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Wind turbine blade heating

Can it pay even more?

René Cattin

Icing in Switzerland

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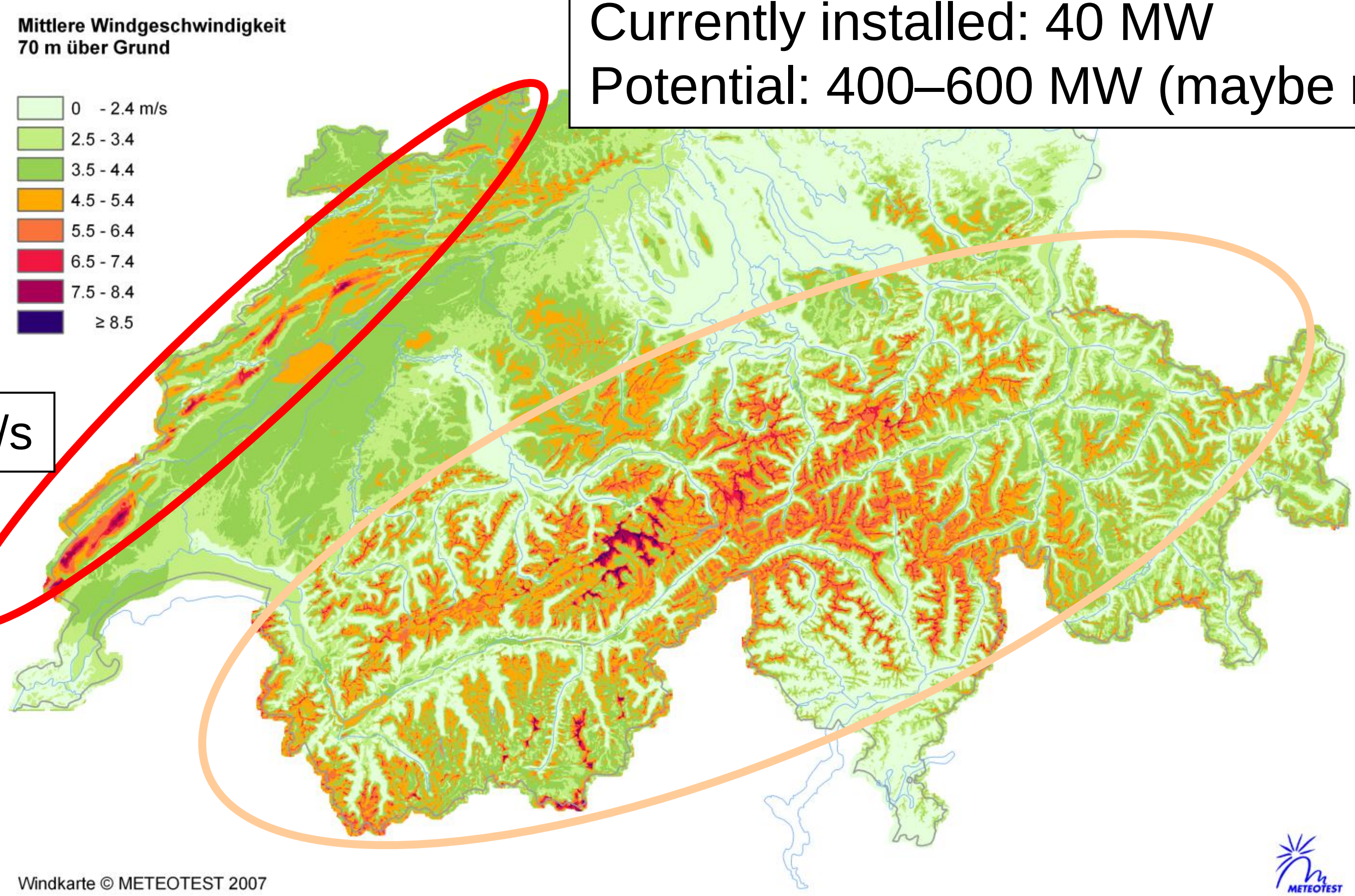
Wind map of Switzerland

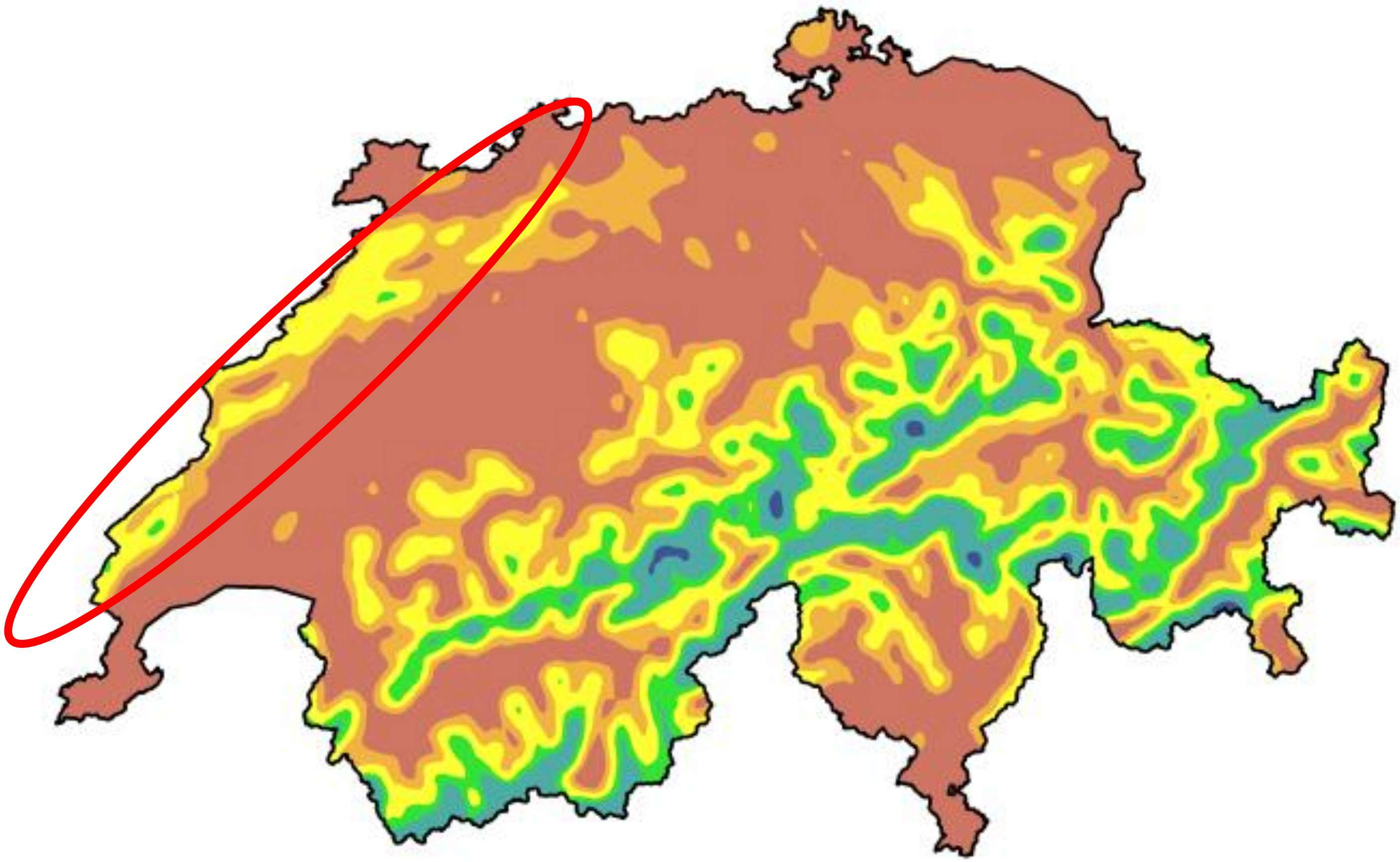
Currently installed: 40 MW
Potential: 400–600 MW (maybe more?)



6-7.5 m/s

Icing in Switzerland

Wind map of Switzerland | Icing map of Switzerland



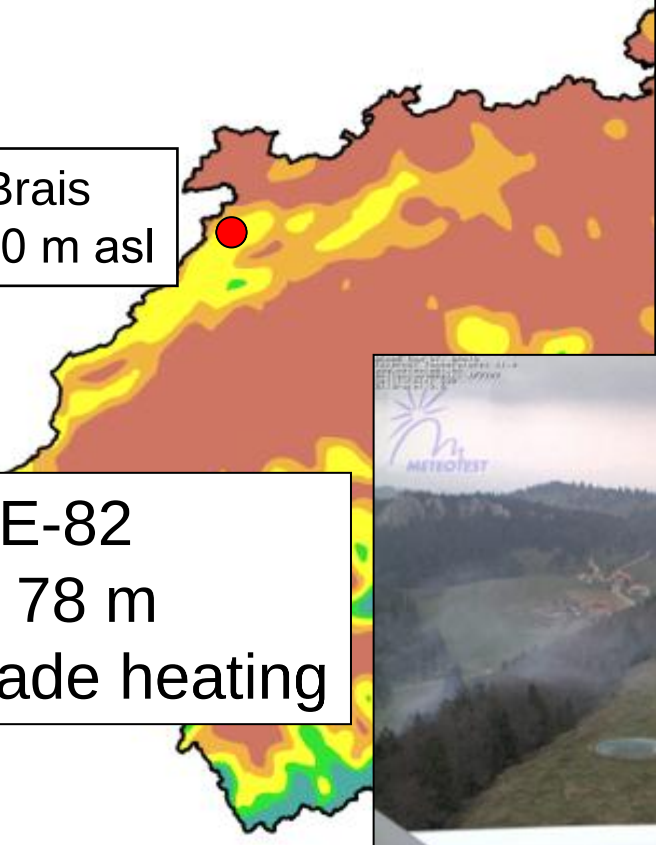
Windkarte © METEOTEST 2007

→ Almost all Swiss sites under icing conditions

St. Brais

Wind map of Switzerland

St. Brais
1‘100 m asl



Windkarte © METEOTEST 2007

2 Enercon E-82
Hub height 78 m
Enercon blade heating

The Project

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The research project

(2009 to 2011)

1) Monitoring of a 2-MW-wind turbine in the Jura arc (2/3 of the planned Swiss wind parks) concerning **icing, turbulence and wind shear**

2) Evaluation and validation of different **systems for ice detection and de-icing**
   → Enercon ice detection **via power curve**
   → **Moog/Insensys** ice detection system
   → Ice detection via **temperature and relative humidity**
   → **Goodrich** ice detector prototype

   → Performance of Enercon **blade heating** system

   → Verification via **camera images**

The Project

The research project
(2009 to 2011)

3) Evaluation of the **production loss** due to icing and of the **gained energy** based on use of ice detection and de-icing systems

→ WEA1: **blade heating off, ice detection on**
→ WEA2: **blade heating on, ice detection on**
How much additional production on WEA2 compared to used energy for blade heating?

→ Calculation of **scenarios** for the whole winter time

→ **Heating during operation** versus heating during standstill

The Project

The research project

(2009 to 2011)

4) Evaluation of the **additional loads** caused by icing
   → Moog/Insensys system

5) Evaluation of the **noise emissions** of a wind turbine under icing conditions
   → noise measurement campaigns

The Project

The research project
(2009 to 2011)

4) Evaluation of the **additional loads** caused by icing
→ Insensys system

5) Evaluation of the **noise emissions** of a wind turbine under icing conditions
→ noise measurement campaigns

Collaboration between
→ Federal Office of Energy
→ Meteotest
→ ADEV Windkraft AG (Operator)
→ Enercon
→ Moog/Insensys

Instrumentation

Instrumentation: Camera system

→ The eye is / cameras are still the **best ice detectors**

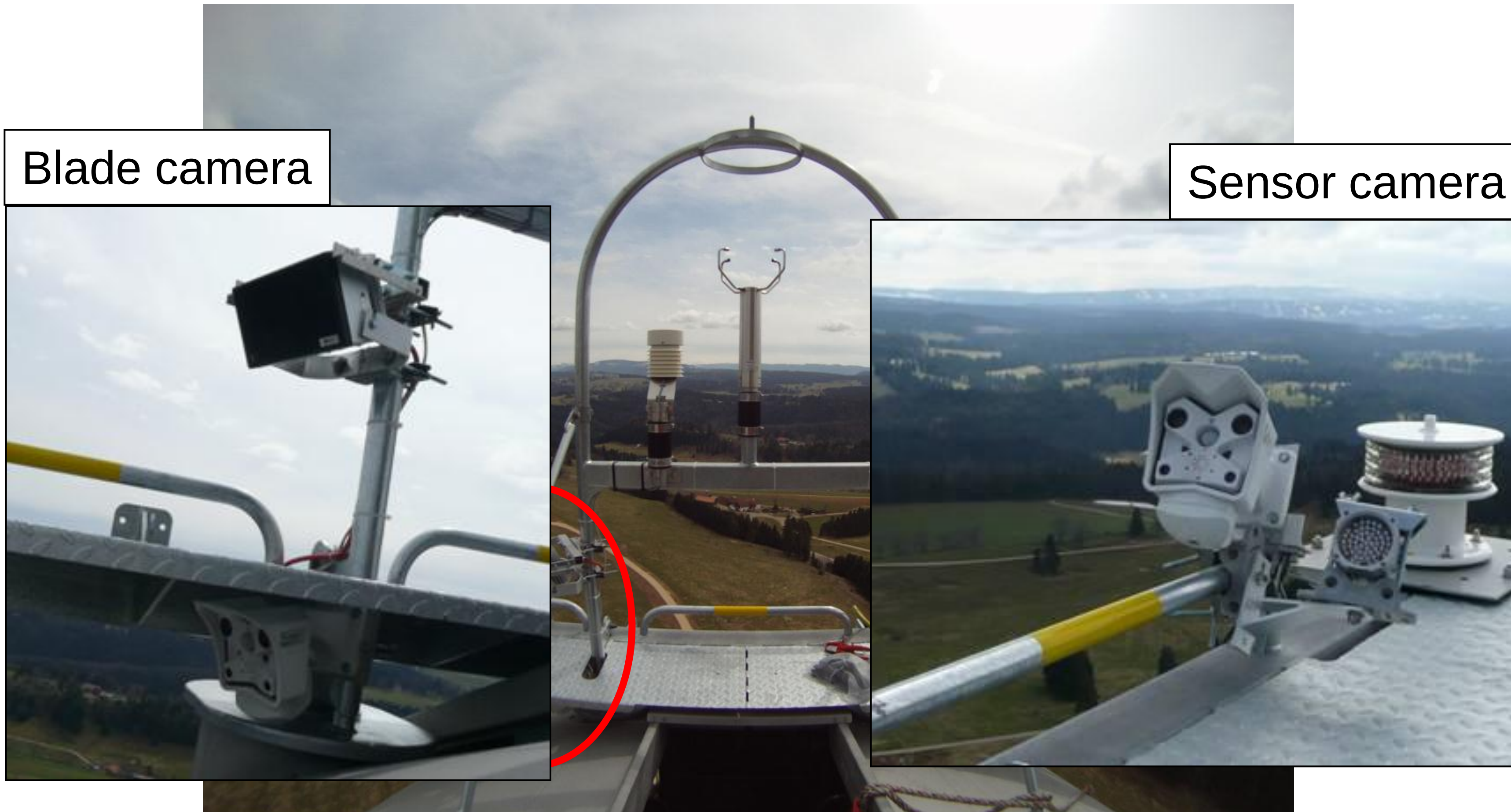
Commercial Mobotix Webcams mounted at nacelle

Developed and tested at the **Guetsch site** (Andermatt, Switzerland)
→ www.meteotest.ch/cost727/index.html

