MYTHBUSTERS

Wind turbines in cold climate edition

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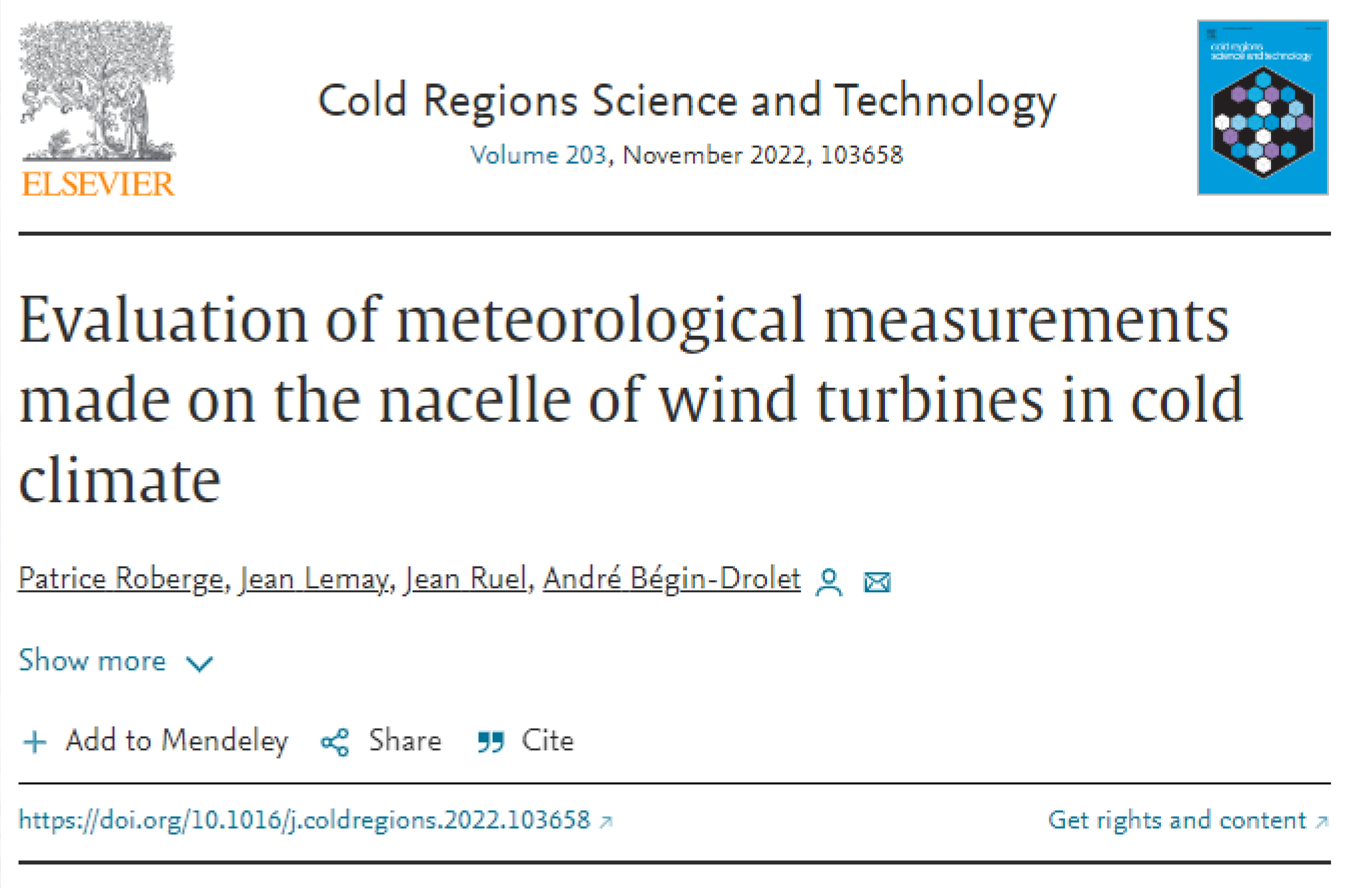
Context

- Full paper with details
- DOI: https://doi.org/10.1016/j.coldregions.2022.103658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Evaluation of meteorological measurements made on the nacelle of wind turbines in cold climate

Patrice Roberge, Jean Lemay, Jean Ruel, André Bégin-Drolet

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Myth #1

A 3°C temperature threshold should be used for icing losses assessment

Myth #1 : Context

A 3°C temperature threshold should be used for icing losses assessment

- At which temperature should we filter out losses?
- Logical value: 0°C
- Often used value: 3°C

Myth #1 : Context

Importance of a temperature threshold for icing losses calculation

- 3°C threshold ➡ 5°C threshold = ↗ 5% icing losses[1]
- 3°C threshold ➡ 0°C threshold = ↘ 11% icing losses[1]
- Losses not categorized as icing

1- Canovas Lotthagen, Z., 2020. Defining, Analyzing and Determining Power Losses-Due to Icing on Wind Turbine Blades. Masters degree. Malardalen University, Sweden.

