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anemos wind atlas improvements based on a new remodelling approach

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Abstract

The anemos wind atlas for Germany (D-3km.M2) represents a database containing long-term time series for all relevant atmospheric parameters. MERRA-2 reanalysis data are used as input and driving data (Fig 1). Ahead of the downscaling to 3 x 3 km², the WRF parametrization is tested with measurements in the optimization process.
The basic task after the simulation with WRF is the new "Remodelling" approach of the anemos wind atlas with the support of numerous high quality measurements.
On the one hand a systematic bias can be corrected in the remodelling process to improve the quality of the anemos wind atlas. On the other hand intensive verification of the wind atlas allows for an estimation of prediction accuracy of the simulation output. In the verification process statistic parameters as mean value, Pearson correlation, bias, RMSE and extreme values are analysed. Furthermore the vertical profile, diurnal and annual cycle and frequency distribution are verified.

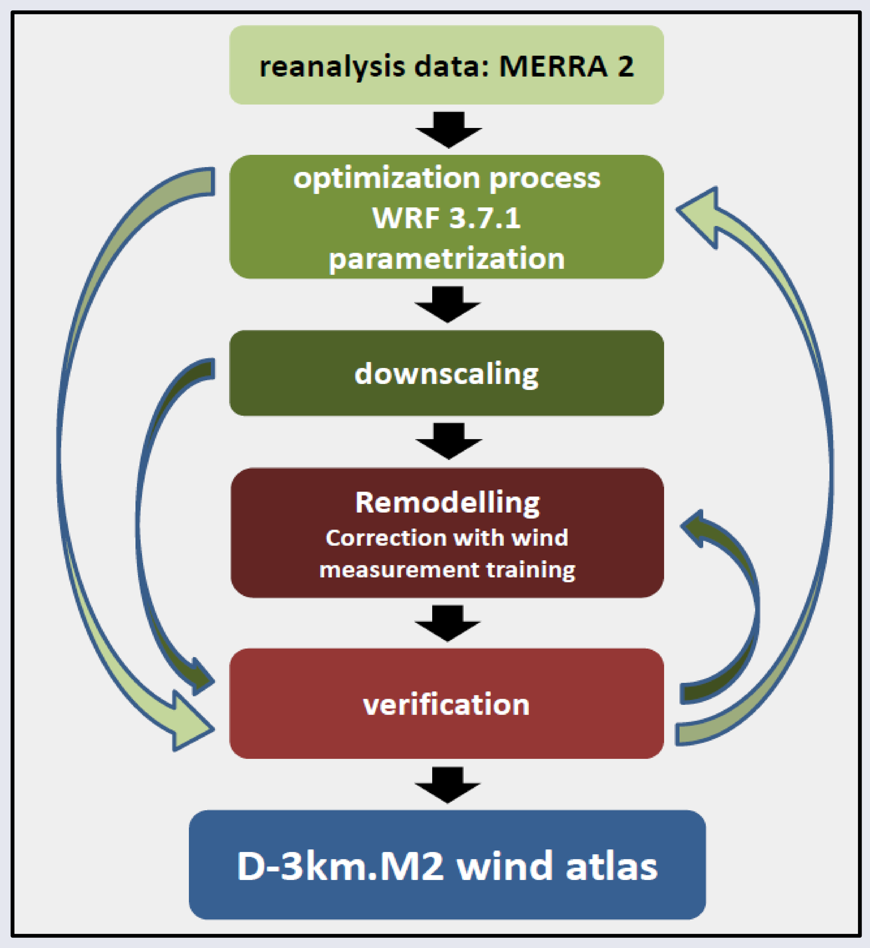

Fig. 1: Process chain of the anemos wind atlas. The arrows show the input of measurements.

Objectives

The long-term time series from the anemos wind atlas, with a high spatial and temporal resolution in wind speed and direction, are widely used for applications in wind energy, e.g. for long-term correlation of short-term measurements, energy yield and market value calculations, energy losses of wind turbines (legal grounds, wake effects, icing, sector management) and initial site search. These applications require a high quality of the wind atlas data. This will be achieved with the new remodelling approach and an intensive verification of the wind atlas.

