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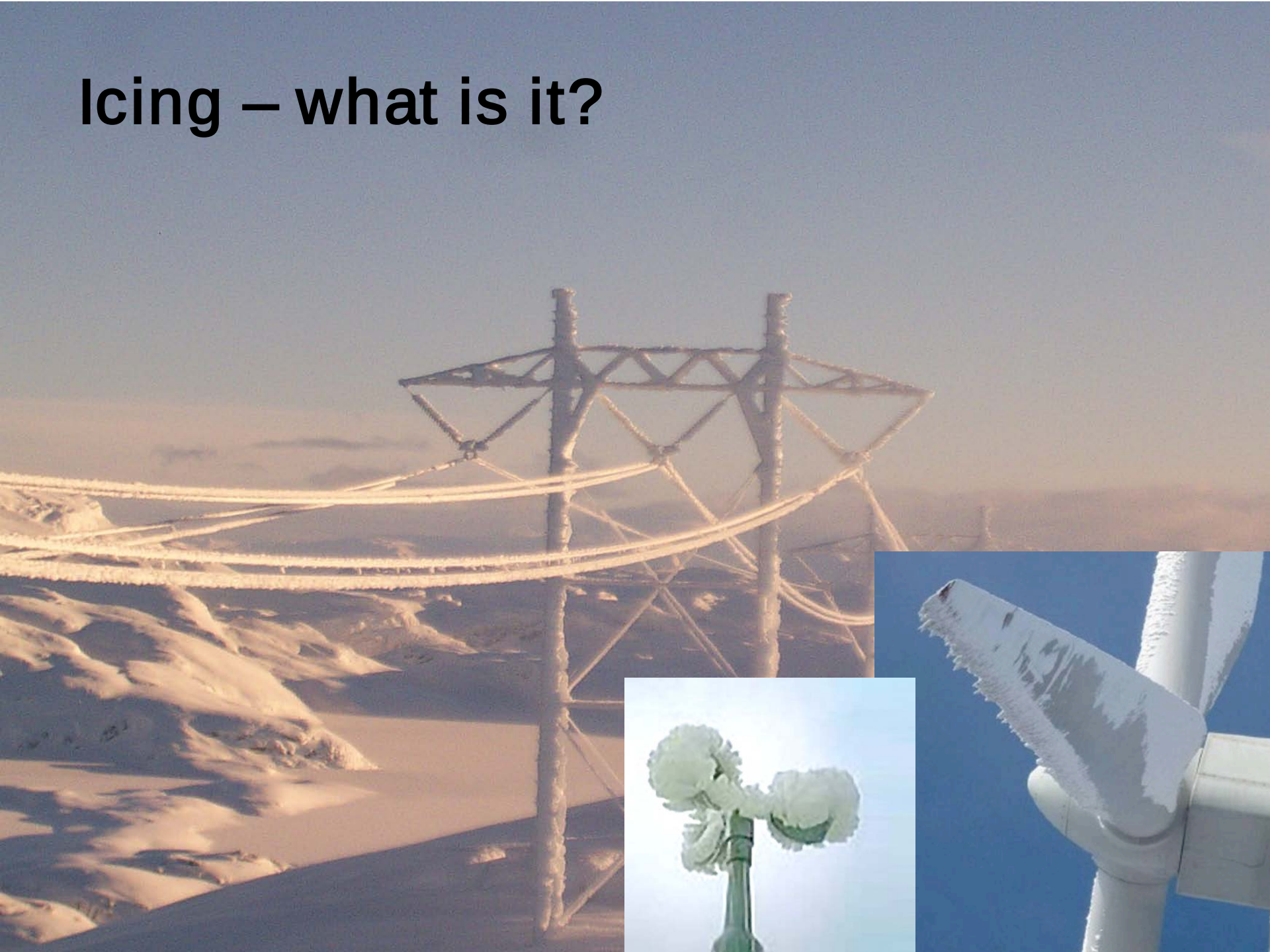
10 Years of experiences with calculation of production losses caused by Icing

Øyvind Byrkjedal

WinterWind, Skellefteå, 7 February 2017

Icing – what is it?



Where does icing occur?

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

➡ in-cloud icing

Typically 100 million cloud droplets per m^3

Typical droplet size 20 µm

Lifting of air masses

Gaustatoppen 11.09.2016,
Foto: Øyvind Byrkjedal

Air flow over the mountain:

