GOBIERNO DE ESPAÑA

MINISTERIO DE MEDIO AMBIENTE Y MEDIO RURAL Y MARINO

AEMet Agencia Estatal de Meteorología

Verification of wind gust forecasts

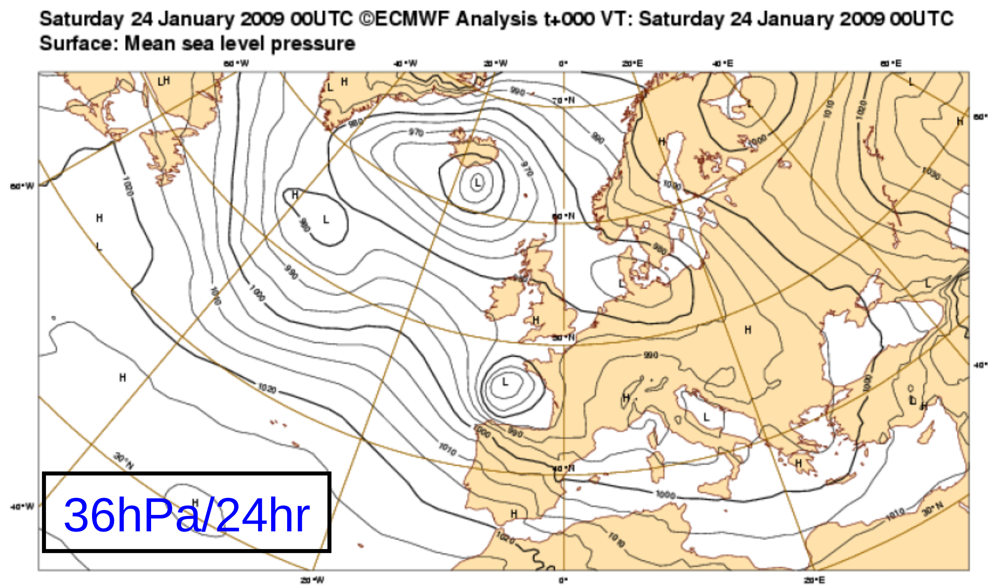
Javier Calvo and Gema Morales

Outline

- Motivation
- Errors in 10m wind
- Description of the methods for WGE
- Verification against AEMET automatic station network
- Conclusions

The explosive cyclogenesis of 23-25 January 2009

- Very strong winds Northern part of Spain.
- Generalized destruction



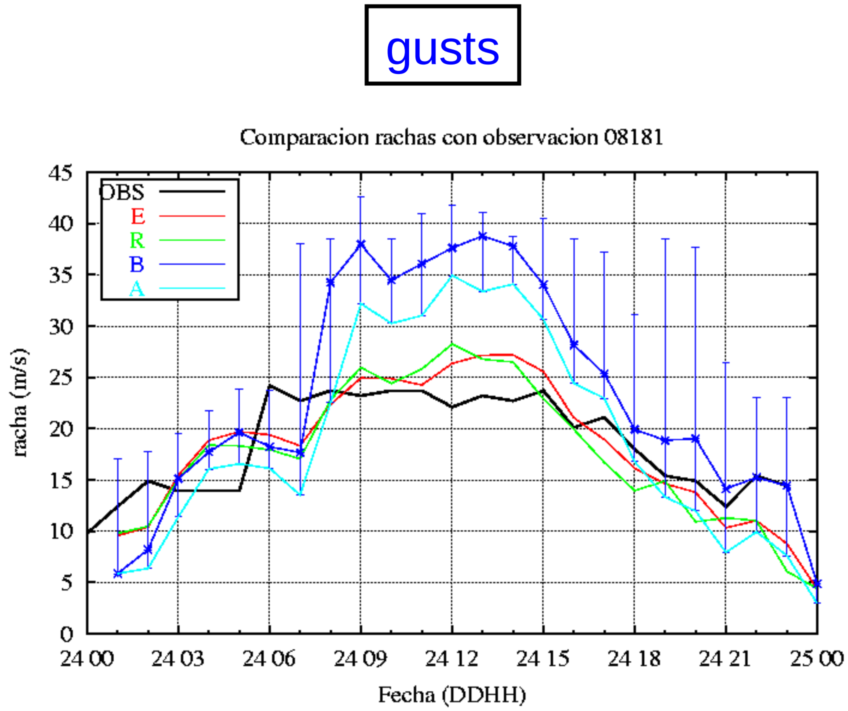
Several stations with gusts above 130 km/hr

- Several deaths including 4 kids who died when a sport center collapsed in Sant Boi (Barcelona)

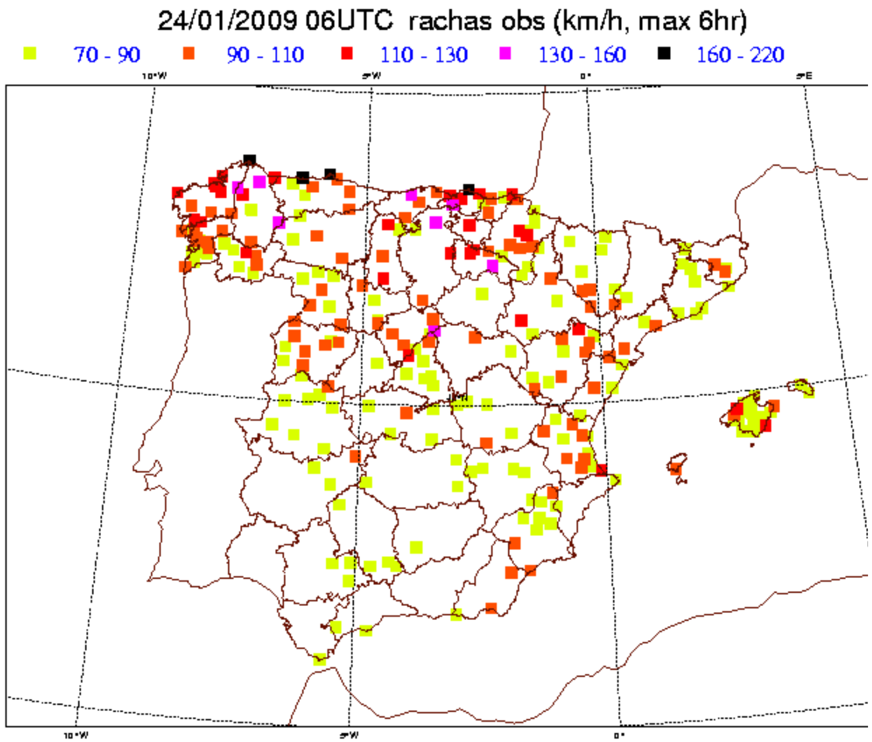
Who's to blame?

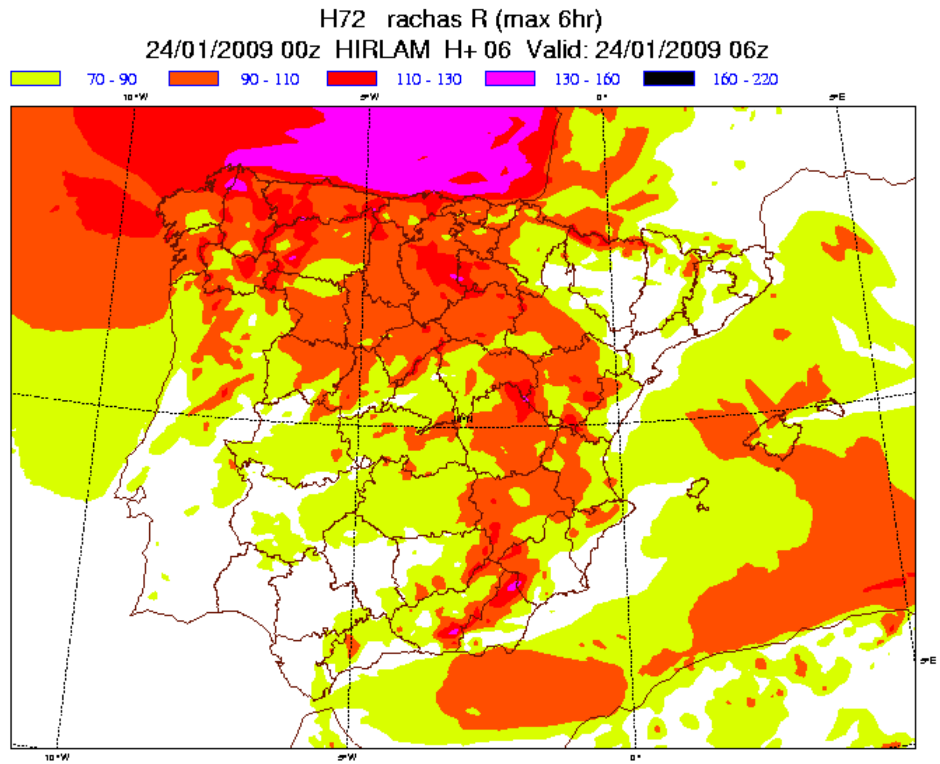
- Comparison of H+24 with observations from Barcelona airport

- HIRLAM 5km
- Comparison of different methods for gust estimation



24/01/09. Forecasts vs observations: Max 00/06 and 07/12





Very high values predicted but underestimated. Translation and patterns well captured.

