Icing on wind turbines

A survey of research efforts and needs

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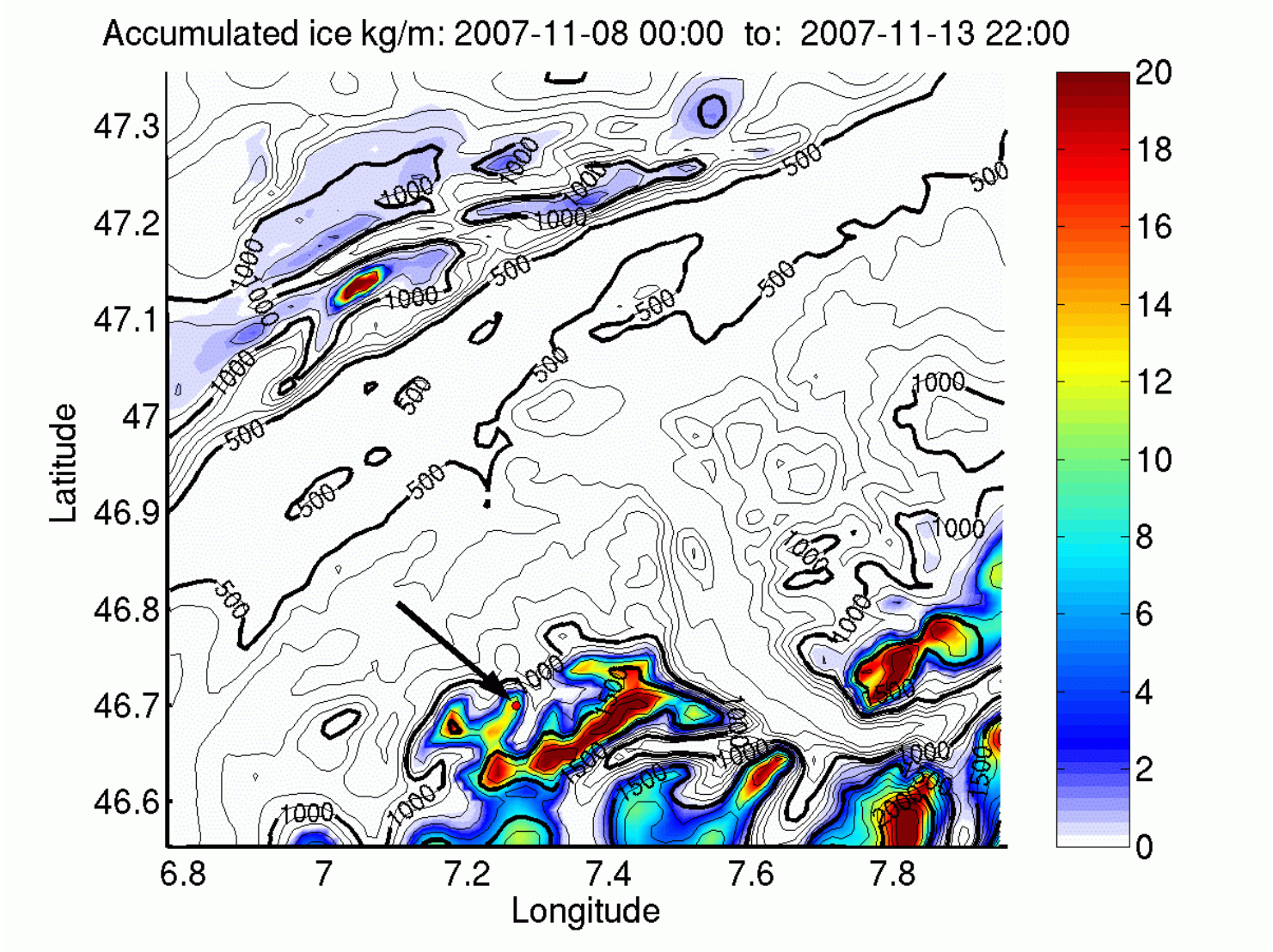
Introduction

Issues

- Icing simulations (climatology / forecasts)
- Icing measurements (point / blade)
- Effects of icing on wind turbines
- De-icing and Anti-icing
- Health and Safety (ice throw / noise)

Icing simulations: climatology



Icing simulations: climatology

What is it?

