ESTIMATING ENERGY LOSSES CAUSED BY BLADE ICING FROM PRE-CONSTRUCTION WIND DATA

(UNDERSTANDING, PREDICTING, ADJUSTING)

WINTERWIND 2015, Piteå

Till Beckford

3 February 2015

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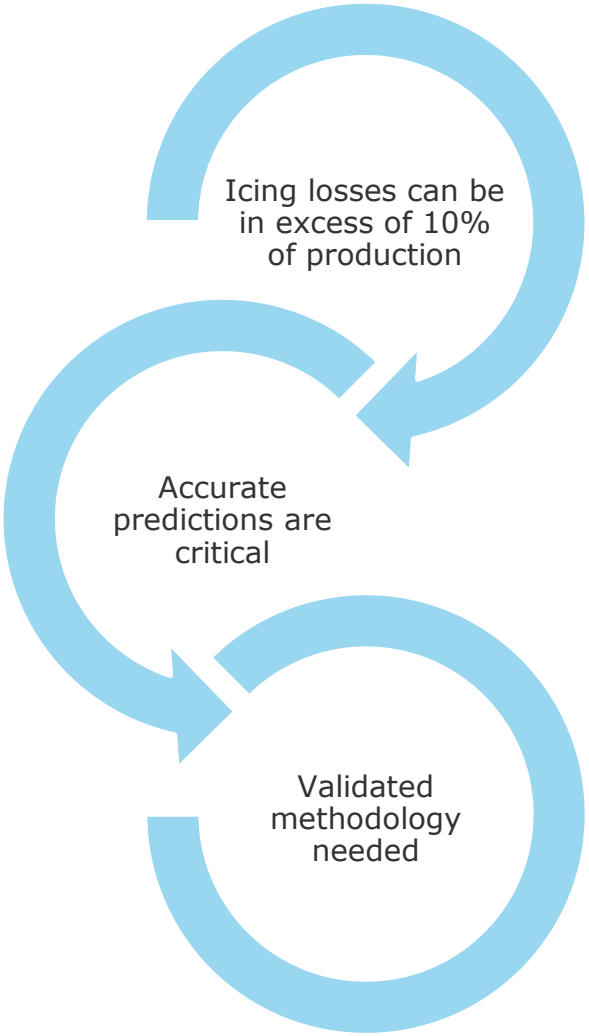
Introduction



Over 60 masts analysed, predominantly in Sweden, some in Norway and Finland

Analysed icing from over 450 sensors

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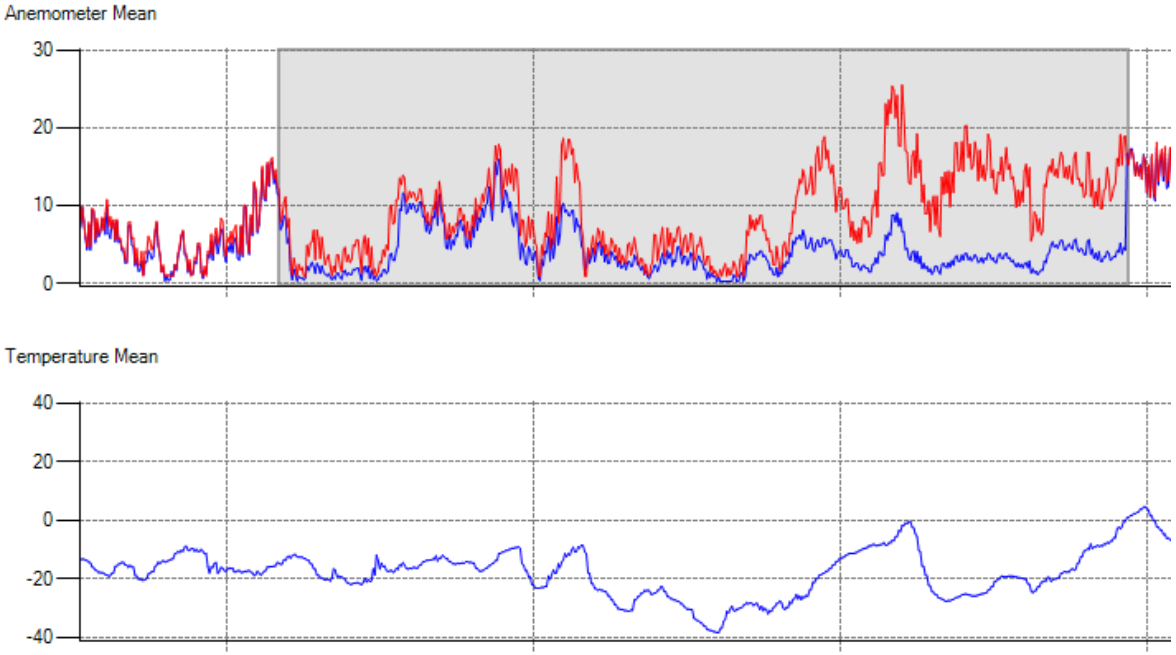
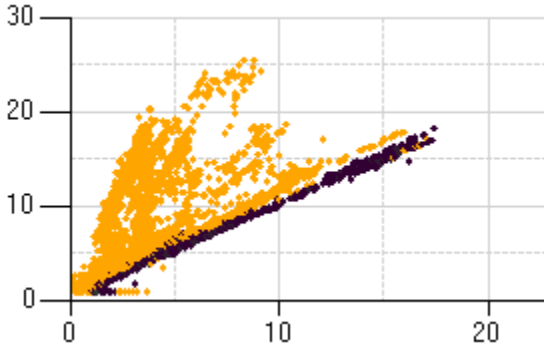
1.2.3. Understanding icing in pre-construction meteorological data