Video motion detection for capturing the moving blades

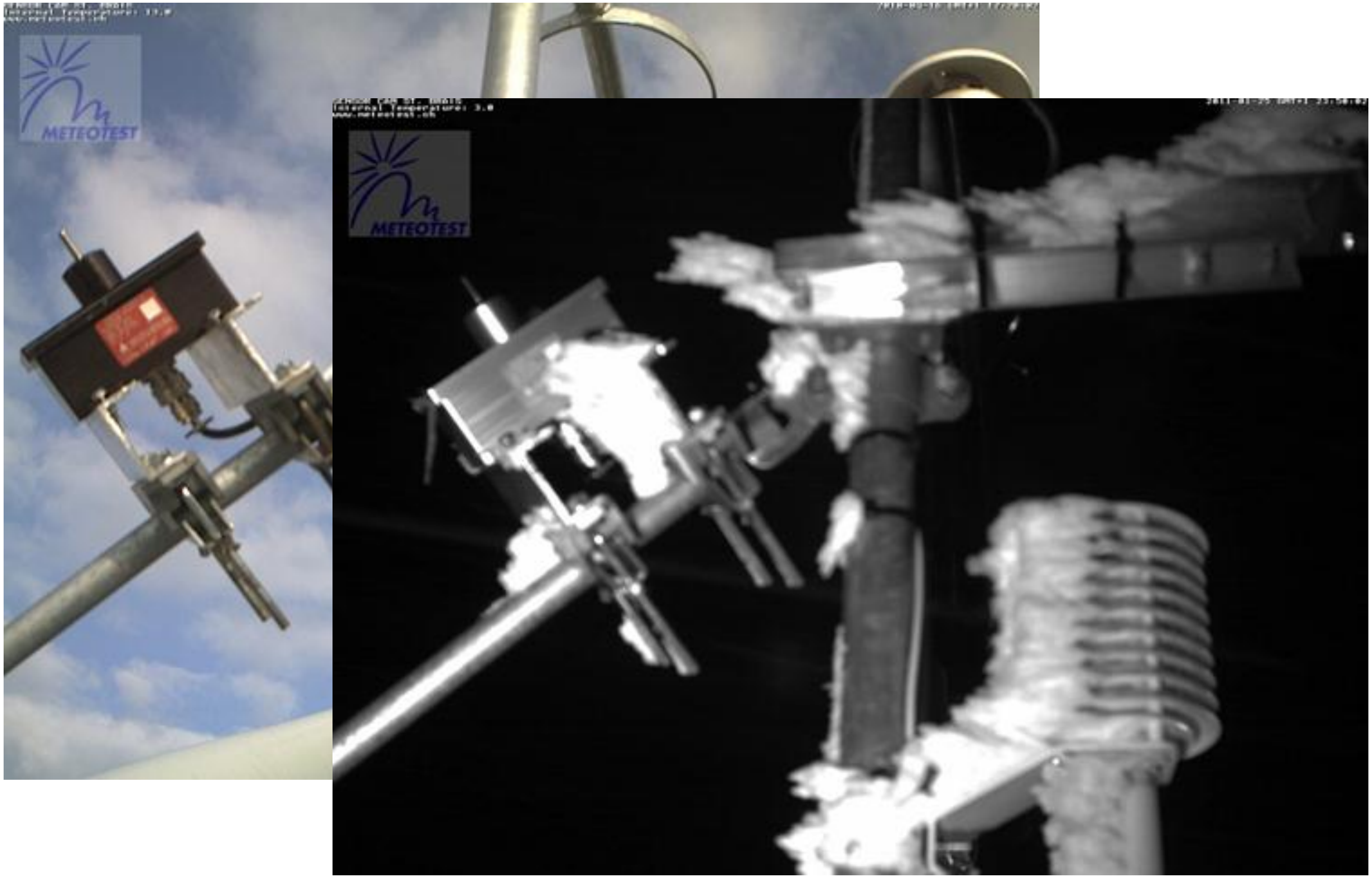
Instrumentation

Instrumentation



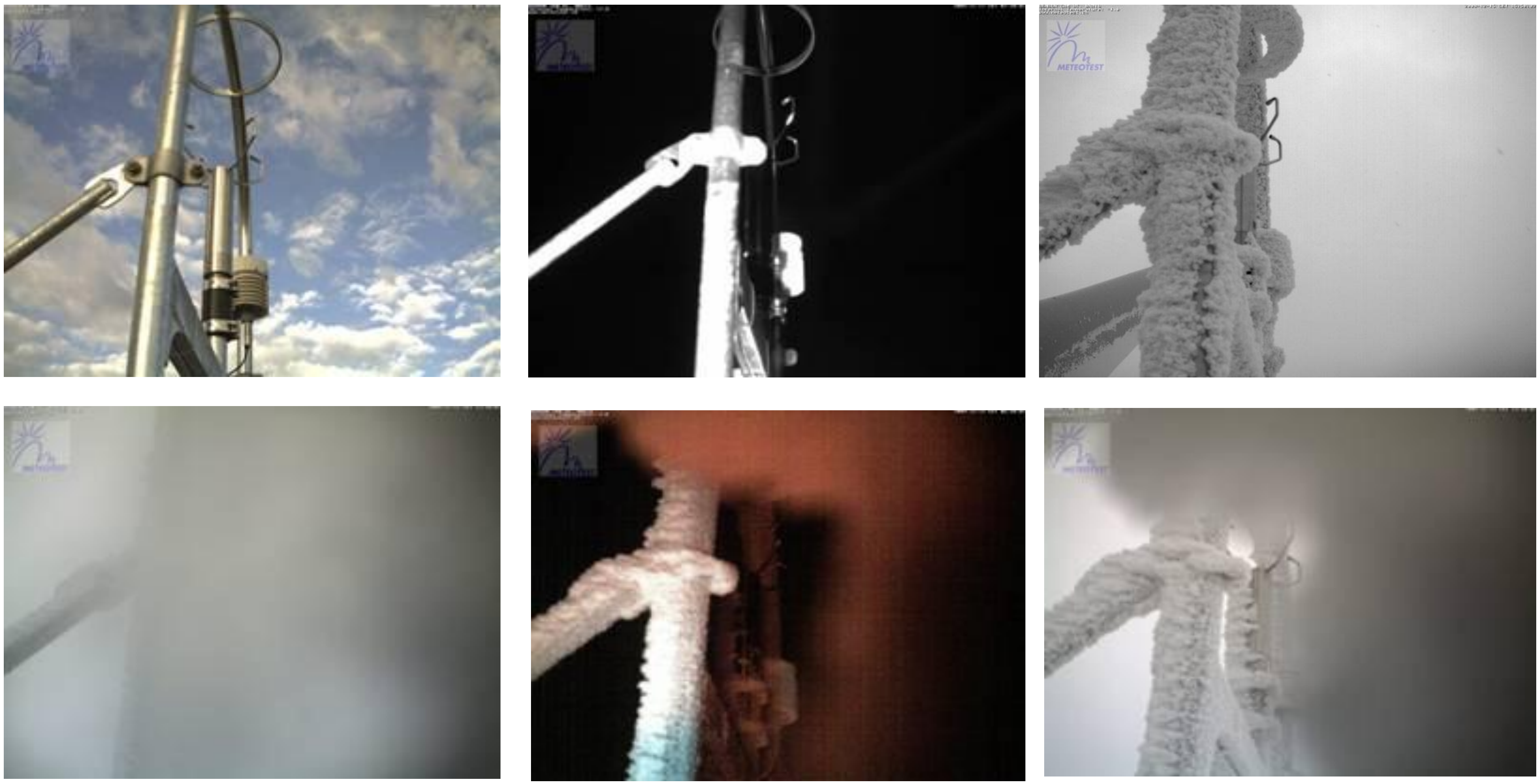
Instrumentation

Sensor camera: image taken every 30 minutes



Instrumentation

Sensor camera: image taken every 30 minutes



→ Very high availability of sensor camera

Instrumentation

Blade camera: image taken by motion detection

Instrumentation

Blade camera: problems

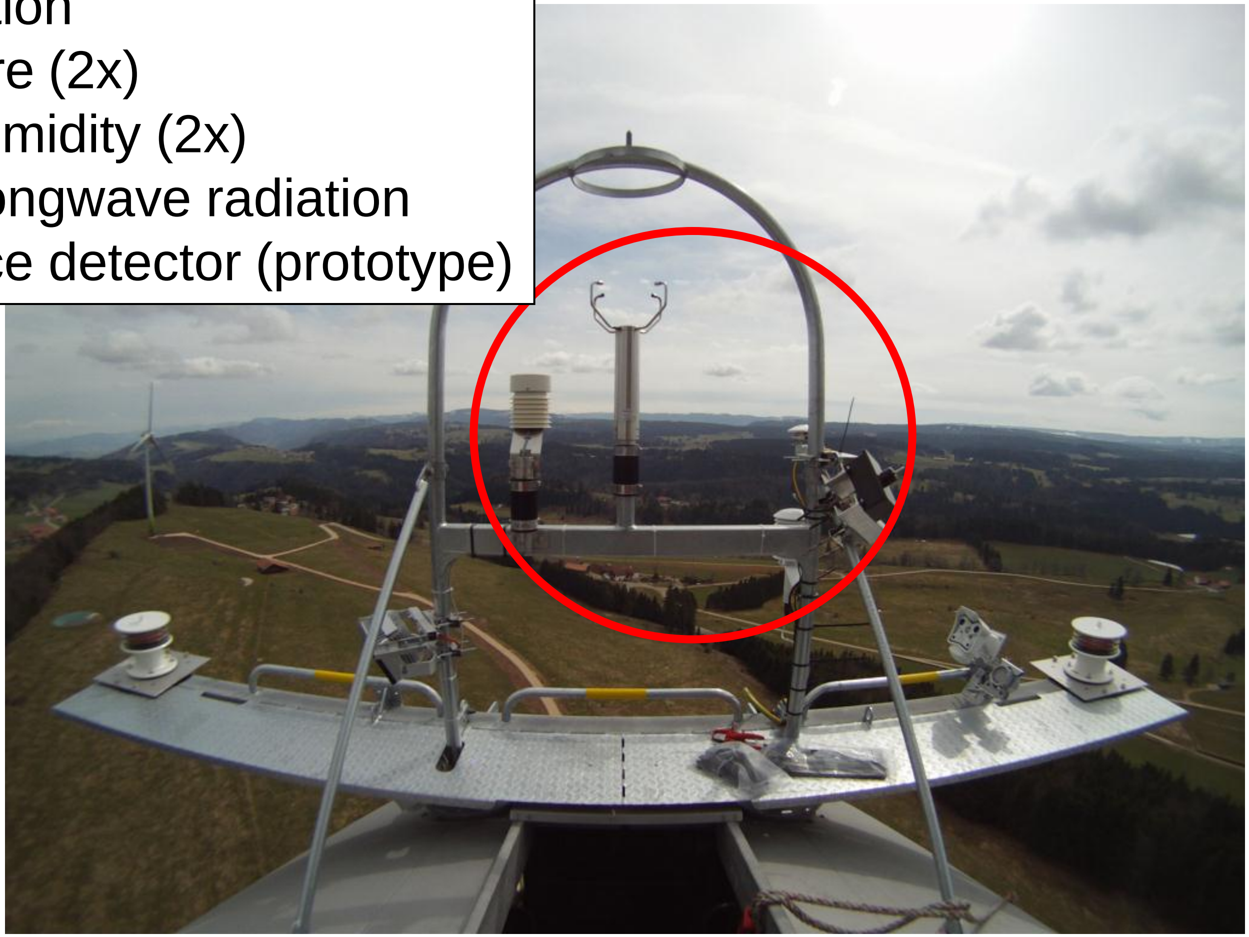
Instrumentation

Latest images displayed on website (protected by password)
All images archieved

Instrumentation

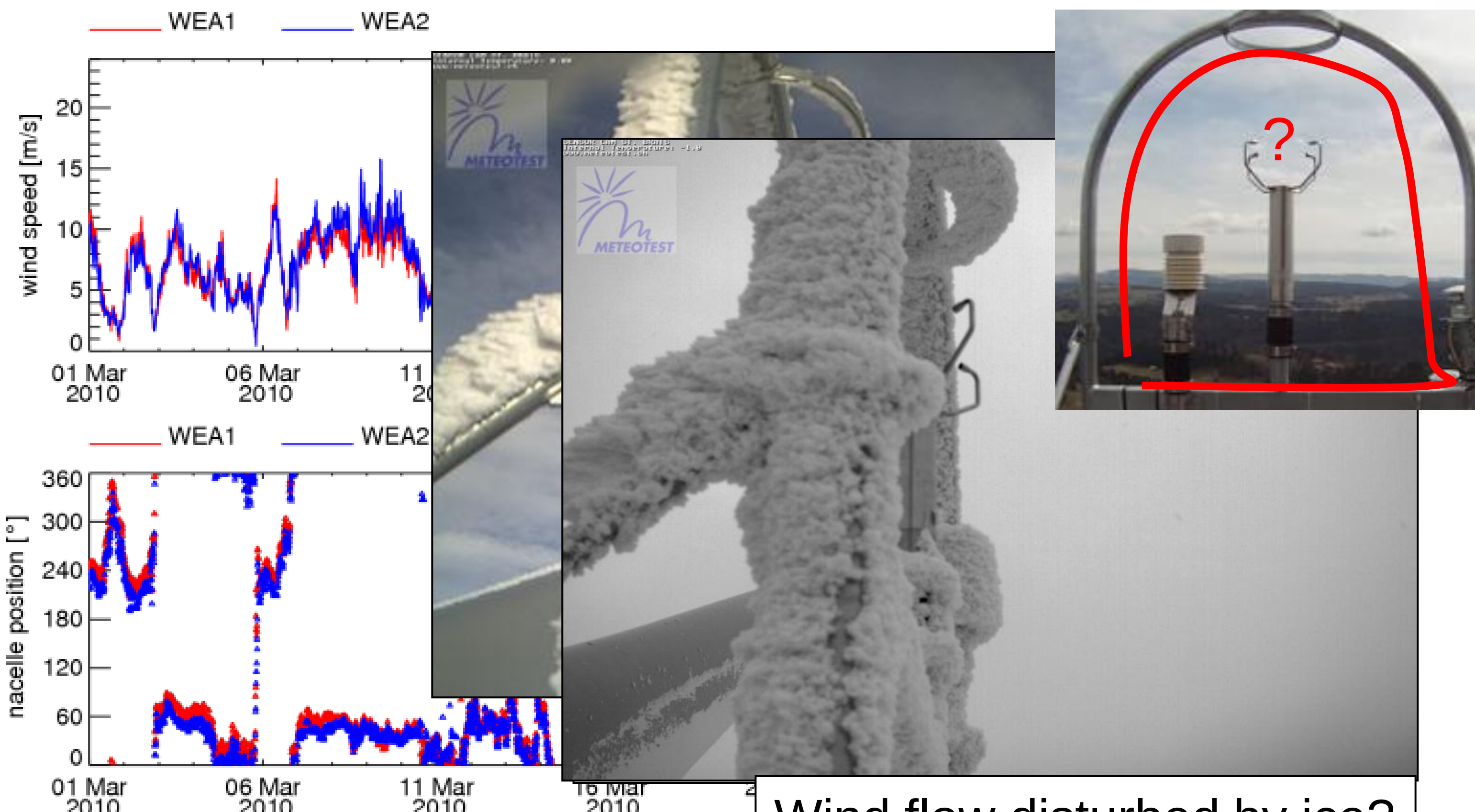
Wind speed
Wind direction
Temperature (2x)
Relative humidity (2x)
Incoming longwave radiation
Goodrich ice detector (prototype)

umentation



Instrumentation

Operational data: wind speed / wind direction



Wind flow disturbed by ice?

Instrumentation

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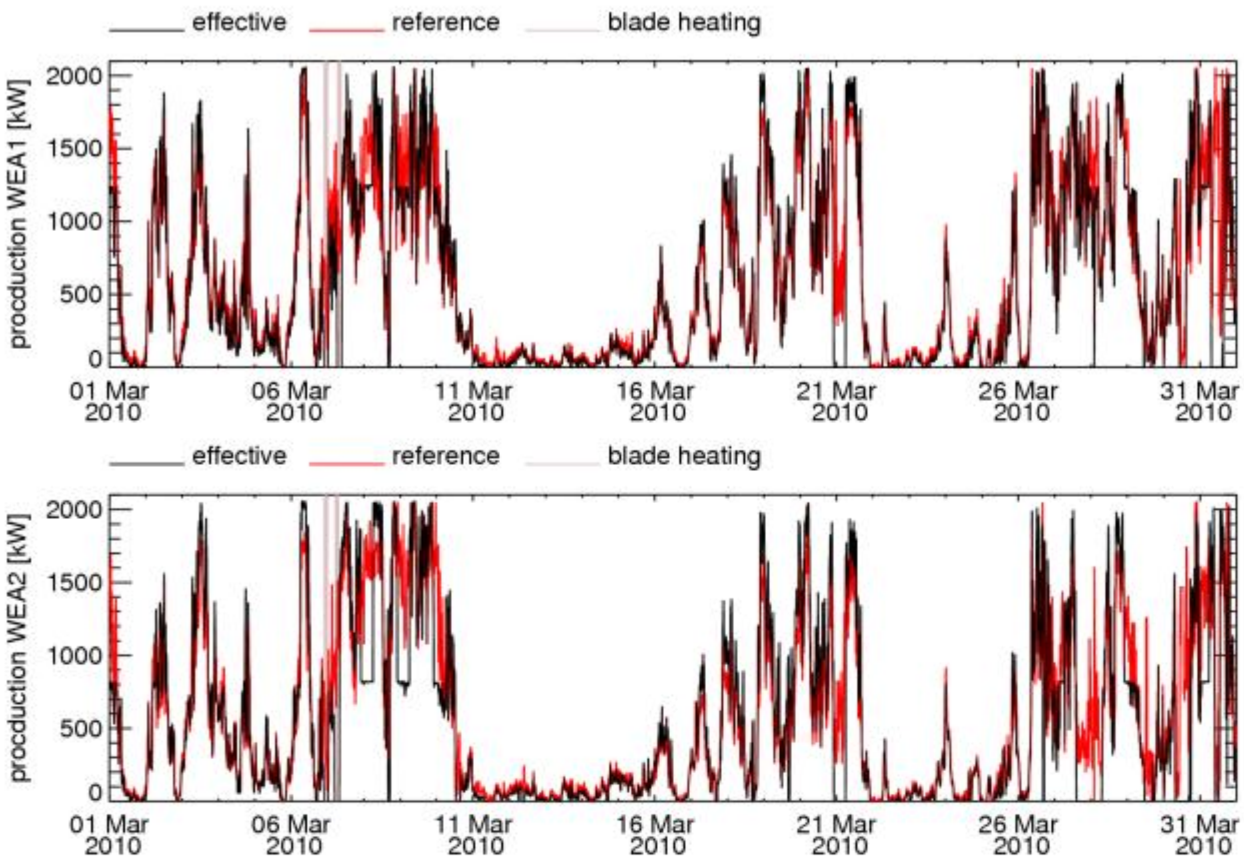
Operational data: power production



