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Calibration of ensemble wind forecasts for wind energy applications

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The operation of wind farms and the safe integration of wind power into the transmission grid requires high-quality wind and wind power forecasts from numerical weather prediction (NWP) models. While deterministic NWP forecasts provide point-forecasts for each forecast horizon, ensemble forecasts allow the quantification of forecast uncertainties which can be of great value for e.g. optimal trading strategies in future liberalized electricity markets.

However, ensemble forecasts are subject to systematic forecast errors and spread deficiencies. To correct the deficiencies of ensemble wind forecasts, a systematic comparison of state-of-the-art calibration approaches is presented. The Ensemble Model Output Statistics (EMOS; Thorarinsdottir and Gneiting, 2010) and the variance deficit method (VDC; Alessandrini et al., 2013) are designed for the univariate calibration of wind speed ensembles. Pinson (2012) suggests an adaptive wind vector calibration (AUV) which smoothly adapts the model parameters to changes in weather conditions and models the wind vector correlation. While AUV and VDC yield physically consistent ensemble trajectories which is advantageous from a meteorological point a view, EMOS provides predictive distributions.

The calibration techniques are applied to 10 m and 100 m ECMWF ensemble forecasts and evaluated at offshore and onshore measurement towers in Central Europe in 100 m height and at the offshore wind farm EnBW Baltic 1 in 67 m hub height for lead times up to 120 h. The location of the towers in regions of largely differing site characteristics (offshore, coastal, flat and mountainous environments and onshore surrounded by low and high vegetation) strongly influences the forecasts errors.

Both the univariate and bivariate calibration models decrease the ensemble deficiencies considerably and lead to strong improvements of probabilistic skill scores. At offshore sites, bivariate AUV and univariate EMOS outperform the univariate VDC. At onshore sites with complex topography, the bivariate AUV calibration clearly outperforms the other calibration models both for the entire wind speed range and particularly for high wind speed ensembles. It is found that the power transformation applied to the calibrated wind ensemble at EnBW Baltic 1 preserves the calibration and yields reliable AUV and EMOS power forecasts with considerable improvements of probabilistic scores.