Weather Intelligence for Wind Energy
WILL4WIND

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Using MNWP models of different horizontal resolution to estimate available wind power resources at specific locations

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Introduction and objectives

In the complex terrain of Croatia and relatively sparse measuring network, it is beneficial to test the capability of progressively finer MNWP models to reproduce relevant wind speed distributions and power estimations as well. Therefore, we will use two methods for wind power estimation in order to find whether the modeled time series can be used for assessment of wind energy potential at locations without measurements.

Understanding and modeling wind speed statistics (WSS) is crucial for assessment of wind energy potential. Modeling WSS generally includes seeking for appropriate probability density function (PDF). Majority of studies and software for estimation of available wind power uses two-parameter Weibull PDF:

$$f(v) = \frac{k}{A}\left(\frac{v}{A}\right)^{k-1} \exp\left[-\left(\frac{v}{A}\right)^{k}\right]$$

where v is the wind speed, A is the scale parameter and k is a dimensionless quantity called the shape parameter. Upon the estimation of Weibull PDF parameters, available wind power can be calculated according to the following relation:

$$P = \frac{1}{2}\rho A^3 \Gamma\left(1 + \frac{3}{k}\right)$$

Using statistical tests, we will try to determine whether is the two-parameter Weibull PDF appropriate to fit the wind speed frequency distributions in different climate regions of Croatia. We also want to compare wind power estimations based on two-parameter Weibull PDF with those obtained using the wind frequency histogram method (WFHM).

Methods

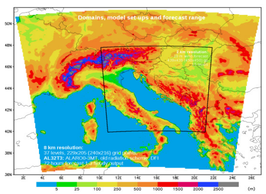

Fig1. ALADIN model 8 km and 2 km domains with basic informations about different datasets

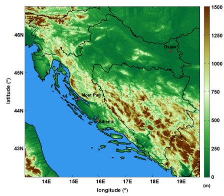

Fig2. Location of Most Pag, Šibenik and Osijek stations inside Croatian territory

Statistical verification of ALADIN 8 km (hydrostatic), dynamically adapted[1,2] DADA 2 km (hydrostatic) and ALADIN 2 km (nonhydrostatic) forecasts (Fig1.) was performed during period 2010-2012. Continuous statistical scores like RMSE, MBIAS and MAE were averaged over monthly periods (Fig4.) to show their seasonal variability at Most Pag, Šibenik and Osijek stations (Fig2.).

Two-parameter Weibull PDF was fitted to measured and modeled 10 m wind speed data by using the maximum likelihood method[3]. Goodness of fit was performed with Chi-square and Kolmogorov-Smirnov tests (Table2.).

Since the two-parameter Weibull PDF has proven to be inappropriate for description of measured and modeled wind speed distributions and for power assessment as well (Table2.), an alternative method for estimation of available wind power resources was used. The WFHM estimates wind power density (WPD) by using the median values and relative frequencies of N histogram classes:

$$WPD = \frac{1}{2} \cdot \rho \cdot \sum_{i=1}^{N} median\left(v_i^3\right) \cdot f_i$$

where v_i and f_i denote median value and the frequency of the data in i^{th} histogram class, while N stands for total number of histogram classes.

Results

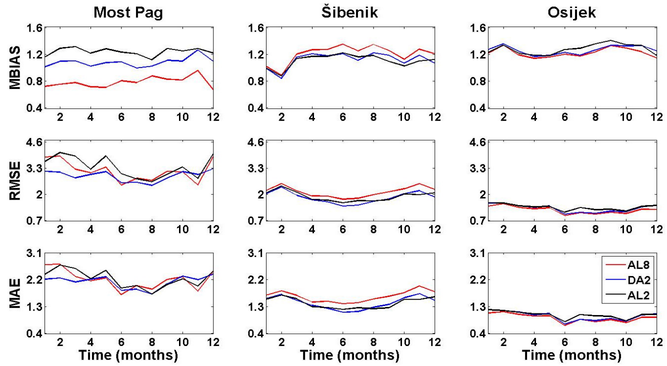

Fig4. Monthly averaged continuous statistical scores (MBIAS, RMSE and MAE) at Most Pag, Šibenik and Osijek stations in period 2010-2012.

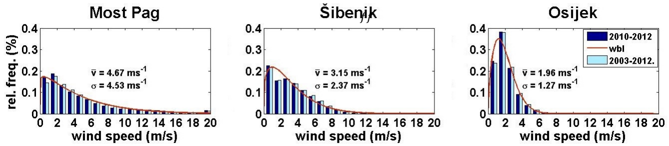

Fig5. Histograms of wind speed for periods 2003-2012. and 2010-2012. with Weibull fit and basic parameters for the latter one.

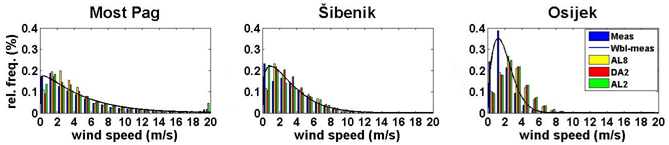

Fig6. Histograms of measured and modeled wind speed at Most Pag, Šibenik and Osijek stations in period 2010-2012. with Weibull fit for measurements.

