



Mapping of icing in Sweden

On the influence from icing on wind energy production

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Outline

- The meso-scale model WRF
- Calculations of icing
- Icing map
- Production loss due to icing
- Future development

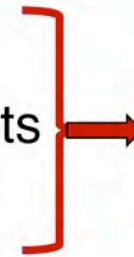
Icing

- ISO standard – atmospheric icing on structures
 - ice loads are important in the design of masts, powerlines, other structures in cold climate



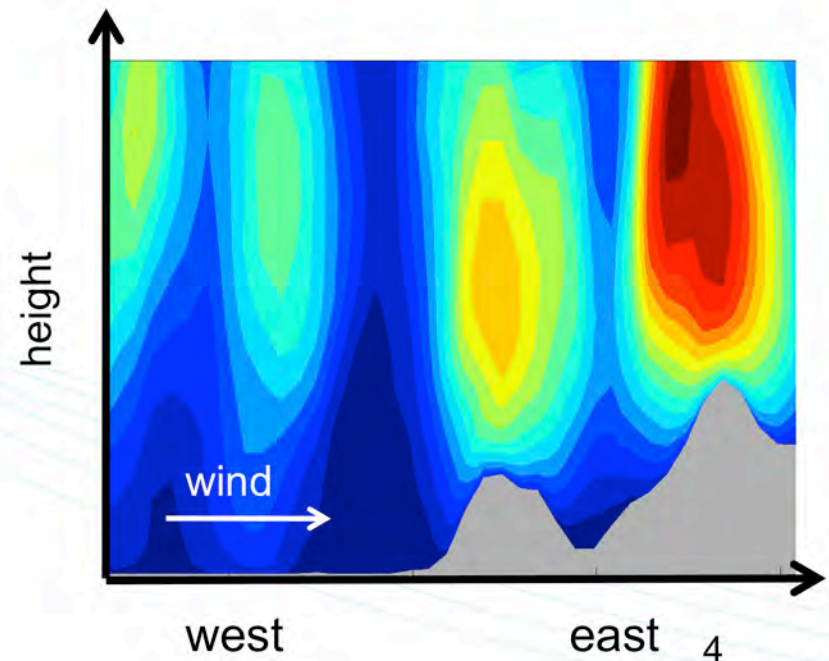
Icing conditions

- Temperatures below freezing
- cloud or fog containing small water droplets
- Something to freeze to



in-cloud
icing

- Lifting of airmasses
→ condensation

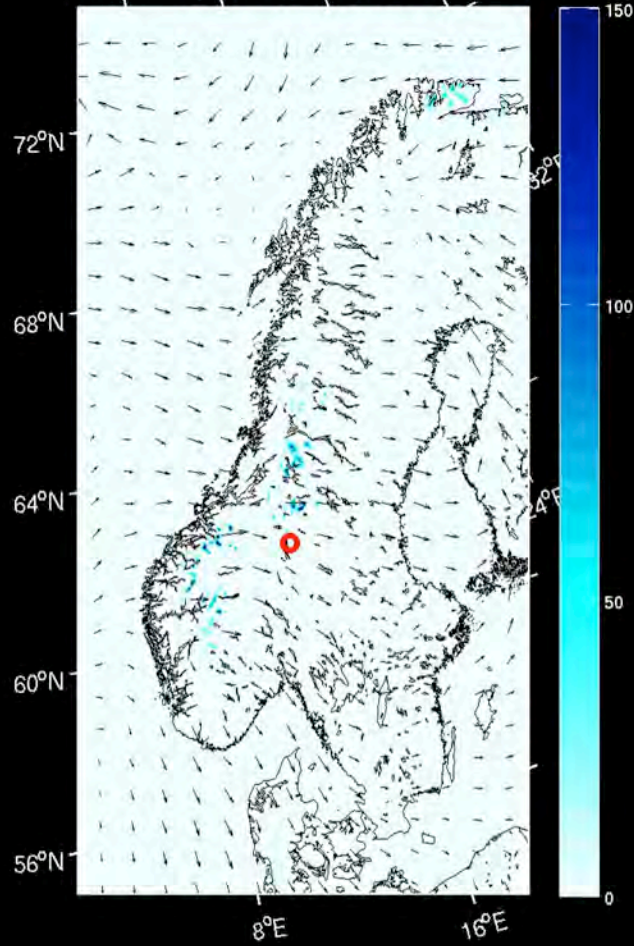


Mesoscale model

- The meso-scale refers to the time and spatial scale of the features resolved by the model. The model resolves low-pressure systems and fronts.
- WRF – Weather Research and Forecasting
- The model describes the atmosphere dynamics (wind, temperature and humidity), and includes physical description of radiation, cloud formation, precipitation, snow, surface processes, etc.
- The model performs calculations in the time domain, no steady-state model
- Typical model resolution down to 1km x 1km

