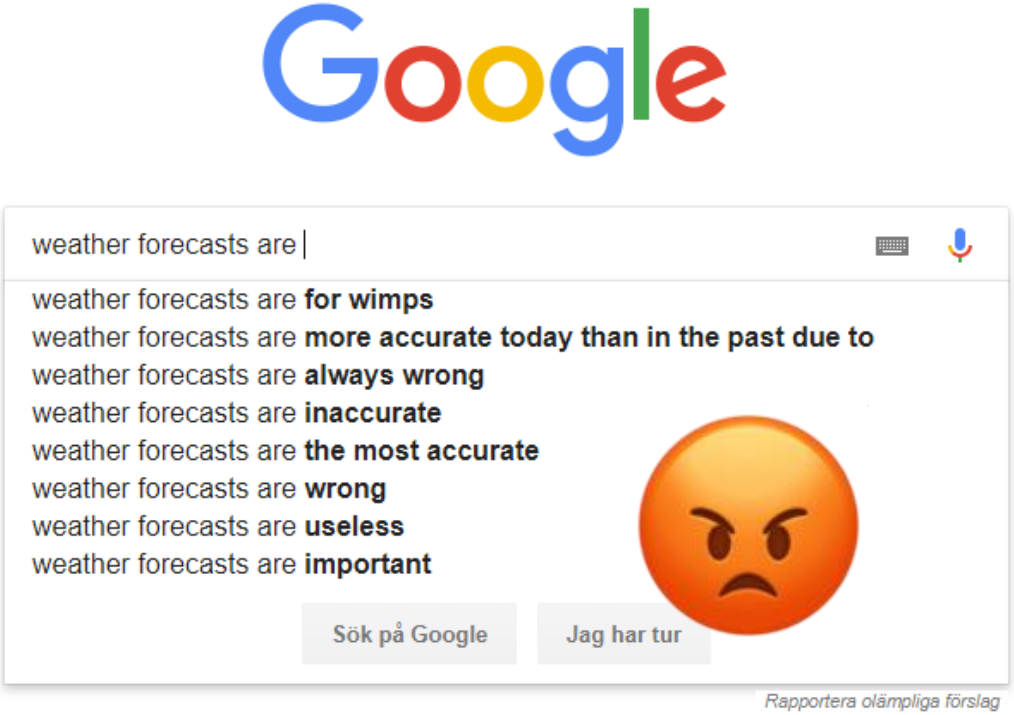
KJELLER
VINDTEKNIKK

Forecasting of Atmospheric Icing
Validation and Applications within Wind Energy

Leon Lee

Winterwind 2019
Umeå, February 5-6, 2019

What's your personal opinion on weather forecasts?



