# Wind Speed Predictions with an Analog-based Method in Complex Terrain

Weather Intelligence for Wind Energy
WILL4WIND

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ALADIN
DHMZ

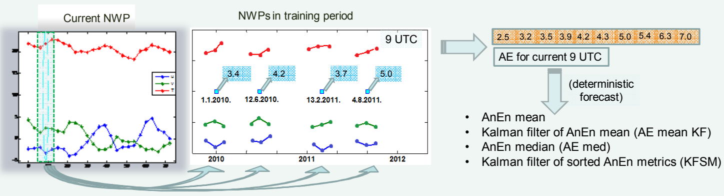
## Introduction

The first step to build an analog ensemble (AnEn) method is the search for similar past predictions (i.e. analogs) across several variables (e.g., wind speed, wind direction, temperature) to the current prediction[1]. It is computed as follows:

$$\|NWP_t A_{t'}\| = \sum_{i=1}^{N_A} \frac{w_i}{\sigma_{f_i}} \sqrt{\sum_{j=-\tilde{t}}^{\tilde{t}} (F_{i,t+j} - A_{i,t'+j})^2}$$

$F$ – NWP
$A$ – analog
$N_A, i$ – predictors
$t$ – time (now)
$t'$ – time (in the past)
$\tilde{t}, j$ – time frame

The measurements corresponding to the analogs form the AnEn. AnEn can be used to generate deterministic (e.g., the AnEn mean or median) and probabilistic short- or medium-range forecasts.




## Methods

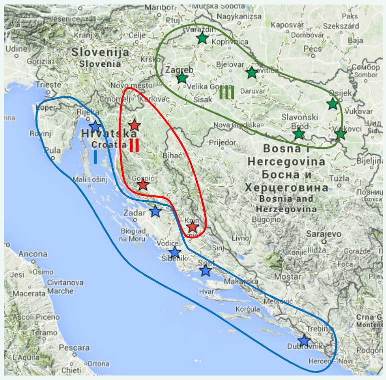



Fig1. Locations and their grouping.

- Training period: year 2010 & 2011.
- Verification period: year 2012.
- Starting models:
  - i. ALADIN 8 km (A8): 37 levels; 240 x 216 grid points; 72-hourly forecast, 3 hours output; hydrostatic
  - ii. ALADIN 2 km (A2): 37 levels; 450 x 450 grid points; 24-hourly forecast; 1 hours output; non-hydrostatic
  - iii. DADA 2 km (DA): 15 levels; 450 x 450 grid points; 72-hourly forecast; 3 hours output; hydrostatic
- 14 stations divided into 3 groups (Fig1):
  - I. Coastal area with largest wind speeds (bora)
  - II. Mountain area
  - III. Continental part with smallest wind speeds

## Objectives

- To evaluate performance of AnEn methods, compared to starting NWP model.
- To test adjustment to terrain complexity and sensitivity to horizontal resolution of starting NWP model.

## Results

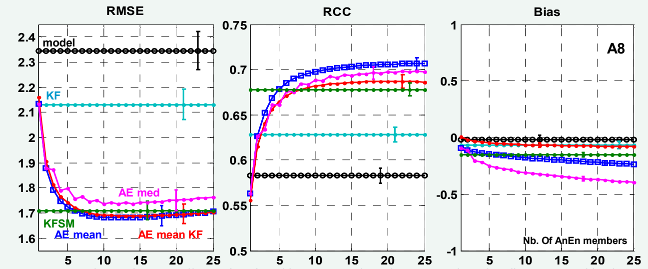



Fig2. RMSE, rank correlation coefficient (RCC) and bias vs. number of AnEn members for all stations and lead times for 6 different deterministic forecasts during 2012 year. A8 model is used and mean values of bootci confidence intervals are shown.

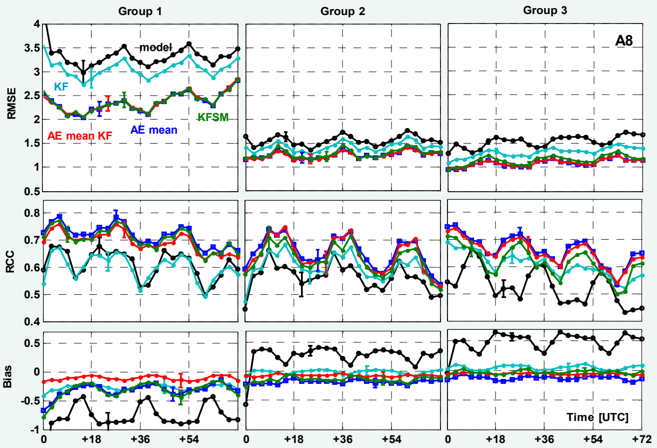



Fig3. RMSE, RCC and bias values calculated for 6 different deterministic forecasts vs. lead time for 3 different groups of stations during 2012 year if A8 model is used.

