DYNAMICAL DOWNSCALING OF WIND RESOURCES IN COMPLEX TERRAIN OF CROATIA

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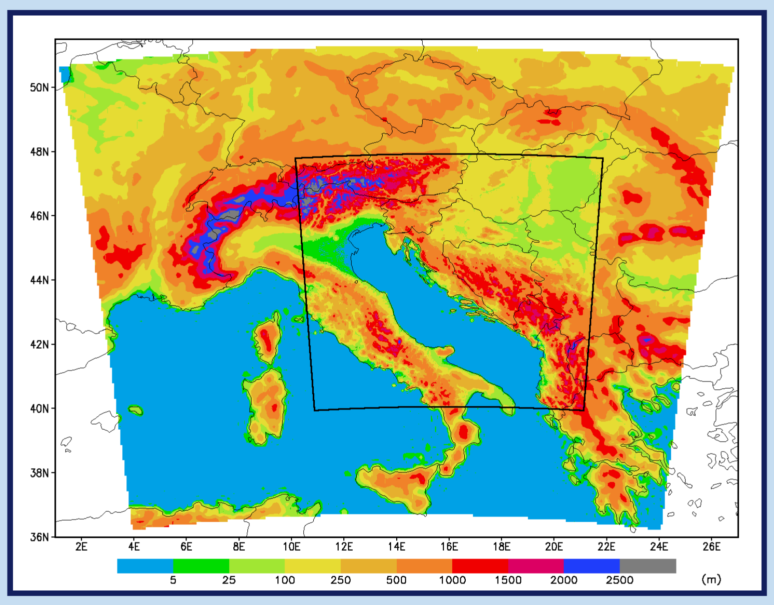
Abstract summary

For reliable **wind resource estimates**, the global model reanalysis data needs to be downscaled to provide information for **regional interpretation**. This is especially true in **complex terrain of Croatia**, where a significant portion of wind energy potential is related to phenomena arising from the **non-linear dynamical interaction** of the high, steep mountains and the troposphere, such as cross-mountain **Bora** and along-mountain "Jugo" wind (channeled Sirocco).

Global model reanalysis data (ERA-40) is **dynamically downscaled** to 8 km resolution, with the use of full-physics prognostic **mesoscale ALADIN/HR** model (Žagar et al., 2006) and dynamically adapted to 2 km grid resolution over Croatia. Verification showed that **dynamical downscaling was sucessful**, resulting in accurate wind resource estimates in the area.



BORA WINDSTORMS !

i) RAPID ONSET& HURRICANE FORCE GUSTS (70 ms^{-1})

ii) HIGH FREQUENCY

iii) GUSTS MORE THEN TWICE GREATER THAN WIND SPEED

iv) NONLIN. FLOW REGIME (Fr<1)

v) 2 GUST REGIMES

***Figure 1**: Outer and inner domains of ALADIN/HR model setup: - the model orography at 8 km and 2 km grid resolutions are shown respectively.*

Objectives

- Estimate **wind resources** of Croatia
- Evaluate the **accuracy of dynamical downscaling** for wind resource applications subject to orographically forced non-linear dynamical flows, such as **Bora**

Methods

Input data: subset of ERA-40 dataset (1992-2001)

Model characteristics:

i) Operational ALADIN/HR, hydrostatic, full-physics (Bubnova et al., 1995) at 8 km grid resolution and 37 hybrid vertical levels, single nesting

