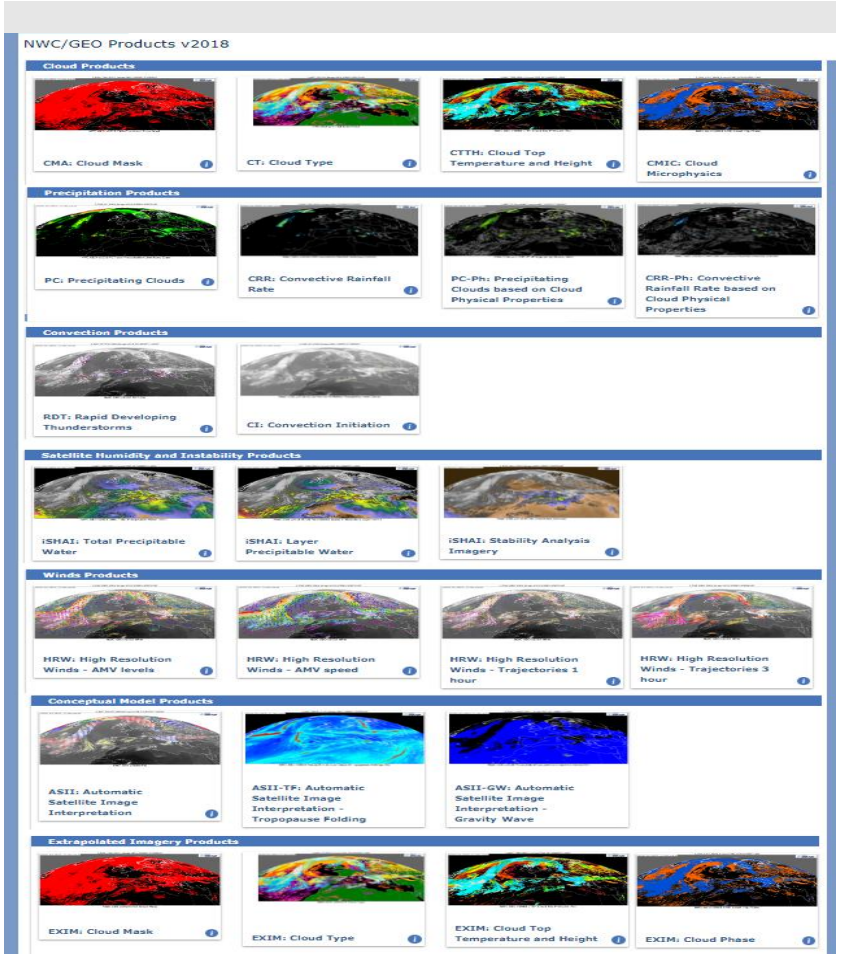
Real time visualization of NWCSAF/HRW outputs

is available for MSG satellite in Europe, with update every 15 minutes, also in NWCSAF Helpdesk

nwc-saf.eumetsat.int

> For the moment only for the geostationary version.

> Running the latest version of the software with the default configuration.



How to reach NWCSAF/HRW-High Resolution Winds

Complete and detailed info on NWCSAF/HRW software can be found in:

> The official NWCSAF Helpdesk documentation

(www.nwcsaf.org > Science > Scientific Documentation):

- ➔ **“Algorithm Theoretical Basis Document (ATBD)”**
- ➔ **“Validation Report (VR)”**

Thank you very much for your attention!

Any questions?

For any further help:

jgarciap@aemet.es