OFFSHORE WIND ENERGY DEVELOPMENT IN THE ADRIATIC SEA: THE P.O.W.E.R.E.D. PROJECT AS PLANNING POLICY

Università Politecnica delle Marche, Ancona, May 2013

The Adriatic Basin Wind Map by IPA POWERED project

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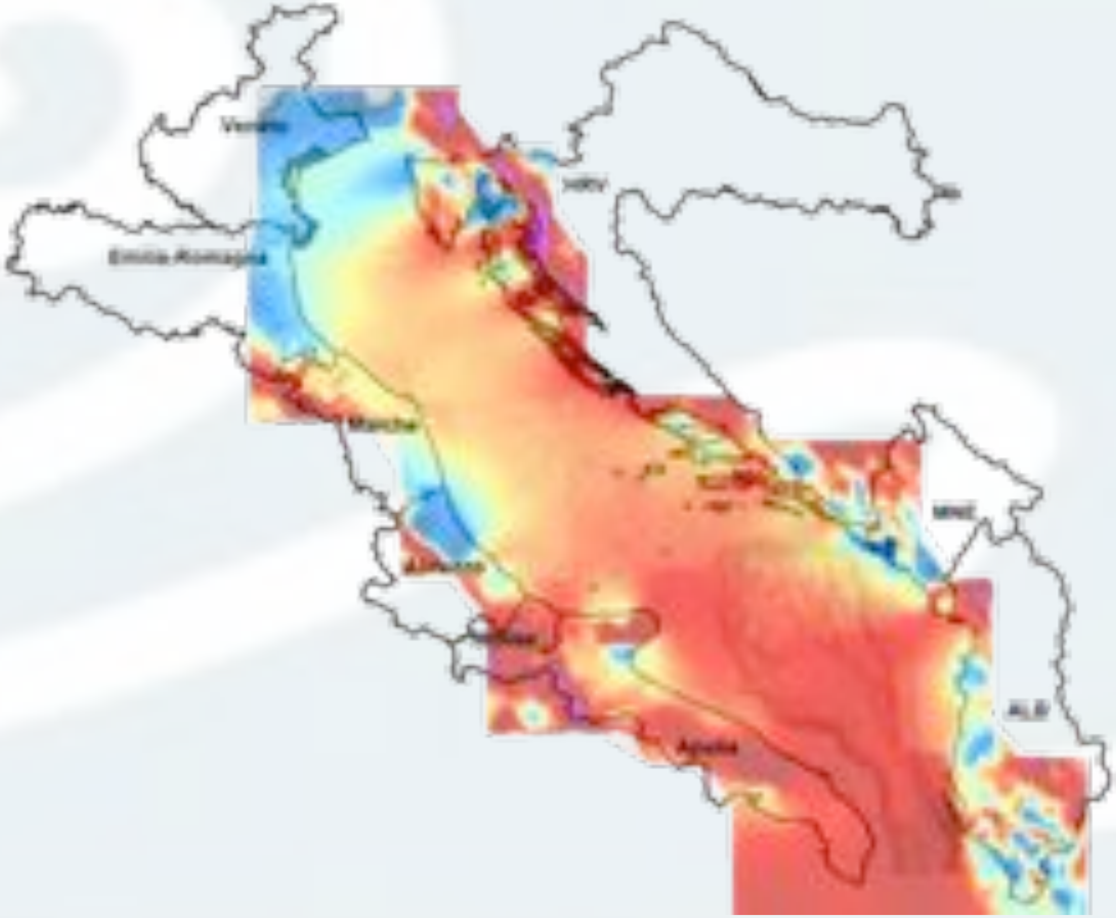
REGIONE MARCHE · Svim · Adriatic IPA · POWERED green energy in Adriatic sea

THE AIMS OF THE POWERED PROJECT

- State of art of the Offshore Wind Energy Technology (COMPLETED)
- State of art of the energy policy (COMPLETED)
- Study of the Adriatic sea wind resources (IN PROGRESS)
- Analysis of the potential enviromental impacts of the offshore wind energy in Adriatic sea (IN PROGRESS)
- Analysis of the transports and fishing activities interference (IN PROGRESS)
- Analysis of the available and proposed grid infrastructures (COMPLETED)
- Analysis of the Adriatic Industrial Ports capability (COMPLETED)
- GUIDELINES for the offshore wind energy development in Adratic sea (TO BE STARTED)



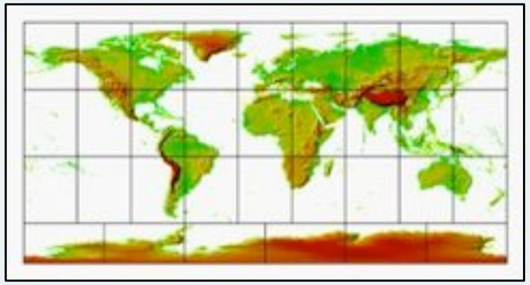
The Present Work

1. Description of the simulated area;
2. Description of the adopted Numerical Weather Prediction (NWP) model;
3. Description of the implemented procedure;
4. Analysis of the results;
5. Analysis of the grid resolution on the wind resources results;

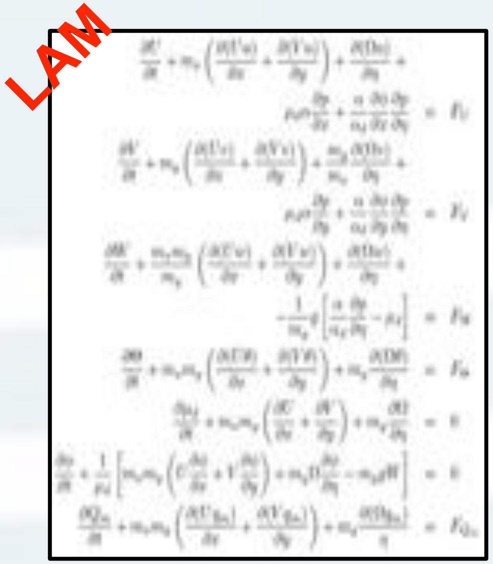
POWERED PARTNERSHIP

- Abruzzo Region
- Montenegro – Min. of Economy
- Veneto Agricoltura
- Provincia of Ravenna
- Marche Region
- Molise Region
- Apulia Region
- UNIVPM - Ancona
- Cetma Consortium
- Micoperi Marine Contractors Srl
- Italy – Min. for Envir. and Land and Sea
- Albania – Min. Economy, Trade and Energy
- Municipality of Komiza

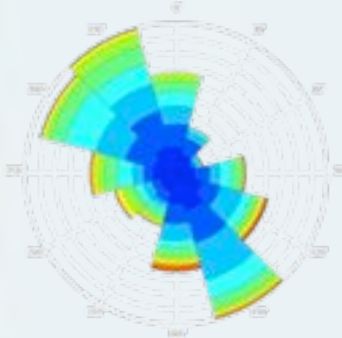
THE ADOPTED NWP MODEL: MM5v3

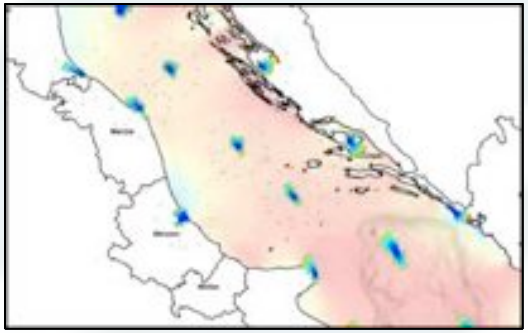


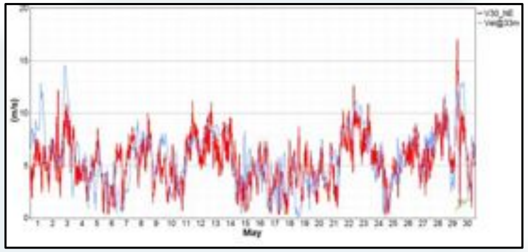
DS083.2
METEO DATA



TERRAIN → REGRID → INTERPF → MM5





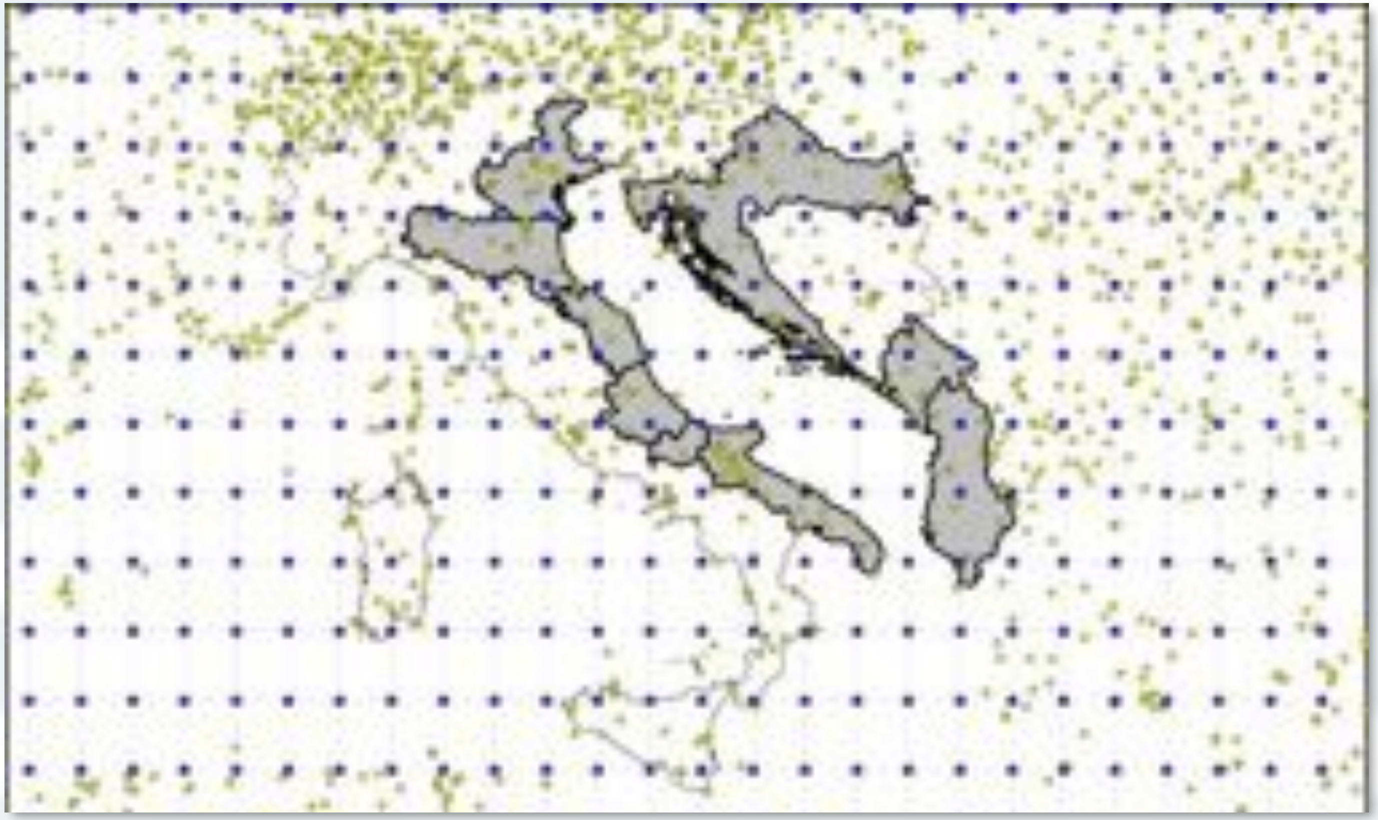


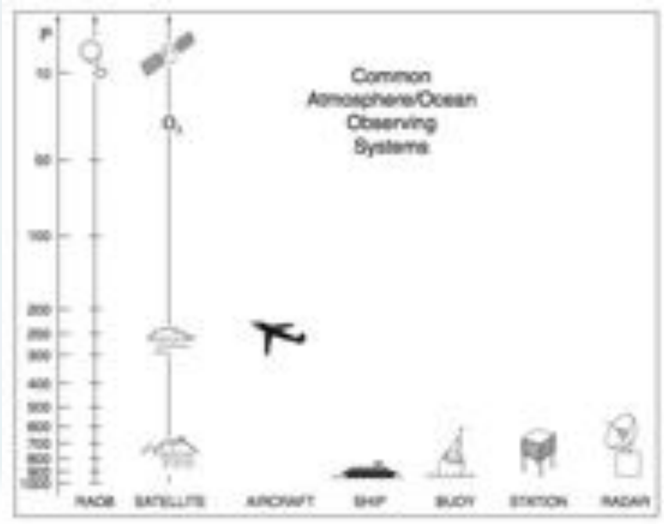
"The PSU/NCAR mesoscale model (known as MM5) is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation."

The Implemented Hindcasting Procedure

DS083.2 METEO DATA

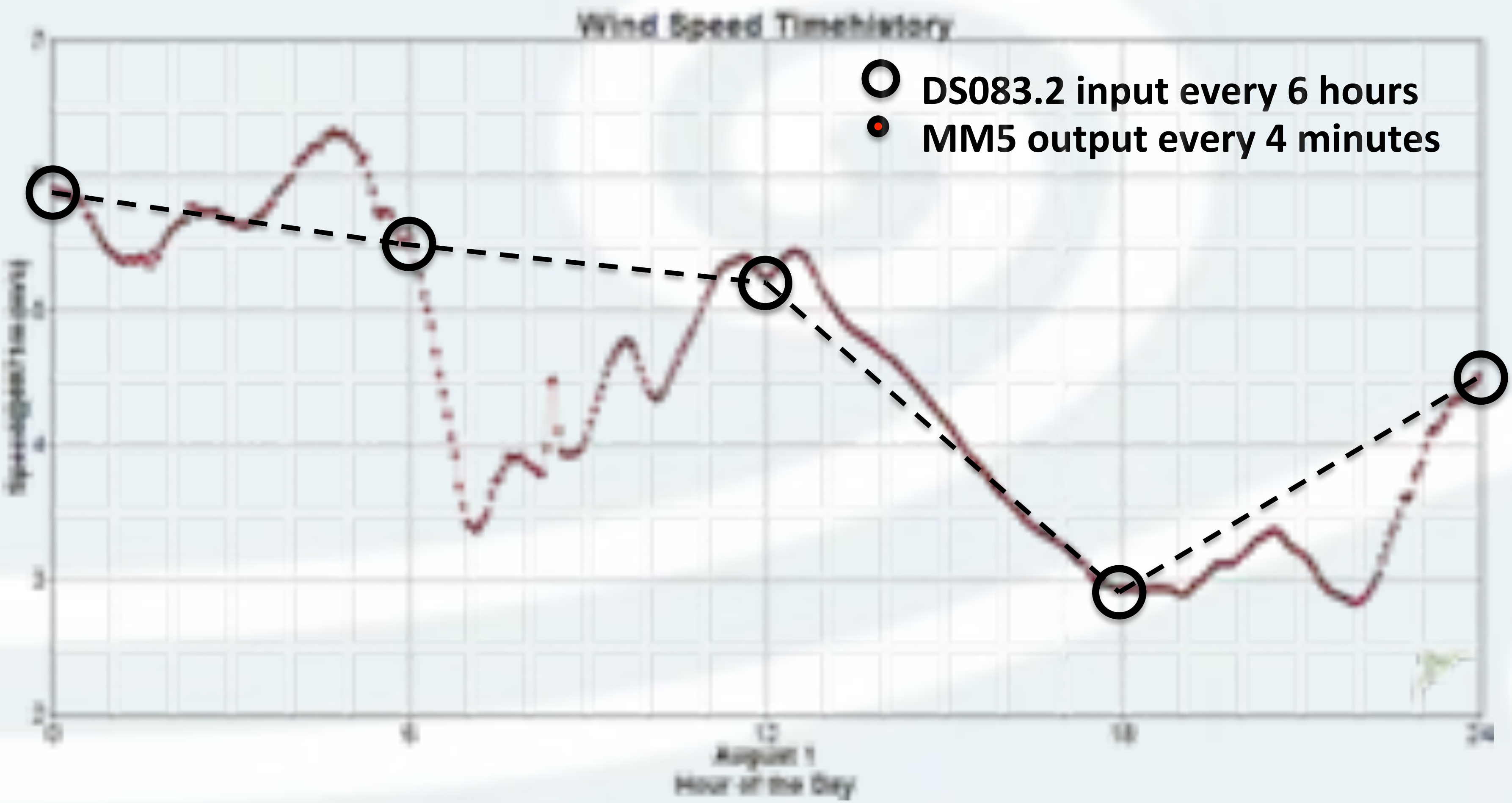
- Meteorological Data deriving from a FNL reanalysis procedure Data available from 1999-07-30 to a near-current date
- Data available with a time step of 6 hour
- Data available with a spatial grid of 1 degree (~ 80 km)





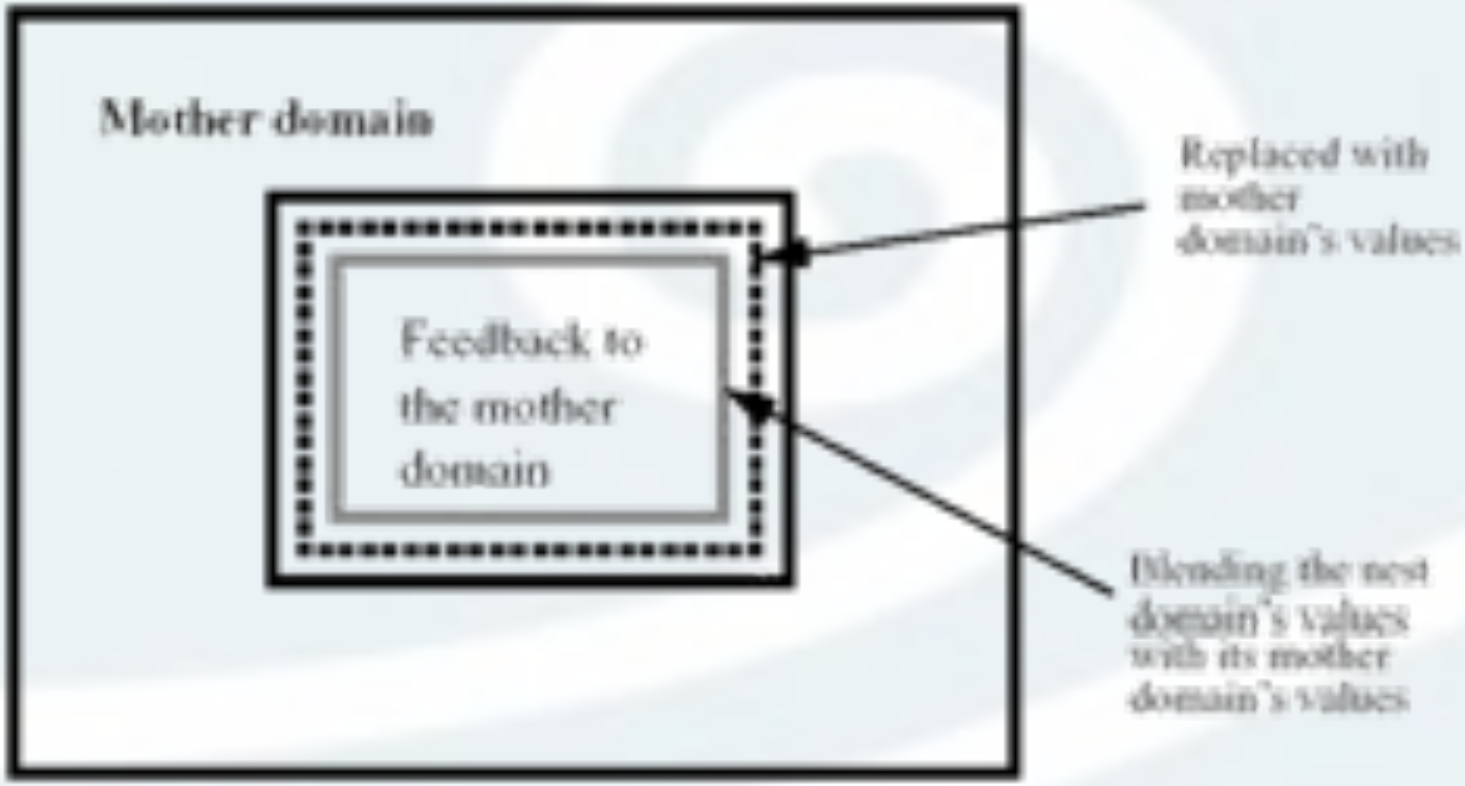
DS083.2 are obtained from the Global Data Assimilation System (GDAS), which continuously collects observational data from the Global Telecommunications System (GTS), and other sources, for many analyses

THE IMPLEMENTED HINDCASTING PROCEDURE



Using the MM5 code is possible to describe the wind behaviour in the period separating two DS083.2 input. This is very useful especially to evaluate the wind turbine energy production.

