EXPLOSIVE CYCLOGENESIS OF EXTRA-TROPICAL CYCLONE KLAUS AND ITS EFFECTS IN SPAIN. A CASE STUDY OF HURRICANE FORCE GUSTS

GOBIERNO DE ESPAÑA — MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

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Damages in Catalonia. Photos, Joan Arús

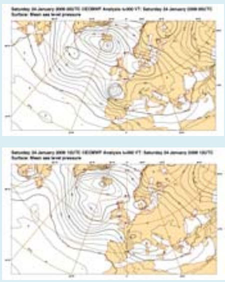
Extremely intense winds and hurricane force gusts were reported in many places of the Iberian Peninsula when Klaus swept the Peninsula. In Catalonia, the damages were significant and four children died when municipal sport centre collapsed.

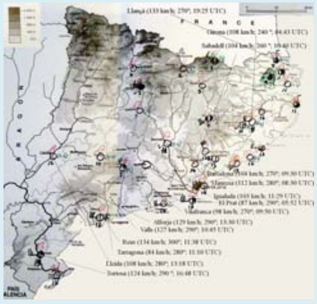
A study about the verification of different gust estimation methods is shown in the poster, using operational HIRLAM-AEMET numerical prediction model as a reference.

ENVISAT/ESA image of Klaus over France
24-01-09
10:12 UTC

Synoptic and mesoscale settings

• A low latitude explosive cyclogenesis took place at the west of the Iberian Peninsula due to the positive interaction between an incipient surface low pressure system and an upper level positive potential vorticity anomaly, PV.
• The resultant extratropical depression deepened very rapidly and it swept the north of the Iberian Peninsula and, later on, the south of France.
• The deterministic models, ECMWF & HIRLAM, forecasted relatively well the trajectory and deepening of the depression.
• Wind speeds around 90-100 Km/h were reported in many places and gusty winds around 120-130 km/h or more were sensed in low altitude areas. More intense winds and gusts were reported in high mountain areas.
• The wind effects were different at northwestern (i.e. Galicia) and northeastern of Spain (i.e. Catalonia).





Operational map from 24/01/09 elaborated in Barcelona GPV (AEMET Regional Surveillance Center). Some notes have been added later on:

- T maxima, 23rd, in red.
- T minima during the night of 22nd-23rd in black.
- Precipitation (mm) in green, 7 UTC 24th – 7 UTC 23rd.
- Precipitation areas in green*.
- Sky conditions*.
- Direction and speed wind (in kt)*.

*At the observation time

Notes and remarks of gust values and reporting time were added: Place (Km/h; direction; HH:MM)

Wind gust estimation methods (turbulent component)

Method based on a conceptual model about how gusts may form

1.- TKE method (Brasseur, MWR 2001)

- A parcel at a a given height z_p will be able to reach the surface if the mean TKE is greater than the buoyant energy . Such parcels are assumed to bring their momentum to the surface as gusts.

$$F_{gust} = \max(F_p) \quad for \quad z_p \; satisfying$$

$$\frac{1}{z_p}\int_0^{z_p} TKE(p) \geq \int_0^{z_p} \frac{\Delta\theta_v(z)}{\theta_v}dz$$

• We can also estimate bounds for the gusts:
- Upper bound: Maximum wind in the Boundary Layer
- Lower bound: Only considered parcels satisfying

$$\frac{\overline{w'w'}(z_p)}{2} \geq \int_0^{z_p} \frac{\Delta\theta_v(z)}{\theta_v}dz$$

Methods based on empirical relationships of wind spectra

2.- ECMWF method (Cy28r1, Beljaars, 2004)

http://www.ecmwf.int/research/ifsdocs/CY28r1/Physics/Physics-04-09.html

$$F_{gust} = F_{10m} + \sigma_u(z_0)\, c_u\left(\frac{z_i}{L}\right) u_*$$

• This stability term is nearly constant for strong winds so the most important term is u_*.
• σ decreases with z_0. This term has been disabled at ECMWF from Cy31r1 on due to a more realistic treatment of z_0 in the model.
• This algorithm is currently used in the operational versions of HIRLAM model at AEMET.

