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Can we predict icing of structures and wind turbines reliably using high-resolution ensemble forecasts?

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Icing of man-made structures, such as overhead transmission lines, radio towers, or wind turbines, is a common problem in many places around the globe exposed to harsh winter-time conditions. This contribution focuses on the icing of wind turbine blades, which can be a major limiting factor for the operation of wind farms, reducing the energy yield, leading to unplanned downtimes, and causing dangerous ice throw. The issue of blade icing is ever more relevant as wind farm projects are pushing towards higher latitudes (e.g., the Nordics) as well as higher terrain (e.g., the Alps). The ICE CONTROL project, an Austrian research initiative, attempts to tackle this problem using probabilistic forecasts, dedicated measurements and verification of wind turbine icing.

The question addressed in this contribution is about the type of forecasting system (deterministic vs. ensemble; high- vs. low-resolution) needed to accurately predict meteorological icing conditions and, ultimately, ice loads on turbine blades.
Coarse- and high-resolution, deterministic and probabilistic icing forecasts for the last two winter seasons have been produced for a hilly wind farm site at Ellern, Rhineland-Palatinate, Germany. The Weather Research and Forecasting (WRF) model has been run at resolutions of 12.5 km and 2.5 km. An 11-member multi-physics ensemble has been set up with the aim of accounting for the significant model uncertainties in the atmospheric parameters relevant for icing (e.g., temperature and cloud liquid water content). Ensemble members have been coupled to global ensemble forecasts by the European Centre for Medium-Range Weather Forecasts (ECMWF EPS).

Relative operating characteristics (ROC) curves and reliability diagrams are used to assess the ability of the model setups to reliably discriminate between freezing vs. non-freezing as well as icing vs. non-icing events. Verification results show that, as far as forecast discrimination power is concerned, a coarse-resolution multi-physics ensemble is already superior to a high-resolution deterministic model forecast, indicating that probabilistic icing forecasts could be feasible in an operational context. Calibration of the ensemble and assessment of reliability proves to be a challenge given the rare-event character of icing at the site considered. Currently, other measurement sites are evaluated and will be included in the analysis in the near future.