Wind Gust Estimation Methods

- Turbulent gusts
  - Based on information from vertical diffusion scheme: Stability, momentum drag, TKE, roughness.
  - Errors highly correlated with errors in wind speed
- Convective gusts
  - Produced by downdrafts from deep convection
  - Difficult to parameterized often ignored

Turbulent gusts: Methods tested

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- ECMWF method (A. Beljaars, 2004)
- HIRLAM 7.1 (Ben W. Schreur)
- AROME method (Gwenaelle Hello)

Empirical relationships

- Brasseur et. al 2001

Conceptual model based on buoyancy and TKE in the BL

ECMWF method (Cy28r1, Beljaars, 2004)

- Empirical relationship based on observed turbulence spectra

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

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

$$c_u\left(\frac{z_i}{L}\right) = \begin{cases} 2.29\left(1 - \dfrac{0.5 z_i}{12L}\right)^{1/3} & L < 0 \\ 2.29 & L > 0 \end{cases}$$

This term is negligible for strong winds so the most important term is u_*

$$\sigma_u(z_0): \quad decreases\ with\ z_0 \quad \approx (5-8)$$

From cycle 31r1 on ECMWF has dropped the roughness term due to a more realistic treatment of z_0 in the model (A. Beljaars, personal communication)

HIRLAM 7.1 reference (Ben W. Schreur)

- Developed at KNMI and included in Hirlam reference from version 7.1

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

Takes into account the turbulence spectrum and is calibrated to give the maximum 3” gust in 10’ interval during an hour as it is measured.

AROME method (Gwenaelle Hello)

- The method used in AROME: Similar to the Schreur method with a simpler gust factor.

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

TKE method (Brasseur, 2001)

Brasseur, O.,2001: *Development an Application of a Physical Approach to Estimating Wind Gusts*. Mon. Wea. Rev., 129, 5-25

- Based on a conceptual model about the formation of the gusts.

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

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

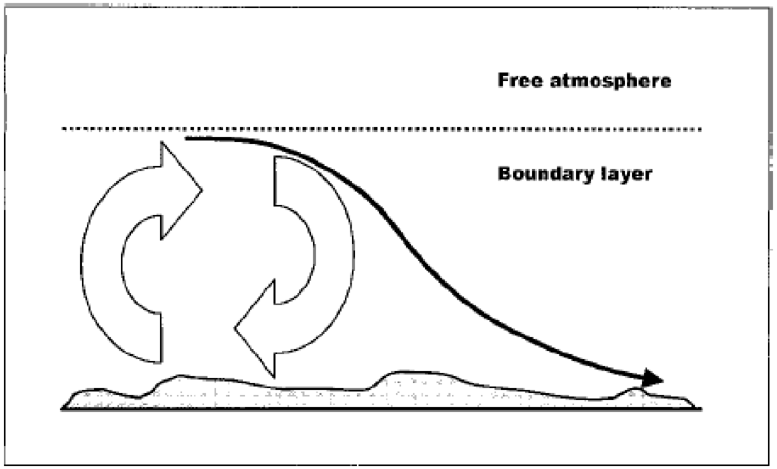
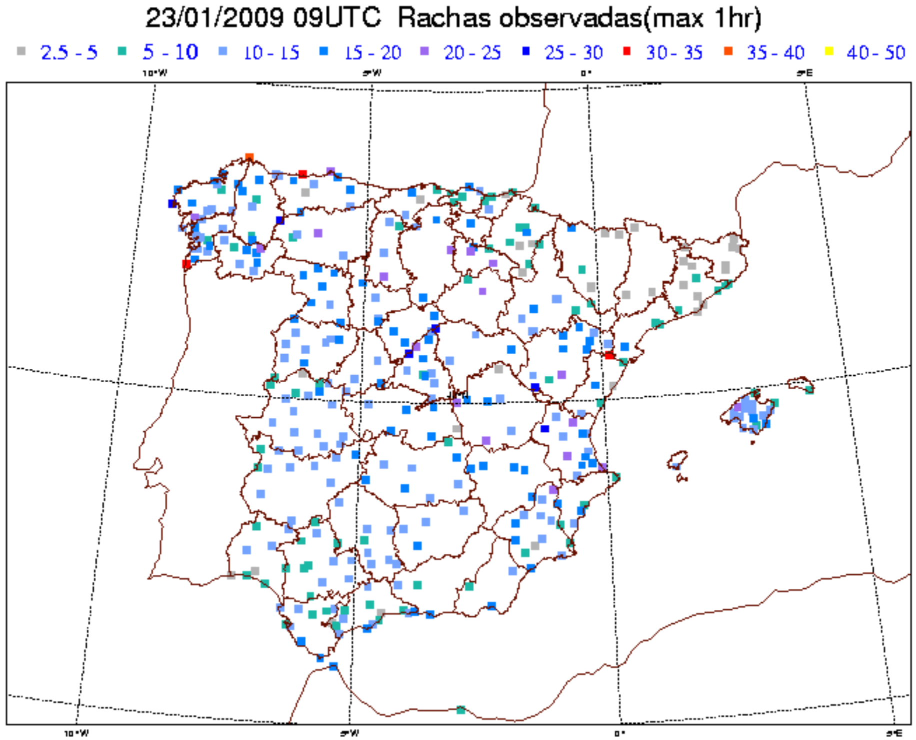


FIG. 1. Proposed mechanism explaining gusts observed at the surface: turbulent eddies are triggering the deflection of air parcels flowing in the boundary layer downward to the surface.

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

Verification against AEMET automatic station network.

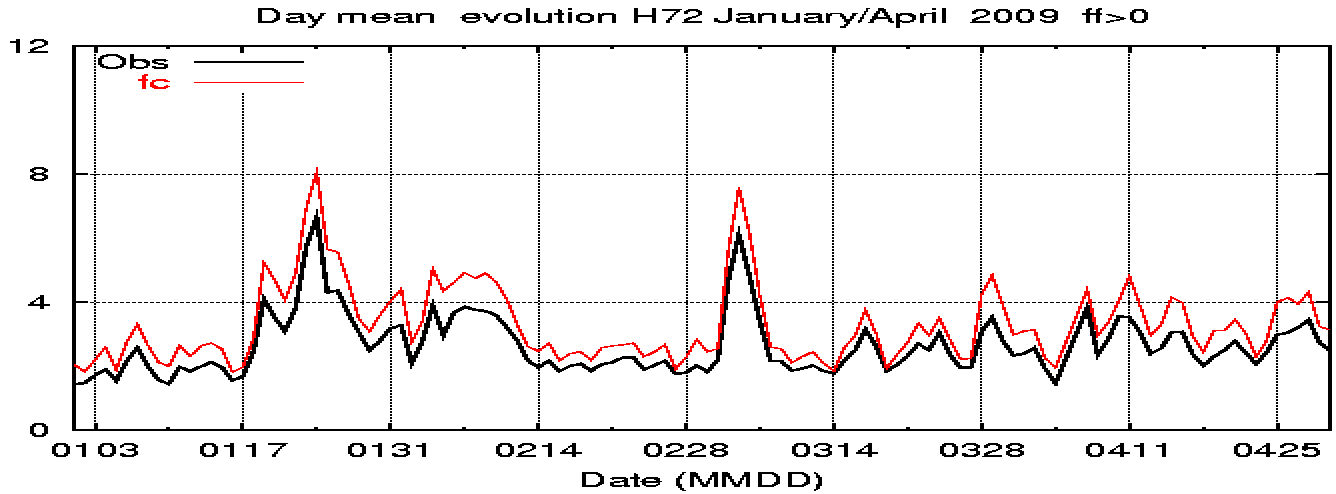
- Using HARMONIE/HIRALM verification with some extensions and adapted to use AEMET observation network
- 340 stations. Period January-April 2009 ≈ $2*10^6$ obs
- Hourly verification: We compute the maximum in 1 hour of the 3” gusts reported every 10’ in 1 hour
- Model: estimate 3” gust every time step and compute 1 hour maximum