Ice detection

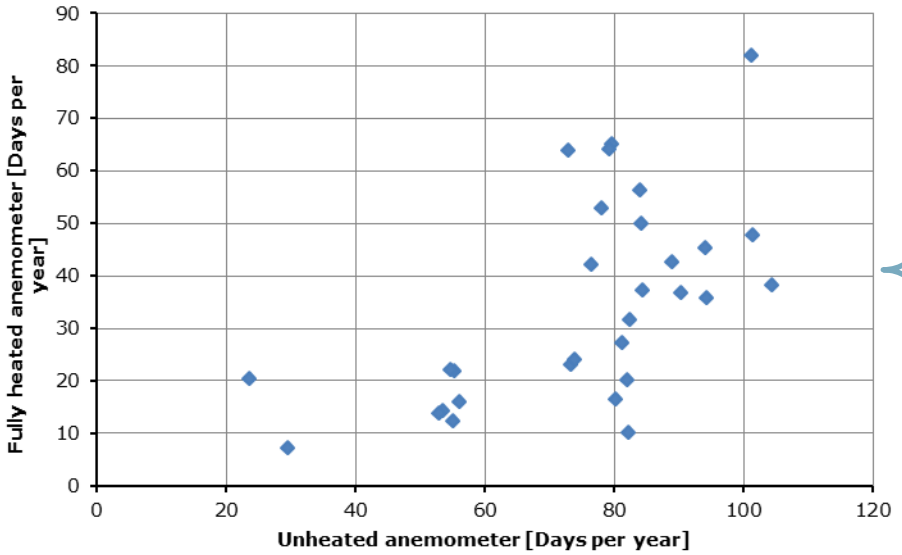




1.2.3. Understanding icing in pre-construction meteorological data

Findings - Sensor type

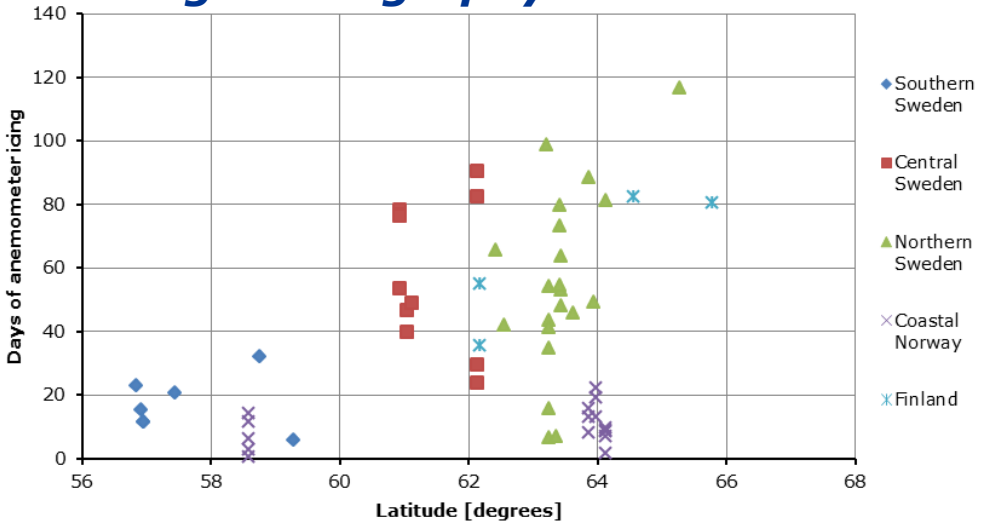
- Partially heated cup anemometer icing ≡ unheated cup anemometer icing
- Wind vane icing ≪ cup anemometer icing
- Fully heated cup anemometer icing < unheated cup anemometer icing



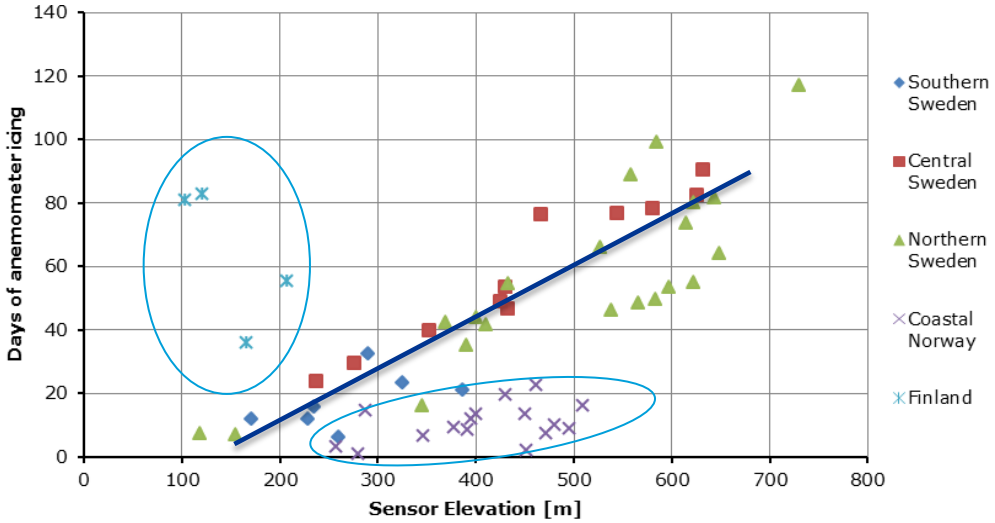
- Benefit is inconsistent
- Largely dependent on the power supply

1.2.3. Understanding icing in pre-construction meteorological data

Findings - Geography



- No correlation
- Large variety of icing within regions



- Linear correlation in Sweden
- Swedish regions lie on same trend
- Norway and Finland have separate icing climates

