Improving the representation of resolved and unresolved topographic effects on surface wind in the WRF model

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Outline

1.- Background and motivation
2.- Parametrization of the topographic effects
3.- Numerical experiment
4.- Results
5.- Conclusions

Motivation:

- Improve WRF's ability to reproduce the surface wind climatology over complex terrain.

WRF's high wind speed bias

The high bias in the surface wind is present since early versions of the WRF model

Cheng and Steenburgh, *Wea. Forecasting*, 2005

The **high bias over the plains and valleys** has been associated with the drag exerted by the unresolved topography.

Mass and Ovens, *WRF's users workshop* 2010

Mass and Ovens, AMS 2011

Parametrization of the topographic surface drag

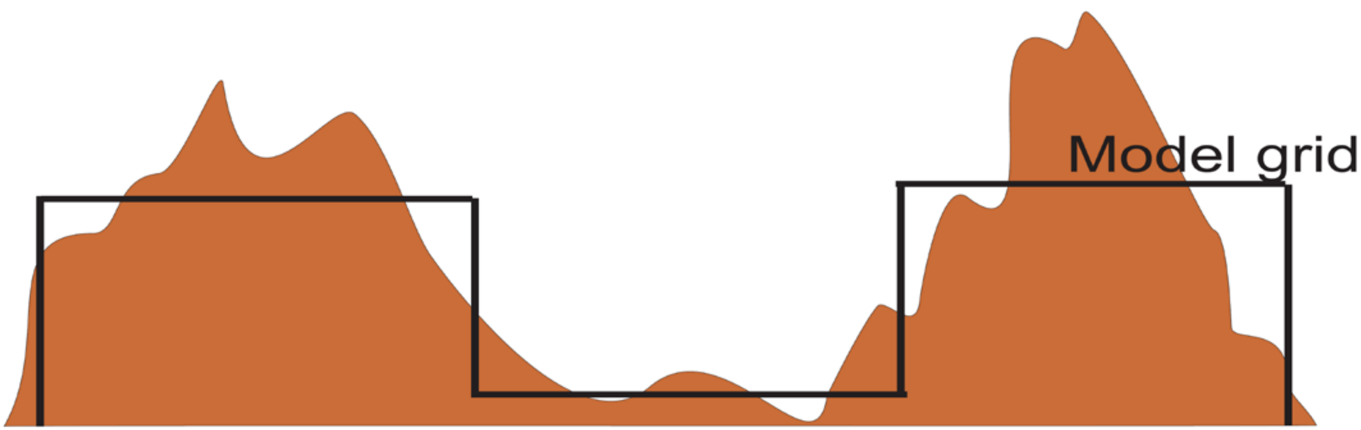
The drag exerted by the unresolved topography has been parametrized in other mesoscale models

