DNV·GL

ENERGY

Estimating icing losses at proposed wind farms

An update of DNV GL's empirical methods for estimating icing losses at proposed wind farms

Till Beckford

07 February 2017

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Contents

- Operational data
- Pre-construction data
- Icing drivers

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Experience from operational data

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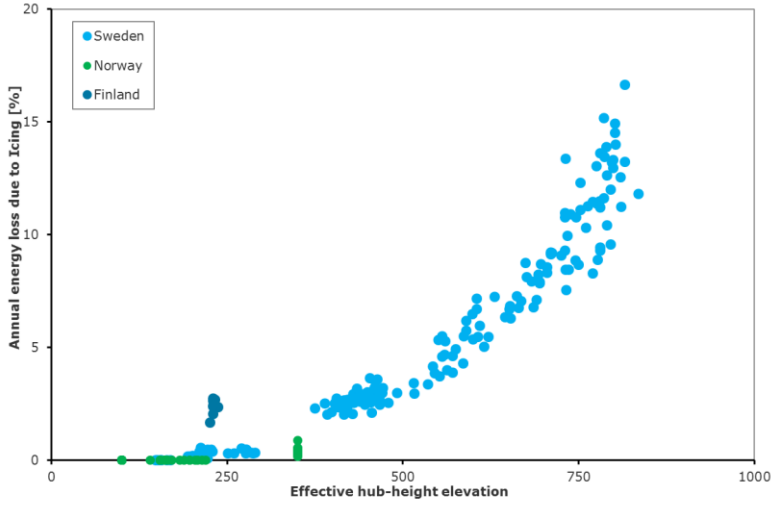
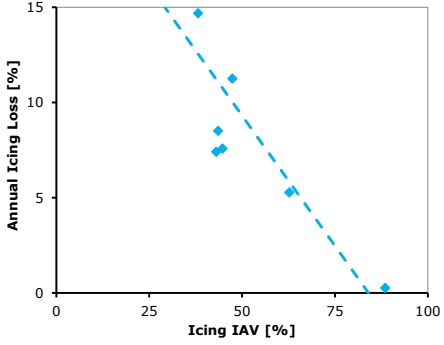
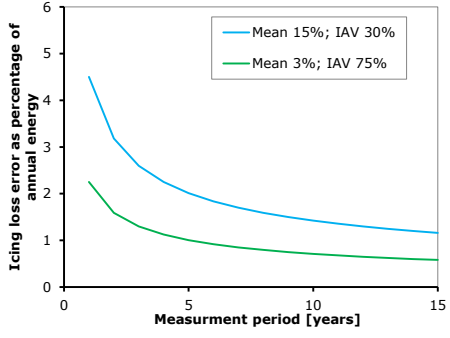
Previously at Winterwind…

- Analysed SCADA data from 20 wind farms in the Nordic region
- Strong relationship between elevation and annual icing loss
- A single Swedish climatology observed
- High inter-annual variability







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New data analysed in 2016/2017

- Data from 8 new wind farms in Sweden and 1 new wind farm in Norway
  - 5 in northern Sweden
  - 3 in the south
- Total of 29 operational wind farms analysed!

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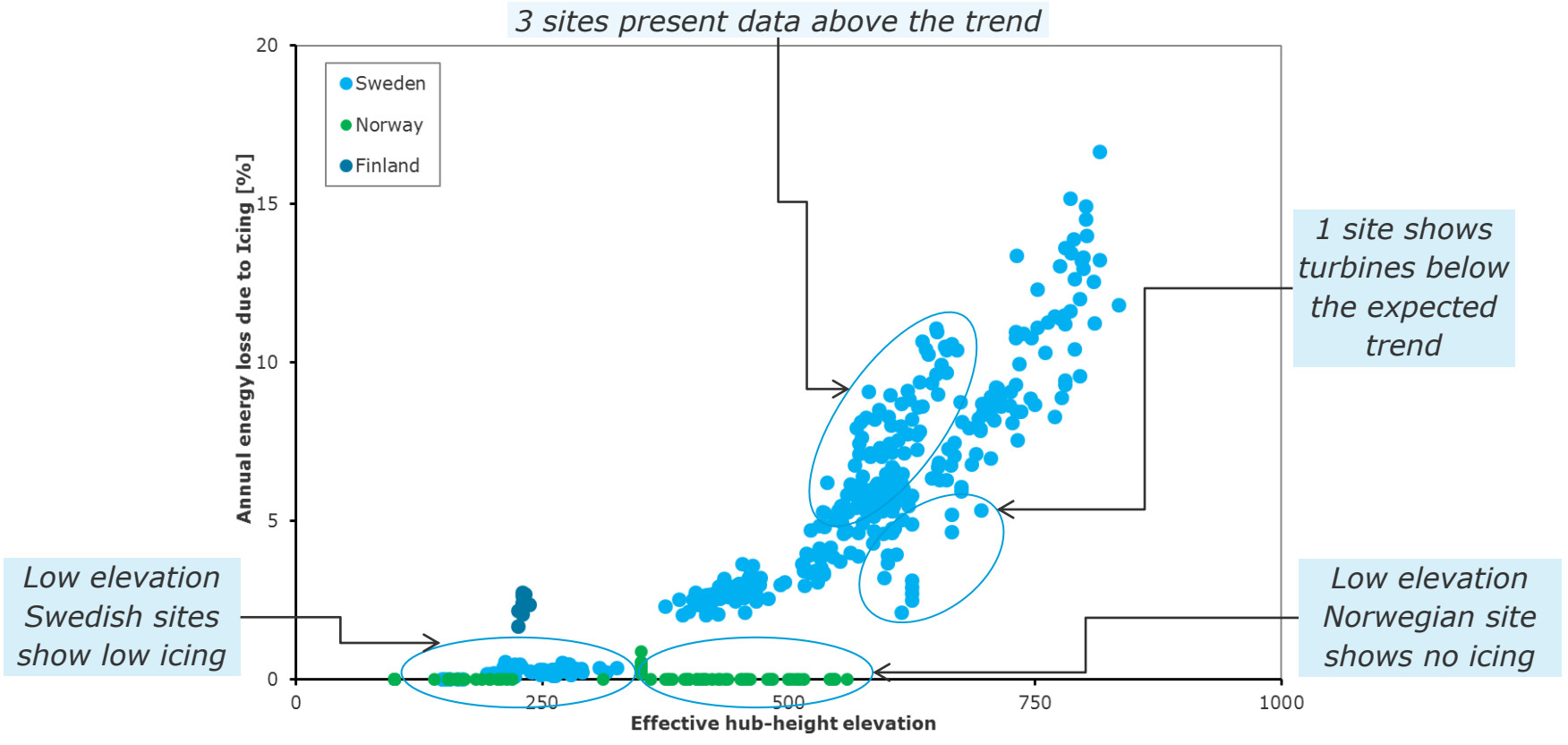
Icing loss vs elevation