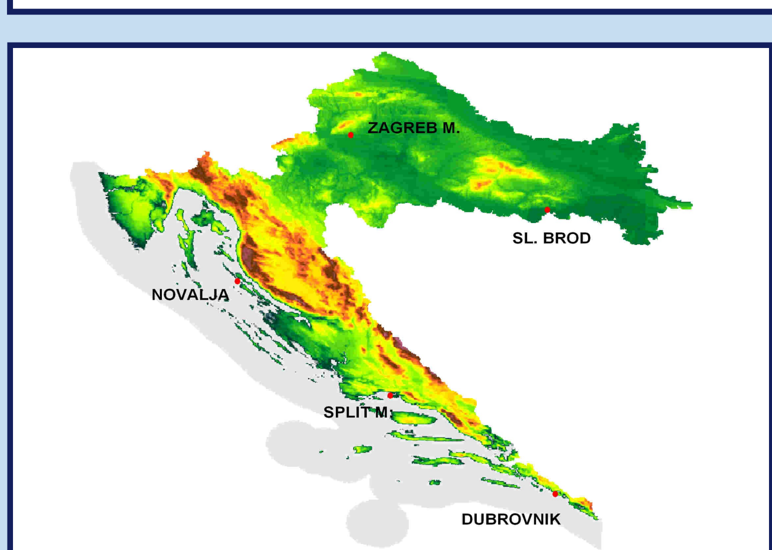
ii) Operational ALADIN/DADA dynamical adaptation module at 2 km

Output: 10-yearly period, 1-hr output frequncy, final grid resolution of 2 km, wind fields at 10 m and 80 m AGL

Verification:

i) A set of stations representing different climate regimes in Croatia

ii) Traditional scores, wind roses, histograms...



3 CLIMATE REGIMES !

- CONTINENTAL
- MARITIME
- MOUNTAINOUS

***Figure 2**: Measurement stations selected for verification representing different climate regimes of Croatia.*

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Results

Results of dynmical downscaling are shown at 10 m AGL and at 80 m (Fig. 3).

The highest wind resources are found in:

-Mountaneous regions (Dinaric Alps, especially Velebit and Plješevica) - Maritime areas (west of Dinaric Alps, especially regions prone to Bora, such as Vratnik pass)

The lowest wind resources are found in:

-Parts of continental Croatia, Istria peninsula, Lika and hinterland of Ploče area

Interannual variability of mean wind speed is up to **25%**.