e.g. **ETA** model

Mesinger, *AMS,* 1996

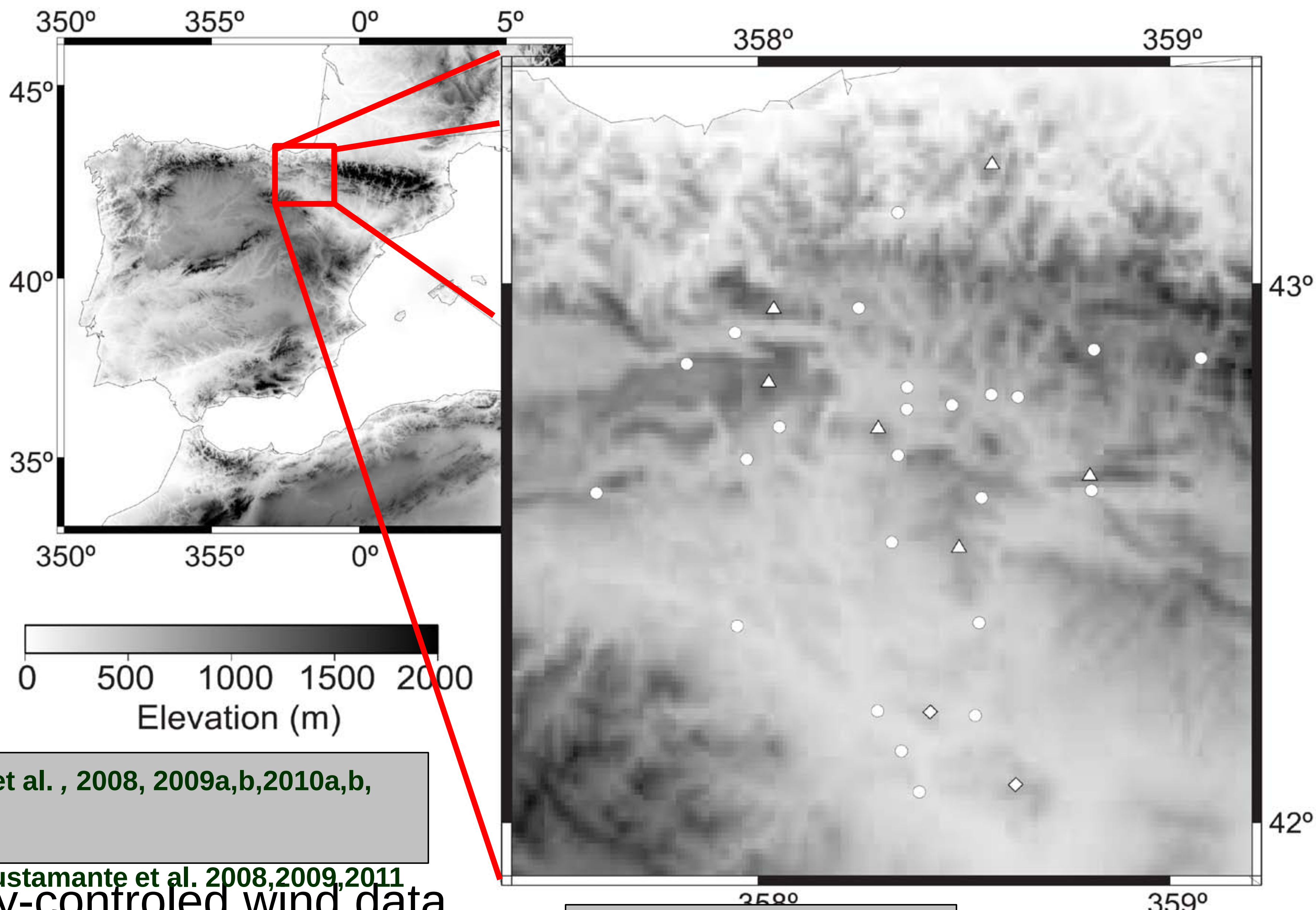
HIRLAM model

Rontu, *Tellus,* 2006



WRF doesn't parametrize the effects of the unresolved topography

Region of study



Jiménez et al. , 2008, 2009a,b,2010a,b, 2011

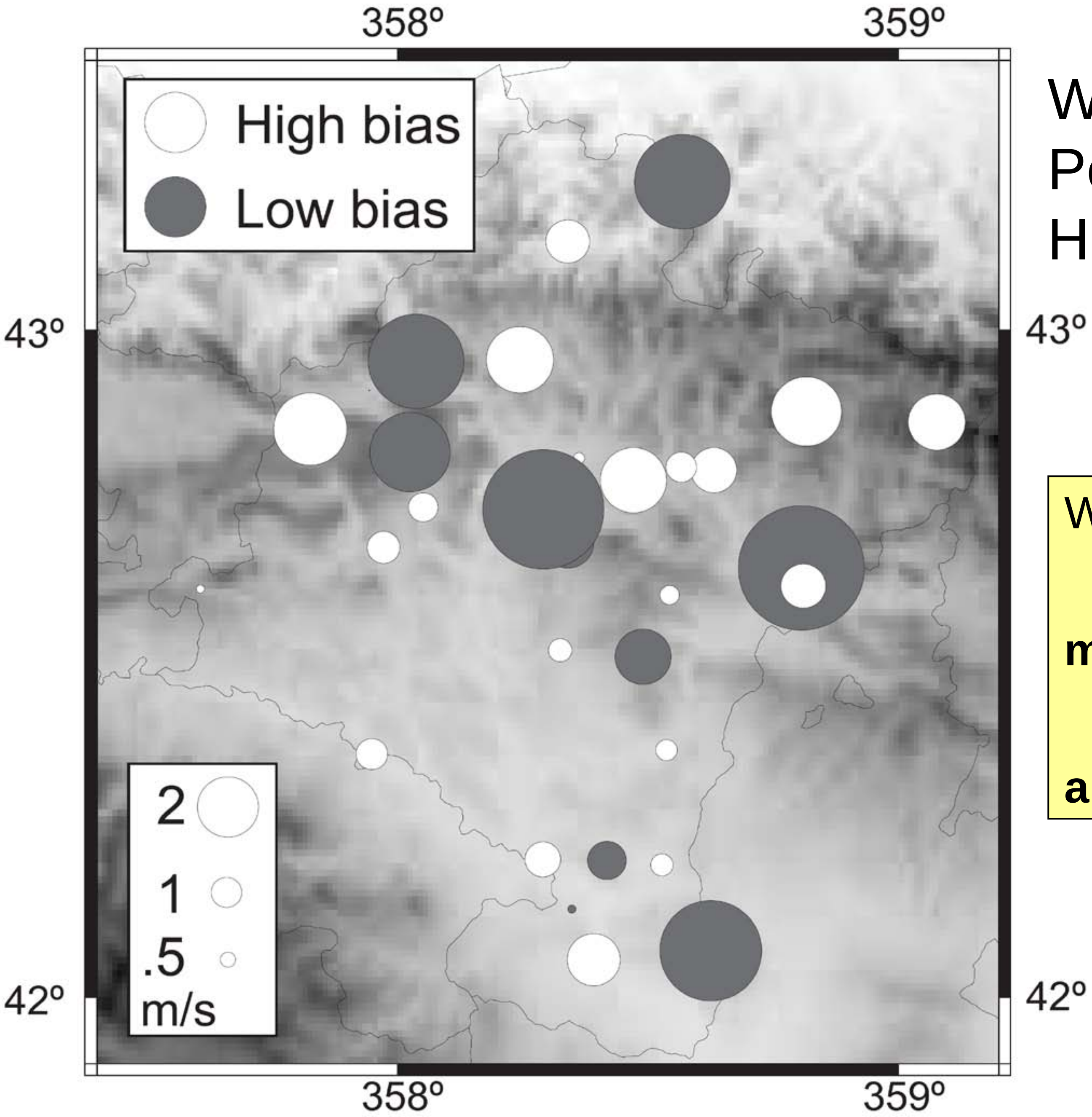
Garcia-Bustamante et al. 2008,2009,2011

Jiménez et al. *JAOT,* 2010

1.- Quality-controled wind data

2.- The observational network provides a good temporal (1992-2005) and spatial coverage

WRF biases



WRF simulation:
Period: **1992 – 2005**
Horizontal resolution: **2km**

Jiménez et al. *JAMC,* 2010

Wind speed …

… **low bias** at the **hills and mountains (-2.93 m/s).**

… **high bias** over the **plains and valleys (1.06 m/s).**

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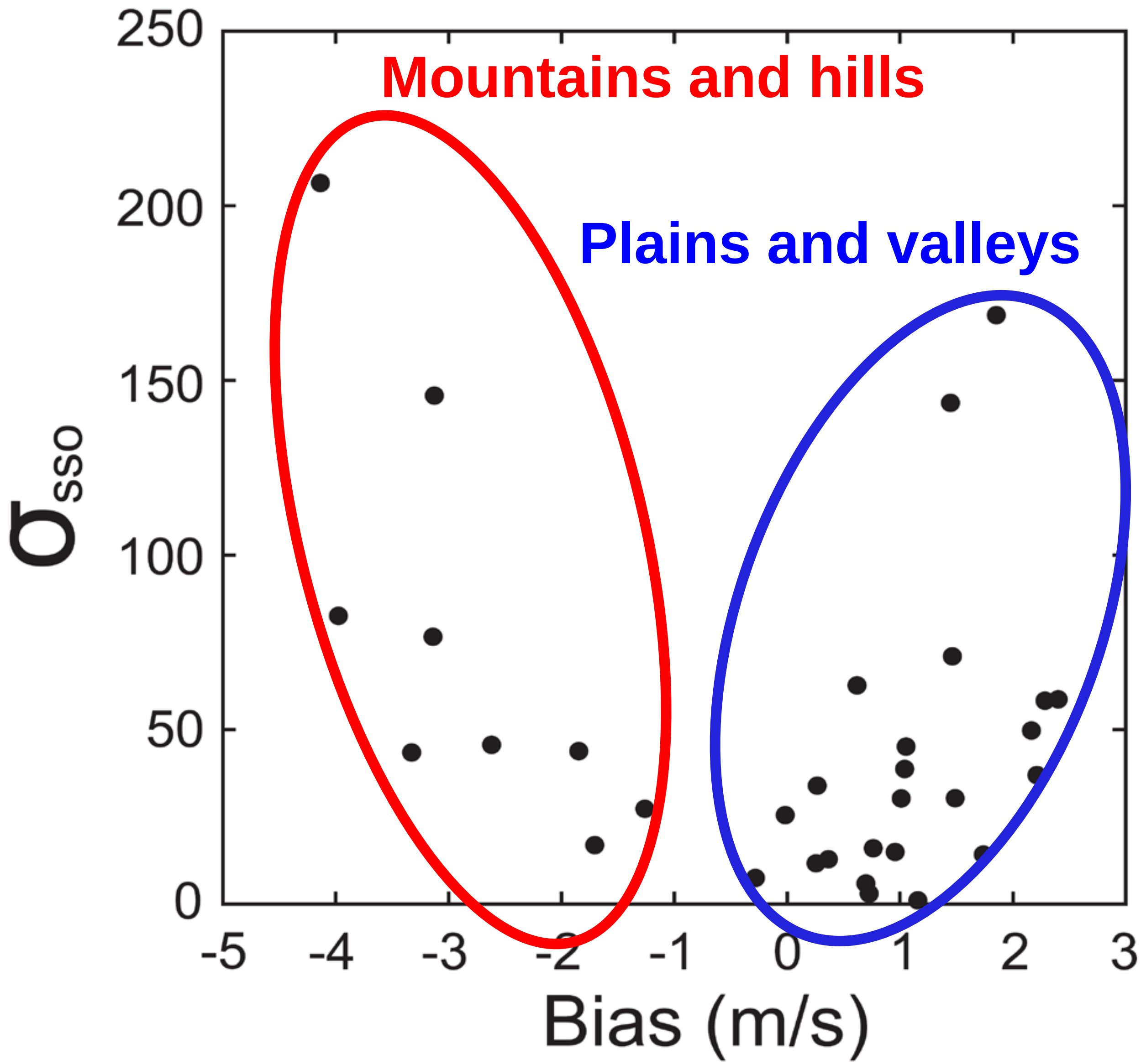
Standard deviation unresolved terrain *VS.* Wind speed bias