Icing on Structures

Icing on Structures

Cloud icing (rime icing, glaze icing)
Precipitation icing (freezing rain, wet snow)

Icing on Structures

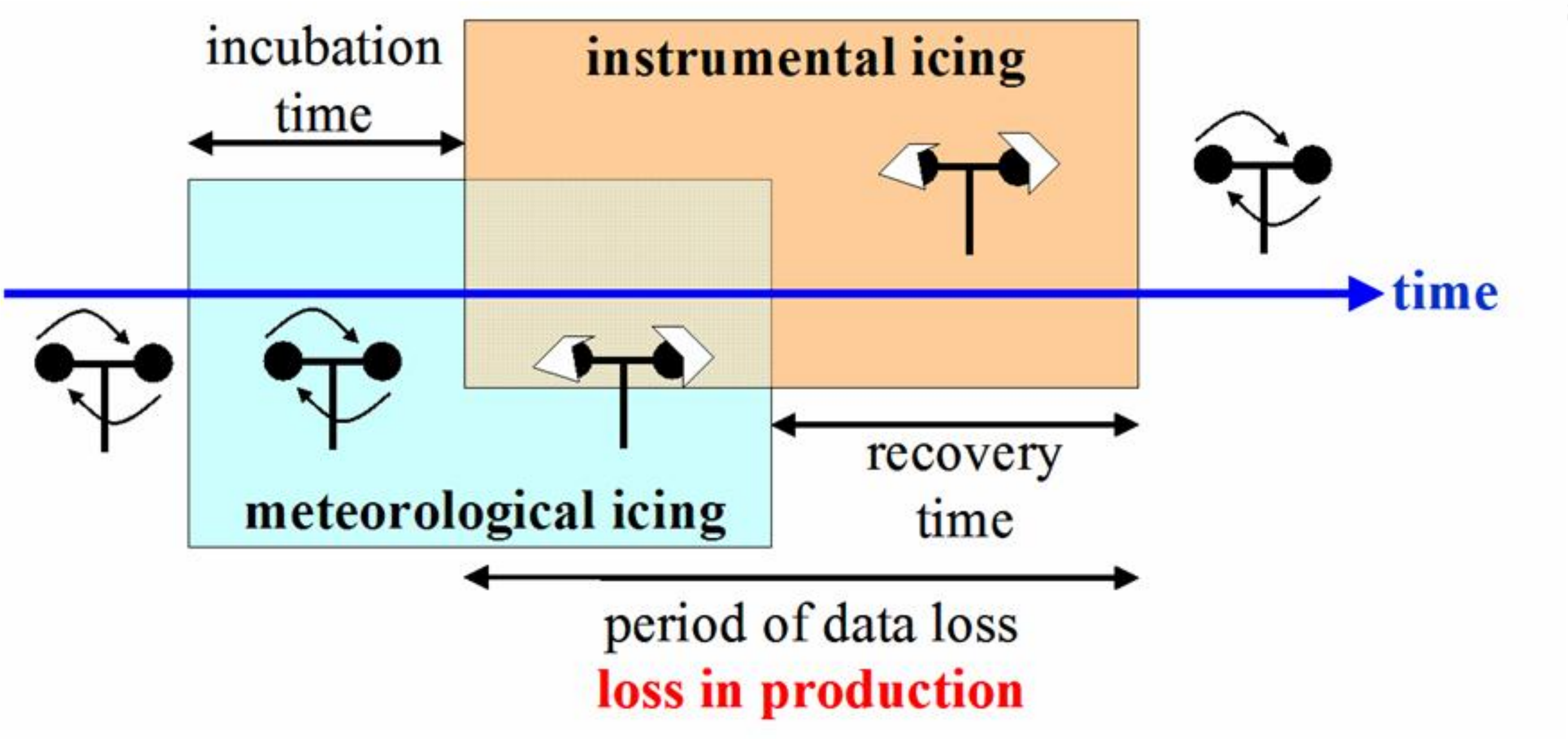




Wind turbine:
Reduced production
Additional loads
Imbalance
Fatigue
Increased noise
Ice Throw

Icing on Structures

Meteorological and instrumental icing



Icing at St. Brais

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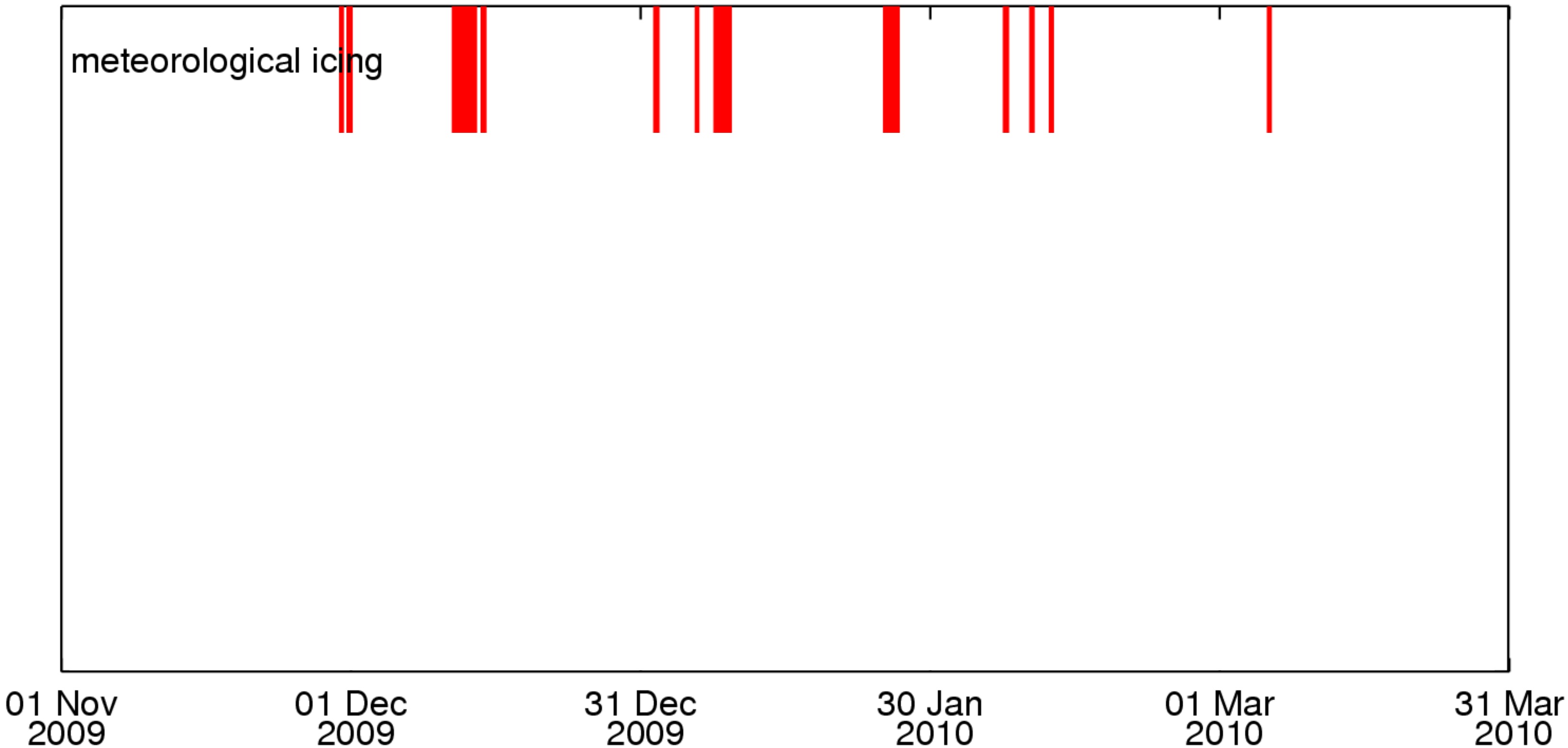
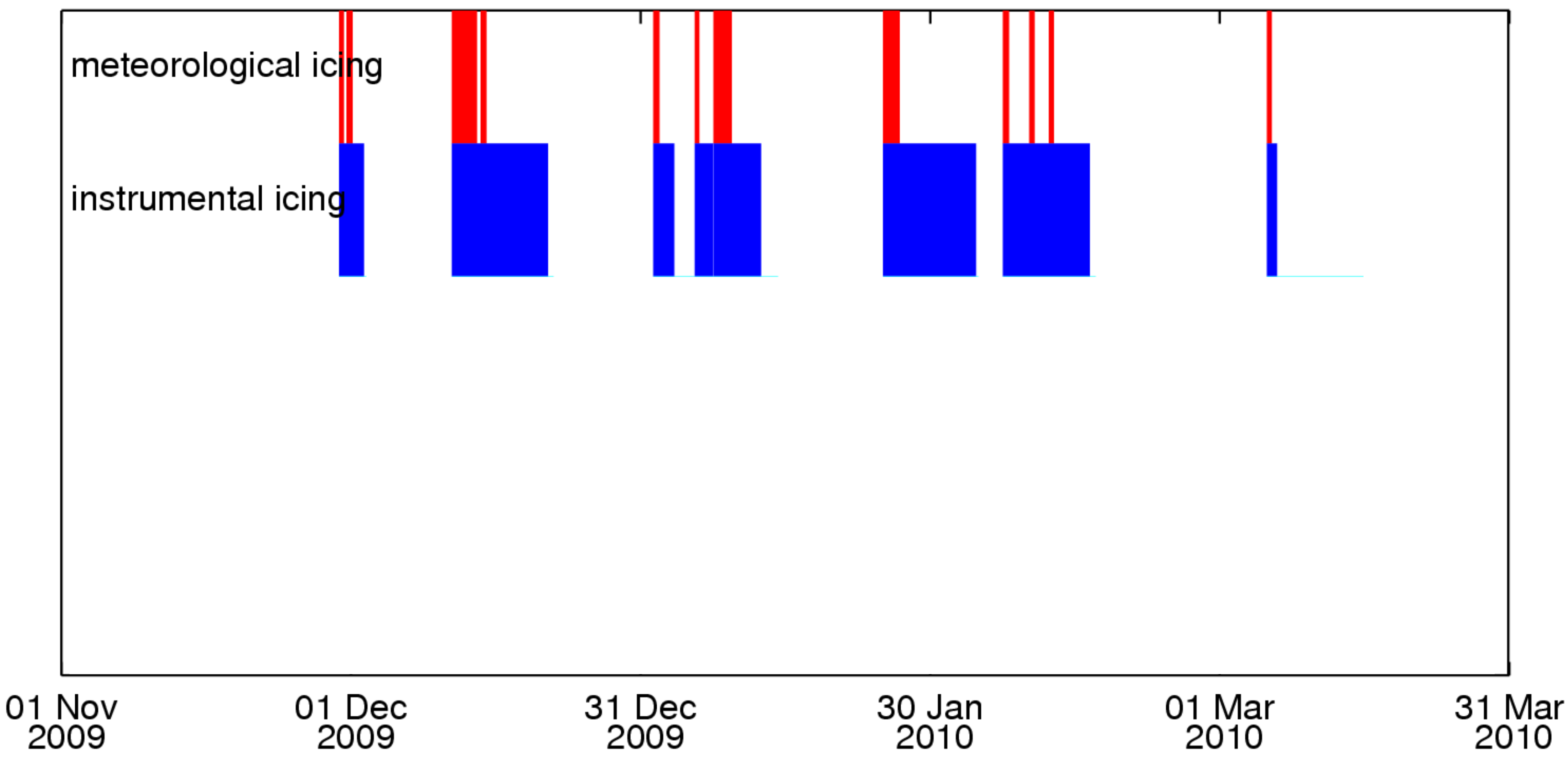
Meteorological and instrumental icing 2009/10



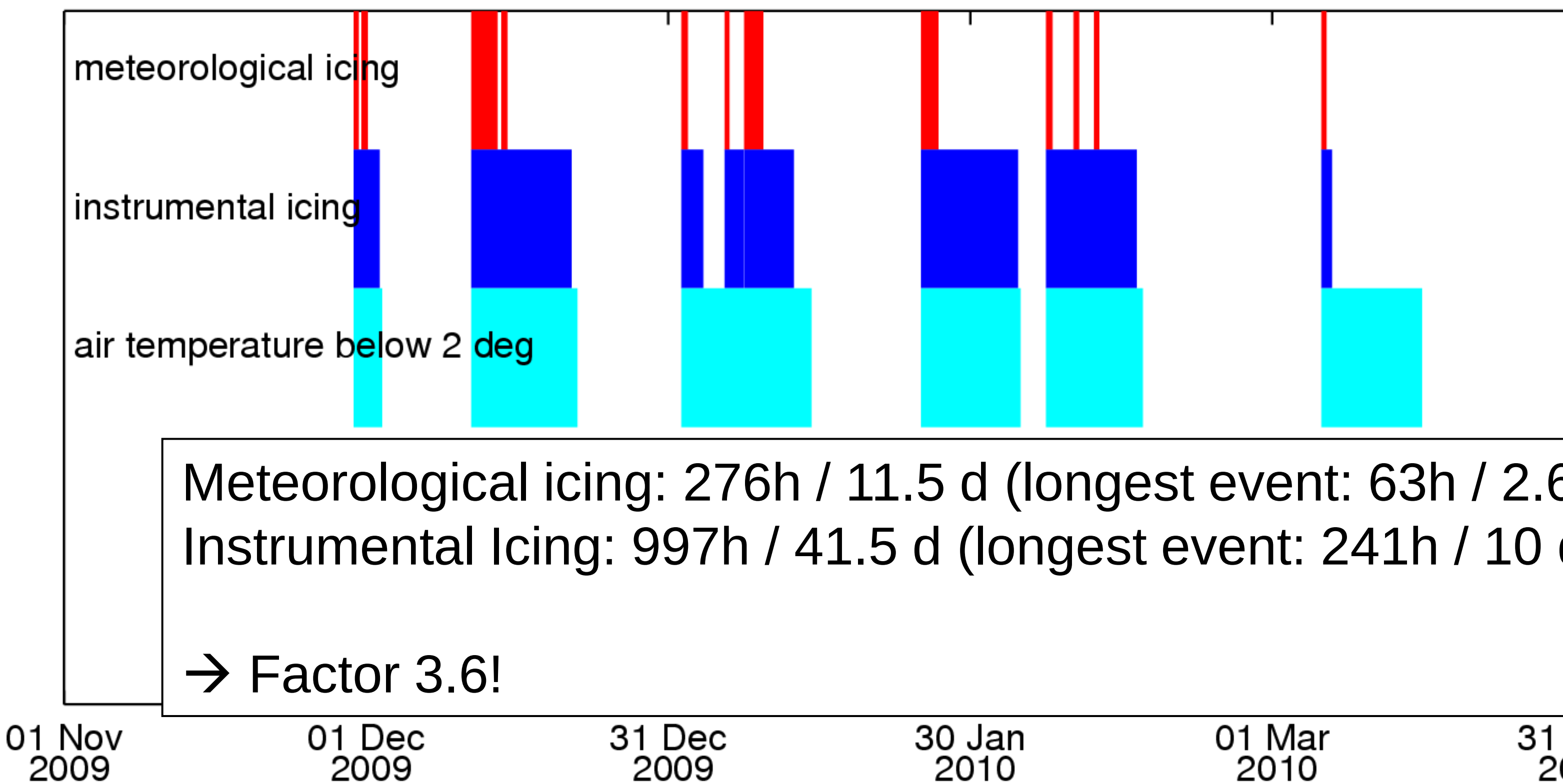
Icing at St. Brais

Meteorological and instrumental icing 2009/10



Icing at St. Brais

Meteorological and instrumental icing 2009/10



Meteorological icing: 276h / 11.5 d (longest event: 63h / 2.6d)
Instrumental Icing: 997h / 41.5 d (longest event: 241h / 10 d)

→ Factor 3.6!