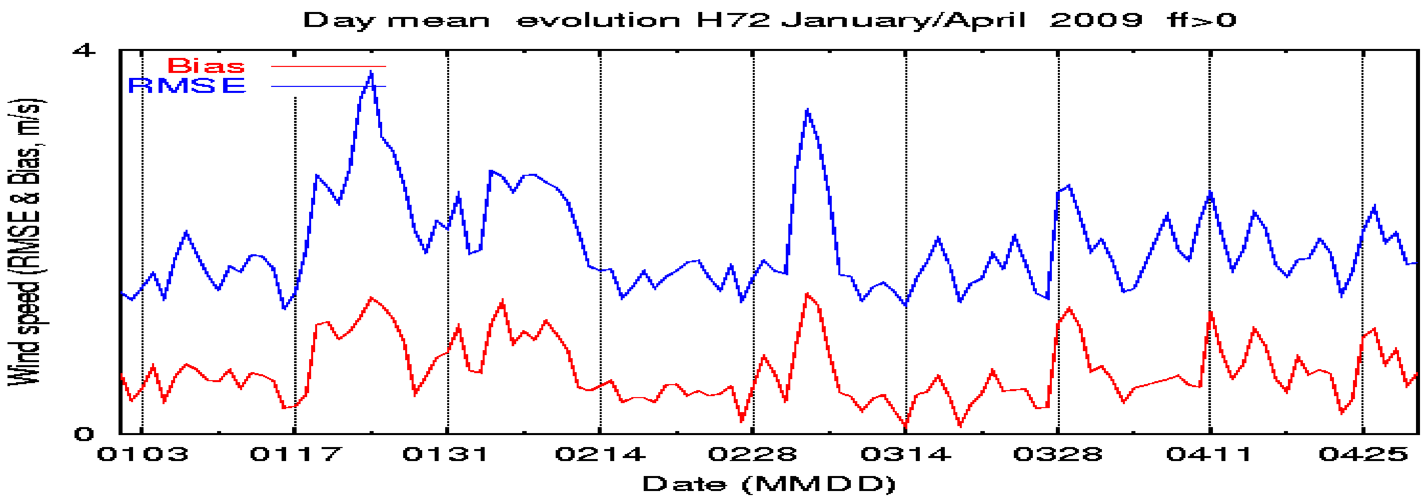
10m wind Speed

10m wind speed. Evolution of area/day means

HIRALM 0.05 H+1/24 Forecasts



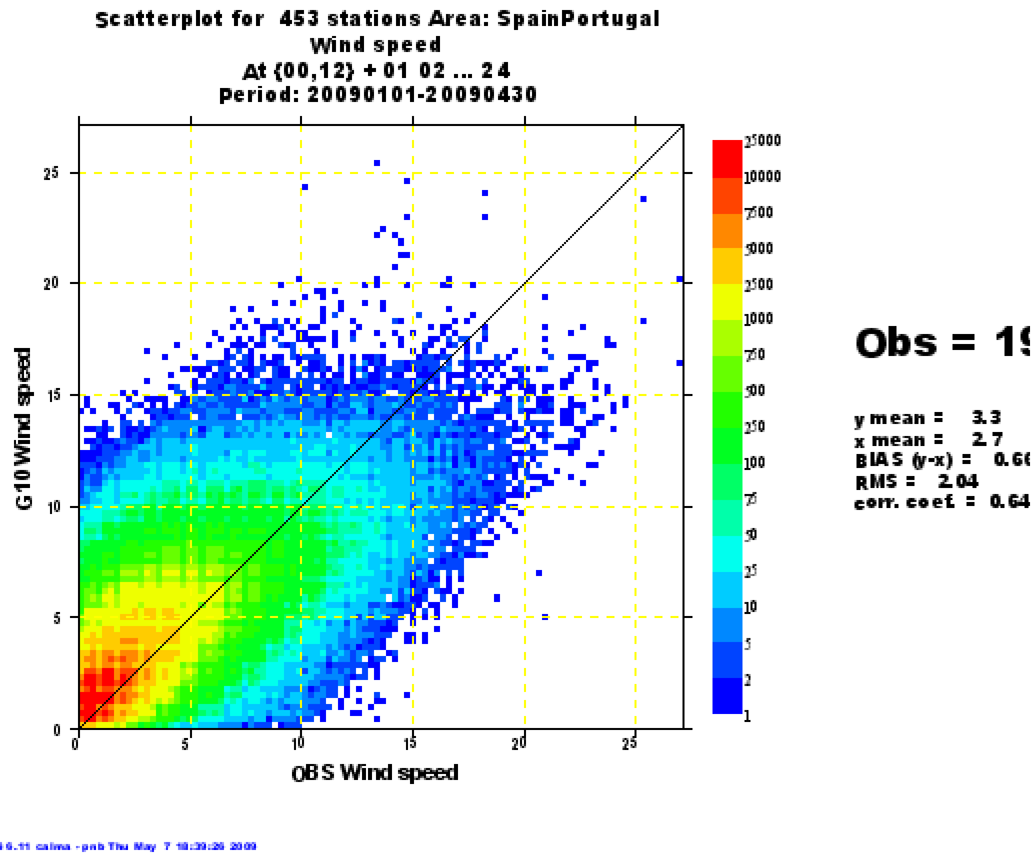
Mean values



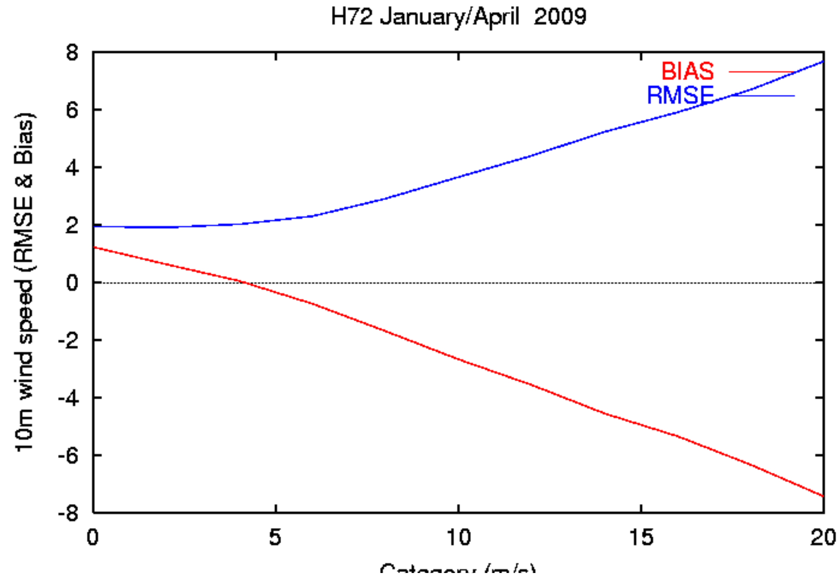
RMSE and Bias

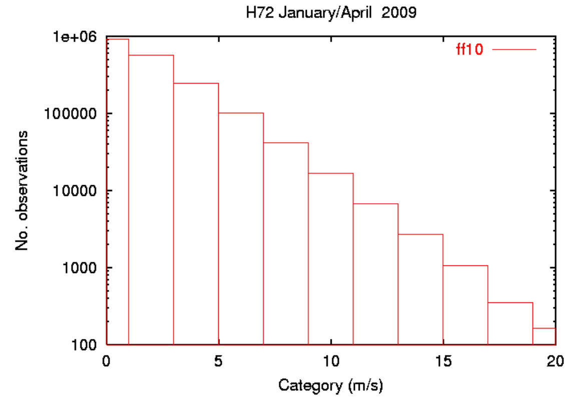
10m wind speed function of the observed category