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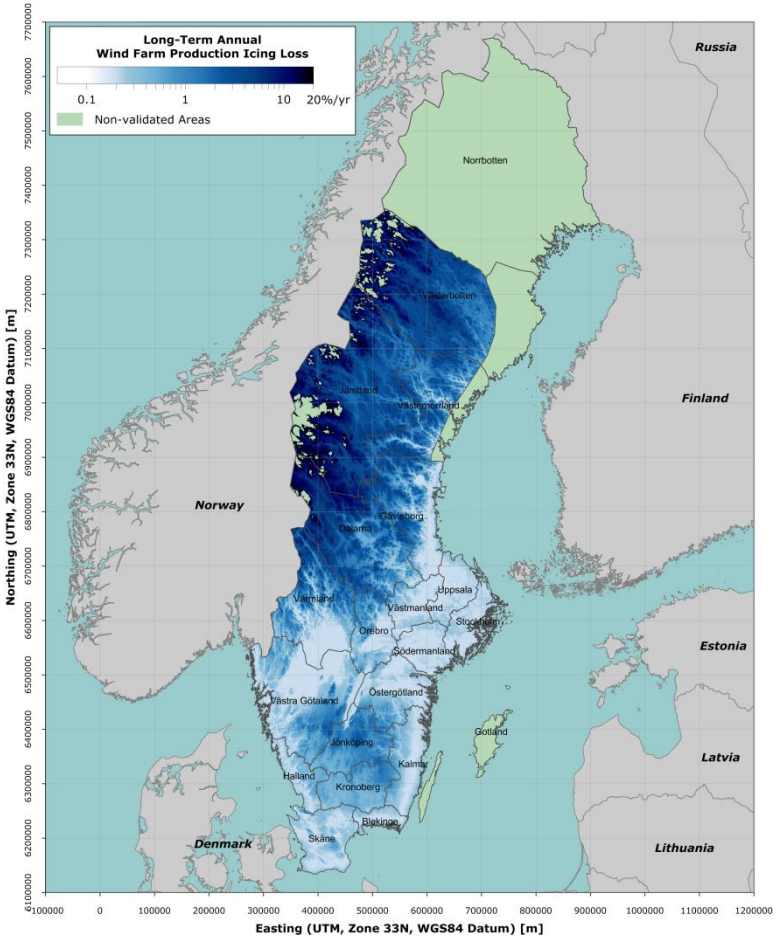
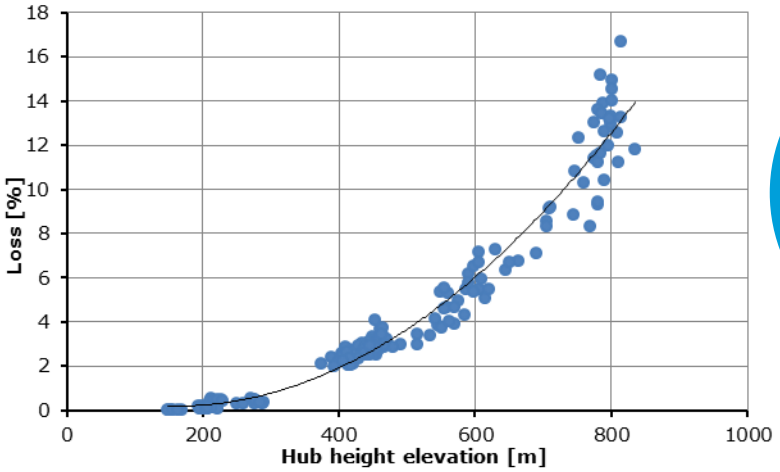
1.2.3. Predicting icing losses based on pre-construction data

Icing map of Sweden

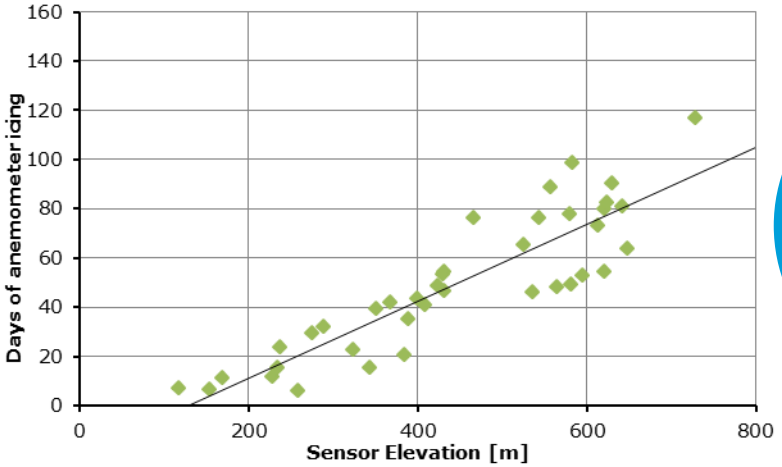


1.2.3. Predicting icing losses based on pre-construction data

Lessons learnt from wind farm and anemometer data



Production loss scales non-linearly with elevation



Anemometer icing scales linearly with elevation

Non-linear relationship between anemometer icing and wind turbine energy loss

1.2.3. Predicting icing losses based on pre-construction data

Methodology

$$Energy\ loss\ due\ to\ icing = time\ spent\ iced \times severity\ of\ icing$$

- $time\ spent\ iced$: given by anemometer data
- $severity\ of\ icing$: cannot be directly measured from typical met masts

