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Evaluation of the wind resource for a coastal site in Mexico by combining WindSim with WRF

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Abstract

This study presents the results obtained from a downscaling process for a one-year period using the mesoscale Weather Research and Forecasting (WRF-ARW) regional model and the steady-state Computational Fluid Dynamics (CFD) microscale model WindSim for a spatial resolution down to 200m for a complex coastal site in Northern Mexico. Two different procedures were carried out in order to obtain results on annual time scales which are relevant for wind resource assessment purposes. The first approach was developed by using the output of WRF-ARW runs for 96 typical weather patterns as boundary and initial conditions for the CFD simulations. As an alternative, virtual wind towers were constructed from the WRF output and used to scale the CFD flow fields for each of 12 angular sectors. Results are finally compared against three ASOS stations.

Objectives

This work aims at presenting two methods for the evaluation of the wind potential of a coastal zone at a micrositting level through the coupling of a steady-state CFD solver with a mesoscale model.

Introduction

Problem statement The surface wind parameters of sites with either highly complex topography or complex local land-atmosphere interactions are not accurately predicted by most Numerical Weather Prediction (NWP) models due to their limitations for capturing microscale phenomena.

Possible fixes (1) Non-stationary flow models (transient RANS or LES). (2) Meso-/micro-coupling based on steady-state models[1-3].

Rationale Micro-scale solvers can account for variations in orography and roughness, while incorporating the mesoscale flow patterns through meso-/micro-coupling [4-6].

Methods (1)

Mesoscale model

- WRF-ARW [7] initialized with NARR and High Resolution Sea Surface Temperature data
- 3km spatial resolution domain nested in a 9km resolution domain centered in Puerto Peñasco city in the Northwest Mexico (figure 1)
- 35 sigma levels with the first 4 within 150 meters a.g.l.
- Noah LSM and Kain-Fritsch were applied as land surface physics and cumulus parameterizations respectively
- PBL turbulence model: MYJ
- Consecutive 72-hour runs with the first 12 hours discarded

CFD model

- Commercial CFD solver/wind farm simulation environment (WindSim) [8]
- RANS approach with k-epsilon turbulence closure scheme.

Site

Coastal line on one side, as well as medium complex topography on the other. The site has a vegetation cover varying from desert-like through semi-arid.