- Speed up of the wind
- Reduction of pressure
- Reduction of temperature

⇨ Relative humidity > 100%
The air becomes saturated

⇨ Condensation at the mountain tops

Sheltering from upwind terrain

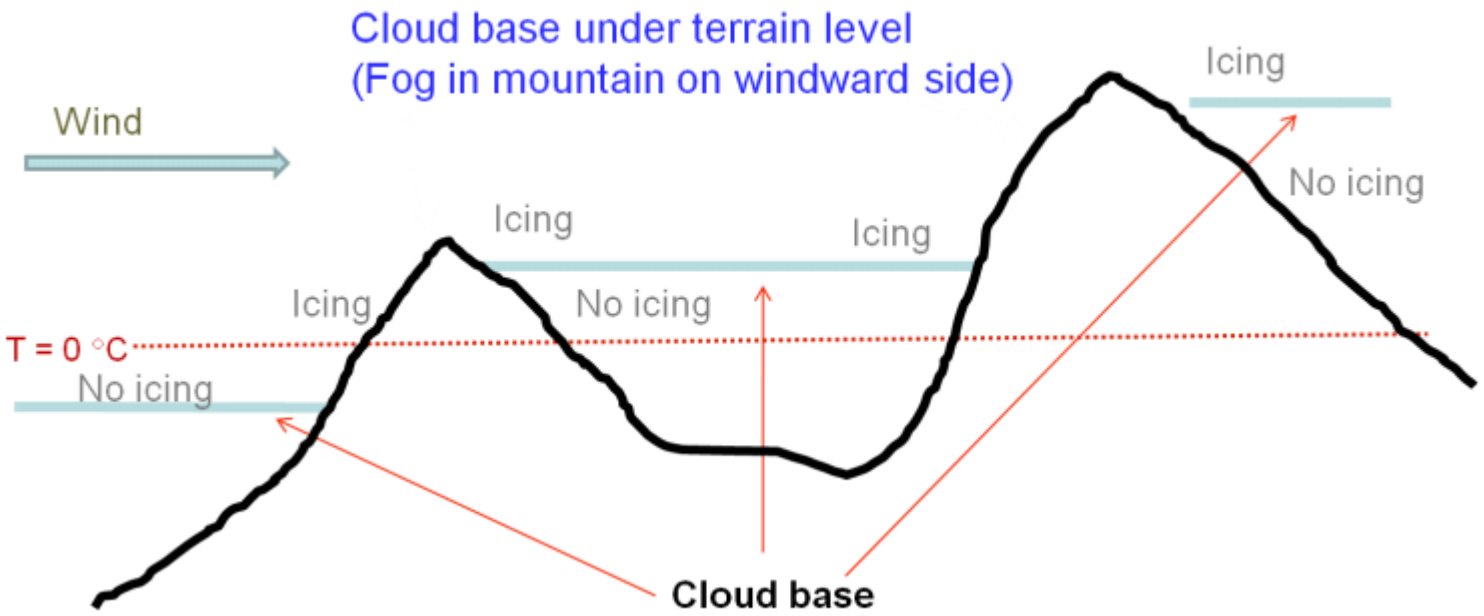


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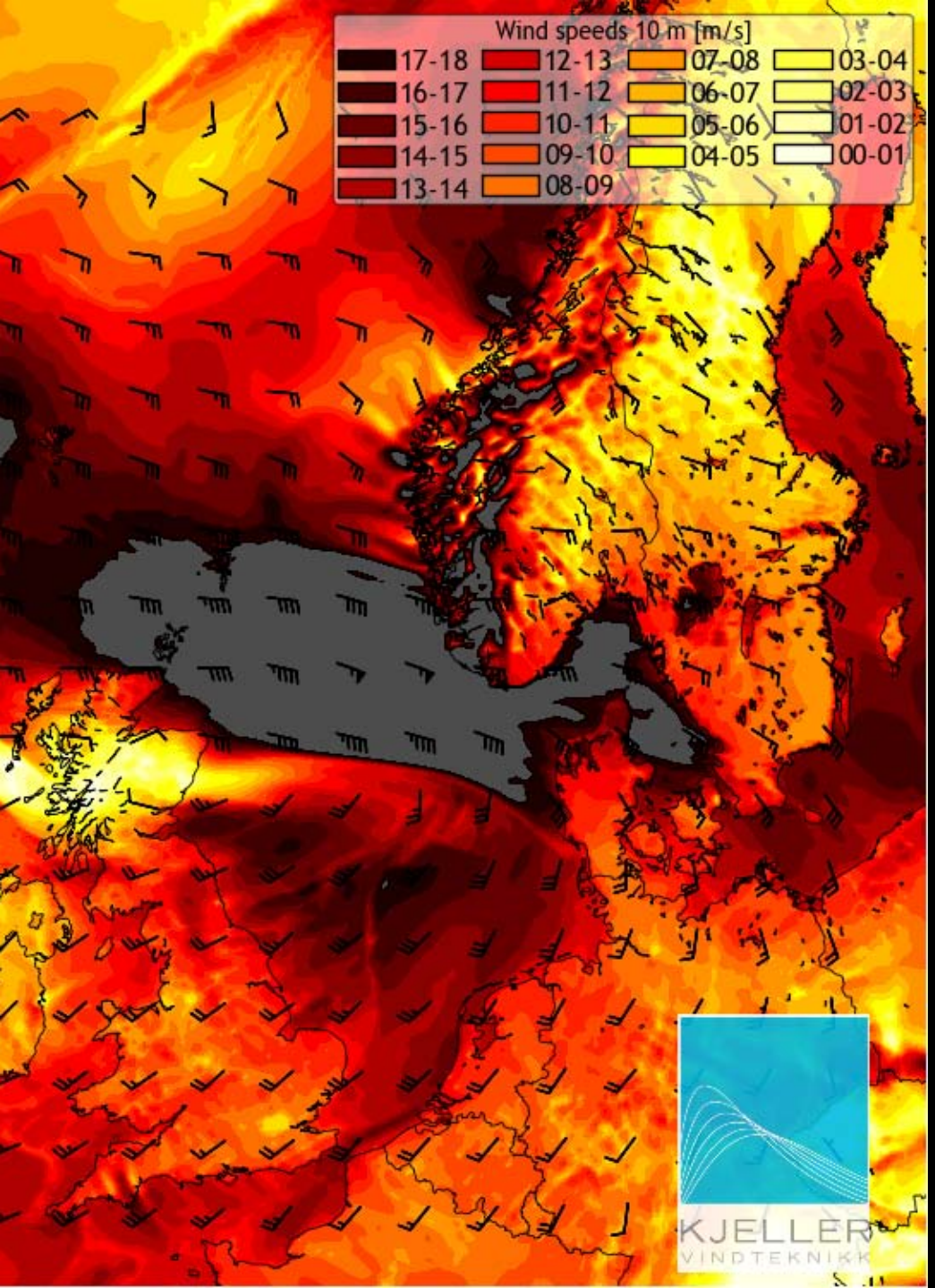
Figure: Svein Fikke, IWAIS2015

