Development of an ensemble-based forecasting tool of hazardous icing conditions for German transmission system operators

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Objective

During the winter season, atmospheric icing poses a significant risk to the transmission system (e.g. Thorkildson, et al. 2009). Icing of the transmission system could result in cut-off and ultimately in electrical power outage situations. The overarching goal of this work is therefore to provide a forecasting tool that detects hazardous atmospheric icing conditions to transmission system operators (TSO). To achieve this, we avail ourselves of a forecasting tool that is well established in aviation meteorology where icing is a common hazard. We tailored this forecasting tool to enhance TSO's situational awareness prior to icing events and in turn, to strengthen the resilience of the grid.

Method

We chose the German Weather Service's (DWD) existing icing forecast system ADWICE (Advanced Diagnosis and Warning System for Aircraft Icing Environments) (Tafferner et al., 2003; Leifeld, 2004; Kalinka, et al., 2017) as a launching pad for our development. ADWICE is a postprocessing model that computes scenario- and severity-based icing for aeronautical purposes by investigating on the vertical temperature and humidity profiles taken from DWD's ICON-EU numerical weather prediction model.

Atmospheric icing patterns are influenced by a multitude of variables that cannot be determined exactly. Those uncertainties will not be considered by a deterministic model. Binary model output (icing yes/no) will miss significant icing situations. To circumvent these restrictions, we followed an ensemble-based approach. Therefore, ADWICE is expanded by ICON-EU's ensemble prediction system ICON-EU-EPS (ADWICE-EPS) as input.

Due to the different scopes of applications (aviation versus electrical grid security), further model data is implemented into the algorithm. Firstly, we maintain ADWICE's ability to distinguish between different icing regimes (scenarios) and choose scenario freezing (precipitation icing algorithm) as a basis for further development. Secondly, we identify gaps in the original forecast model for aeronautical purposes that need to be filled for the application in the energy sector. Lastly, we propose modifications and evaluate the resulting forecasts for selected case studies against 2-dimensional polarimetric radar data (Steinert, 2014).

Results

The typical vertical structure and thus the mandatory condition for precipitation icing is captured by ADWICE's algorithm. It is shown that scenario freezing's cloud and precipitation algorithms lack important factors for the prediction of the selected precipitation icing cases. The evaluation results revealed strong indications that ADWICE's threshold of a minimum vertical thickness of a precipitating cloud was not met within some areas where freezing rain actually occurred.

With the inclusion of additional model fields, the modification of ADWICE's algorithm to detect precipitating clouds and the consideration of the vertical thickness of the melting and refreezing layer, an improvement of the prediction quality is observed in the case studies.

Conclusions

In general, the findings suggest that the modifications generated better results than the original tool. For the two precipitation icing case studies, certain aspects of the ADWICE algorithm cause biases. By implementing further data, those are lowered substantially.

Limitations for this work arise particularly from the selected case studies. Further work will include a systematic statistical verification in order to analyse the generality of the improvements.

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