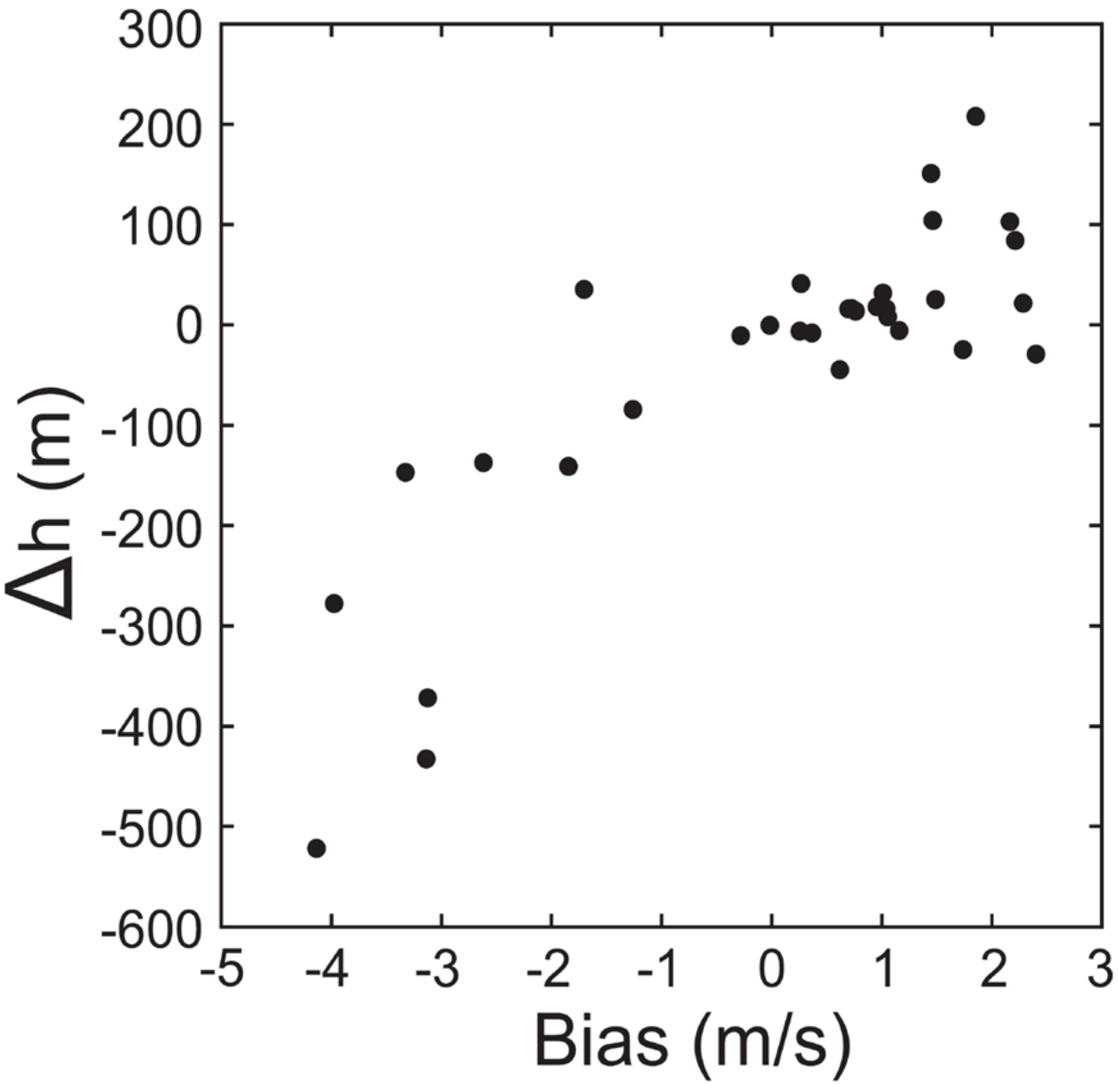
Topographic data at 90 m

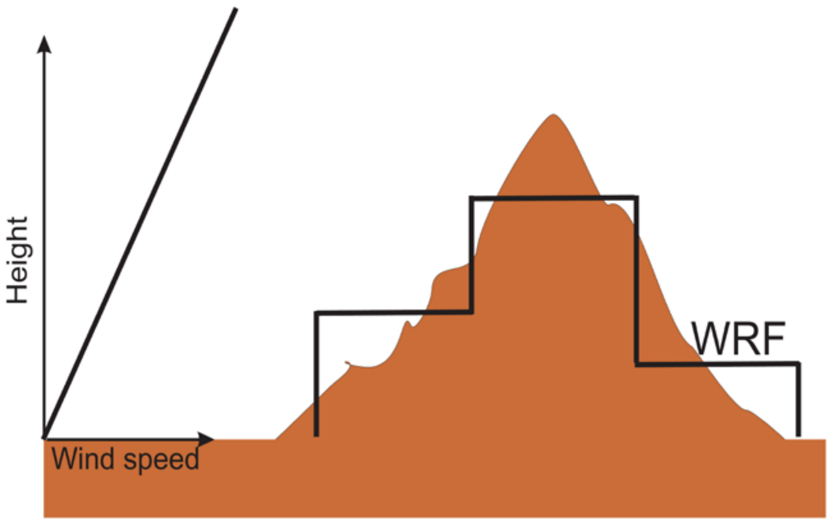
Farr et al., *Rev. Geo.* (2007)

A high standard deviation can produce both a high and low wind speed bias.