Myth #1 : Context

Why did we end up with a 3°C threshold?

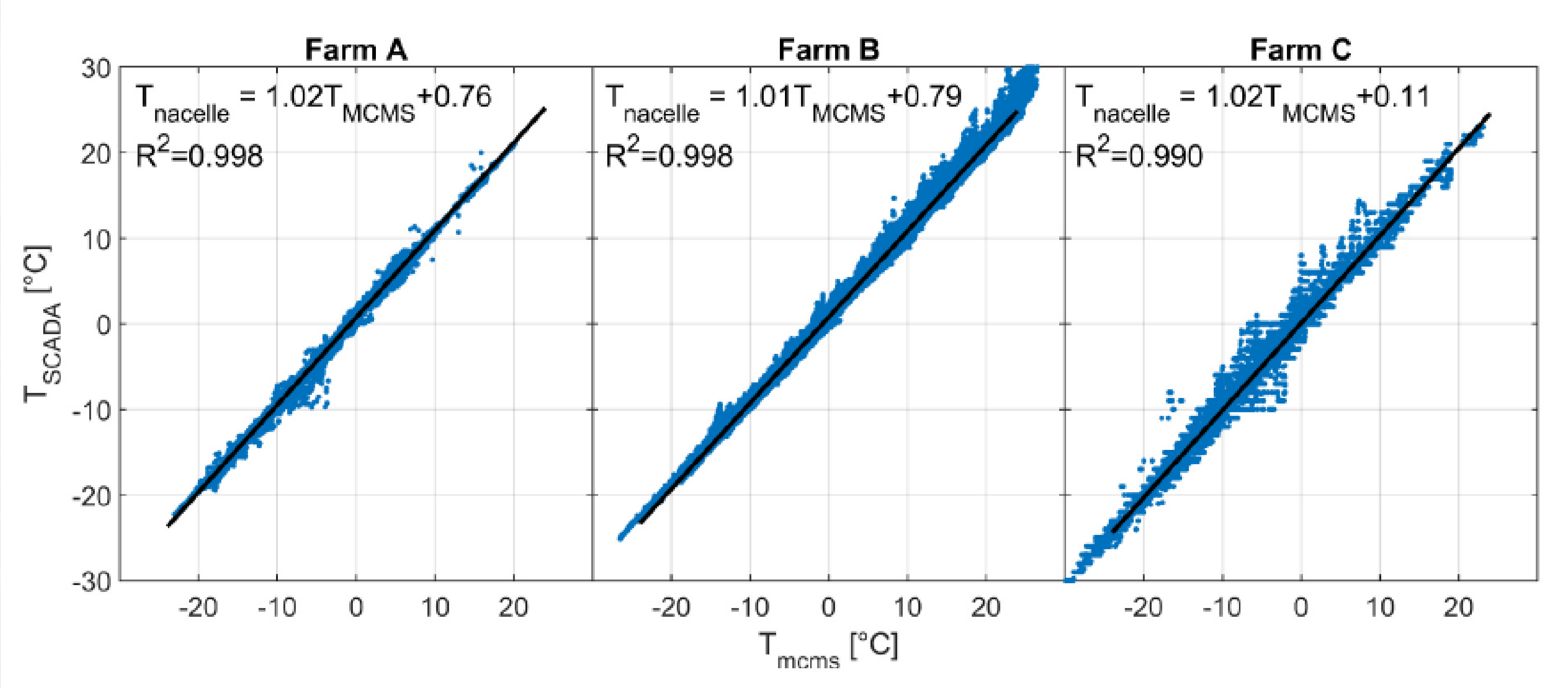
Bias of 3°C in the SCADA temperature (Davis, 2014)

Myth #1: Investigation

- **How?** With field data
- 3 wind turbines, 3 wind farms, 3 turbine manufacturers
- A **Meteorological Conditions Monitoring Station (MCMS)** installed on each turbine nacelle
- **Step 1**: Temperature bias?
- **Step 2**: Turbine performance

Myth #1: Investigation

- 200 to 454 days
- Calibrated temperature measurement on the nacelle
- Solar radiation effect removed
- Biases between 0.11°C and 0.76°C



