

Improved predictions of atmospheric icing at MET-Norway

Björg J.K. Engdahl^{1,2}, Bjørn E.K. Nygaard³, Gregory Thompson⁴, Lisa Bengtsson^{5,6}

¹ Norwegian Meteorological Institute, Oslo, Norway

² Institute for Geosciences, University of Oslo, Norway

³ Kjeller Vindteknikk, Kjeller, Norway

⁴ National Center for Atmospheric Research, Boulder, CO, USA

⁵ National Oceanic and Atmospheric Association, Boulder, CO, USA

⁶ Cooperative Institute for Research in Environmental Sciences, University of Colorado, USA

bjorgjke@met.no, bjorn.nygaard@vindteknikk.no, gthompsn@ucar.edu, lisa.bengtsson@noaa.gov

Abstract— A correct representation of supercooled liquid water (SLW) in numerical weather prediction (NWP) models is essential for forecasts of atmospheric icing on infrastructure and aircraft. Preliminary tests have shown that the operational NWP model HARMONIE-AROME (HA), used operationally at MET-Norway and several other European meteorological agencies, has a tendency to produce too much ice at the expense of supercooled liquid water. In order to improve the model's ability to forecast atmospheric icing events, we have implemented elements of the Thompson scheme from WRF into the cloud microphysics scheme in HA. The new modified microphysics scheme has already shown promising results in idealised test cases. Full scale 3-D simulations with HA have now been carried out for two weeks in February 2017, both with the old and the new scheme, and compared with observations at the Hardingnuten site. Preliminary results show an increase in SLW and estimated ice loads with the modified scheme

Keywords— Atmospheric icing, numerical weather prediction, modelling of supercooled liquid water, cloud microphysics, ice accretion on power lines

I. INTRODUCTION

Atmospheric icing occurs when water droplets in the atmosphere freeze on objects that it comes in contact with. This can be very dangerous as it can bring down power lines and other infrastructure, and cause problems for road and air traffic. Not all liquid freezes below 0°C, liquid droplets in the atmosphere that exists below freezing temperature are called supercooled liquid droplets. Supercooled liquid water (SLW) is the cause of atmospheric icing, and an adequate representation of SLW in numerical weather prediction (NWP) models is therefore essential when forecasting such conditions [1].

In January 2014 a major power line in the mountainous regions of western Norway, collapsed due to heavy icing. The ice loads were measured to be more than twice the design loads of the power lines. This sparked the initiation of the Wind Ice and Snow Loads Impact on Infrastructure and the Natural Environment (WISLINE) project funded by the Norwegian research council and lead by the Norwegian Meteorological Institute (MET-Norway), where one of the main goals is better predictions of atmospheric icing and ice loads.



Fig. 1 The measurement site at Hardingnuten during the icing event at Feb 9 2017. The Icetroll icing detector (left) and the transmission lines next to the site (right).

MET-Norway utilizes the NWP model HARMONIE-AROME (hereafter HA) for their operational forecasts [2]. HA is based upon the AROME model ([3], [4]), and is used operationally in many European countries [5]. The use of HA in this research project is important as it ensures that our findings can be transferred from research to operations in a seamless manner.

The cloud microphysics scheme in a NWP model parameterizes the in-cloud processes determining the amount of SLW. The scheme in HA is called ICE3 and is mostly based on physics by Cohard and Pinty ([6], [7]) that can be traced back in literature to Lin [8], Rutledge and Hobbs [9], and Ferrier [10]. Studies [11] have shown that microphysics schemes based on [8], have a tendency to produce an excess of ice at the expense of SLW. The same studies show that microphysics schemes such as the Thompson 2008 [12] (hereafter T08) scheme have a better representation of SLW.

The T08 scheme was made for the widely used NWP model Weather Research and Forecasting (WRF). It was made with emphasis on icing forecasting for aviation purposes. We have therefore implemented elements from T08 into ICE3 [13] in order to improve the representation of SLW. Idealized experiments in 1D showed a clear increase in the amount and prolonged existence of SLW with the modified microphysics scheme.

For this study we utilize HA with the modified microphysics scheme in full 3D model simulations for observed icing cases, and compare the results with icing observations at Hardingnuten, Norway. We focus on two weeks in February, 2017 during which icing was detected at Hardingnuten. We want to find out if HA with the modified

microphysics scheme can produce a more realistic ice load estimate, compared with the old scheme.

II. METHODOLOGY

The Hardingnuten observation site is located at 1229 m.a.s.l. near Rjukan in southern Norway. Two transmission lines of 300 kV and 420kV run in parallel close by, where atmospheric icing is frequently observed. The site measurements consist of an IceTroll icing sensor, a heated 2D wind sensor and a temperature sensor [14]. In addition the Norwegian transmission system operator, Statnett, has installed load cells in suspension towers of the passing power lines, in order to measure in real time the ice load on the power line conductors. Figure 1 shows the measurement site.

The first two weeks of February, 2017 posed a difficult forecast challenge as icing occurred several times, but there were also days without any icing at all. The temperature was very low during this period, less than -10°C , when the heaviest ice accretion was detected. This is a suitable case to study, as both hit and misses can be tested. The model is evaluated by calculating the ice load on a reference object (ISO 12494) based on the liquid water content, temperature, and wind speed from the model simulations, and compare those ice loads to the measurements collected with the IceTroll icing sensor

HA is a convection permitting NWP model. For these test-experiments we used a horizontal grid distance of 2.5km and 65 vertical levels, with cycling every 6 hour. We ran HA cy40h1.1 both with the original microphysics scheme (details in [13]) and the modified scheme from Jan, 29 to Feb, 14, 2017, both deterministic runs. Note that these simulations are only test runs, and deviate significantly from the setup used in operational weather forecasting at MET-Norway. As the model requires some spin-up time, only the period from Feb 1-14 will be analysed here.

