On the uncertainty in the AEP estimates for wind farms in cold climate

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Outline

- Annual variability in wind
- Calculations of wind, icing and power production for a wind power site.
- Estimation of production losses due to icing using different operating strategies.

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Health risk warning:

- All results shown are based on model calculations:
  - WRF - Weather Research and Forecast model
  - Icing calculations based on ISO 12494 – Atmospheric icing on structures
  - Production loss calculations based on KVT model IceLoss

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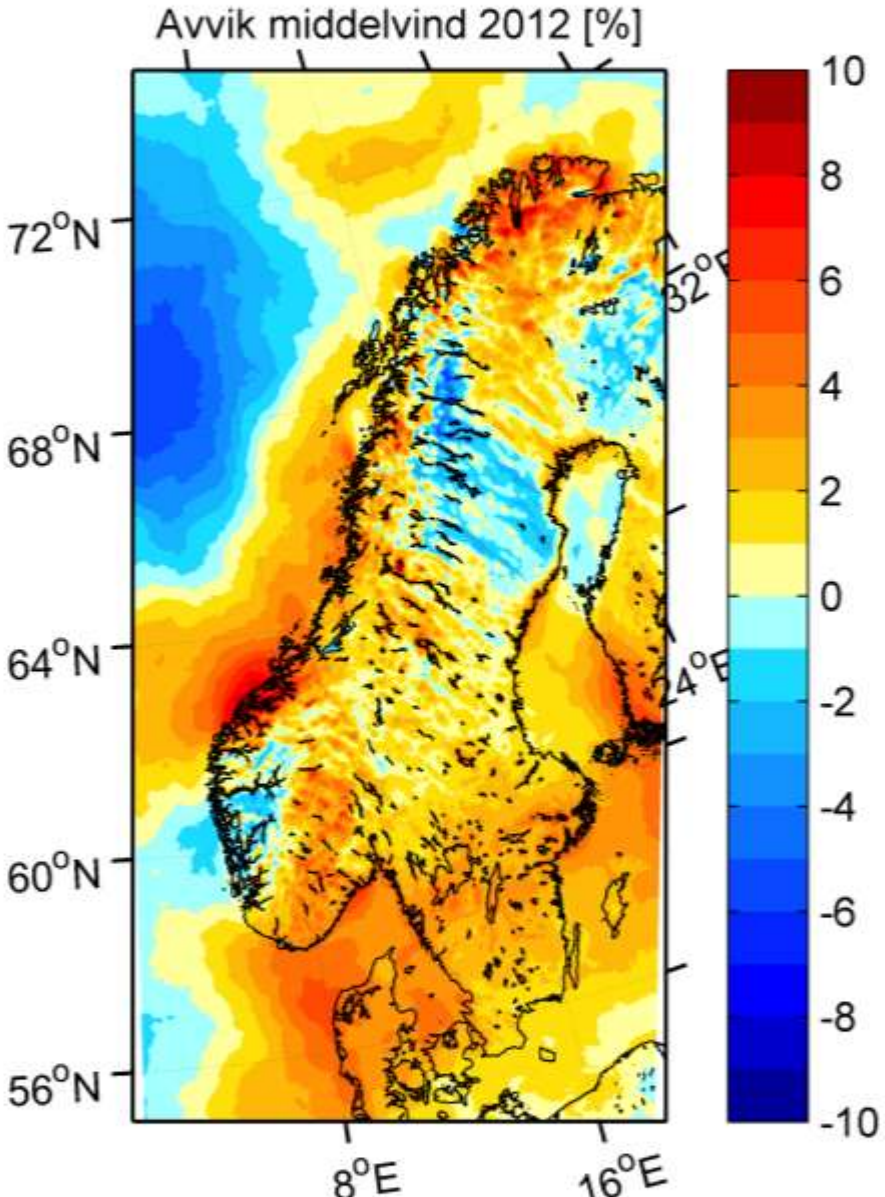
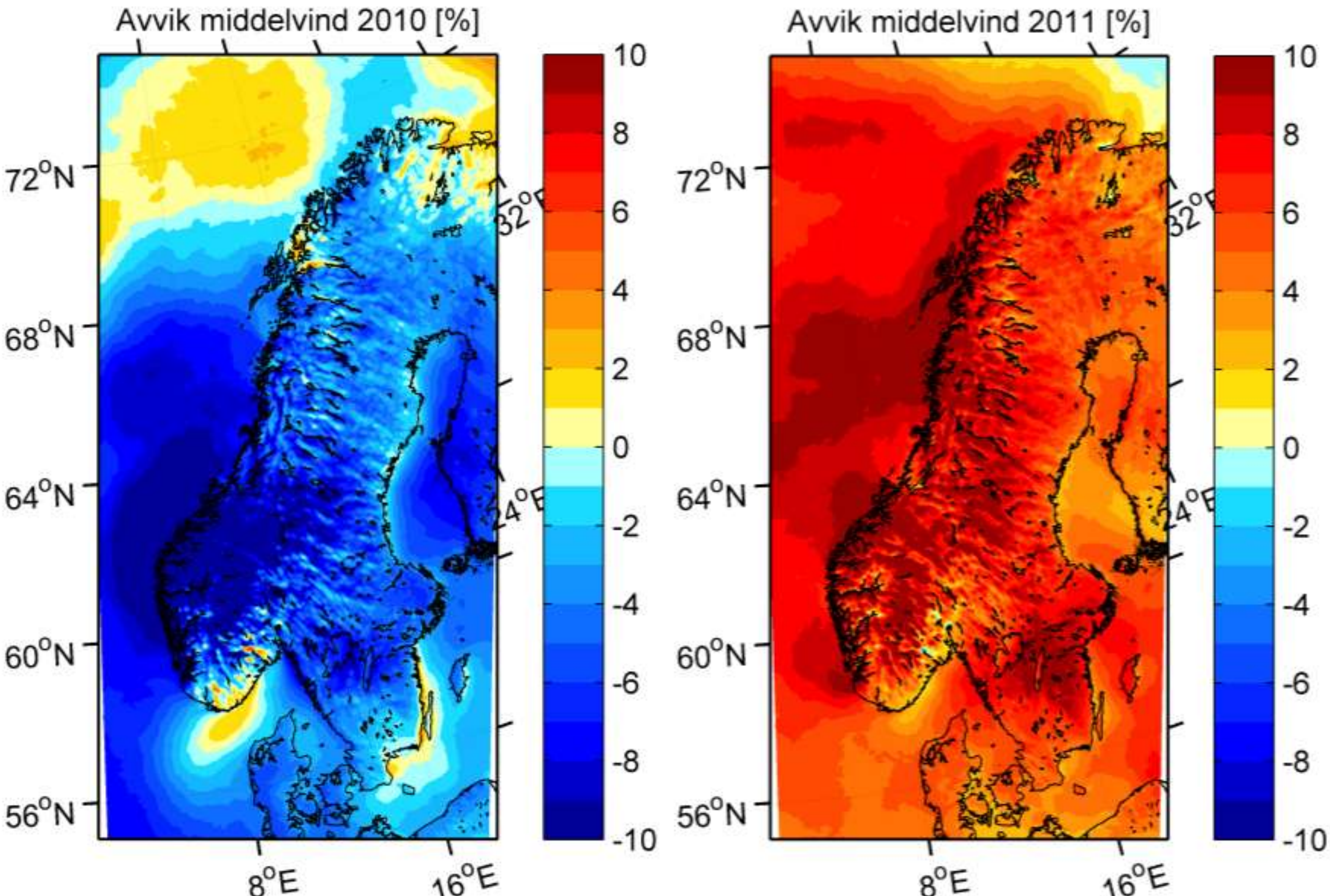
KVT wind index - 2012