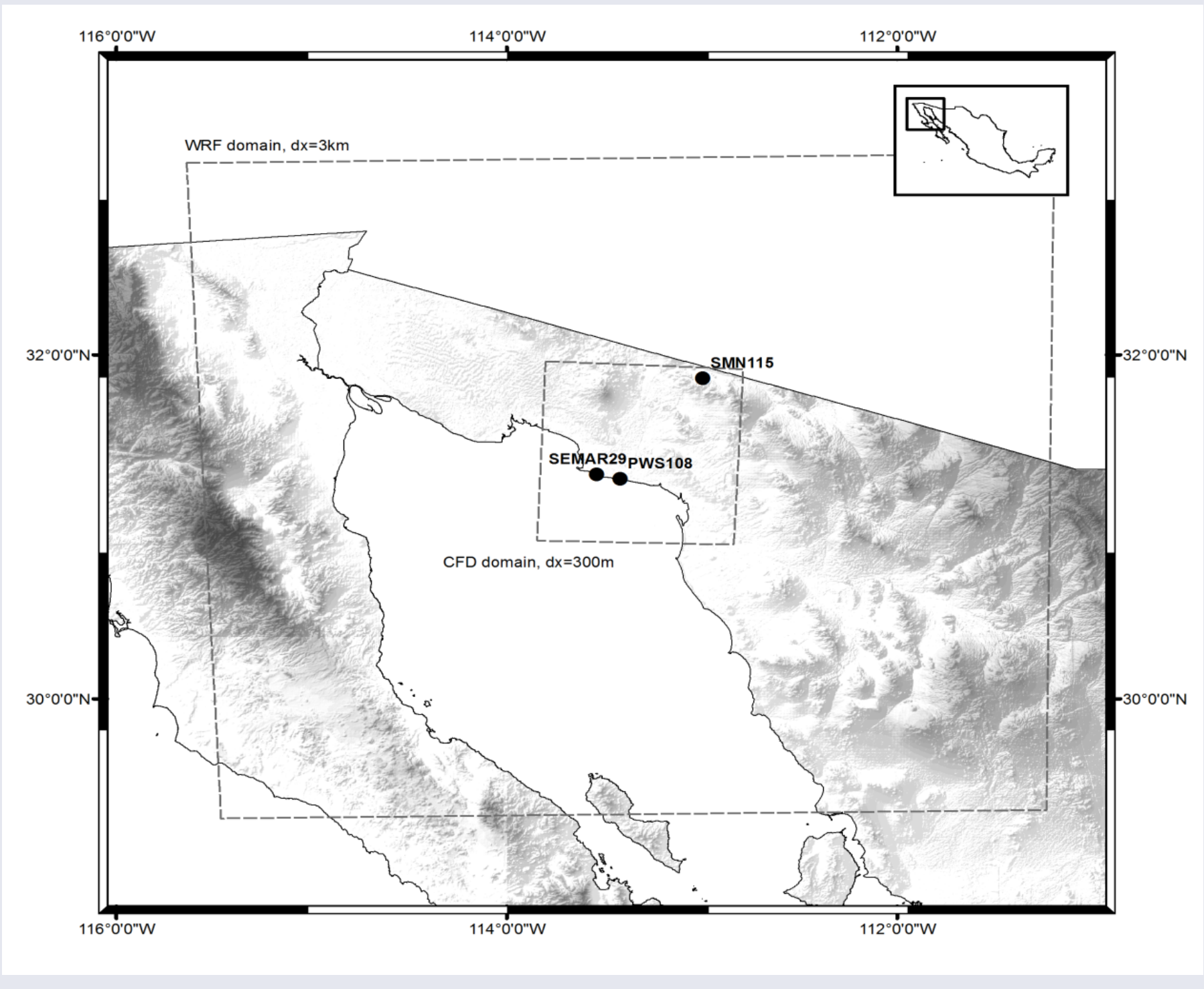

Figure 1 Location of ASOS, CFD and WRF domains

ID code	Station names	Elevation	Latitude	Longitude
SMN115	Sonoyta	393	31.865	-112.996
PWS108	Playa La Joya	1531	28.367	-108.917
SEMAR29	Puerto Penasco	3	31.306	-113.539

Table 2. Description of the three ASOS stations used for the comparisons

Methods (2)

First approach

- ➢ 96 typical weather patterns were classified based on the statistical treatment of the wind speed and potential temperature from a WRF outputs.
- ➢ These patterns were used as in- and outflow conditions at the lateral boundaries as well as initial conditions of wind and potential temperature for the CFD simulations

Second approach [9]

- ➢ Virtual wind towers were built from the WRF-ARW points within the CFD domain and used to scale the wind fields simulated with WindSim using the same CFD domain of the former approach for twelve angular sectors.
- ➢ Inverse distance weighting of the wind fields against all the introduced virtual towers for every directional sector.

Validation

Automatic Surface Observation Stations (ASOS)
a) Mexican Navy (SEMAR29)
b) Private sources (PWS108)
c) Mexican National Weather Service (SMN115),