Myth #1: Investigation

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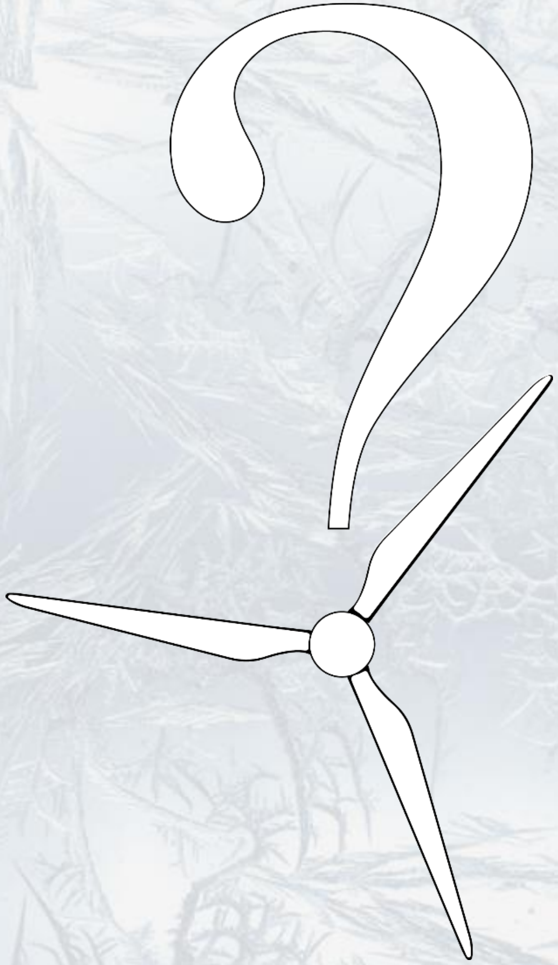
Bias smaller than 3°C!

Myth #1: Investigation

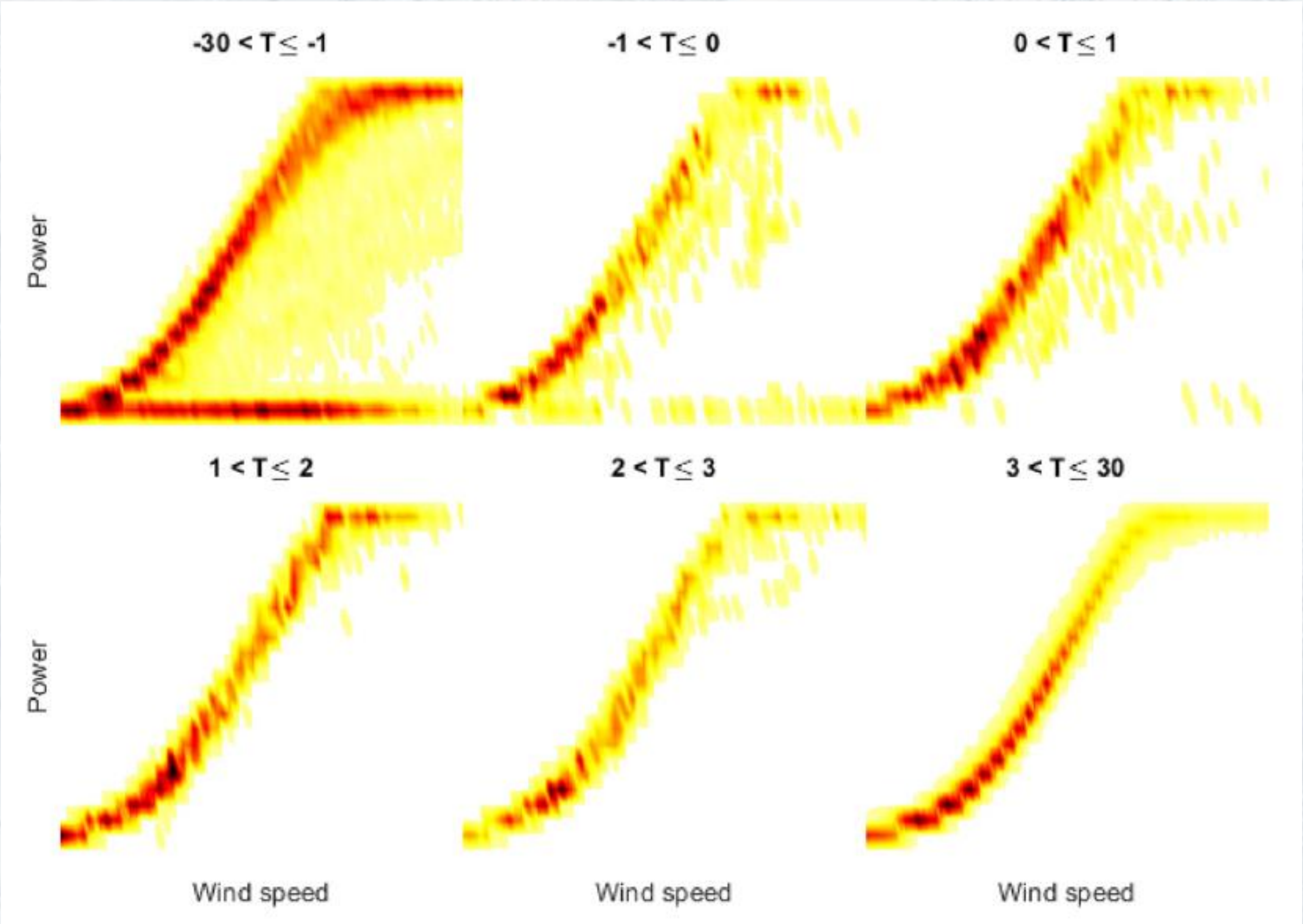
What threshold should we use then?