Icing at St. Brais

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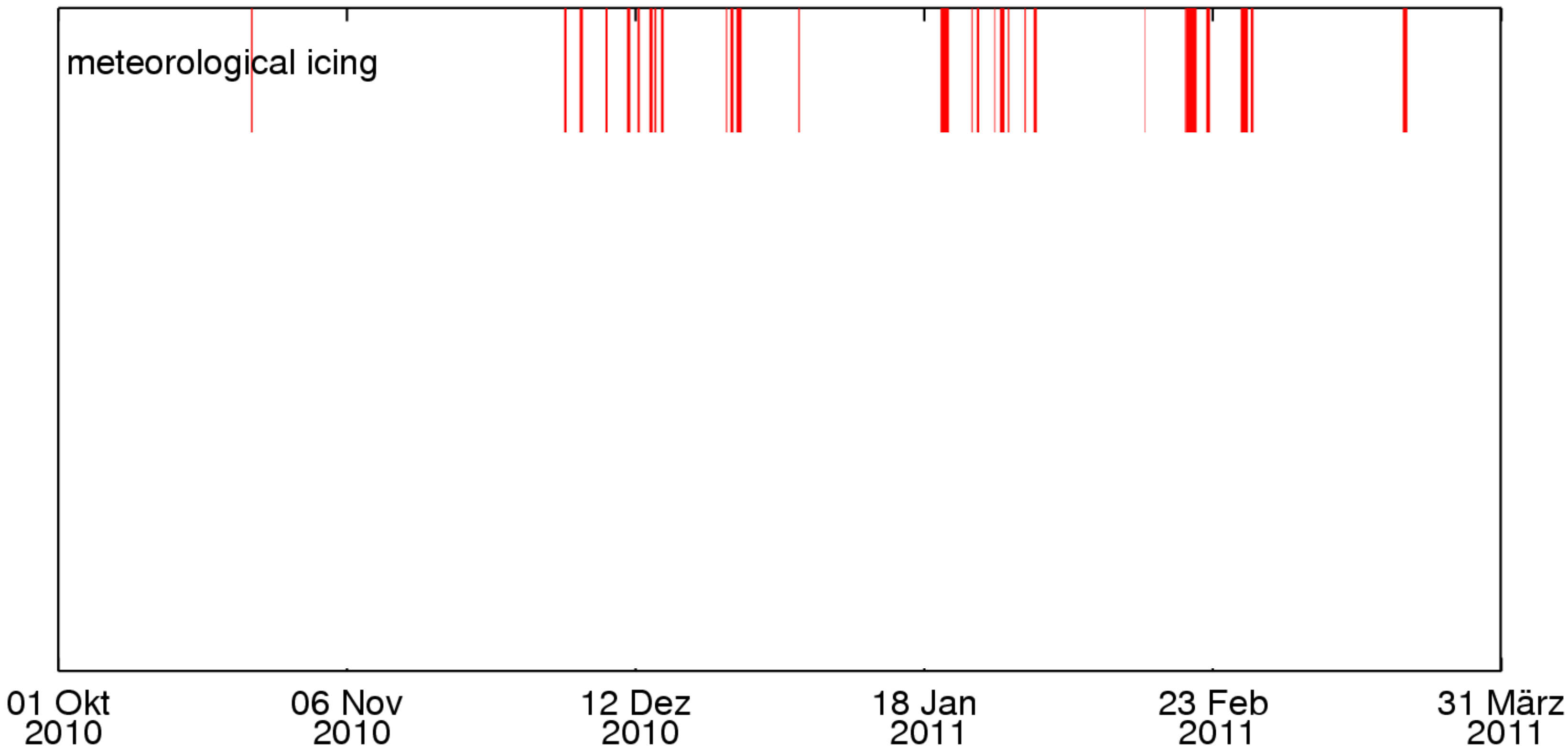
Meteorological and instrumental icing 2010/11



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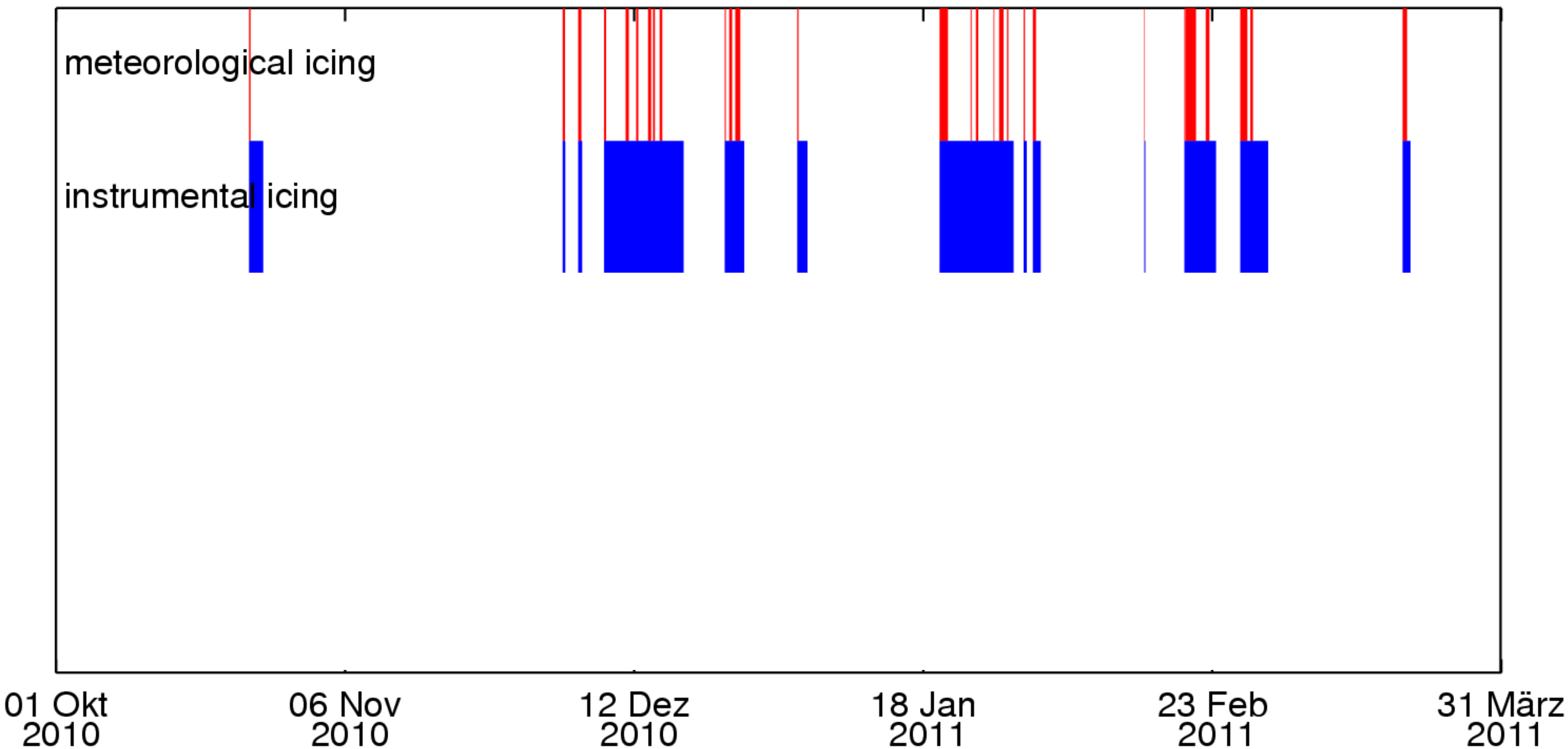
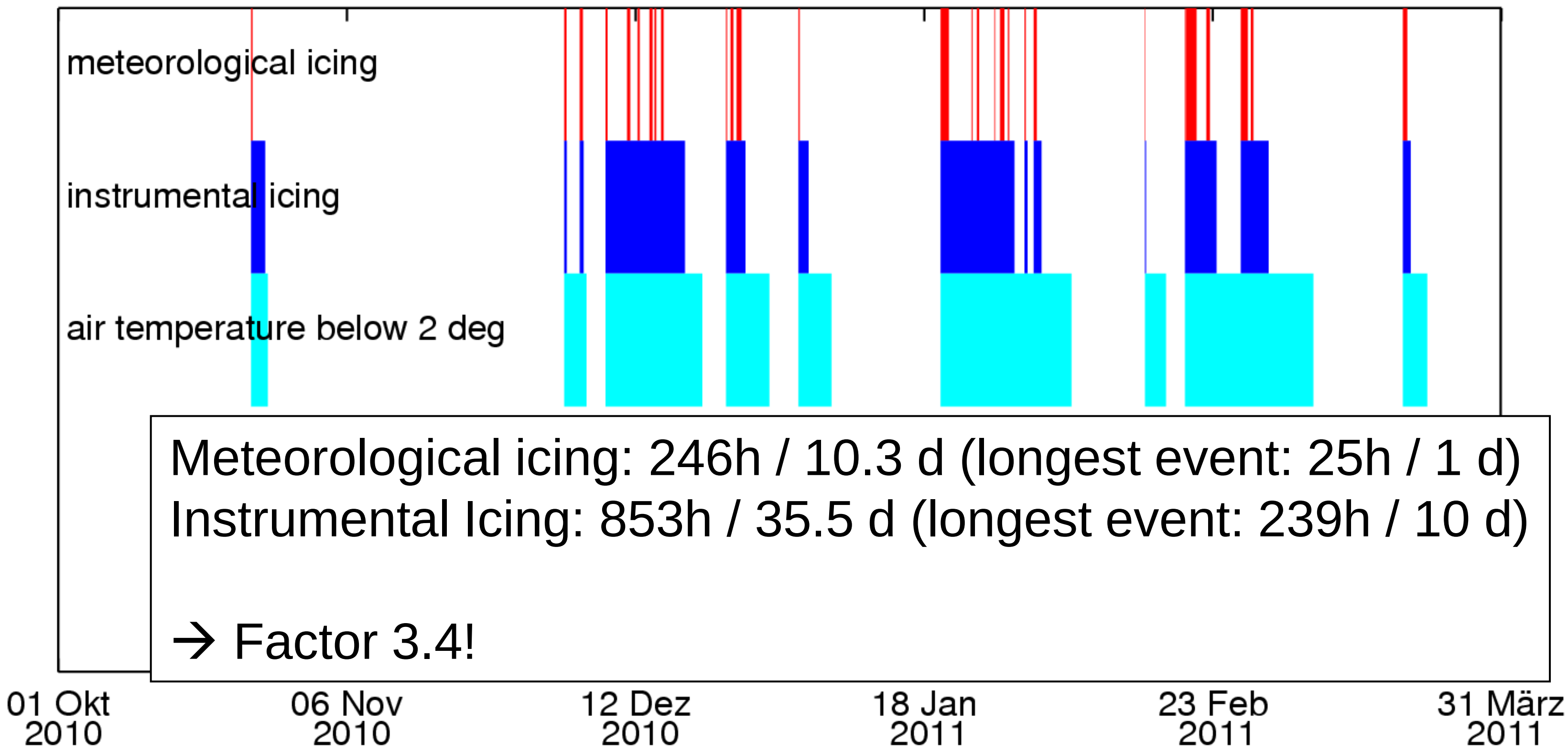
Meteorological and instrumental icing 2010/11



Icing at St. Brais

Meteorological and instrumental icing 2010/11



Meteorological icing: 246h / 10.3 d (longest event: 25h / 1 d)
Instrumental Icing: 853h / 35.5 d (longest event: 239h / 10 d)

→ Factor 3.4!

Icing at St. Brais

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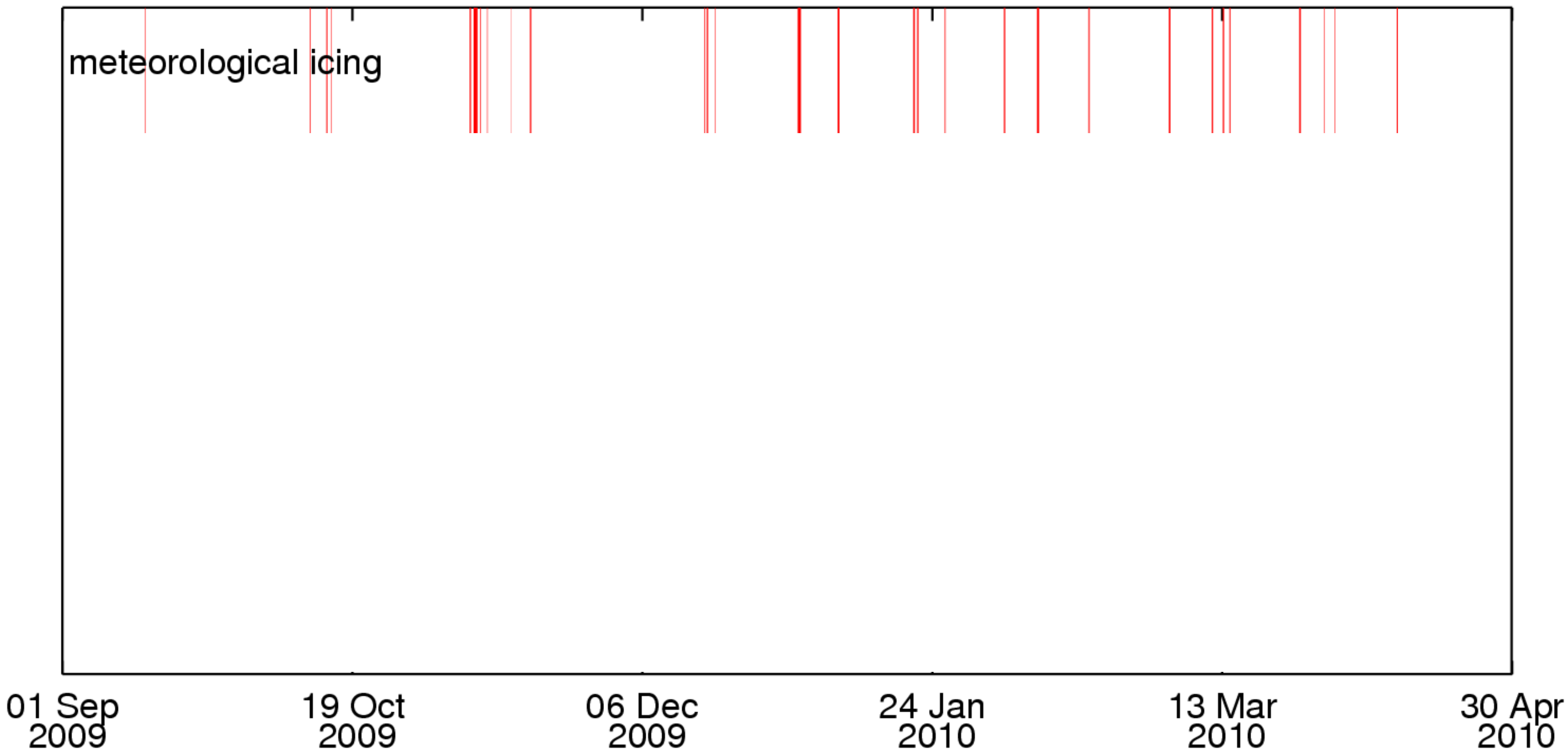
Comparison with Guetsch (2‘300m asl)