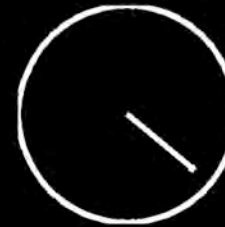


Icing rate [g/hr] at 115m

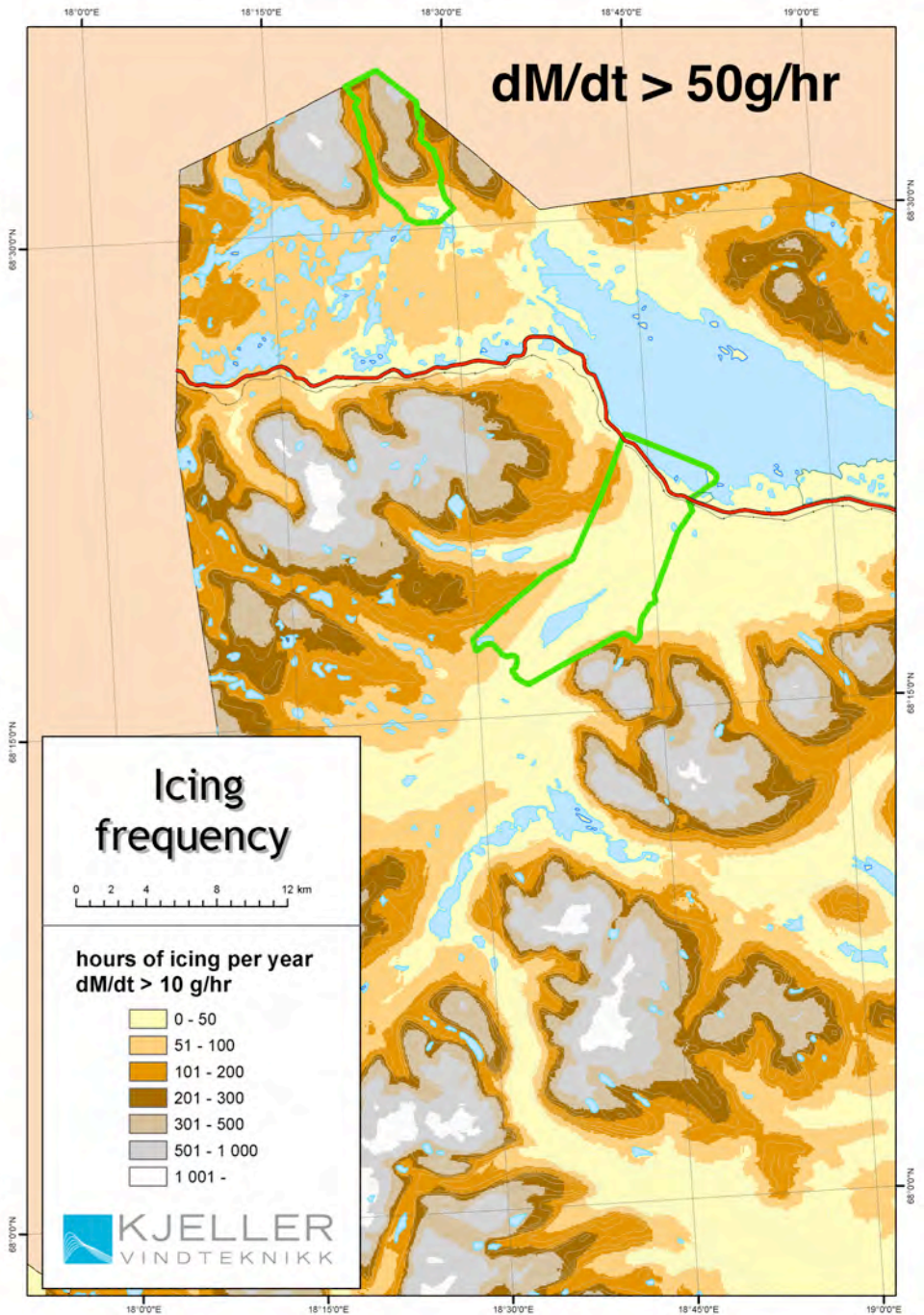
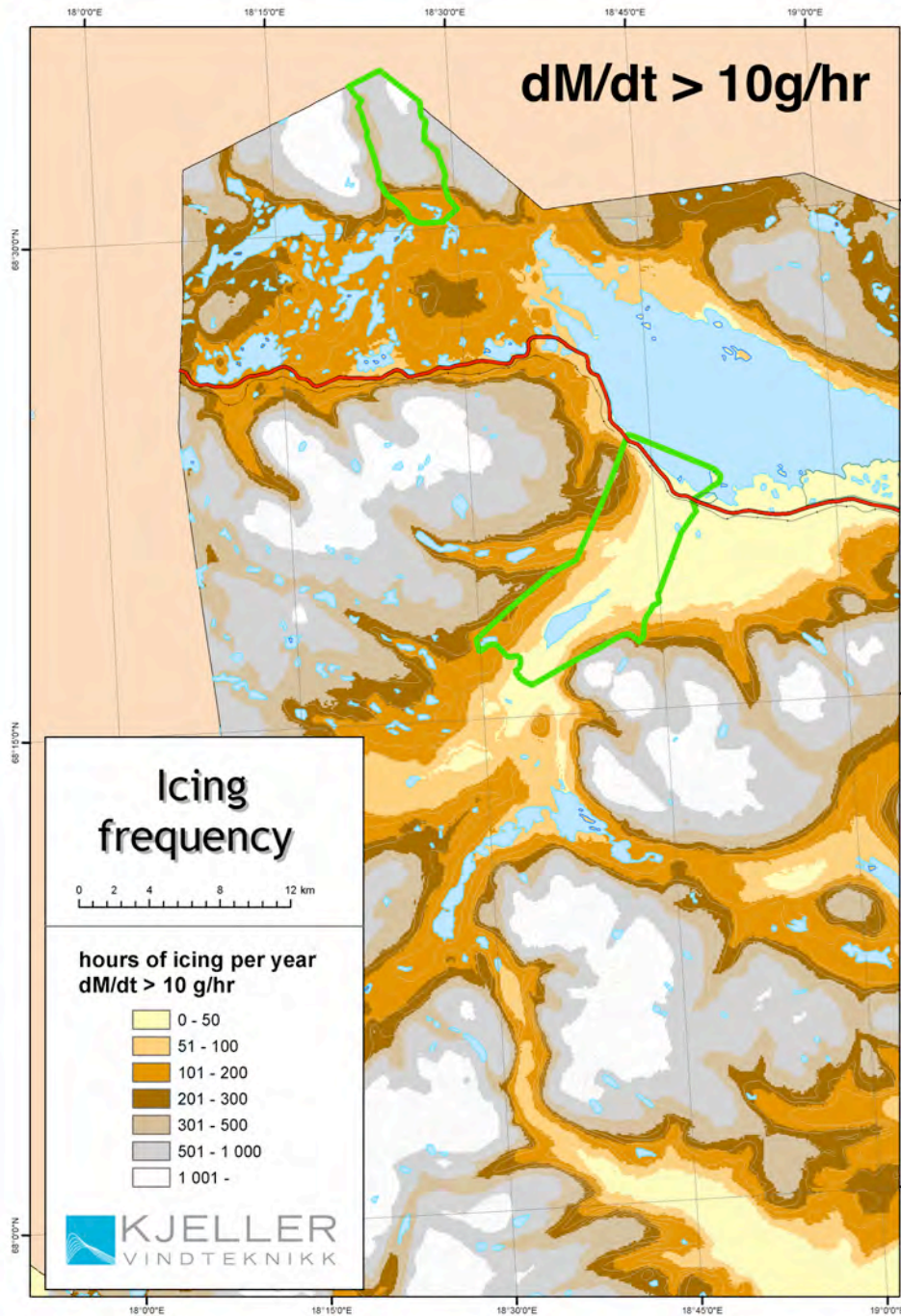