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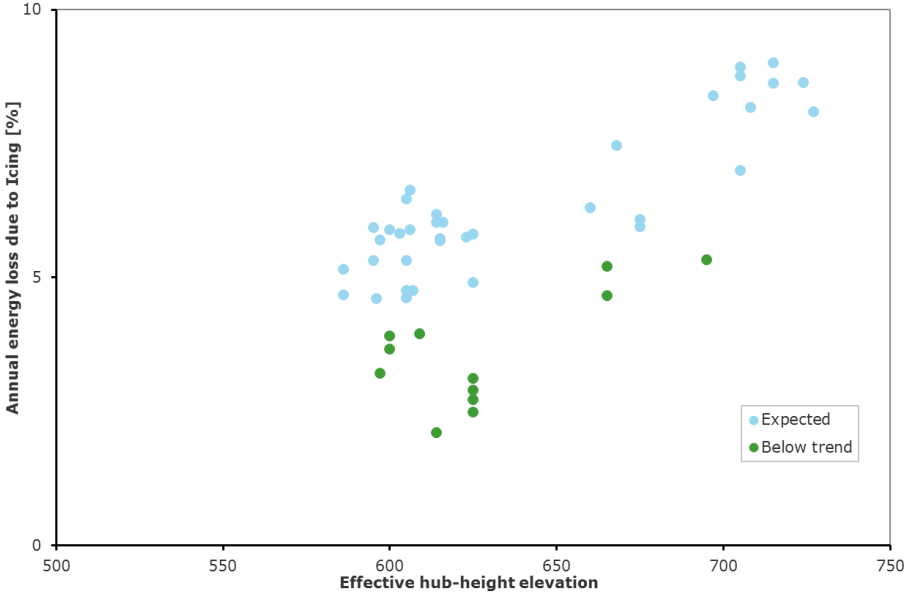
Icing loss vs elevation - turbines below expectation

- Observations from one site, northern Sweden
- Why do some turbines show a reduced level of icing?
- No physical or control change at the turbines
- Turbines with low icing all located to the north west of the summit
  - Leeward location gives sheltering
  - Foehn effect?