Parametrization with just information of the variance of the unresolved topography is not sufficient.

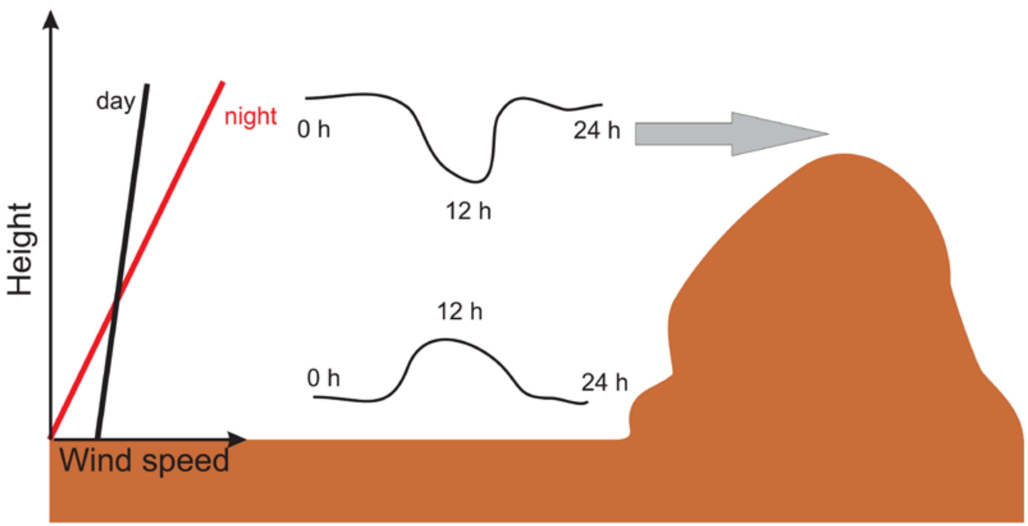
Elevation difference
VS.
Wind speed bias

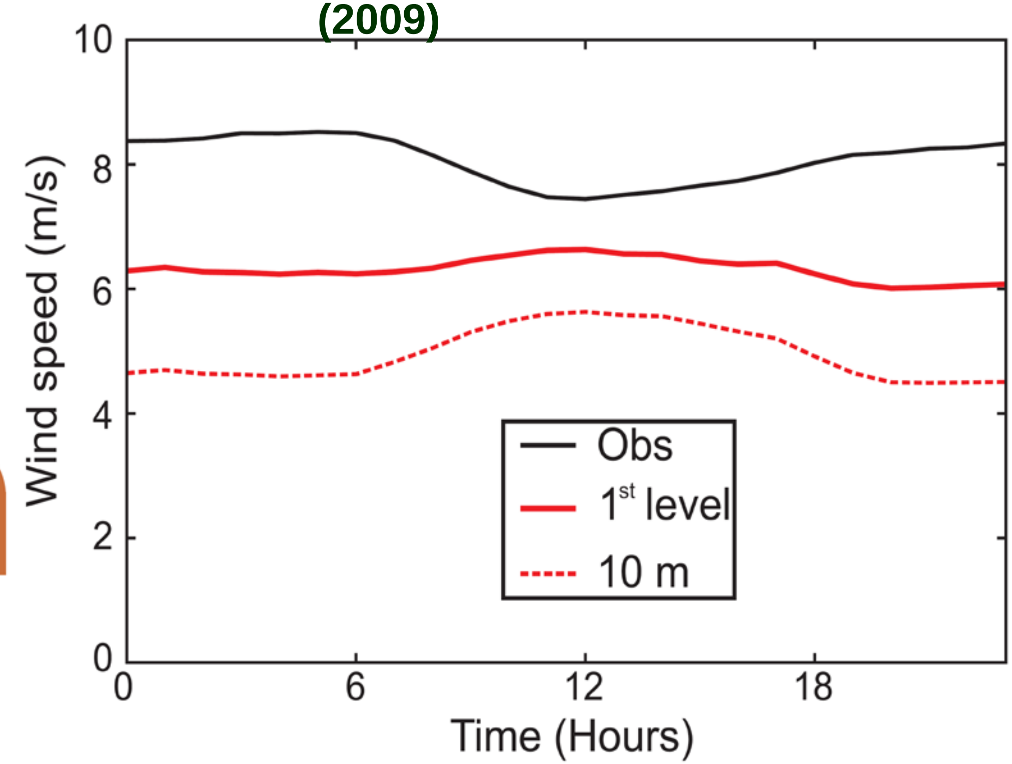




Diurnal wind variations at the mountains

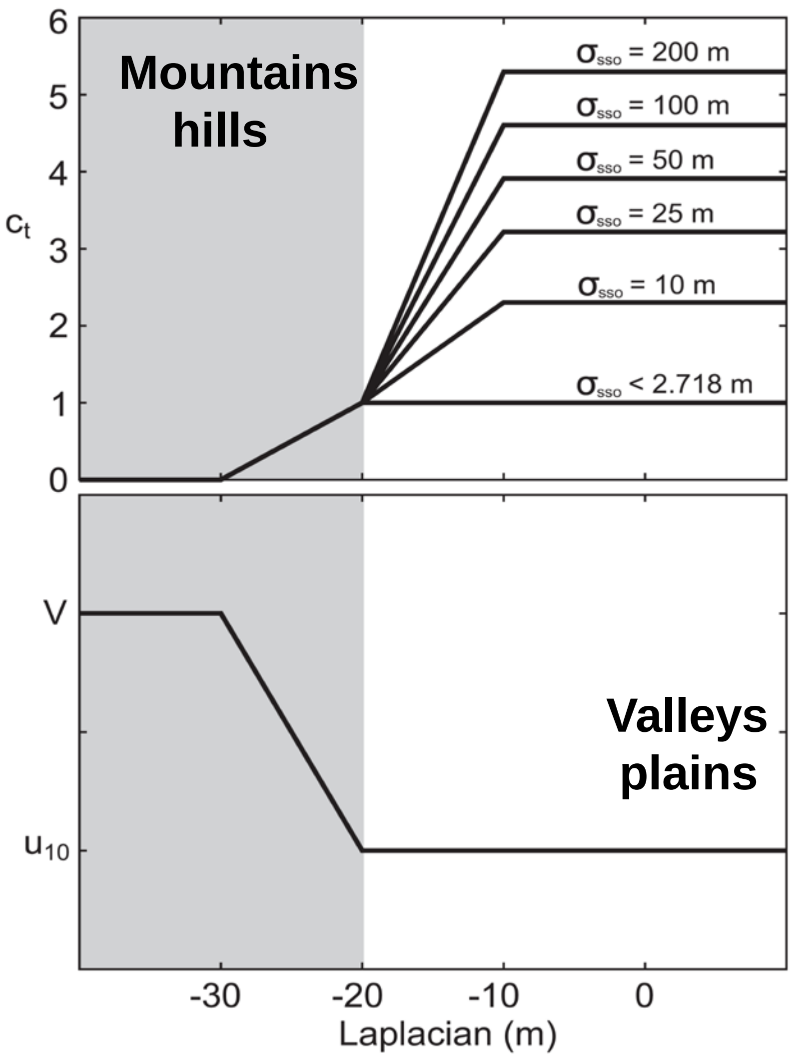
Jimenez et al., FDT (2009)