Frequency distribution

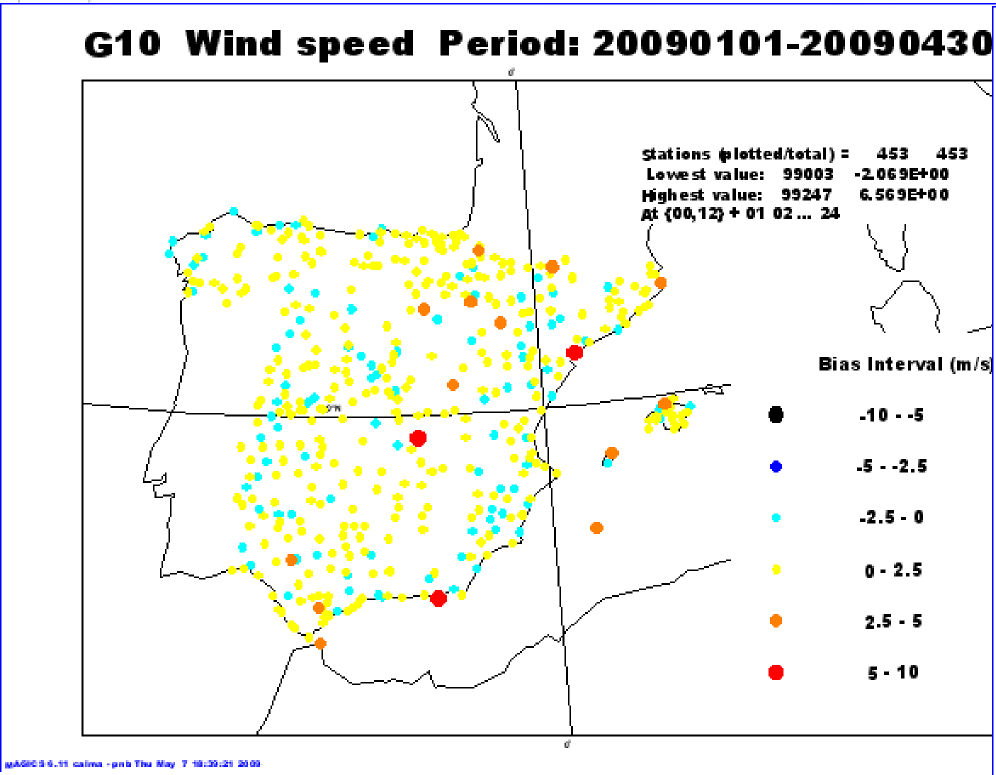


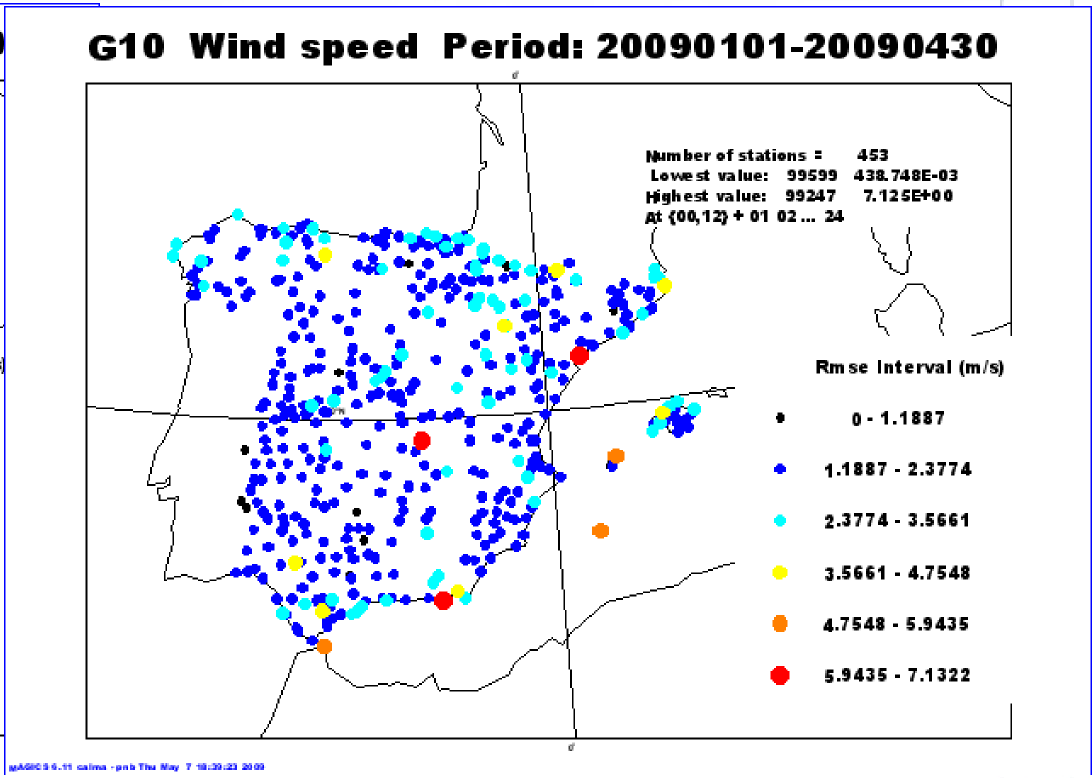
RMSE and Bias function of the observed category





10m wind speed. Maps of errors

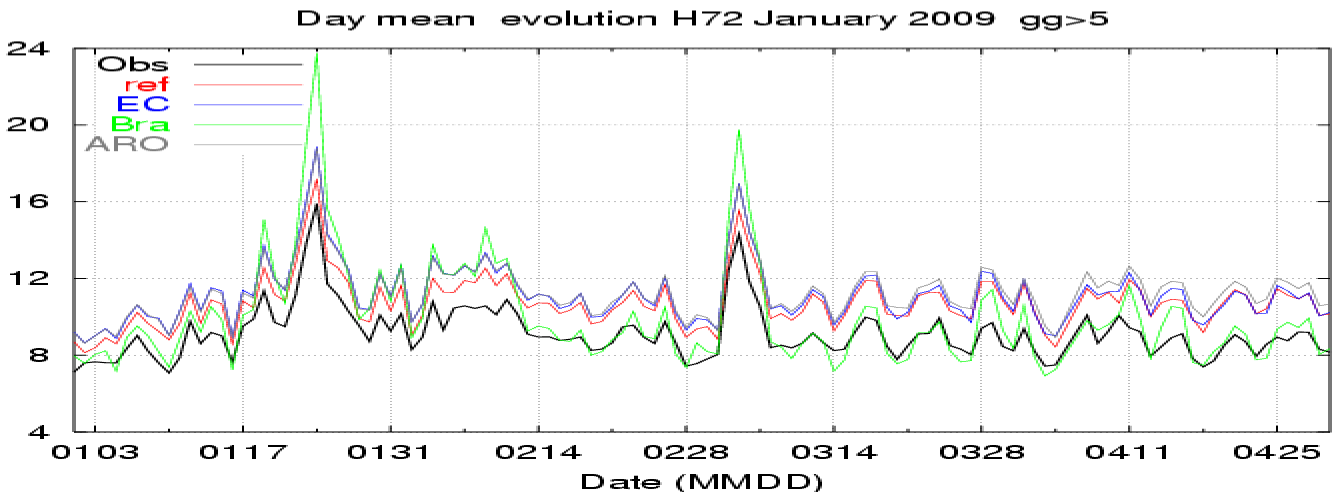




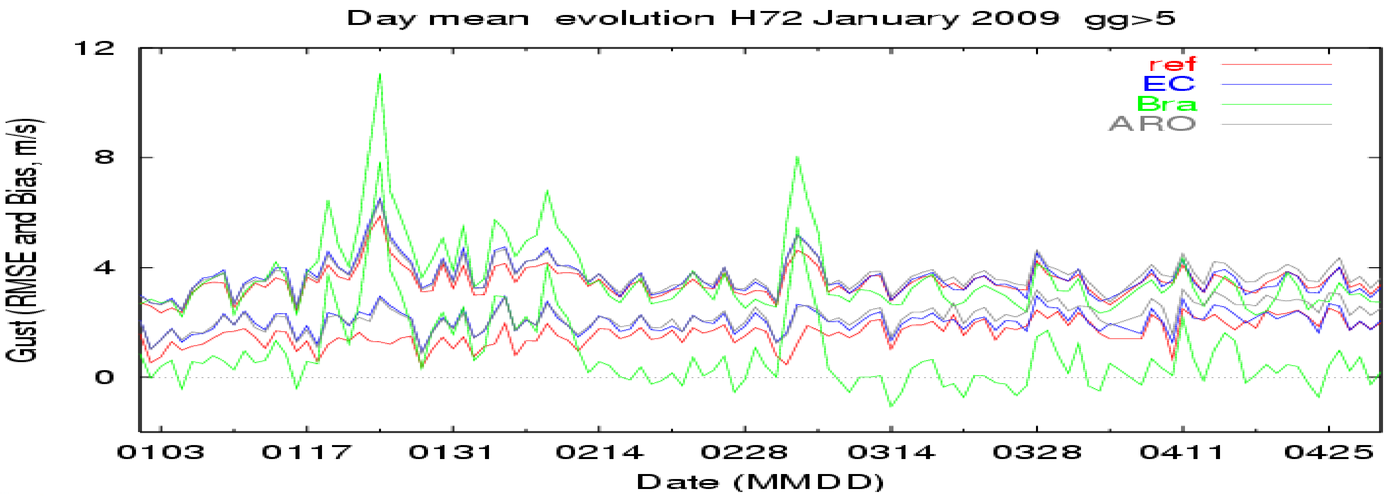
- Bigger errors in mountain areas but also greater values