3.- KNMI method (Schreur & Geertsema, 2009)

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$$F_{gust} = F_{10m}\, gust\_factor\,(TKE_{nlev}, F_{10m})$$

• The gust factor depends mainly on parameterized TKE and on 10m wind. It is in HIRLAM system from version 7.1 on

4.- AROME method (G. Hello)

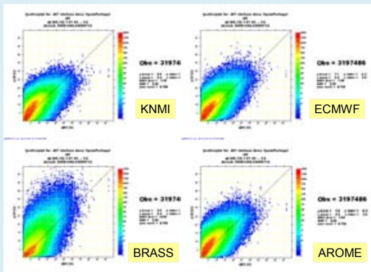
$$F_{gust} = F_{10m}\left[1 + 4\sqrt{\frac{TKE_{nlev}}{F_{10m}^2}}\right]$$

• Similar to the KNMI method with a simpler gust factor.

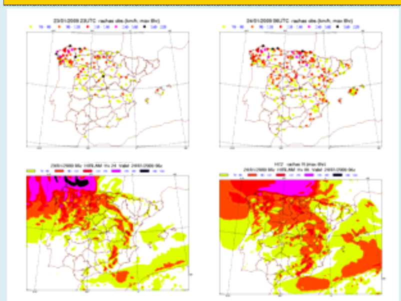
•Simulations with operational HIRLAM model at 5 km resolution.

Verification against hourly AEMET station for 8 months

• Results from the objective verification

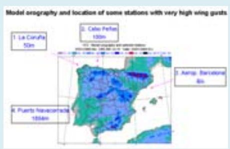


HIRLAM simulations of gusts associated with extratropical cyclone Klaus



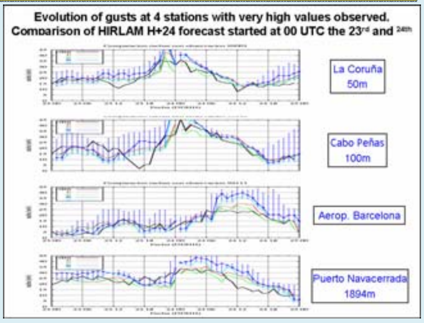
Comparison of model gust maxima with observations: lefts panels January 23rd 18/24 UTC, right panels January 24th 00/06 UTC. Only values above 70 km/hr are plotted.

• In the figures on the right, it is showed the model simulations at some select locations where very high values of gusts were registered. We combine two 24 hr integrations starting the 23rd and 24th at 00 UTC.
•. We show the results from the different gust methods. For the Brasseur method also an estimation of the minimum and maximum gust is given (bounds for the gust forecast).
• The evolution is well captured by the model with the maxima translating eastwards and producing the highest values in Catalonia in the morning of the 24th.
•Note that Barcelona airport is very close to Sant Boi where the sport center collapsed and the model reproduce well the gusts at this location.



• OBS Observation
• Ew ECMWF method
• R KNMI method
• B Brasseur method including bounds
• A AROME method

Evolution of gusts at 4 stations with very high values observed. Comparison of HIRLAM H+24 forecast started at 00 UTC the 23rd and 24th



CONCLUSIONS

• We have tested different methods for wind gust estimation using HIRLAM 0.05 km H+24 forecast and verifying against AEMET automatic station network over a period of 8 months and using hourly observations. These methods have also been applied and verified to Klaus case.

• For Klaus case study the model reproduce well the synoptic patterns and the deepening of the cyclone.
- The evolution and even the values of the gusts are well captured.
- Absolute maxima are underestimated.

• From the 8 months objective verification:
- Despite the differences in the algorithms, performance is similar, specially for the 'empirical' approaches.
  - ECMWF and AROME methods perform slightly better above 15 m/s.
  - The method based on buoyancy/mean TKE method works well for lower gusts (<15 m/s/) but overestimates significantly high values.
- The uncertainty associated with the prediction of very high values (>30 m/s) is big.

• We think that the methods can be improved:
- Inclusion of a stability factor in the Brasseur method.
- Tune the KNMI method to produce higher gust.

•Despite the uncertainty in the prediction of high values, the methods for wind gust estimation seem to be a very useful forecast tool.

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