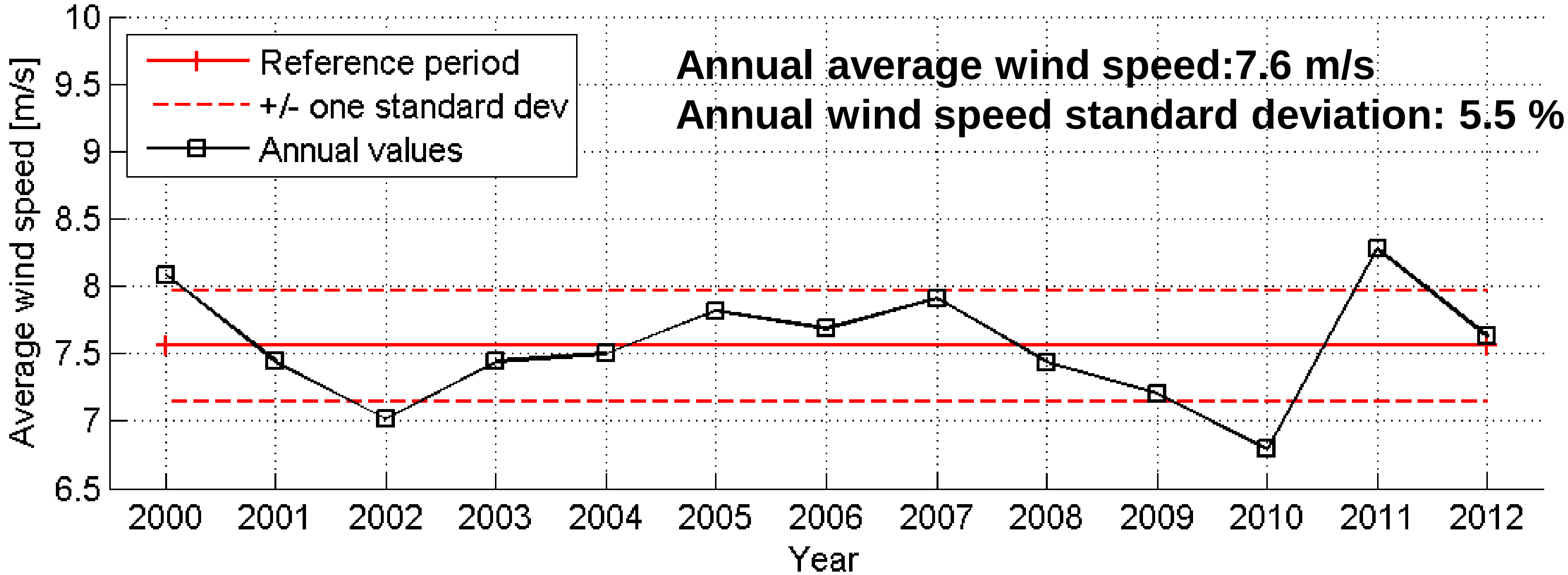
- Southern Sweden:
  - 2-6 % higher average wind speed than for a normal year
- Northern Sweden
  - some areas with higer wind speed than for a normal year
  - some areas with lower wind speed than for a normal year