Stor-Svuku

01-Dec-2009 00:00:00





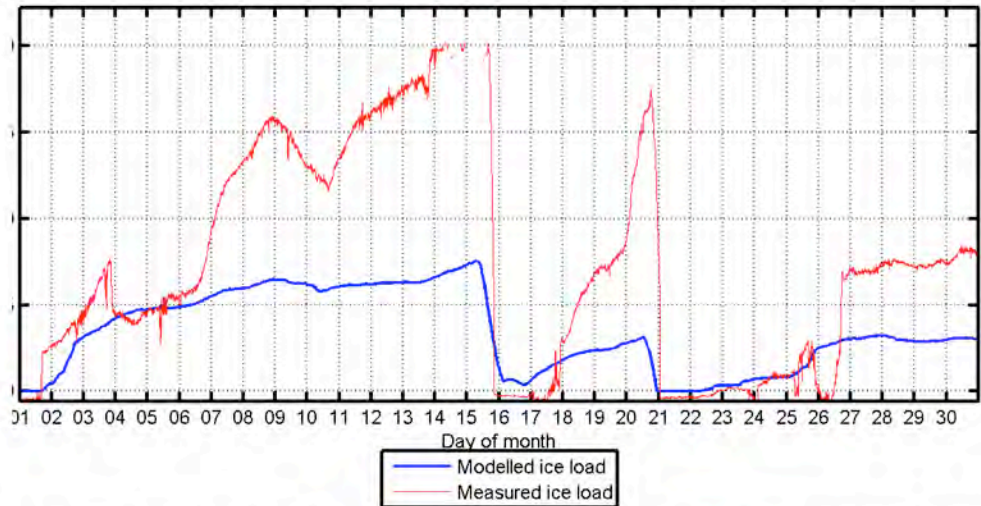


Model verification

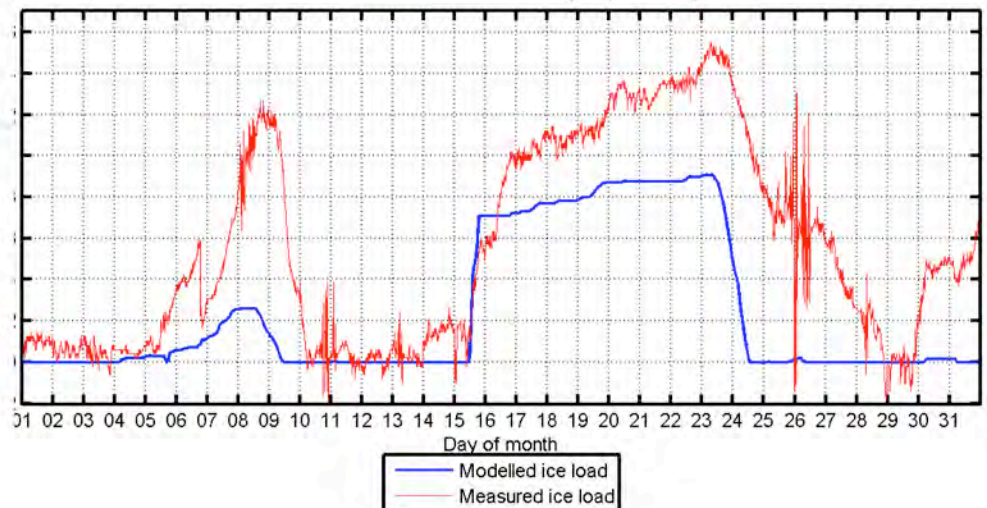
- A project funded by Energimyndigheten:
 - ice measurements at 8 sites
 - production data from 3 wind farms
- This has led to a large improvement in our knowledge about icing and its effect on wind power production

Modeling of ice load

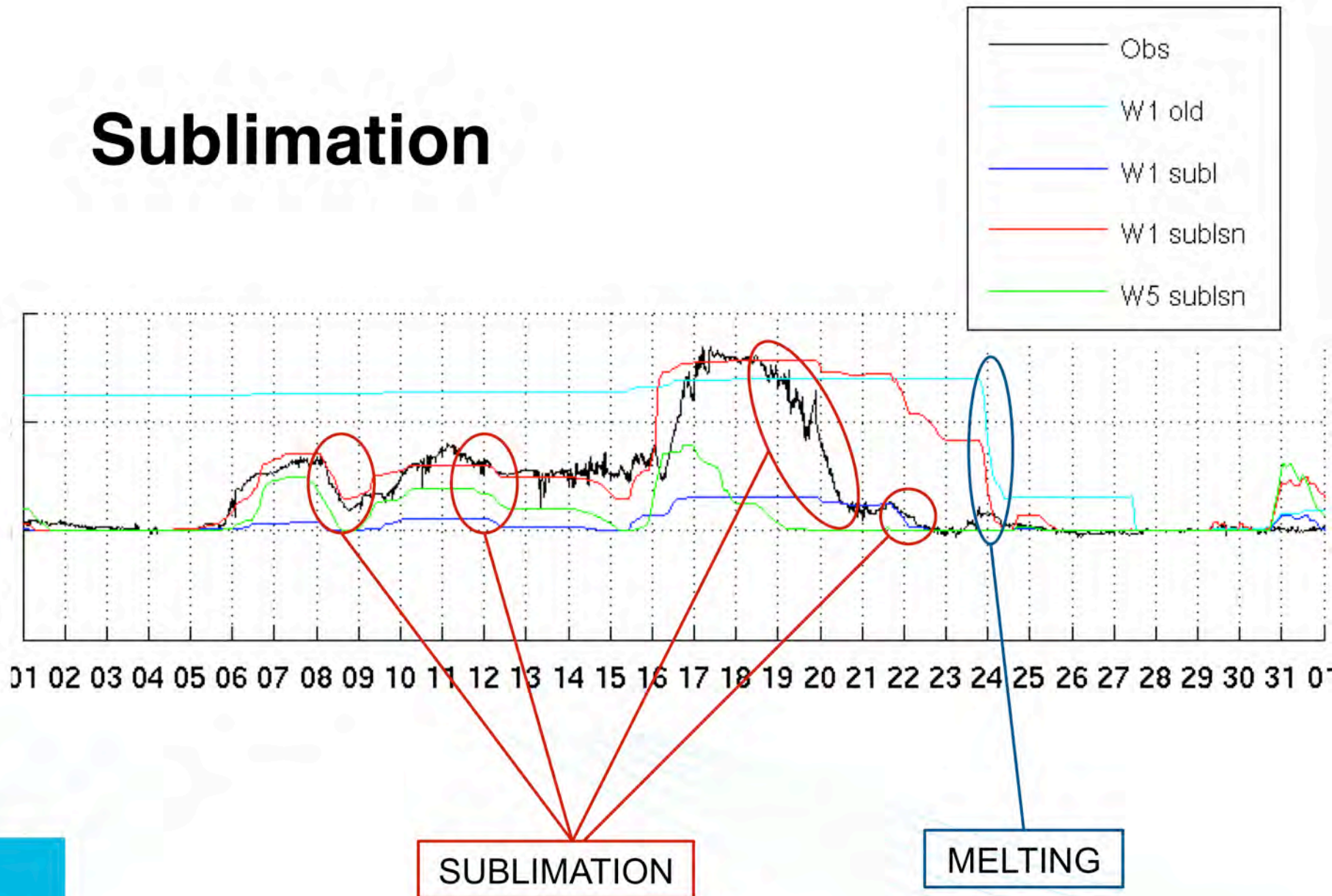
Ice load:
model (blue)
observed (red)