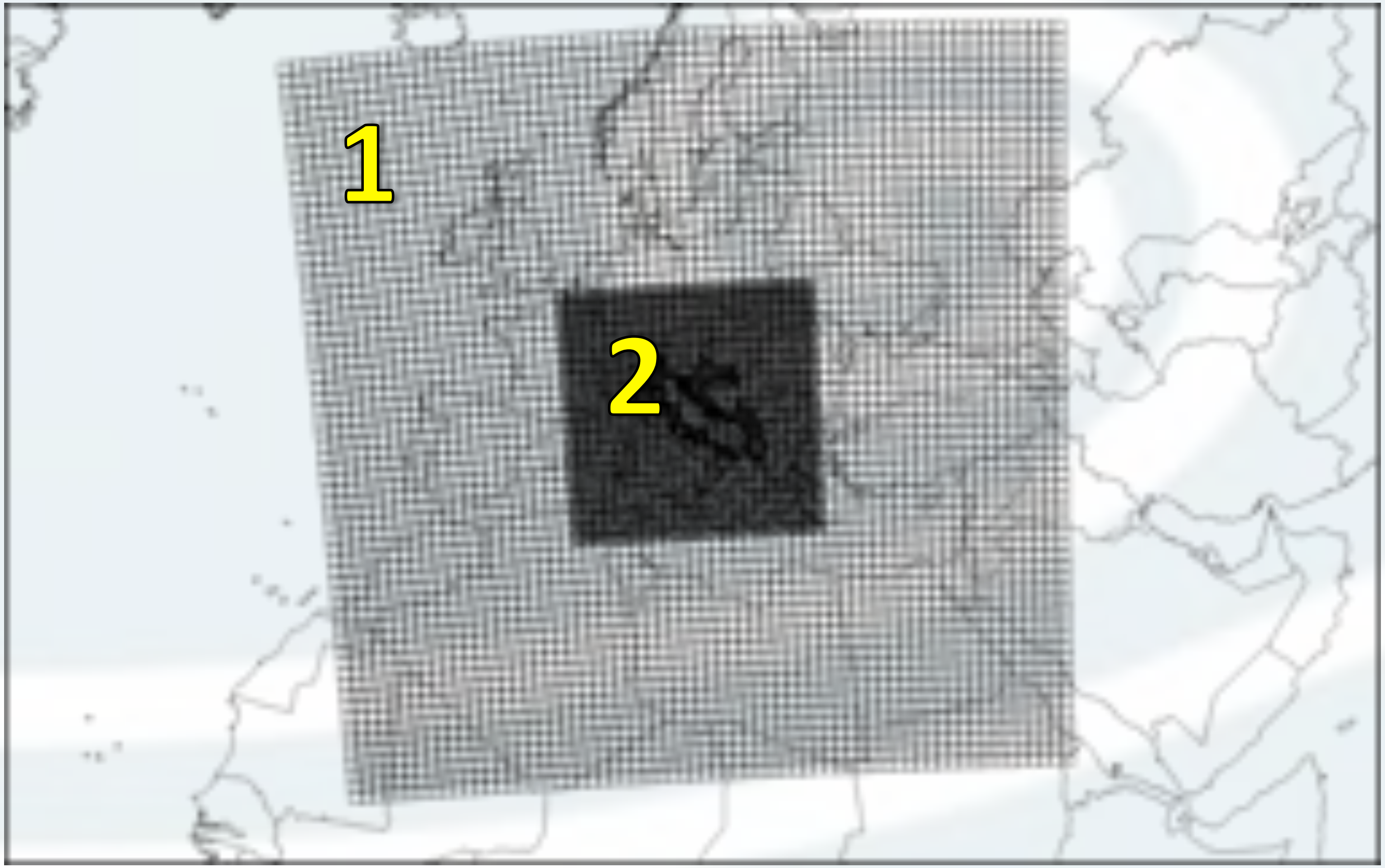
THE IMPLEMENTED HINDCASTING PROCEDURE



The hindcasting analysis is implemented with a **two way nesting** procedure. In this way the initializing meteo data are ingested by the coarser mother domain and they propagate to the finer nested domains; at the same time the more accurate results of the nested domains are fed back to the mother ones so to improve the global solution accuracy.

Numerical simulations with a 3 [km] horizontal spatial resolution are carried out by using four nested domains, while 1 [km] simulations use five nested domains.

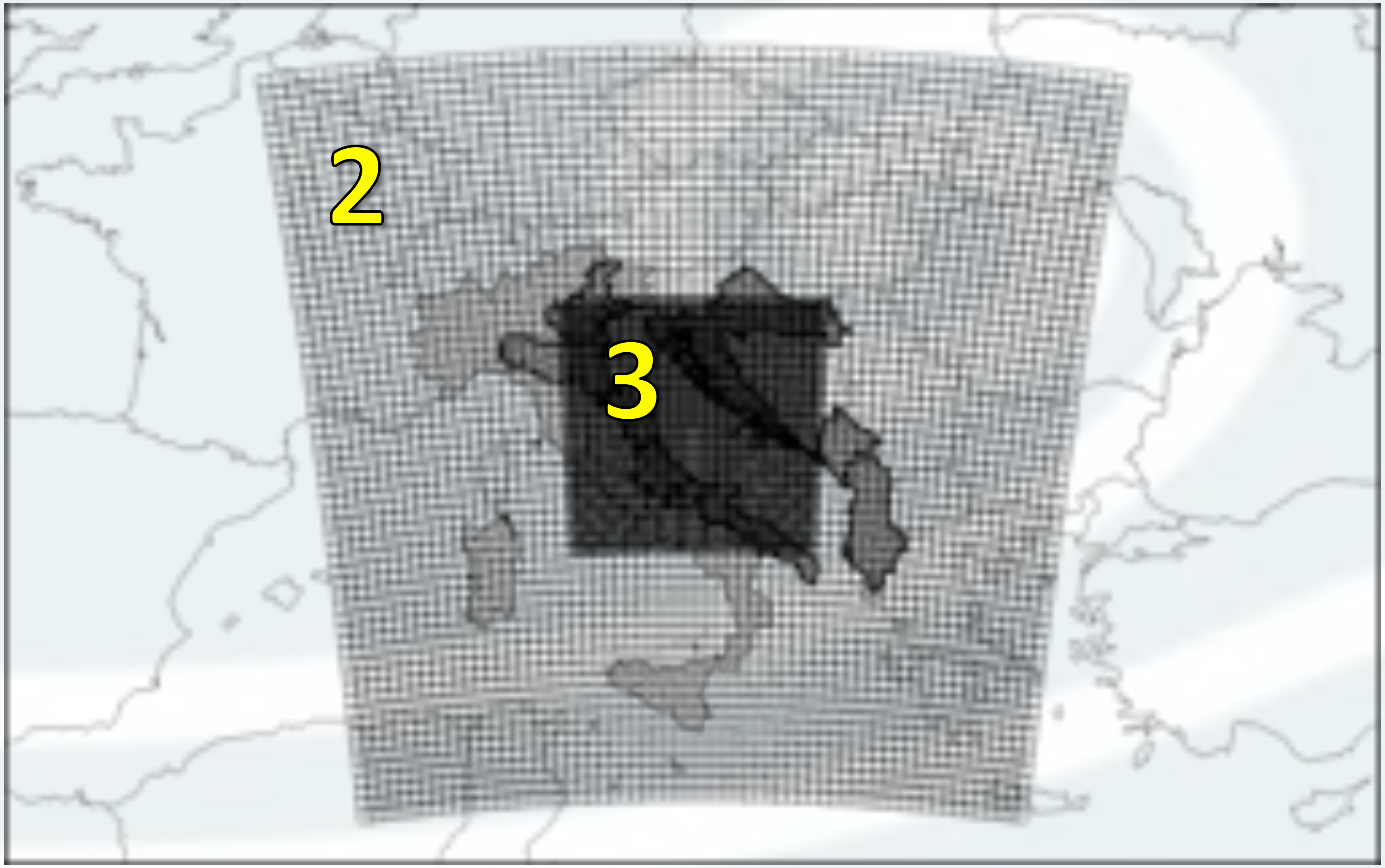
THE IMPLEMENTED HINDCASTING PROCEDURE



DOMAIN 1 – Horizontal Spatial Resolution of 81 km - Continental
DOMAIN 2 – Horizontal Resolution of 27 km - Subcontinental

Each calculus domain has the same number of cells but the two way approach imposes a 3:1 growth ratio of the spatial resolution.
The main consequence of these expansion ratio is that the mother domain is so large to cover a large part of Europe and North Africa. With a so large mother domain is possible to fully take in account synoptic phenomena and to propagate their effects to inner domains.

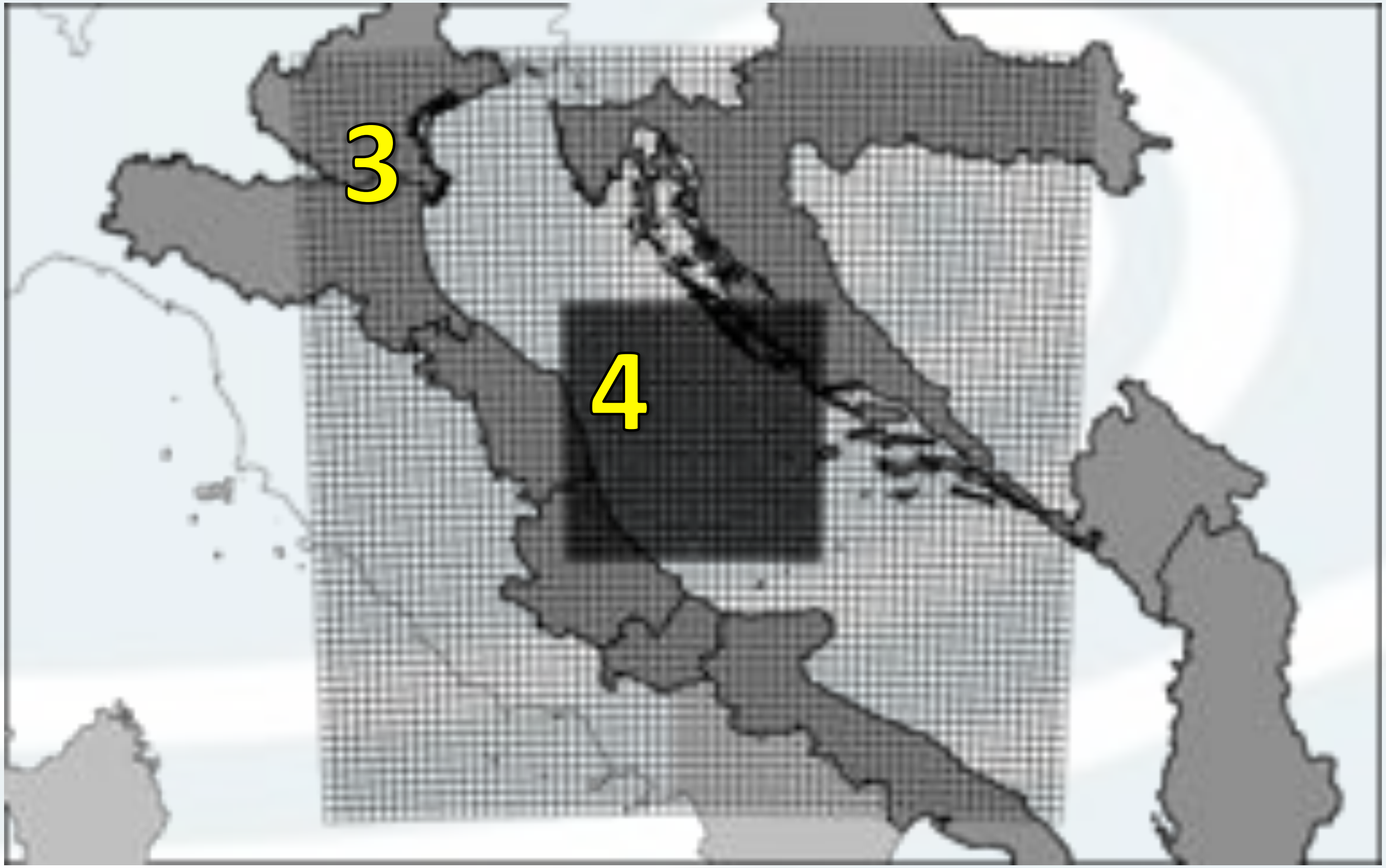
THE IMPLEMENTED HINDCASTING PROCEDURE



In this example the second domain covers all the POWERED partners countries and also the main mountains areas surrounding the Adriatic Basin.

DOMAIN 2 – Horizontal Spatial Resolution of 27 km – Subcontinental
DOMAIN 3 – Horizontal Spatial Resolution of 9 km – Interregional

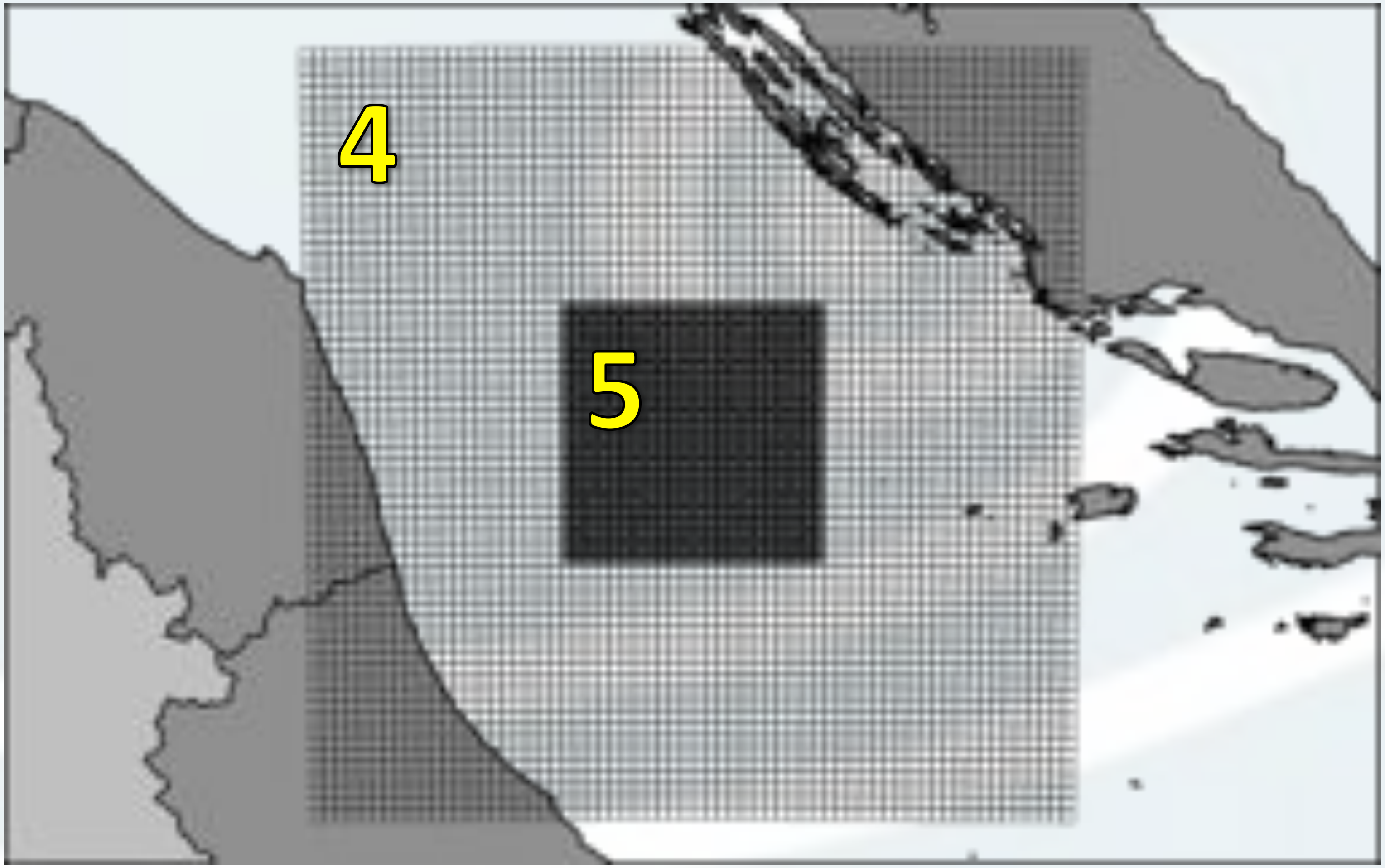
THE IMPLEMENTED HINDCASTING PROCEDURE



DOMAIN 3 – Horizontal Spatial Resolution of 9 km - Interregional
DOMAIN 4 – Horizontal Spatial Resolution of 3 km - Regional

The third domain covers part of the Adriatic basin and also a significant area of land surfaces that strongly interacts with wind behaviours.

THE IMPLEMENTED HINDCASTING PROCEDURE



The fourth domain is the final step for a 3 [km] Powered analysis while the fifth domain is the final one for the 1 [km] simulations.

The finer domains are able to take in account local wind phenomena that originates by interactions with local complex terrains.