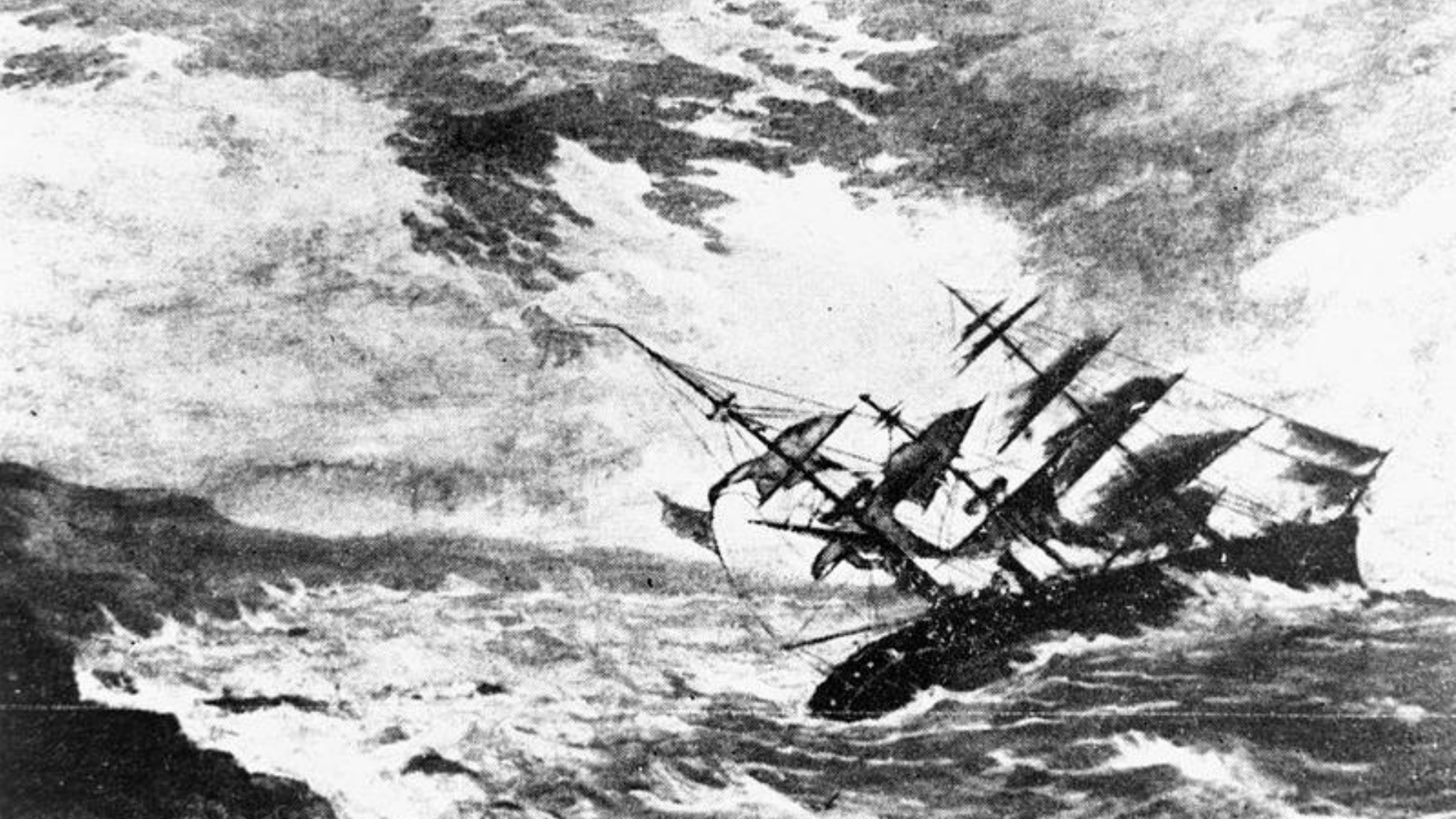


Figure 19: Damaged stairs from an ice fall

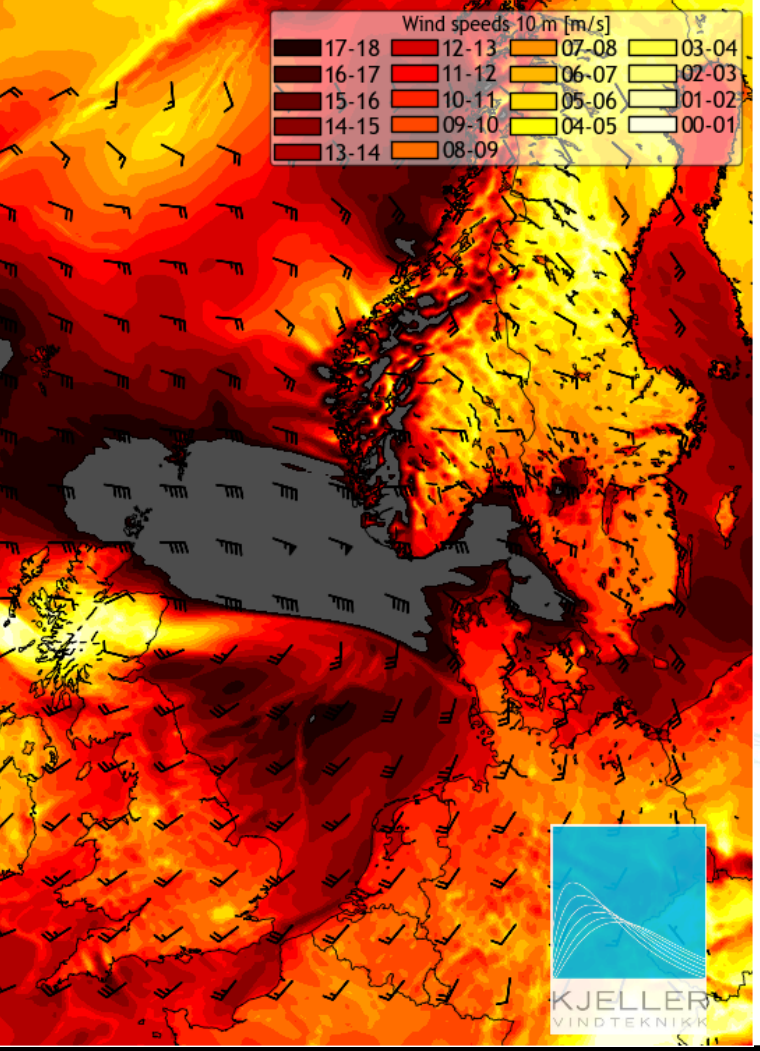
Photo: Statkraft

Ålvikfjellet, 420 kV Sima-Samnanger, January 2014
Photo: Ole Gustav Berge Statnett

Forecasting of icing - motivation

Important to know: **WHEN will** icing occur?

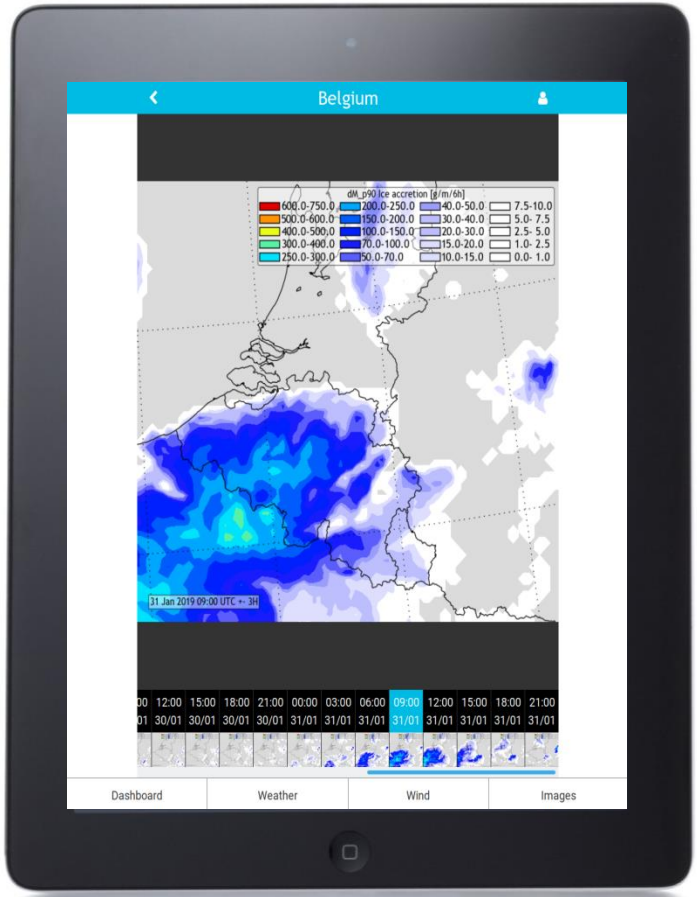
- Power trading
- Blade heating systems:
  - Start the heating before icing starts
  - Avoid unnecessary stops during heating
- Risks of ice throw / ice fall
  - Planning of maintenance
  - Public safety
- Monitoring of exposed power lines
  - Avoid damages



Approach by Kjeller Vindteknikk

- Explain meteorological processes of icing
- Mesoscale model simulations
- Dynamic modeling
  - Wind, Temperature, Solar radiation, Moisture, Clouds, Precipitation etc.
- Icing exposure and sheltering
- Calculations in the time domain

Forecast of icing intensity



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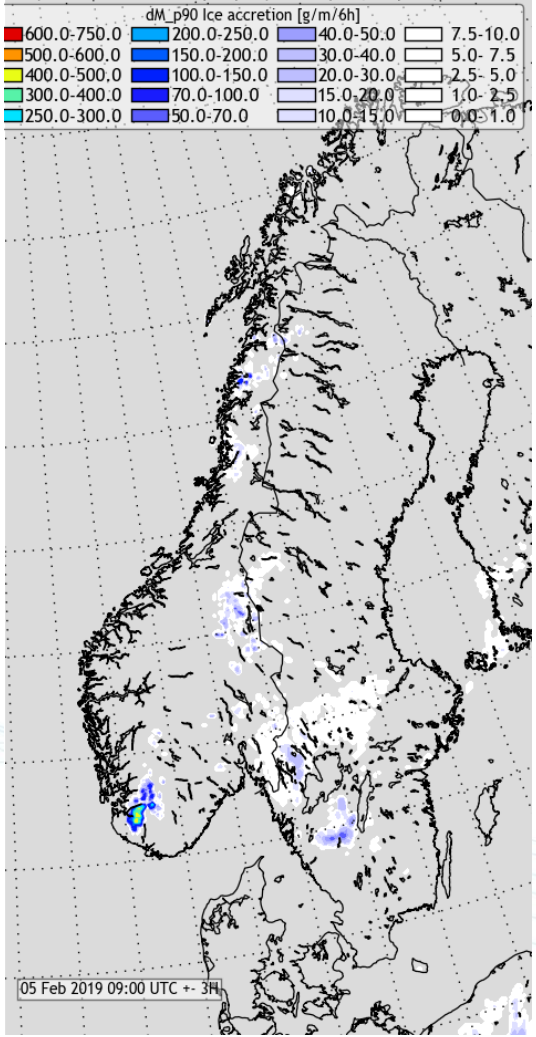