Results

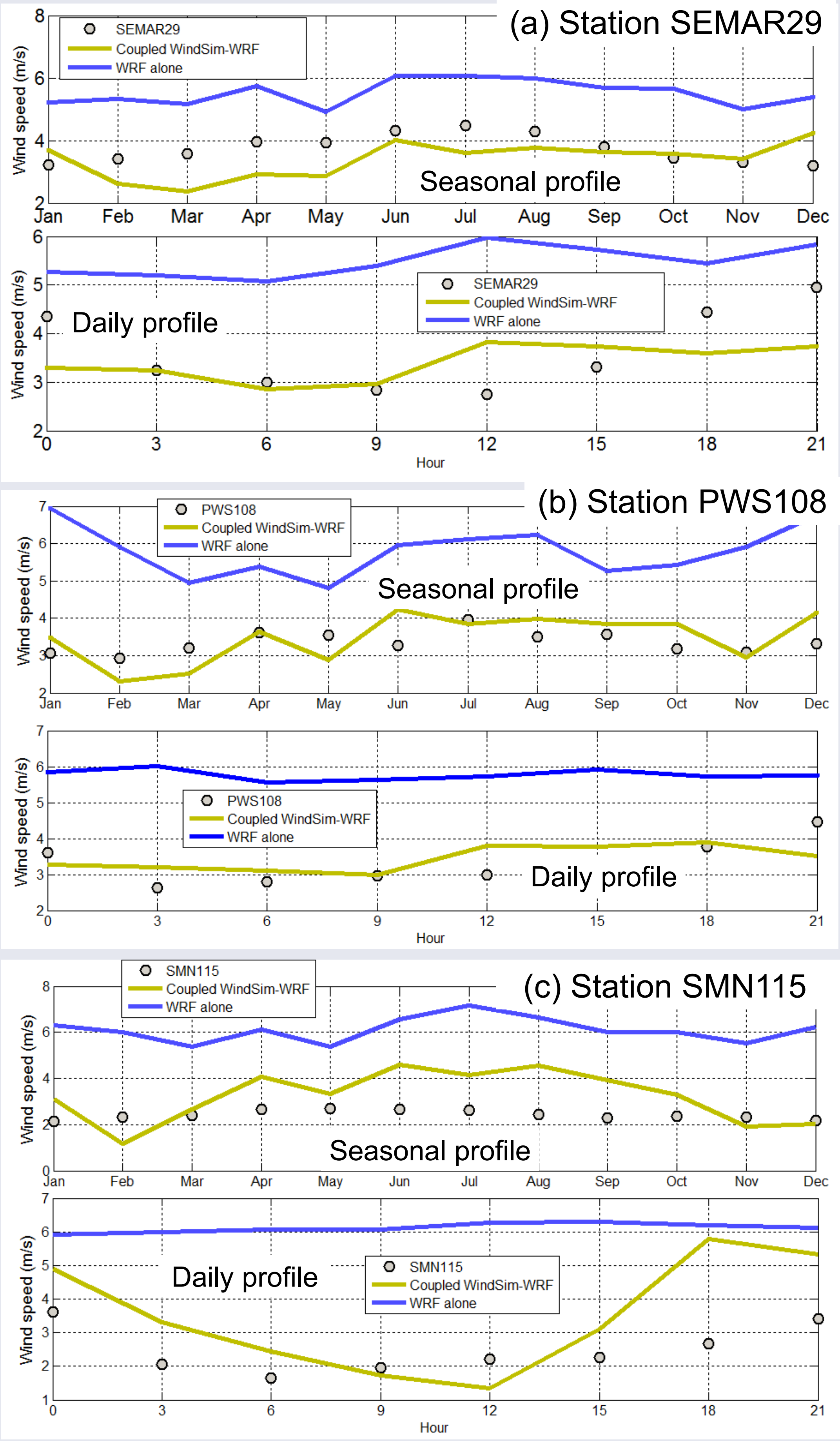

Figure 2 Seaonal and dialy profiles for WRF alone alone and WRF-WindSim and comparison with ASOS measurements