DOMAIN 4 – Horizontal Spatial Resolution of 3 km - Regional

DOMAIN 5 – Horizontal Spatial Resolution of 1 km - Local

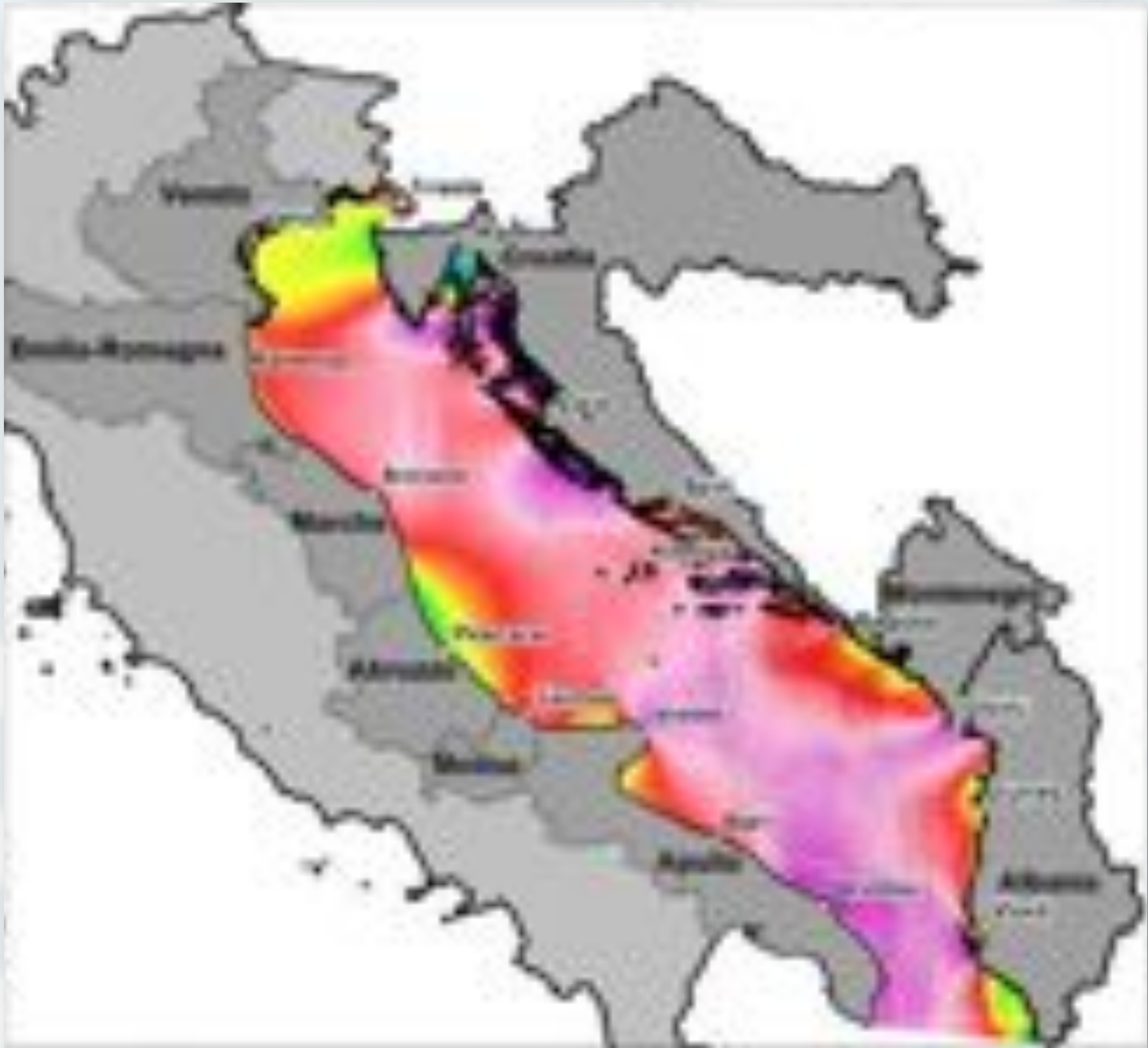
Description of the Simulated Area

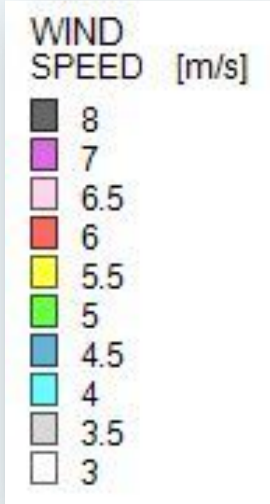
79 DOMAINS HAVING A SPATIAL GRID RESOLUTION OF 1 Km

12 DOMAINS HAVING A SPATIAL GRID RESOLUTION OF 3 Km

Long term analyses are actually obtained with a 3 [km] resolution for the years from 2008 to 2011, while 1 [km] simulations are carried out for the 2010 year.

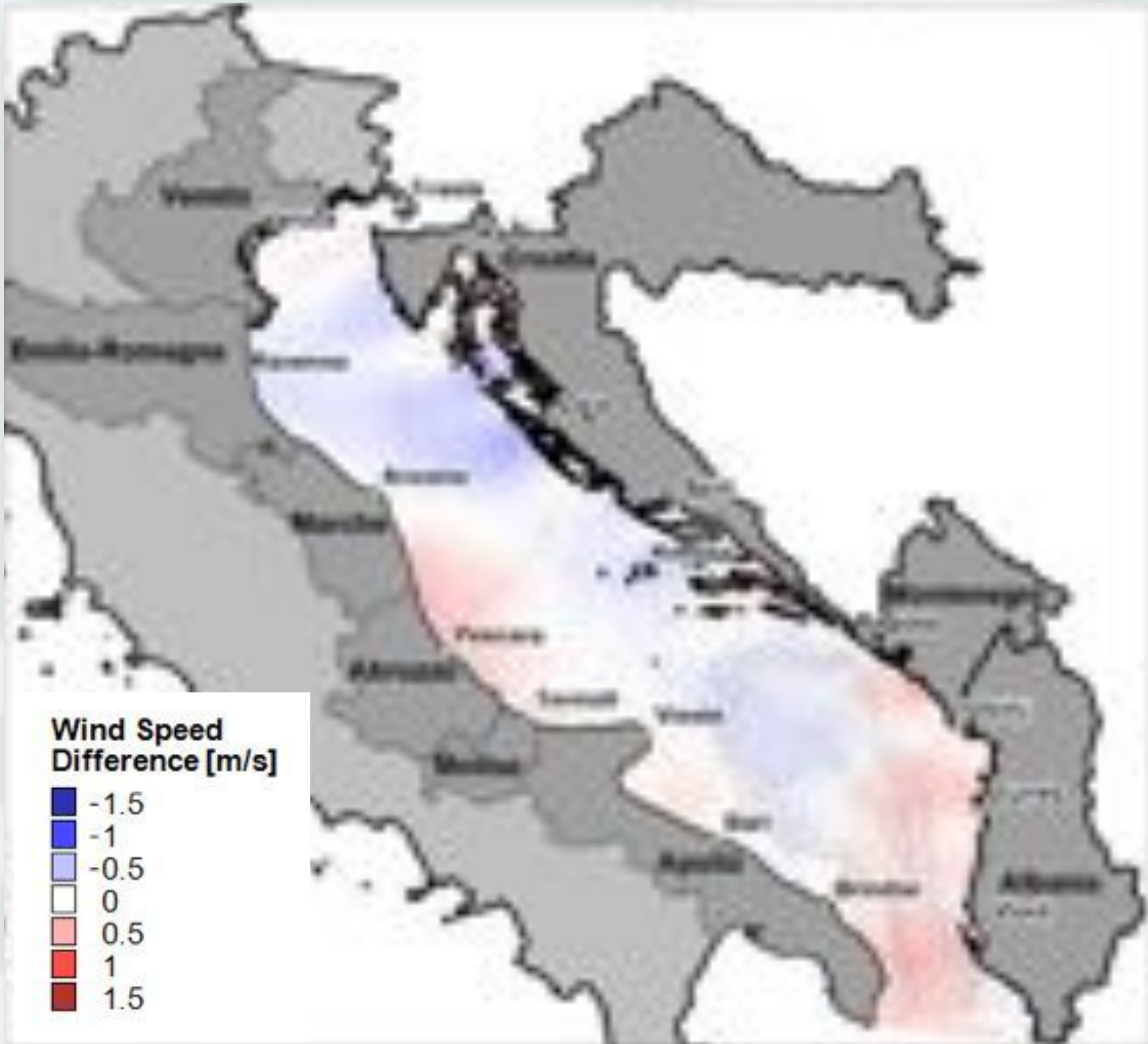
3 km Simulations Wind Results - 2008





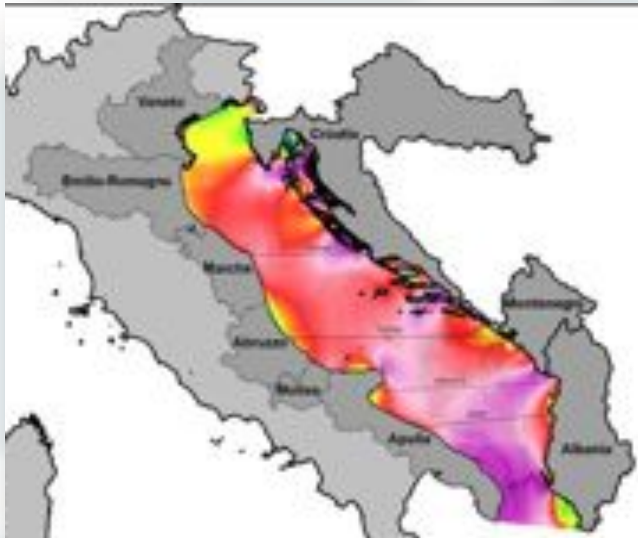
Year 2008
Height
90 [m] a.s.l.

3 km Simulations Wind Results – 2009 vs. 2008

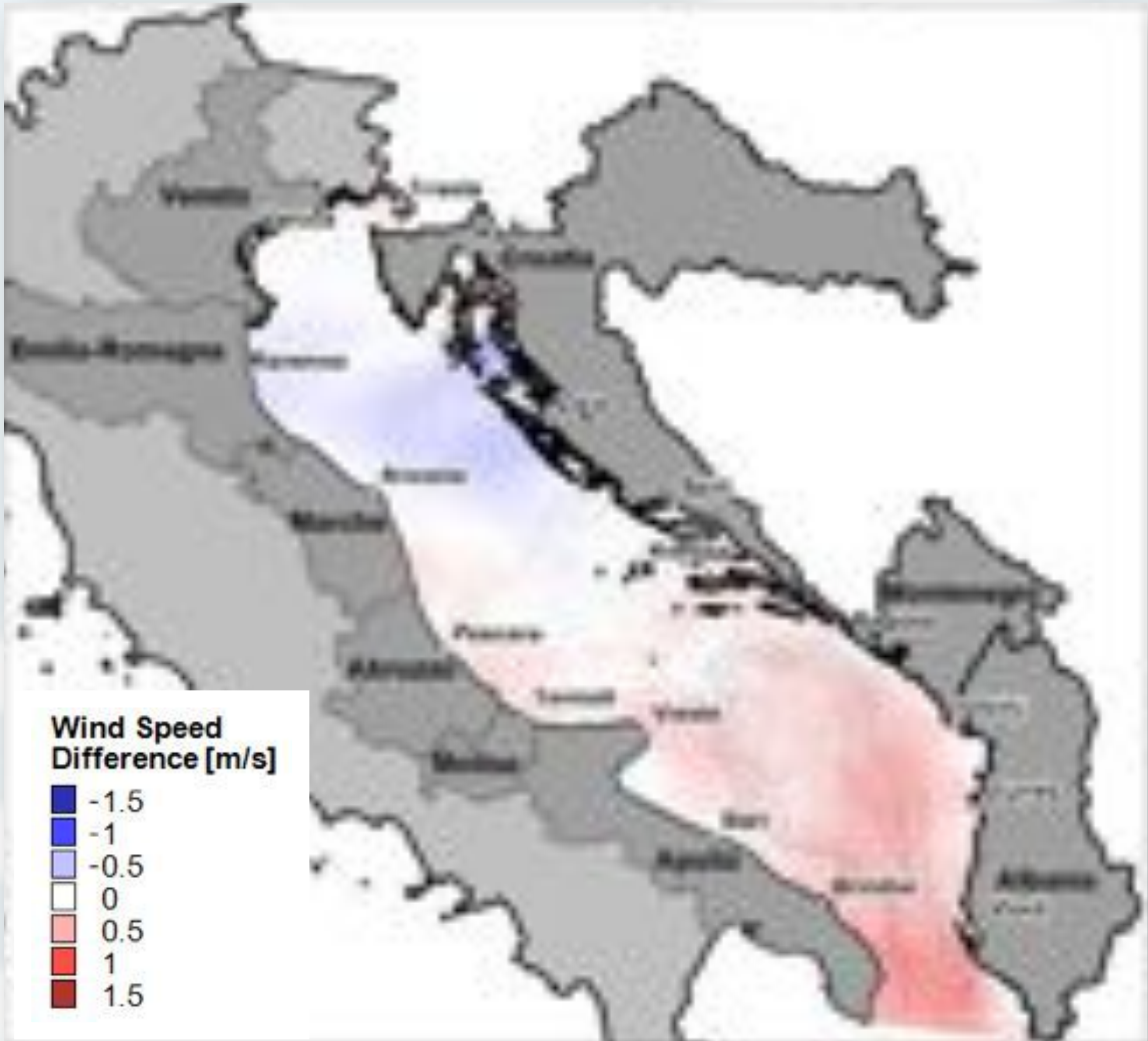


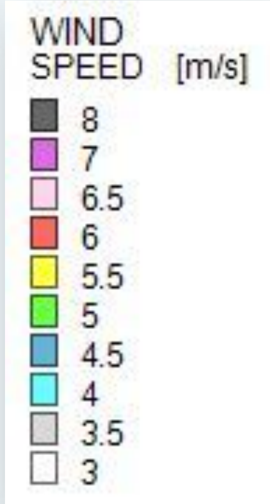
WIND
SPEED [m/s]
8
7
6.5
6
5.5
5
4.5
4
3.5
3

Year
2009
Height
90 [m] a.s.l.

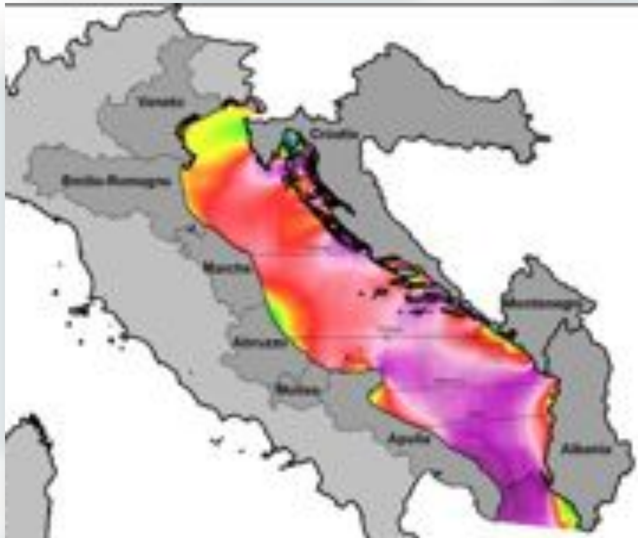


3 km Simulations Wind Results – 2010 vs. 2008

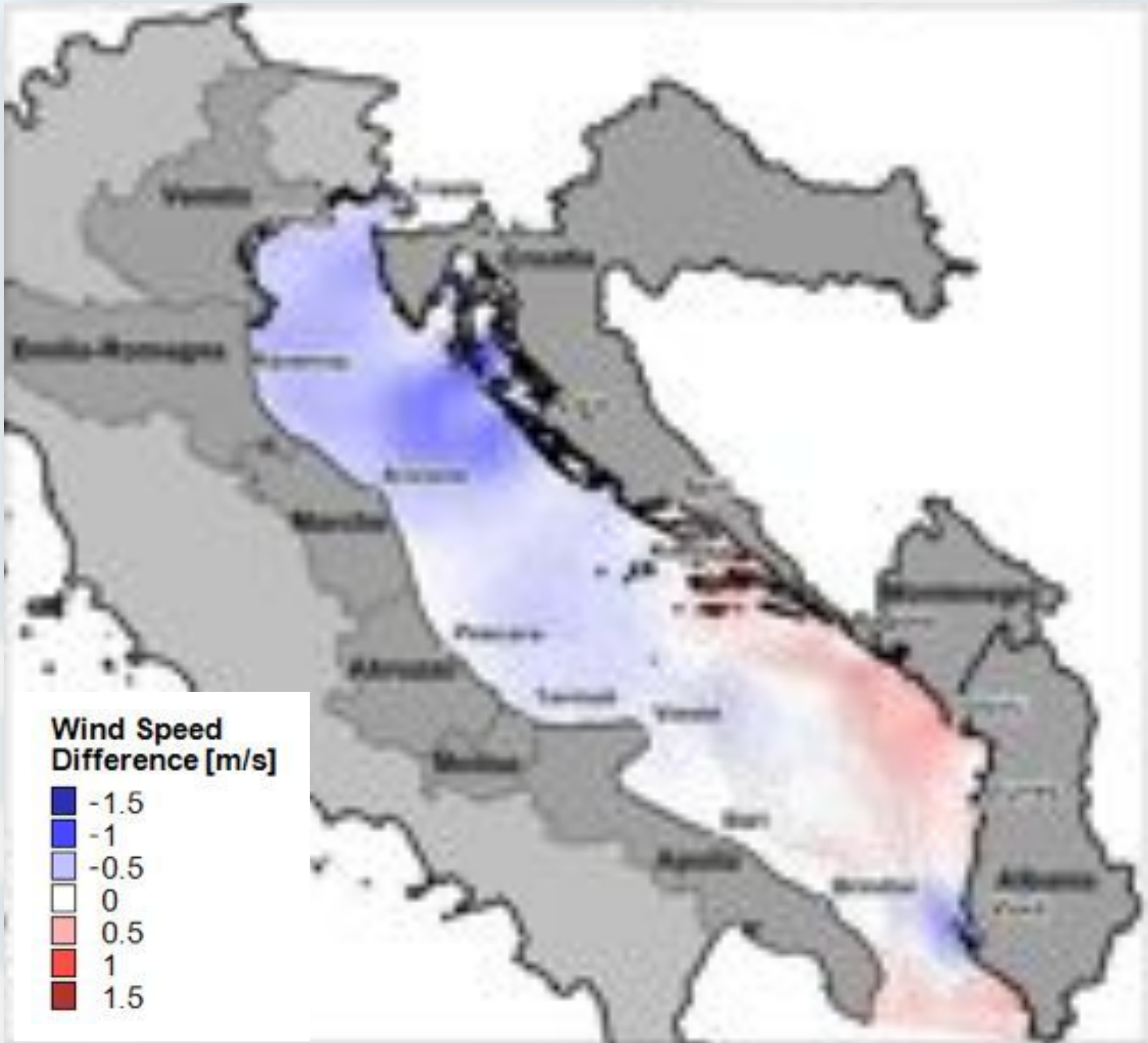




Year
2010
Height
90 [m] a.s.l.

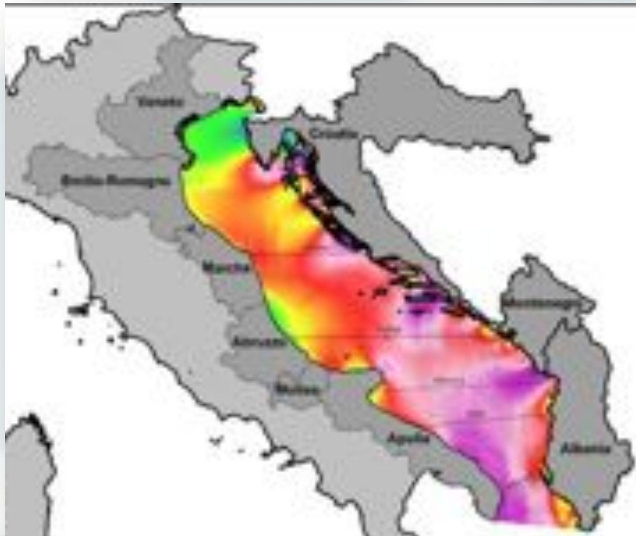


3 KM SIMULATIONS WIND RESULTS – 2011 VS. 2008

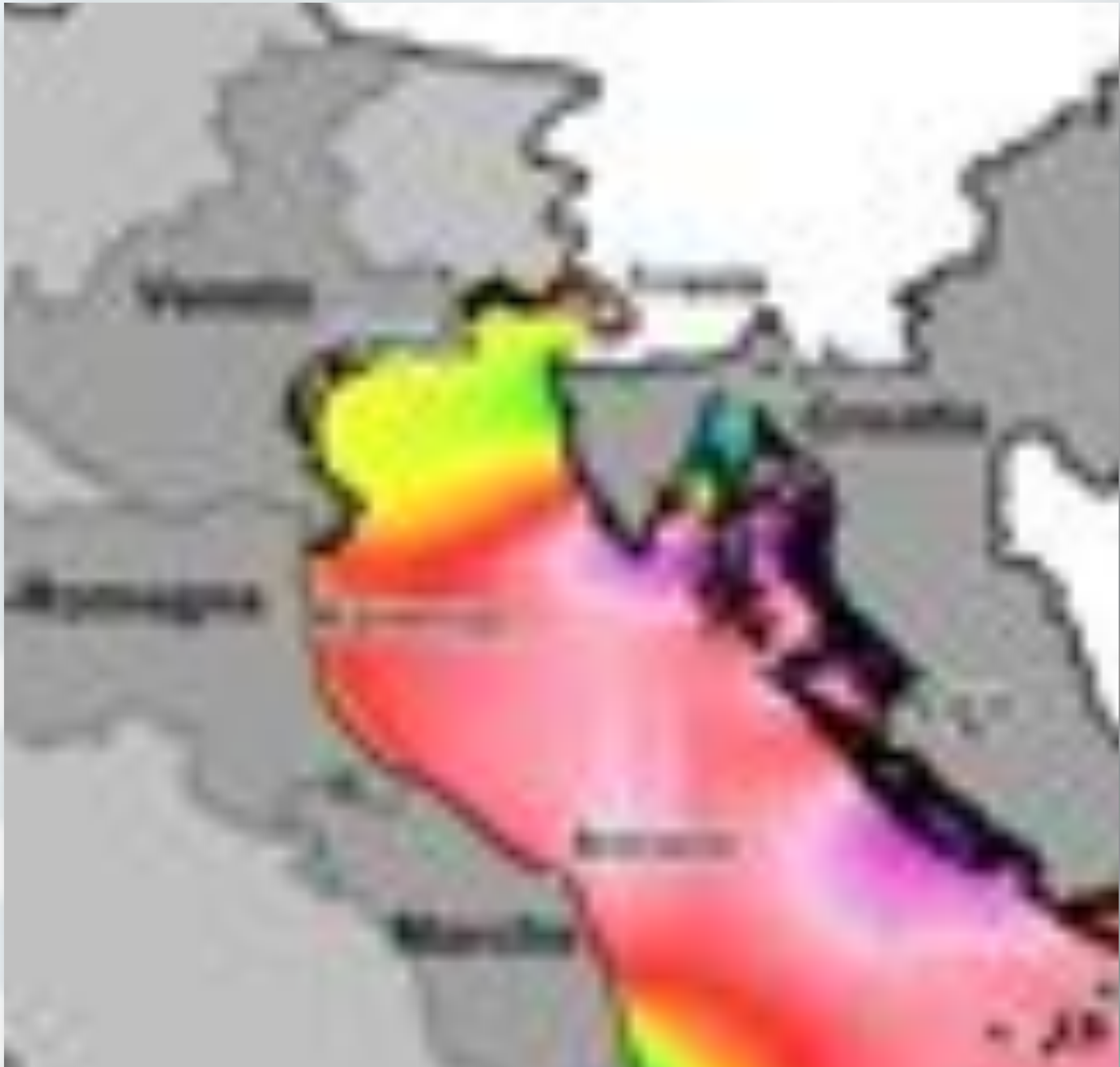


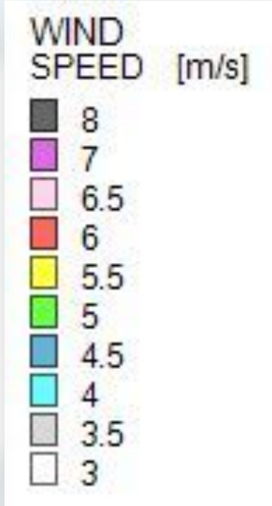
WIND SPEED [m/s]
8
7
6.5
6
5.5
5
4.5
4
3.5
3

Year 2011
Height
90 [m] a.s.l.