Wind Gusts

Gusts. Evolution of area/day means

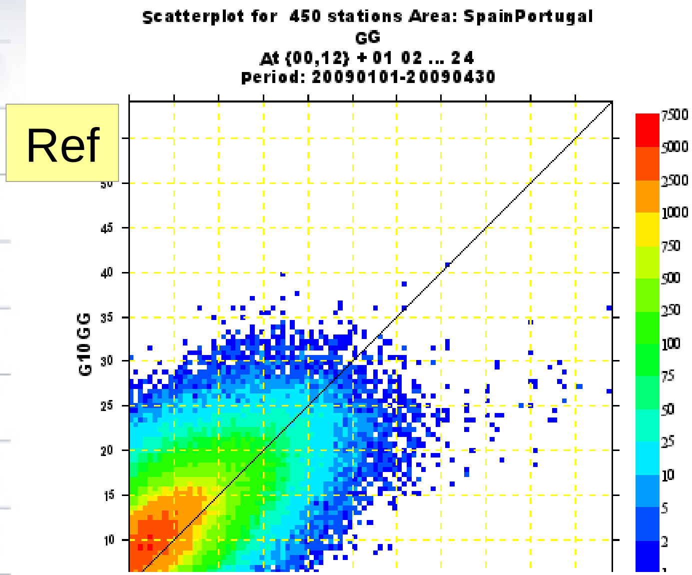


Mean values



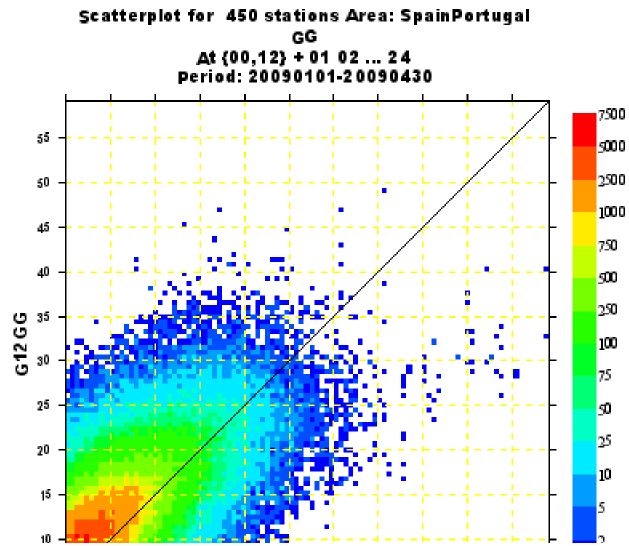
RMSE and Bias

Gust. Frequency of events Forecast-Observation



Obs = 66062

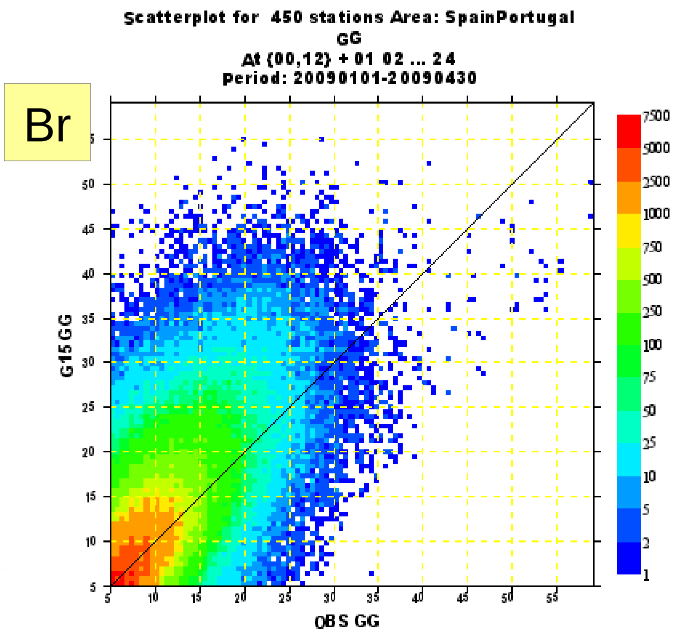
y mean = 11.4 y stdev =
x mean = 9.8 x stdev =
BIAS (y-x) = 1.67
RMS = 3.79
corr. coef. = 0.586



EC

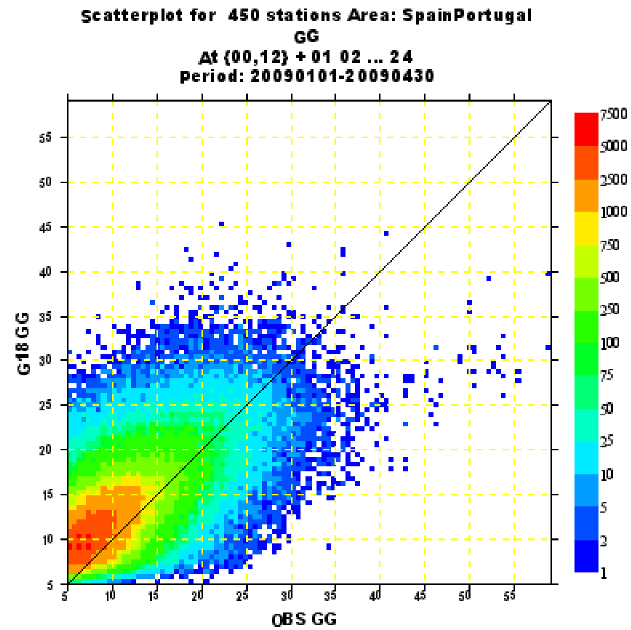
Obs = 660622

y mean = 11.9 y stdev = 3.8
x mean = 9.8 x stdev = 3.9
BIAS (y-x) = 2.19
RMS = 4.02
corr. coef. = 0.616



Obs = 66062

y mean = 11.3 y stdev =
x mean = 9.8 x stdev =
BIAS (y-x) = 1.57
RMS = 4.68
corr. coef. = 0.605



Aro

Obs = 660622

y mean = 12.1 y stdev = 3.7
x mean = 9.8 x stdev = 3.9
BIAS (y-x) = 2.35
RMS = 4.09
corr. coef. = 0.609

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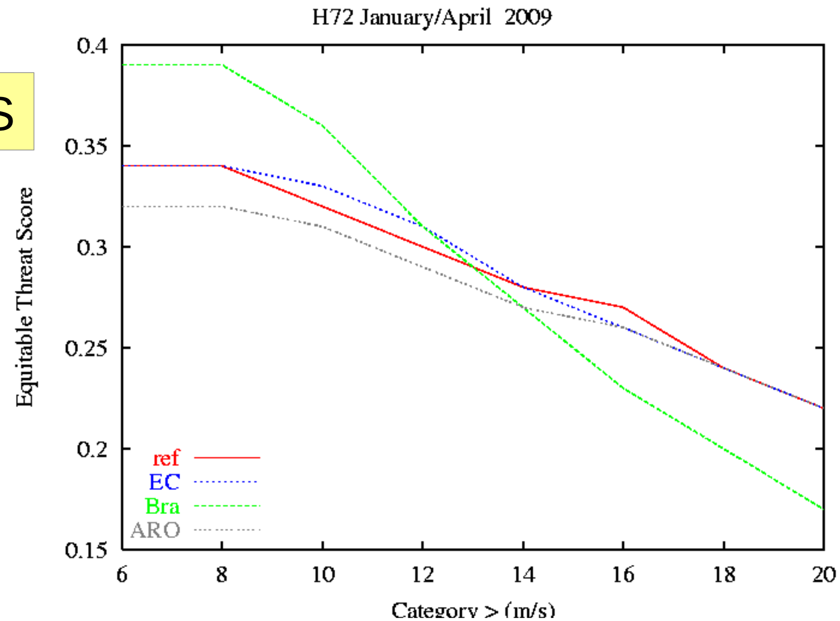
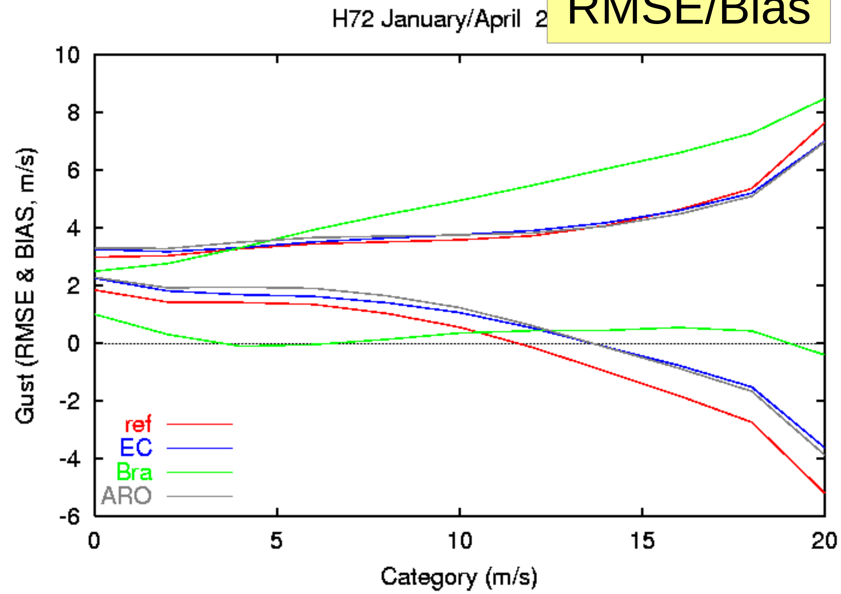
Gust. Different performance scores function of observed category