The wind speed at the mountain sites is in certain ways decoupled from the surface effects being more in agreement with the up stream wind at this level

Numerical scheme



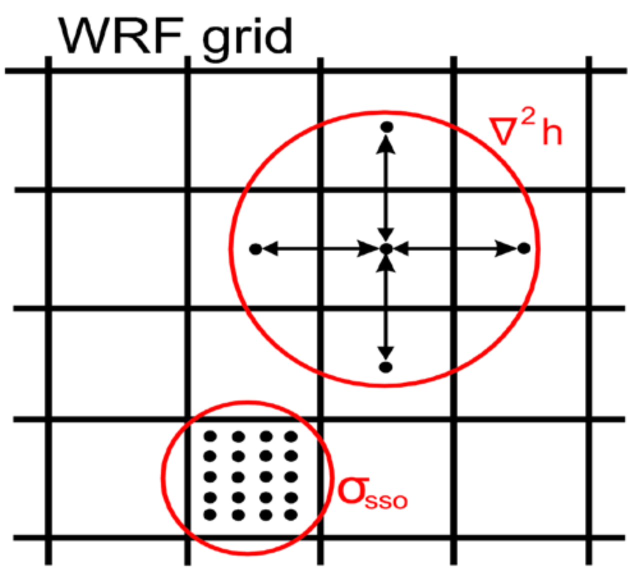
Surface drag

$$\frac{\partial u}{\partial t} = \ldots - c_t \underbrace{\frac{u_{star}^2}{z}}_{} \frac{u}{V}$$

Unresolved terrain

$$c_t = c_t(\nabla^2 h, \ln \sigma_{sso})$$

Resolved terrain



1.- The laplacian of the resolved topography is used to distinguish between valleys and mountains

2.- The drag is suppressed over the mountains/hills

3.- The drag over the valleys/plains is proportional to the log of the standard deviation of the subgrid scale orography.

Jimenez and Dudhia, JAMC (submitted)

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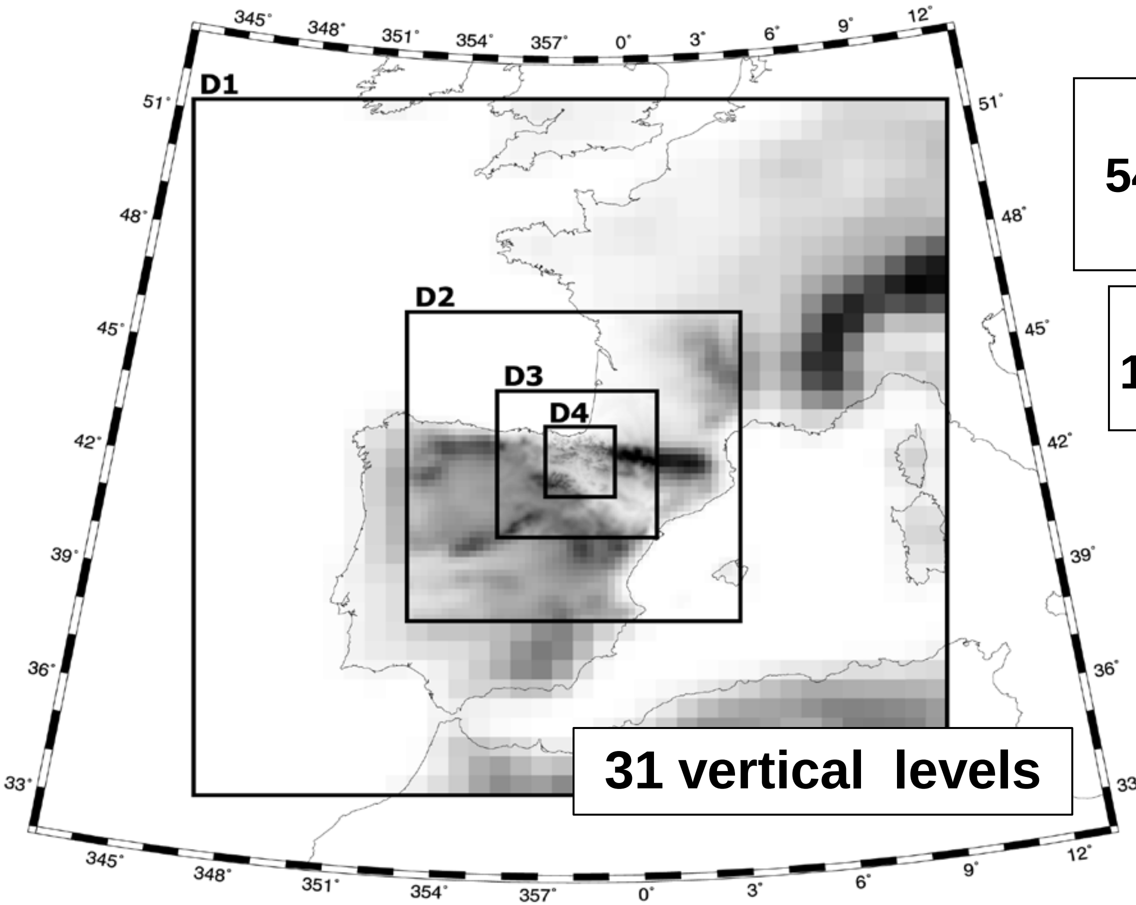
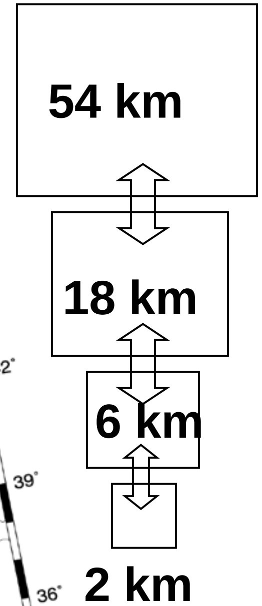
3.- Numerical experiment