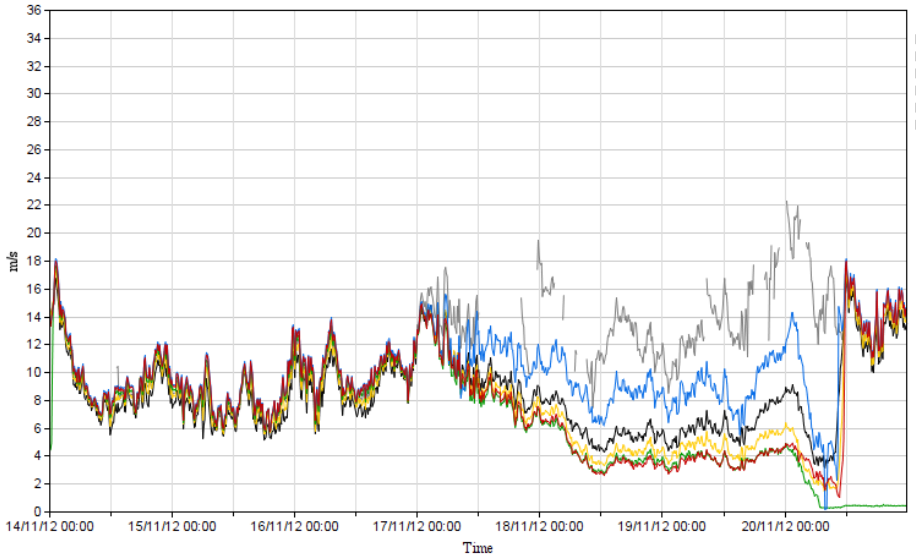


Approach by Kjeller Vindteknikk

- Understand and explain the meteorlogical processes that result in icing and icing losses
- Meso scale model simulations
- Dynamic modelling of wind, temperature, solar radiation, moisture, clouds, rain fall, snow, etc
- Icing exposure and sheltering
- Calculations in the time domain

Pre 2007

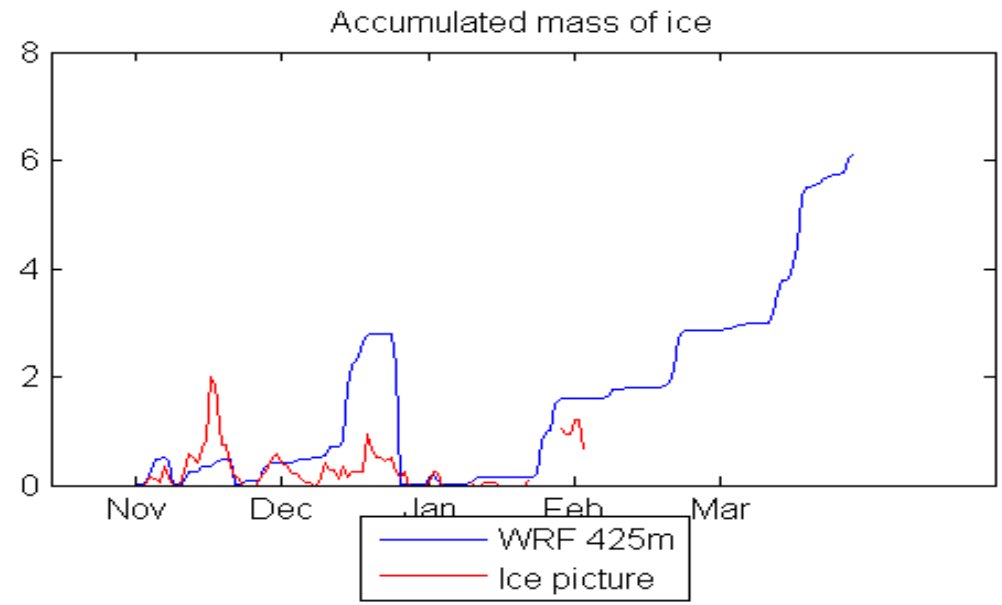
- Influences of icing on wind measurements
- **Ice filtering** of wind measurements
- **Icing measurements** at a few sites:
  - web camera
  - instrument testing



$$\frac{dM}{dt} = \alpha_1 \alpha_2 \alpha_3 \cdot w \cdot A \cdot V$$

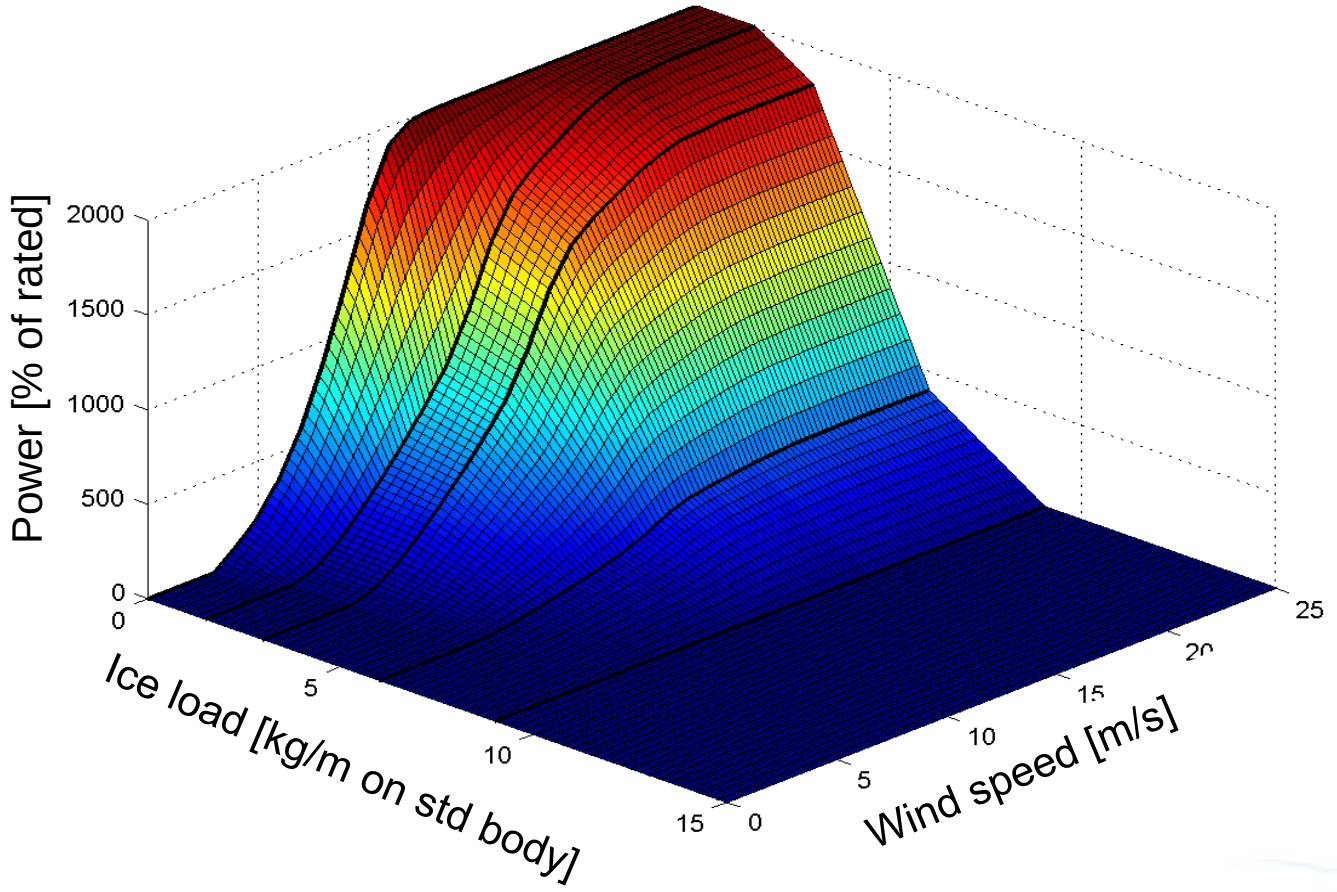
w – liquid water content
V – wind speed
A - collision area
a_1, a_2, a_3 - coefficients