3 KM SIMULATIONS WIND RESULTS - 2008

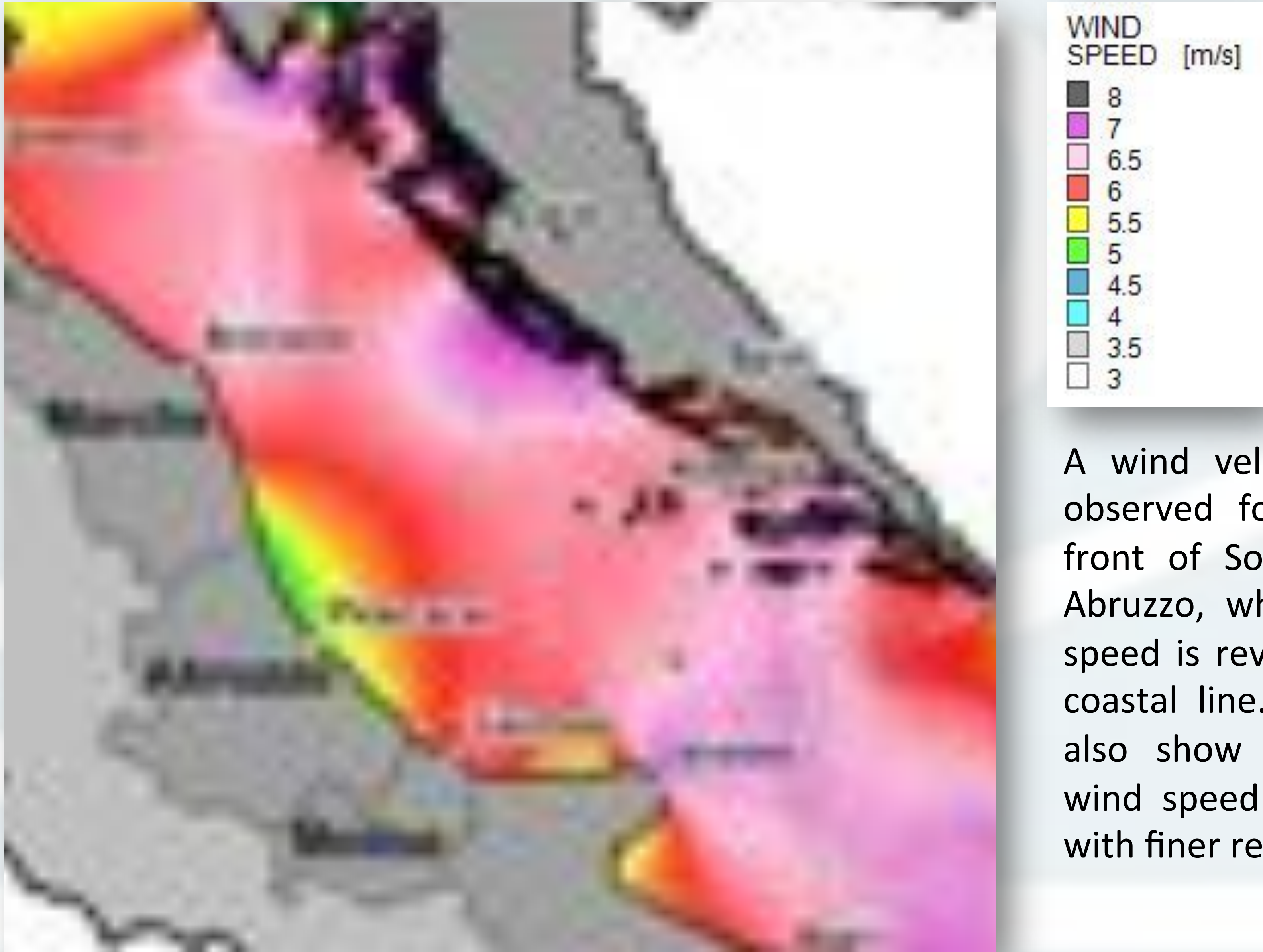




Year
2008
Height
90 [m] a.s.l.

The sea area in front of the Veneto region shows lower wind velocities with respect to the other Adriatic Basin zones. An interesting velocity may be observed just before Trieste. Mean wind speed increases at lower latitudes, particularly for the Croatian island's areas, where velocities greater than 7 [m/s] was found.

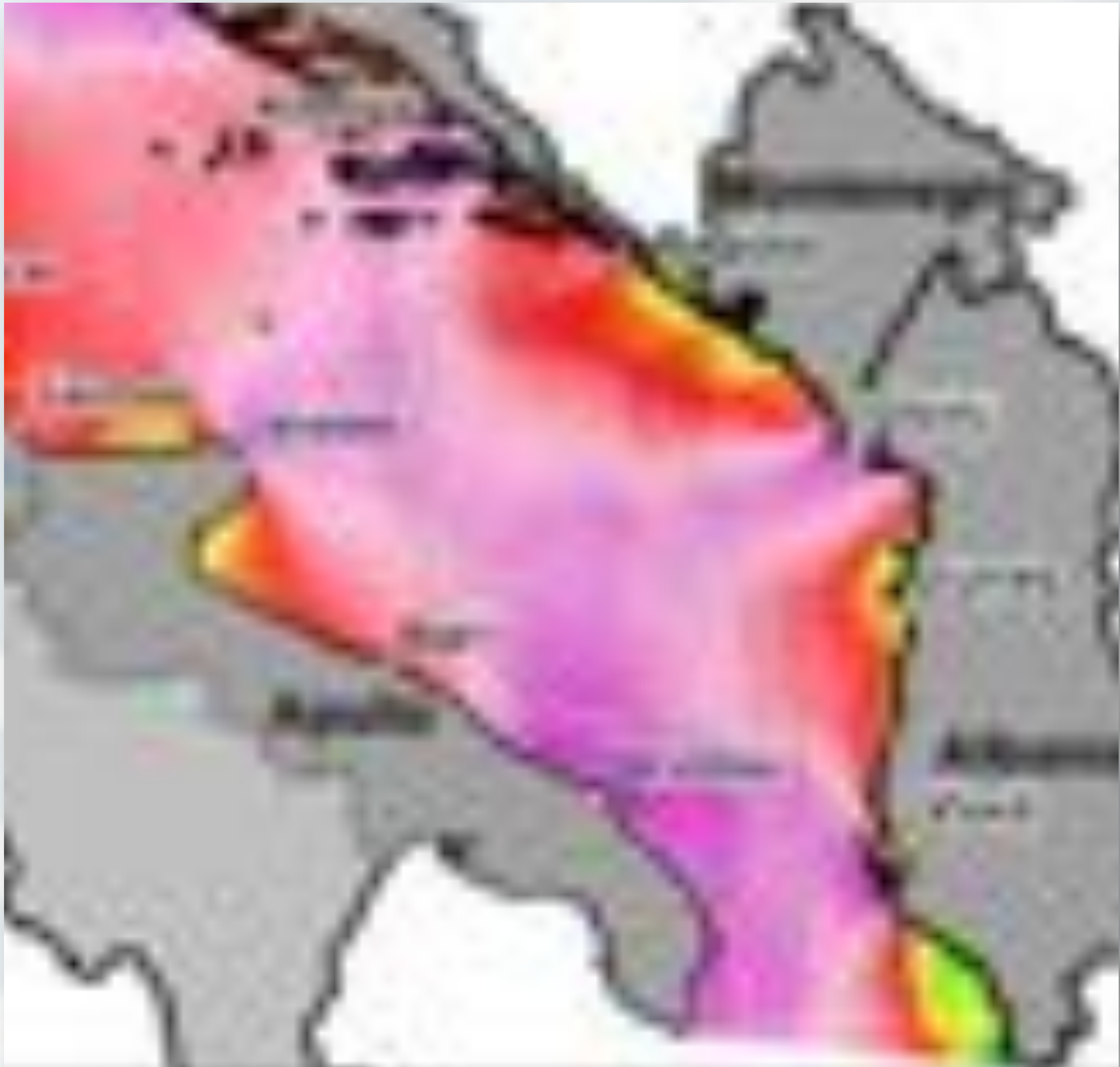
3 KM SIMULATIONS WIND RESULTS - 2008

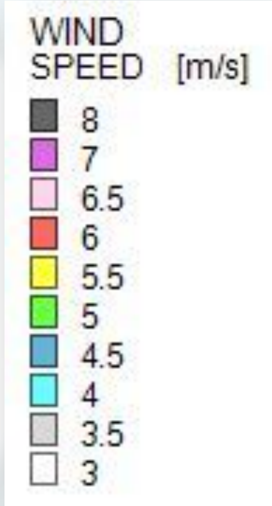


Year
2008
Height
90 [m] a.s.l.

A wind velocity decrease may be observed for the coastal areas in front of South Marche and North Abruzzo, while an interesting wind speed is revealed in front of Molise coastal line. South Croatian islands also show an interesting average wind speed to be deeper analysed with finer resolutions.

3 km Simulations Wind Results - 2008

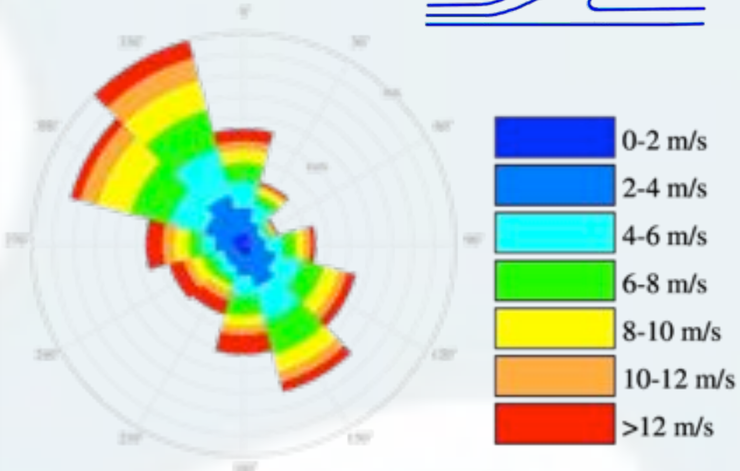




Year
2008
Height
90 [m] a.s.l.

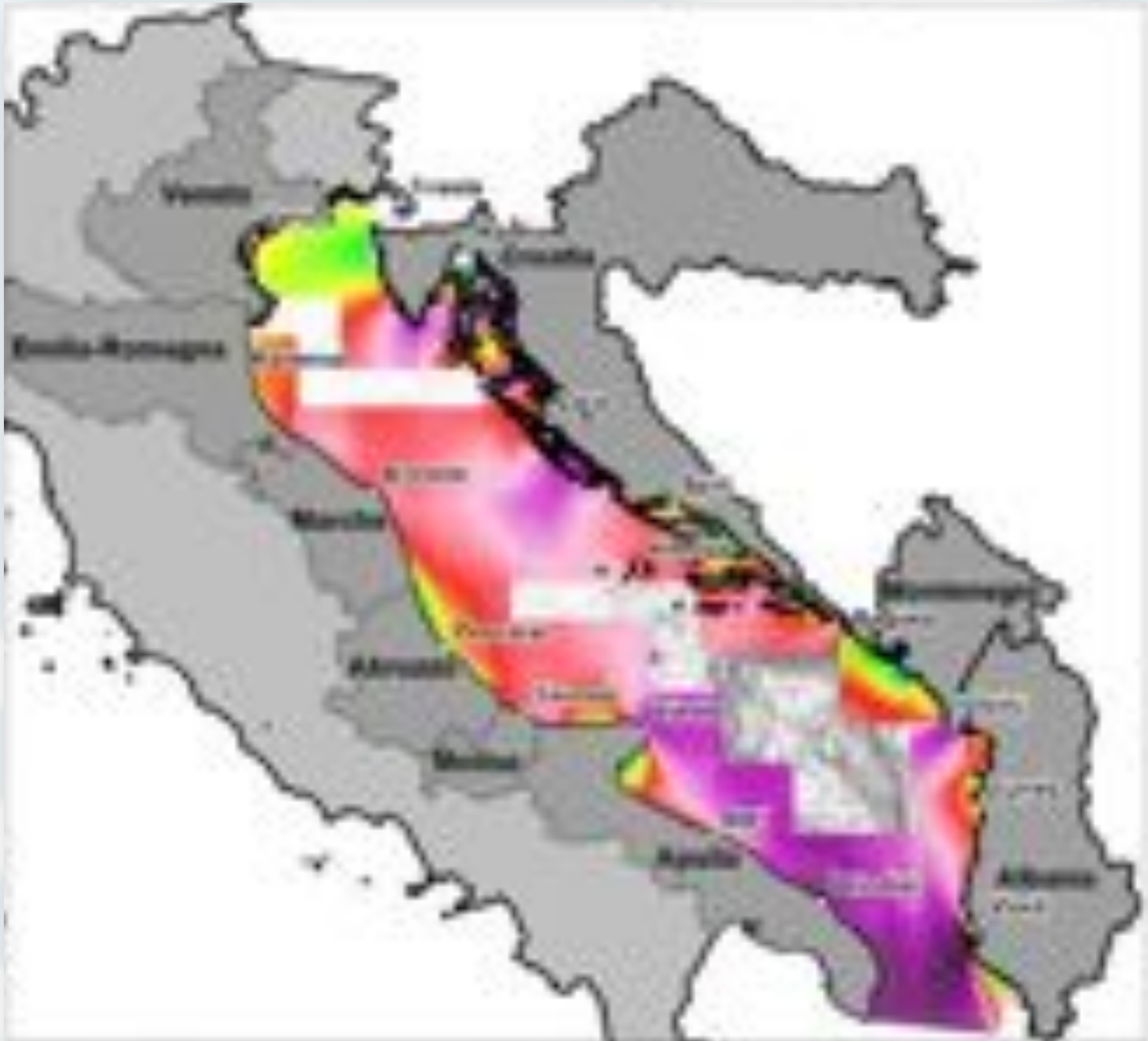
The south part of the Adriatic Basin is doubtless the more interesting area with respect to the average wind speed. Velocities greater than 7 [m/s] may be observed both for Apulia, South Montenegro and North and South Albania .

3 KM SIMULATIONS WIND RESULTS - 2008



Annual wind roses show a NNW-SSE directionality in the south Adriatic Basin while an omnidirectional behaviour may be observed at higher latitudes. Wind roses near coastal line show instead different occurrences due to interactions with the local terrain conformation.