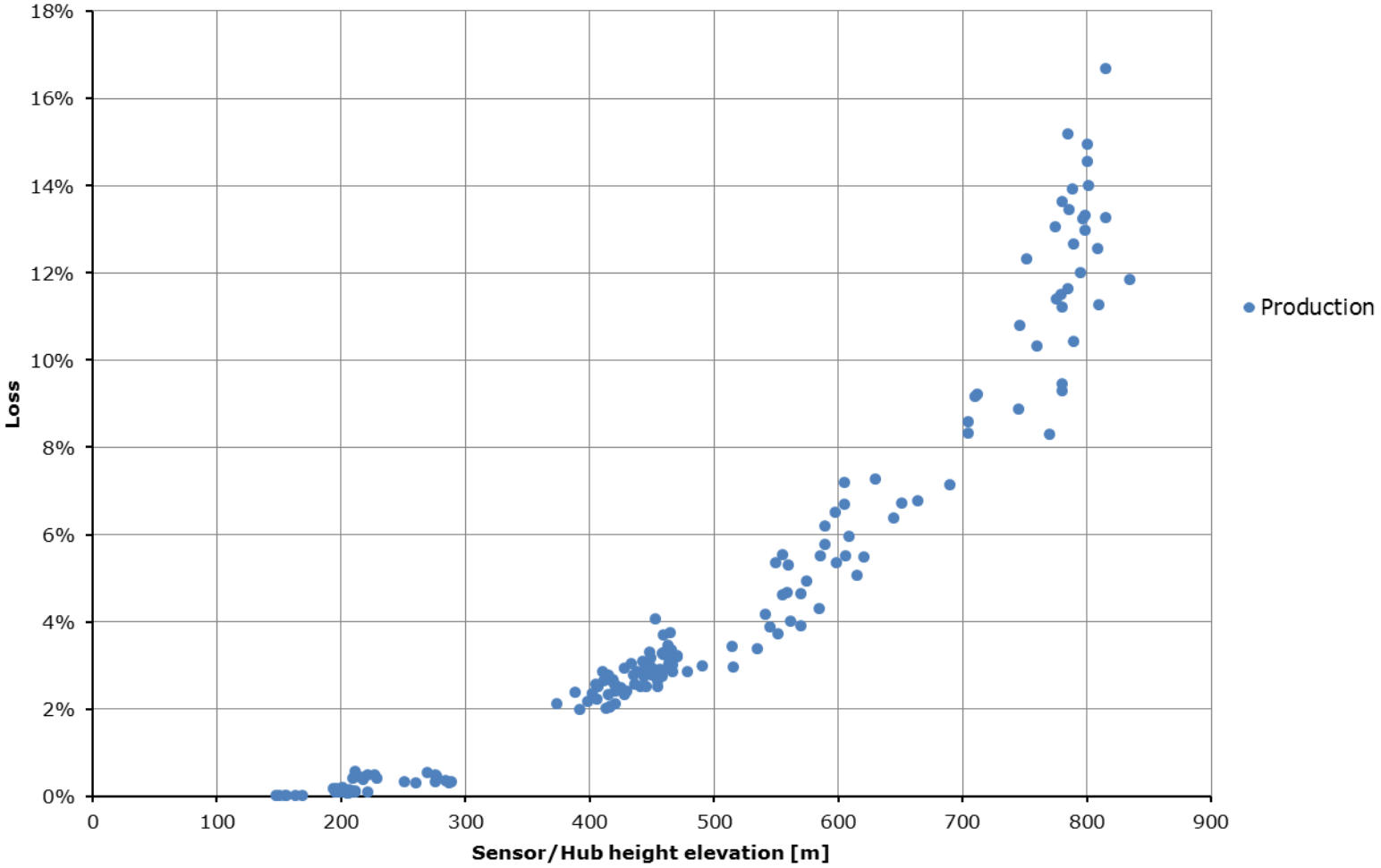
small amount of icing = low severity

large amount of icing = high severity

$$Energy\ loss\ due\ to\ icing = k \times time\ spent\ iced^2$$

1.2.3. Predicting icing losses based on pre-construction data

Validation



1.2.3. Predicting icing losses based on pre-construction data

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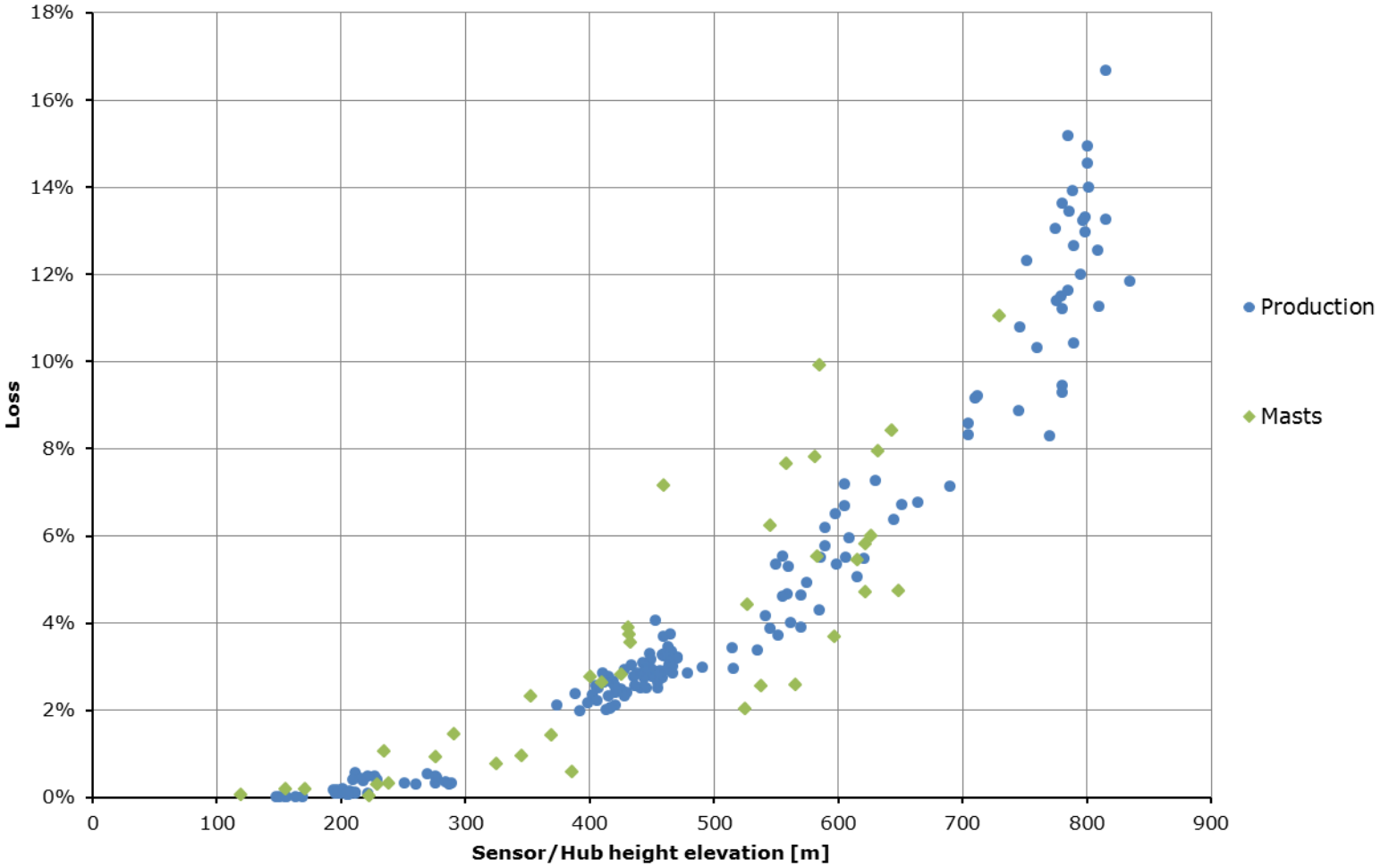