According to ISO12494



- Methods to estimate icing losses based on ice filtering of measurment data
- Calculation of icing intensity using **METAR data**
- Calculation of icing intensity **meso scale model** data.
- Validation of ice load against sparce measurements
- Created first regional icing maps

- Use of the modelled ice loads to estimate production losses based on Seifert and Richerts wind tunnel experiments (1998)
- No SCADA data to validate these calculations was available.



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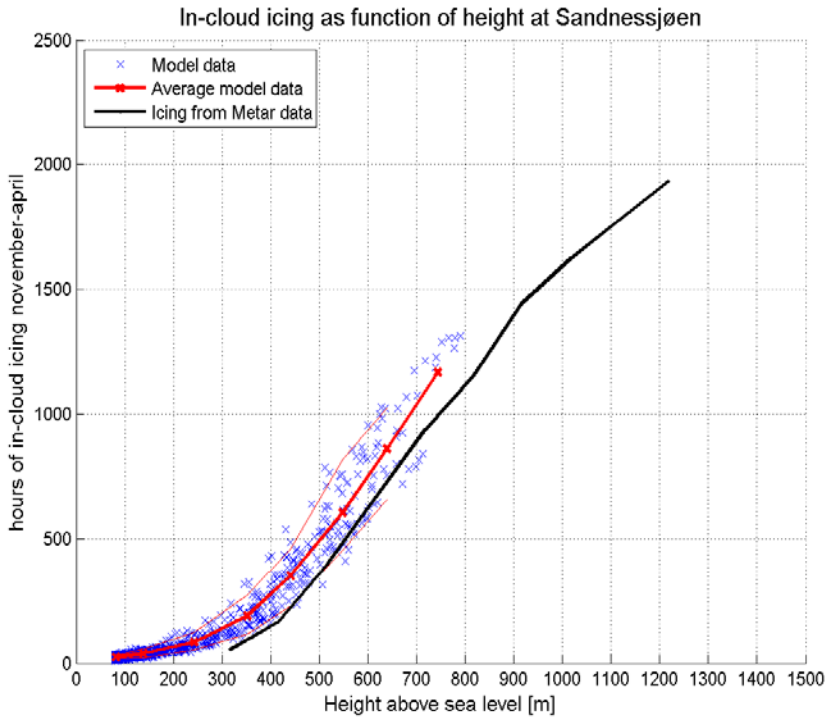
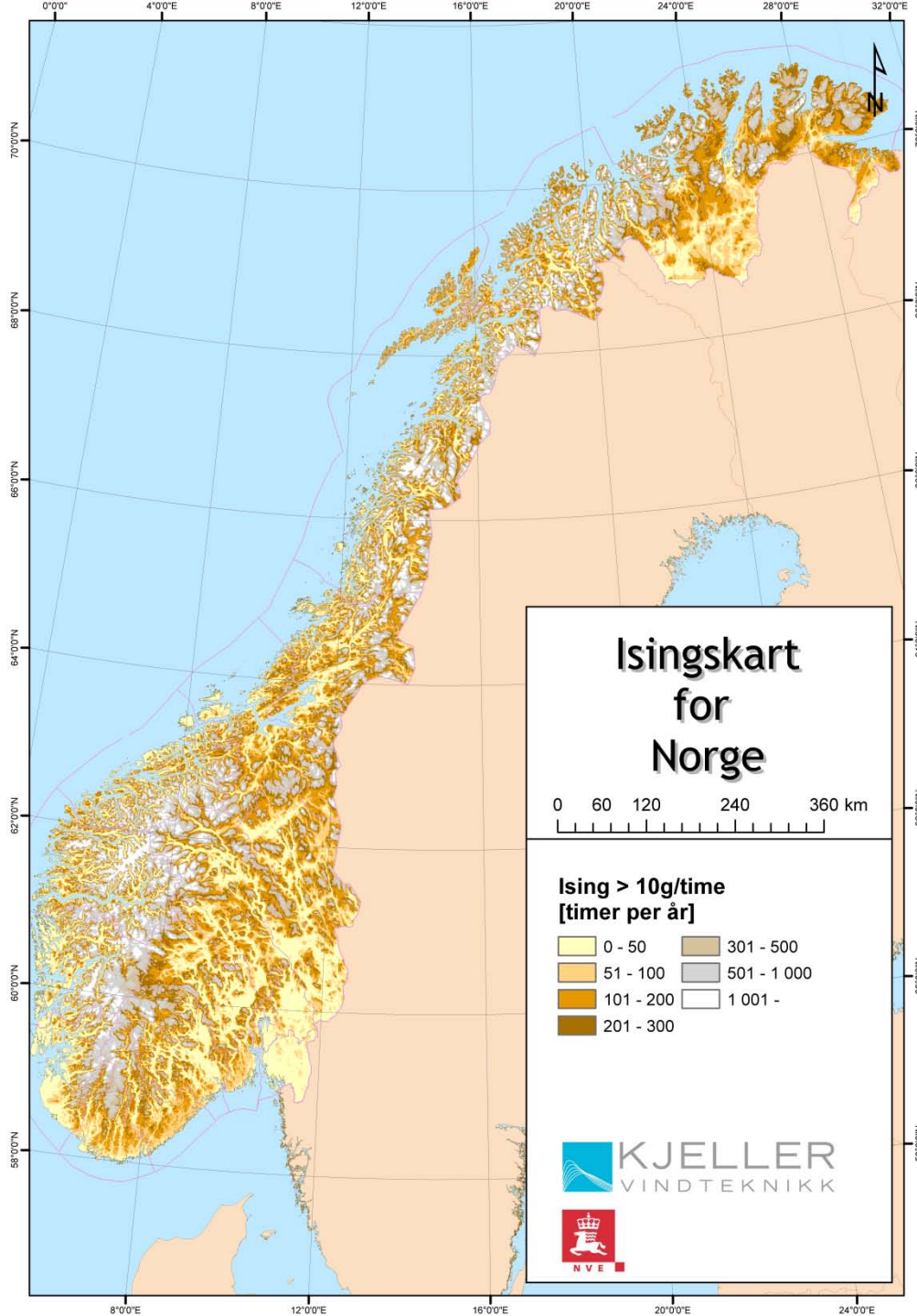
2009