Remodelling Method

The "Remodelling" is an optimization method only for the wind speed variable. The general idea is to use subrid-information which is not part of the WRF simulation for the improvement of the wind speed.
In the first step, the difference in height a.s.l. between the grid cell mean and the measurement site is corrected by means of CFD model simulations.
In the second step, the training process, each measurement is divided into eight wind direction sectors. For each sector a linear regression $wspd_{obs} = m \cdot wspd_{wrf^*} + b$ is carried out. The training algorithm searches for the best regression coefficients, where the regression line converges to $y = x$ under preservation of the frequency distribution. After that, each training site provides a set of regression coefficients m' and b', which are used in the last step for a sectorial multiple regression analysis $b', m' = c_0 + c_1 \cdot x_1 + c_2 \cdot x_2 + \cdots$ that includes only *significant* subgrid-information, e.g. roughness and orography.
The aim is to calculate global scale-parameters c_i for any type of subgrid-information x_i from the training data. This procedure enables to calculate site-specific wind speed time series with a higher quality.

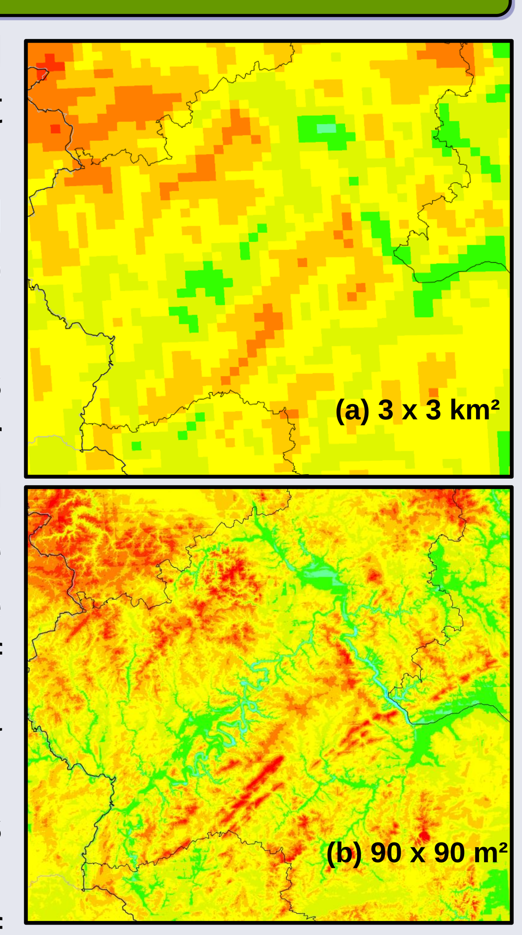

Fig.2: Remodelling approach on the 3 km² wind sp. time series (a) induce the potential to calculate site-spec. time series (b) e.g. for 90 m².

Verification Results

For the wind atlas verification, 45 intern measurements of 100 m height are used. Fig. 3 shows the bias in percent of the mean wind speed (period 1y) for the original WRF output (WRF_{org}, before the Remodelling Process) and the D-3km.M2 (after the Remodelling Process). The onshore overestimation and offshore underestimation (stations 42-45) of wind speed in WRF_{org} is strongly reduced due to the Remodelling approach (D-3km.M2). More than 87 % of the onshore stations hold a bias between ±7 % after the remodelling process.