KVT wind index – 2010 and 2011



Wind power site



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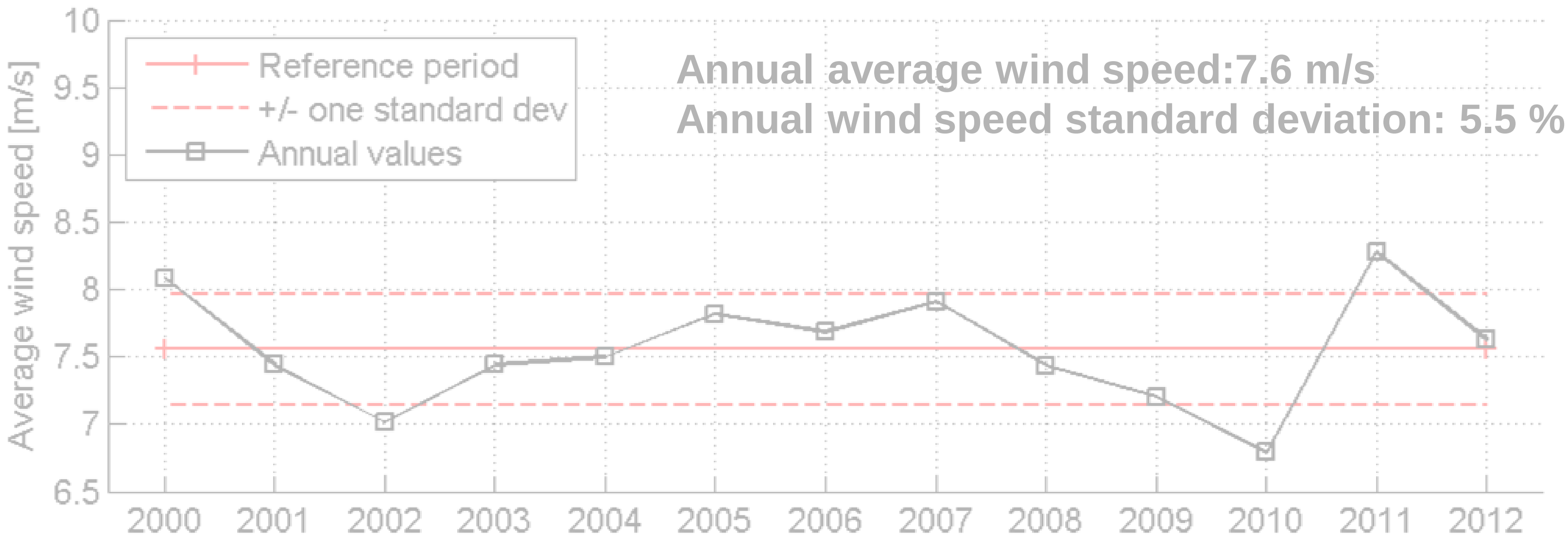
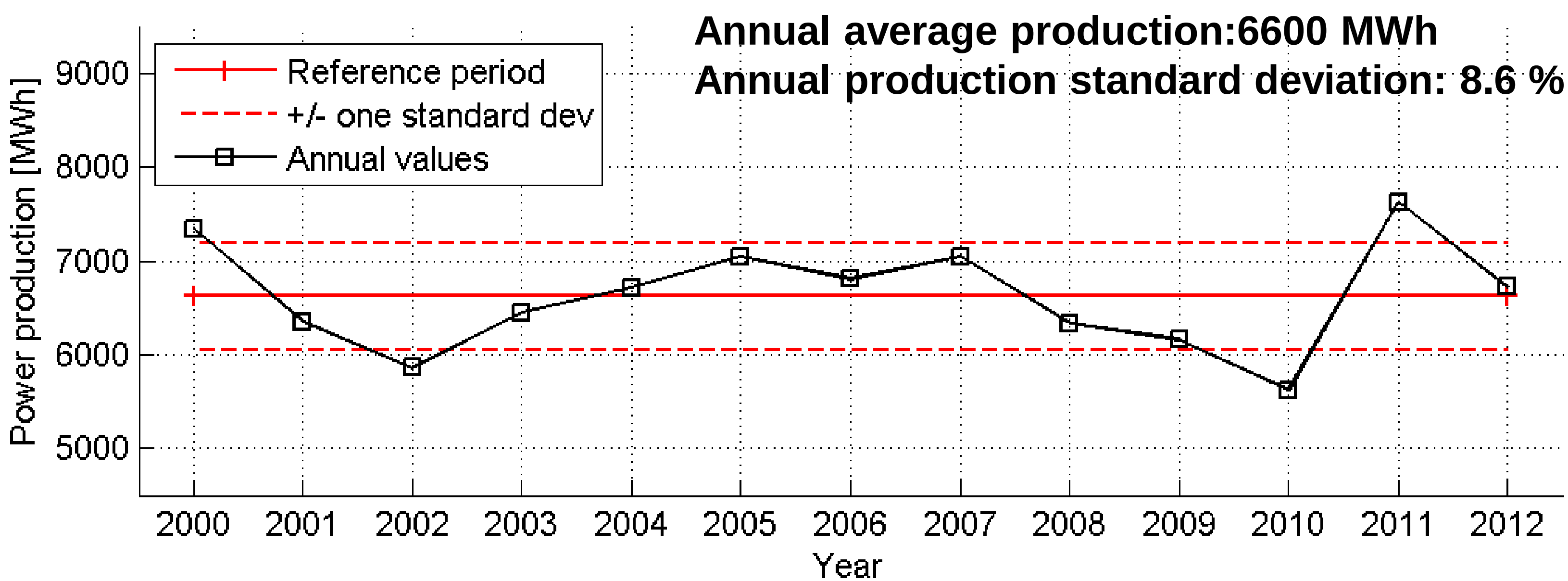
Wind power site