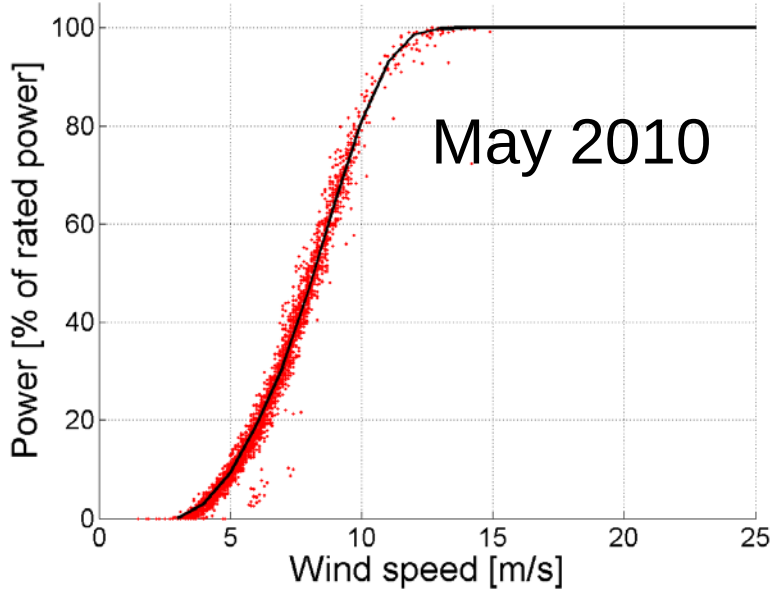
- Wind and **icing map for Norway** finalized.
- Modelled icing hours validated using METAR data at airports.

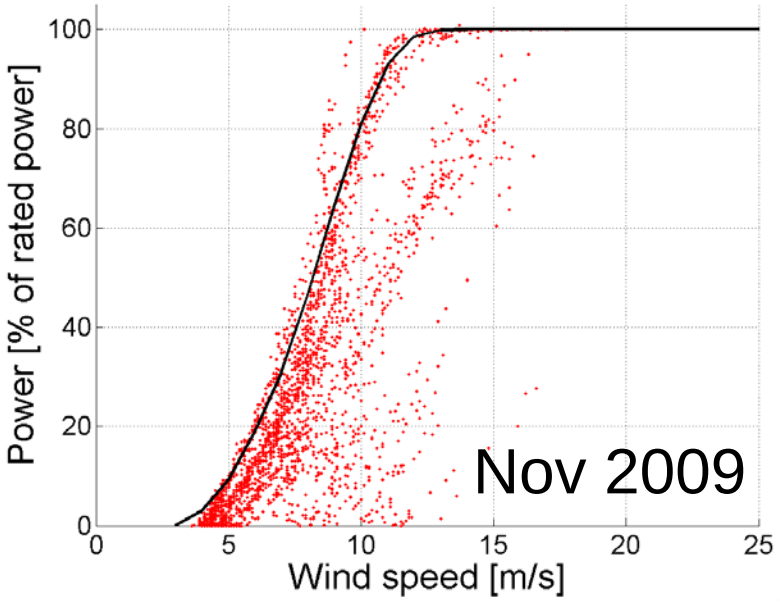




2010

- Energimyndigheten: the wind pilot project started
- **Measurmements of icing** at several Swedish locations became available:
  - Improved calculations of icing
- **Access to SCADA data** from a number of wind farms:
  - Further development of the IceLoss model