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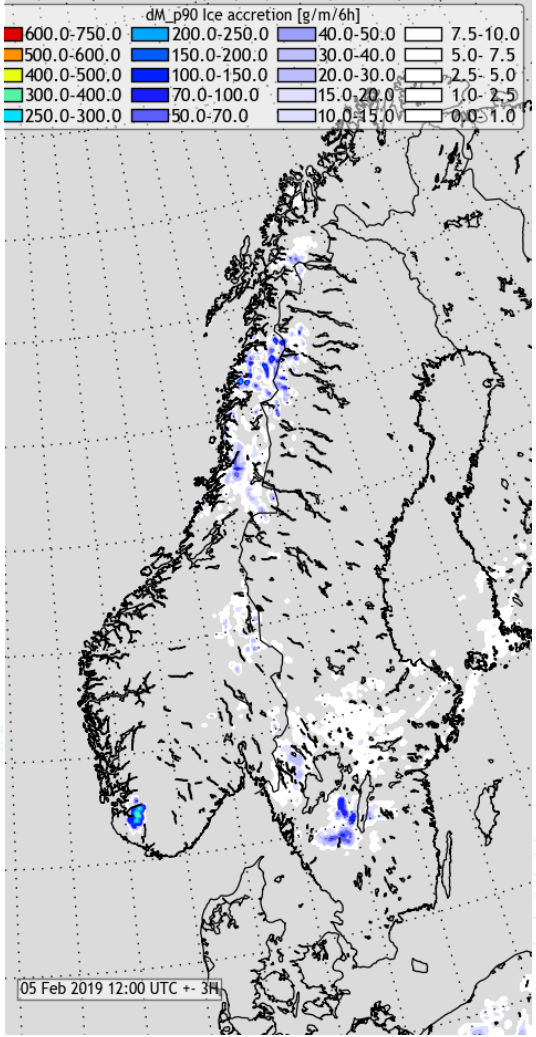

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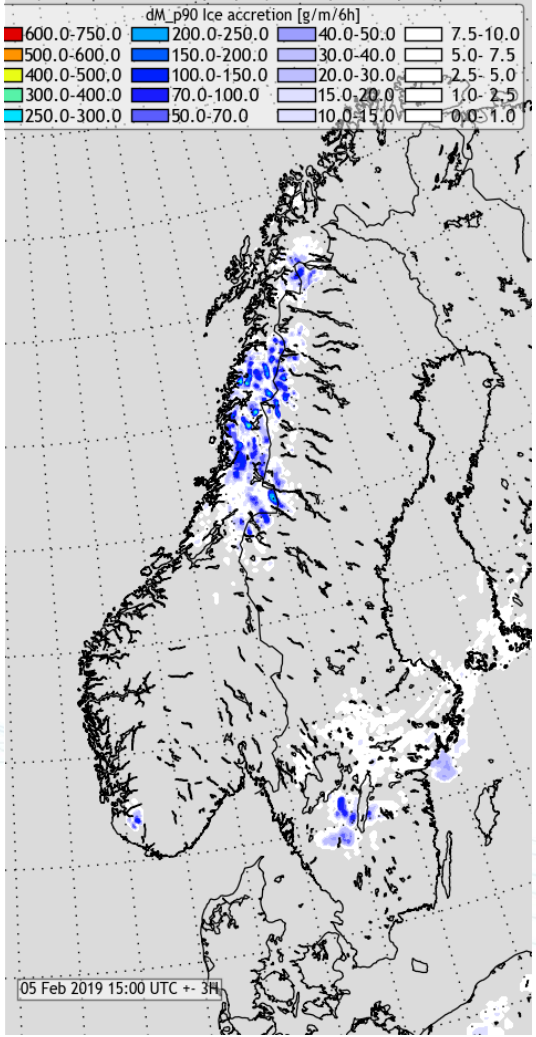

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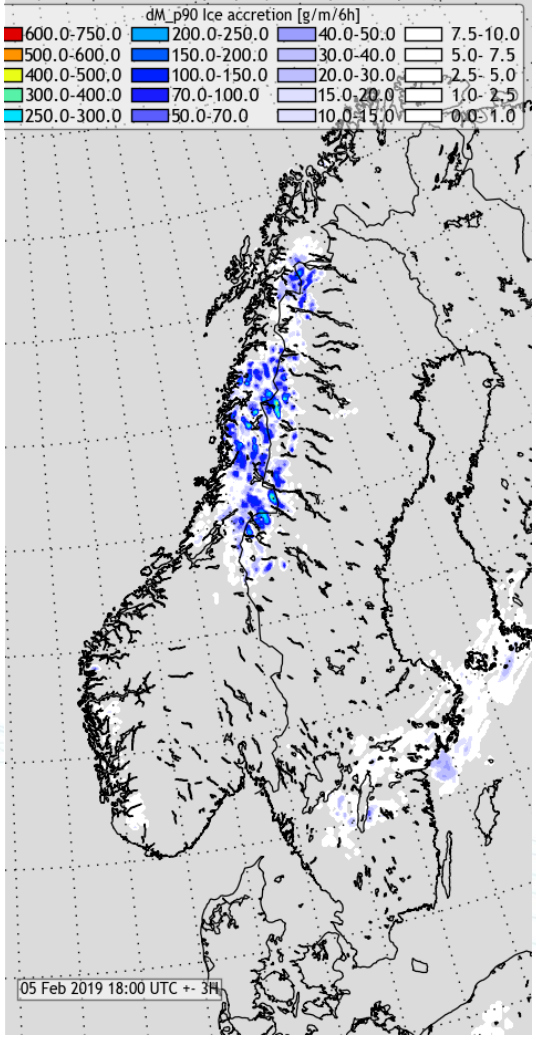