- Information on average icing conditions (10 years or more)

Why is it needed?

- Energy yield calculation including icing conditions
- Siting of wind turbines
- Cost/benefit analysis for de-icing or anti-icing systems

Icing simulations: climatology

Ideal world

Icing climatologies are available:

- High resolution (100 x 100 m), Long term (> 10 years)
- Icing probability, intensity, severity
- Information valid for wind turbines
- Reasonable computing time (max. 1 month)

Icing simulations: climatology

To do list

- **Develop a wind turbine ice accretion model**
  - Input: time series
  - full blade coverage
  - ice accretion, melting and sublimation
- **Validate** the simulated meteorological conditions
- **Validate** the simuated ice accretion models
- Improved cloud microphysics (MVD)
- Mechanical icing model for wind turbines
- Downscaling, long term correlation and post-processing
- Climate change

Icing forecasts

What is it?

- Forecast of the icing conditions for the next 0-5 days

Why is it needed?

- Grid management (ramps due to icing events)
- Spot market
- Preventive heating

Icing forecasts

Ideal world

Operational wind power production forecasts considering icing:

- Production losses due to icing included
- High availability (every day at the same time)
- Information on uncertainty

To do list

- Solve climatology issues
- Post-processing with measurements
- Probabilistic forecasts → uncertainty

Icing measurements

Icing measurements

What is it?

- Measurement of
  ice accretion, intensity, persistence, ice load
- At one point and on a wind turbine blade

Why is it needed?

- Energy yield calculation under icing conditions
- Validation of icing simulations / icing models
- Control of wind turbines / de-icing systems

Icing measurements

Ideal world

Instruments are available which can measure:

- Ice accretion, intensity, persistence, ice load
- At one point and on wind turbine blade
- Automatically, reliably and accurately (maintenance free)
- During operation and standstill of wind turbine
- Accurate measurements of LWC and MVD