1.2.3. Predicting icing losses based on pre-construction data

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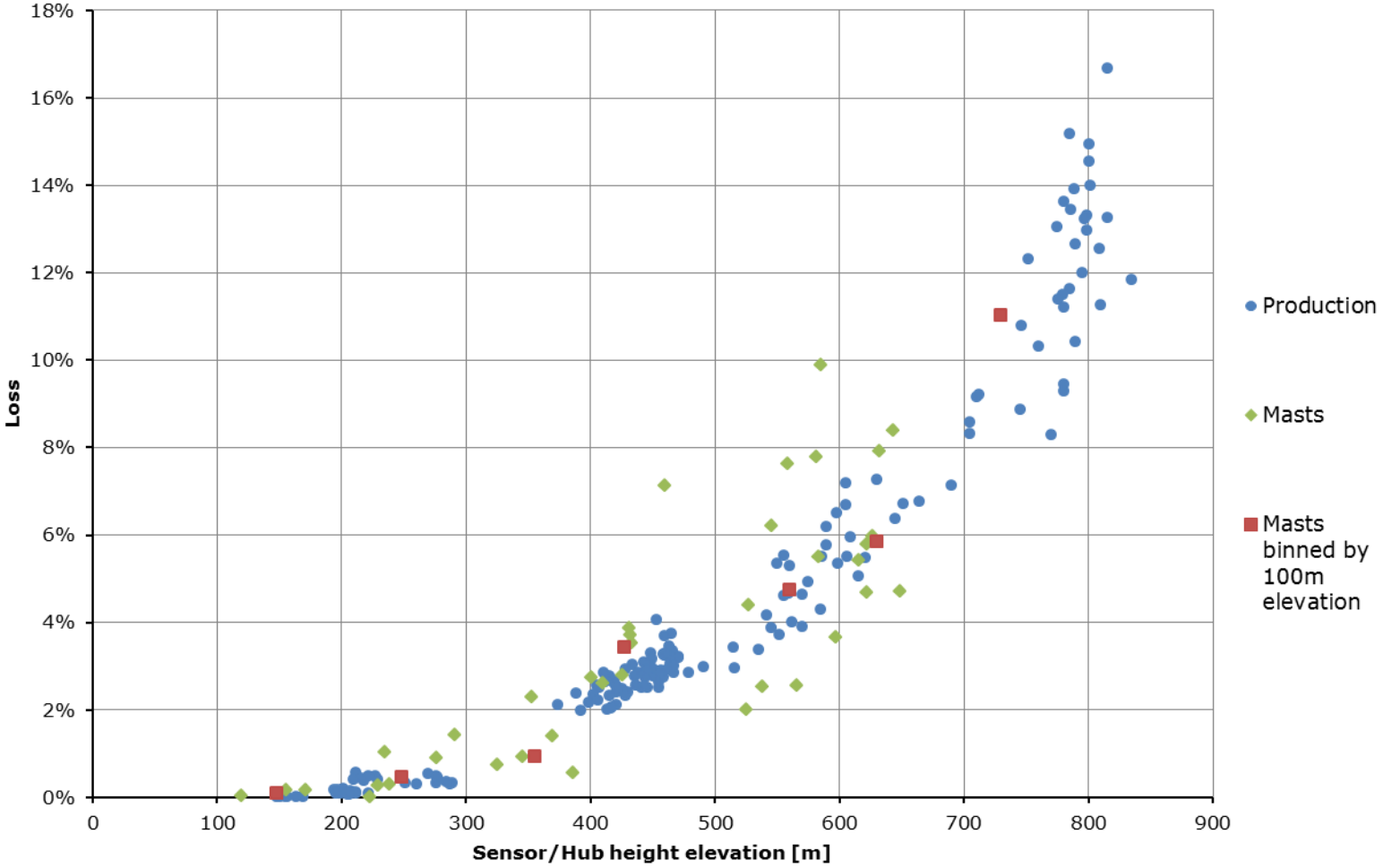
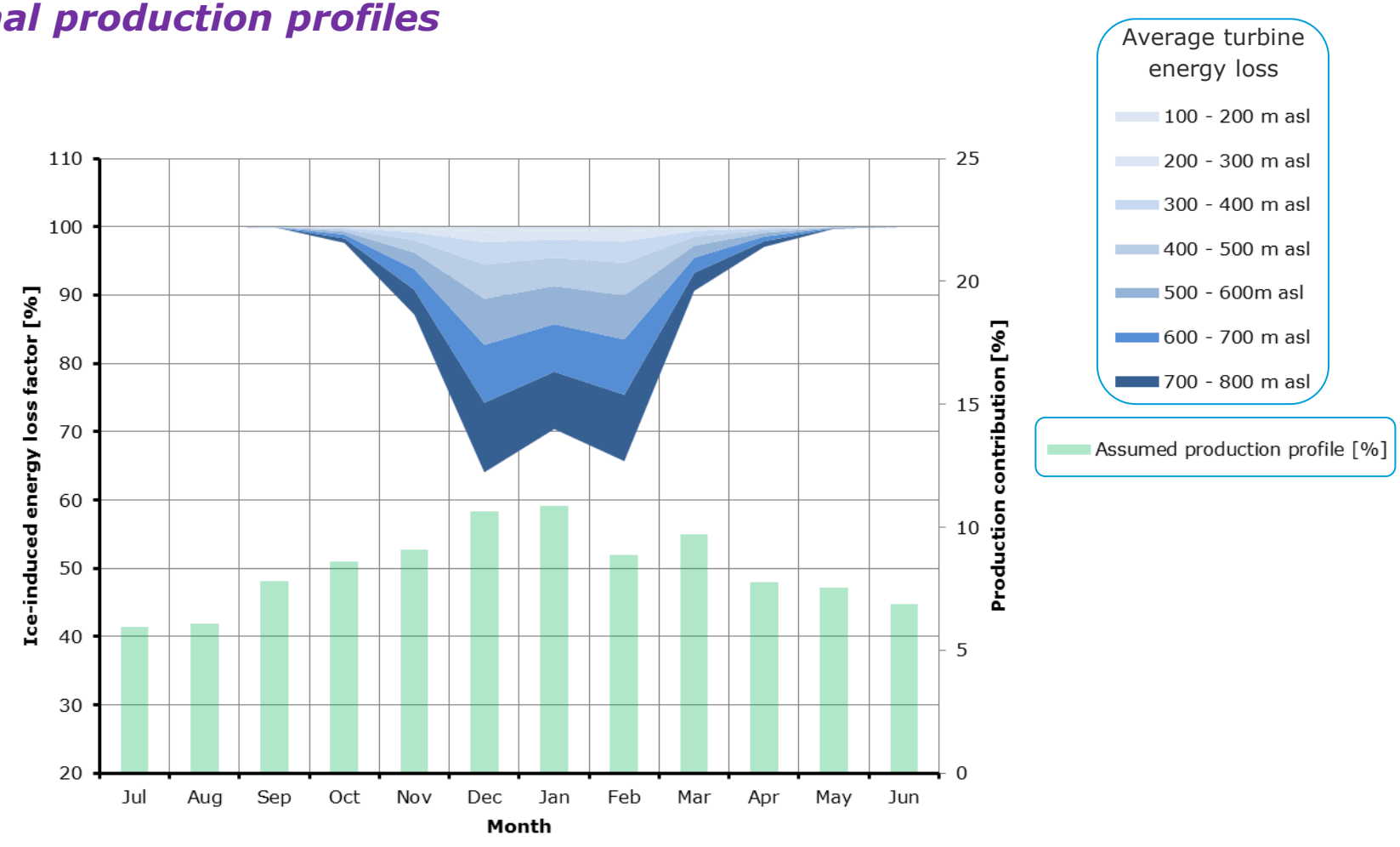