Ice load:
model (blue)
observed (red)



Sublimation



SUBLIMATION

MELTING

Modeling of ice load

- The model describes:
 - timing of ice accumulation
 - timing of sublimation and melting
- The model underestimates large ice loads
- Some icing events found in the model but not from observations.
- Uncertainty also for the observations.

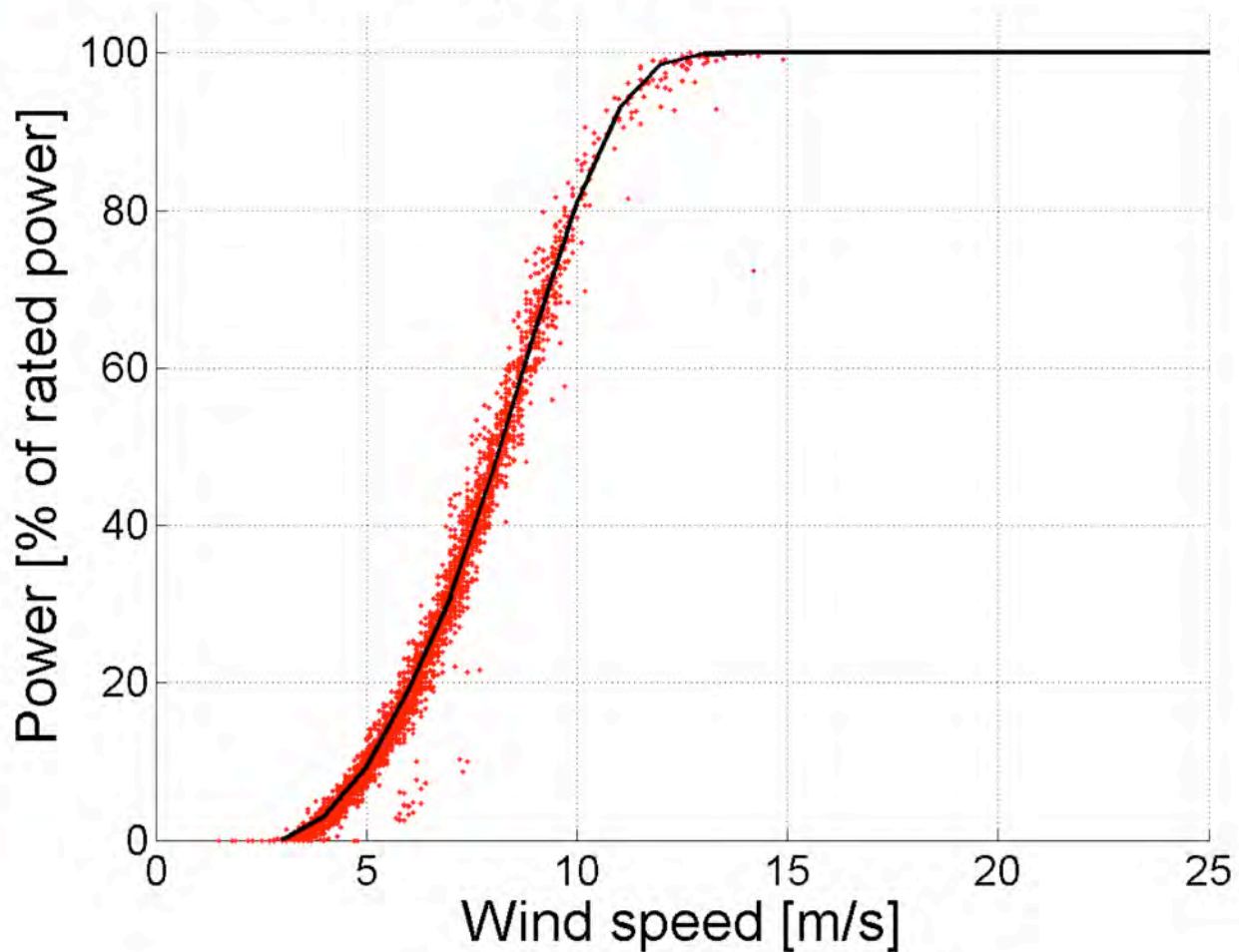
Power production

- Icing will change the aerodynamic properties of the WT blade.
- Result in reduced power output.