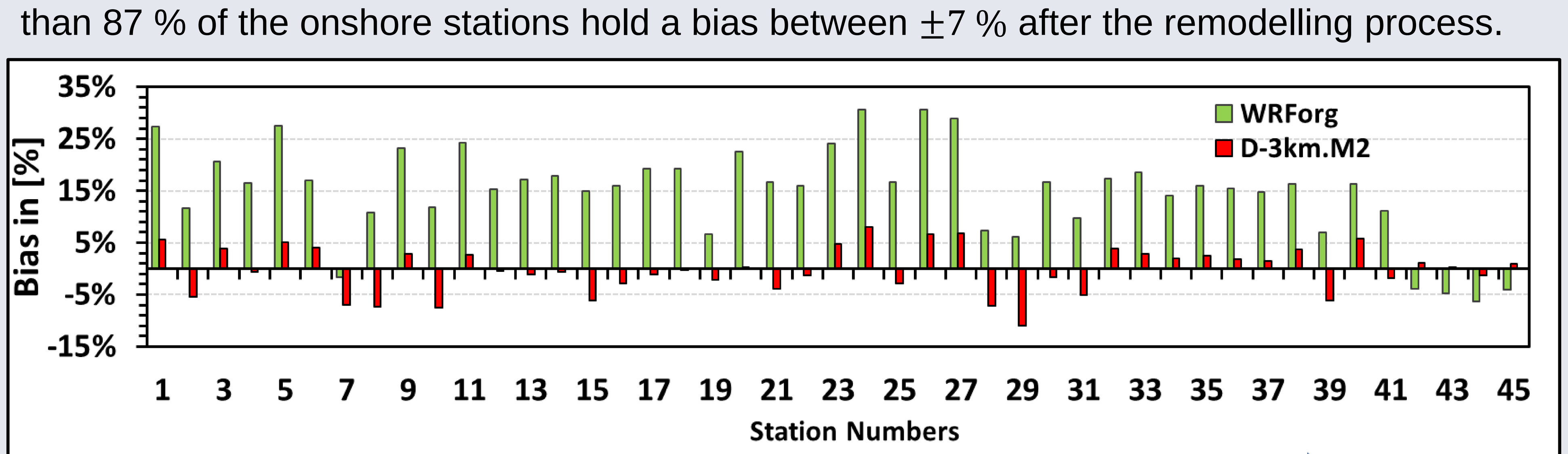

Fig. 3: Bias of mean wind speed between measurements and WRF_{org} (green) or rather D-3km.M2 (red). Stations are sorted from south (complex) to north (flat). The measured period is one year and the height is 100 meters over ground.

Verification Results

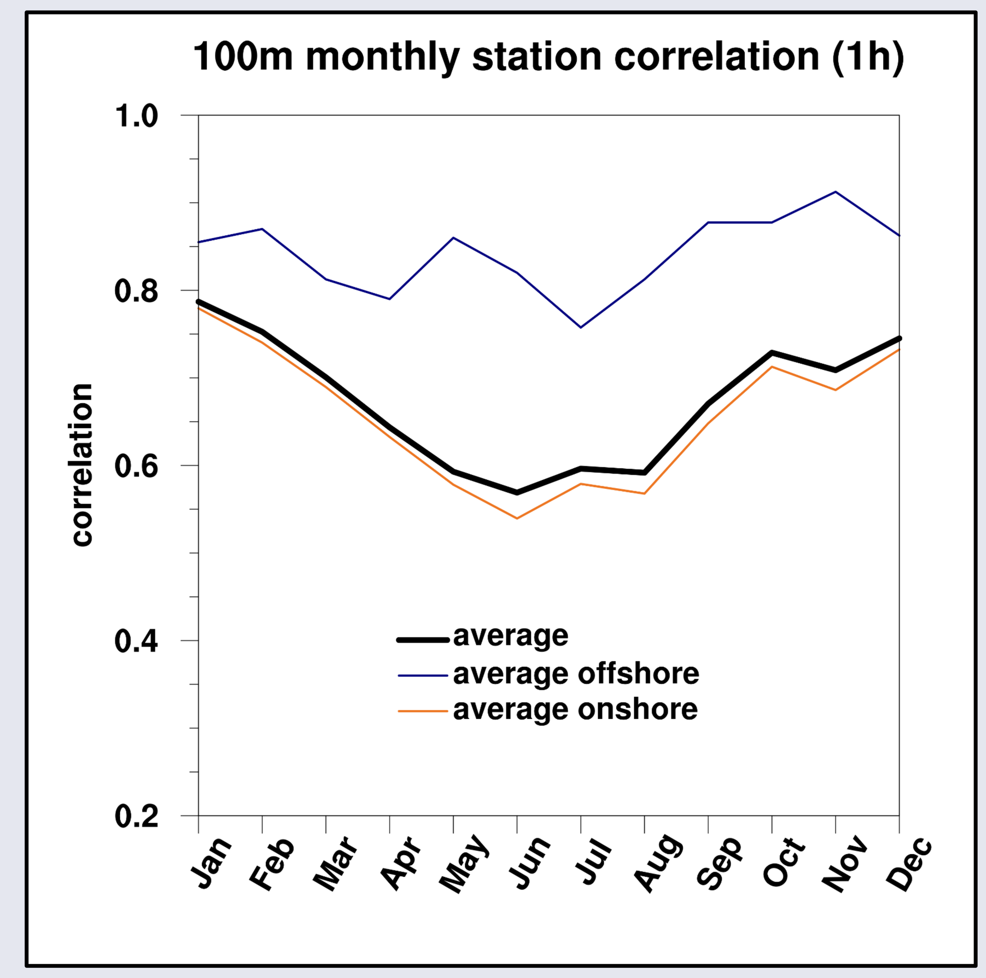

Fig. 4: D-3km.M2 hourly average correlation (R²) for each month of the year over 49 measurements (black), separated into 45 onshore (red) and 4 offshore (blue).