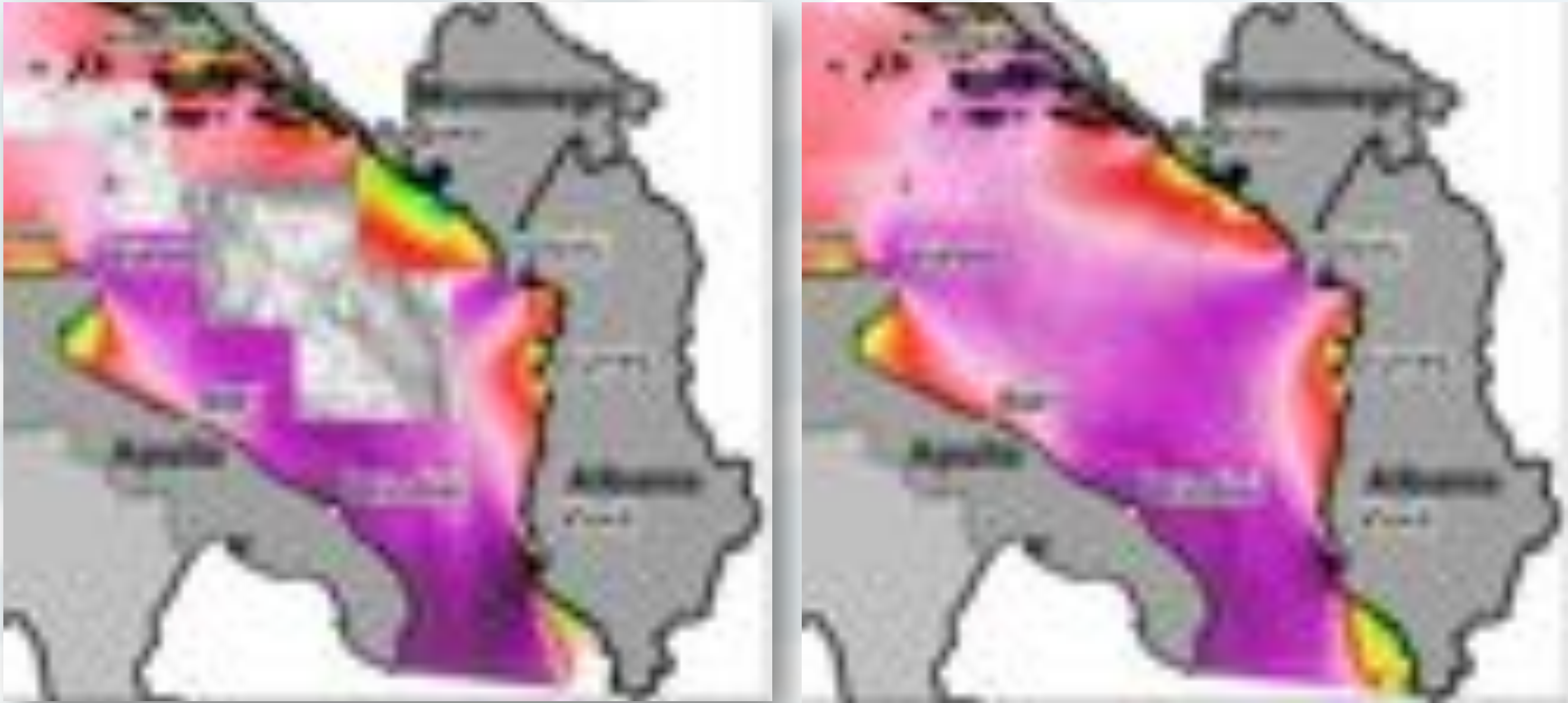
1 km Simulations Wind Results - 2010



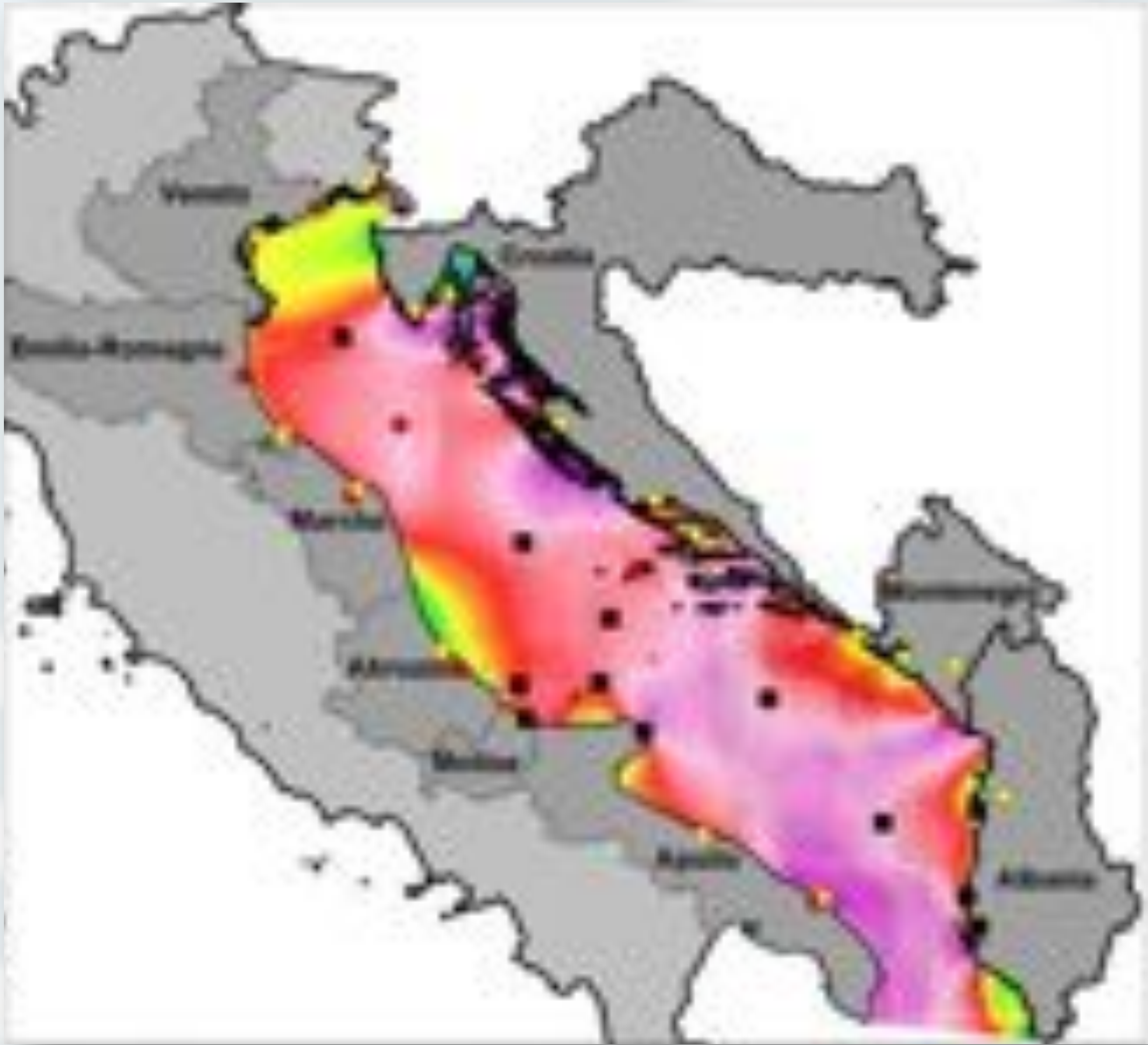
Numerical simulations with an horizontal spatial resolution of 1 [km] show the same trends revealed by the 3 [km] results, although a more detailed definition is observed near coastal lines, especially for islands areas like the ones present in Croatia country.

1 KM VS. 3 KM SIMULATIONS WIND RESULTS - 2010

Improving the horizontal resolution up to 1 [km] allow to better define local wind resources expecially with respect to terrain conformation just behind the coastal lines.



VIRTUAL METEO MAST NETWORK

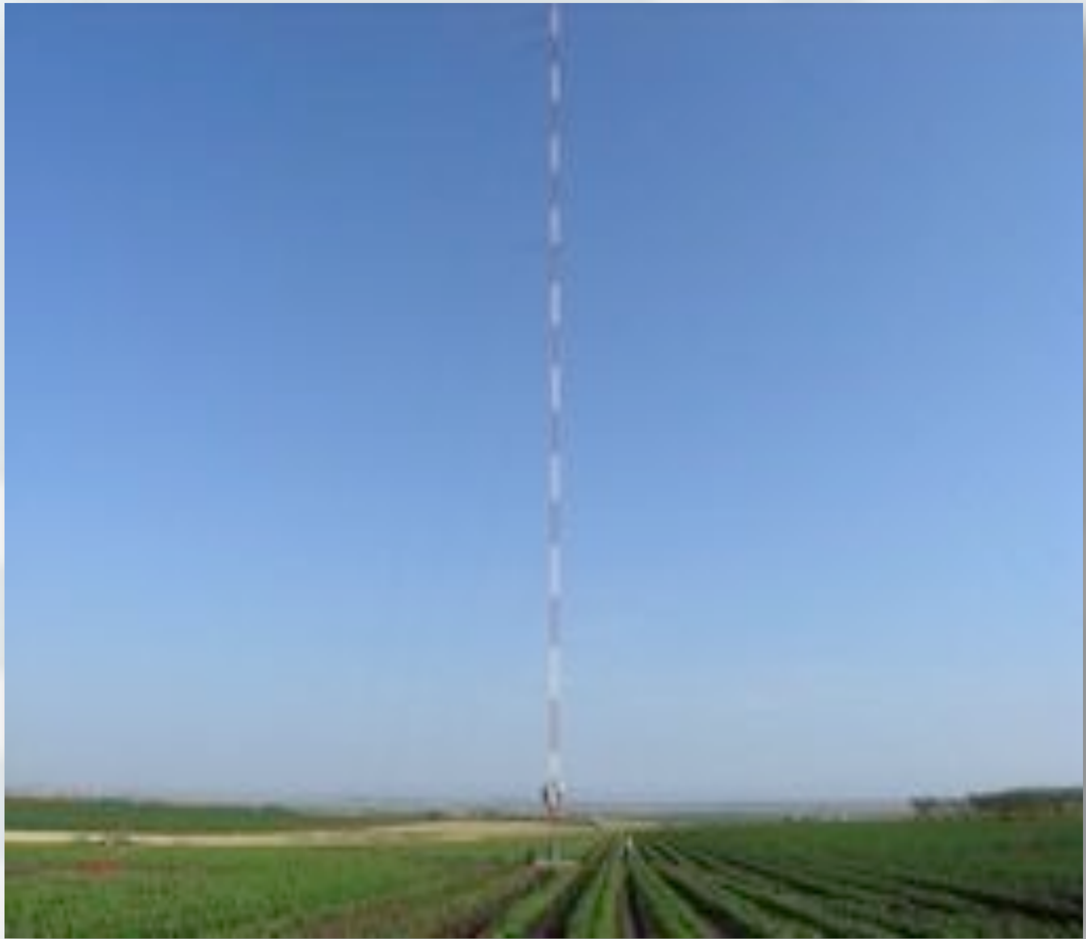


● POWERED MAST
■ SAMPLE MAST
◆ AFIS (*)

Several Virtual Meteo Mast was extracted in significant point over the Adriatic Basin so to analyze in a detailed way the wind behavior. Direct comparisons with experimental data becoming from Powered partners and Powered sponsors was carried out.

ON-SHORE WIND RESULTS COMPARISONS

Powered Sponsor Meteo Tower

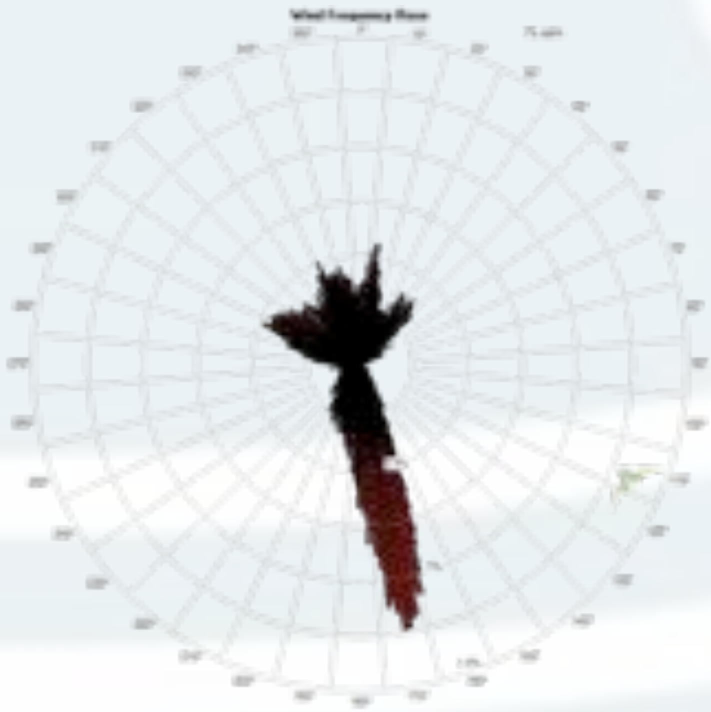


WPD meteo mast

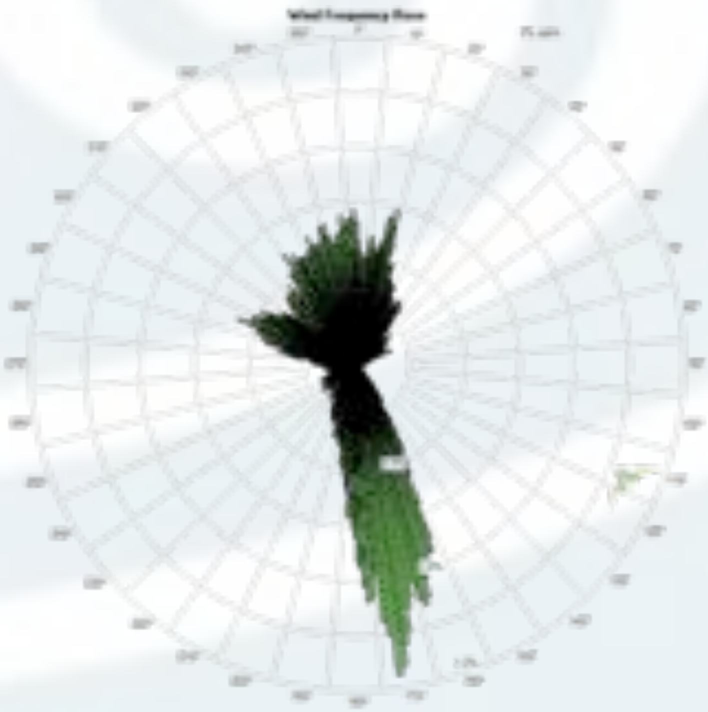
Lattice Tower: 100 [m] height
Four Measurement Planes: 40 [m], 60 [m], 80 [m] and 100 [m];
Speed Sensors: 4 NRG#40C, 1THIES;
Direction Sensors: 2 NRG#200P

ON-SHORE WIND RESULTS COMPARISONS

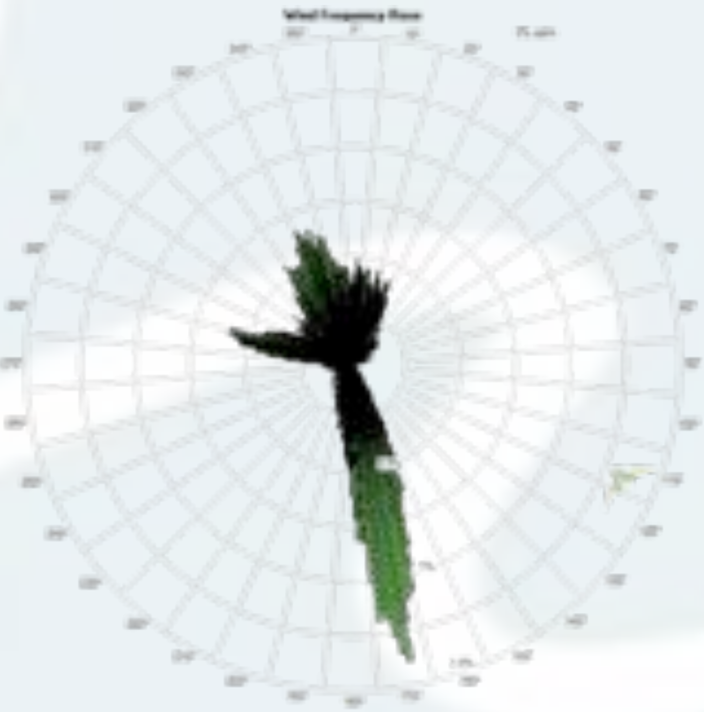
A comparison among experimental results and numerical results, obtained with different horizontal resolutions, show a good agreement with a clear identification of the most relevant wind direction.



Annual Directional Occurrences
Experimental Results
Wind Rose @ 58 [m]



Annual Directional Occurrences
P3 Numerical Results
Wind Rose @ 51 [m]

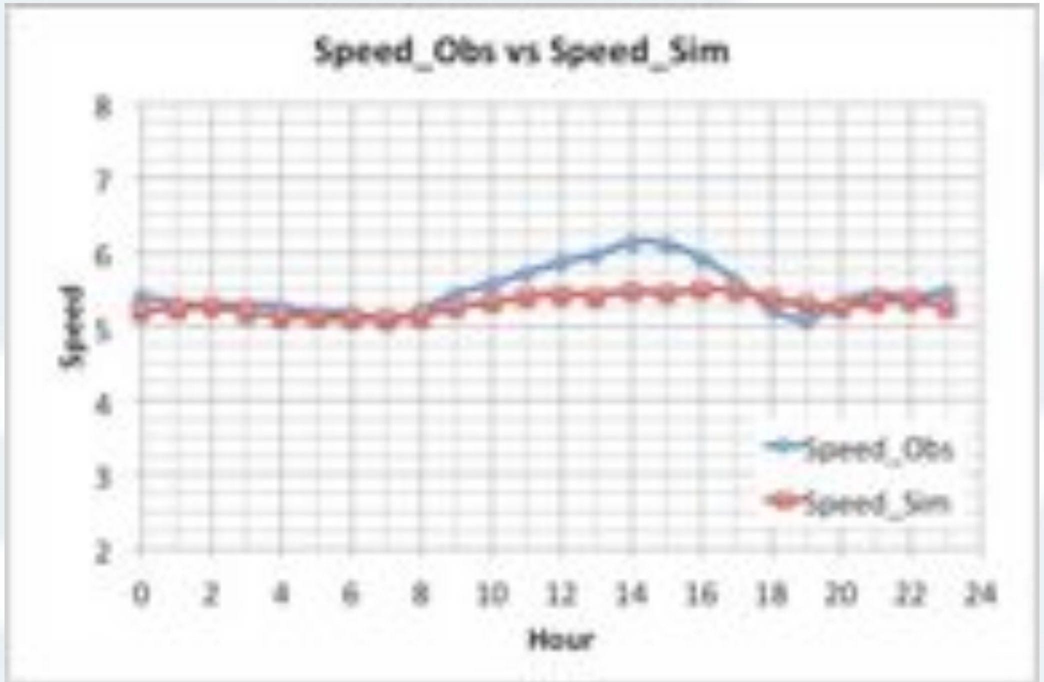


Annual Directional Occurrences
P1 Numerical Results
Wind Rose @ 51 [m]

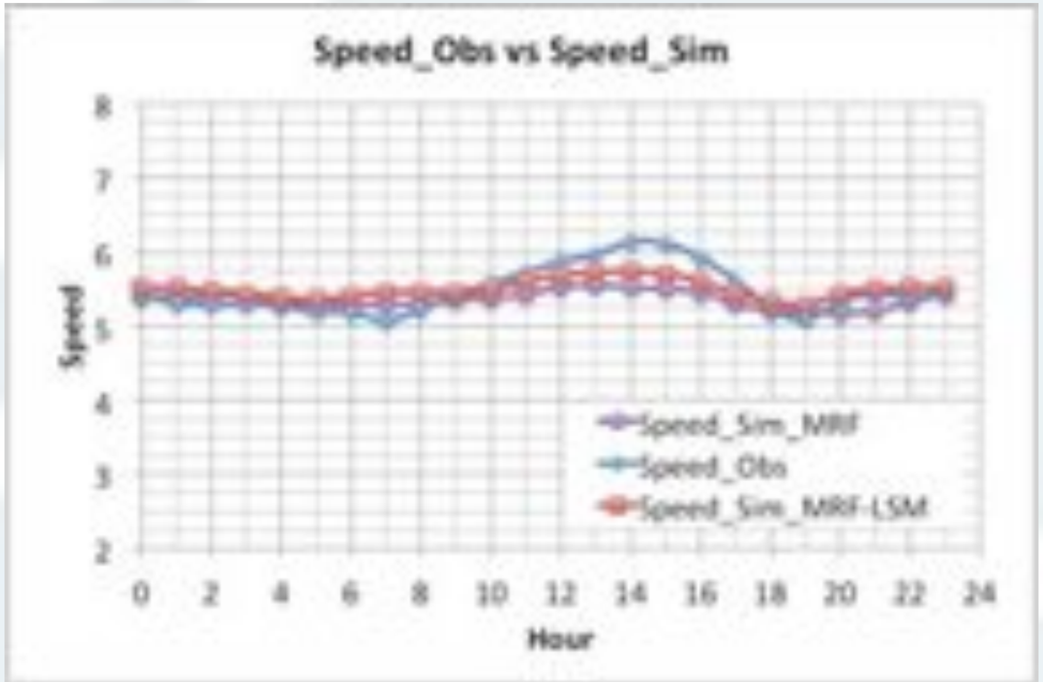
ON-SHORE WIND RESULTS COMPARISONS

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.48	5.30	-0.18	-3.29%	10.66

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.48	5.36	-0.12	-2.18%	6.87
5.48	5.50	0.02	0.36%	6.88



Annual Mean Diurnal – Exp. Vs. P3
Wind Speed Profile @ 40 [m]



Annual Mean Diurnal – Exp. Vs. P1
Wind Speed Profile @ 40 [m]