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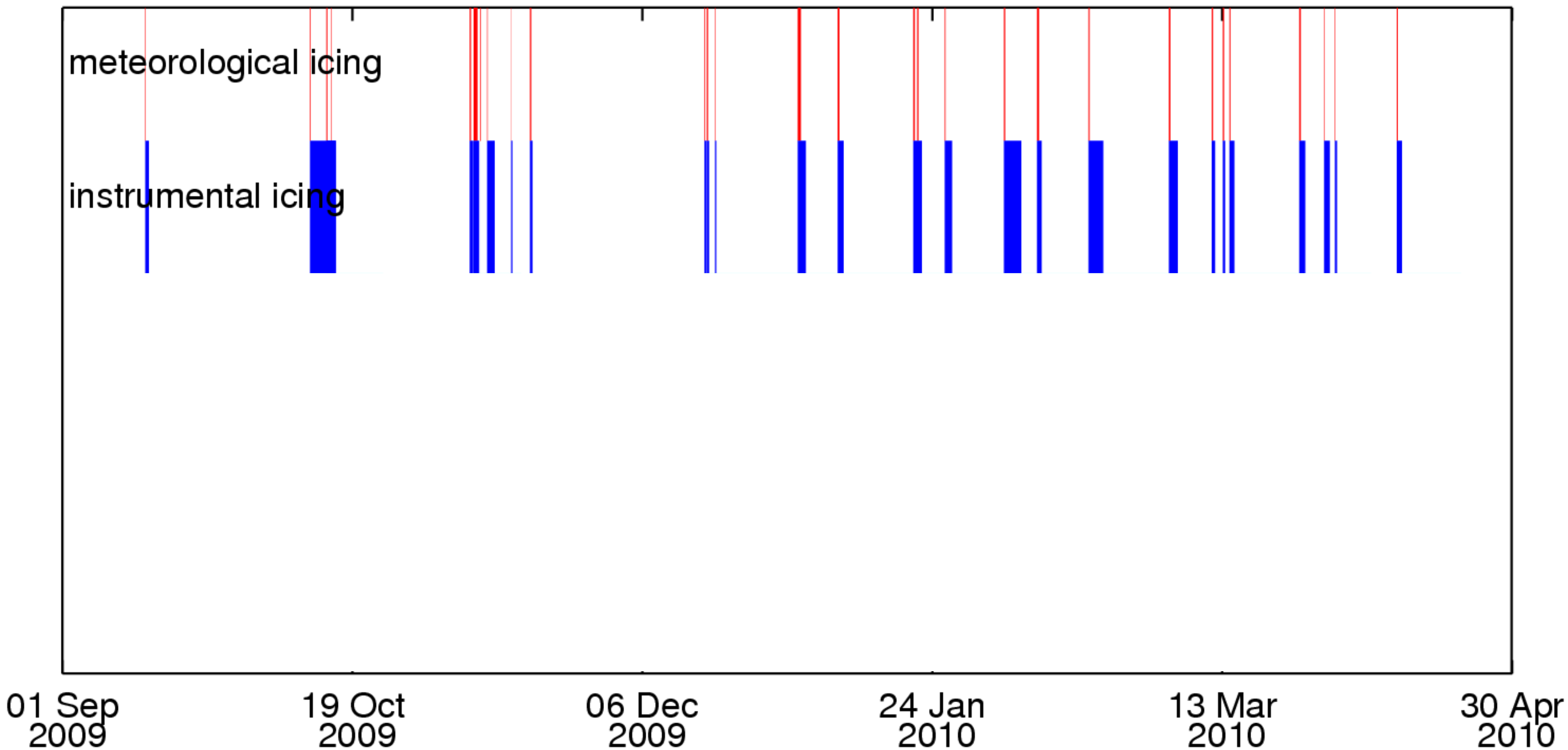
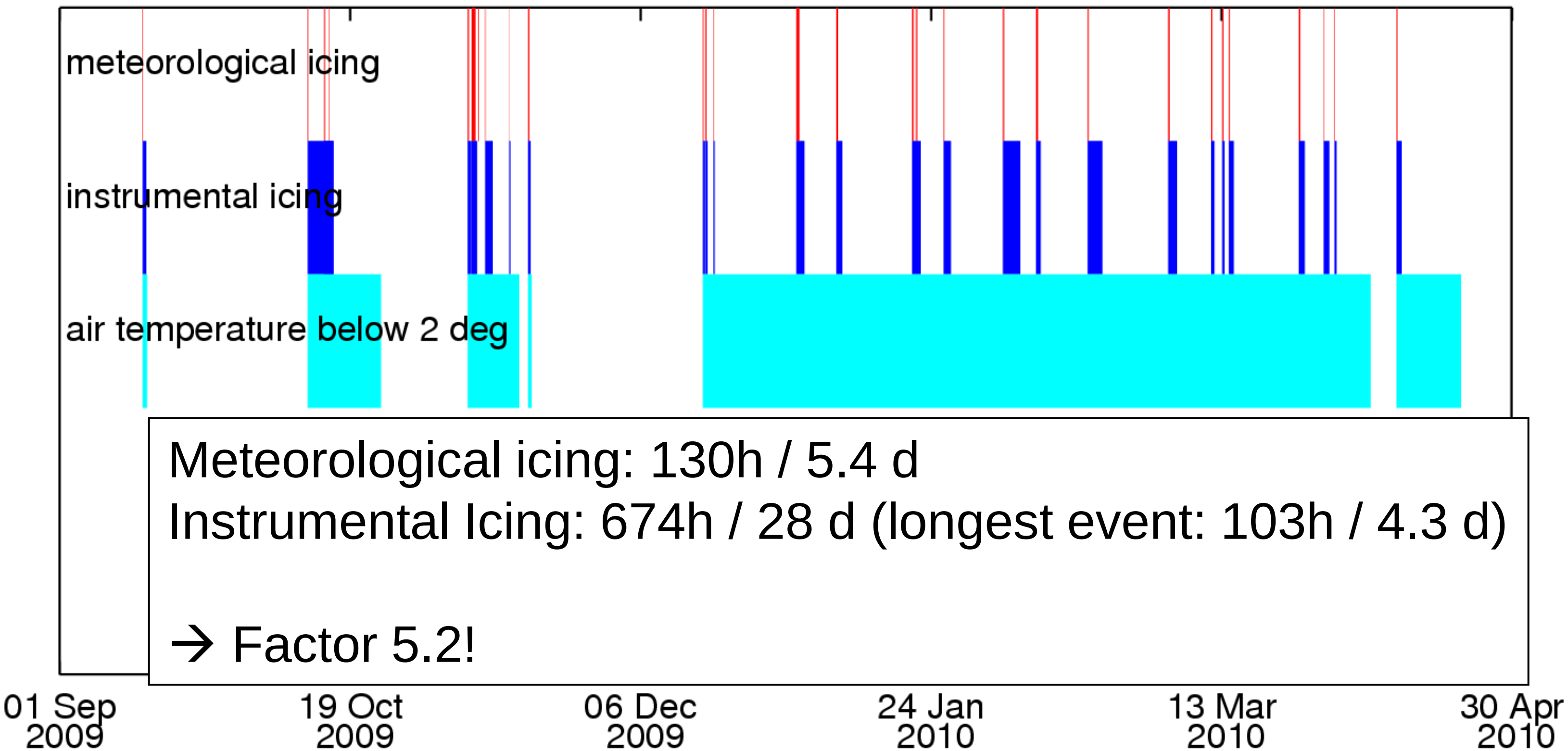
Comparison with Guetsch (2'300m asl)



Icing at St. Brais

Comparison with Guetsch (2'300m asl)



Meteorological icing: 130h / 5.4 d
Instrumental Icing: 674h / 28 d (longest event: 103h / 4.3 d)

→ Factor 5.2!

Icing at St. Brais

Summary Icing Events

	Anzahl Ereignisse met. Vereisung	Meteorologische Vereisung	Instrumentelle Vereisung	Faktor
St. Brais 2009/10	12	276h / 11.5 Tage	997h / 41.5 Tage	3.6
St. Brais 2010/11	26	247h / 10.3 Tage	853h / 35.5 Tage	3.4
Gütsch 2009/10	24	130h / 5.4 Tage	674h / 28.1 Tage	5.2

→ Icing conditions are very site specific

Blade Heating

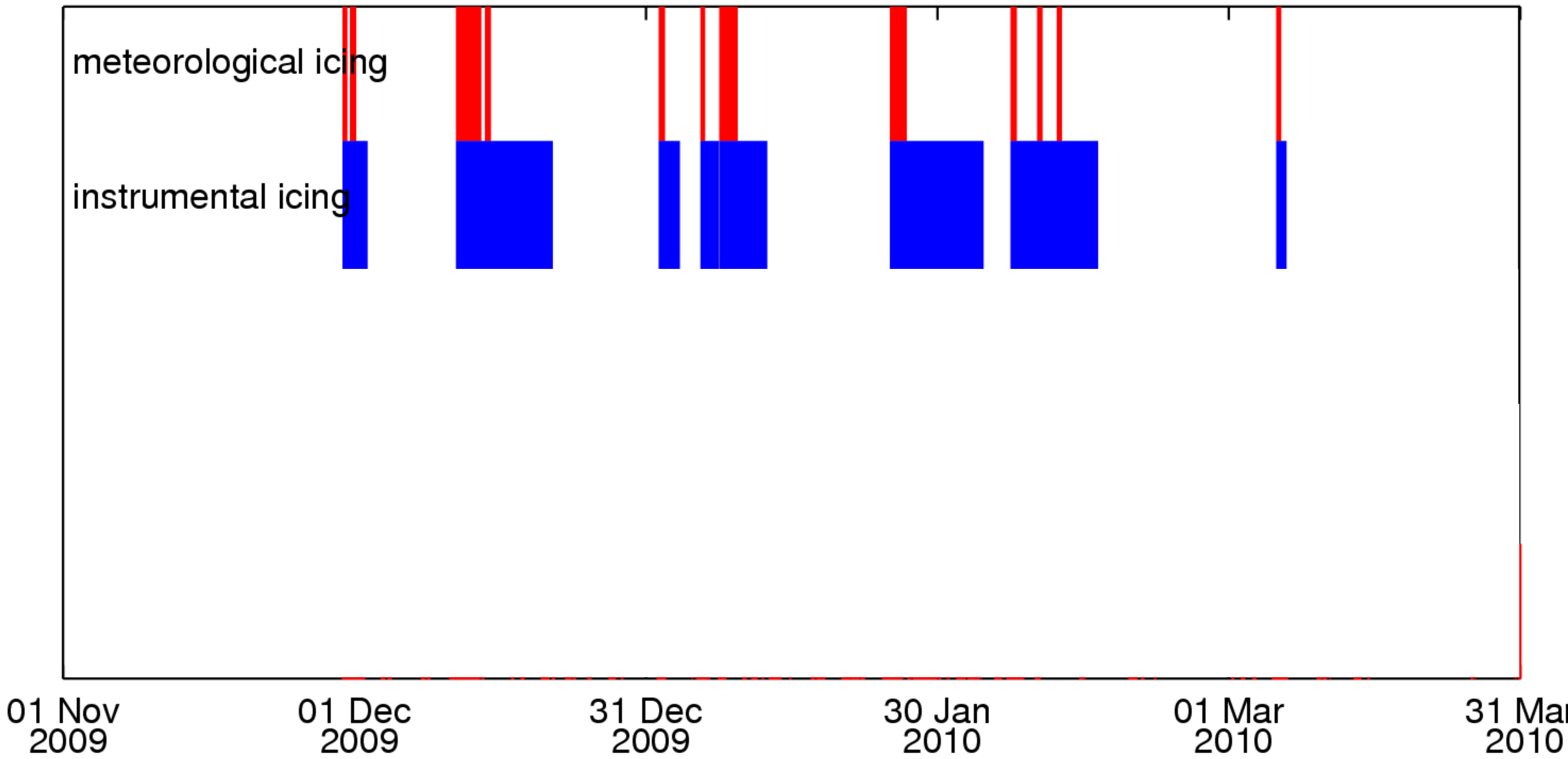
Blade heating

Status 2009/10 and partly 2010/11:

→ **turbine is stopped** when icing is detected
→ blades are **heated for 3 h** (80 kW)
→ turbine is **automatically restarted**

Blade Heating

Blade heating 2009/10



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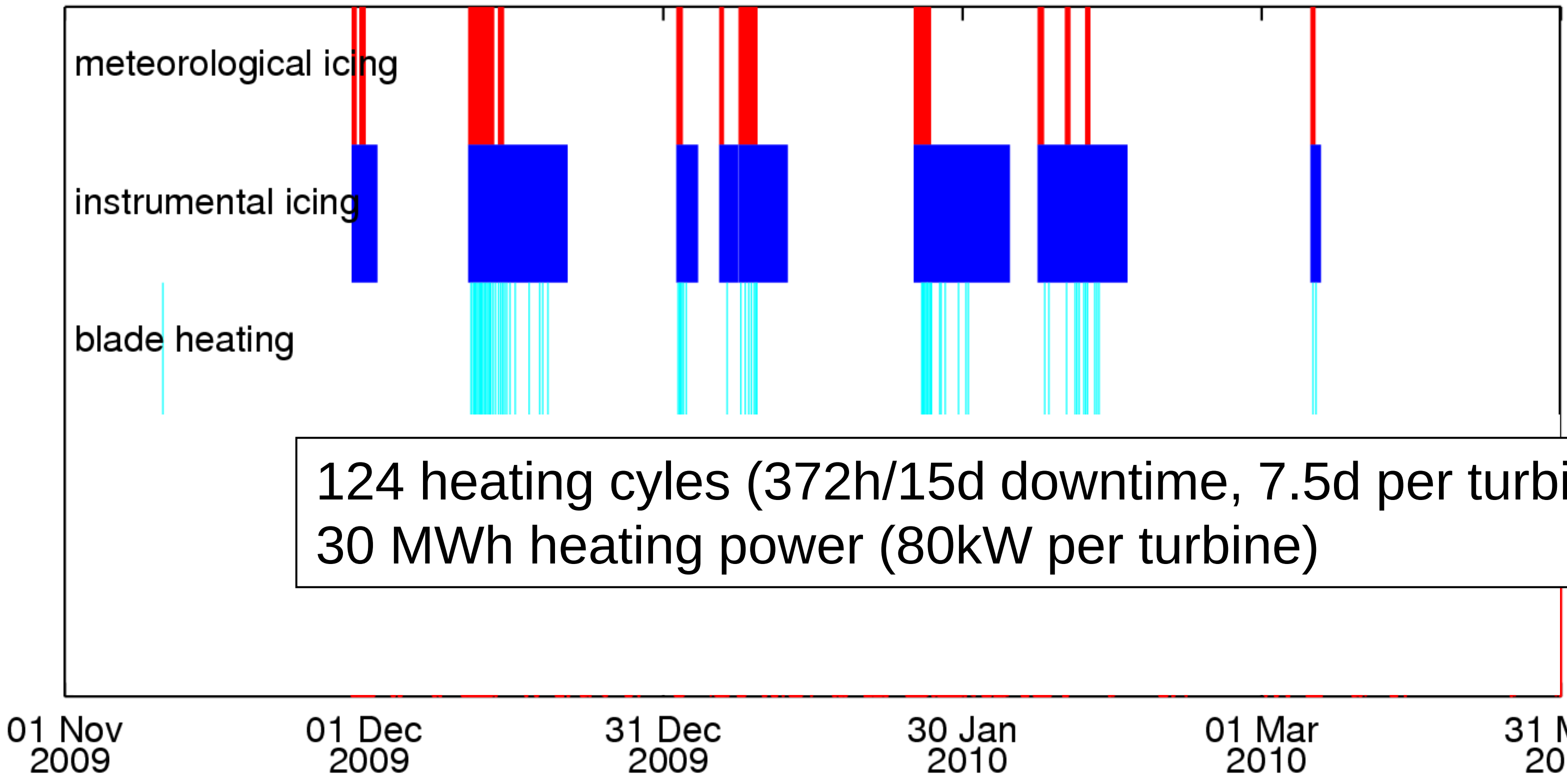
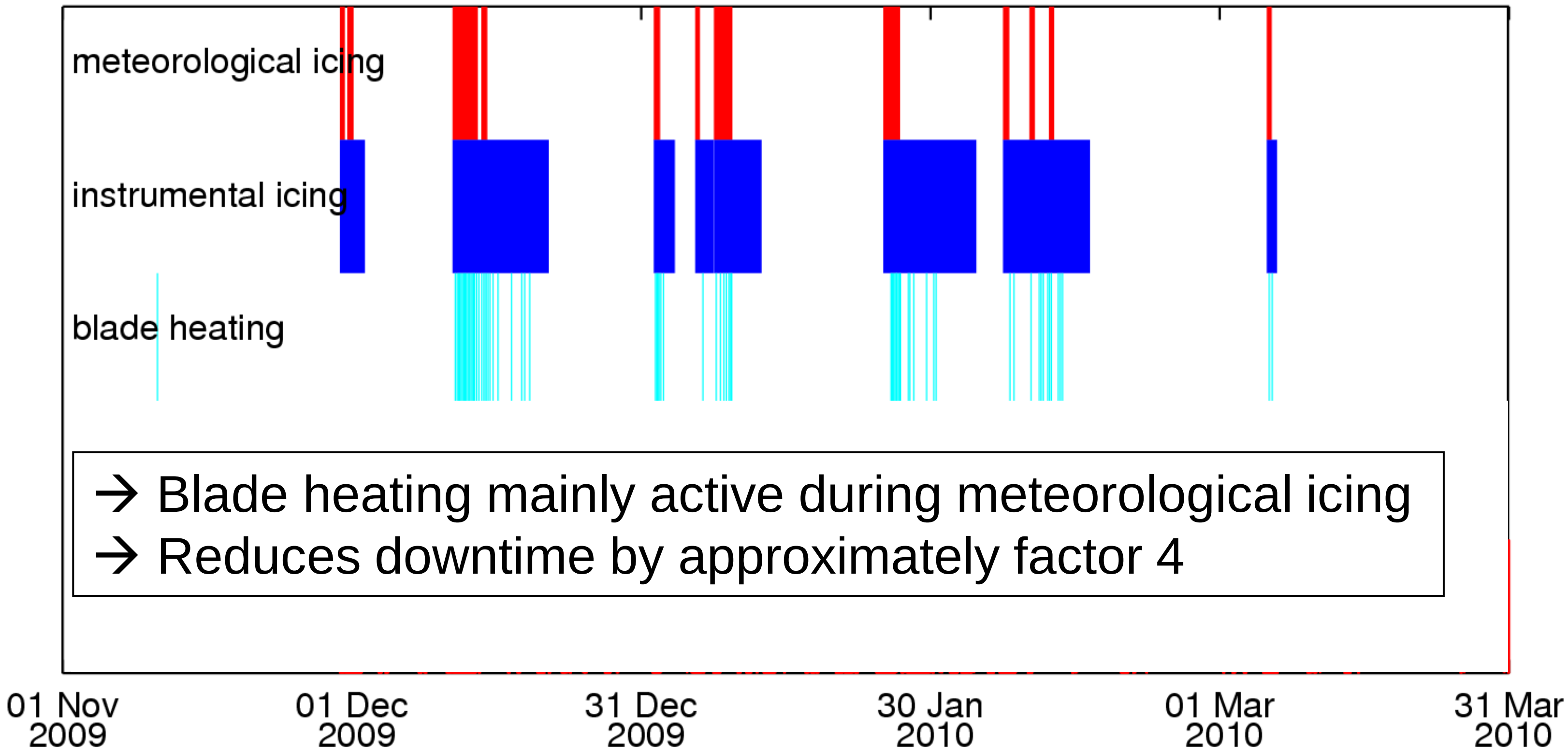
Blade heating 2009/10



124 heating cyles (372h/15d downtime, 7.5d per turbine)
30 MWh heating power (80kW per turbine)

