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Uncertainty quantification for wind turbine icing forecasts using deterministic sampling

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For planning, trading, and safely operating wind power in cold climates, reliable next-day forecasts of icing on wind turbines are needed. The modelling chain for icing and related production losses starts with a numerical weather prediction model. The forecasted meteorological parameters are used as input to the icing model and further into the production loss model. The production losses are estimated from the icing intensity and ice load with an empirical model. The icing related production loss forecasts are uncertain owing to errors in the meteorological initial conditions and model formulations, in the employed ice growth models, and in the production loss models. Probabilistic forecasting provides the statistically best forecast and its uncertainty, and therefore, it is valuable when using next-day forecasts of wind power production in cold climates.

Here a probabilistic forecast addressing the uncertainties in the ice growth model formulations was generated. Five uncertain parameters in the icing model were assessed based on literature studies and personal communication. The impact of these uncertainties on the icing and production loss result are examined by using a method of Uncertainty Quantification, namely deterministic sampling. The uncertain parameters are perturbed within an estimated range of uncertainty. This generates an ensemble of icing forecasts with the benefit of both uncertainty estimations for each forecast and higher skill for the ensemble mean compared to a deterministic forecast. The method of deterministic sampling is also compared to random sampling. In random sampling tens of thousands model runs are conducted, however with deterministic sampling only a few model runs are needed to get similar performance of the ensemble.

The performance of the setup is examined for the winter 2013/14 and 2014/15 where wind turbine observations are available from four sites in Sweden. The mesoscale numerical weather prediction model HARMONIE-AROME is used for the meteorological parameters. Forecasts has been run for up to +42 hours for a total of 29 weeks period with a horizontal resolution of 2.5 km over a Swedish domain of 1100x1600 km2. The validation demonstrates that using deterministic sampling for the uncertainty of the icing model leads to improved the icing related production loss forecasts for both winter periods.