31 vertical levels



WRF 3.1.1

Skamarock, 2008

Two way nesting

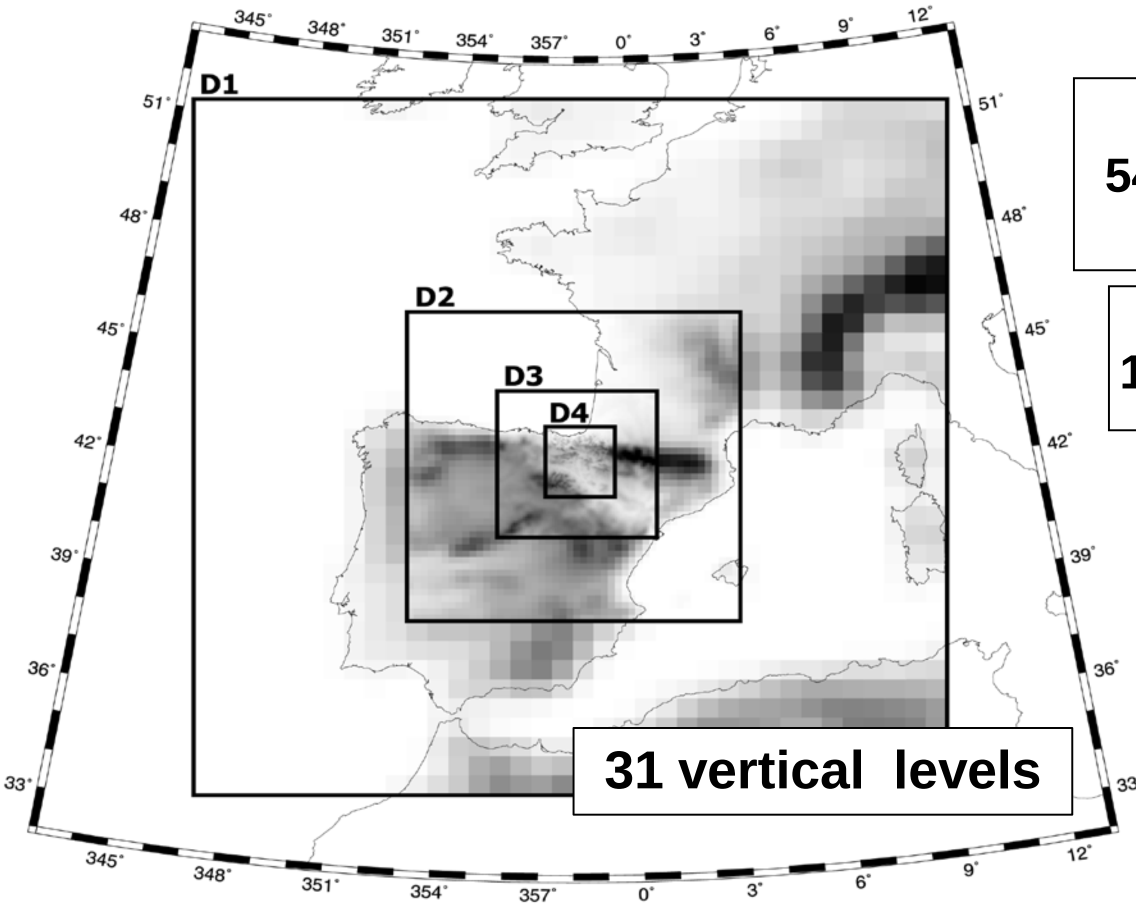
Initial and boundary conditions every 6 hours from the final NCEP Analysis

The **winter of 2002** (December, January and February) is simulated:

1.- Using the default WRF (**WRFref**)