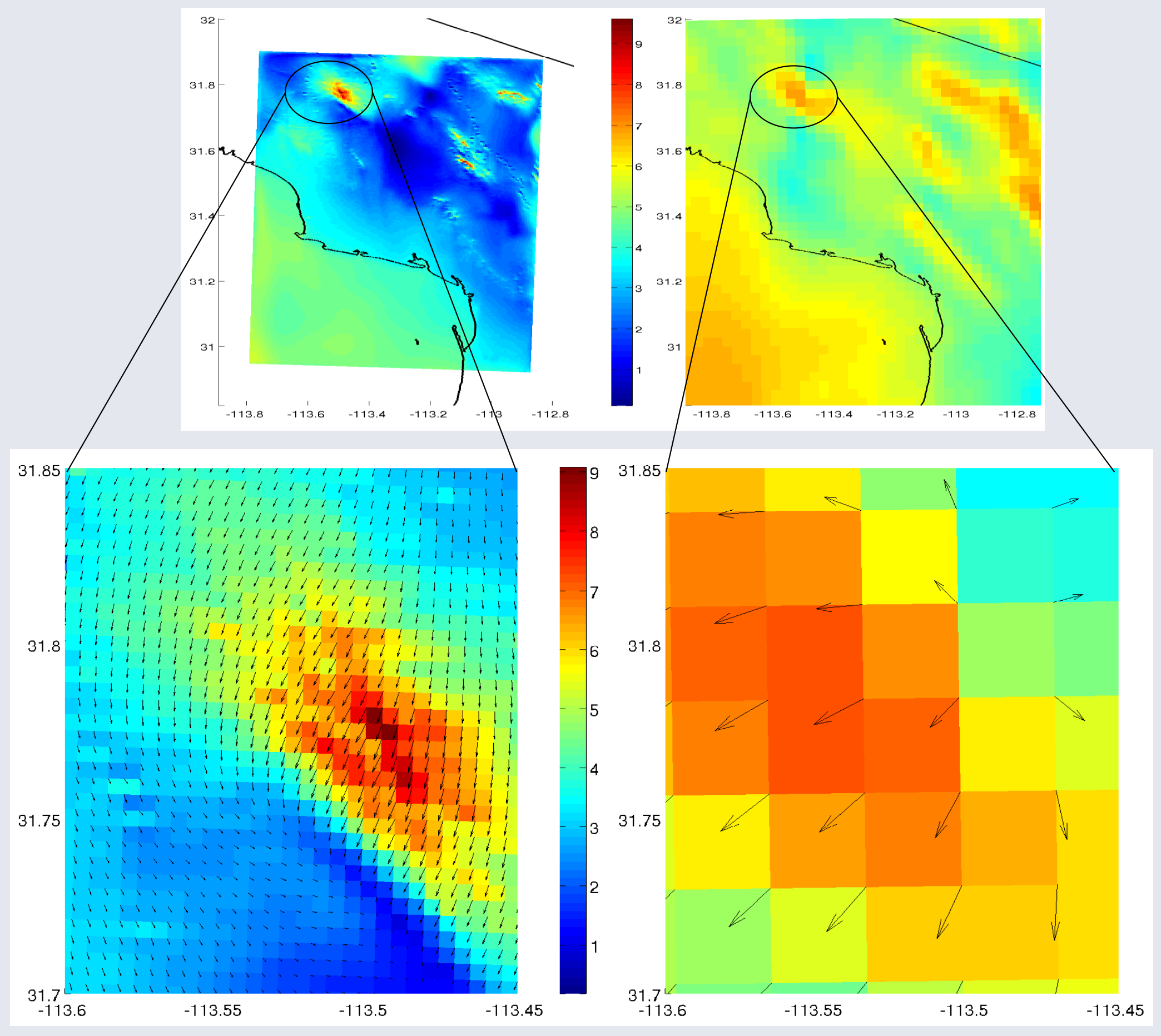

Figure 3 Example of one case out of 96 for the boundary coupling. Note the improvement of the coupling against the WRF alone for capturing the wind flow around one hill within domain.