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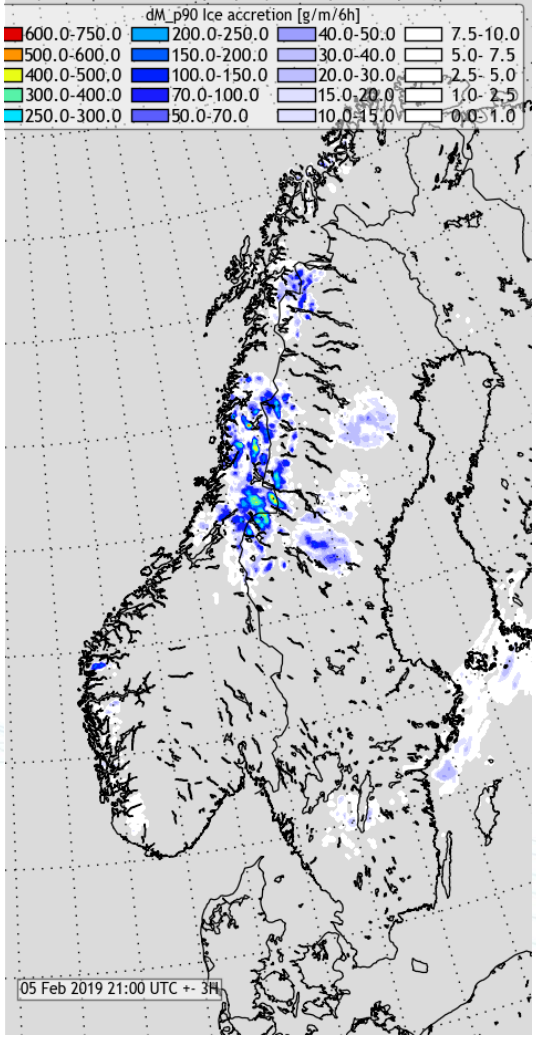

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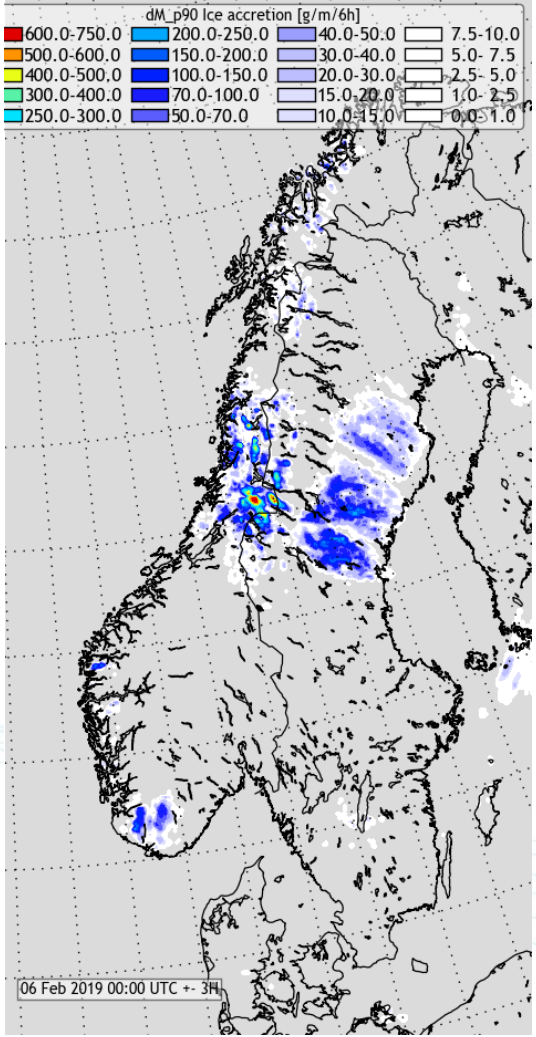

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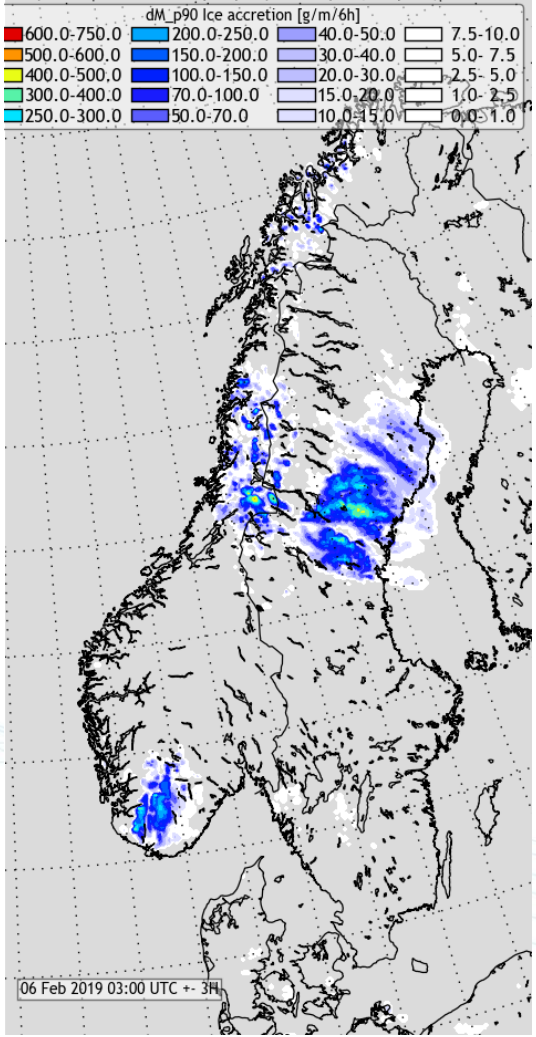

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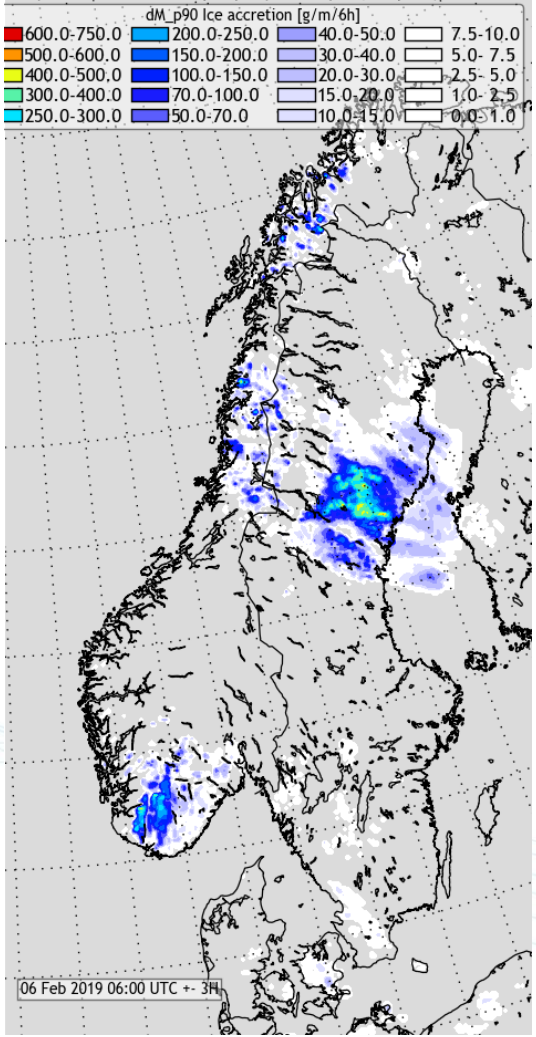