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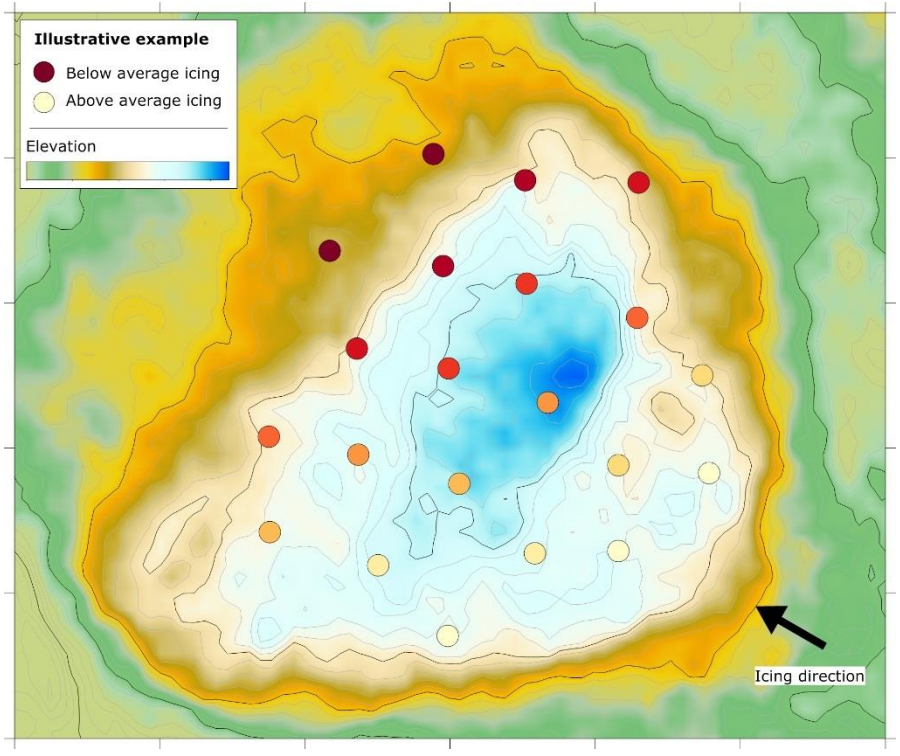
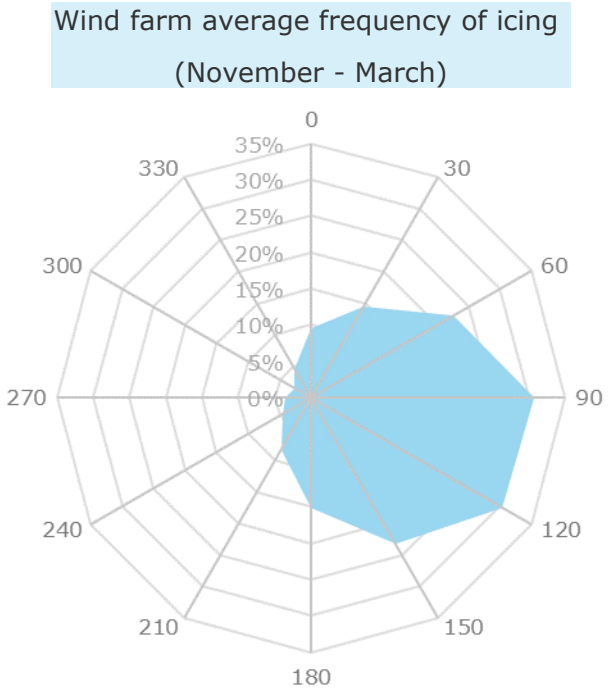
Icing loss vs elevation - Foehn effect illustration





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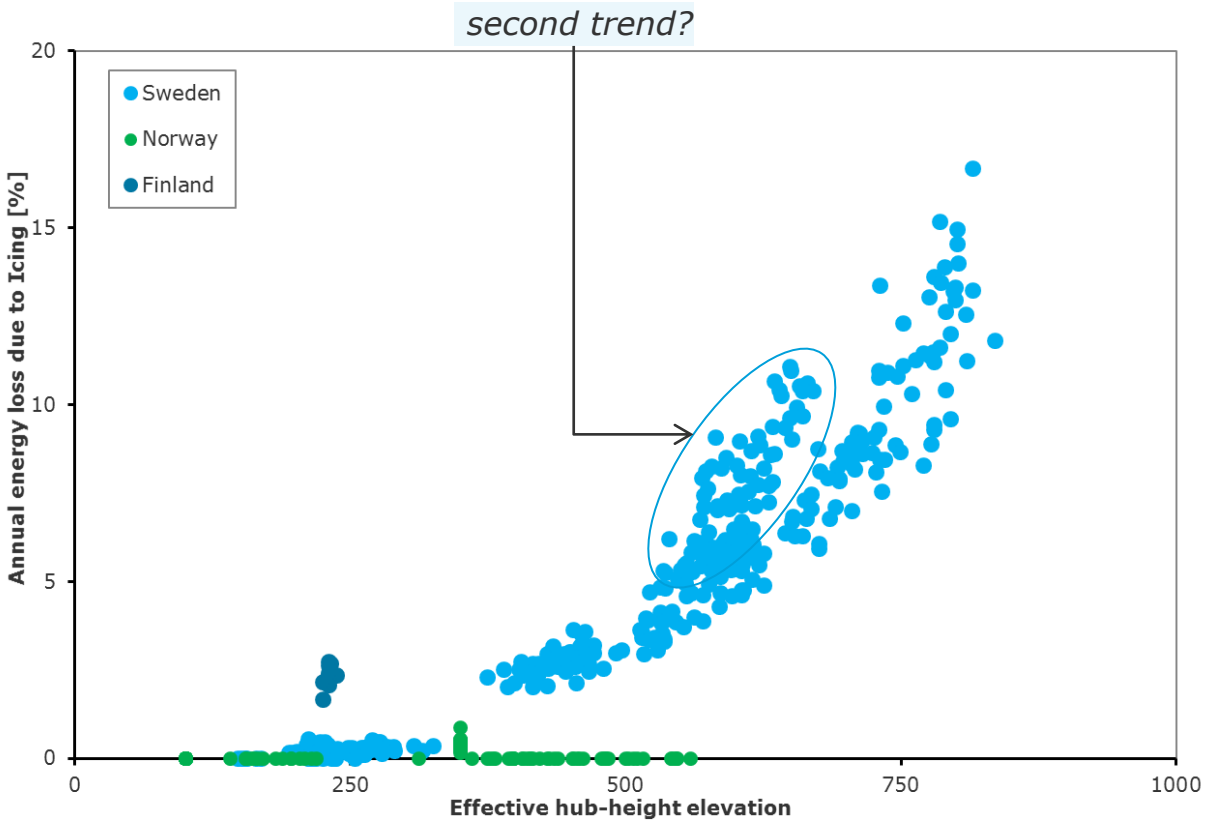
Icing loss vs elevation