On-Shore Wind Results Comparisons

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.48	5.30	-0.18	-3.29%	10.66

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.48	5.36	-0.12	-2.18%	6.87
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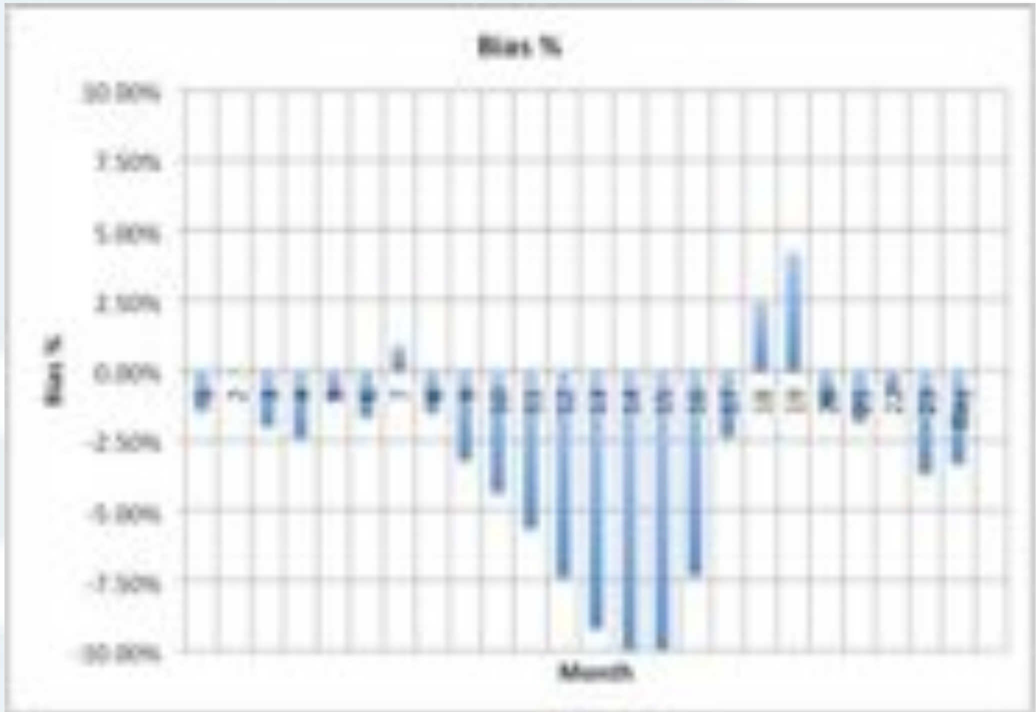
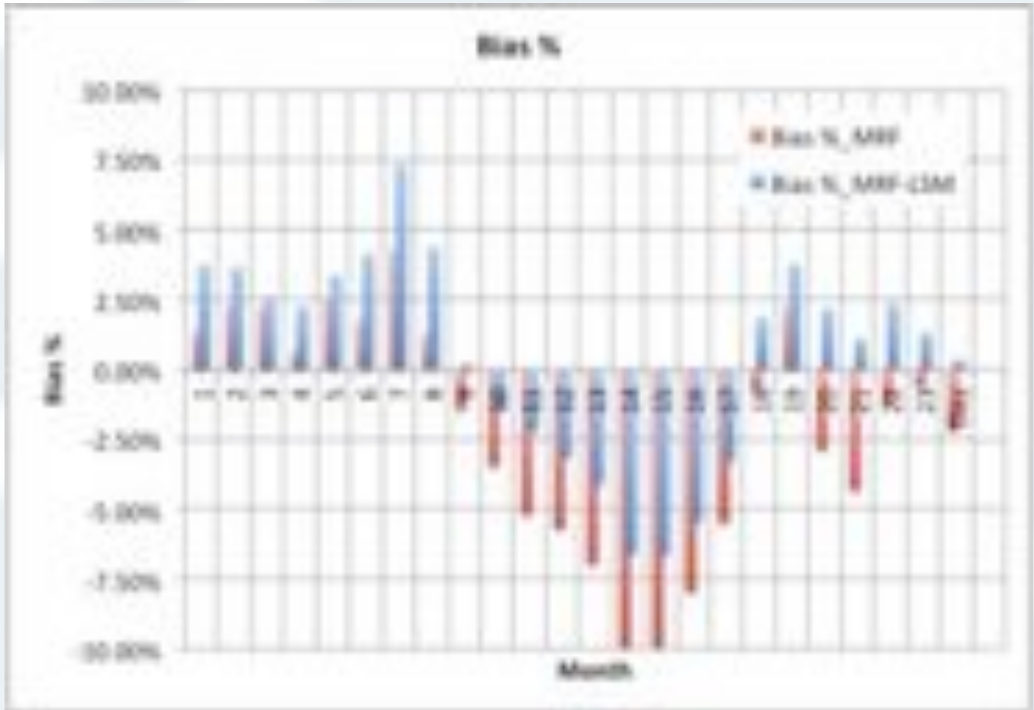


Bias % Annual Mean Diurnal- Exp. Vs. P3
Wind Speed Profile @ 40 [m]



Bias % Annual Mean Diurnal- Exp. Vs. P1
Wind Speed Profile @ 40 [m]

ON-SHORE WIND RESULTS COMPARISONS

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.48	5.30	-0.18	-3.29%	10.66

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.48	5.36	-0.12	-2.18%	6.87
5.48	5.50	0.02	0.36%	6.88

Monthly Mean – Exp. Vs. P3
Wind Speed Profile @ 40 [m]

Monthly Mean – Exp. Vs. P1
Wind Speed Profile @ 40 [m]

On-Shore Wind Results Comparisons

<Vobs>	<Vsim>	Bias	Bias%	Bias°
6.32	6.20	-0.11	-1.80%	24.08

<Vobs>	<Vsim>	Bias	Bias%	Bias°
6.32	6.16	-0.15	-2.42%	20.85
6.32	6.32	0.00	0.02%	21.13

Annual Mean Diurnal – Exp. Vs. P3
Wind Speed Profile @ 100 [m]

Annual Mean Diurnal – Exp. Vs. P1
Wind Speed Profile @ 100 [m]

ON-SHORE WIND RESULTS COMPARISONS

<Vobs>	<Vsim>	Bias	Bias%	Bias°
6.32	6.20	-0.11	-1.80%	24.08

<Vobs>	<Vsim>	Bias	Bias%	Bias°
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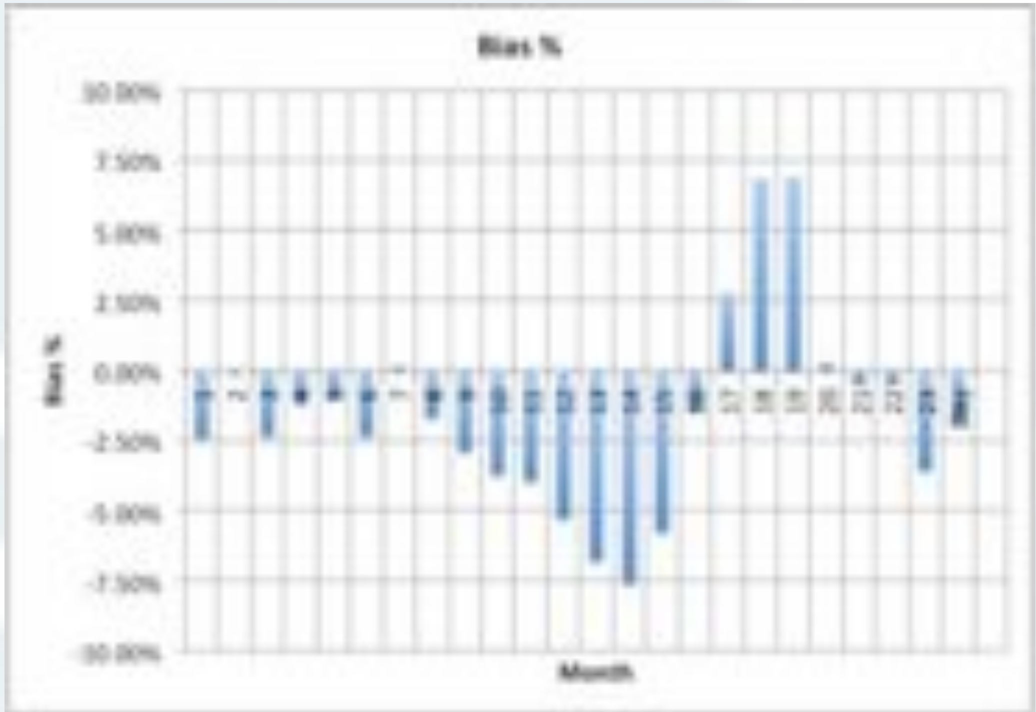
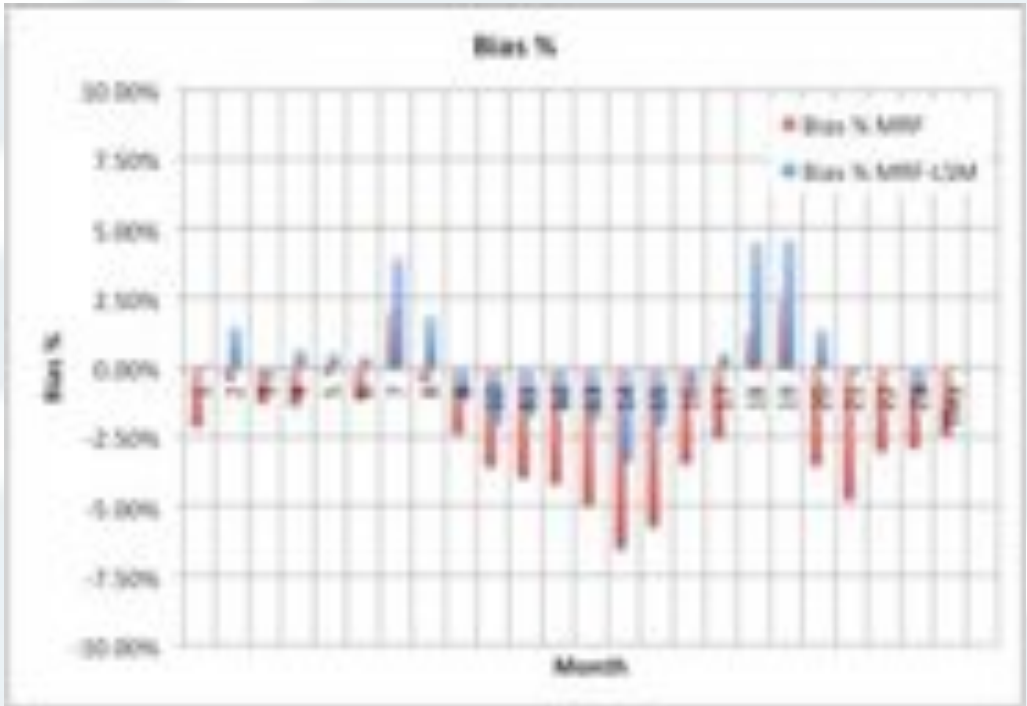
6.32	6.32	0.00	0.02%	21.13



Bias % Annual Mean Diurnal – Exp. Vs. P3
Wind Speed Profile @ 100 [m]



Bias % Annual Mean Diurnal – Exp. Vs. P1
Wind Speed Profile @ 100 [m]

ON-SHORE WIND RESULTS COMPARISONS

<Vobs>	<Vsim>	Bias	Bias%	Bias°
6.32	6.20	-0.11	-1.80%	24.08

<Vobs>	<Vsim>	Bias	Bias%	Bias°
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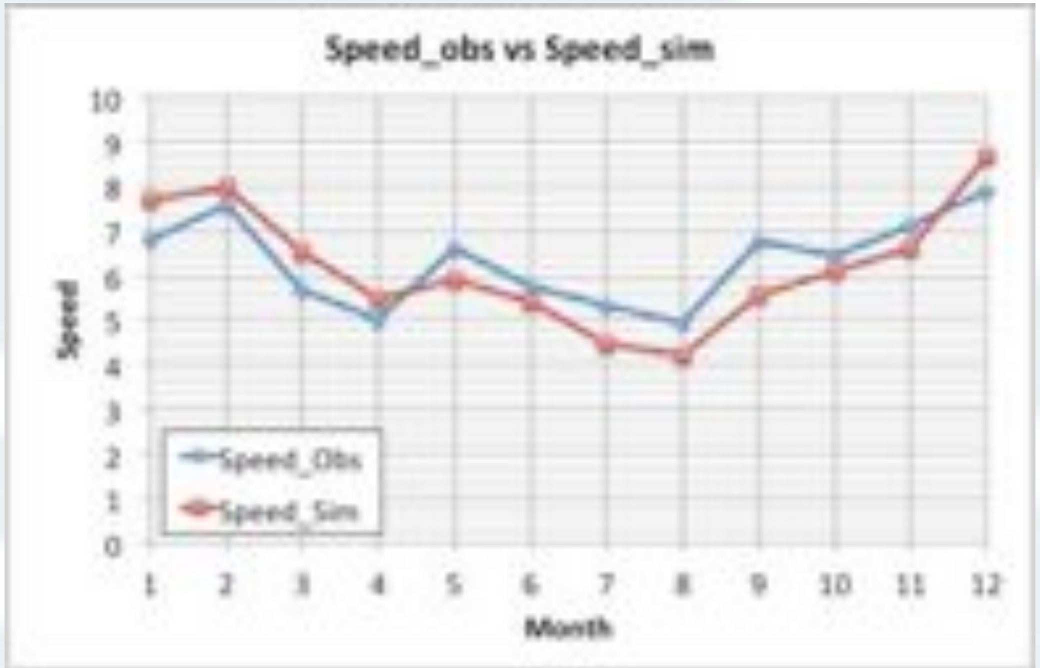
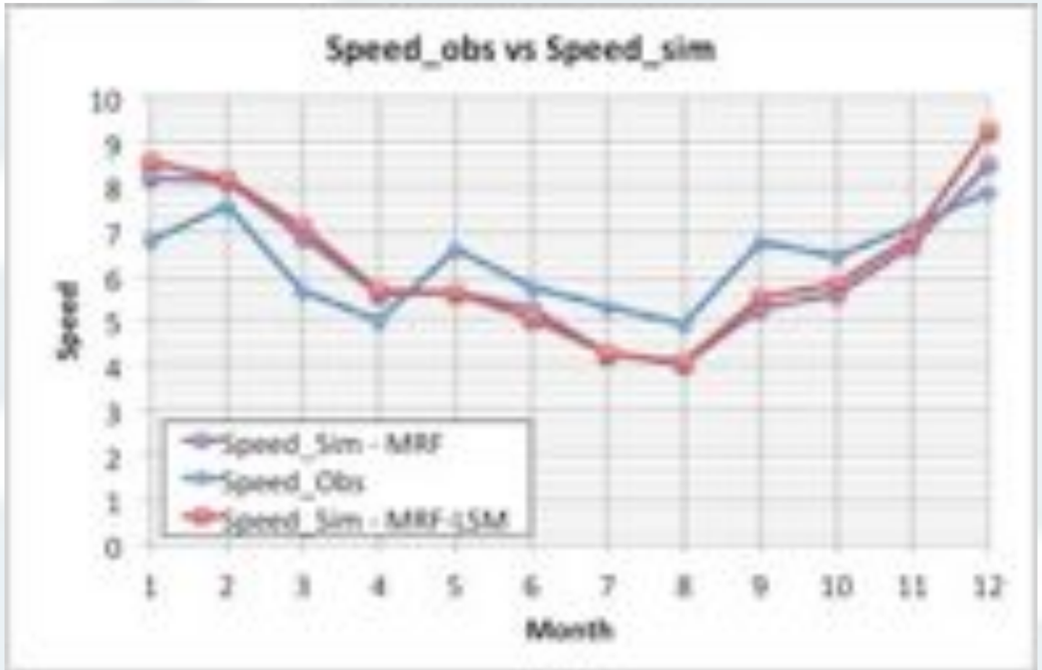
6.32	6.32	0.00	0.02%	21.13



Monthly Mean – Exp. Vs. P3
Wind Speed Profile @ 100 [m]

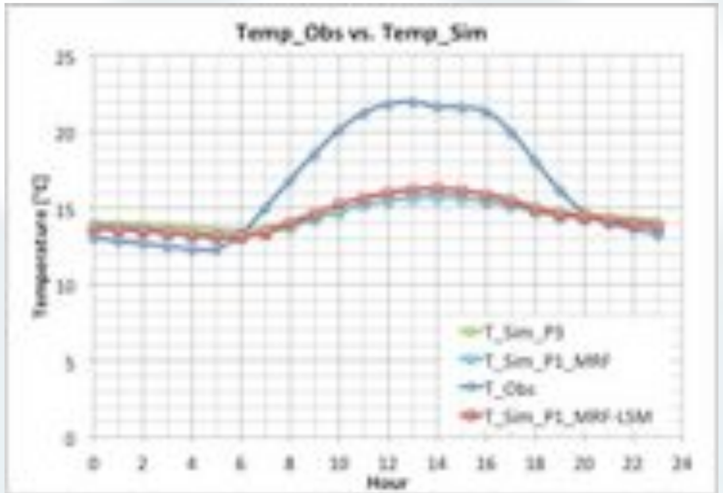


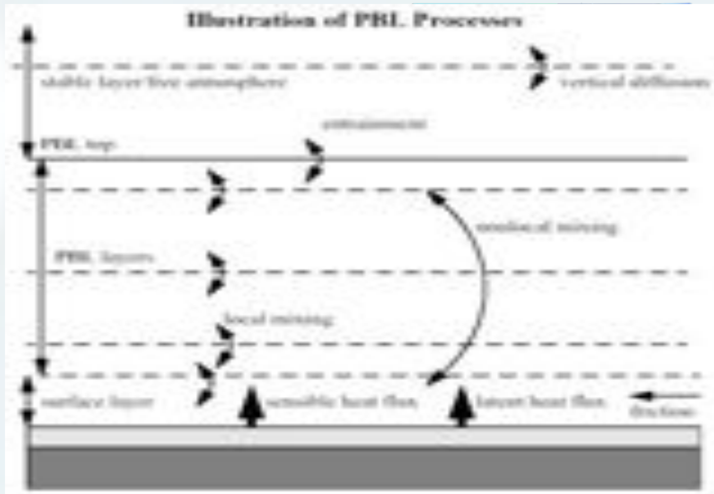
Monthly Mean – Exp. Vs. P1
Wind Speed Profile @ 100 [m]

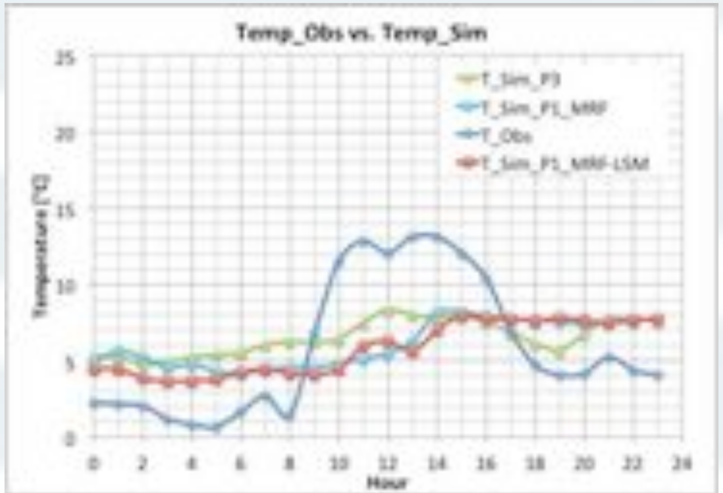
ON-SHORE WIND RESULTS COMPARISONS

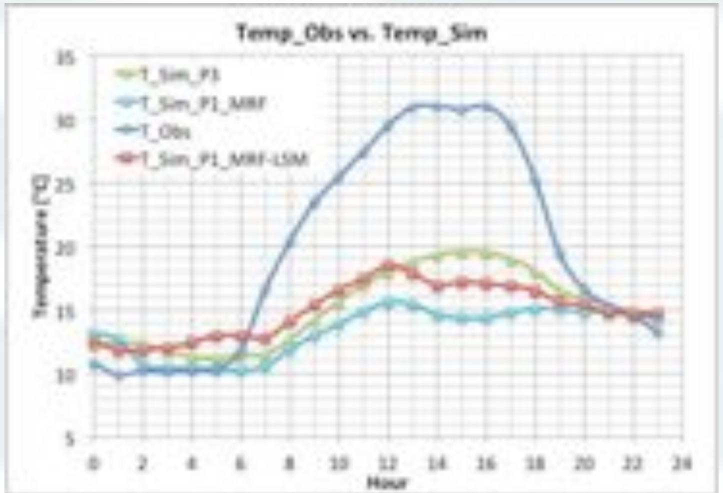
It is possible to observe a direct correlation between a different temperature behaviour and a wind speed overestimation or underestimation. This is mainly due to the energy exchange between the land and the mixing boundary layer.