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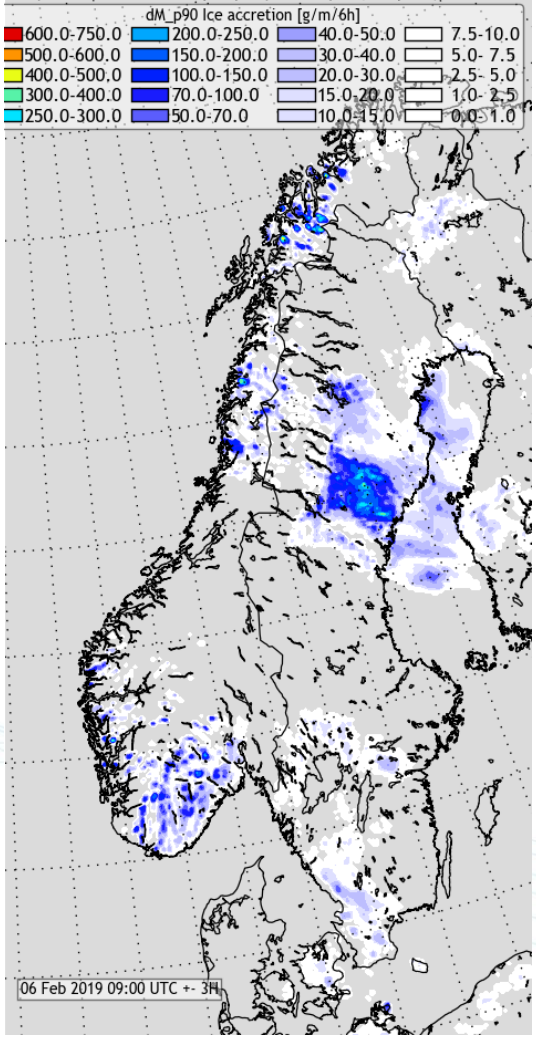
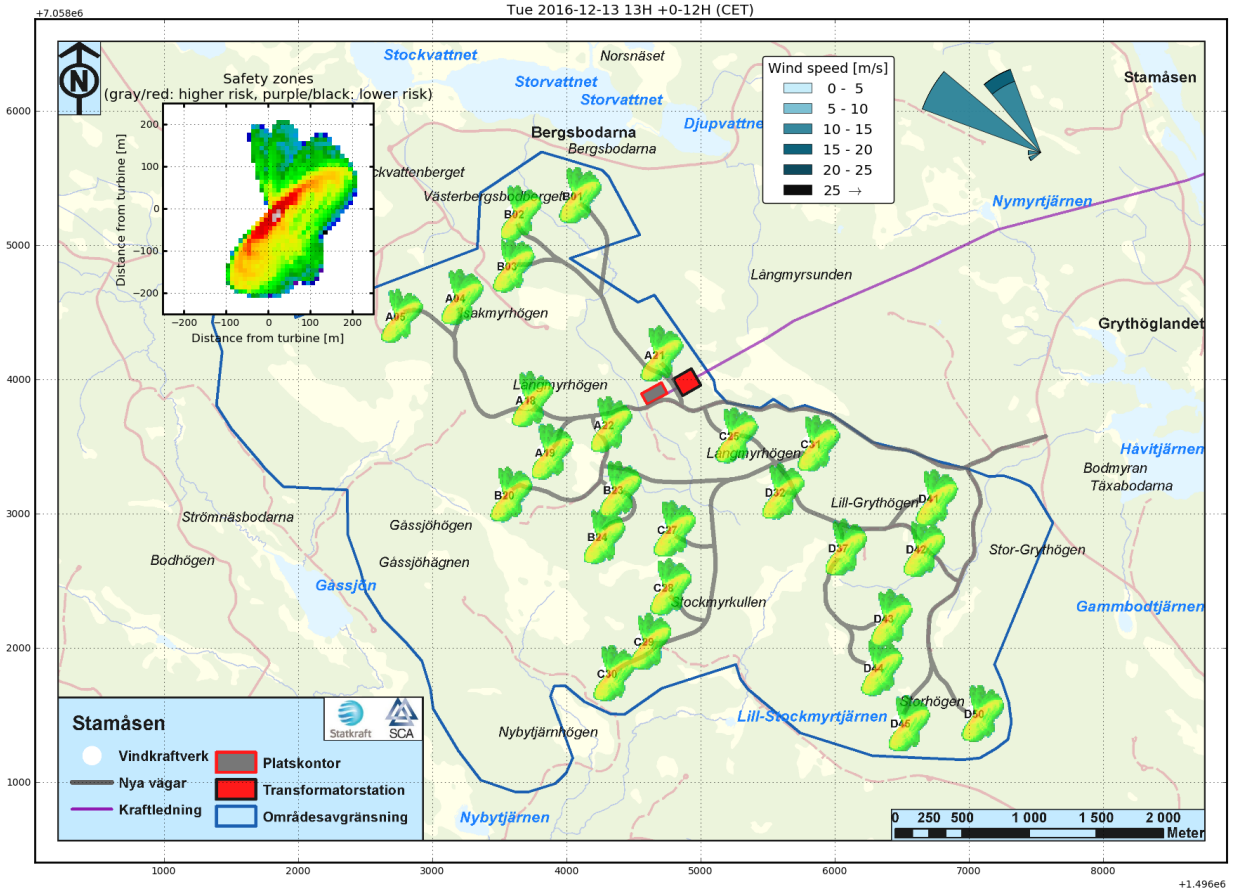
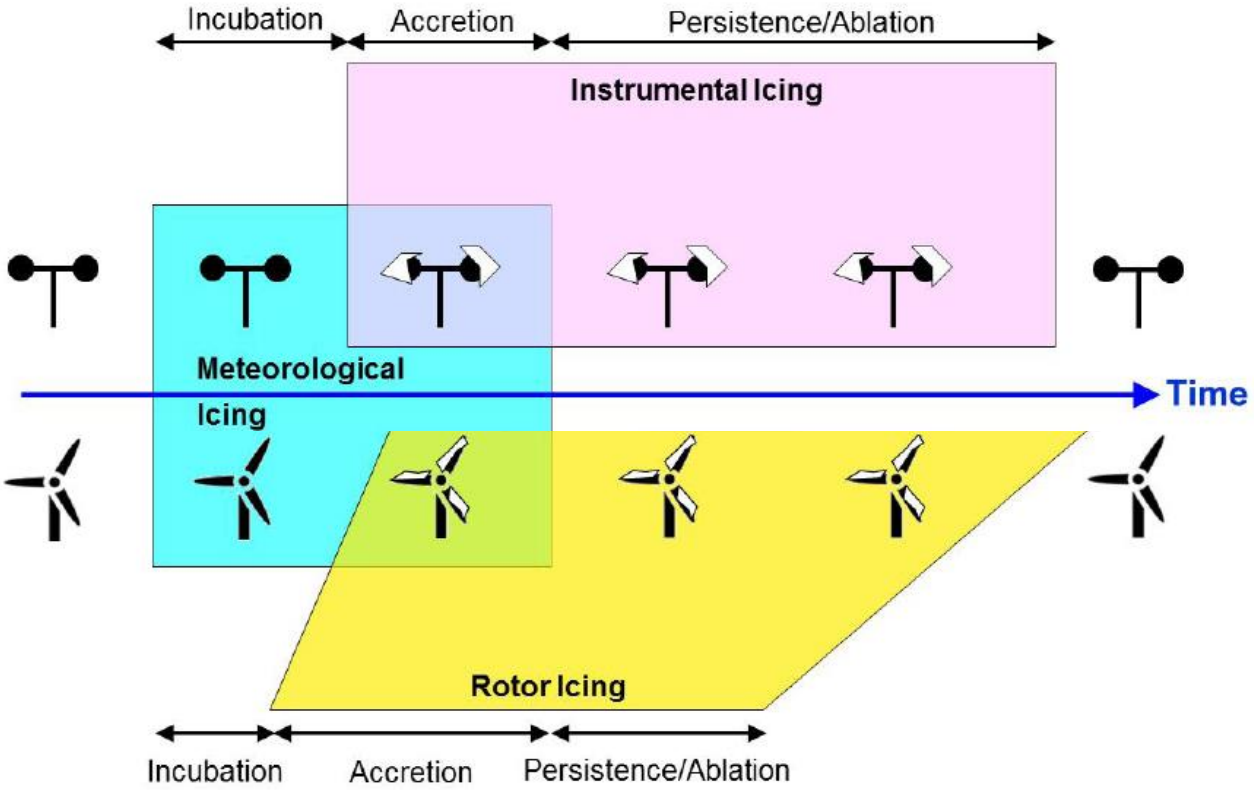