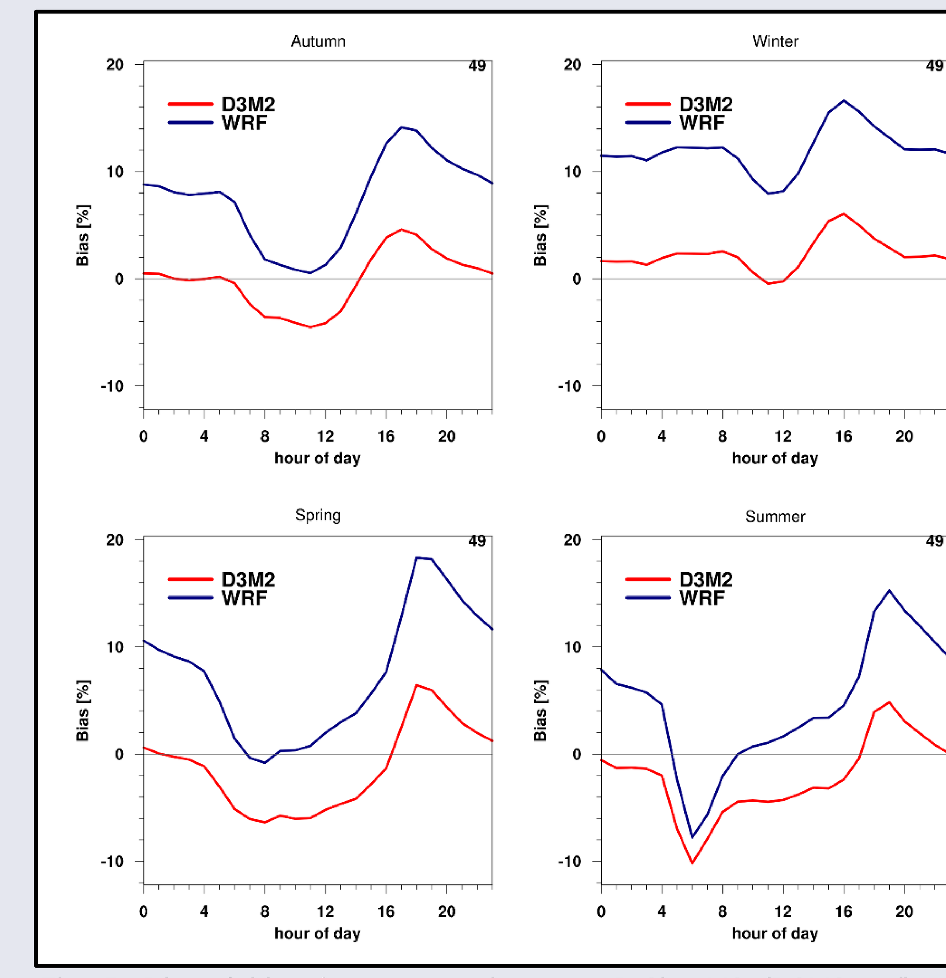

Fig. 5: Diurnal bias for seasons between D-3km.M2 (D3M2 red) and WRF_{org} (blue). 1 hour temporal resolution of the time series.

The monthly averaged correlation (hourly data) between measurements and D-3km.M2 shows an annual cycle (Fig. 4) with the correlation coefficient between 0.6 (summer) and 0.8 (winter). The offshore stations have no significant annual cycle. The correlation of WRF_{org} is not shown here due to no significant improvement after the Remodelling.
However, strong improvements in bias are seen in the diurnal cycle for each season (Fig. 5). The WRF_{org} has a consistently positive bias in each of the four seasons. During daytime the bias is less than during the night. This causes changes in stability of the planetary boundary layer, with the highest amplitude in summer (strong gradient in bias over day). After the remodelling approach the overestimation is reduced with still a positive bias in winter and an underestimation during the rest of the year.