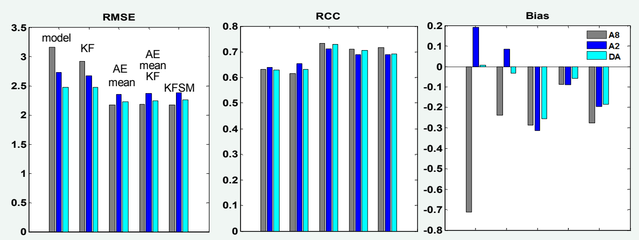



Fig4. Mean value of RMSE, RCC and bias calculated for 5 different deterministic forecasts during 2012 year for group I using A8, A2 and DA model data.

- AnEn deterministic forecasting produces the best results with 10-15 AnEn members (RMSE reduction up to 30%) (Fig2).
- Even though average bias for starting model is very small, its reduction can be seen if dependency on lead time is considered (Fig3).
- Different AnEn methods have similar dependency on lead time as KF, while reducing RMSE and improving correlation even more, especially in complex terrain with higher wind speeds (group 1).
- Results for AnEn forecasting started with different models differ much less than ones for the starting models themselves (Fig4). They show that AnEn methods often work best with A8 starting model.
- Frequency bias[2] (Fbias) shows that moderate wind speeds (category 2) are forecasted too often, while strong winds to rarely (Fig5).
- Strong wind seems to be the hardest category to predict. Critical success index (CSI) suggests that there is a slight improvement in AnEn forecasting high wind speed category (3) with better starting model (Fig6).

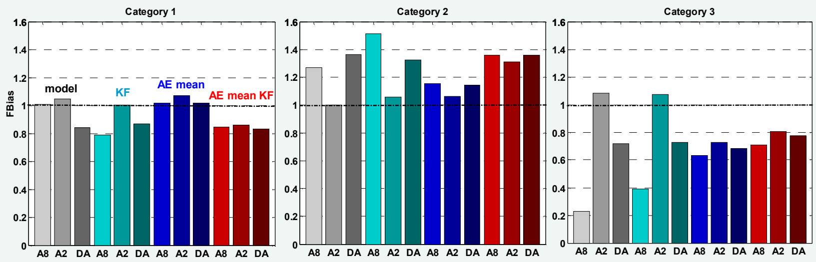



Fig5. Frequency bias calculated for 4 different forecasts for group 1 during 2012 year using A8, A2 and DA model data. Thresholds between categories are 50th and 90th percentiles , so category 1 represents breeze (or no wind at all), category 2 moderate wind and category 3 strong wind.

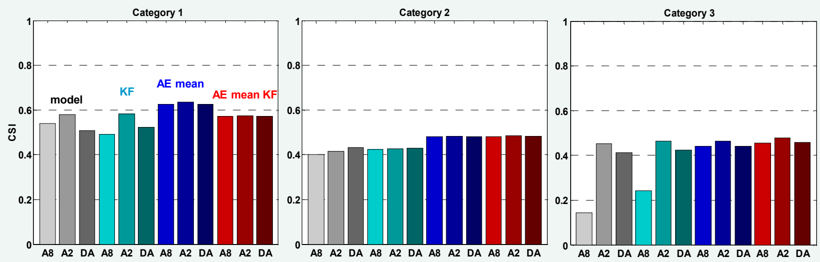



Fig6. Critical success index calculated for 4 different forecasts for group 1 during 2012 year using A8, A2 and DA model data. Thresholds between categories are 50th and 90th percentiles.

## Conclusions

An analog ensemble method adjusts to all sorts of terrain (especially AE mean). It reduces RMSE and bias, while improving RCC. In most cases starting model with 8-km horizontal resolution produces the best results, but using higher resolution improves accuracy for high wind speed forecasting.

## References

[1] Luca Delle Monache, F. Anthony Eckel, Daran L. Rife, Badrinath Nagarajan, and Keith Searight, 2013: Probabilistic Weather Prediction with an Analog Ensemble. Mon. Wea. Rev., **141**, 3498–3516.
[2] Daniel S. Wilks., 2006: Statistical Methods in the Atmospheric Sciences. 2nd ed. International Geophysics Series, Vol. 59., Academic Press, 627 pp.

This project is funded by the European Union