Application of icing forecasts

Forecasting of ice throw zones



Forecast validation



From IEA Wind task 19 - Wind energy in cold climates
Recommended Practices February 2017

IceLoss 2.0

- Two-year research project
- Partly funded by the Swedish Energy Agency
- The next generation state-of-the-art model to give long-term estimates on icing losses
- SCADA data from wind farms

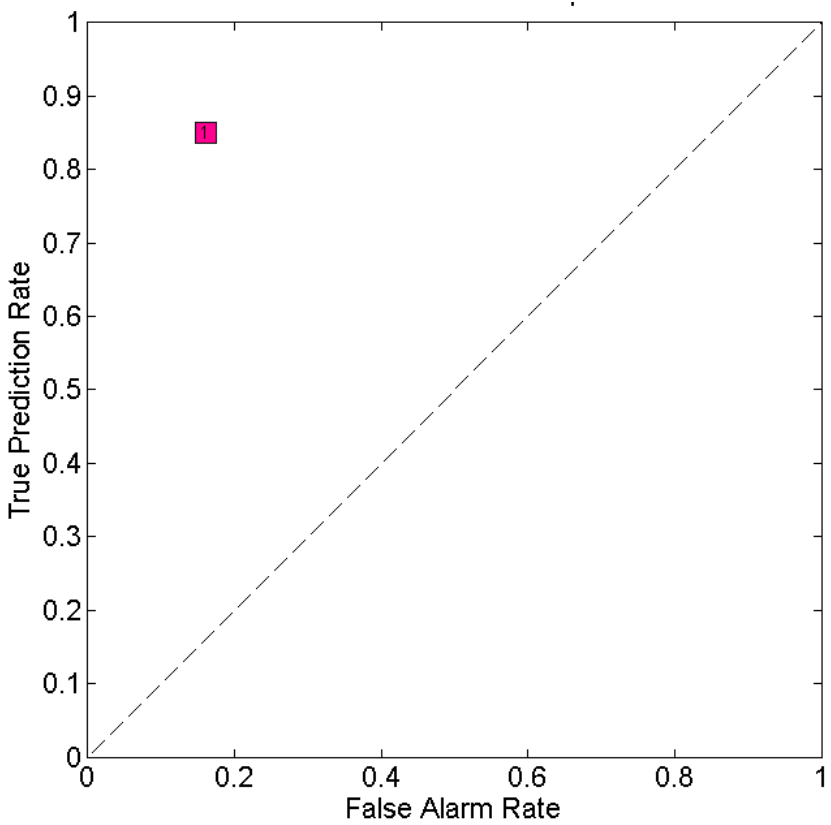
Validation of icing forecasts

- 21 wind farms
- 384 turbines
- 5 years per turbine (average)
- Sweden and Finland

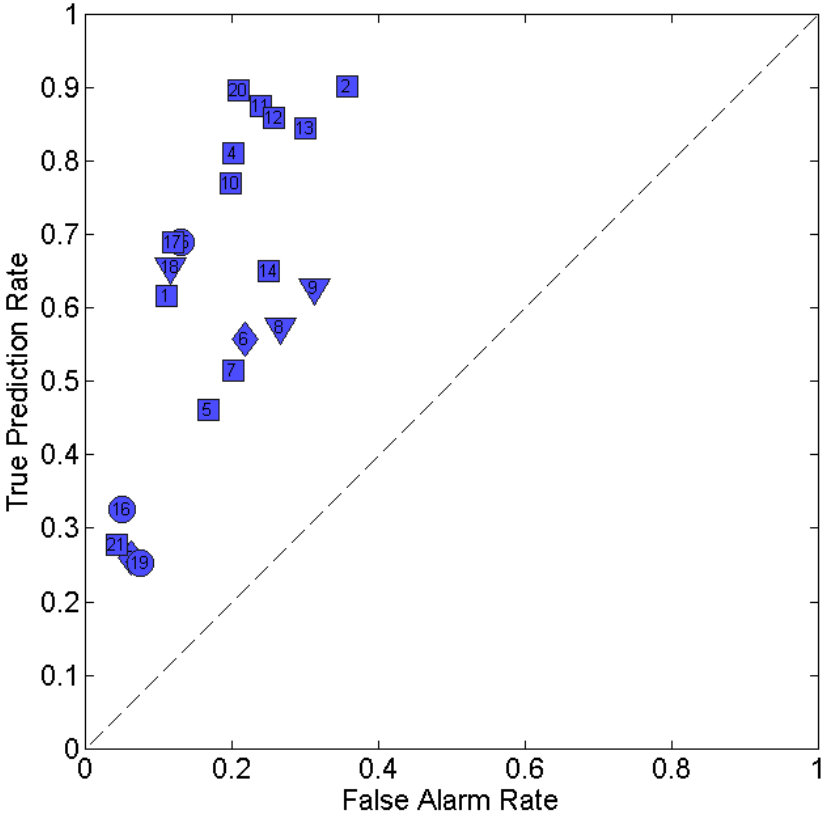
		SCADA	
		Ice	No ice
Forecast	Ice	a	b
	No ice	c	d

