Evaluation of WRF for Forecasting Wind Turbine Icing

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The growth of ice on a wind turbine can pose many problems. Icing can create a potential safety risk due to ice shedding (fig. 1), lead to production losses which reduce profits (fig. 2), and can increase loads, thereby reducing the turbine lifetime. The ability to forecast the amount of icing (fig. 3) could help to minimize these risks both by identifying sites prone to icing during the planning phase, and estimating production losses in the short term.

For this study we examine icing events at a site in Northern Sweden (fig. 4), using WRF and a variety of icing models, in a hind-cast setup for the month of January 2011. The WRF simulated temperature was evaluated against GDAS data over the entire 10 km domain. For evaluating the icing model we utilized production data from 43 of the 47 turbines in the wind park. We utilized the production to estimate observed icing by identifying times when the observed power deviated from the generic power curve by more than 20% and the temperature was below freezing temperature. We then created three observation data-sets depending on how many of the turbines showed the icing signal (all, majority, or any). We found that WRF does a reasonable job capturing the occurrence of icing found at this site, using the Thompson MP Scheme. We also found that both icing occurrence and amount is highly sensitive to the PBL and microphysics schemes used.

Ice Accretion: Growth of ice, function of the heat balance between the heat released via the phase change and other boundary conditions. Nine sensitivities testing three combinations each of the microphysics and PBL schemes in the model (Table 1).

The WRF model was used to provide meteorological input to the icing models. The model was run over 2 domains at 30 km and 10 km resolution respectively (fig. 3). The outer domain was nudged using the NCEP FNL data-set, which was also used for the input and boundary conditions. Nine sensitivities testing three combinations each of the microphysics and PBL schemes in the model (Table 1).

Table 1. PBL and microphysical schemes used in the study

<table>
<thead>
<tr>
<th>Microphysics</th>
<th>SUNYLin (1)</th>
<th>Thompson (2)</th>
<th>WMSM (4)</th>
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</thead>
<tbody>
<tr>
<td>PBL</td>
<td>MVG (2)</td>
<td>MYNN2 (3)</td>
<td>SYSL (2)</td>
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</table>

Fig. 5 shows the balance required between the mass flux and temperature to maintain each type of icing.

Makkonen: ISO standard model for calculating ice accretion on structures (Makkonen, 2000).

Brakel: Asymptotic model, advanced features: Type of icing, amount of water during glaze icing, ability to represent heating from below (Brakel et al. 2000).

Ice Model Evaluation

Fig. 9 shows the model evaluated against our best guess for observed icing on the turbine. The choice of both the microphysics scheme and PBL scheme are key to model results. SUNY-Lin is the preferred job capturing the low level clouds needed to generate icing at wind turbine heights, while Thompson does the best. The MYNN2-PBL scheme shows the earliest onset of icing, while the YSU scheme being the warmest melts ice too quickly at times.

When evaluating the icing models, the teshed ablation model performs the best capturing the lack of ice on the majority of the turbines at the end of the period.

References