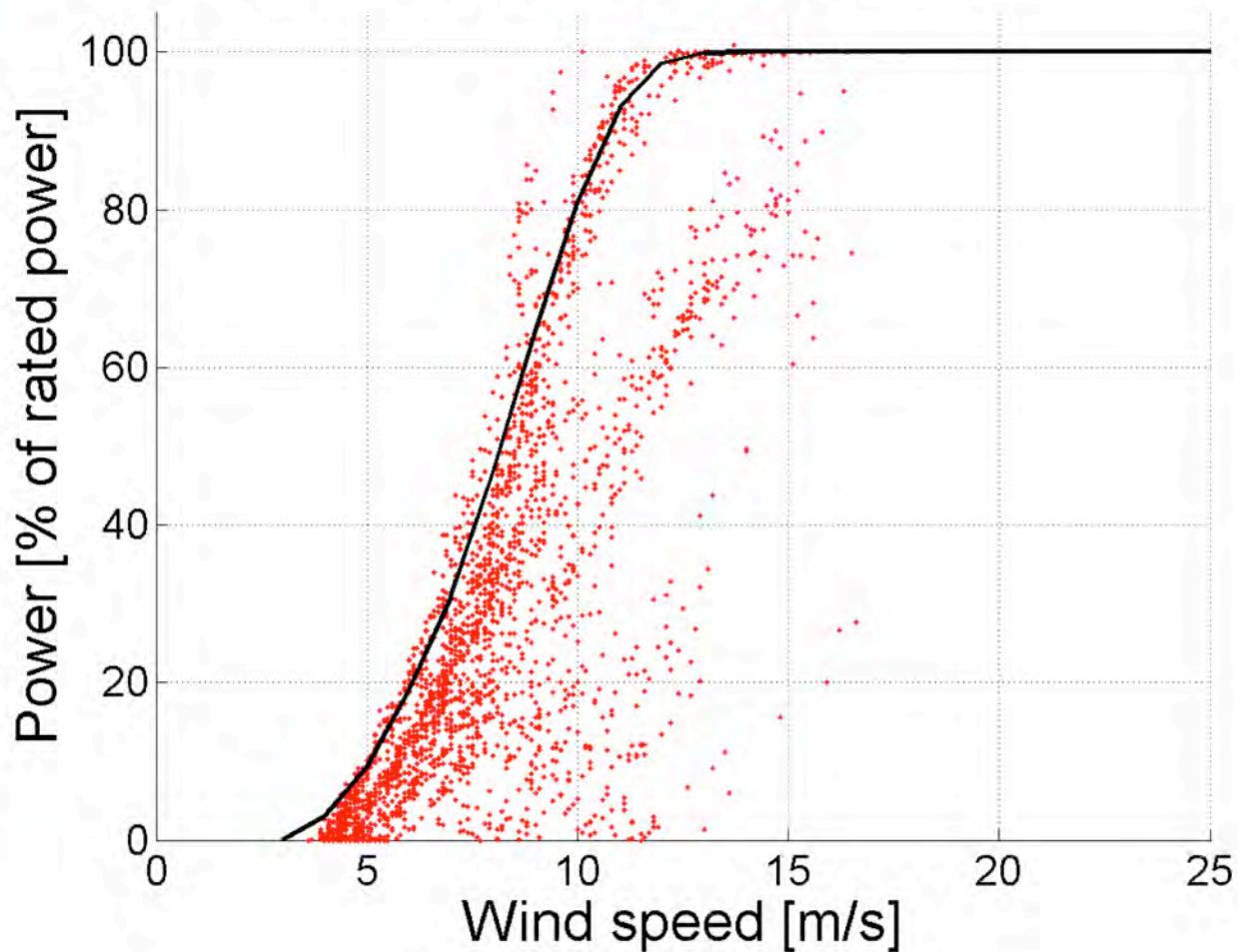
Power production

- Power curve May 2010

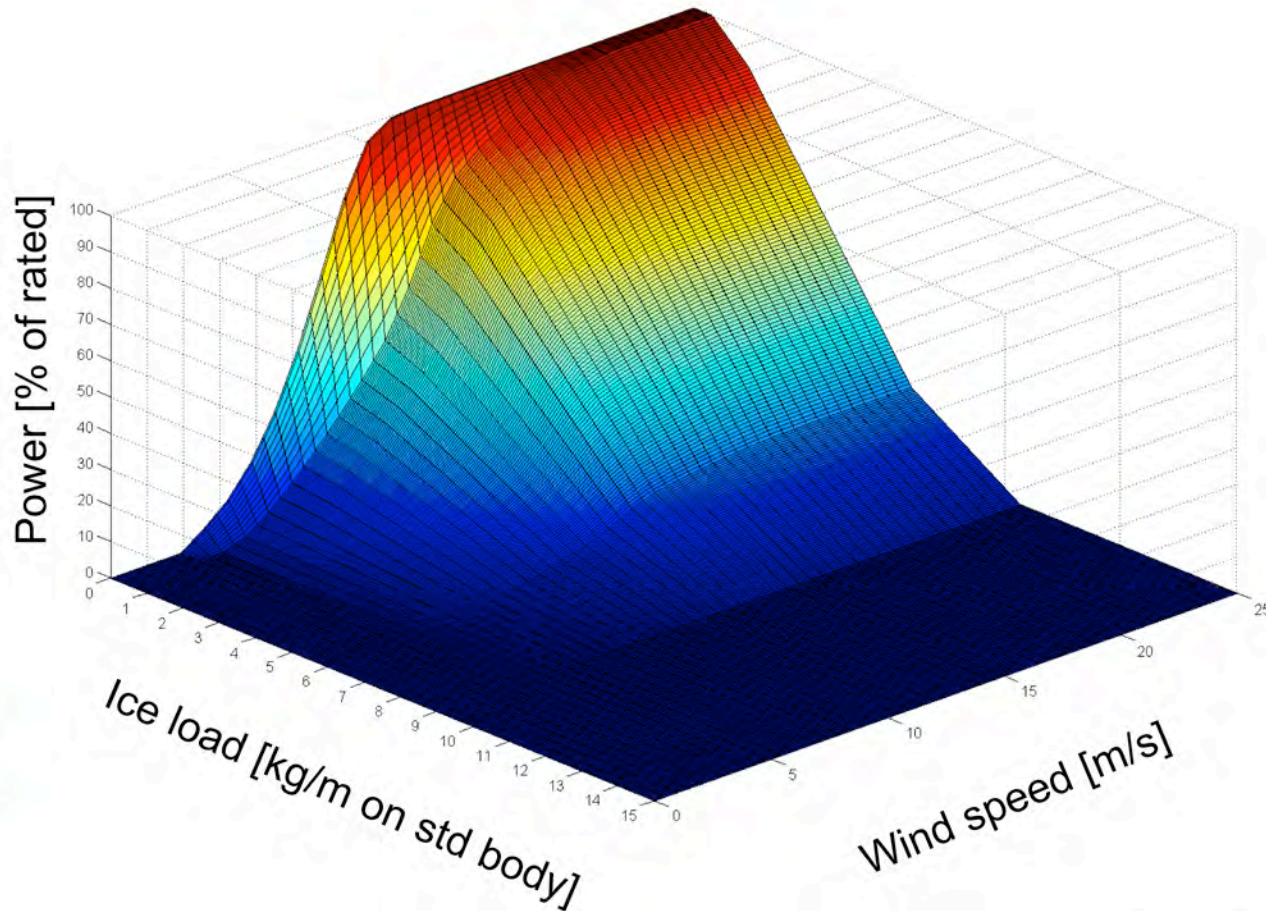


Power production

- Power curve November 2009

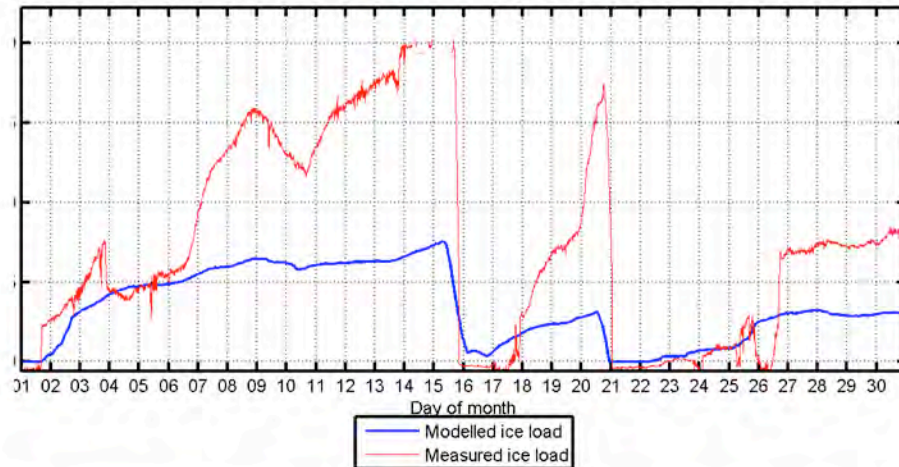


Estimating production loss

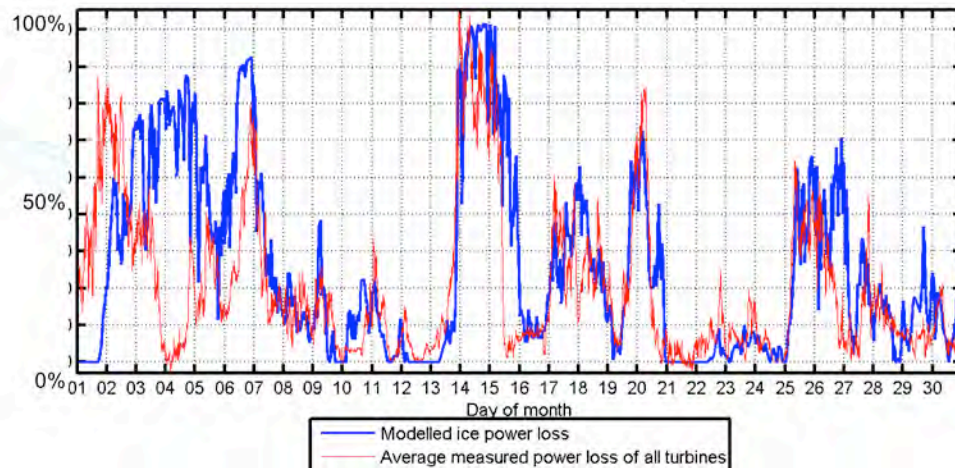


Estimating production loss

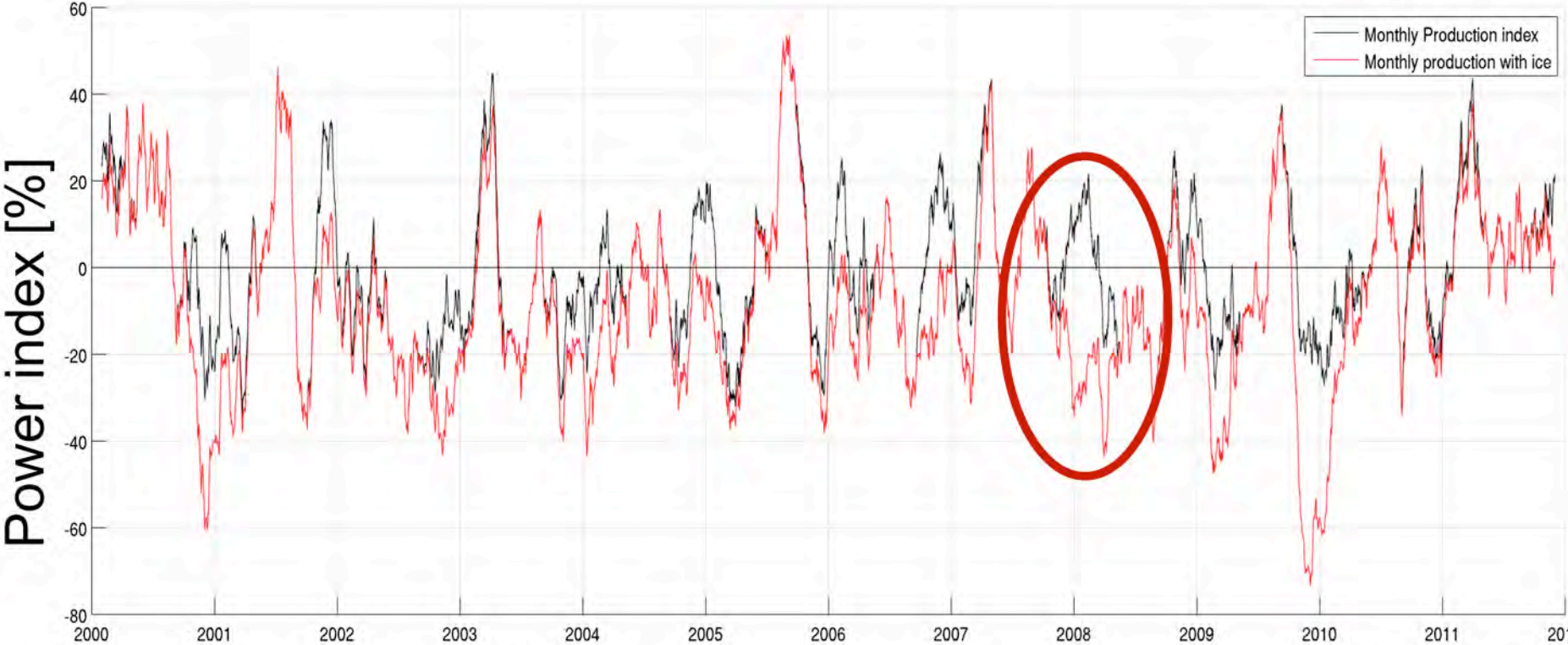
Ice load:
model (blue)
observed (red)



Production loss:
model (blue)
observed (red)



Power production index



Future development

- Meso-scale model:
 - Further development of the meso-scale model and optimize the use of the model for icing calculations
 - Forecasting of icing
- Production loss calculations
 - Calculation of ice loads directly on the blade
 - Calculations of the aerodynamic change of the WT blade and its effect on power yield
- More data needed!
 - Data on droplet sizes and distributions
 - The production loss model is tuned to the available data at a limited number of sites. This is a limitation, how well will other sites be represented?

Thank you!

Wind and icing map are now available for Sweden:
www.vindteknikk.no