- True prediction rate: a/(a+c)
- False alarm rate: b/(b+d)

Validation of icing forecasts



Validation of icing forecasts



IEA Icing Classification

IEA Ice class	Meteorological icing	Instrumental icing	Icing loss
	% of year	% of year	% of gross 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

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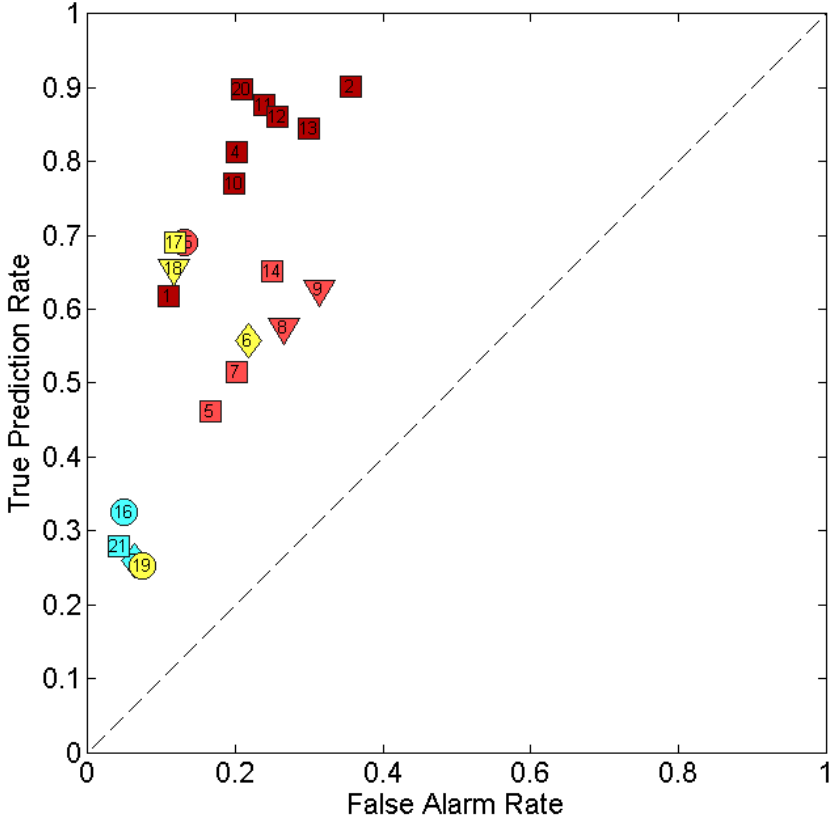
Validation of icing forecasts



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Summary

- Icing forecasts for 21 sites has been compared to data on turbine icing
- The forecasts for wind farms at high icing classes show the highest skill
- Tuning of forecasts for the individual wind farm will improve skill. No such tuning have been carried out for this validation.

Thank you for your attention

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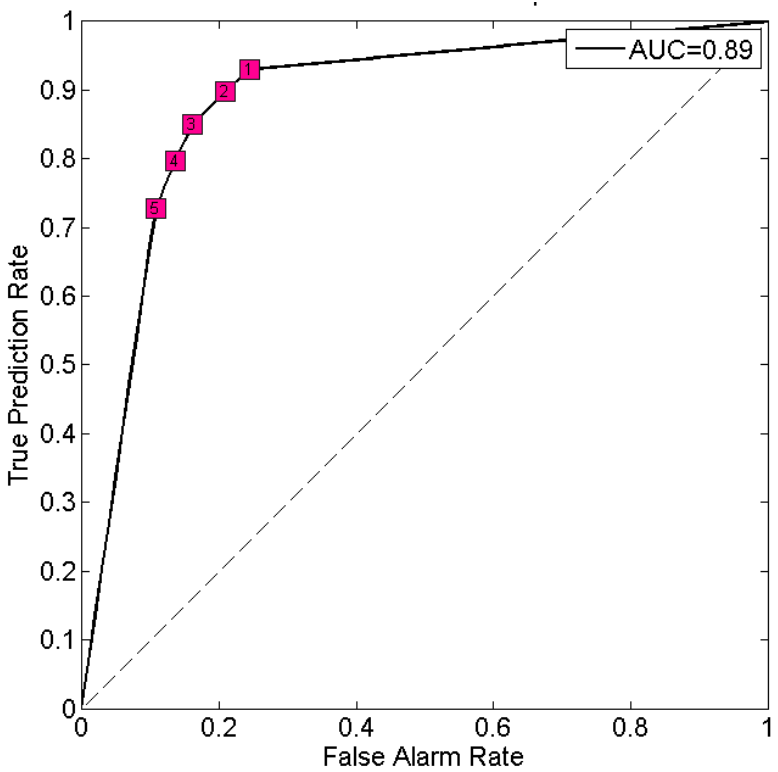
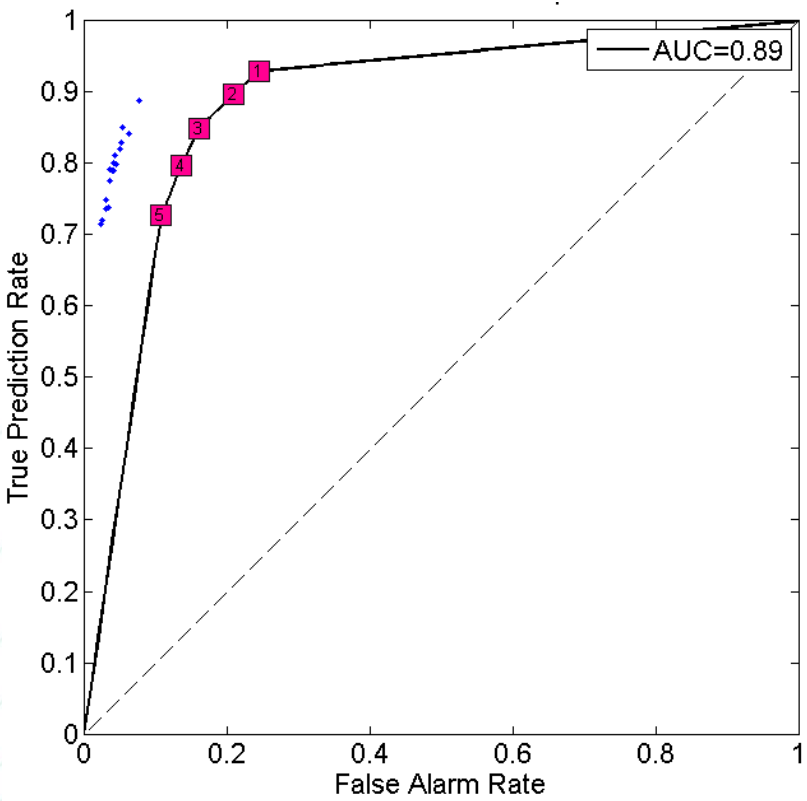
20 YEARS
ANNIVERSARY
1998-2018