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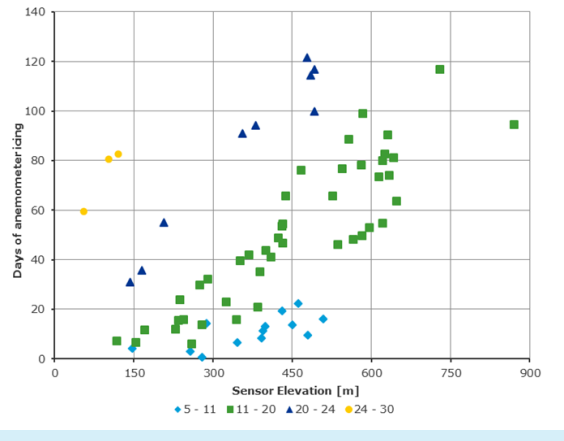
Icing loss vs elevation - second trend

- Previous analysis of anemometer data suggests increased icing from west to east



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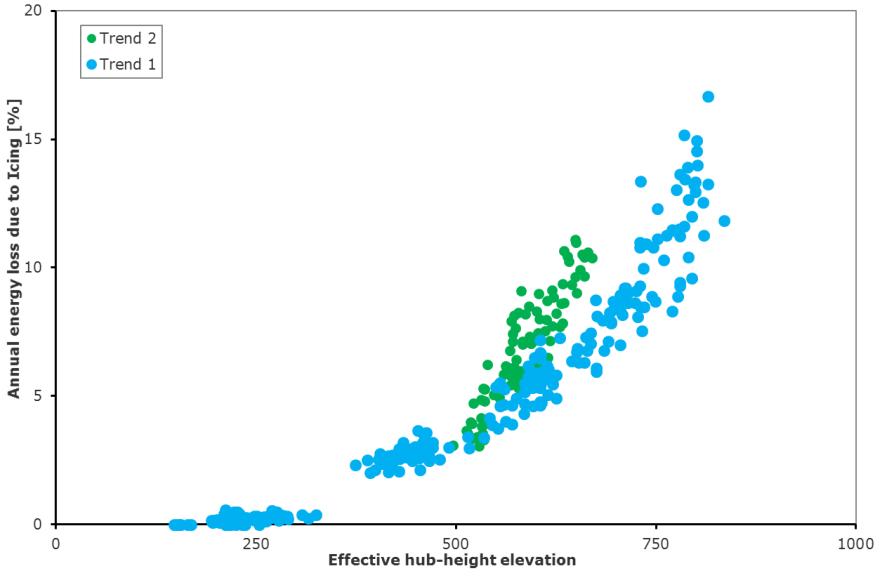
Icing loss vs elevation - second trend

- 3 new sites show an increased level of icing with elevation
- Sites located 100 km apart yet all towards the east of Sweden
- Suggests agreement with anemometer findings
- Further data needed to confirm trend



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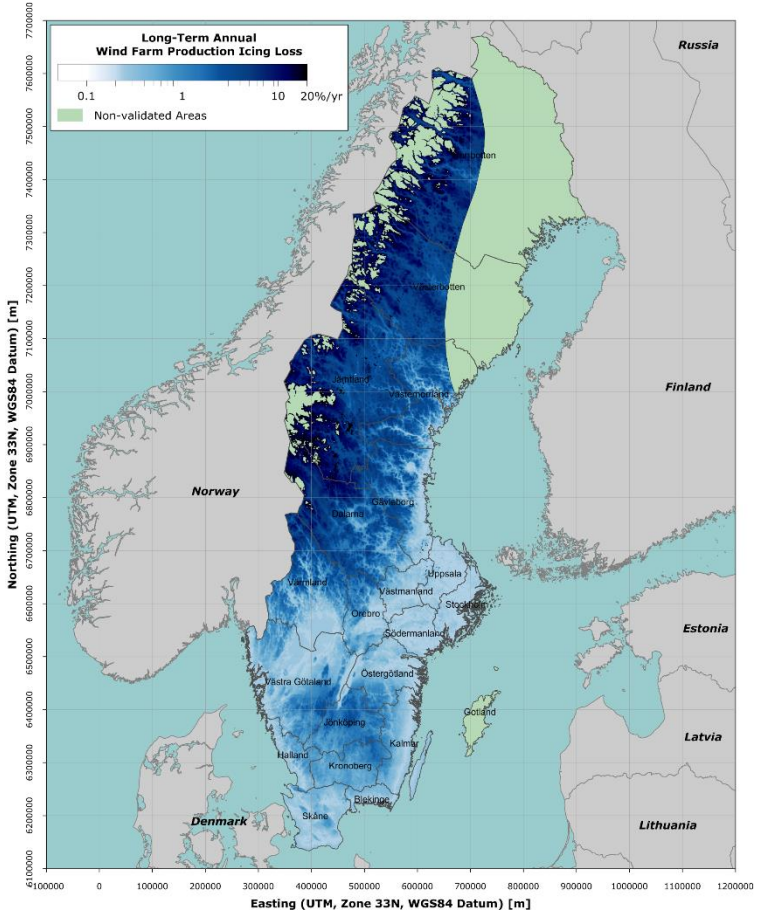
Result – updated Icing Map of Sweden