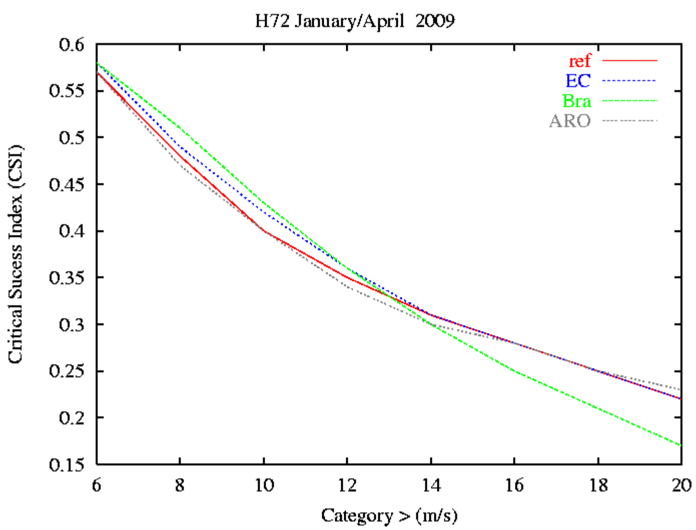
ETS

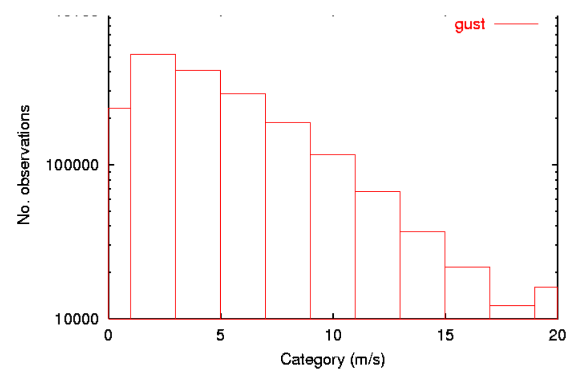


RMSE/Bias

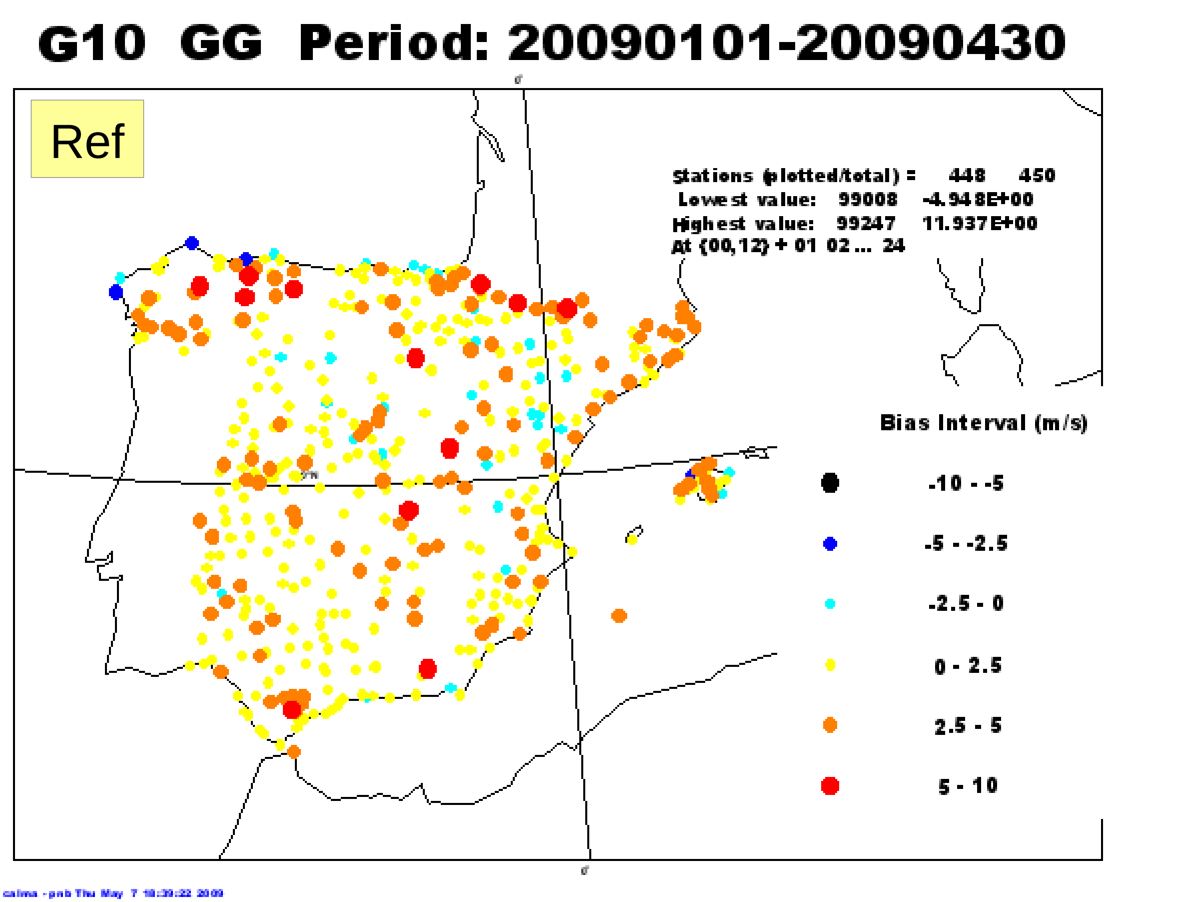


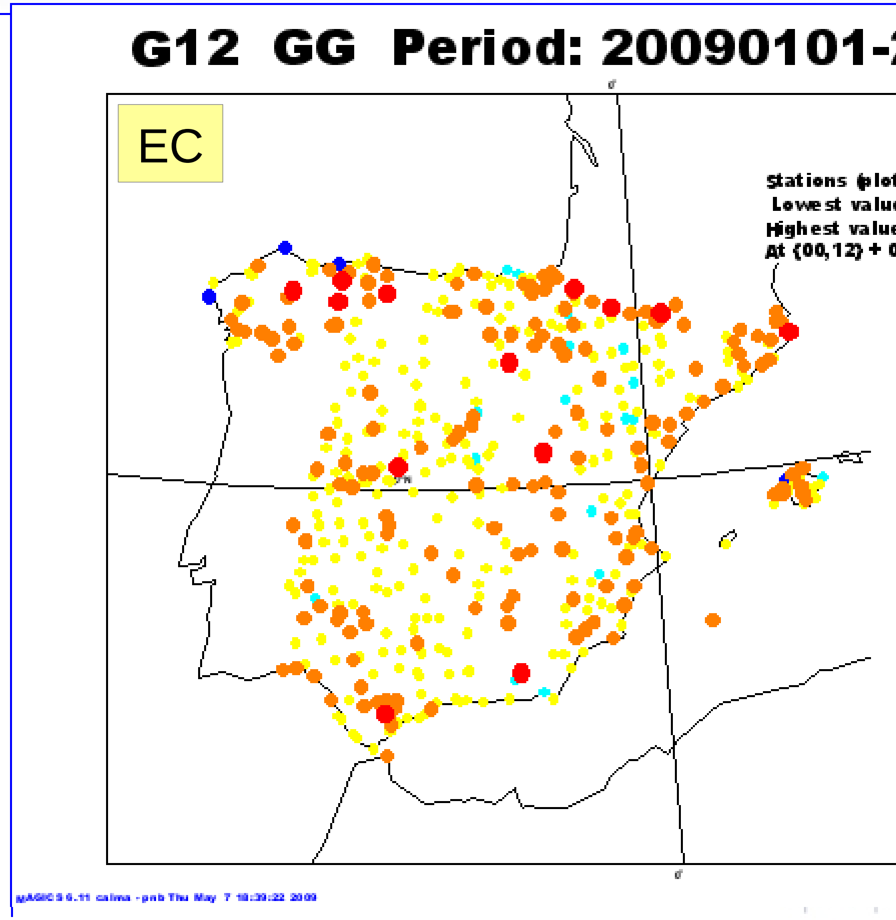
CSI



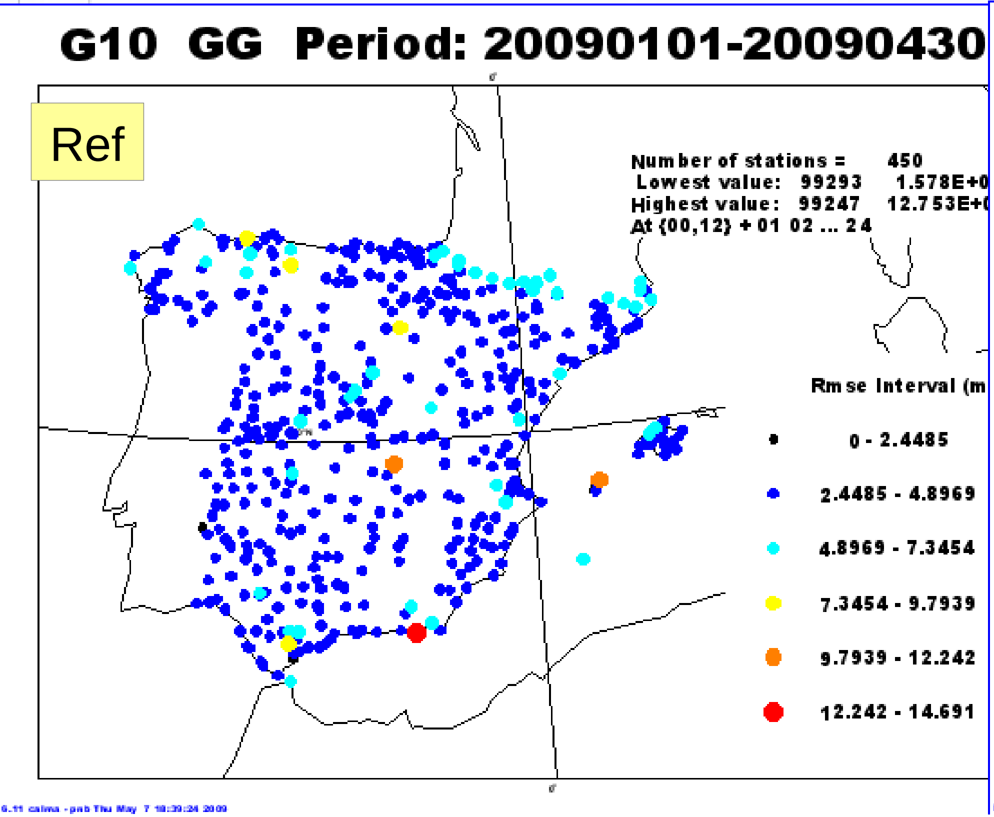


Bias maps

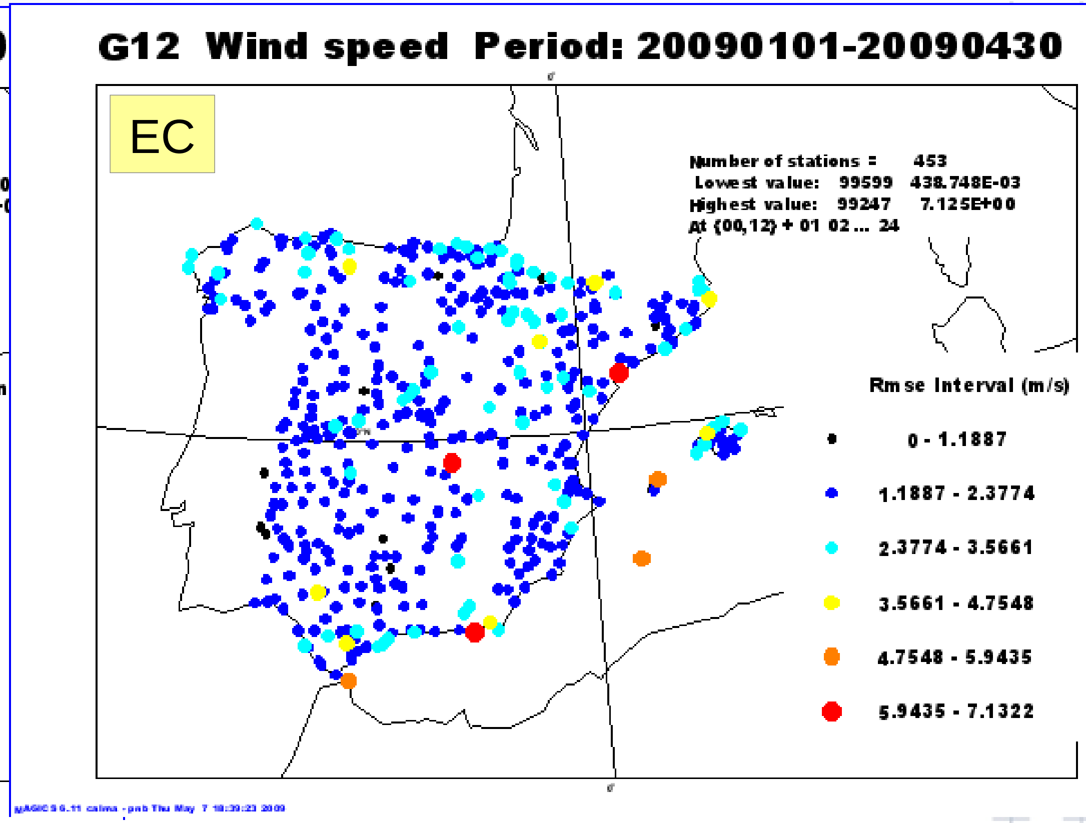

G10 GG Period: 20090101-20090430
Ref
Stations (plotted/total) = 448 450
Lowest value: 99008 -4.948E+00
Highest value: 99247 11.937E+00
At (00,12) + 01 02 ... 24
Bias Interval (m/s)
-10 - -5
-5 - -2.5
-2.5 - 0
0 - 2.5
2.5 - 5
5 - 10


G12 GG Period: 20090101-
EC

RMSE maps



G10 GG Period: 20090101-20090430
Ref
Number of stations = 450
Lowest value: 99293 1.578E+0
Highest value: 99247 12.753E+0
At (00,12) + 01 02 ... 24
Rmse Interval (m
0 - 2.4485
2.4485 - 4.8969
4.8969 - 7.3454
7.3454 - 9.7939
9.7939 - 12.242
12.242 - 14.691