1.2.3. Predicting icing losses based on pre-construction data

Seasonal production profiles



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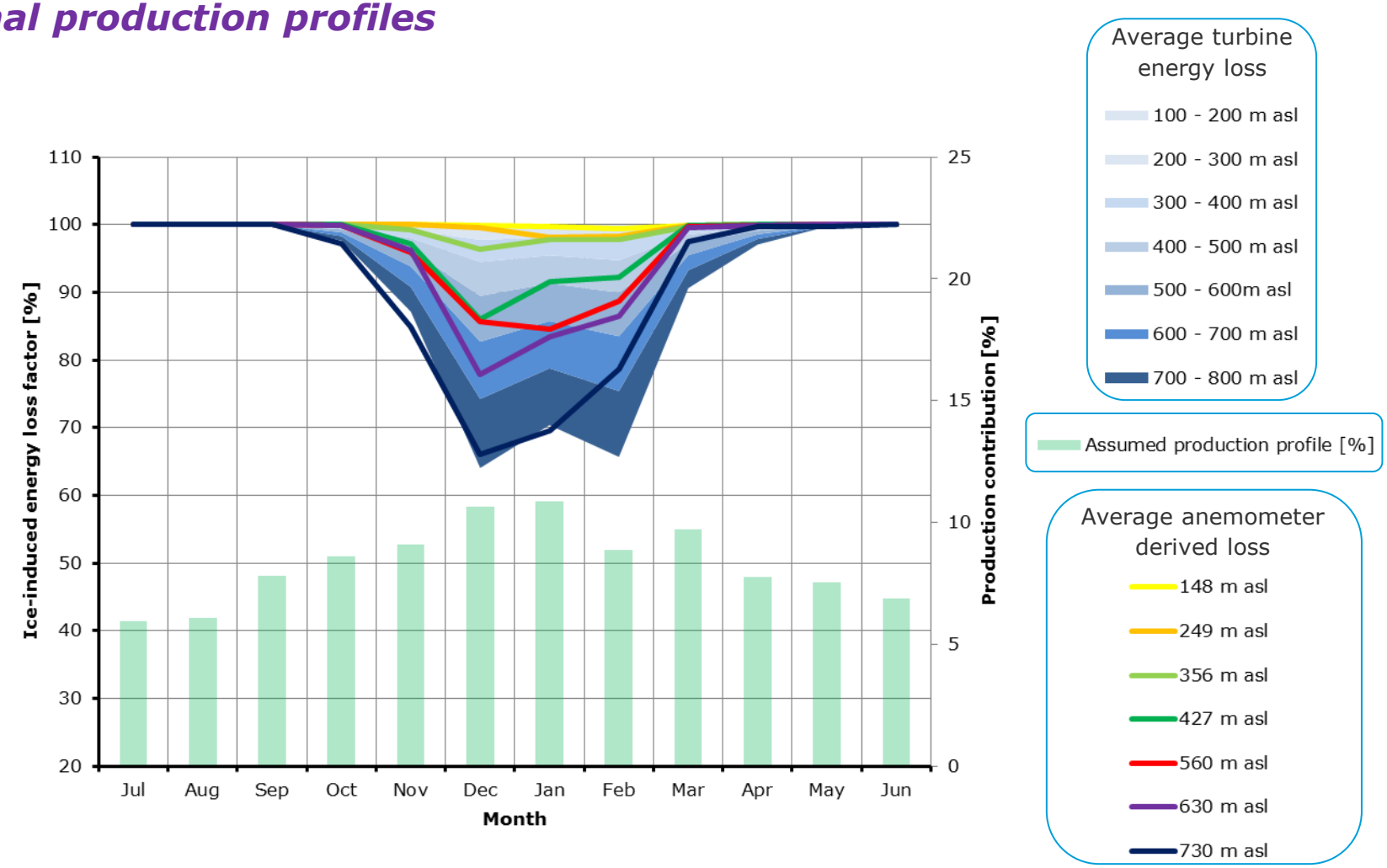
1.2.3. Predicting icing losses based on pre-construction data

