# Comparing observed and modelled cloud base height for ice assessment

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## Introduction

According to BTM, nearly 100 GW of wind power is currently installed in low temperature and icing climates making it one of the largest "non-standard" markets in the world today [1]. Ice accretion on wind turbine blades is one of the largest challenges when operating wind turbines in low temperatures and icing climates. Ice changes the aerodynamics of the turbine blade and causes production losses, potential increase in turbine vibration, increased noise emissions and falling ice present a health and safety risk in the vicinity of the turbine.

Ice accretion on an object requires the presence of liquid water and freezing temperatures. The most typical form of icing in Europe is rime icing as a result of low level clouds below freezing temperatures. If the cloud height is below the level of wind turbine rotor, ice will be collected on the turbine blades.

For assessing icing risks in pre-construction phase for a wind farm, mainly two different methods exist: 1) use icing measurements from a location nearby (turbine production data, ice measurements or met station measurements) or 2) perform meteorological modelling of site icing conditions. Often nearby icing measurements are not available because icing measurements are not systematically part of frequently meteorological measurements. As a result, weather modelling is often solely used to evaluate icing risks.

In this study, long-term cloud base height observations from met stations and airports during 2000-2015 from 144 stations in Finland, Sweden and Norway are studied and compared to WRF modelled cloud base height from same locations. Statistical methods are used to evaluate main similarities and differences in using the two approaches for cloud base height measurements.

## Approach

In order to evaluate icing risks for wind turbines, measurements of cloud base height provide a great proxy. If the cloud base is in the area of the wind turbine rotor and temperature is below freezing, the conditions are suitable for meteorological icing and ice to form on the rotor blades. In this study, 144 met stations in Scandinavia from time period 2000-2015 are selected and observed and modelled cloud base heights are compared. Only cloud base height is compared in order to limit the potential sources of errors in the comparisons.

Cloud base height observations are primarily from long-term weather stations and airports. Using the cloud base height observations in combination with temperature measurements has shown promising results as a meteorological icing proxy for wind power applications. [2] [3] [4].

Based on mesoscale weather simulations using the Weather Research and Forecast model (www.wrf-model.org) a wind and icing map for Norway was produced by Byrkjedal & Åkervik (2009) [5] and compared against icing calculations based on airport data in Harstveit (2009) [8]. The methodology for using airport data to calculate in cloud icing is further described in Harstveit (2002, 2009) [6][7][9][10]. Wind and icing maps has later also been produced for Sweden and Finland using a similar methodology. In this paper, time series of cloud base heights and temperatures are retrieved from Kjeller Vindteknikk's hindcast archives of meteorological simulations.

Statistical methods are used to evaluate Mean Absolut Errors (MAE) and bias of observed and modelled results.

## Main Body of Abstract

Long-term icing estimation is needed for assessing icing risks in pre-construction phase of wind farm. However, interannual variation in icing is large. If field measurements of icing are performed at planned site it is important to know the icing severity during measurement period compared to long-term average. In order to find out how observations and model correlate with each other with different time scales cloud base heights are compared on 1) long-term average, 2) yearly average and 3) monthly average values from multiple elevations above ground level. MAE and biases are calculated per a) station, b) country and c) latitude and longitude coordinates to identify main driver for differences in results.

## Conclusions

Long-term average values of observed and modelled cloud base height correlate well. When going into shorter time scales (yearly and monthly values), mean absolute errors (MAE) and biases increase for the whole 144 station dataset. The reason of increased MAE and bias errors might be the temporal and spatial differences in the WRF modelling results compared to observed values from met stations.

## Learning objectives

Market potential in low temperature and icing climate wind power is huge and icing severity has to be known when building or operating wind farms in icing climate. It is important to understand how different methods can be used for icing estimation without icing measurements. Cloud base height of mesoscale weather simulations and weather observations have not been compared with each other at this extent before.

## References

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