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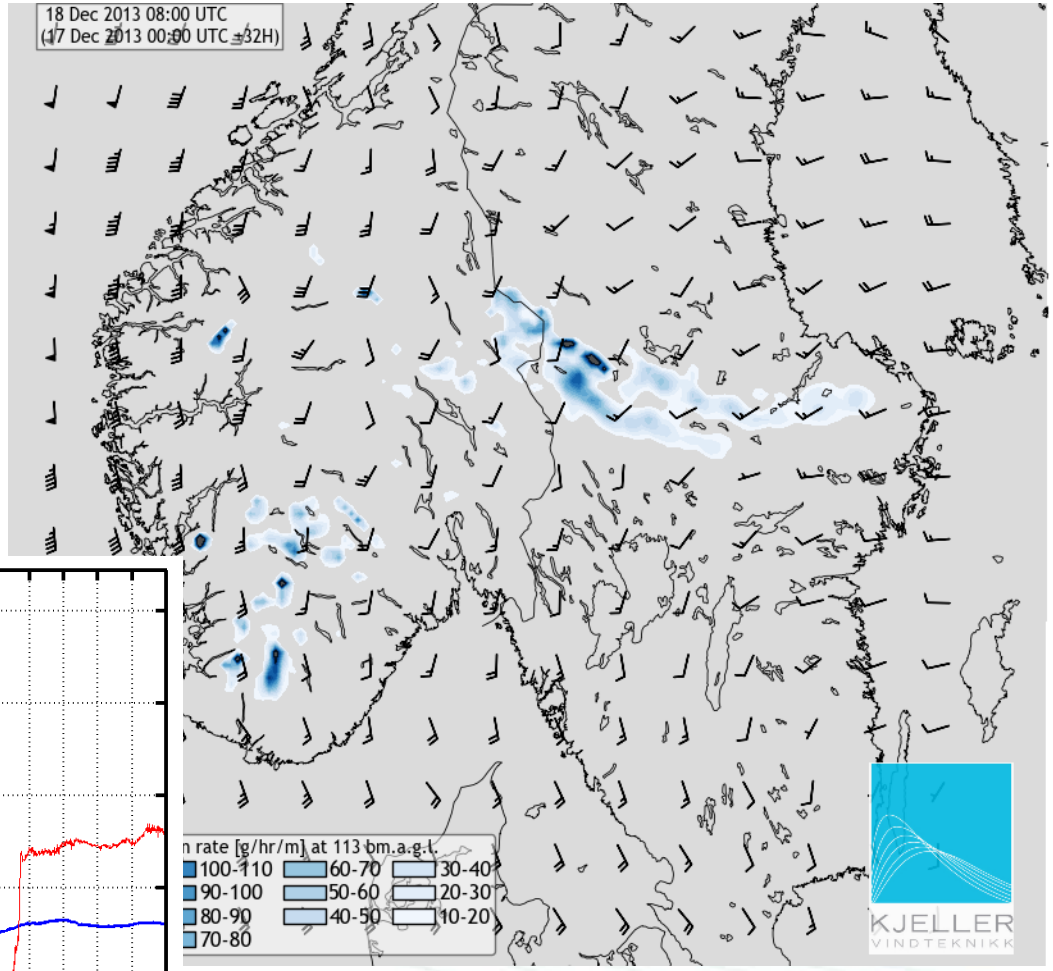
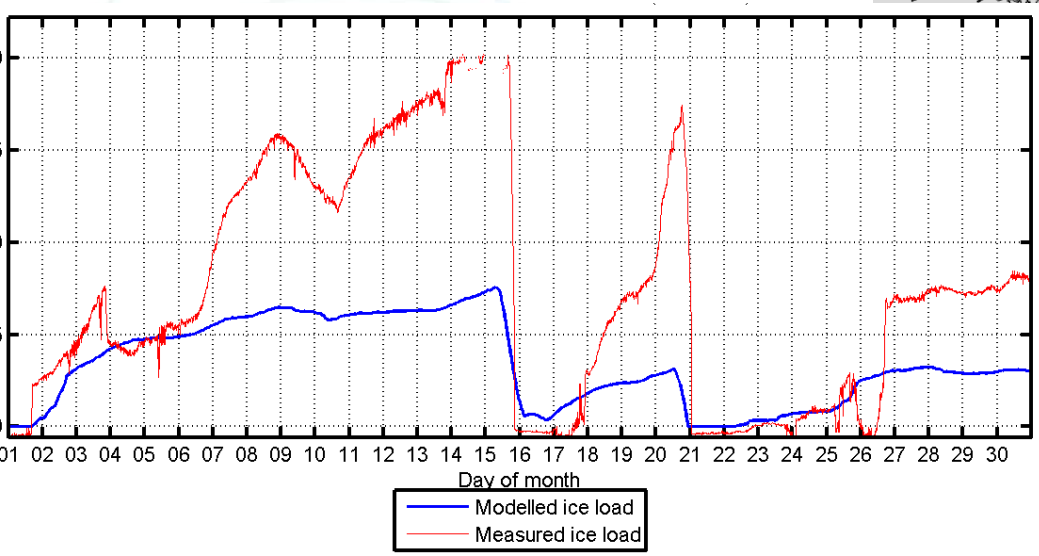
2011

- **IceWind** project with VTT, DTU met.no and others started
- Forecasting of icing and production losses started
- More icing measurements and more SCADA data available





- Developed **the icing map for Sweden**
- Access to SCADA data from several turbines with **ice prevention systems** Validation of models for predicting production losses for turbines with blade heating systems.
- SCADA data from turbines with different **operating strategies**.

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- Contribution to **IEA task 19** Recommended practices.

Table 1: IEA Ice Classification

IEA Ice class	Meteorological icing	Instrumental icing	Production loss
	% of year	% of year	% of annual production
5	>10	>20	> 20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	<1.5	0 - 0.5

icing map

*Best practices for wind energy in cold climates – Resource assessment and site classification

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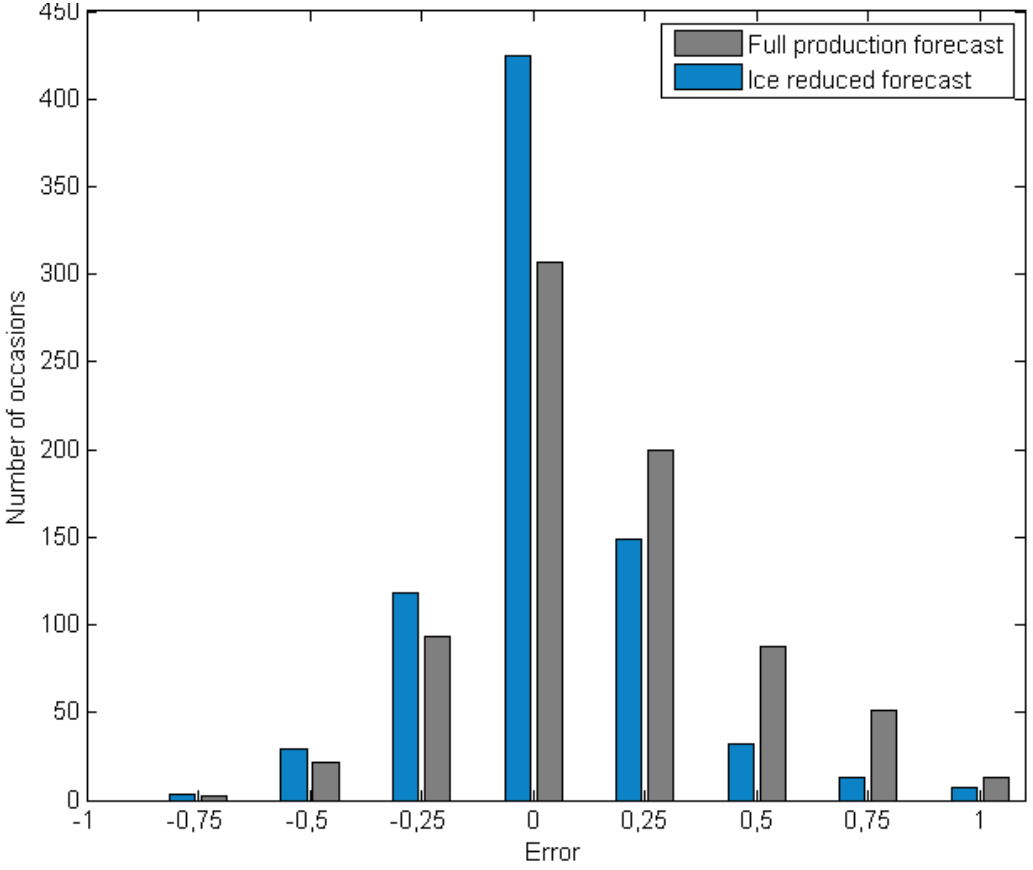
- **Validation** of the operational icing forecasts
- **IceWind**: Recommendations for the use of SCADA data to determine icing periods and icing losses. (N. Davis, DTU)