- Based on majority of Swedish data
  - Excludes second trend sites
- Adjusted non-valid areas based on latest findings
  - More of Västernorrland included
  - Less of Västerbotten included
- No change in annual loss values



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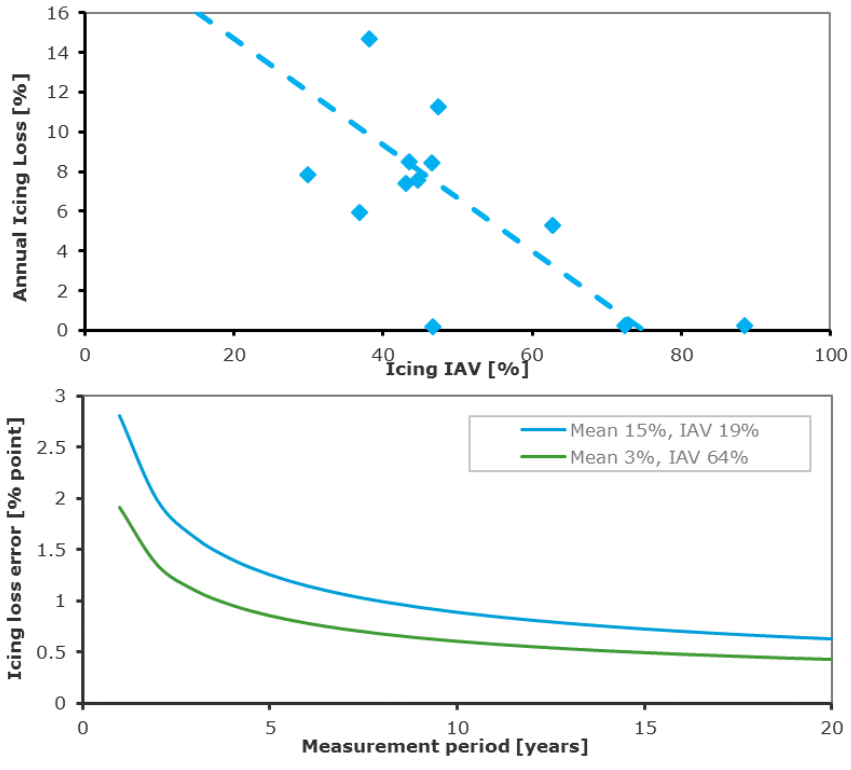
Inter annual variability (IAV)

- Added 5 sites to previous IAV analysis
- Total of 12 sites with 3 or more complete winter periods
- New sites show reduced variability relative to previous data
- Result is reduced uncertainty in energy production
  - However, variability and therefore uncertainty remain high!



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Analysis of pre-construction data

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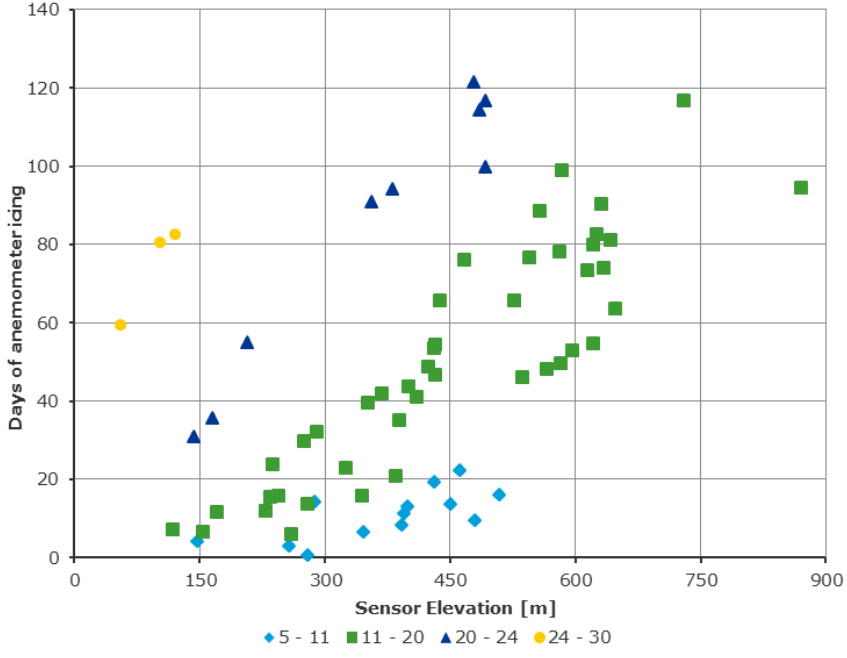
Previously at Winterwind…

- Linear relationship between anemometer icing and elevation
- Identified zones of increasing icing from west to east



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New data 2016/2017

- Added 17 masts
  - 4 in Norway
  - 1 in Finland
  - 12 in Sweden
- More than 90 masts in the dataset