III. RESULTS

We have compared the simulation with the modified microphysics scheme (XCCR) with the control run (CTRL). Figure 2 shows the difference (XCCR - CTRL) in SLW (cloud water and rain) integrated over the five lowest levels and accumulated over the entire simulation period. The results indicate that the modified scheme appears to generate more SLW near the coast, and less further inland compared with the old scheme. One hypothesis to explain this behavior is that the modified scheme produces more SLW in relatively warm air masses, but when the temperature drops below a certain threshold, it produces less, even compared with the old scheme. More analysis is required to explain this.

Figure 3 shows estimated ice accretion on a cylinder based on [15], from the output of SLW from the simulations, and compared with the observed ice accretion. The grid point closest to the observation site, was only at 1039 m.a.s.l. This is considerably lower than the actual observation height, which could have a huge impact on the results. We therefore chose a nearby grid point at 1220 m.a.s.l., to represent the observation site more realistically (CTRL.h and XCCR.h). From fig.3 it is clear that XCCR estimates higher ice loads

than CTRL, maximum 1.91 kg/m and 1.62 kg/m, respectively. Yet the values are far from the observed maximum value of 7.05 kg/m.

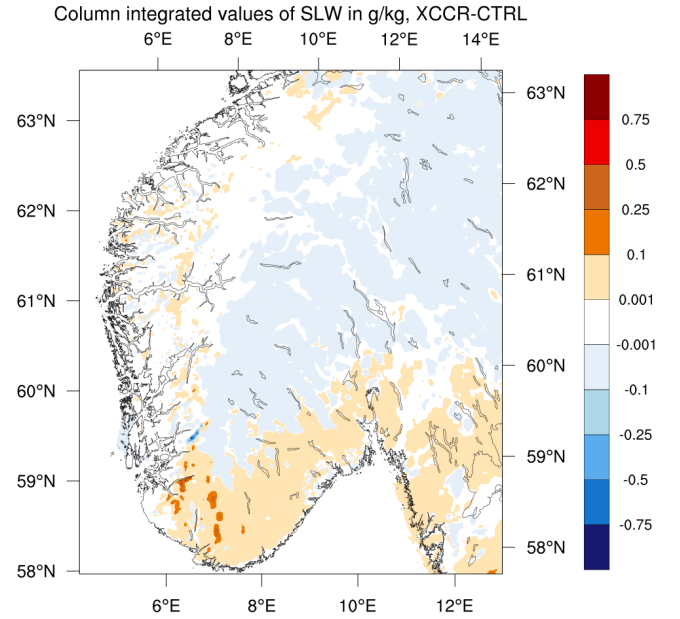


Fig. 2: Difference in column integrated values of SLW (rain and cloud water) between XCCR and CTRL (XCCR - CTRL) in the lowest five model levels, accumulated over the entire simulation period.

Preliminary tests showed that the modelled wind speed was lower for both simulations compared with the observed wind speed, this could result in a lower estimated value for ice loads. A simple bias correction based on the observed and simulated wind speeds was added to reduce the error from the simulated wind speed (CTRL.hw and XCCR.hw). The simulated and observed temperature was quite similar, so there was no need for a bias correction for the temperature. With the wind speed correction, the maximum ice loads from the simulations are increased to 2.01kg/m (CTRL) and 2.36kg/m (XCCR).

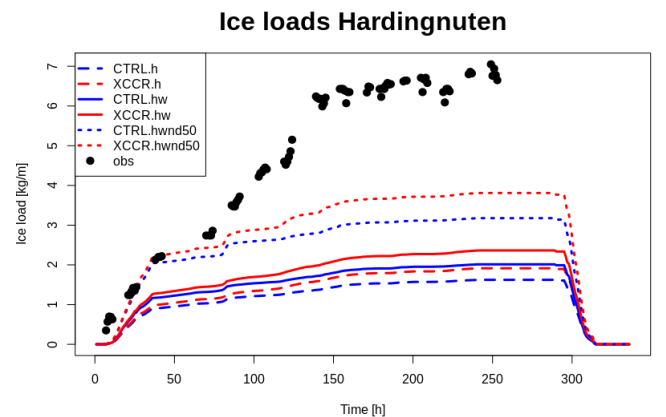


Figure 3: Observed (black dots) and modelled ice loads from Feb 1 - 14 at Hardingnuten. CTRL (blue lines) denotes the control run, and XCCR (red lines) the modified microphysics run. Long dashed lines are height corrected (Nd=100), continuous lines are height and wind corrected (Nd=100), while short dashed lines are height and wind corrected with Nd = 50.

The calculations for the ice loads are sensitive to the cloud droplet number concentration (Nd), which varies a lot with location and can be tricky to estimate. We therefore ran the icing calculations with a lower Nd=50 (from previously Nd=100), to check the sensitivity. This resulted in even higher maximum ice loads, 3.18kg/m (CTRL) and 3.81kg/m (XCCR). Around half of the observed value.

IV. CONCLUSIONS AND FUTURE WORK

The results show that the modified microphysics scheme gives somewhat higher and more realistic ice loads for Hardingnuten in this particular case. However, the spatial distribution of SLW in the lowest levels show that this could potentially vary with location, particularly from sites close to the coast versus inland sites.

Estimating ice loads is difficult as the ice accretion is dependent on a myriad of factors, and the results will be sensitive to the cloud droplet number concentration, wind speed, temperature, height, etc. Our study is still in an early phase of investigation, and these results are only preliminary. In the future we plan to analyse the results further, and do longer simulations with a model setup closer to the operational forecasts. This is in order to compare with observations and for a more robust result.

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