2.- Using the parametrization of the topographic effects (**WRFnew)**

3.- Numerical experiment



54 km

18 km

6 km

2 km

WRF 3.1.1

Skamarock, 2008

Two way nesting

Initial and boundary conditions every 6 hours from the final NCEP Analysis

Physics options

LONGWAVE: **RRTM** SHORTWAVE: **Dudhia** MICROPHYSICS = **WSM 6**

CUMULUS = **grid > 5 km Kain-Fritsch and grid < 5 km NO Cu**

PBL = **YSU** SOIL = **Thermal Diffusion**

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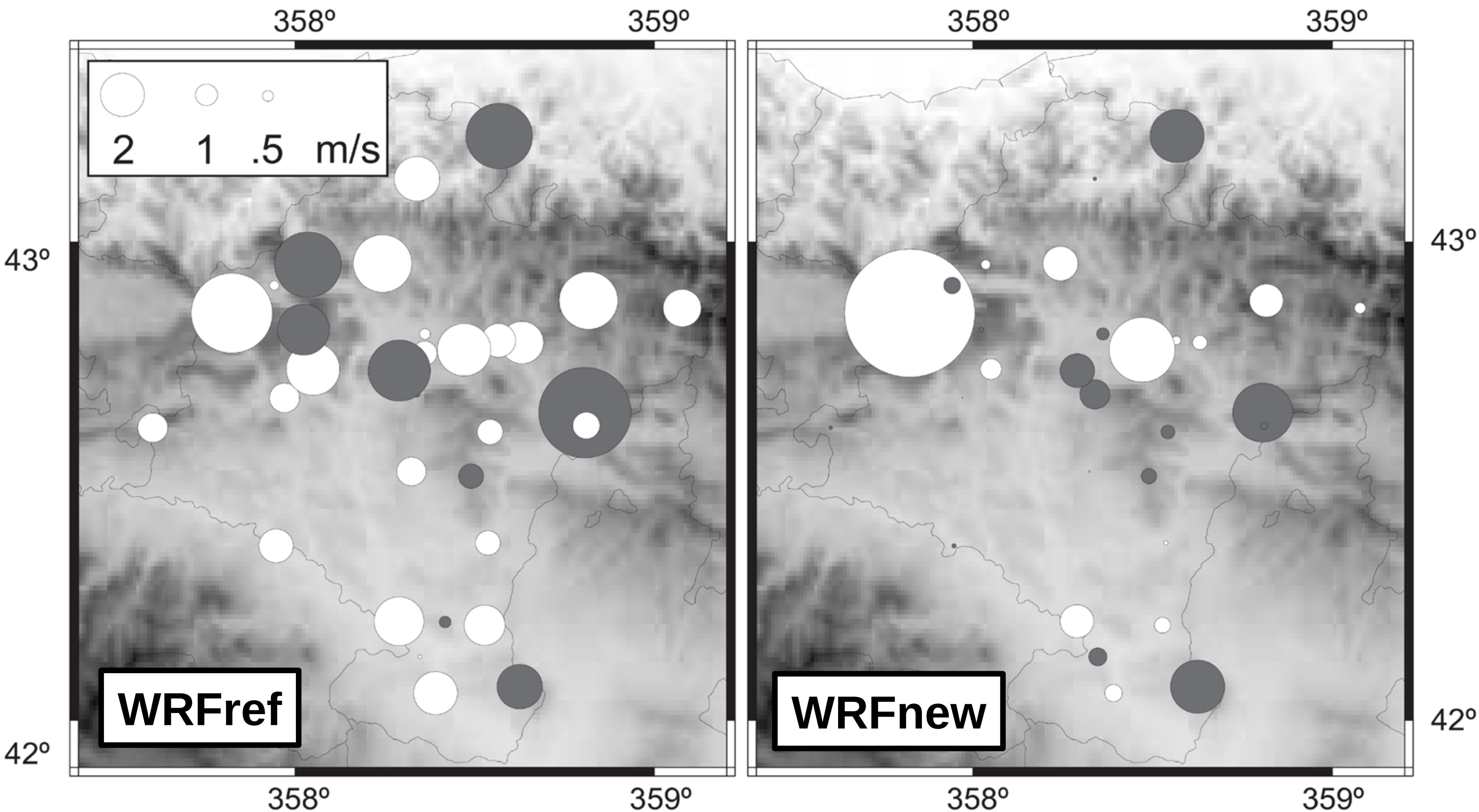
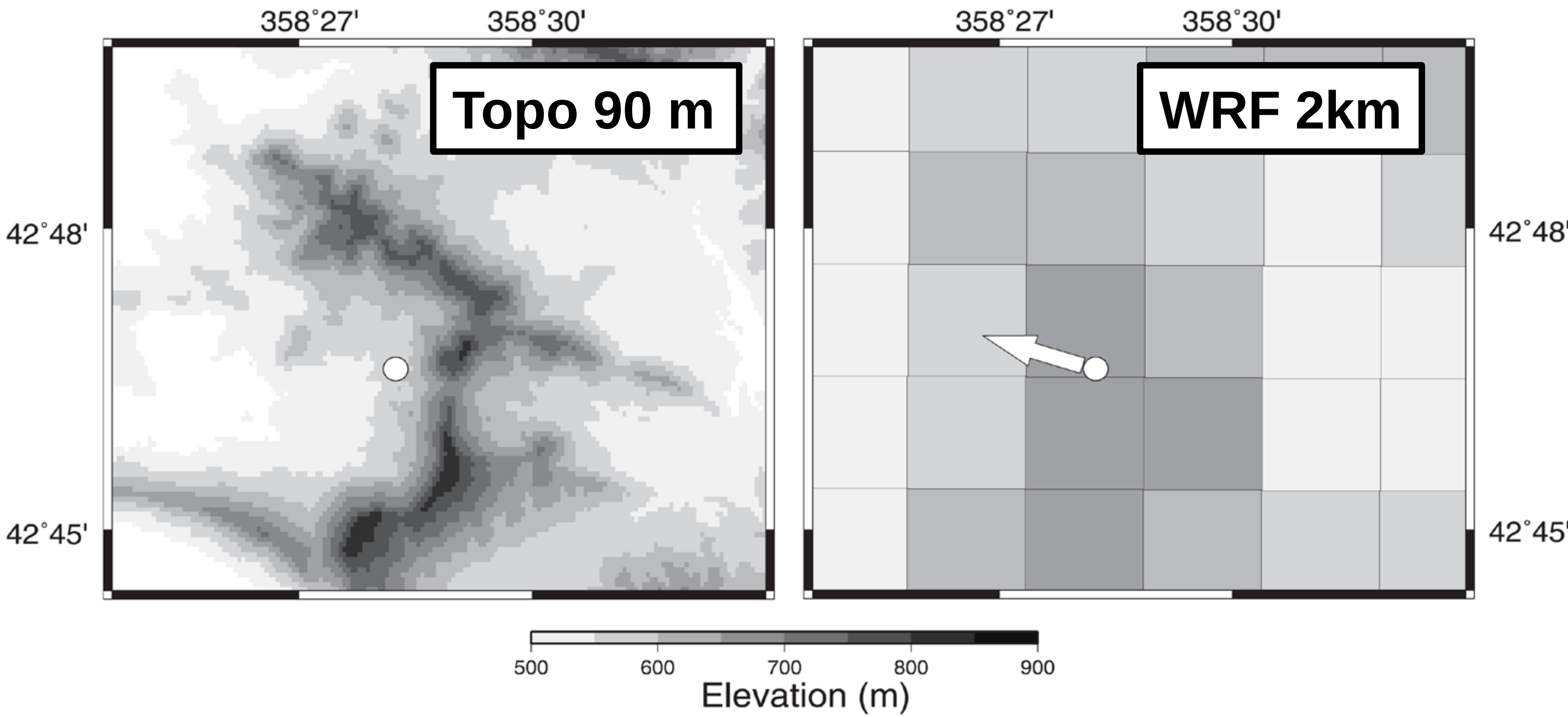
WRF biases