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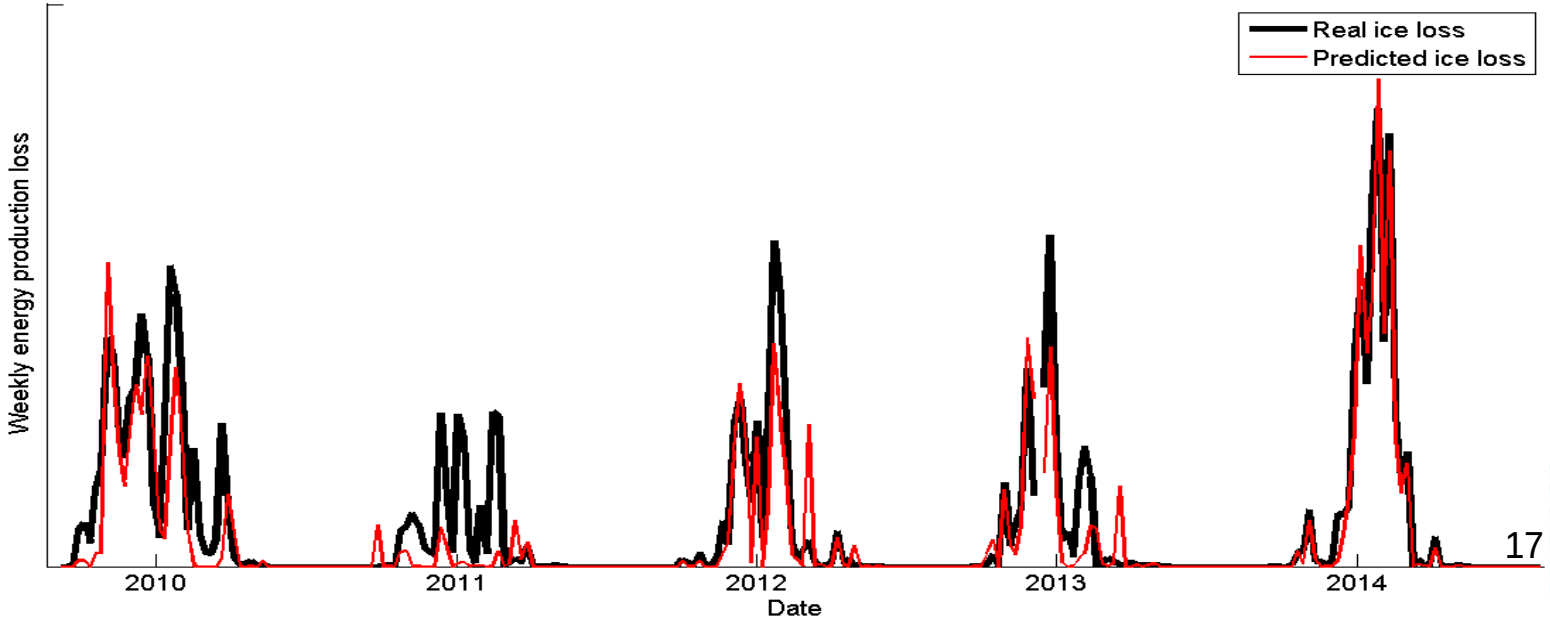
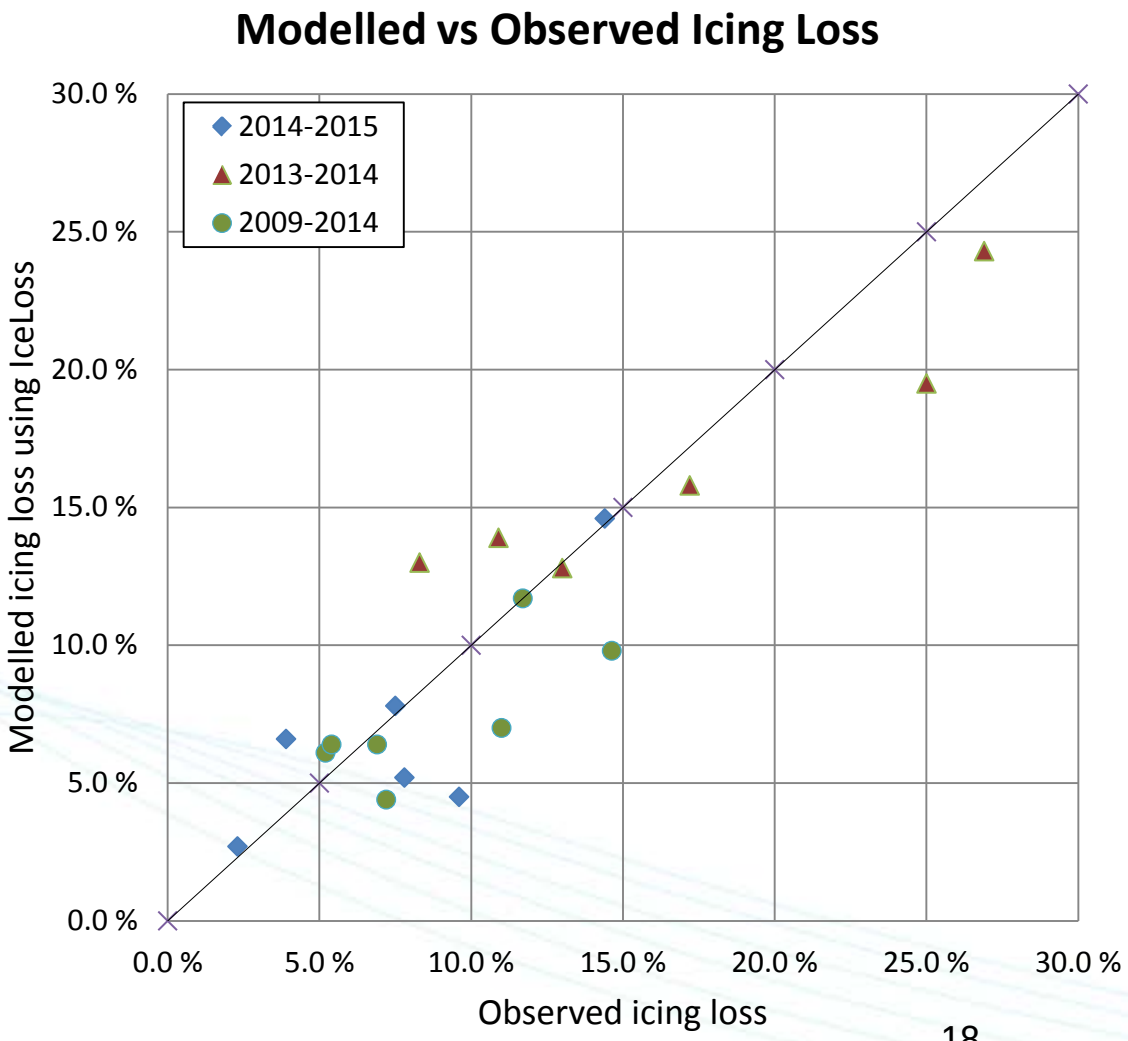
- **ProdOptimize** project: further development of IceLoss: individual turbine calculations.
- Development of a ballistic model for calculation of ice throw (R. Bredesen) – IceRisk
- IceLoss calulations carried out for **more than 100 wind farms**
- Time series of several years of SCADA data – validation of year to year variability in icing losses