Seasonal production profiles



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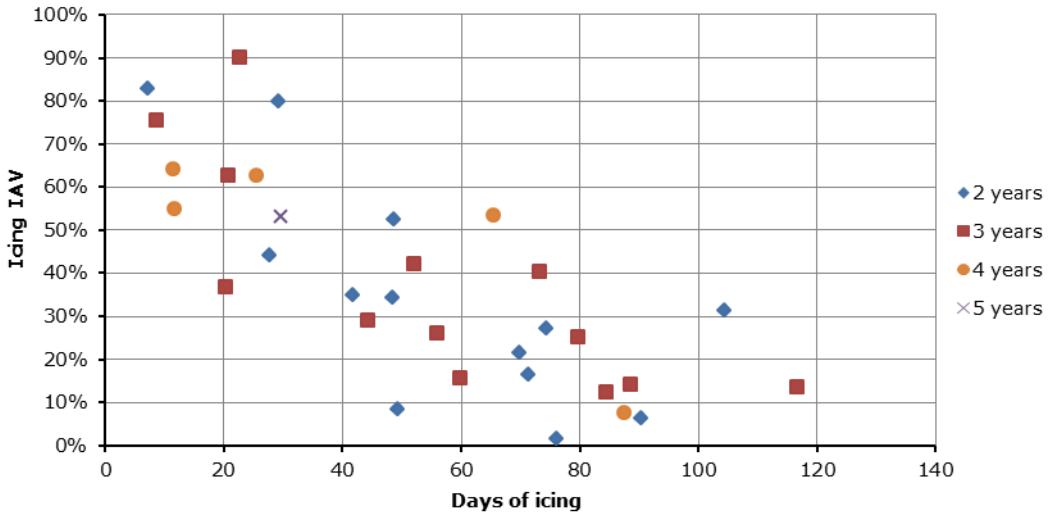
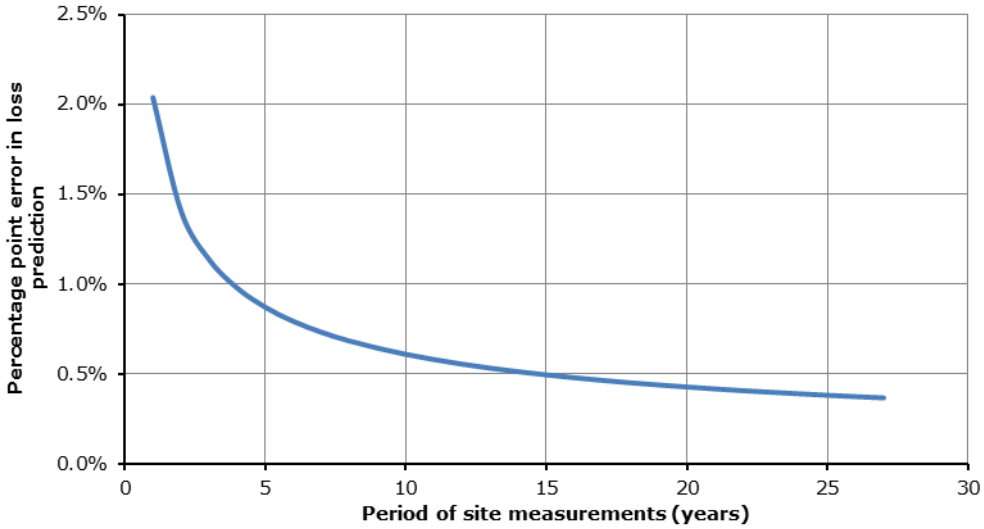
1.2.3. Adjusting icing predictions to the long-term expectation

Why?

- Inter-annual variability (IAV) defined as:
  - IAV [%] = Std Dev / Mean

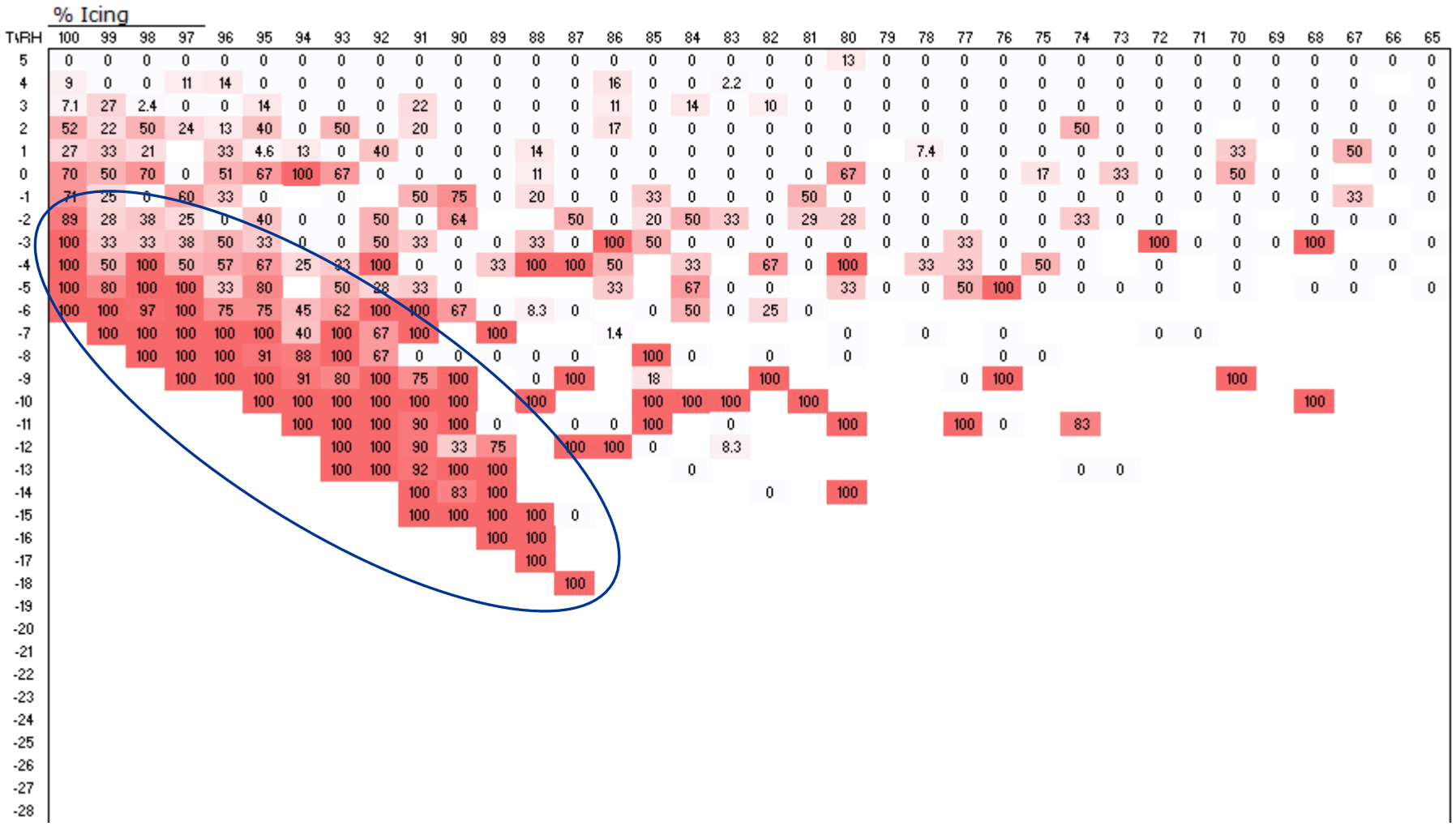


- Example:
  - 55 days/year of measured icing
  - IAV = 35%
  - Annual loss estimate = 3.4%