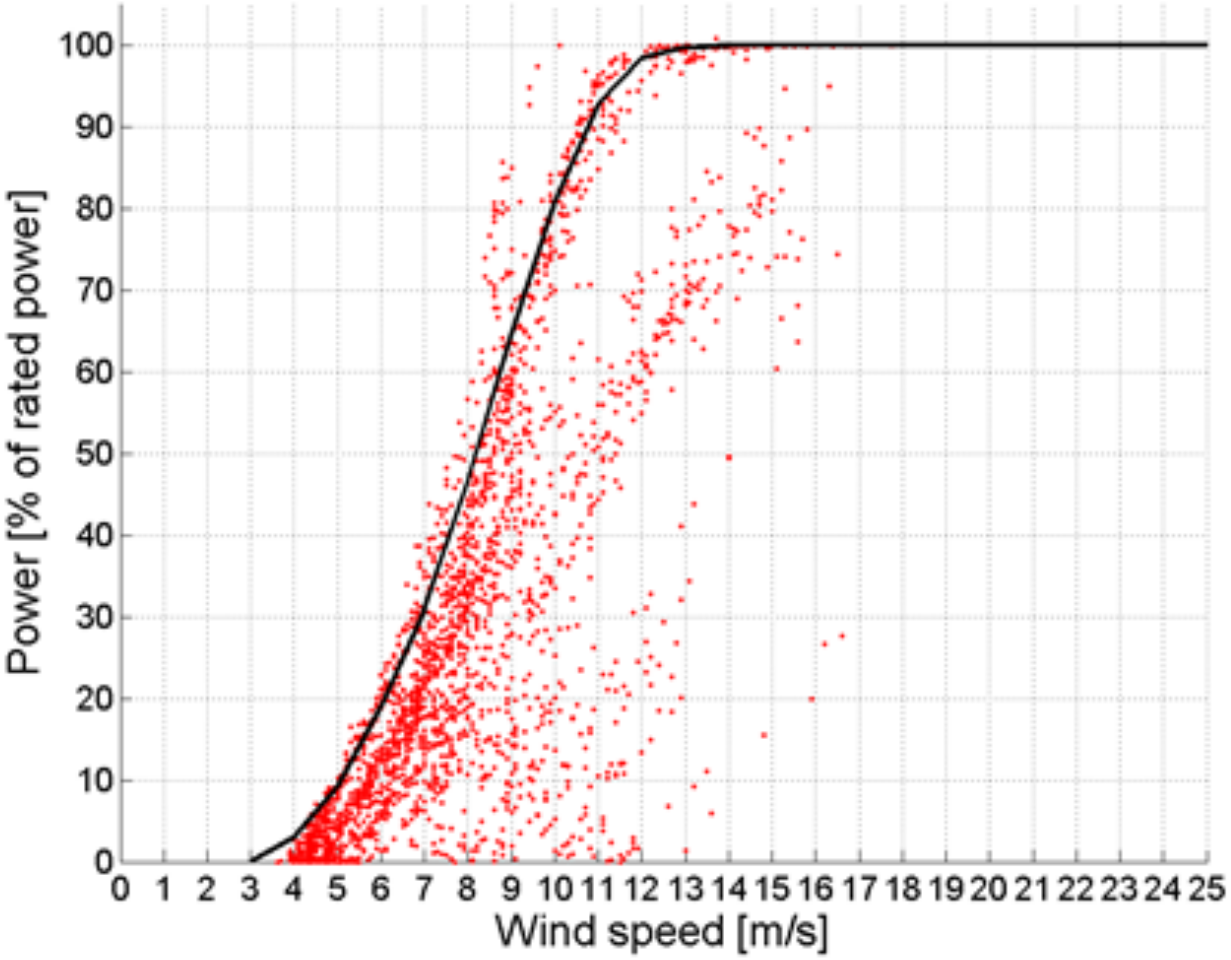
Icing measurements

To do list

- **There is a strong need for better instruments**
  - point measurements
  - blade measurements
  - LWC and MVD
- Combination of instruments / cameras

→ Reliable measurements are a prerequisite to understand icing on wind turbines and therefore for all other issues

Effects of icing on wind turbines



Effects of icing on wind turbines

What is it?

- Effect of icing on power production

Why is it needed?

- Energy yield calculation under icing conditions

Effects of icing on wind turbines

Ideal world

Effect of icing on wind energy production is exactly known:

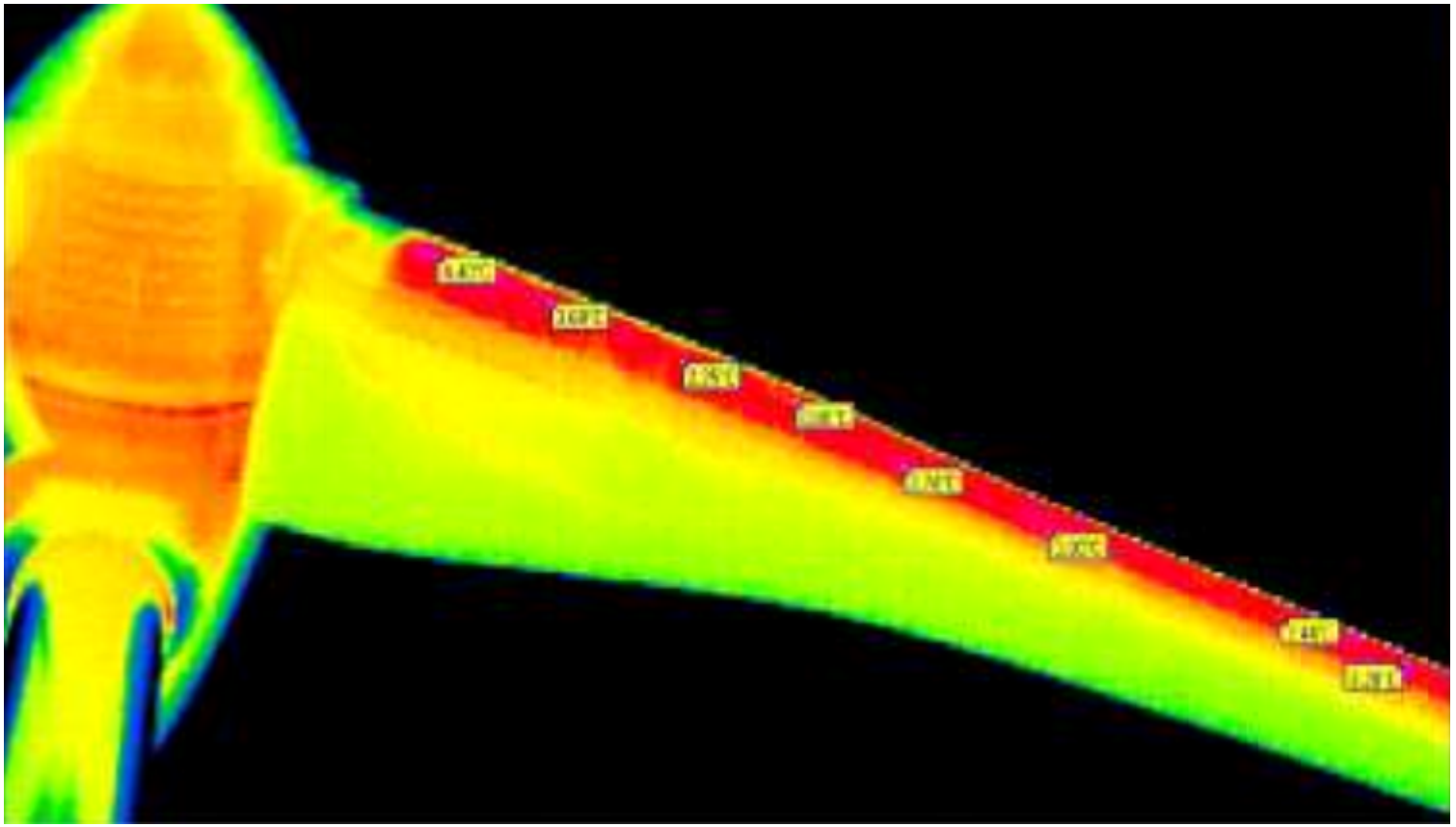
- Specific power curves as function of ice load / icing intensity
- Performance of de-icing and anti-icing systems as function of ice load and icing intensity

Effects of icing on wind turbines

To do list

- Get more and better measurement data (including production and status data)
- Detailed case studies of icing events
  - accretion, intensity, persistence, melting, sublimation
- Long term measurements to validate power curves
- Implement turbine control scenarios

Anti-icing and de-icing



Anti-icing and de-icing

What is it?

- De-icing: remove existing ice from blades
- Anti-icing: prevent ice accretion

Why is it needed?

- Avoid/reduce production losses under icing conditions

Anti-icing and de-icing

Ideal world

- Anti-icing system which completely prevents ice accretion
- De-icing systems which efficiently remove ice
- Efficient control system for de-icing systems
- Performance and costs known
- Additional investment compensated within 1-3 years
- Low maintenance

Anti-icing and de-icing

To do list

- Gain more experience
- More field tests of de-icing systems
- Efficient control systems (start and end of heating)
- Evaluate secondary icing
- Anti-icing field tests

Health and safety

Health and safety

What is it?

- Ice throw and ice fall of wind turbines
- Increased noise with iced blades

Why is it needed?

- Accurate ice throw risk analysis
- Accurate noise assessments

Health and safety

Ideal world

- Ice throw is assessed such as noise and flicker
- Accurate risk analysis possible
- Validated ice throw models