G12 Wind speed Period: 20090101-20090430
EC
Number of stations = 453
Lowest value: 99599 438.748E-03
Highest value: 99247 7.125E+00
At (00,12) + 01 02 ... 24
Rmse Interval (m/s)
0 - 1.1887
1.1887 - 2.3774
2.3774 - 3.5661
3.5661 - 4.7548
4.7548 - 5.9435
5.9435 - 7.1322

Estimation of Convective gusts (Bechtold 2008)

- Method recently implemented in the ECMWF model
- Before different trials for estimating convective gusts from downdrafts using information from deep convection parameterization were not successful.

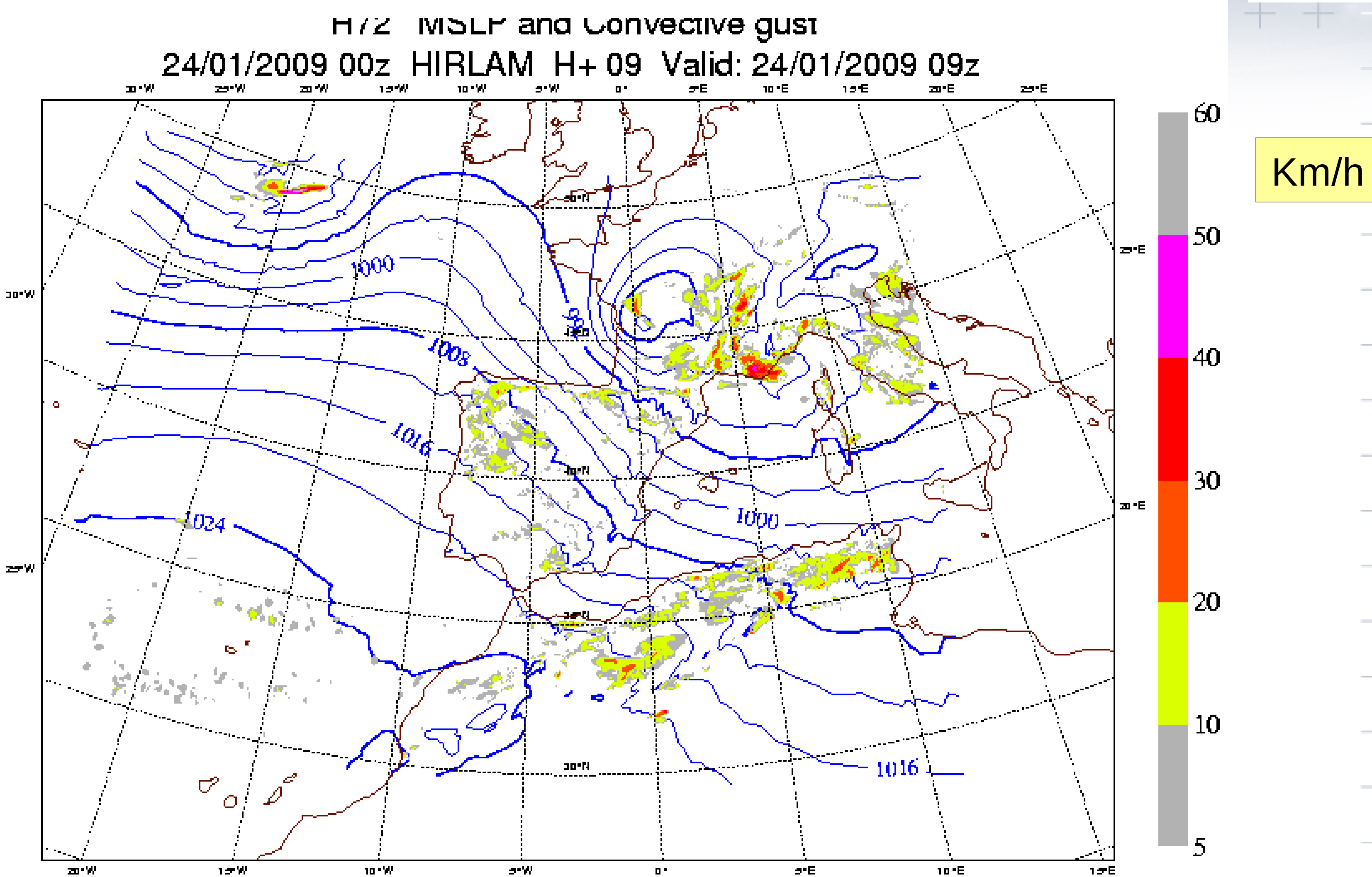
- Convective addition in regions were deep convection is active

$$F_{gust\,conv} = \alpha \max\left(0, F_{850} - F_{925}\right)$$

Tunable 'mixing' parameter

- Contribution only significant in situations with strong wind shear as frontal systems and organized mesoscale convective systems