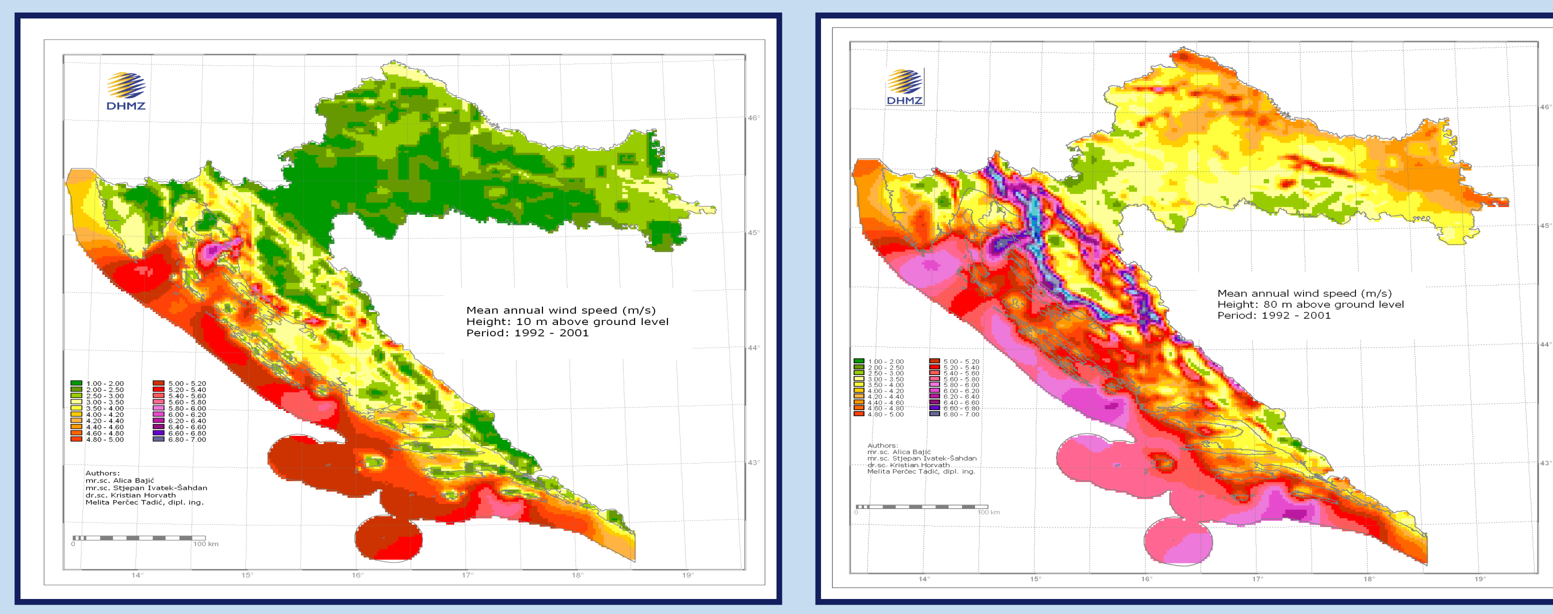

***Figure 3**: Spatial distribution of mean wind speed at 10 m (left) and 80 m (right) AGL, as a direct model output of dynamical downscaling.*

In order to estimate the quality of downscaling, **traditional verification scores** were calculated on 10 m data (Fig. 4):

Most accurate results are found in **flat terrain**, and the **poorest results** are present in highly **urban areas**. On average, direct model output errors are < 10% of mean wind speed value (excl. urban areas).

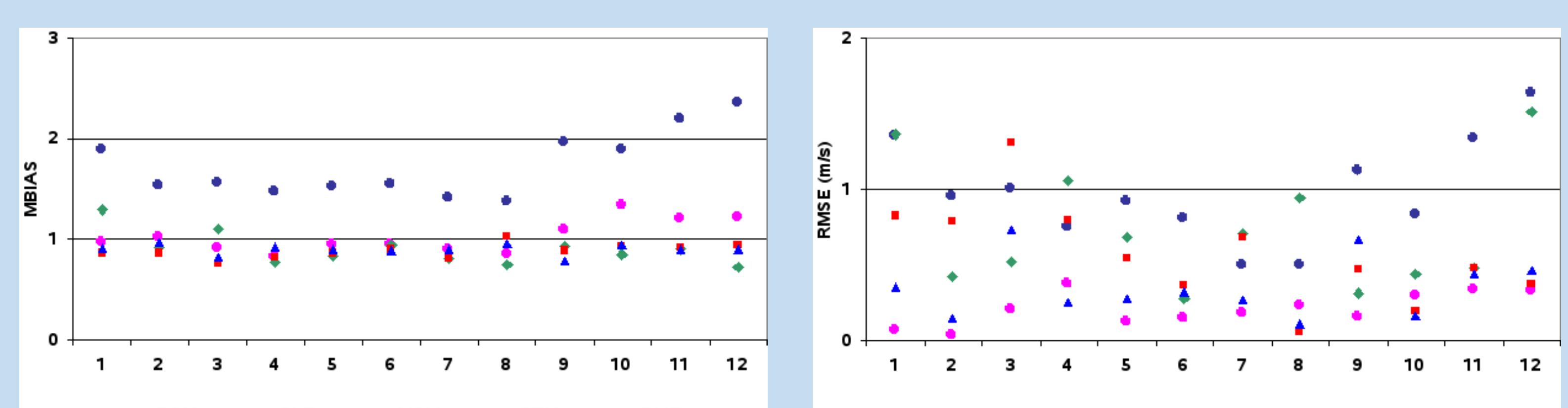

***Figure 4**: Multiplicative BIAS (left) and RMSE (right) for selected stations (cf. Fig. 2).*

Conclusions

Dynamical downscaling is sucessfully performed.

The **greatest accuracy** is obtained in **flat terrain**, followed by coastal & mountain areas, while the procedure is **least accurate** in **urban areas**.

In **mountain and coastal areas**, models on **higher resolution** could be applied for enhanced accuracy, provided they can account for the non-linear dynamics of stratified airflows over mountains and thermal properties of air masses involved.

Turbulent properties of Bora are to be included into next generation wind resource and annual energy production yield studies.

References

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Bubnova R., Hello G., Benard P. and J. F. Geleyn, 1995: Integration of fully elastic equations cast in the hydrostatic pressure terrain-following coordinate in the framework of ARPEGE/ALADIN NWP system. *Mon. Wea. Rev.*, **123**, 515-535.