Blade Heating

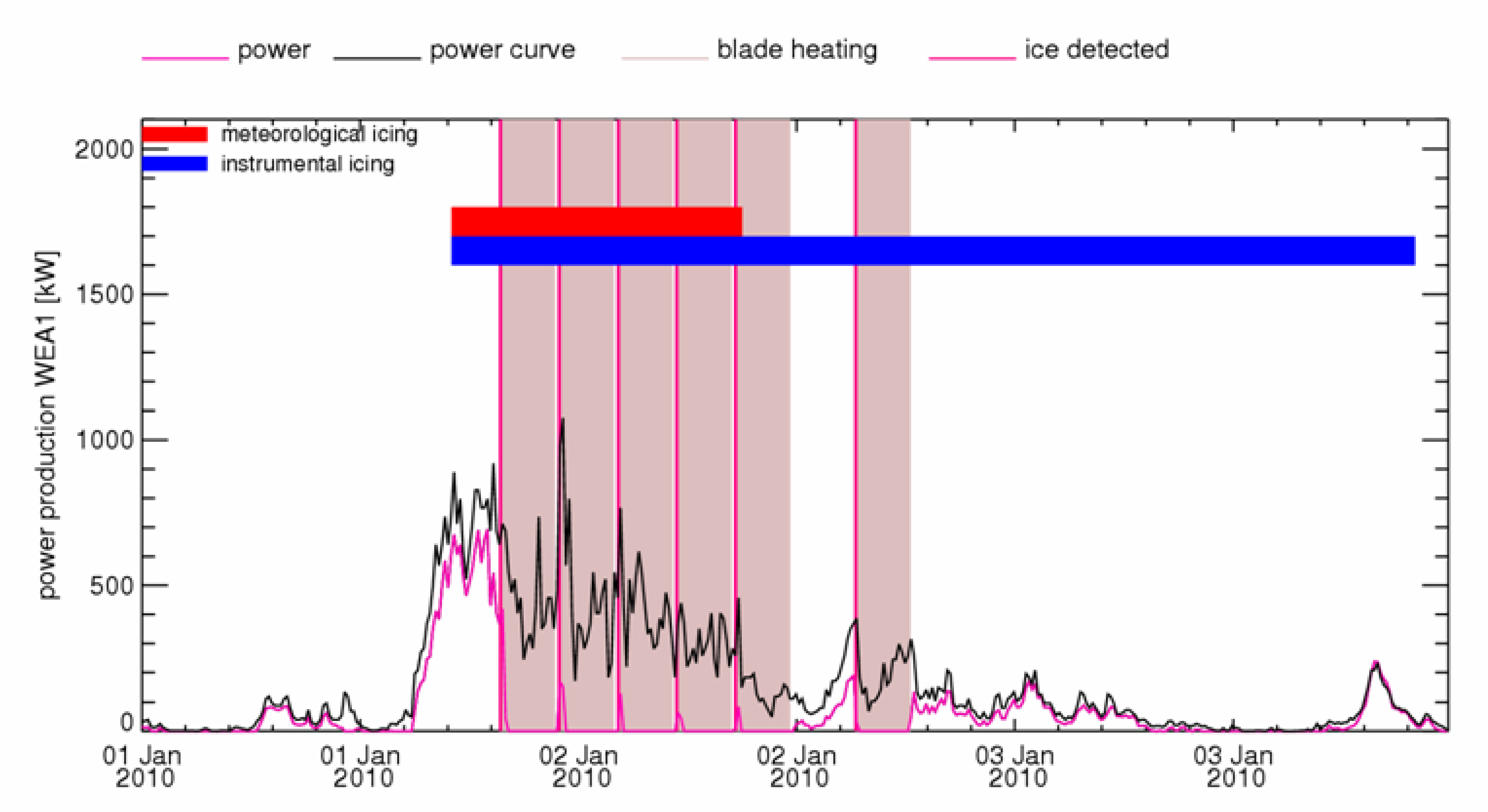
Blade heating 2009/10



→ Blade heating mainly active during meteorological icing
→ Reduces downtime by approximately factor 4

Blade Heating

Example



Blade Heating

Blade heating

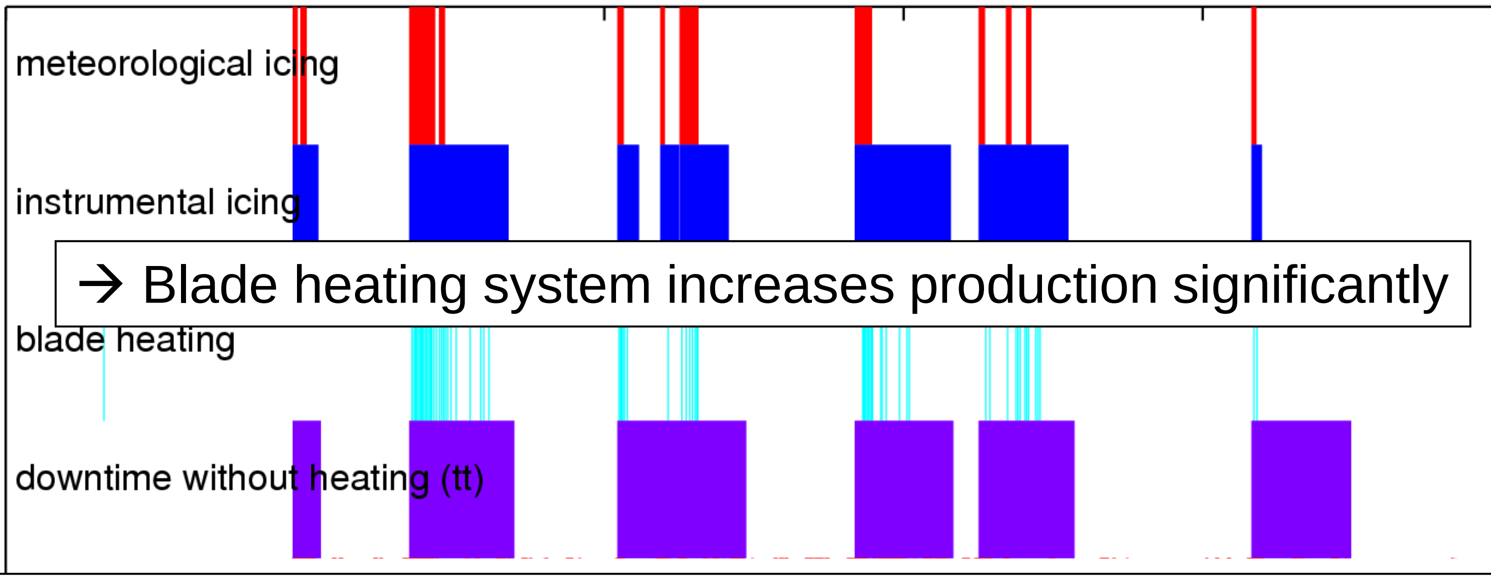
Blade Heating

Case study: No blade heating

Assumptions:
- Wind turbine **without blade heating**
- **Turbine stops** when ice is detected
- **Automatic restart** if temperature was **above 2° C for 6 hours**

Blade Heating

Case study: No blade heating



→ Blade heating system increases production significantly

Meteorological icing: 276h / 11.5d (longest event: 63h / 2.6d)
Downtime without blade heating: 1’349h / 56.2d (longest event: 312h / 13d)

→ Factor 4.8!

Blade Heating

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What was the benefit?

- Production loss without blade heating: **~10%**
- Additional production thanks to blade heating: **~7%**
- Energy needed for blade heating: **~0.4%**
- Production loss due to stopped turbine during heating: **~3%**

Blade Heating

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Experimental proof

→ WEA1: **blade heating off, ice detection on**
→ WEA2: **blade heating on, ice detection on**

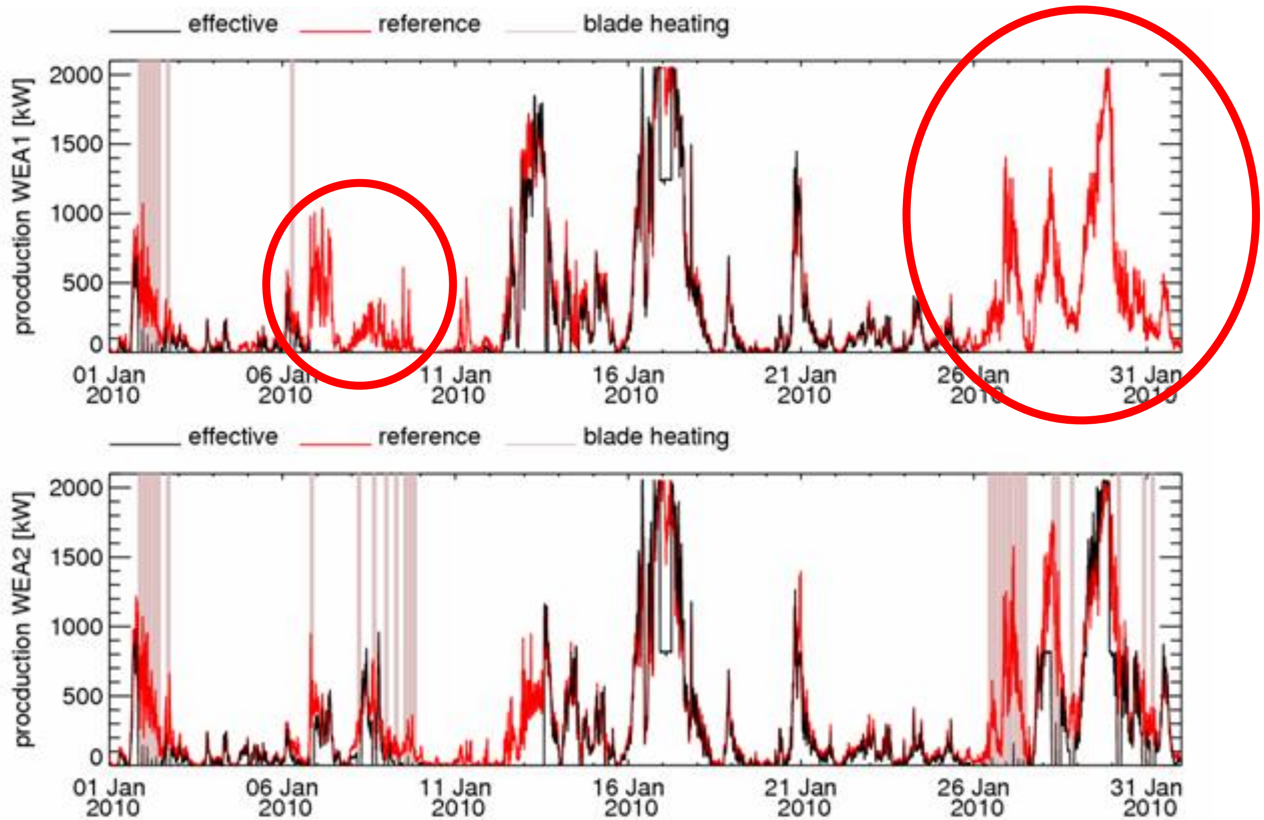
Experiment carried out in **January 2010**
Losses of **operator compensated** through project budget

Blade Heating

Experimental proof

blade heating off
ice detection on

blade heating on
ice detection on



Blade Heating

Experimental proof

Start Ereignis	Ende Ereignis	Produktion WEA 2 [kWh]
6. Jan. 2010 18:48	7. Jan. 2010 16:30	3'892
25. Jan. 2010 20:01	2. Feb. 2010 18:41	96'608
7. Feb. 2010 11:35	8. Feb. 2010 20:27	2'993
Produktionsverlust WEA 1		**103'493**
Eingesparte Energie durch deaktivierte Blattheizung		-7'020
Total Produktionsverlust WEA 1		**96'473**

→ ~ 20% of production in this month

Blade Heating

Heating during operation

Status of WEA1 since January 18 2011:

→ **heating starts** when icing is detected
→ turbine **keeps producing**
→ **heating stops** under given conditions (unknown)

Blade Heating

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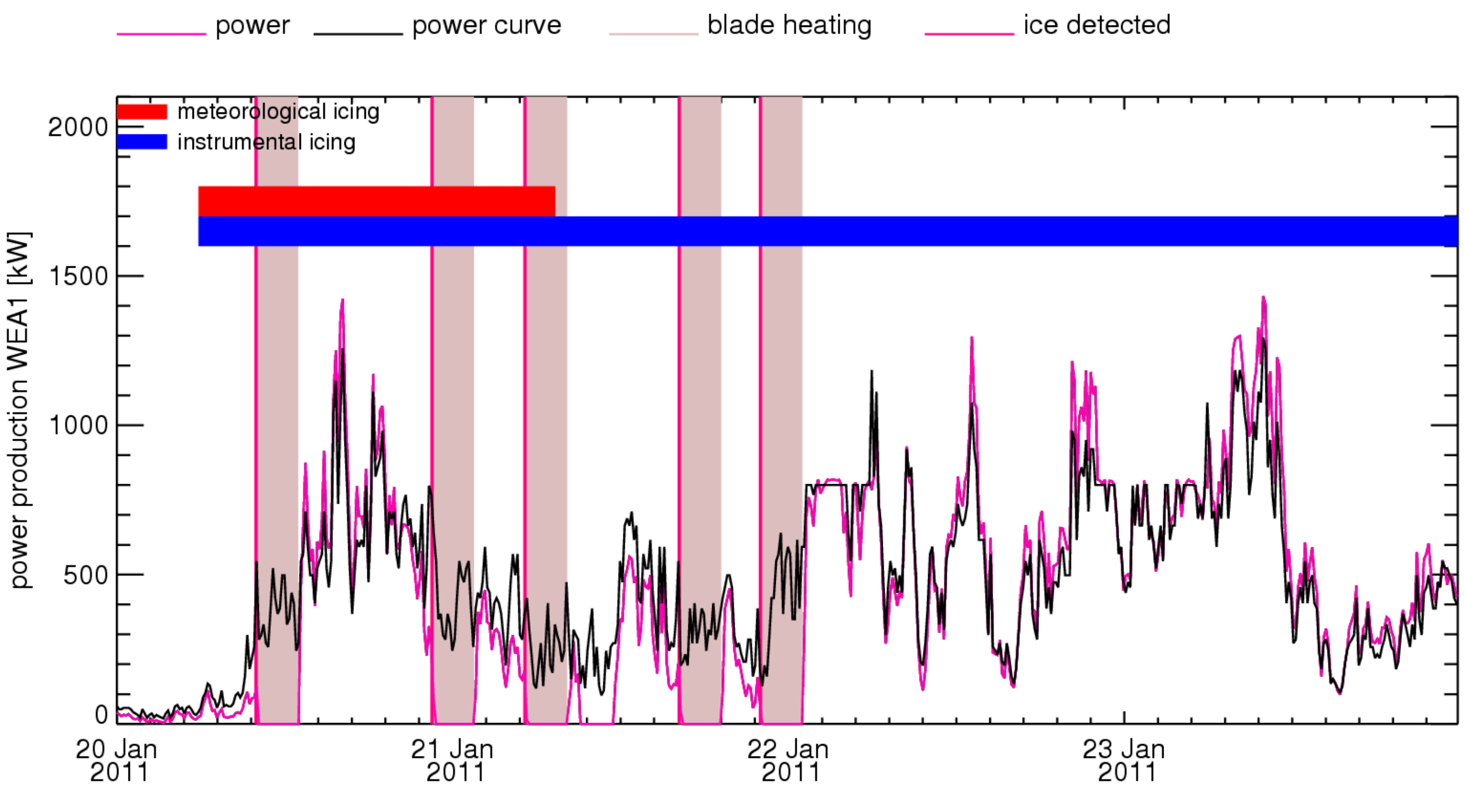
Heating during operation



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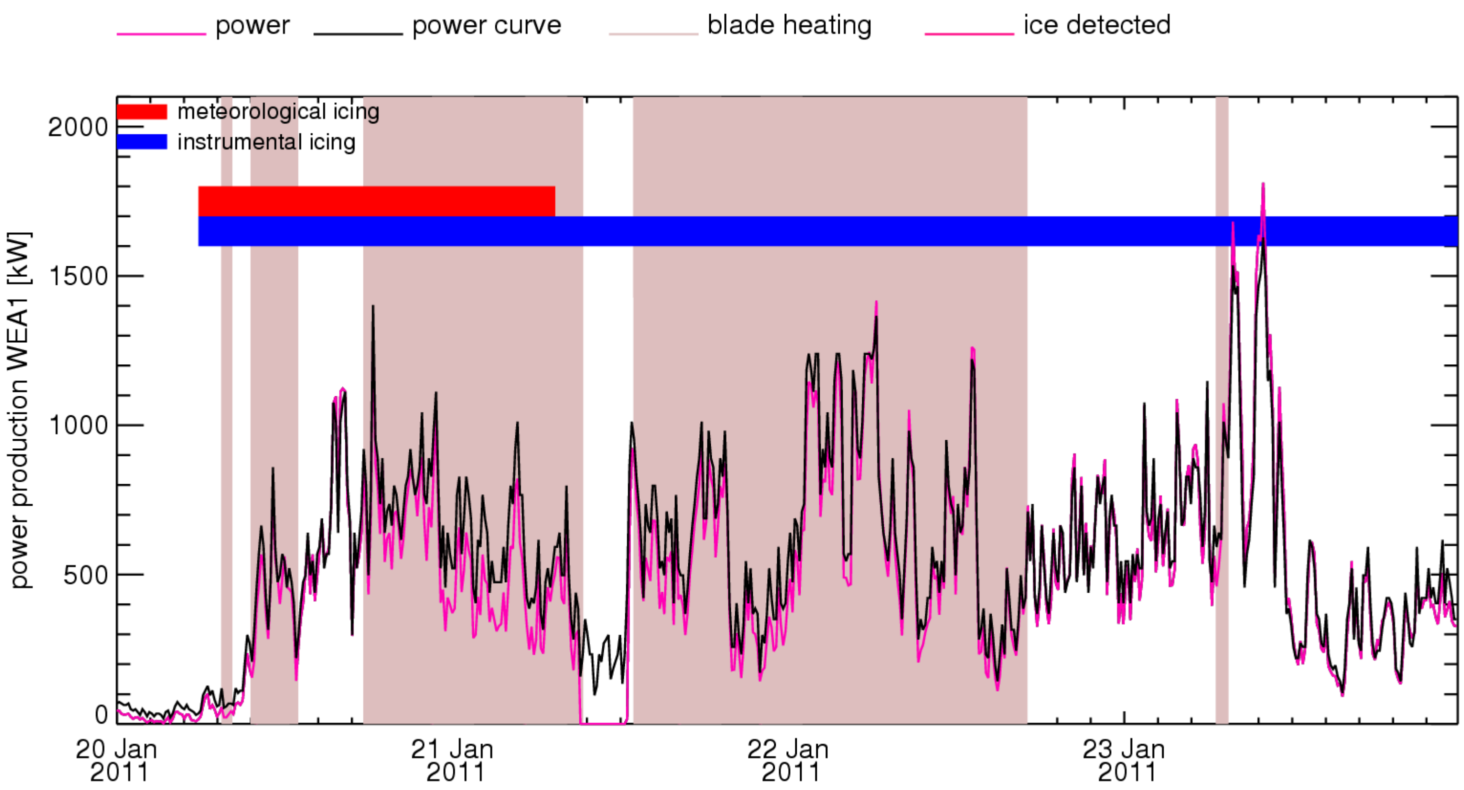
Heating during operation