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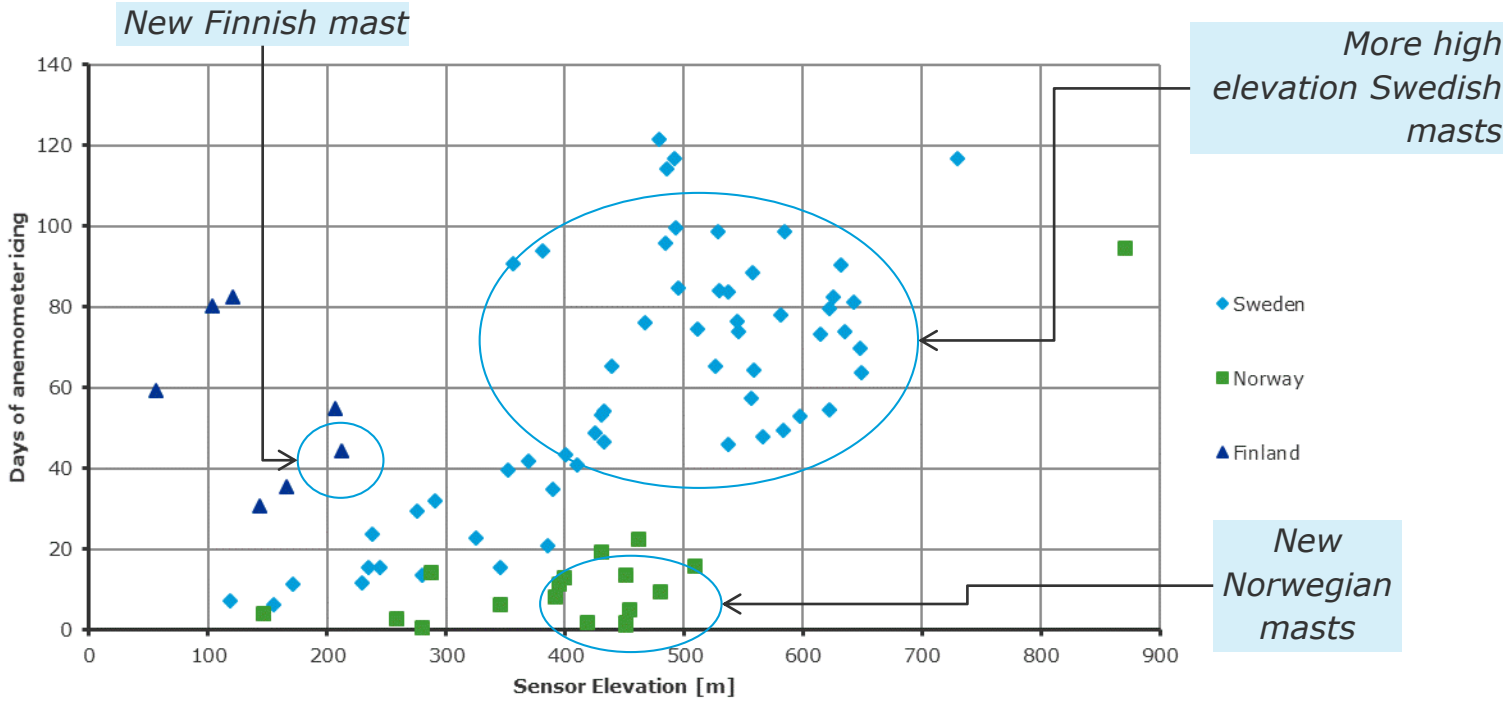
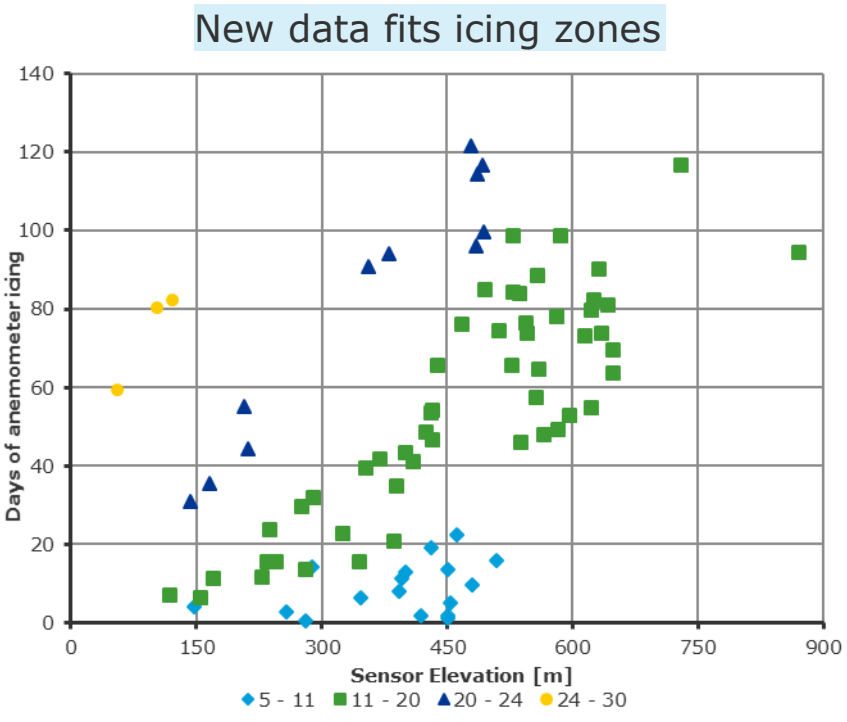
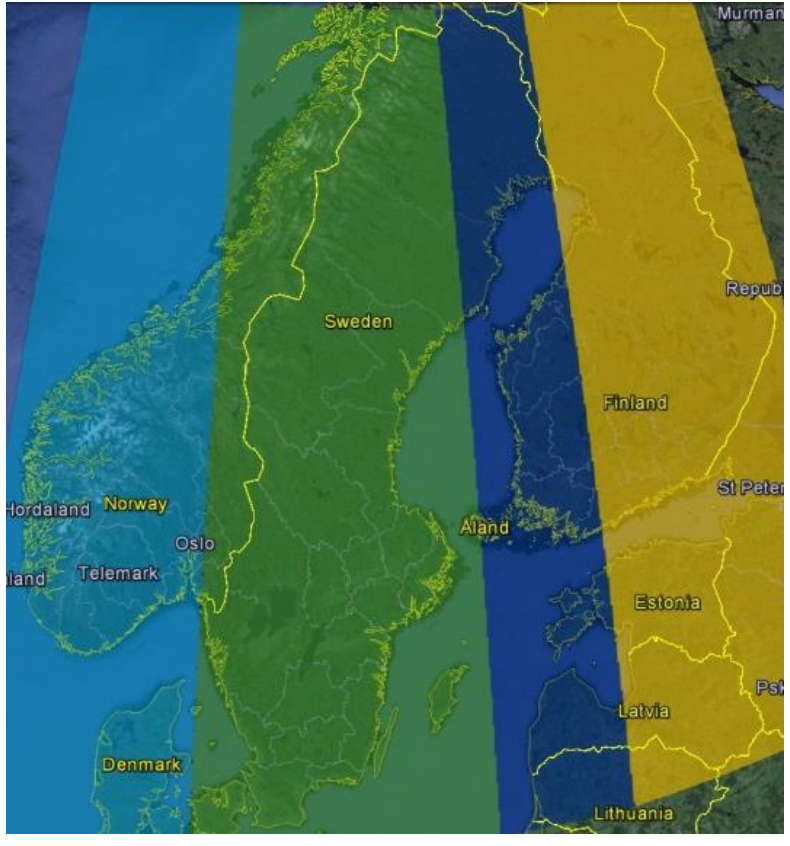
Sensor icing vs elevation