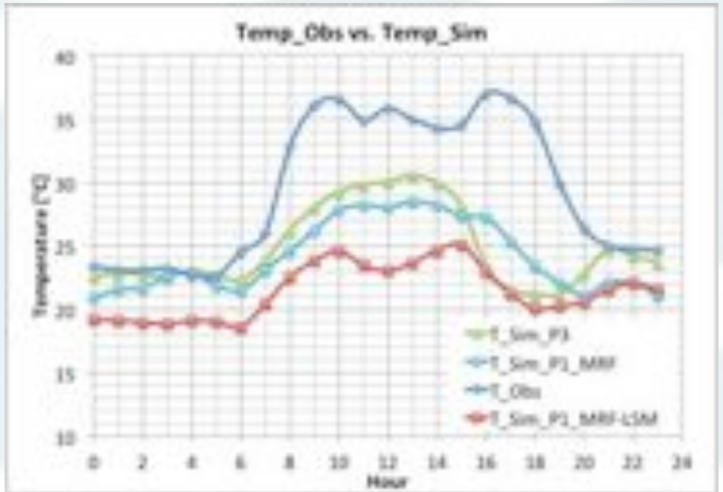
Annual Mean Temperature











21 January Mean Temp. **21 April Mean Temp.** **21 July Mean Temp.**

"OFF-SHORE" WIND RESULTS COMPARISONS

Orecca Project Meteo Tower

Orecca Project meteo mast

Tower: 15 [m] height

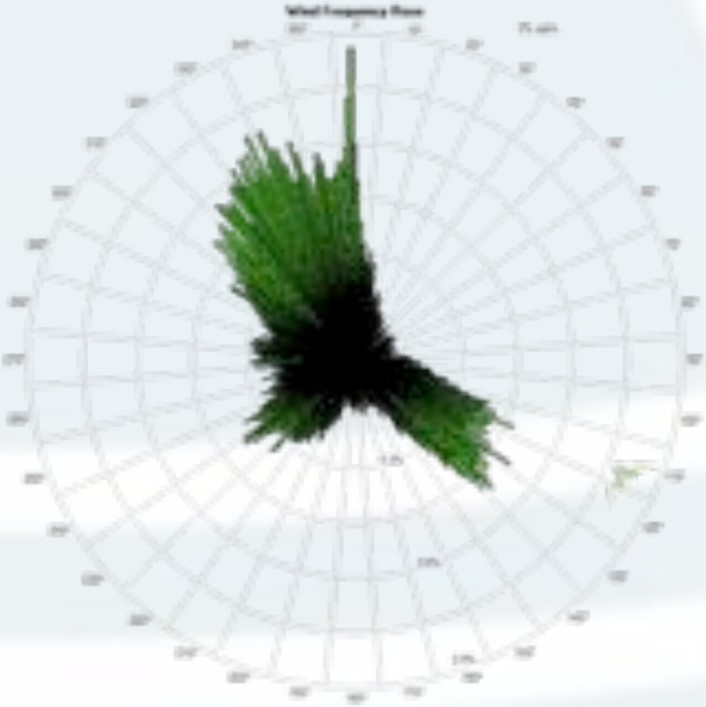
One Measurement Planes: 15 [m];

Speed Sensors: 1THIES;

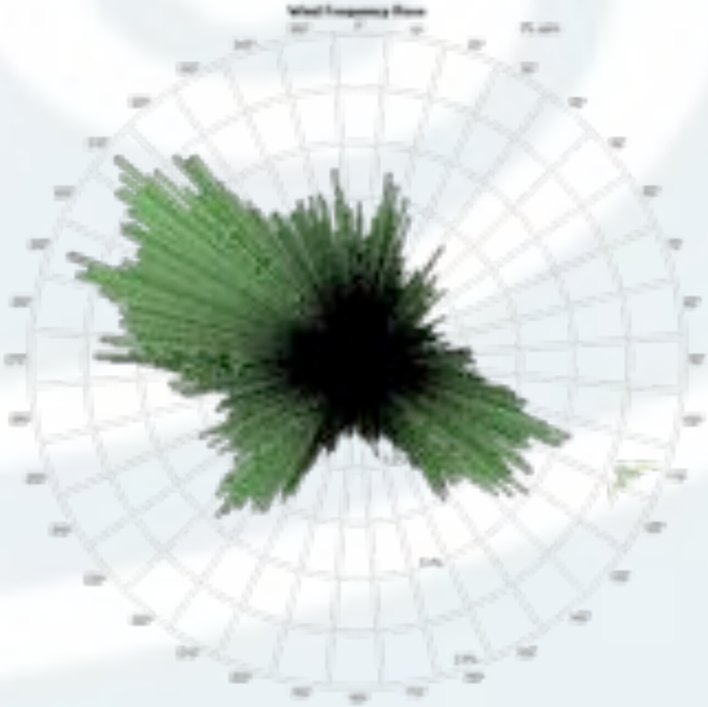
Direction Sensors: 1THIES

Off-Shore Wind Results Comparisons

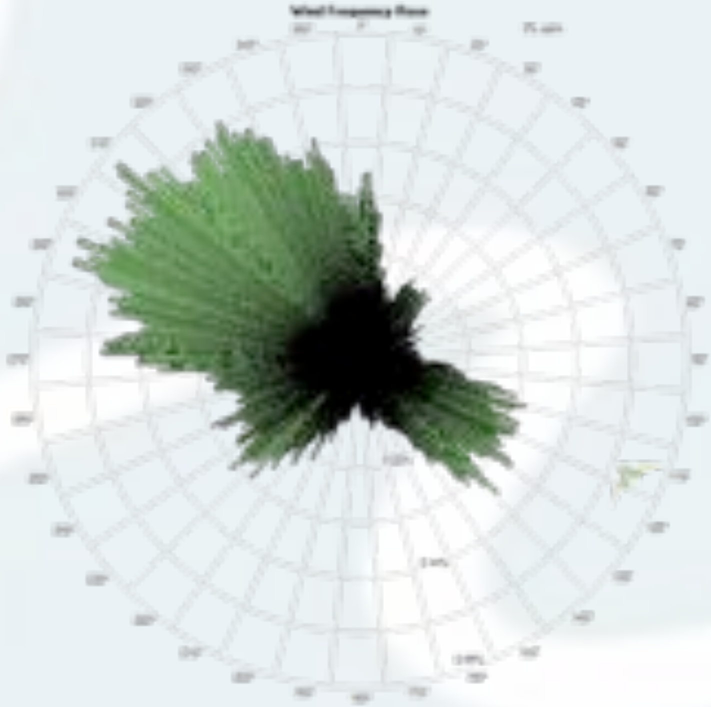
A comparison among experimental results and numerical results, obtained with different horizontal resolutions, show a discrete agreement with a clear identification of the 120° N and 240° N most relevant wind directions. A spread occurrences is instead observed for the fourth sector (270° N – 360° N).



Annual Directional Occurrences
Experimental Results
Wind Rose @ 15 [m]



Annual Directional Occurrences
P3 Numerical Results
Wind Rose @ 10 [m]

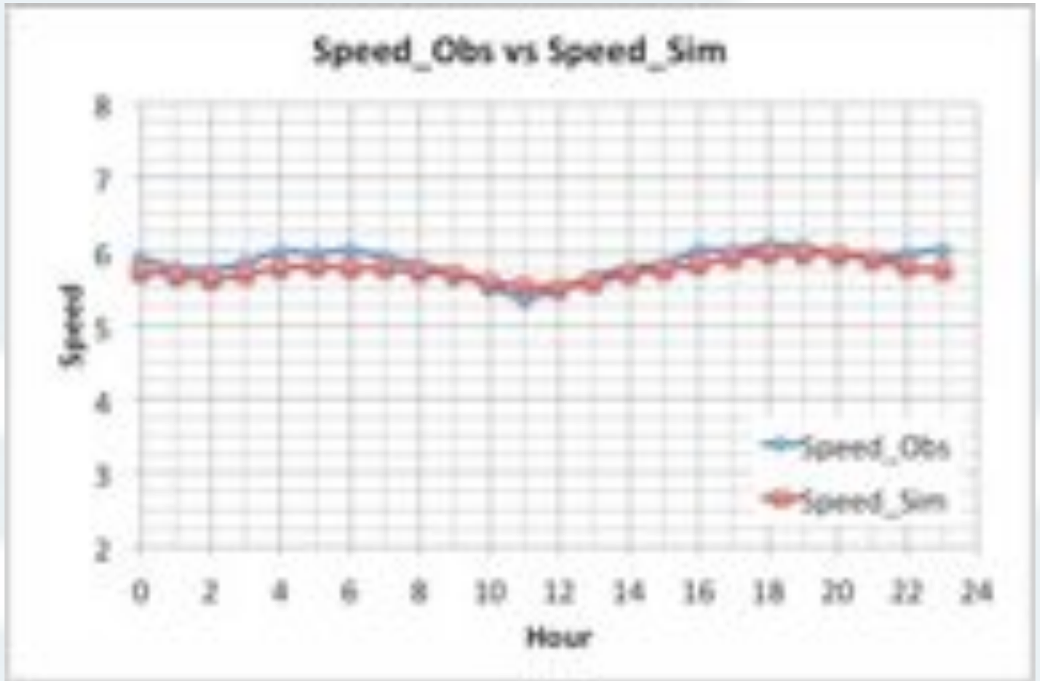


Annual Directional Occurrences
P1 Numerical Results
Wind Rose @ 10 [m]

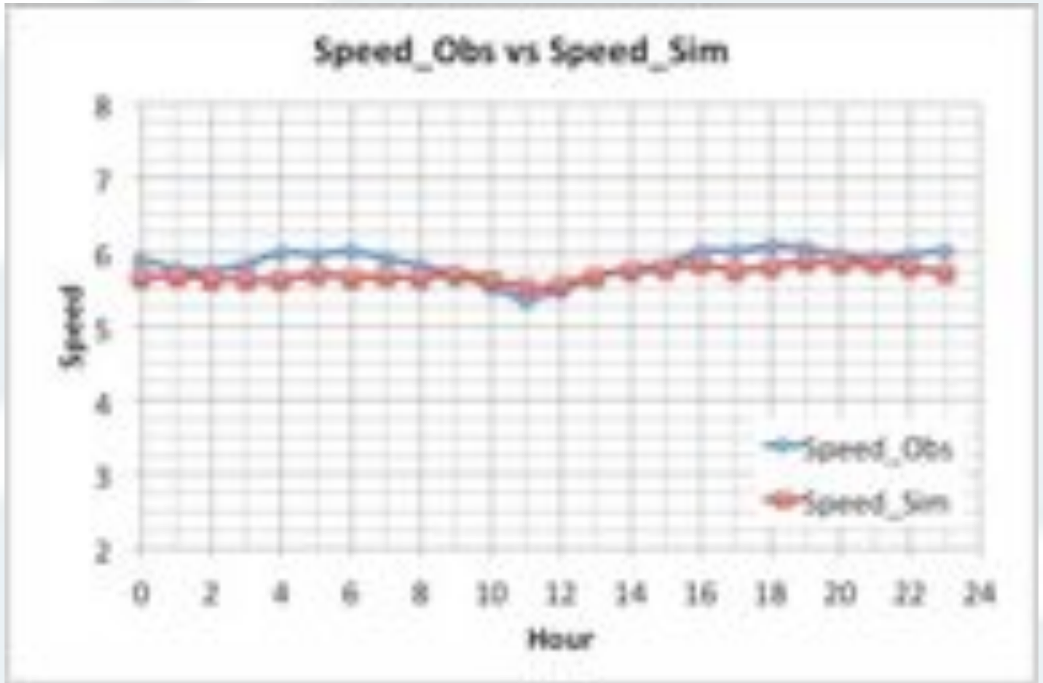
"Off-Shore" Wind Results Comparisons

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.85	5.75	-0.10	-1.70%	6.59

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.85	5.71	-0.14	-2.42%	2.14



Annual Mean Diurnal – Exp. Vs. P3
Wind Speed Profile @ 15 [m]

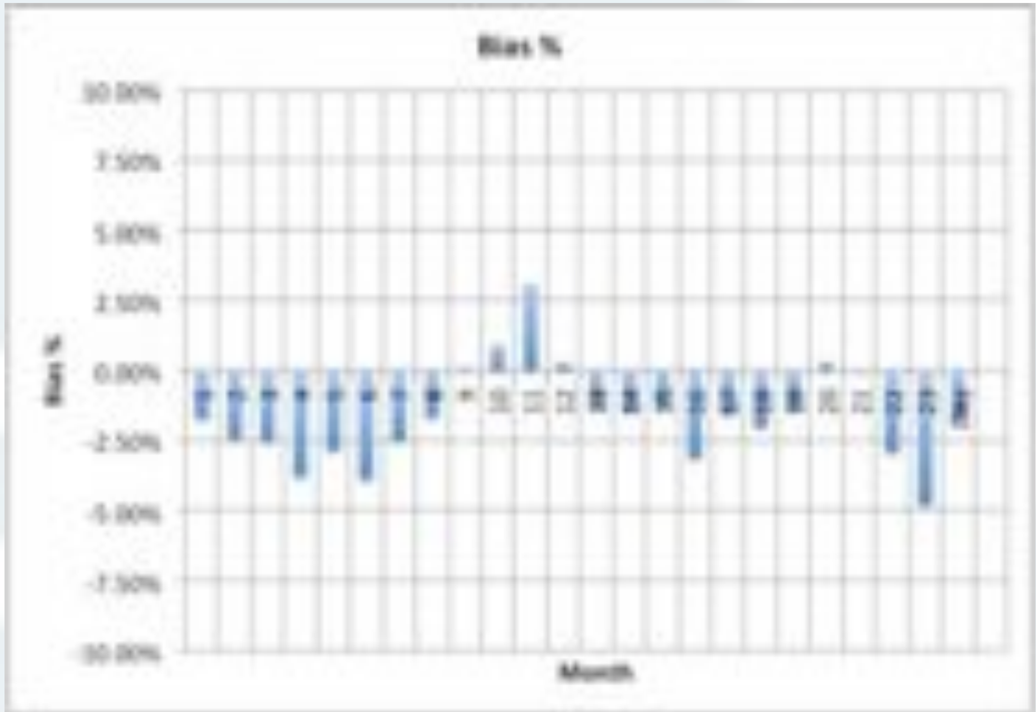


Annual Mean Diurnal – Exp. Vs. P1
Wind Speed Profile @ 15 [m]

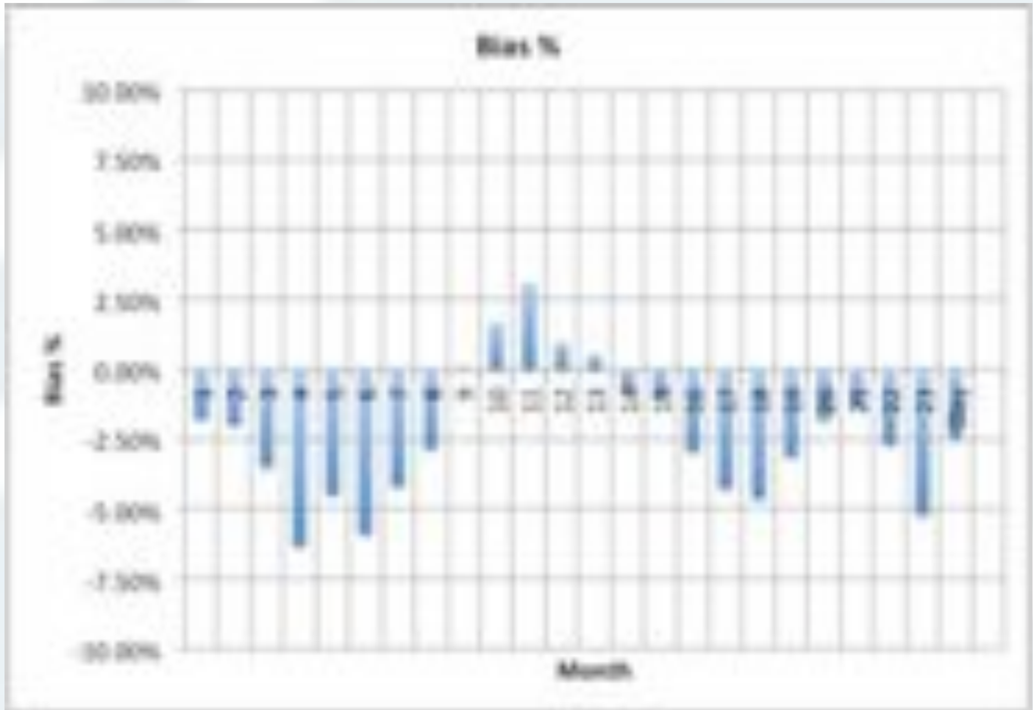
“OFF-SHORE” WIND RESULTS COMPARISONS

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.85	5.75	-0.10	-1.70%	6.59

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.85	5.71	-0.14	-2.42%	2.14



Bias % Annual Mean Diurnal- Exp. Vs. P3
Wind Speed Profile @ 15 [m]

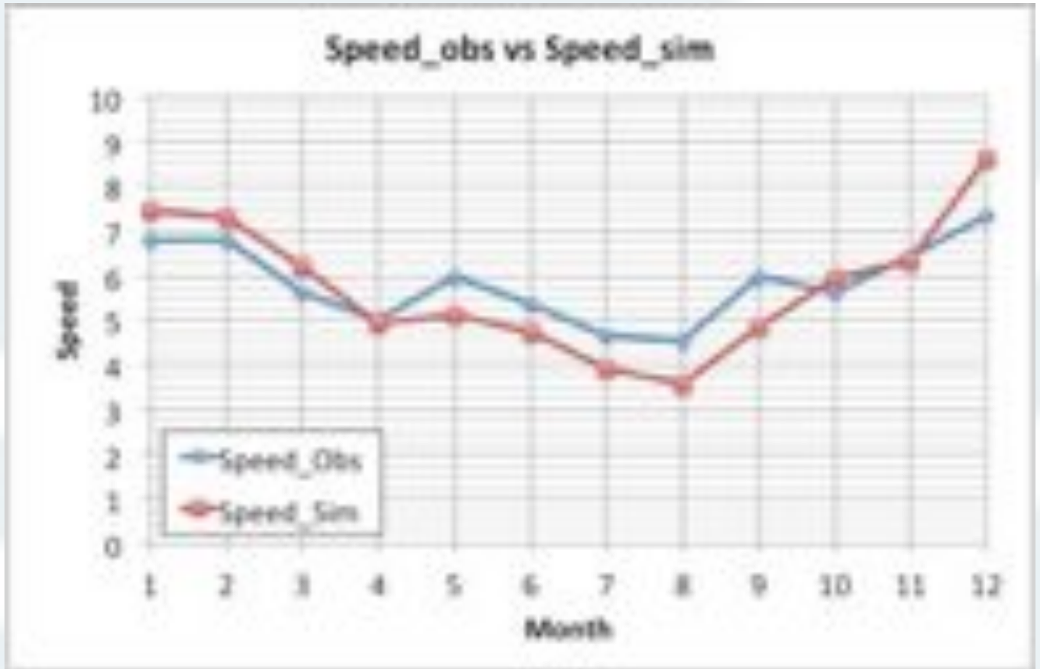


Bias % Annual Mean Diurnal- Exp. Vs. P1
Wind Speed Profile @ 15 [m]