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Heating during operation

4 case studies (no more data available)

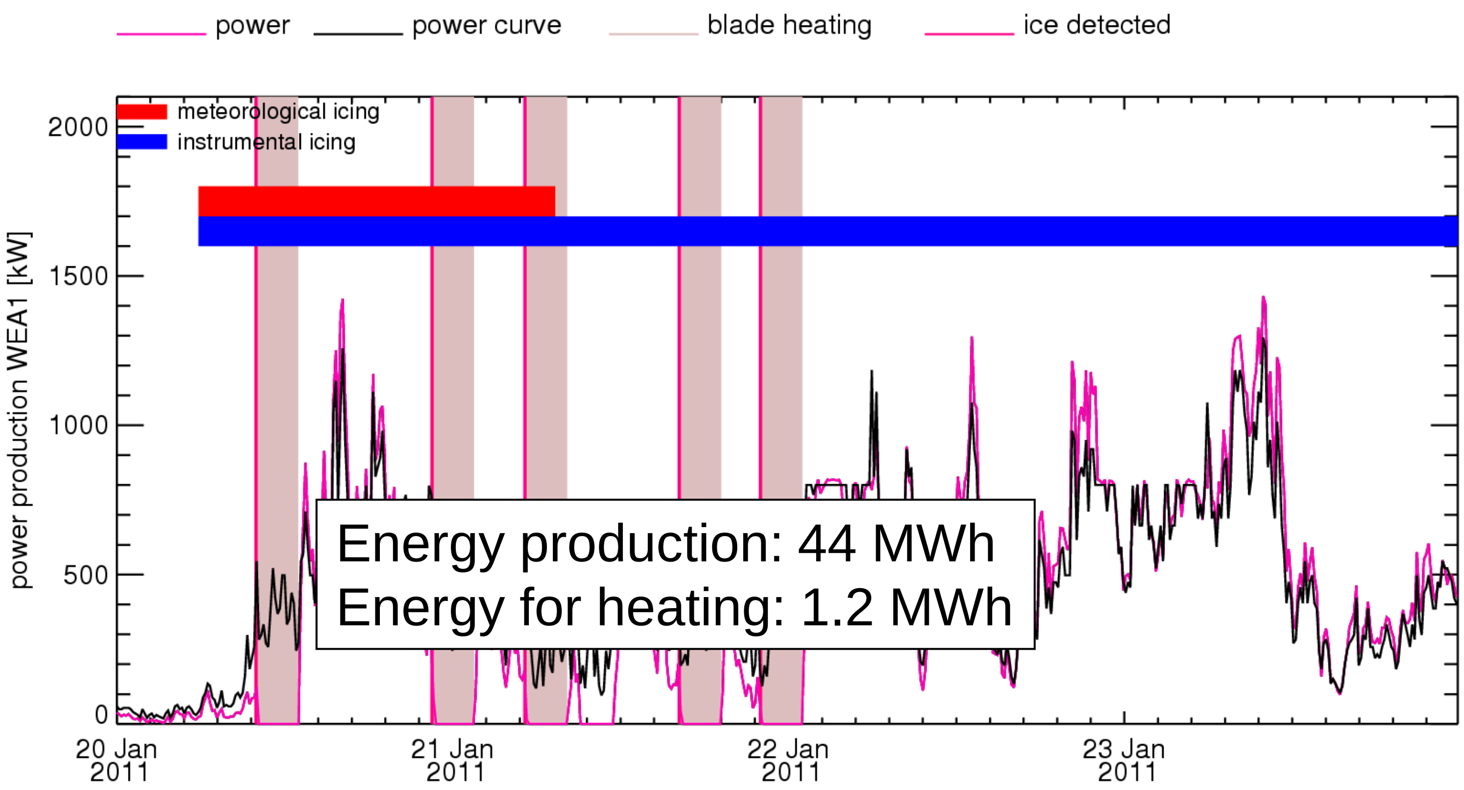
WEA1 = **reference** (heating during operation)
→ production **according wind speed/power curve**

WEA2 = **same production** as WEA1
stop for heating according to **status data WEA 2**

Blade Heating

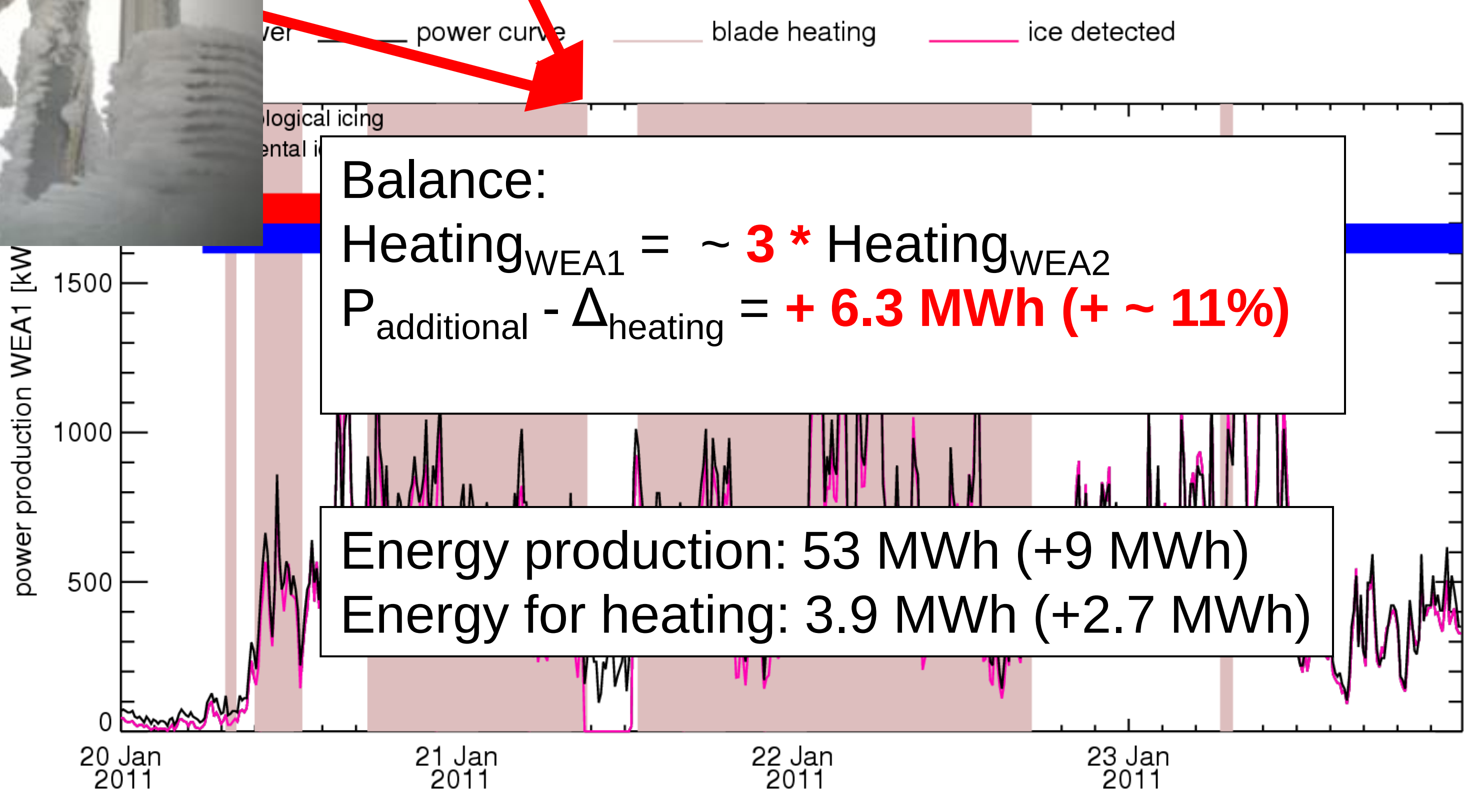
Case 1: Heating during operation

WEA 2



1: Heating during operation

WEA 1



Balance:

Heating_{WEA1} = ~ **3 *** Heating_{WEA2}

$P_{additional} - \Delta_{heating}$ = **+ 6.3 MWh (+ ~ 11%)**

Energy production: 53 MWh (+9 MWh)

Energy for heating: 3.9 MWh (+2.7 MWh)

Blade Heating

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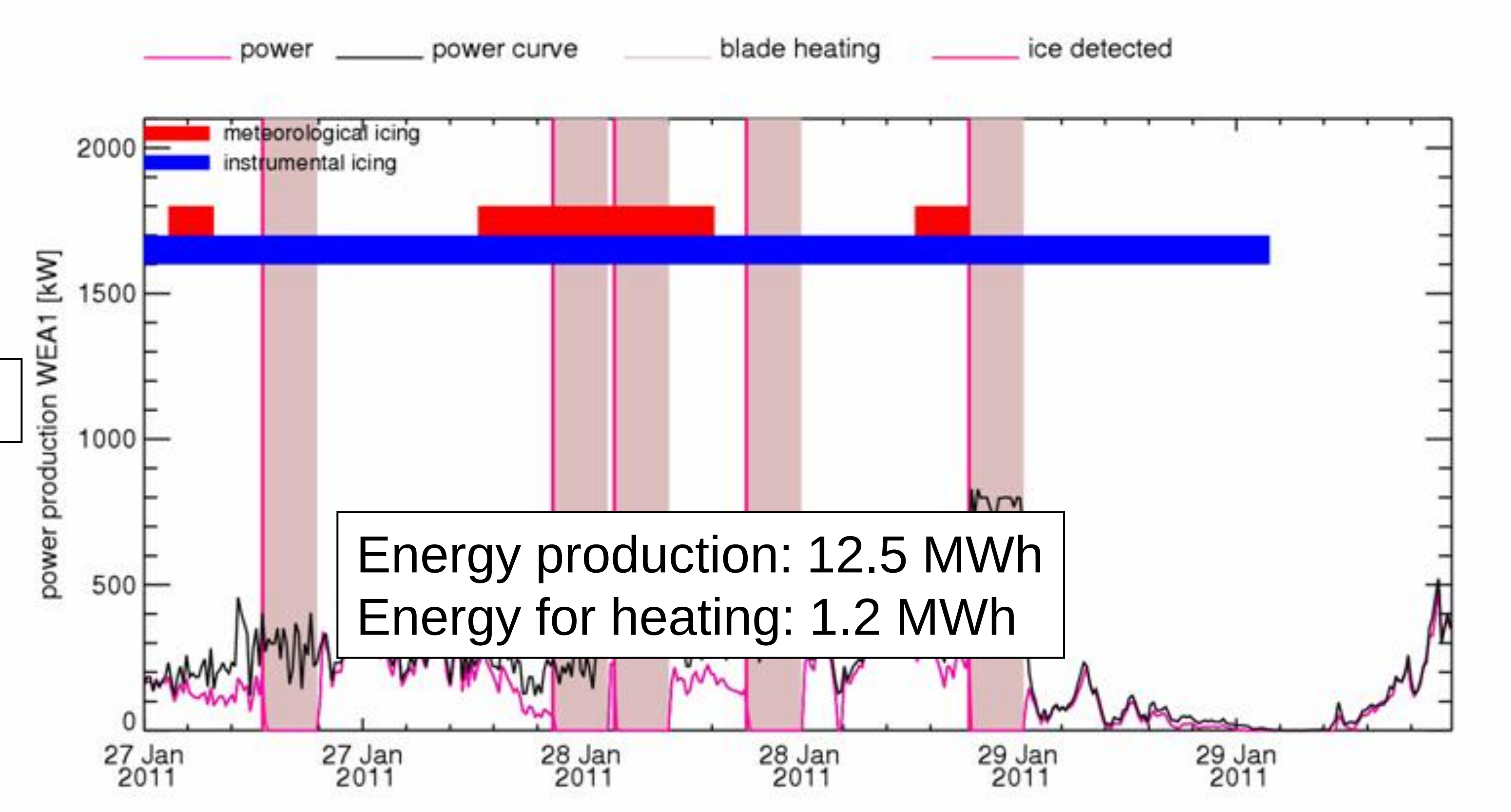
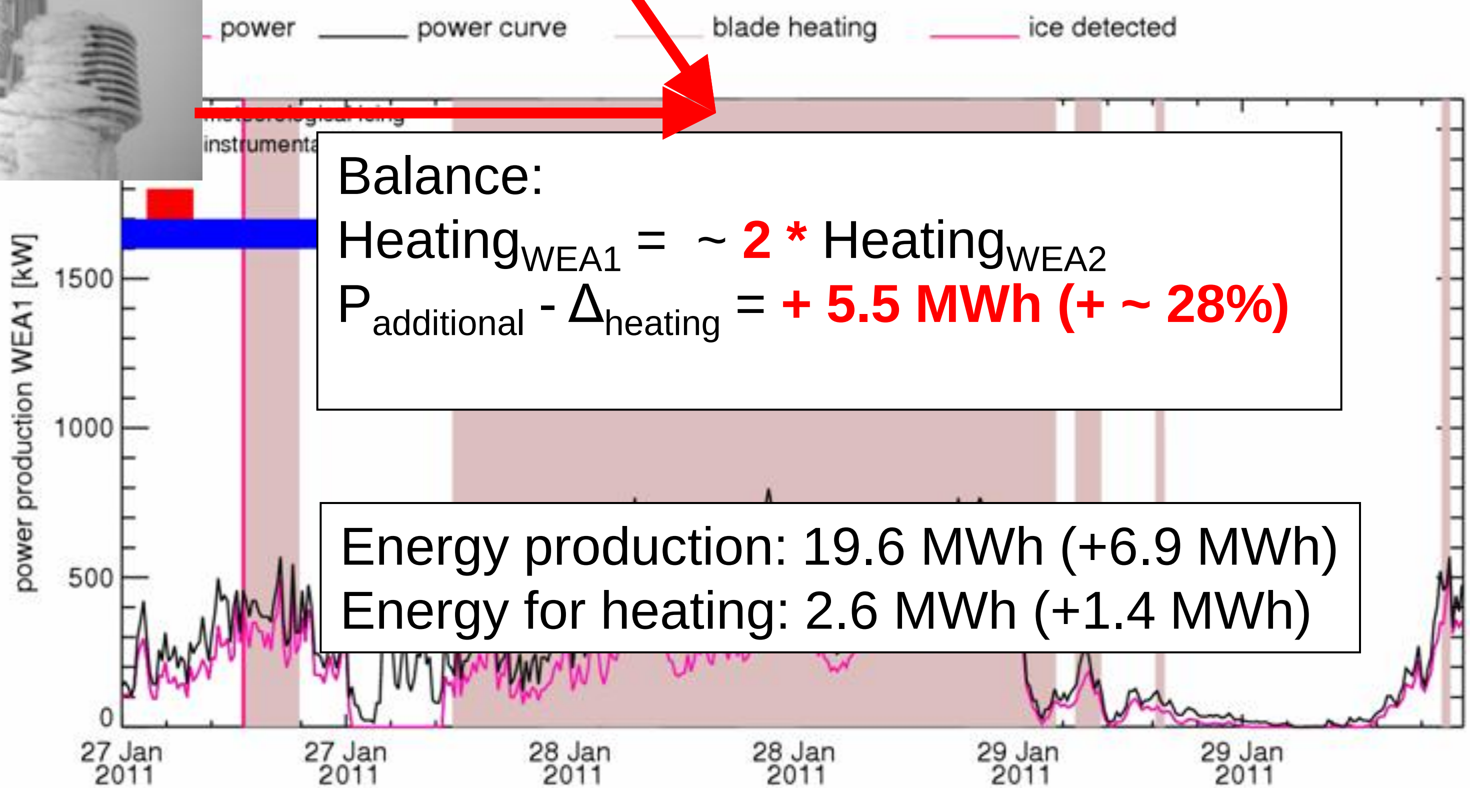
Case 2: Heating during operation