EXTRA MATERIAL

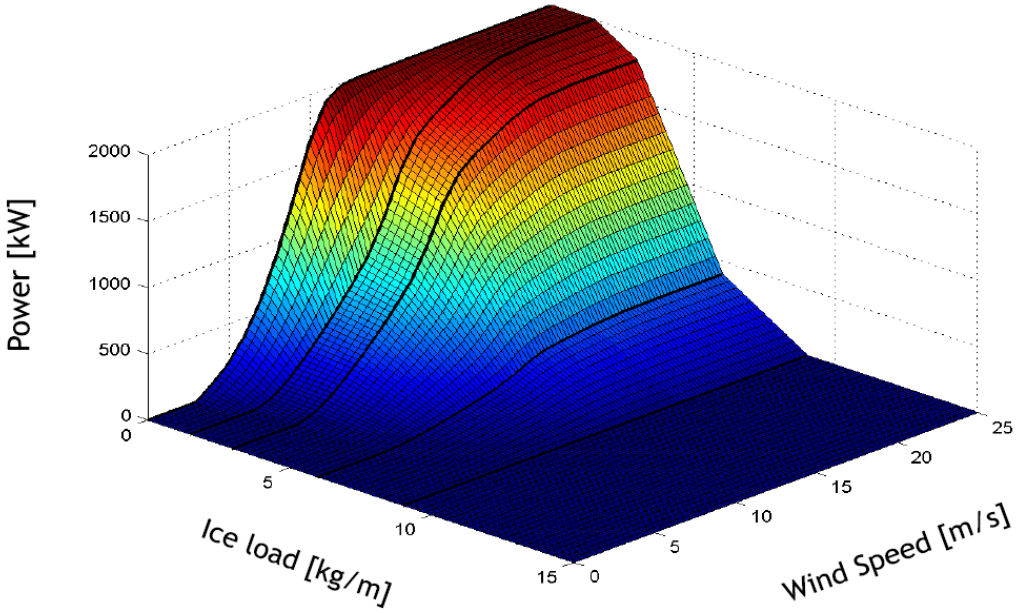
Validation of icing forecasts

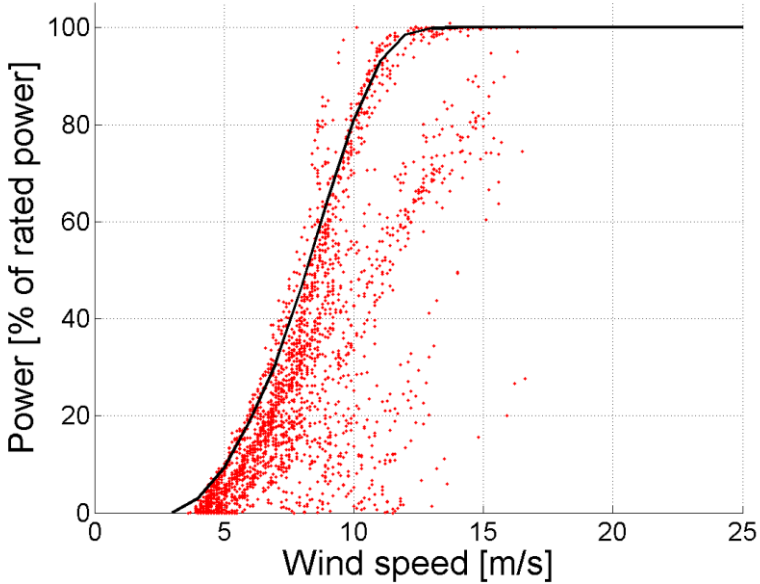


Validation of icing forecasts



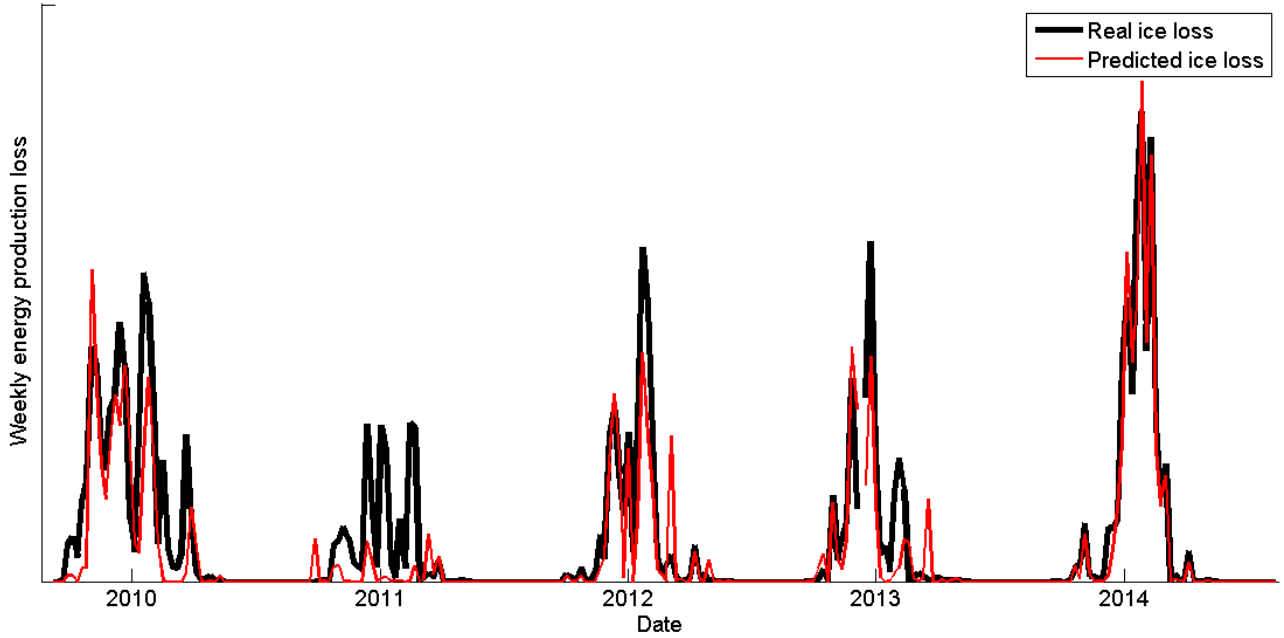
IceLoss


Power [kW]
2000
1500
1000
500
0
0
5
10
15
Ice load [kg/m]
0
5
10
15
20
25
Wind Speed [m/s]


Power [% of rated power]
100
80
60
40
20
0
0
5
10
15
20
25
Wind speed [m/s]

IceLoss

- Modelled vs. Observed icing losses



IceLoss

- Modelled vs. Observed
- So, what to expect?