Icing climates with new data





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Icing drivers – cloud conditions

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Clouds and icing

The observation

- Anemometer icing and turbine energy loss increase, for a given elevation, from west to east across the Nordic region

The hypothesis

- Cloud base height reduces from west to east, causing more in-cloud icing

The data

- Airport weather observations - METAR

The analysis

- Analysed observations from all available stations across the Nordic region
- Compared frequency of low cloud or fog conditions
- Two winters assessed 2013-2014 and 2014-2015

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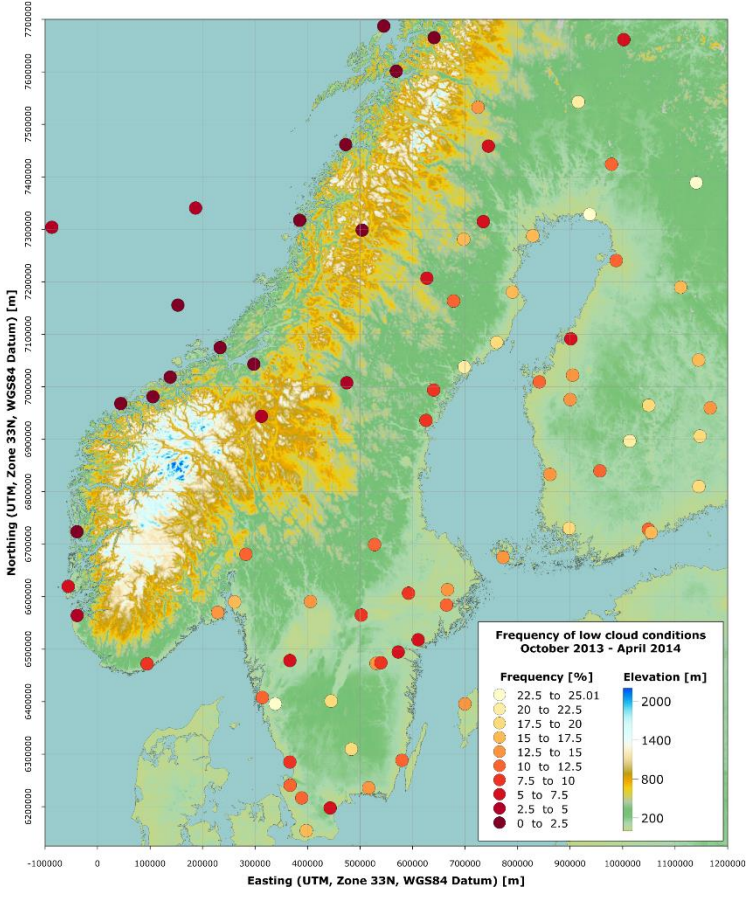
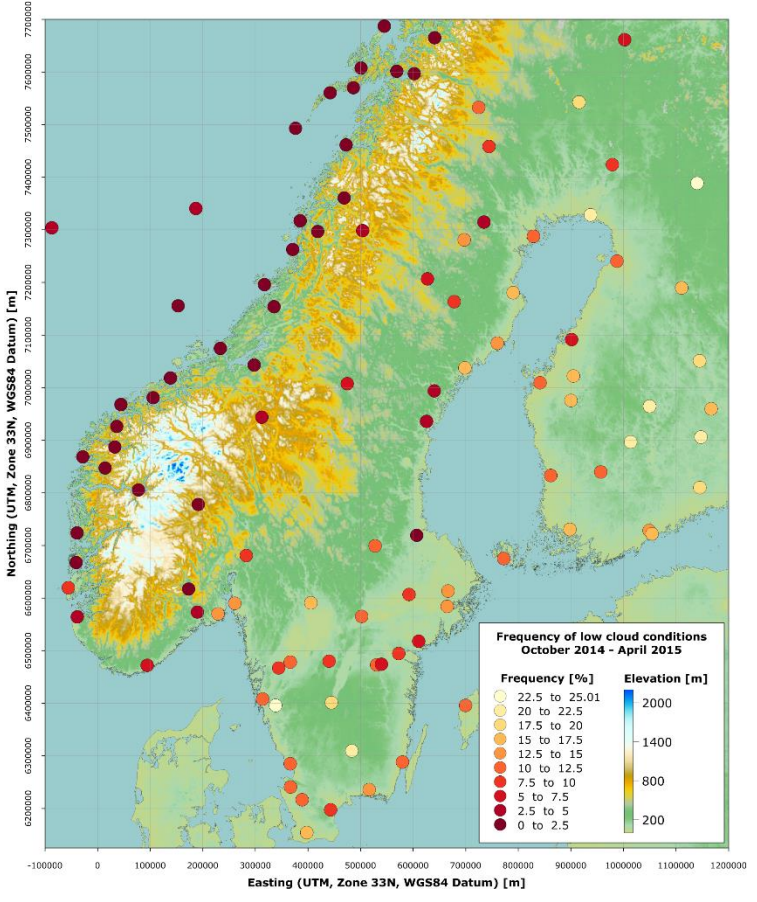
Result - clouds and icing