The surface wind at the nearest grid point is used in the comparison

Representativeness errors

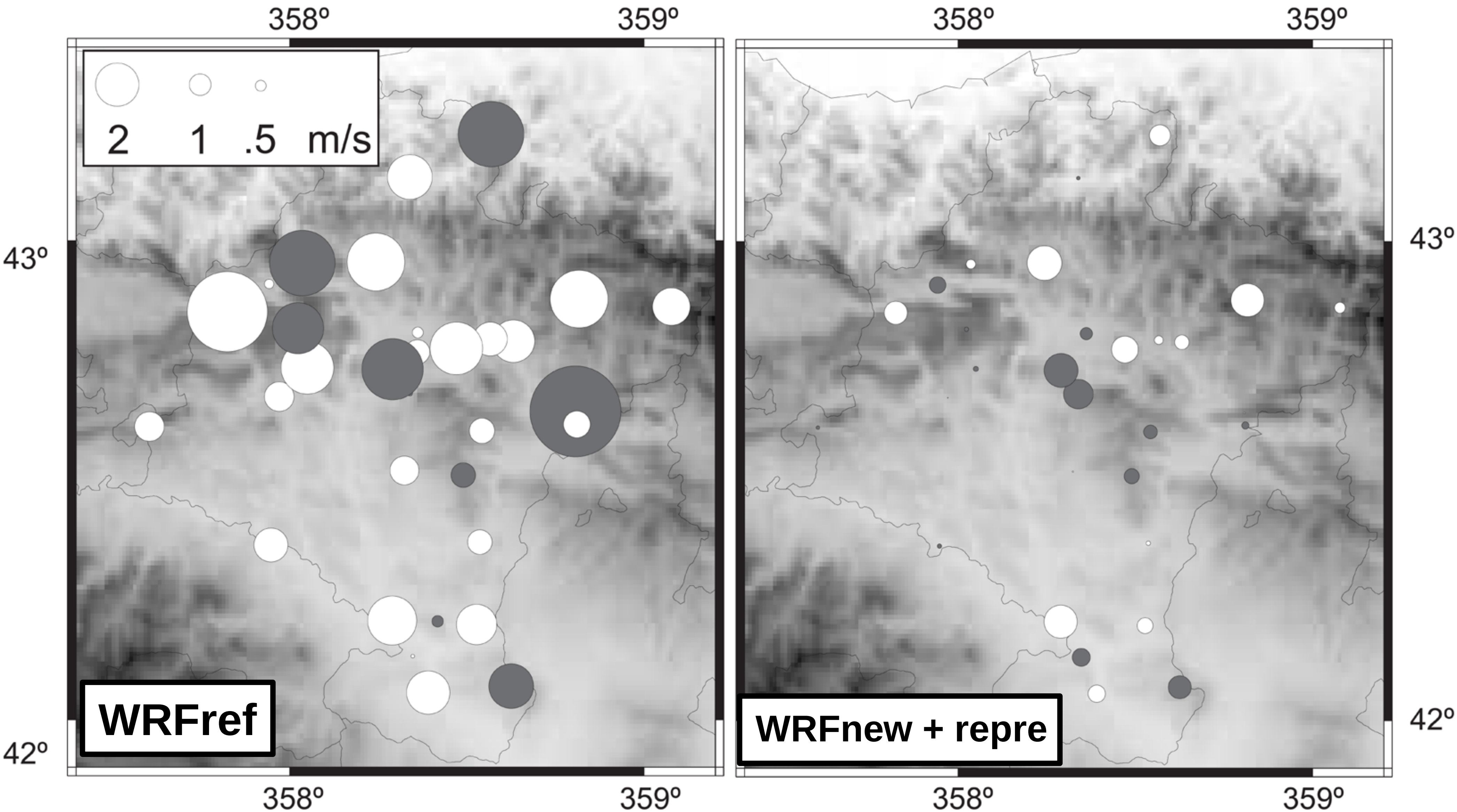


The nearest grid point is not always the most representative of the wind characteristics.

Representative grid points can be found not only in the horizontal direction but also in the vertical direction.

WRFnew + representative grid points

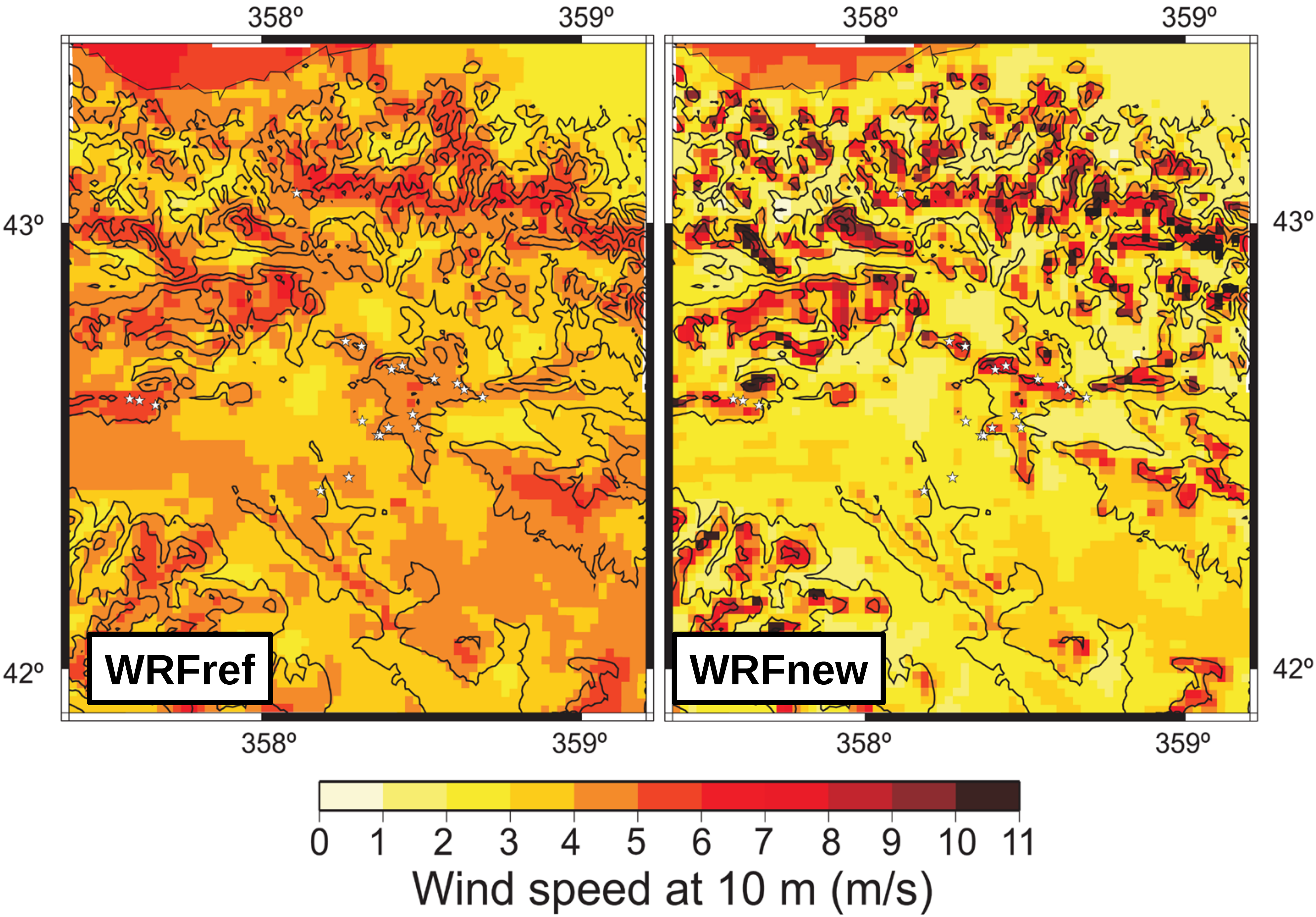
A total of six sites were affected by representativeness errors



MAE: 1.85 m/s

MAE: 0.72 m/s

Applications for wind resource evaluation



Conclusions

1.- The new parametrization corrects for the high wind speed bias over plains/valleys.

2.- The scheme also corrects for the low wind speed bias found over the mountains/hills.

3.- Importance of using representative grid points.

4.- Better wind climatology maps.

Future testings

Research Applications Laboratory (RAL)