Type of the terrain affects flow characteristics and station climatology as well. At stations in complex terrain, wind speeds are in average higher than over relatively flat one. (Fig3., Table2.).

Increased horizontal resolution of DADA 2 km and ALADIN 2 km forecasts has led to improvement over ALADIN 8 km at coastal stations (Fig4., Table1.).

MNWP models of progressively finer resolution are successful in describing the wind speed frequency distributions at stations in complex terrain (Fig6.) and for power estimations as well (Table2.).

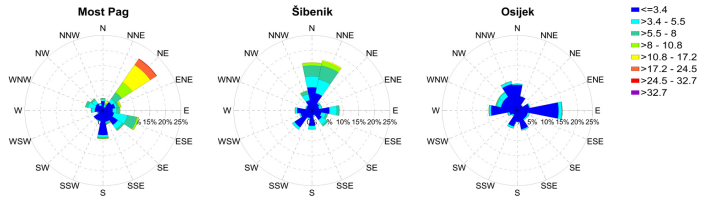

Fig3. Wind roses for Most Pag, Šibenik and Osijek stations during period 2010-2012. Wind speed is given in ms-1.

Table1. Yearly means of verification statistics for ALADIN 8 km (AL8), DADA 2 km (DA2) and ALADIN 2 km (AL2) model at Most Pag, Šibenik and Osijek stations in period 2010-2012.

	MBIAS			RMSE			MAE		
	Mpa	Šib	Osi	Mpa	Šib	Osi	Mpa	Šib	Osi
AL8	0.78	1.21	1.22	3.16	2.12	1.22	2.21	1.64	0.92
DA2	1.08	1.12	1.26	2.92	1.84	1.31	2.13	1.42	0.98
AL2	1.24	1.11	1.28	3.36	1.90	1.36	2.23	1.42	1.02

Table2. Weibull fit parameters (A,k) with goodness of fit statistics (Chi-square and Kolmogorov-Smirnov statistic with critical values at 95% significance level - cv) and power estimations for measured (Meas) and modeled wind speed data at Most Pag, Šibenik and Osijek stations during period 2010-2012.

	Most Pag				Šibenik				Osijek			
	Meas	AL8	DA2	AL2	Meas	AL8	DA2	AL2	Meas	AL8	DA2	AL2
k	1.07	1.48	1.23	1.04	1.25	1.50	1.66	1.28	1.65	1.88	1.88	1.89
A (ms^{-1})	4.81	3.96	5.34	5.55	3.37	3.82	3.61	3.39	2.20	3.33	3.49	3.53
$\bar{v}$ (ms^{-1})	4.67	3.57	4.97	5.46	3.15	3.44	3.22	3.14	1.96	2.96	3.10	3.14
P(Wm^{-2})	314.8	76.4	284.1	533.4	68.5	76.9	47.6	65.7	10.9	30.9	35.6	37.4
P_{Meas}/P	1.00	4.12	1.11	0.59	1.00	0.89	1.44	1.04	1.00	0.35	0.31	0.29
Chi2	216.2	167.9	433.1	430.3	337.5	234.9	27.6	296.2	320.4	98.3	103.9	84.1
Chi2-cv	8.672	5.892	8.672	8.672	6.571	5.226	3.940	6.571	1.145	2.167	2.733	2.733
KS	0.038	0.023	0.043	0.042	0.052	0.039	0.015	0.037	0.054	0.024	0.028	0.026
KS-cv	0.015	0.014	0.014	0.014	0.015	0.014	0.014	0.014	0.015	0.014	0.014	0.014

Table3. Comparison of power calculations obtained by Weibull fit and WFHM method at Most Pag, Šibenik and Osijek stations during period 2010-2012.

	Most Pag				Šibenik				Osijek			
	P_{Meas}	P_{AL8}	P_{DA2}	P_{AL2}	P_{Meas}	P_{A8}	P_{D2}	P_{A2}	P_{Meas}	P_{A8}	P_{D2}	P_{A2}
Weibull	314.8	76.4	284.1	533.4	68.5	76.9	47.6	65.7	10.9	31.6	36.3	37.4
WFHM	301.7	81.5	298.4	448.9	56.2	65.3	47.6	59.6	11.2	30.9	35.6	36.4

P_{Meas}, P_{A8}, P_{D2}, P_{A2} – estimated power from measurements, ALADIN 8 km, DADA 2 km and ALADIN 2 km model (in Wm^{-2})

Two-parameter Weibull PDF fails to describe wind speed frequency distributions at all stations, both for measured and modeled wind speed series (Fig5., Table2). However, Weibull PDF based estimations of wind power do not significantly differ from those obtained with WFHM method (Table3.)

References

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Conclusions

MNWP models have proven to be successful in forecasting the wind speed frequency distributions and for power estimation as well.

Statistical verification of MNWP models has shown that increasement of horizontal resolution (or model complexity) improves overall quality of wind speed forecast in complex types of terrain.

Two-parameter Weibull PDF has proven to be inappropriate in describing the wind speed frequency distributions at stations in different climate regions of Croatia, although power estimations are in good agreement with those obtained by WFHM method.