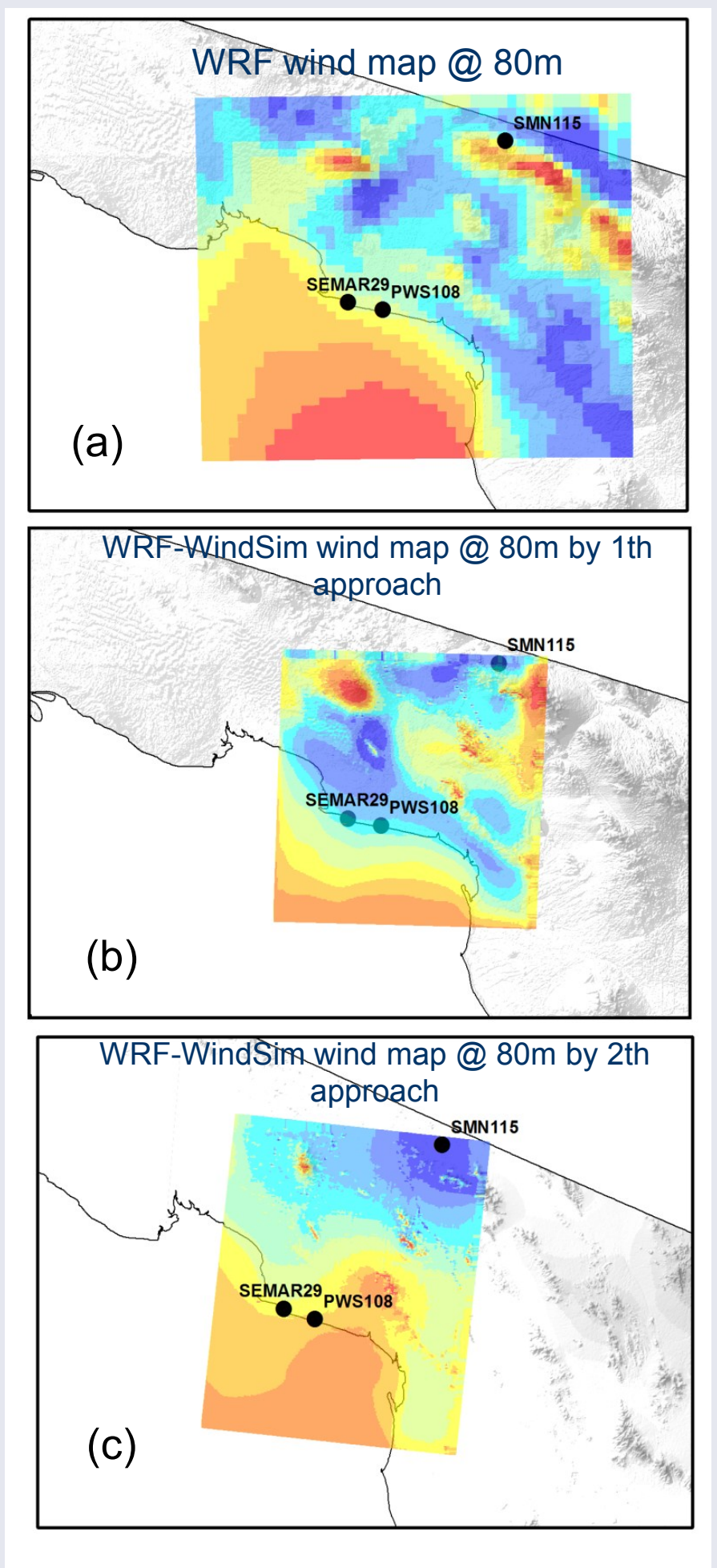

Figure 4 Wind speed maps at 80m from WRF alone (a) and the two coupling procedures (b) and (c).