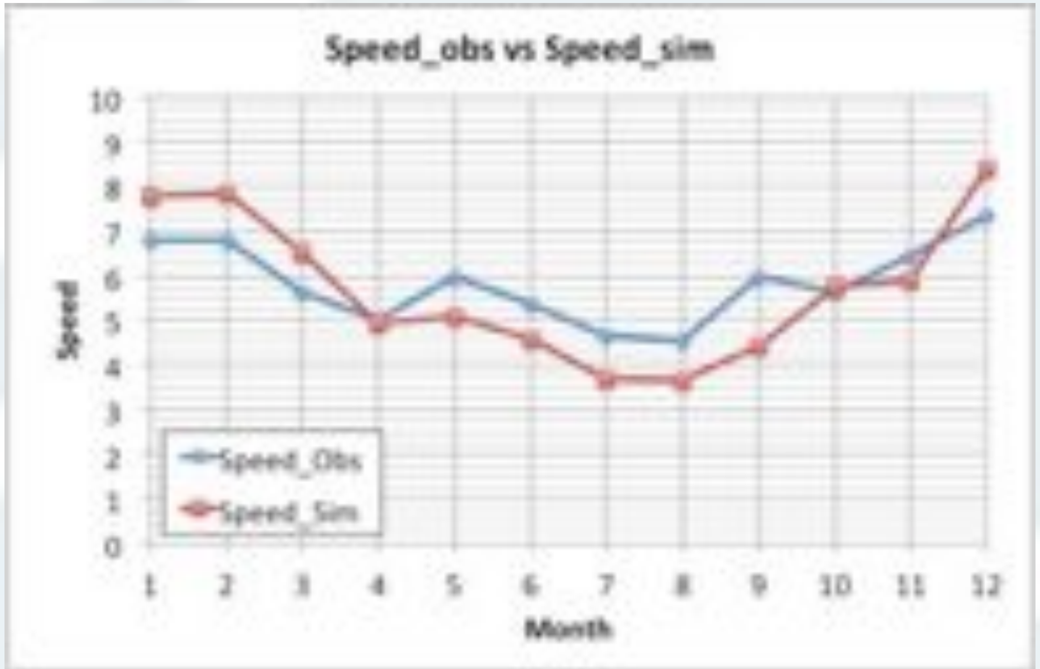
"OFF-SHORE" WIND RESULTS COMPARISONS

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.85	5.75	-0.10	-1.70%	6.59

<Vobs>	<Vsim>	Bias	Bias%	Bias°
5.85	5.71	-0.14	-2.42%	2.14



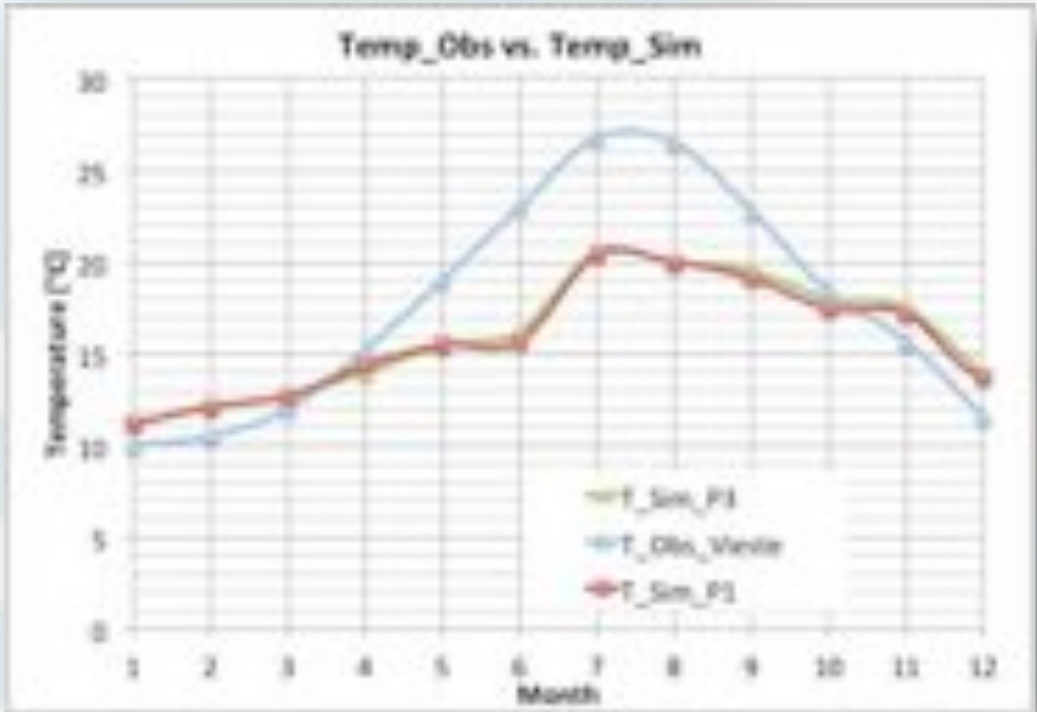
Monthly Mean – Exp. Vs. P3
Wind Speed Profile @ 15 [m]

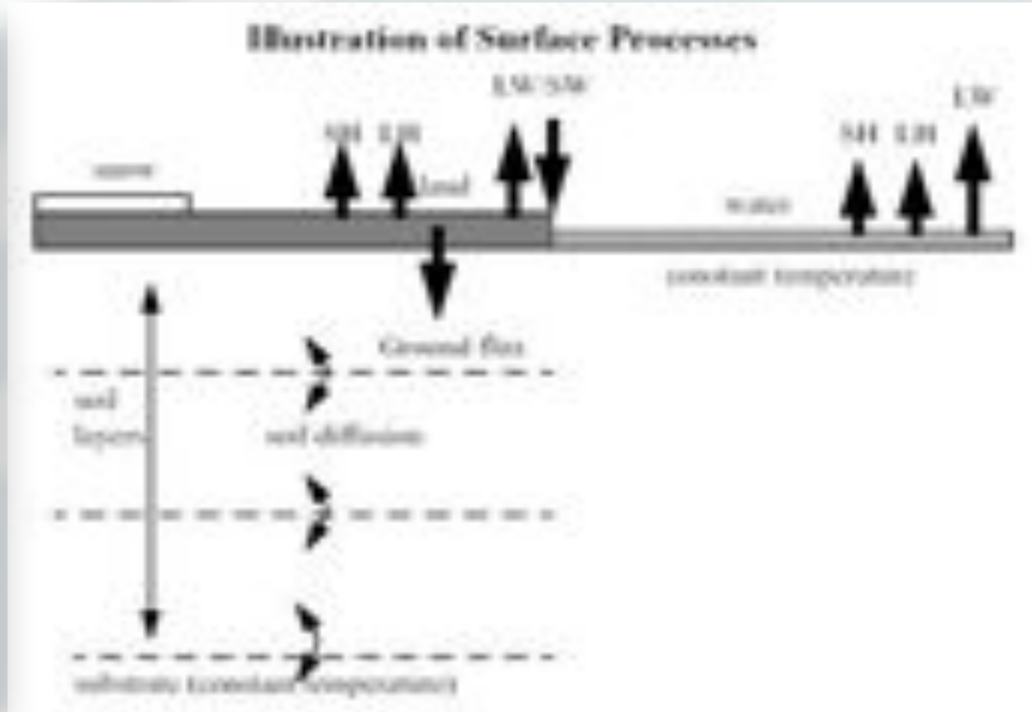


Monthly Mean – Exp. Vs. P1
Wind Speed Profile @ 15 [m]

“OFF-SHORE” WIND RESULTS COMPARISONS

Both the 3 [km] and the 1[km] simulations show the same temperature trend with no evident differences. This results should be observed by remembering that GTOPO30 resolutions are not able to “see” the Pianosa island; in effect it has an extension of 600 [m] x 150 [m] and the digital elevation models do not report its presence. So both simulations see a water surface with the energy exchange reported in figure.

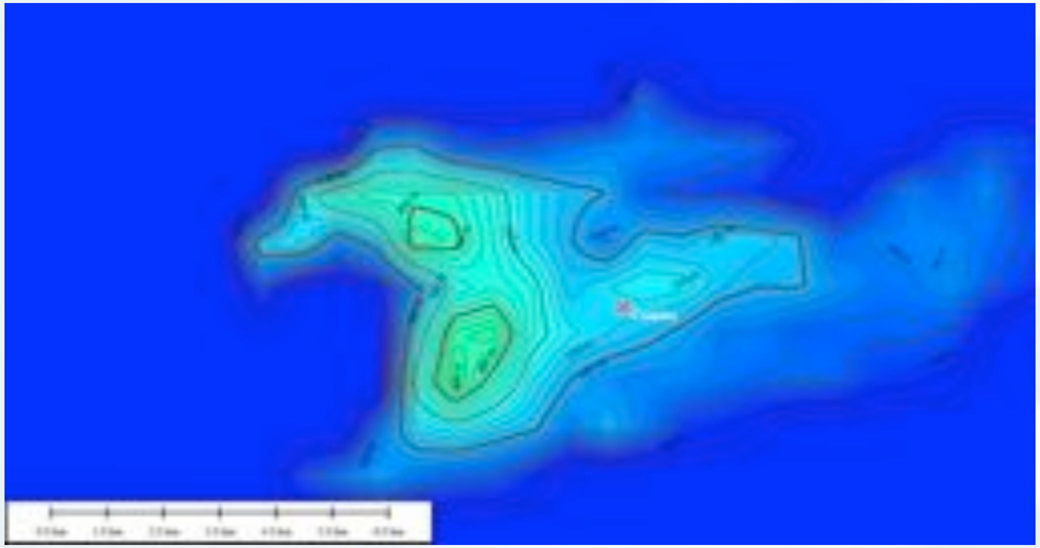


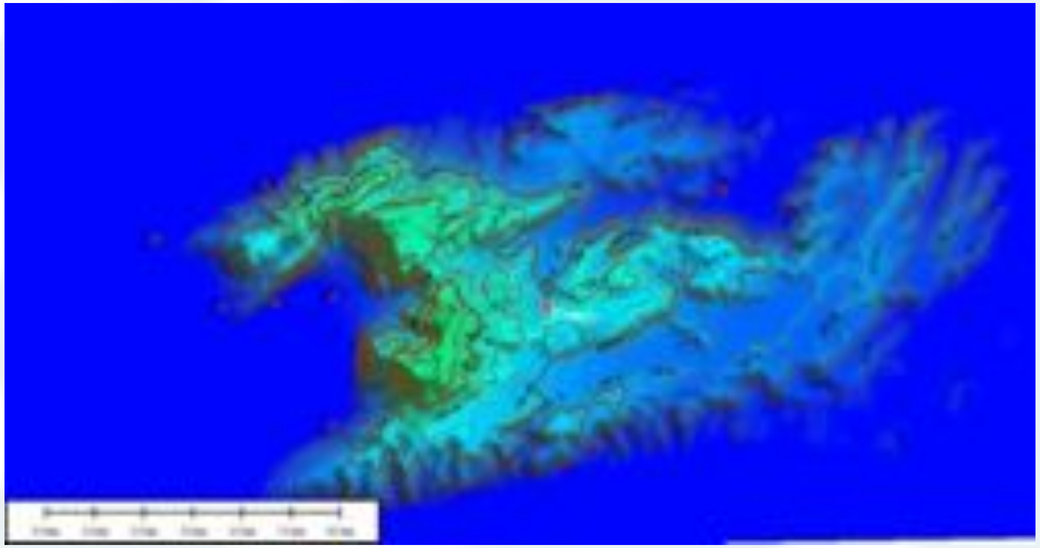


* Experimental temperatures are not available for the Pianosa delle Tremiti meteo tower and so the value of a ISPRA bouy near Vieste are used.

RESULTS IMPROVEMENT (IN PROGRESS)

Horizontal Terrain Grid Resolution:



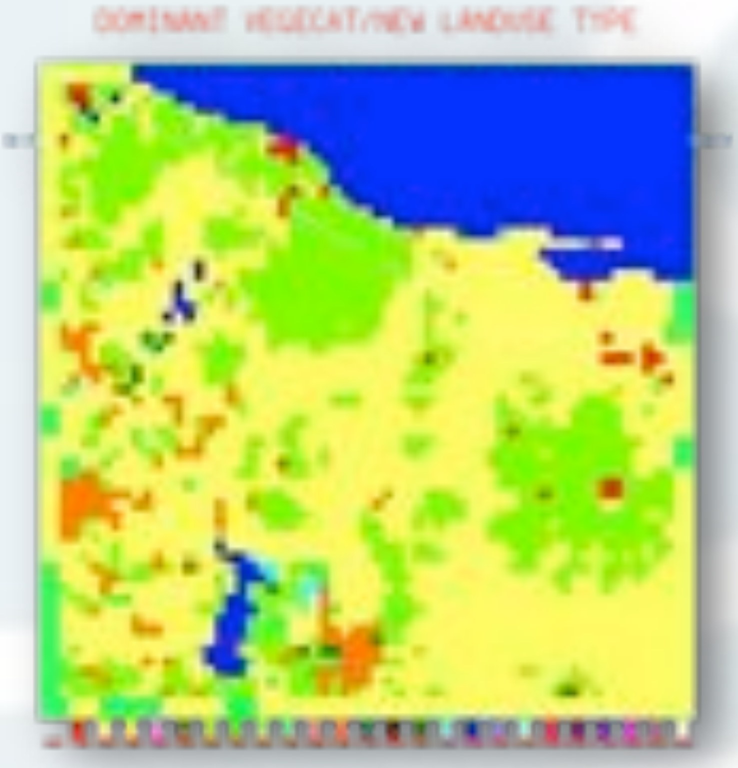


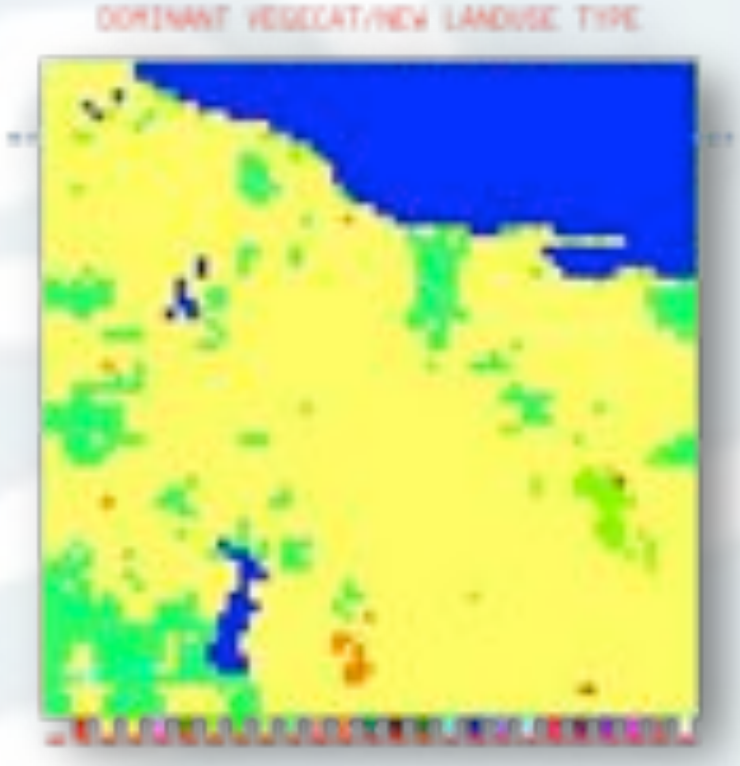
Improving the grid resolution up to about 200 m is possible to better describe the effects of very complex terrains. In this example is reported the island of Komiza, one of the project partner, that is correctly described only improving the terrain resolution.

In order to use this very high resolution in the MM5 mesoscale model, was rewritten its TERRAIN module so to be able to ingest SRTM 3'' (~ 90m) data. This new version was just tested in very complex terrain areas.

RESULTS IMPROVEMENT (IN PROGRESS)

Horizontal Land Use Grid Resolution:

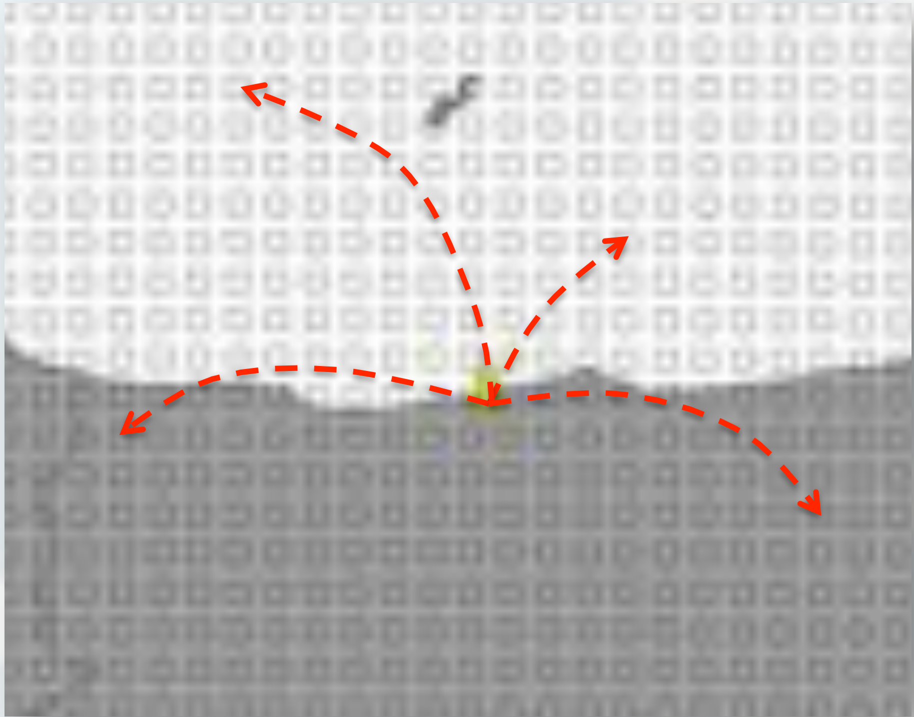


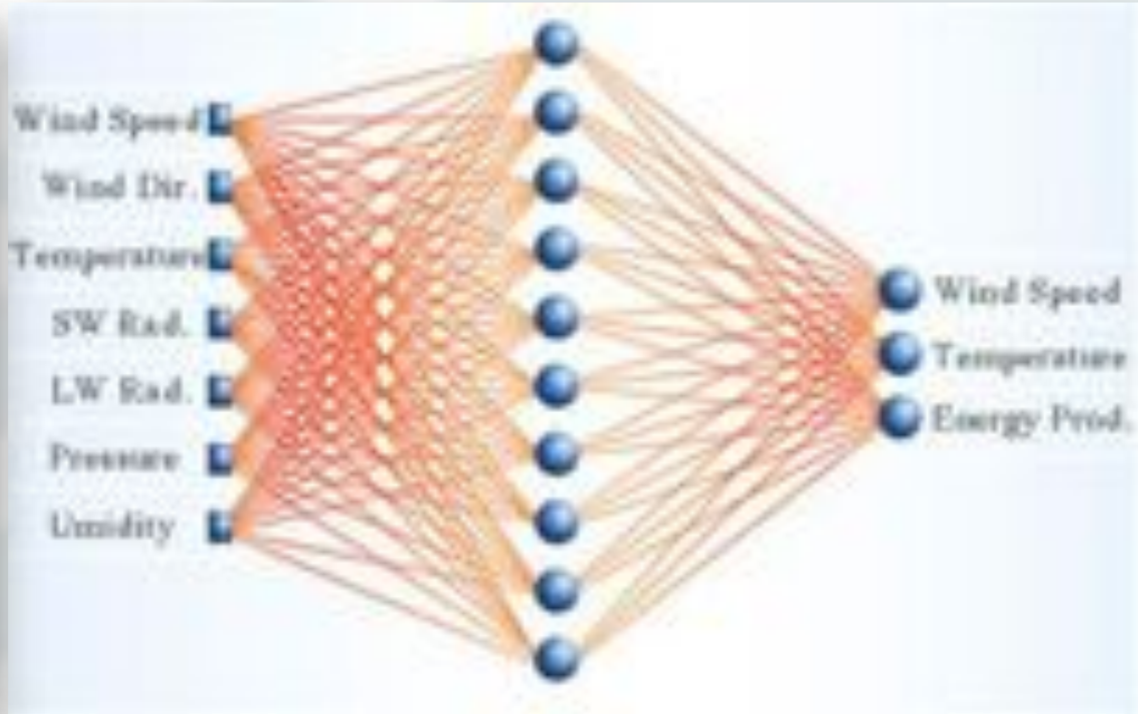


Improving the land use resolution by using the Corine database is possible to better describe the terrain roughness, that directly modify the wind speed profile, but also the soil categories that influence the energy exchange between terrain and lower part of the boundary layer. In order to use this new database in the MM5 mesoscale model, was rewritten another section of the TERRAIN module. This further new version is actually under test in a very complex terrain area.

RESULTS IMPROVEMENT (IN PROGRESS)

FDDA Analysis and Neural Networks:





Other approaches used to improve the wind simulation results are the FDDA analysis and the neural networks. The former, actually tuned on a meteo mast available at the University "Politecnica delle Marche", will be used to ingest meteo data that will be available by the POWERED experimental meteorological mast network. The latter is under development in order to correct systematic errors of the MM5 code results; i.e. with the discrepancies previously described in the diurnal profiles.