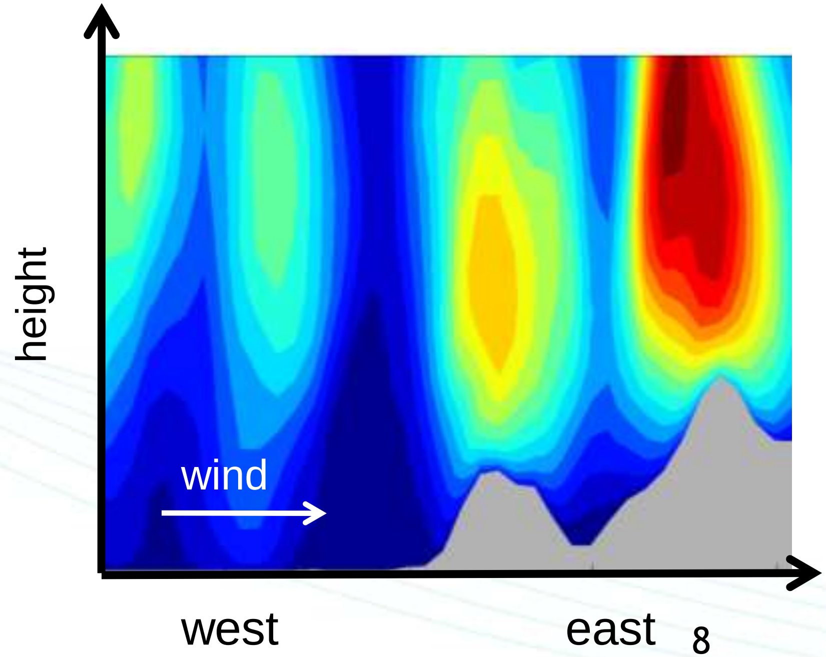
Icing conditions

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

→ in-cloud icing

- Lifting of airmasses

  → condensation



Icing map for Sweden:

- Average number of meteorological of icing hours of per year
- Hours when ice builds up
- Based on the period 2000-2011

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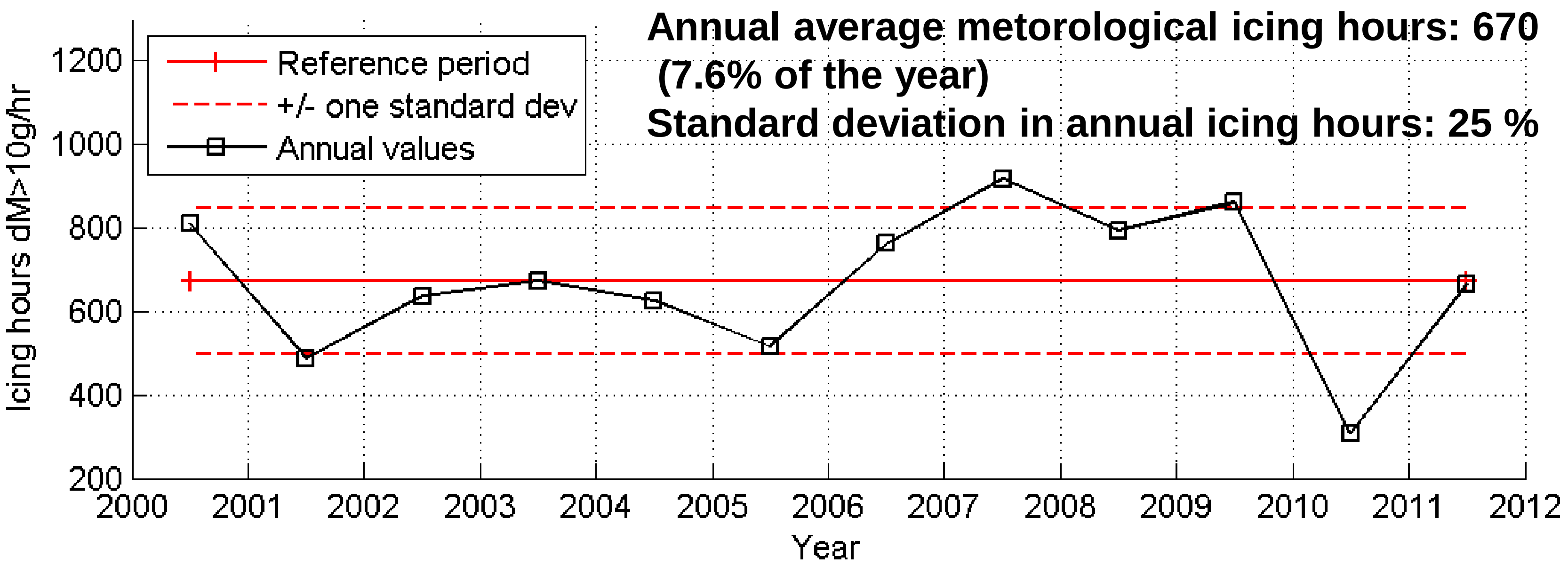
Icing conditions at the site



- Large annual variability in icing
- Expect large variability in the influence of icing.