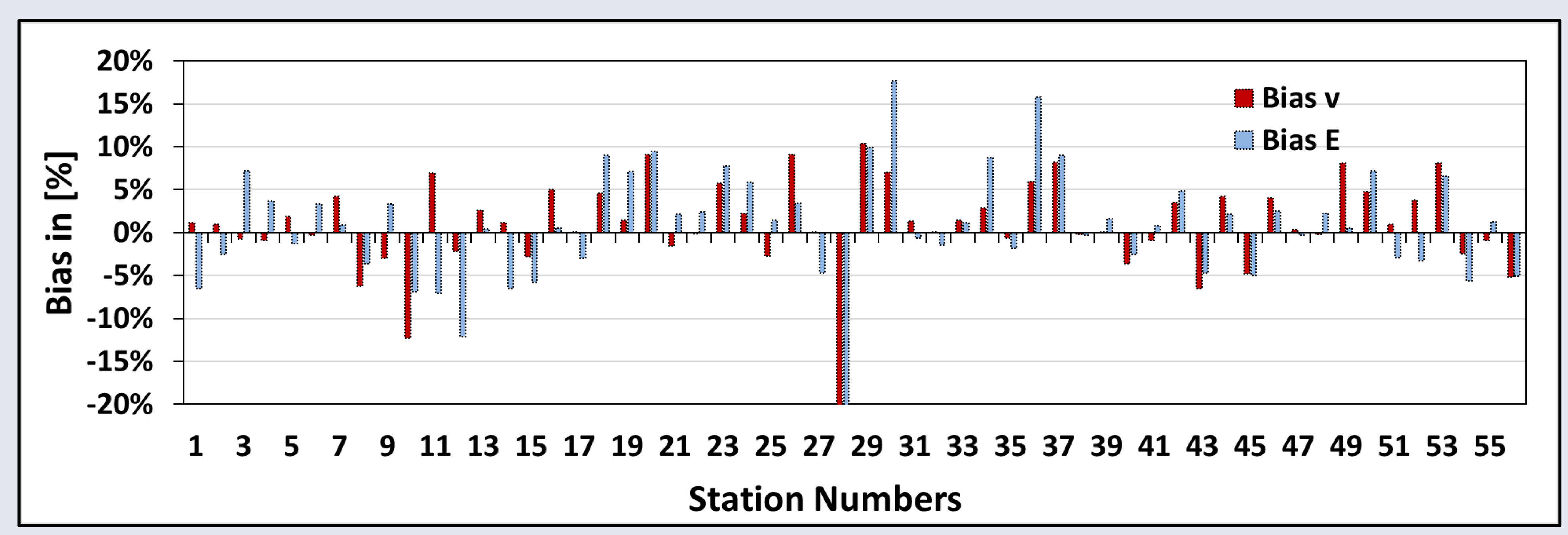

Fig. 6: External verification by Dr. Anselm Grötzner (CUBE Engineering GmbH – Part of Ramboll). 56 Measurements compared with the D-3km.M2. Wind speed bias (red) and energy density bias (blue) are calculated for time series of 1 hour temporal resolution.

Fig. 6 shows an external verification of 1h time series (period 1y) with 56 measurements between 80 - 140 m height. A bias in wind speed of more than 10 % is seen for three stations (all three in complex terrain) and between ±7 % for 88 % of the stations. A similar range is seen for the energy flux density. This shows that the frequency distribution for most of the stations is realistic. These attributes give reason to apply the wind atlas for qualitative energy yield calculations.

Conclusions

The analysis shows a strong reduction of wind speed bias due to the new remodelling approach. There is an improvement particularly over complex terrain.

An accurate wind atlas is most important for energy yield and market value calculations in the wind energy industry. Market values are the combination of time series of the energy yield and the stock-market tariff for electricity. Both show pronounced annual and diurnal cycles. A low uncertainty for the frequency distribution is important for correct calculations of the wind potential and the energy yield of wind turbines.

References

Howard, Tom and Clark Peter, 2007: Correction and downscaling of NWP wind speed forecasts, Meteorol. Appl. 14: 105-116

Mengelkamp, H.-T., H. Kapitza und U. Pflüger, 1997: Statistical-dynamical downscaling of wind climatologies, Journal of Wind Engineering and Industrial Aerodynamics, 67&68, 449-457

Mengelkamp, H.-T., 1999: Wind Climate Simulation over Complex Terrain and Wind Turbine Energy Output Estimation, Theor. Appl. Climatol, 63, 129-139

Staffell, Iain and Pfenninger Stefan, 2016: Using bias-corrected reanalysis to simulate current and future wind power output, Energy 114, 1224-1239

Thogersen, M.L. et. al., Measure-Correlate-Predict Methods: Case Studies and Software Implementation, EMD International A/S

WRF Workshop 2017, Boulder, USA: 18TH Annual WRF Users' Workshop