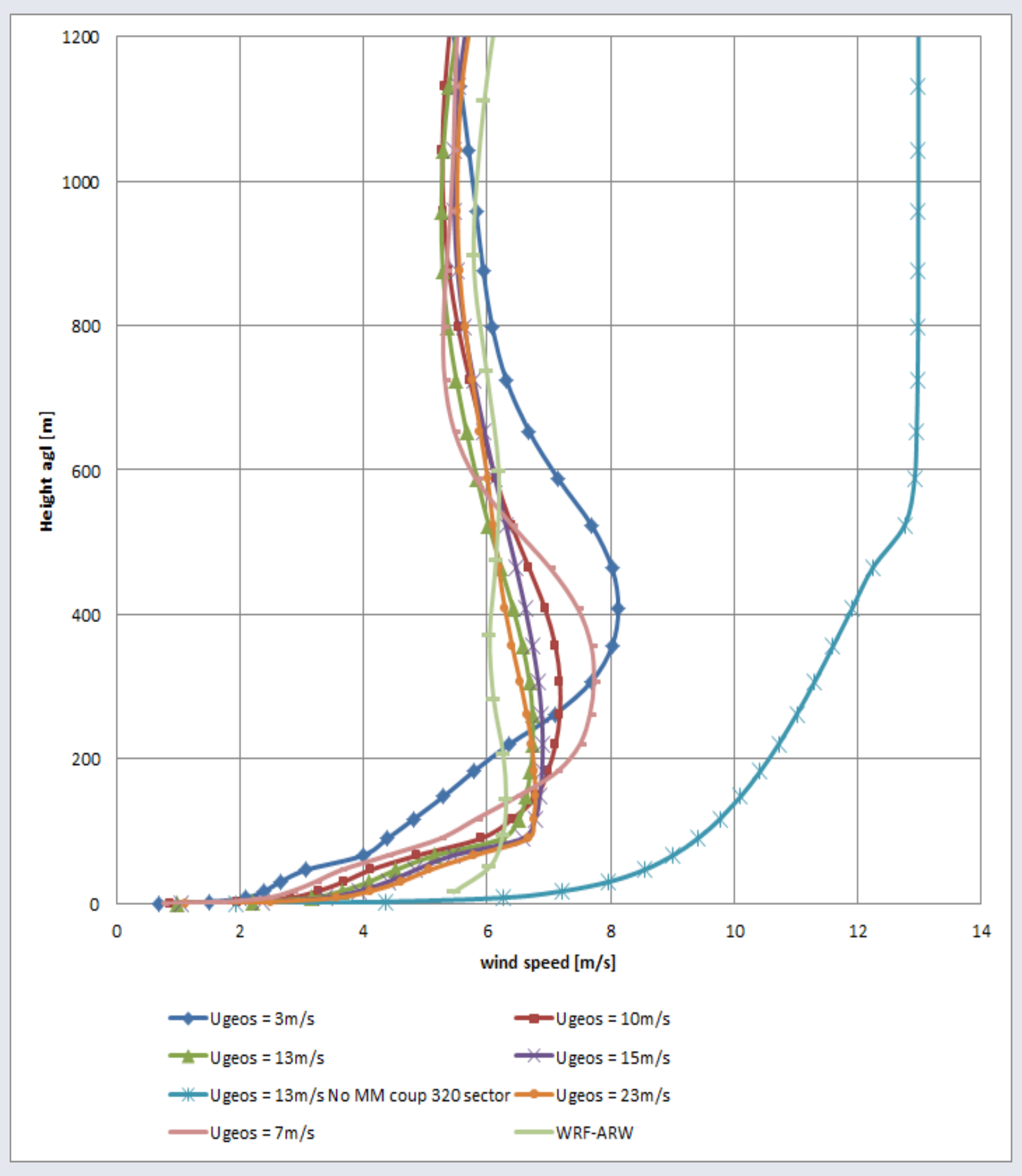

Figure 5. In order to indirectly estimate the boundary values of Turbulent Kinetic Energy and Energy Dissipation, WindSim needs approximate values of Boundary Layer Height (BLH) and Speed above BLH (Uinf). Although the neutral non-coupled simulations are unaffected by these numbers, the coupled cases, in which a variety of temperature and wind profiles are imposed to the boundaries, are strongly affected by the BLH and U inputs.

Conclusions

The coupling of a CFD model with the WRF-ARW has been shown to lead to a greatly improved prediction of surface wind. A computationally efficient scheme was devised, based on 96 characteristic weather conditions capable of modeling different atmospheric stability situations and estimating seasonal and daily variations. A simpler scheme, based on virtual wind tower distributions extracted from WRF simulations was studied for comparison.

While the results obtained with this coupling scheme can be considered successful, several unresolved issues remain:

- ✓ The vertical wind speed profile of the CFD simulation strongly depends on the values of the boundary layer height and the geostrophic wind speed.
- ✓ The fact that the geostrophic wind is fixed at the top boundary forces the wind speed profile to converge to that value at the top of the boundary layer. Although this is true for the simplified boundary layer theory, in larger areas there are important variations in the geostrophic conditions across the top boundary which are not incorporated into the CFD model.
- ✓ From the 96 cases, difficult convergence was observed for cases associated with atmospheric instability conditions.
- ✓ Finding the best method to handle the differences in the treatment of turbulence by the mesoscale compared to the CFD model (PBL schemes versus the K-Epsilon closure scheme) is still an active area of research.

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