new remodelling approach
anemos wind atlas downscaling to 90 x 90 m²

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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. 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 analyzed. Furthermore the vertical profile, diurnal and annual cycle and frequency distribution are verified.

Motivation
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 subgrid-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 "\( \varphi = m \cdot \langle \varphi \rangle + b \)" 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 \( c_i = c_0 + c_1 \cdot x_1 + c_2 \cdot x_2 + \ldots \) 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.

Verification Results
For the wind atlas verification, 45 intern measurements of 100 m height are used. Fig. 2 shows the bias in percent of the mean wind speed (period 1y) for the original WRF output (\( WRF_{\text{org}} \)) before the Remodelling Process) and the D-3km.M2 (after the Remodelling Process).

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

Verification Results
Fig. 1: Remodelling approach on the 3 x 3 km² wind sp. time series (a) induce the potential to calculate site-spacc. time series (b) e.g. for 90 x 90 m².
Fig. 2: Bias of mean wind speed between measurements and \( WRF_{\text{org}} \) (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.
Fig. 3: 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. 4: Diurnal bias for seasons between D-3km.M2 (D3M2 red) and \( WRF_{\text{org}} \) (blue), 1 hour temporal resolution of the time series.
Fig. 5: External verification by Dr. Arwel Jones (CUBRE Engineering GmbH – Part of Ramboll). Wind speed bias (red) and energy density bias (blue) are calculated for time series of 1 hour temporal resolution.