Estimation of Convective gusts. Case study 24-25 January 2009



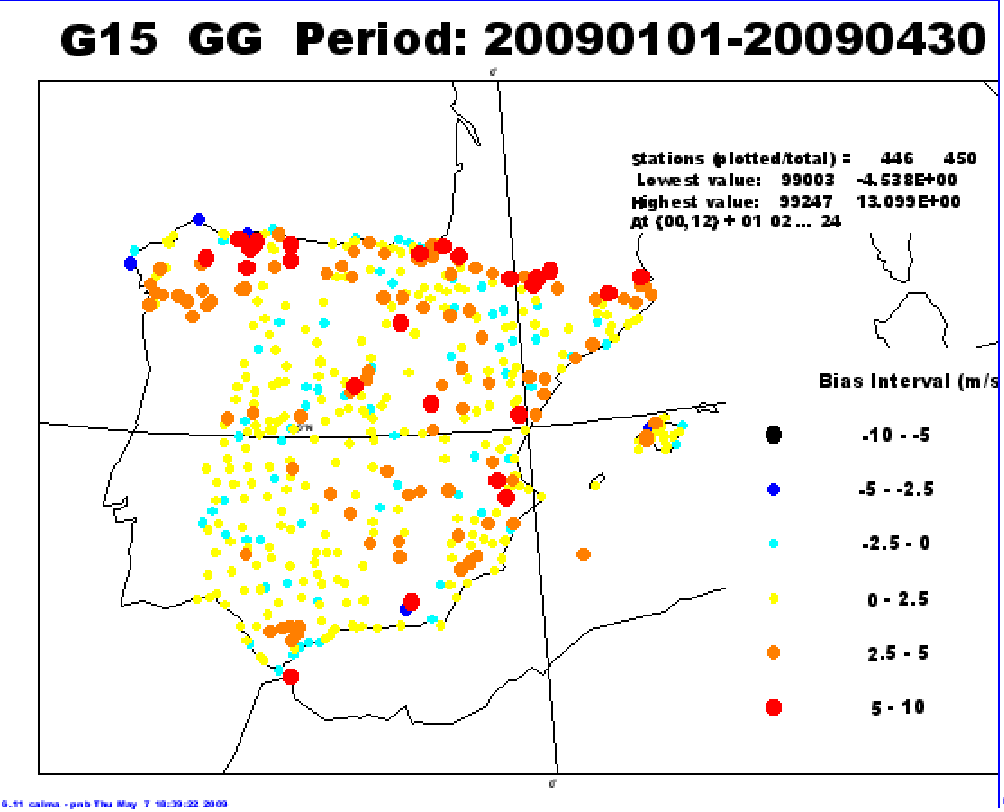
- Small addition in regions where deep convection is active and there is vertical wind shear (tipically less than 8 m/s)
- Problem: Deep convection is not a smooth field

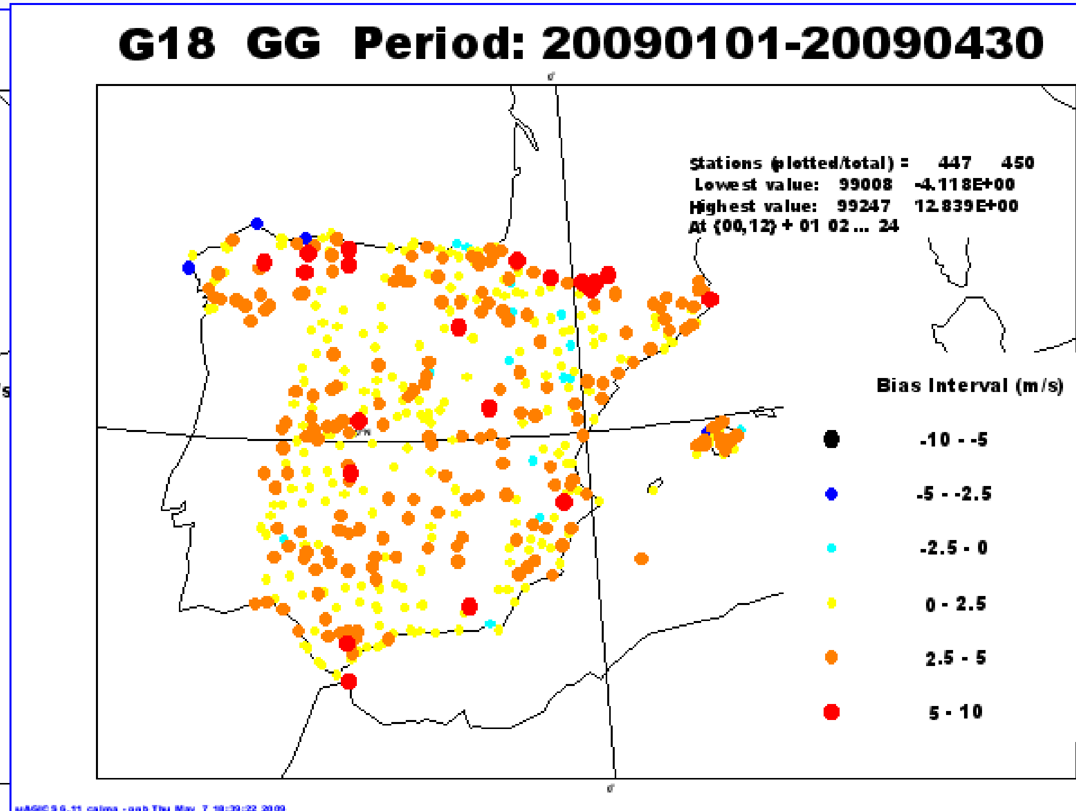
Conclusions

- Tested different methods for wind gust estimation using HIRLAM 0.05 km H+24 forecast and verifying against AEMET automatic station network (> 2.000.000 observations used)
- Despite the differences in the algorithms performance is very similar, specially for the 'empirical' approaches.
- Buoyancy/TKE method works well for lower gusts (<15 m/s/) but overestimates significantly high values.
- A very simple method for convective gusts is able to enhance gusts when convection is active and there is vertical wind shear. We expect it will no degrade objective scores.
- The evolution of the gusts is well captured by the model but very high values (>30 m/s) are often underestimated
    - It's important to keep this in mind due to their economic/safety impact: life risks, impact in infrastructures, inssurances companies, high speed trains.

The end

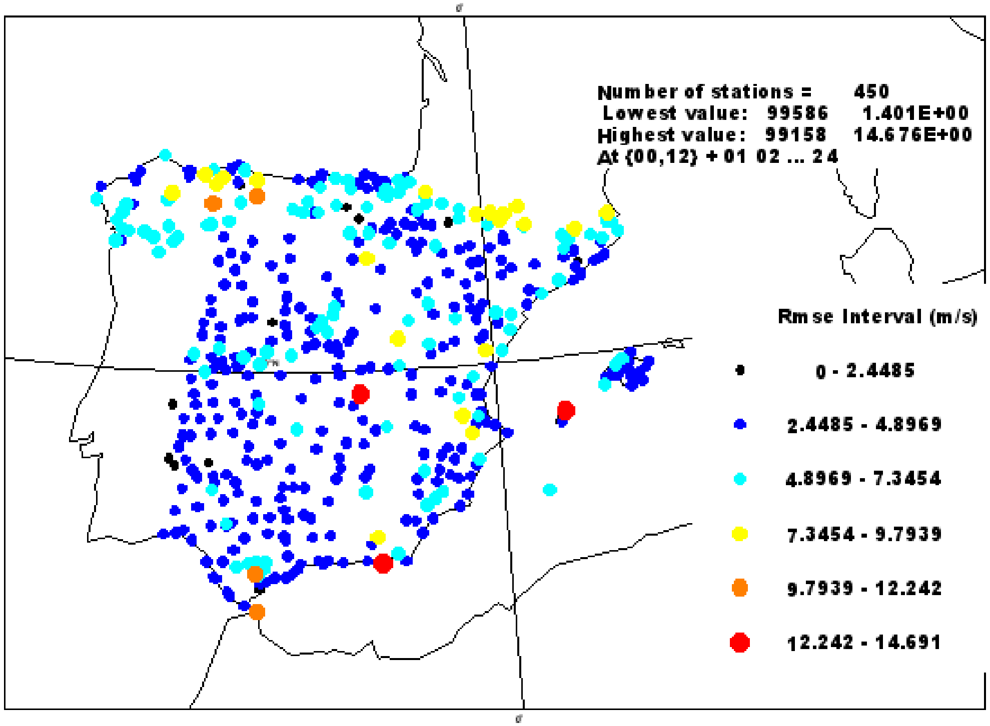
Bias maps


G15 GG Period: 20090101-20090430
Stations (plotted/total) = 446 450
Lowest value: 99003 -4.538E+00
Highest value: 99247 13.099E+00
At {00,12} + 01 02 ... 24
Bias Interval (m/s
-10 - -5
-5 - -2.5
-2.5 - 0
0 - 2.5
2.5 - 5
5 - 10


G18 GG Period: 20090101-20090430
Stations (plotted/total) = 447 450
Lowest value: 99008 -4.118E+00
Highest value: 99247 12.839E+00
At {00,12} + 01 02 ... 24
Bias Interval (m/s)
-10 - -5
-5 - -2.5
-2.5 - 0
0 - 2.5
2.5 - 5
5 - 10

RMSE maps

G15 GG Period: 20090101-20090430



G18 GG Period: 20090101-20090430