1.2.3. Adjusting icing predictions to the long-term expectation

Icing matrix – site data



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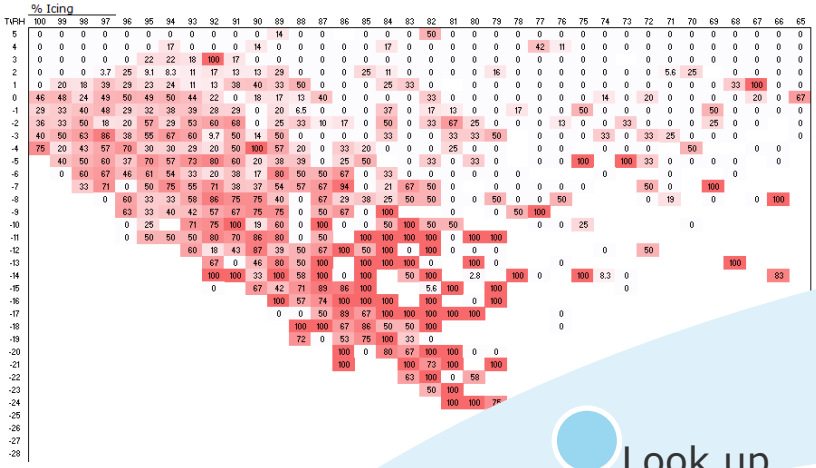
1.2.3. Adjusting icing predictions to the long-term expectation

Long-term correction procedure



Select long-term reference data

Create matrix from reference data

Look up icing values

Compare

Short-term period

Long-term period

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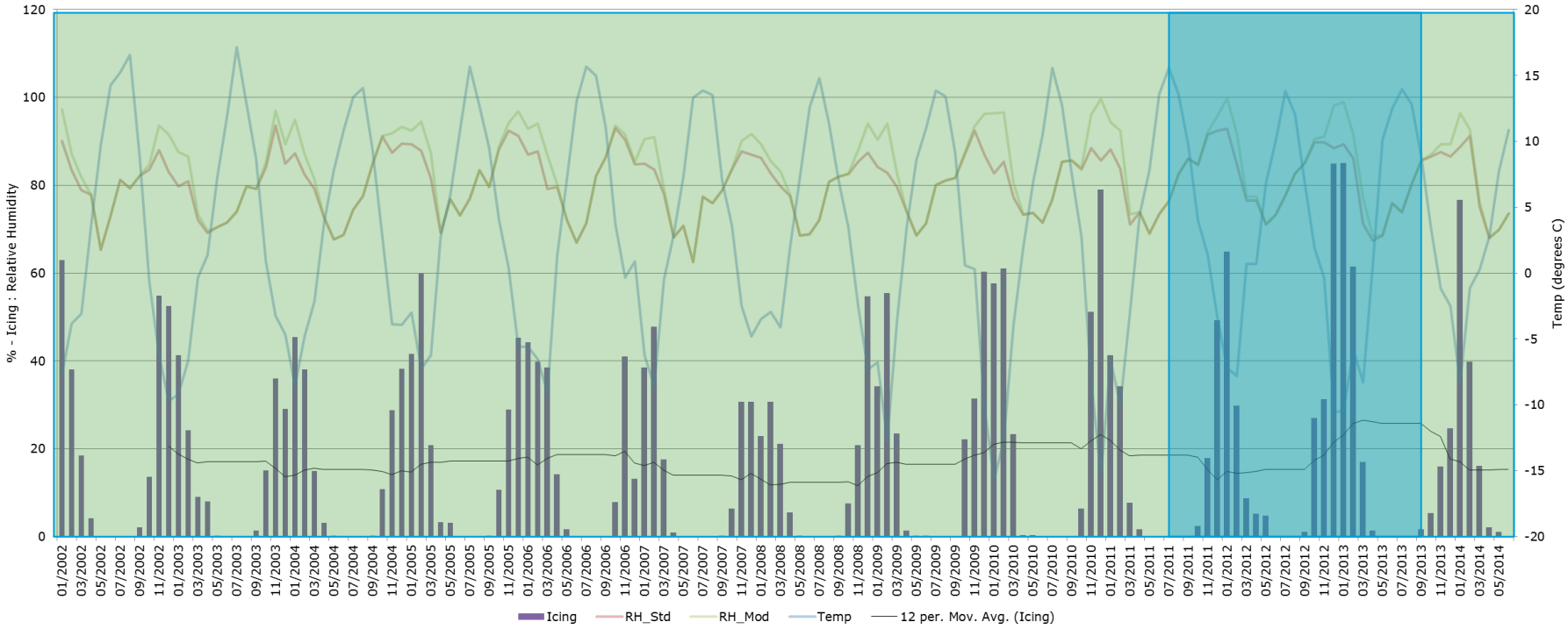
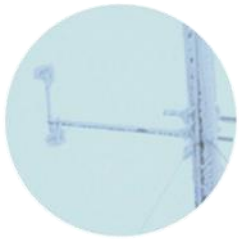
1.2.3. Adjusting icing predictions to the long-term expectation

Long-term comparison



Short Long

Conclusions



Understanding icing in pre-construction meteorological data

- Icing can be reliably identified in pre-construction anemometer data
- Icing is independent of anemometer type, heating is effective but inconsistent
- In Sweden, icing correlates with altitude, not latitude. Norway and Finland have separate icing climates

Predicting icing losses based on pre-construction data

- DNV GL has a validated method for reliably converting anemometer data to the expected annual energy loss
- The seasonal loss profile is also well represented

Adjusting icing predictions to the long-term expectation

- DNV GL has a method to extrapolate historical data and assess the iciness of site measurements relative to the long-term expectations
- Further validation work is under way for the long-term adjustment

Questions?

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Thanks to Carla Ribeiro and Staffan Lindahl

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