- **Validation** of the icing map based on reported production values for several Swedish wind farms.
- **Frontlines** project: development of methods to calculate icing on power lines. (KVT, Statnett, VTT, met.no, STRI, UiT)
- **WISLINE** project: Icing in a climate perspective (met.no, KVT, NCAR)



- Frontlines: Development of methods to estimate the **liquid cloud water** based on IceTroll measurements. (E. Iversen, Winterwind 2017)

- Frontlines: Wind tunnel experiments to improve the ice accretion models

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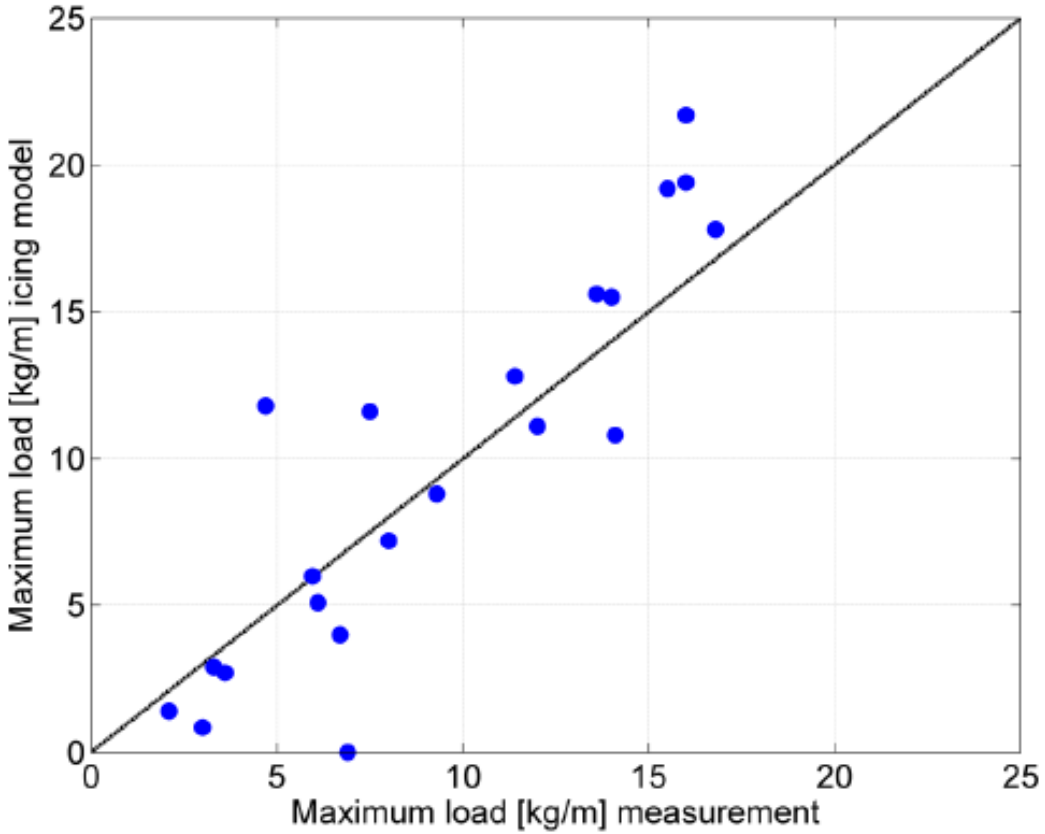
- Frontlines: Validation of modelled and measured maximum ice loads on a power line



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2017 and onwards

- Improved knowledge of ice buildup and the modelling of icing from the **Frontlines and WISLINE** projects

- Continue development in a new R&D project, **NoIce4Wind**:
  - Ice buildup on turbine blades,
  - icing forecasting
  - ice throw from wind turbines

- Continue contribution to IEA task 19 recommended practices

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Thank you for your attention!

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