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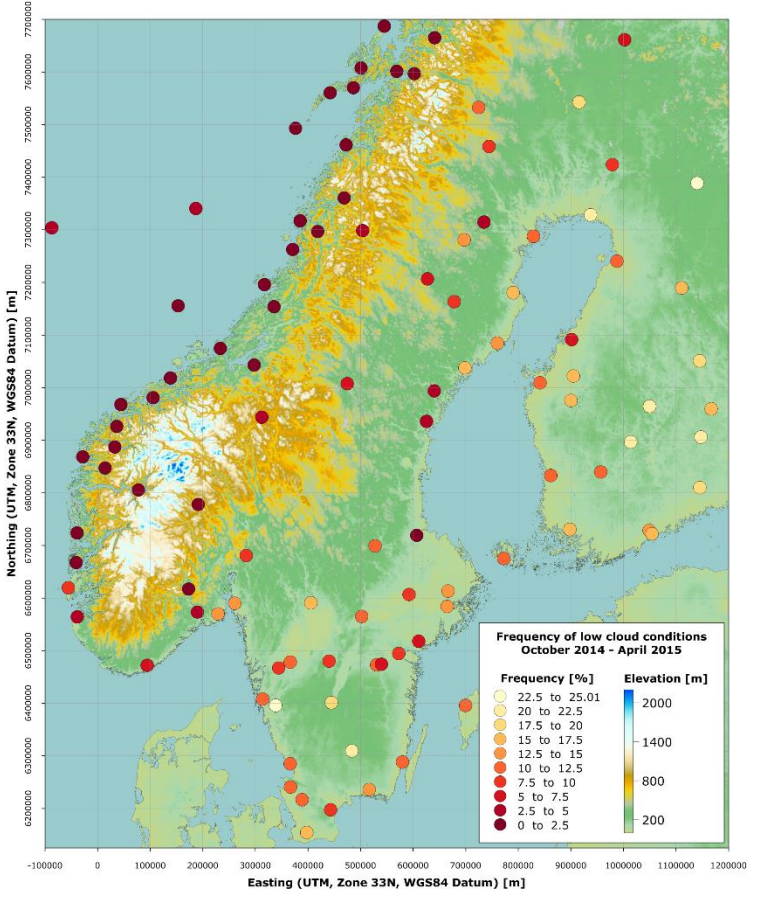
Result - clouds and icing

- Frequency of conditions where icing may occur increases with increased longitude
- Trend agrees with observed anemometer and turbine icing



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Conclusions

New operational data

- Observed an impact of layout on turbine icing
- Observed second trend in icing loss vs elevation
- Revised DNV GL Icing Map of Sweden

Next steps…

- Addition of more Finnish data

Pre-construction analysis

- New data supports linear elevation trend
- New data supports icing zones

Next steps…

- Analyse impact of mast position on icing

Icing drivers

- Frequency of low cloud conditions increases from west to east
- Supports observed increase in icing from west to east

Next steps…

- Analysis of temporal variation

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Many thanks

Thanks to Carla Ribeiro and Julien Haize

Till Beckford
Till.Beckford@dnvgl.com
+44 (0)2038164223

www.dnvgl.com

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