WEA 2



Energy production: 12.5 MWh
Energy for heating: 1.2 MWh

Heating during operation



WEA 1

Balance:
Heating_{WEA1} = ~ **2 *** Heating_{WEA2}
$P_{additional} - \Delta_{heating}$ = **+ 5.5 MWh (+ ~ 28%)**

Energy production: 19.6 MWh (+6.9 MWh)
Energy for heating: 2.6 MWh (+1.4 MWh)

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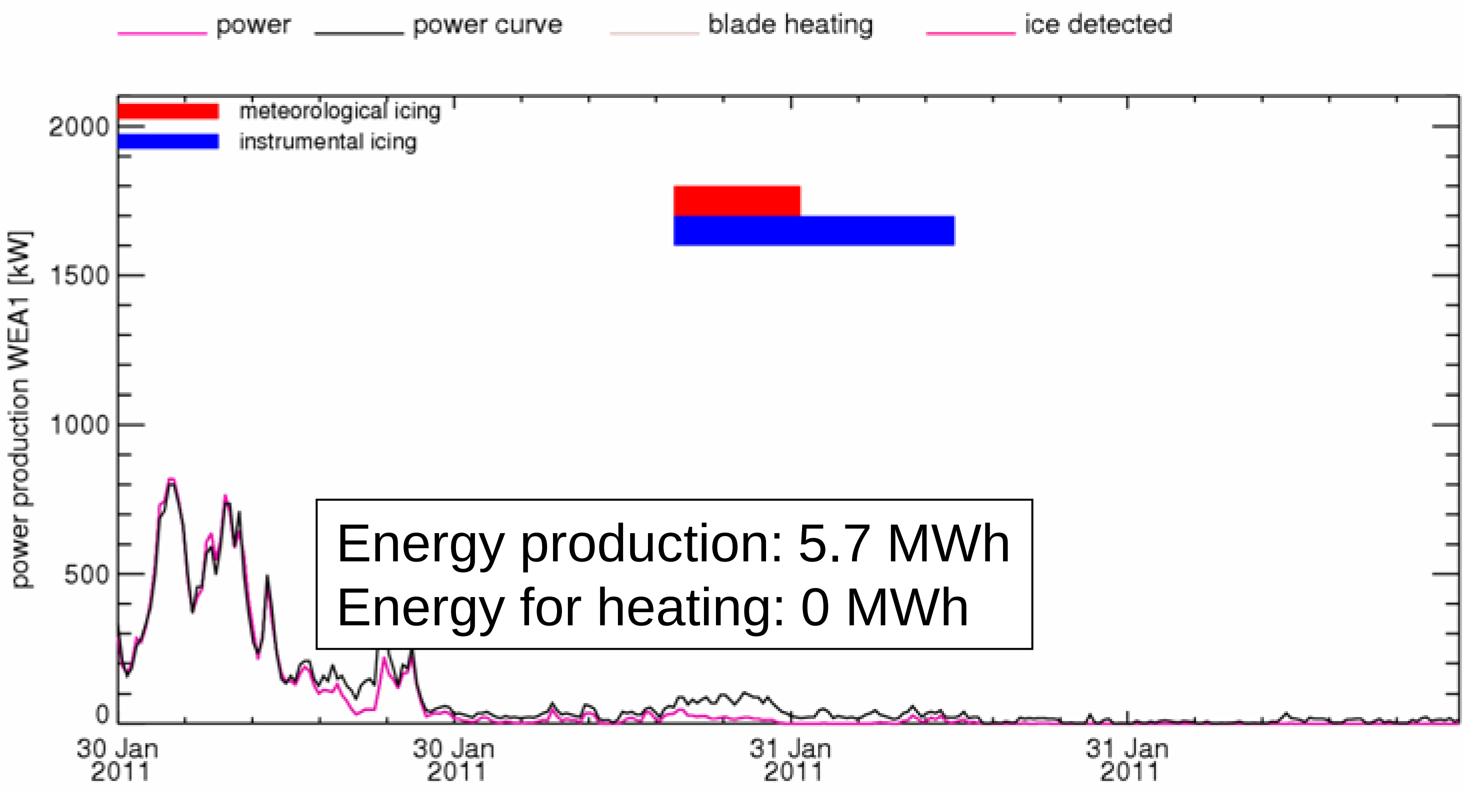
Case 3: Heating during operation

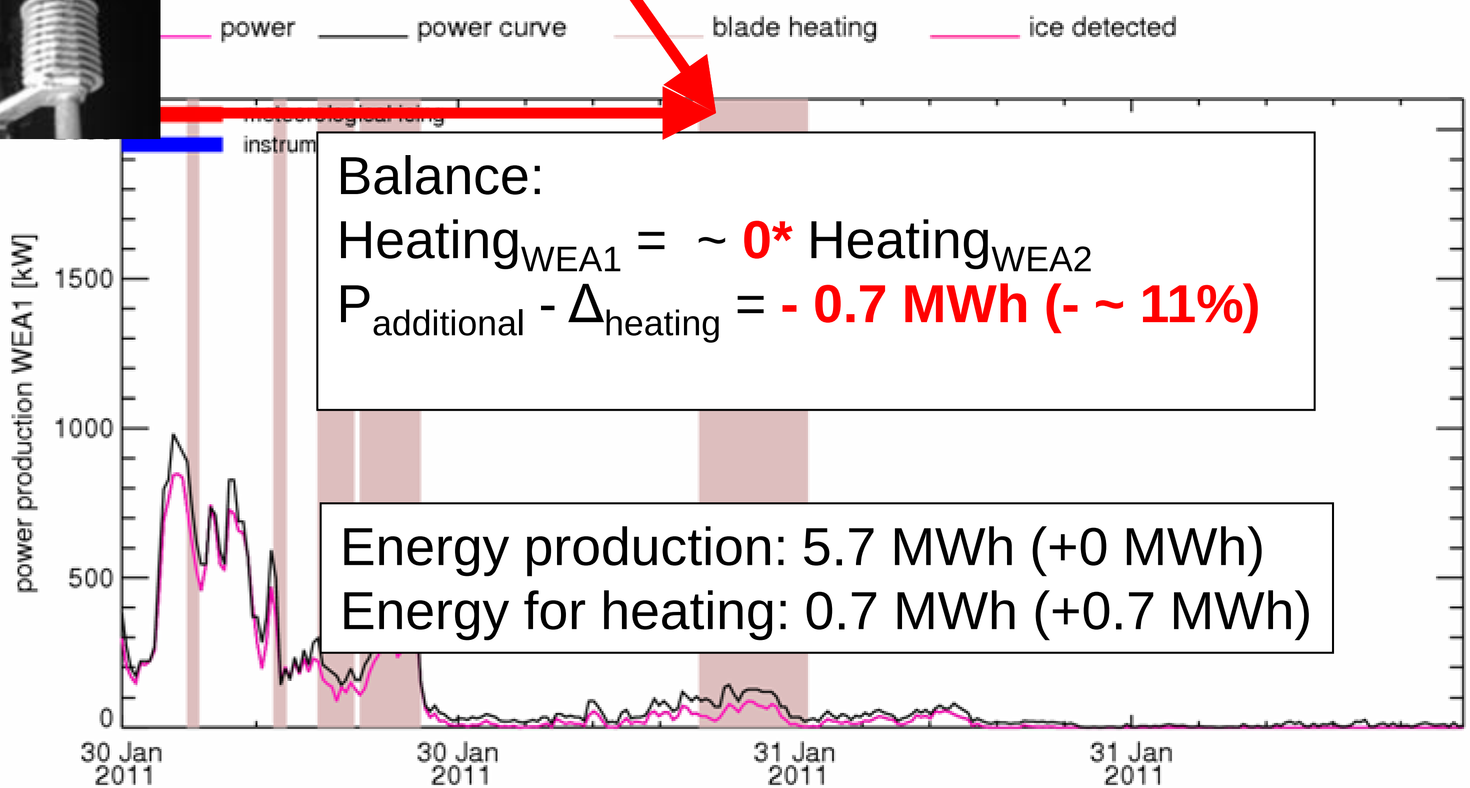
WEA 2



Energy production: 5.7 MWh
Energy for heating: 0 MWh

Case 3: Heating during operation

WEA 1



Balance:

Heating_{WEA1} = ~ **0*** Heating_{WEA2}

$P_{additional} - \Delta_{heating}$ = **- 0.7 MWh (- ~ 11%)**

Energy production: 5.7 MWh (+0 MWh)

Energy for heating: 0.7 MWh (+0.7 MWh)

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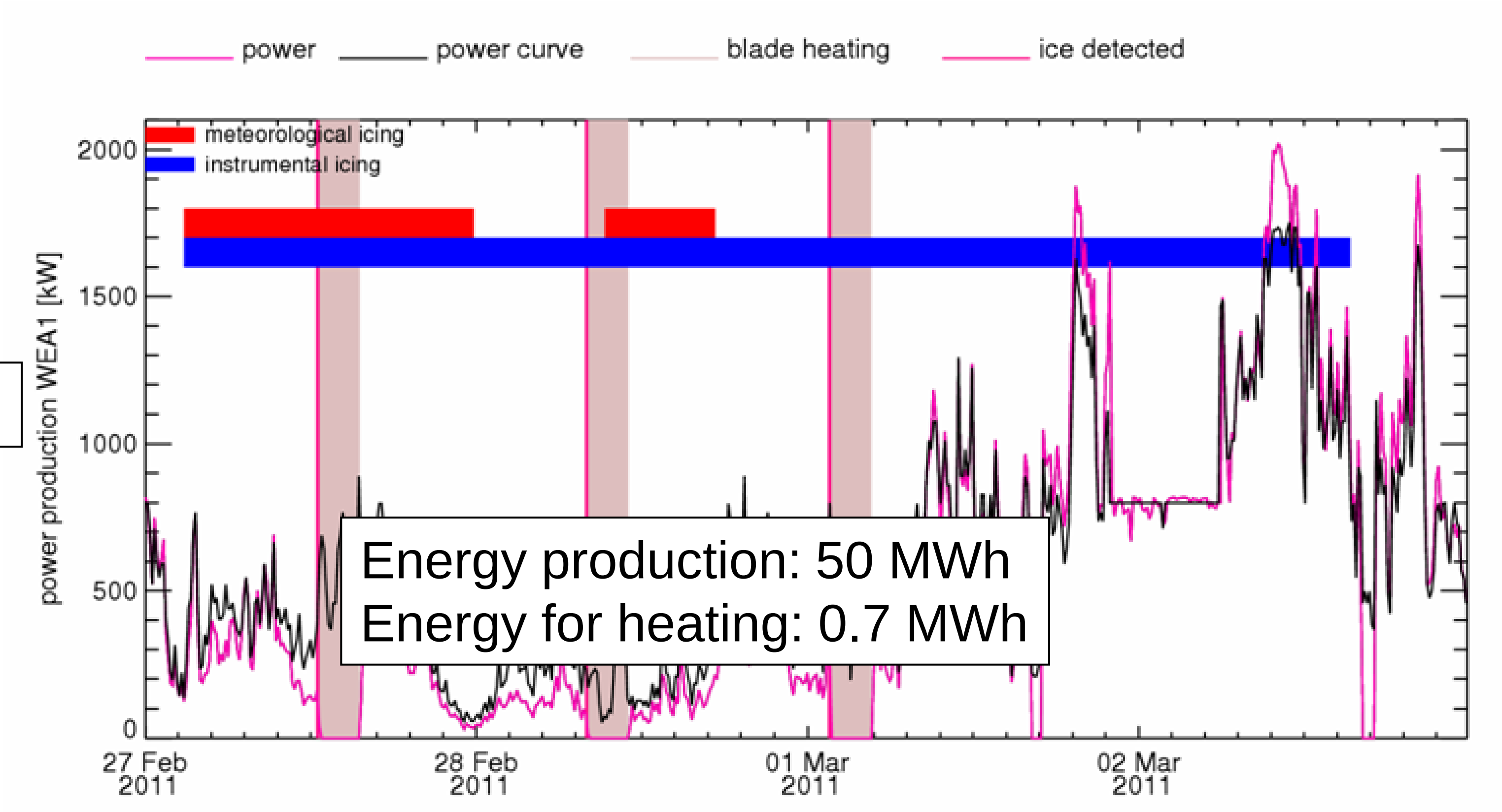
Case 4: Heating during operation

WEA 2



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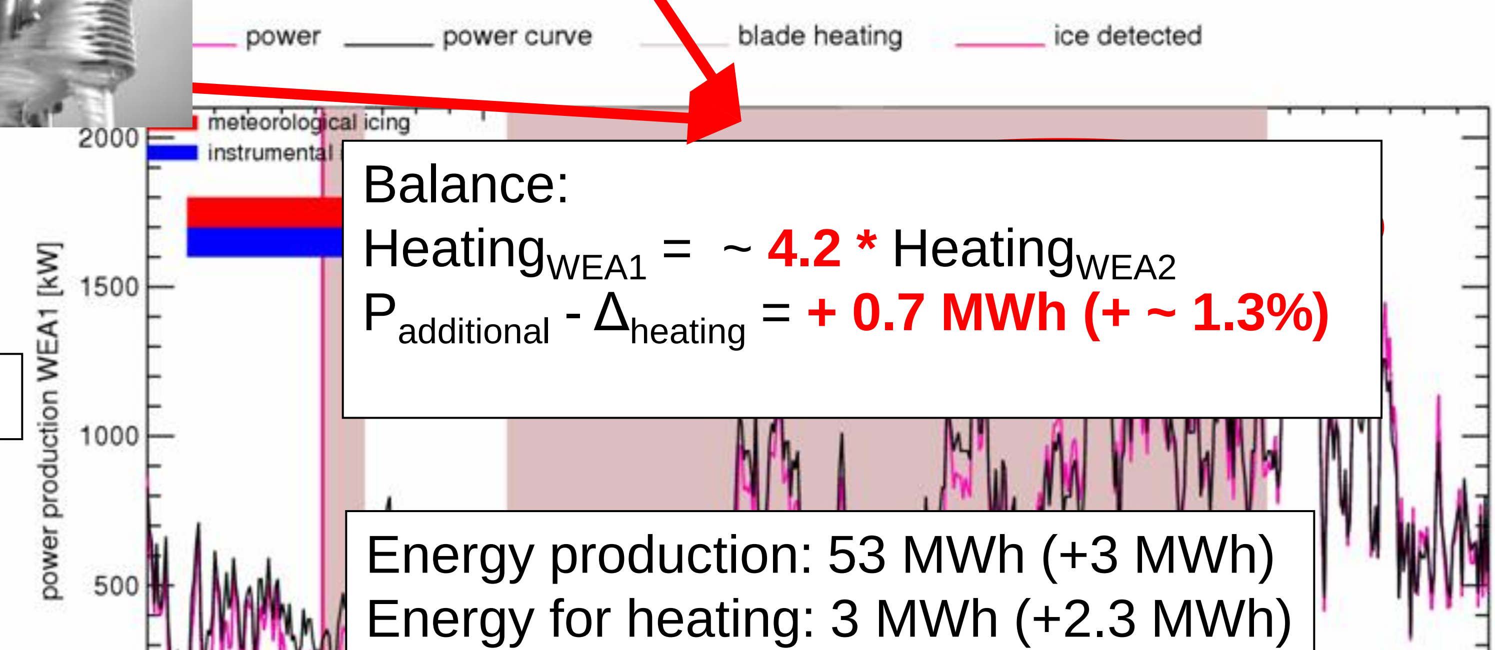
Case 4: Heating during operation



WEA 1

Balance:

Heating_{WEA1} = ~ **4.2 *** Heating_{WEA2}

$P_{additional} - \Delta_{heating}$ = **+ 0.7 MWh (+ ~ 1.3%)**

Energy production: 53 MWh (+3 MWh)

Energy for heating: 3 MWh (+2.3 MWh)

→ Positive energy balance in 3 out of 4 cases

→ Benefit dependant on efficiency of heating control

→ Blade is mostly ice-free

→ Heating control has room for optimisation (via relative humidity?)

Summary

Summary I

- Icing has **significant impact** on power production at St. Brais
- Instrumental icing periods **~ 4 times longer** than meteorological icing
- Icing conditions are very **site specific** (**site classification** needed during **site assessment**)

Summary

Summary II

- Blade heating mainly active **during the periods of meteorological icing**.
- **Without blade heating** production losses of approximately 10%
- Blade heating during stand still allowed **~7% more production**
- Energy needed for blade heating: ~**0.4% of annual production**.
- Production **loss of ~3% remains** because wind turbine **stops** for heating.
- Blade heating needs **several cycles** to melt away the ice
- **Leading edge** ice is ice free, **flaps are not** (heating during stand still)
- No **„ice free signal“** → **automatic restart** is a risk
- **Heating during operation** furthers reduces the production loss (**another 5-15%** of the remaining 3%?).
- **Efficient** heating: Blades remain **mostly ice free**
- **Heating control** can be **optimized** (benefit dependant on heating control).
- **Ice throw risk lower** when heating during operation?

Thank you

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METEOTEST
Fabrikstrasse 14
CH-3012 Bern
www.meteotest.ch
rene.cattin@meteotest.ch

for your attention!