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Estimation of production loss due to icing

- Operating strategies during icing:
  1. Continue power production with iced blades
  2. Stop the turbine

Continue power production with iced blades:
- Reduced power curve during icing

Stop the turbine:
- When ice is detected to influence the power production

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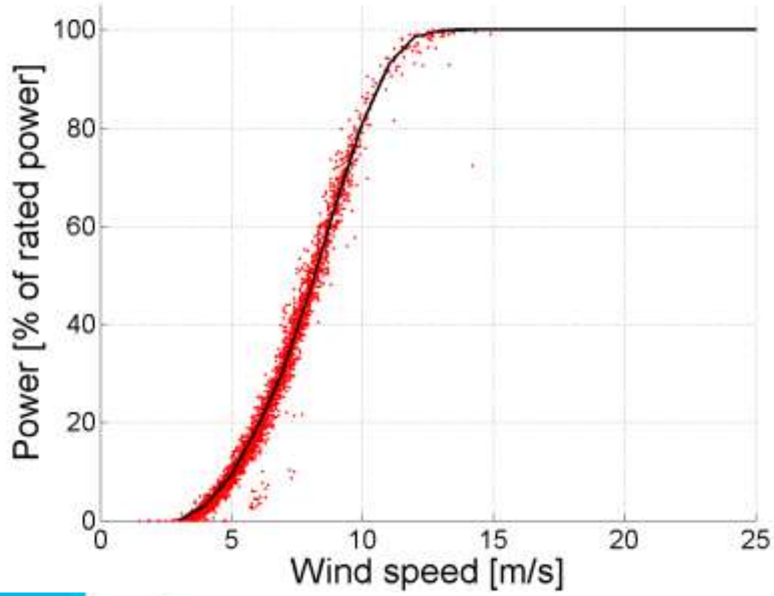
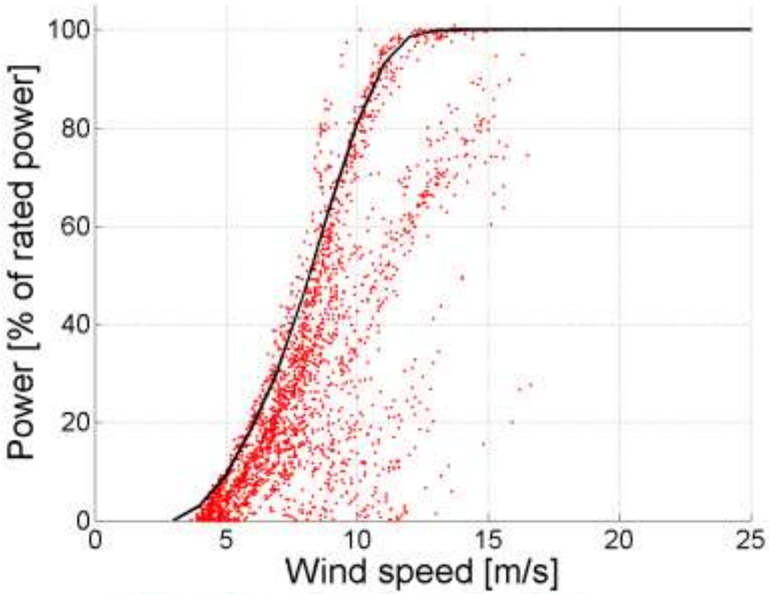
Production loss

Continue production with iced blades:

Power curve May 2010



Power curve November 2009



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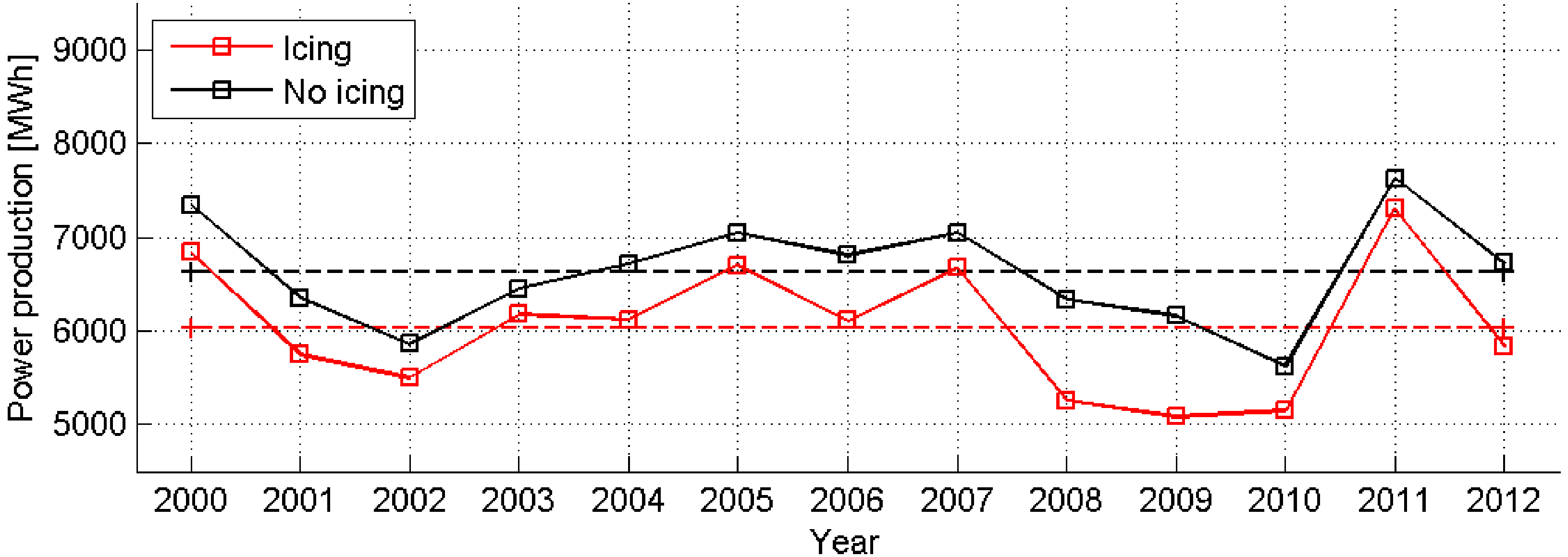
Production loss with iced blades

- Annual average power production without icing: **6600 MWh**
- Annual average power production with icing: **6000 MWh**
- Average production loss: **600 MWh (9 % reduction in AEP)**
- Annual production standard deviation (iced blades)**: 11.6 %**



Estimation of production loss due to icing

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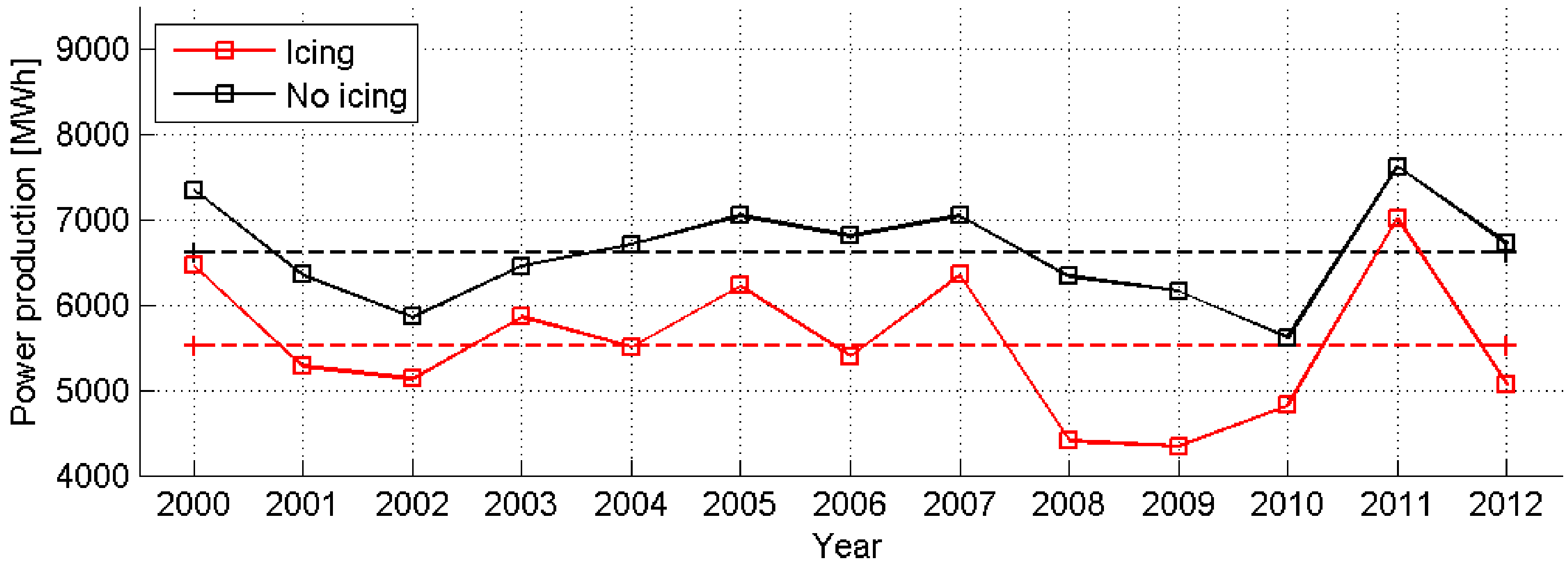
Turbine stop during icing conditions