- Effect of ice load on noise is clearly known
- Noise assessments include icing

Health and safety

To do list: Ice throw

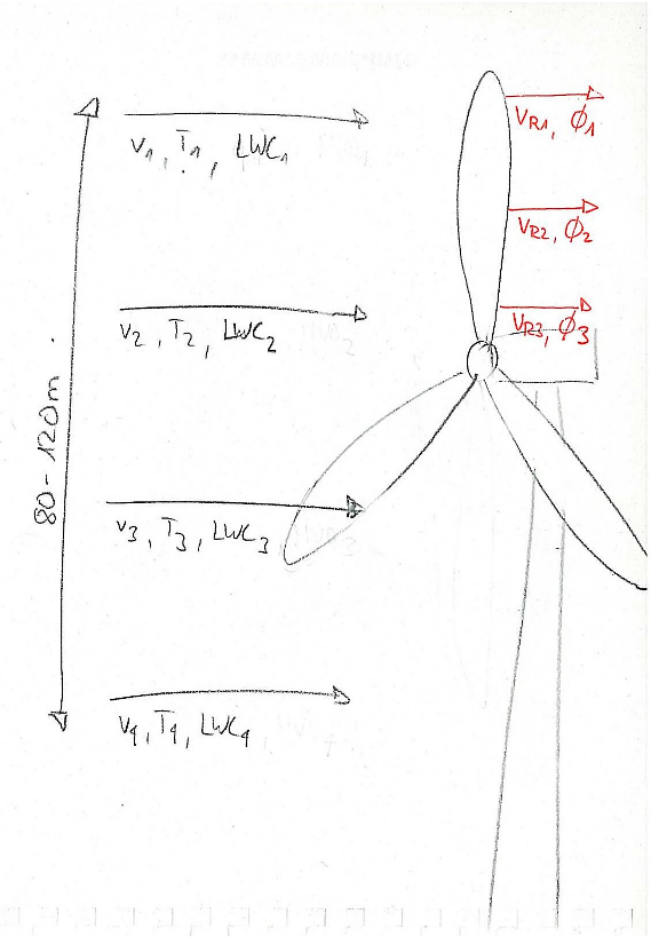
- Systematic empirical ice throw studies
- Preferred blade positions for ice throw
- Flying characteristics
- Ice throw and ice fall / heated and unheated blades
- Mechanical icing model

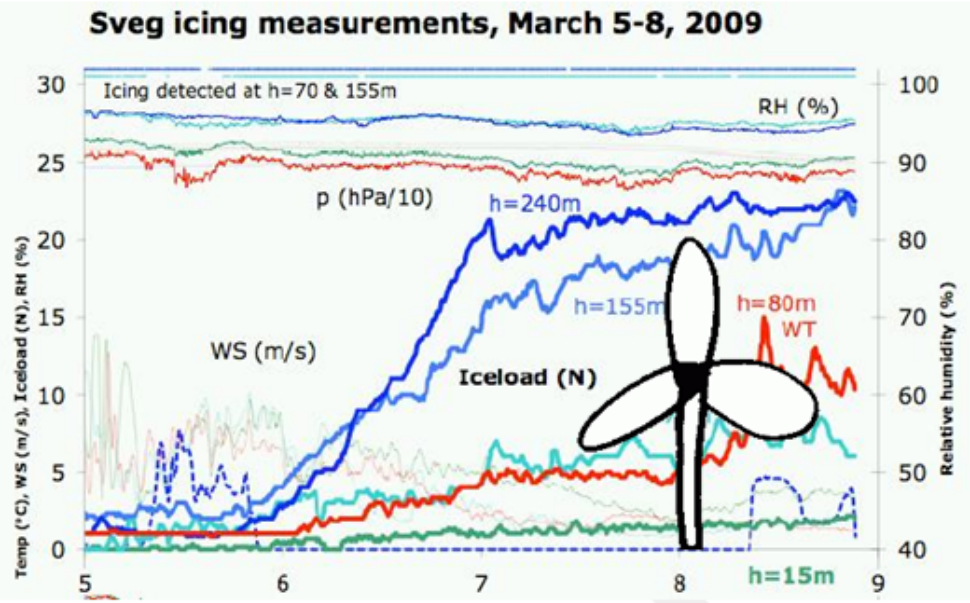
To do list: Noise

- Carry out noise measurements under icing conditions

General conclusions

Task 1: Measure icing on wind turbines





General conclusions

Task 1: Measure icing on wind turbines

→ Good instruments

→ Comprehensive measurement campaigns

→ Test centres / large (EU-)projects

Task 2: Develop wind turbine ice accretion model

Task 3: Validate Task 2 with Task 1

Task 4: Use results of tasks 1-3 to further work on:

- Power curves
- De-icing and anti-icing
- Ice throw
- Numerical weather models

Thank you…

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…for your attention