Reasons to stop the turbine when icing is detected:

- Reduce risks related to ice throw
- Local regulations
- Reduce vibrations and fatigue loads

Production loss - stop during icing

- Annual average power production without icing: **6600 MWh**
- Annual average power production with icing: **5500 MWh**
- Average production loss: **1100 MWh (17 % reduction in AEP)**
- Annual production standard deviation (stop during icing)**: 14.7 %**



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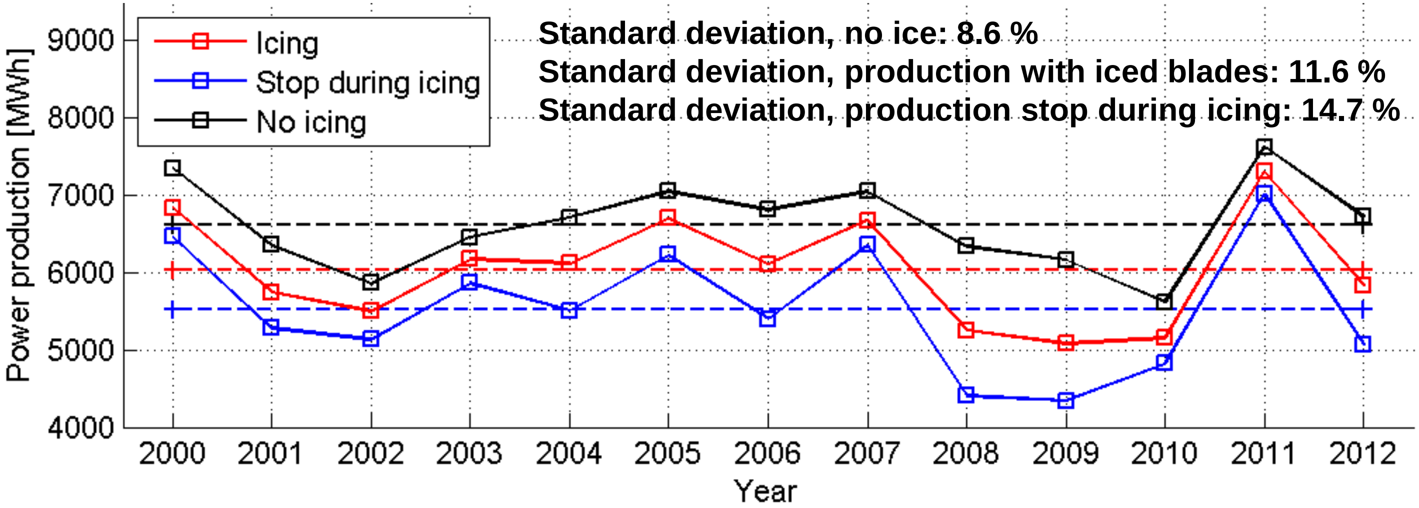
Summary

- Operating strategies during icing:
  1. Continue power production with iced blades
  2. Stop the turbine



Continue power production with iced blades:

- Reduced power curve during icing
- Red curve
- **Estimated production loss: 9 %**

Stop the turbine:

- When ice is detected to influence the power production
- Blue curve
- **Estimated production loss: 17 %**

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Summary

- Significant year to yer variability in wind speed
- Icing has an even higher year to year variability
- Production losses due to icing will increase the variability in annual energy production
- Calculation of production losses due to icing is dependent on the operational strategy

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Icing map for Sweden available from

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