What about turbine performance?



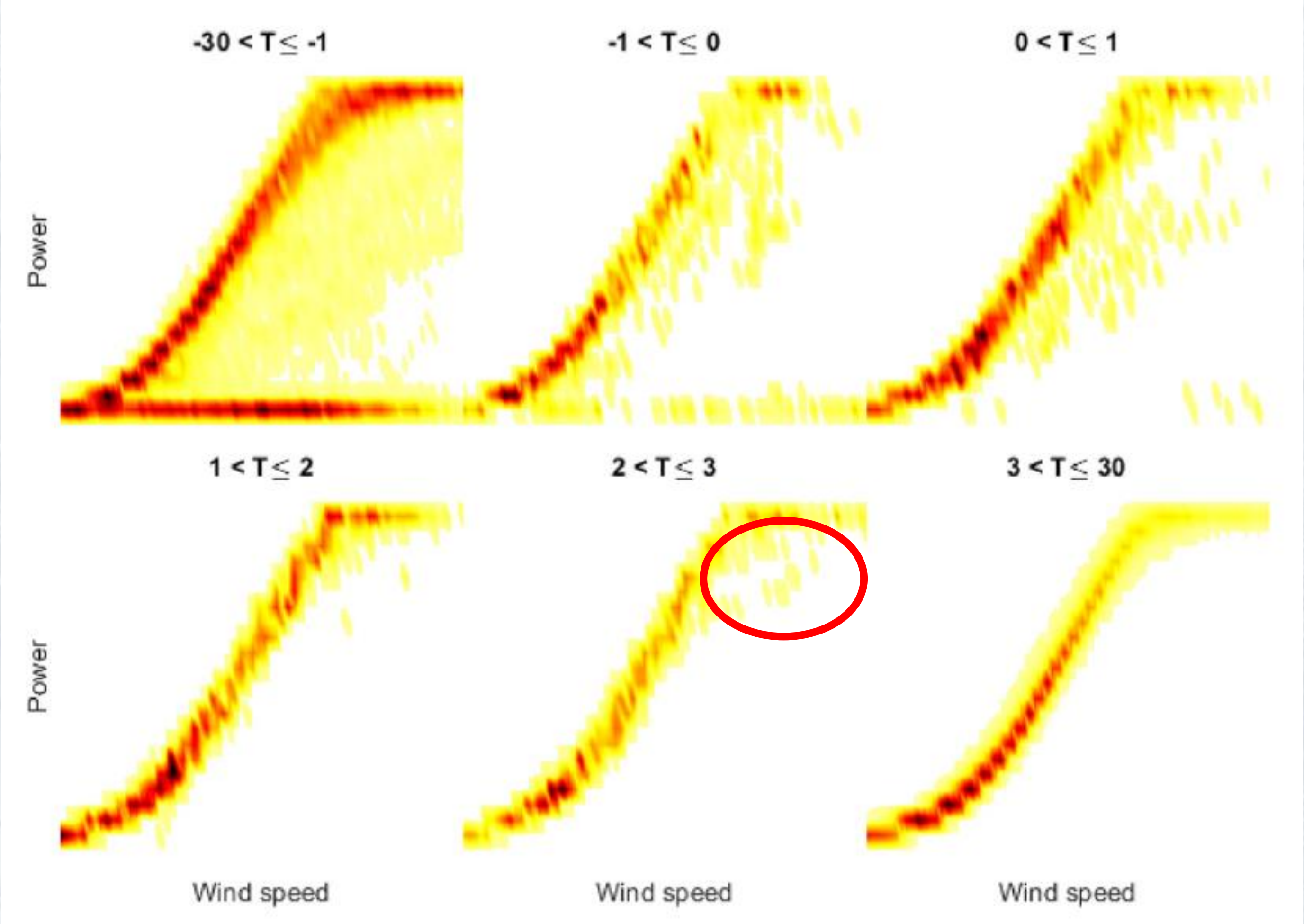
Myth #1: Investigation

- Point density on power curves
- Different temperature ranges



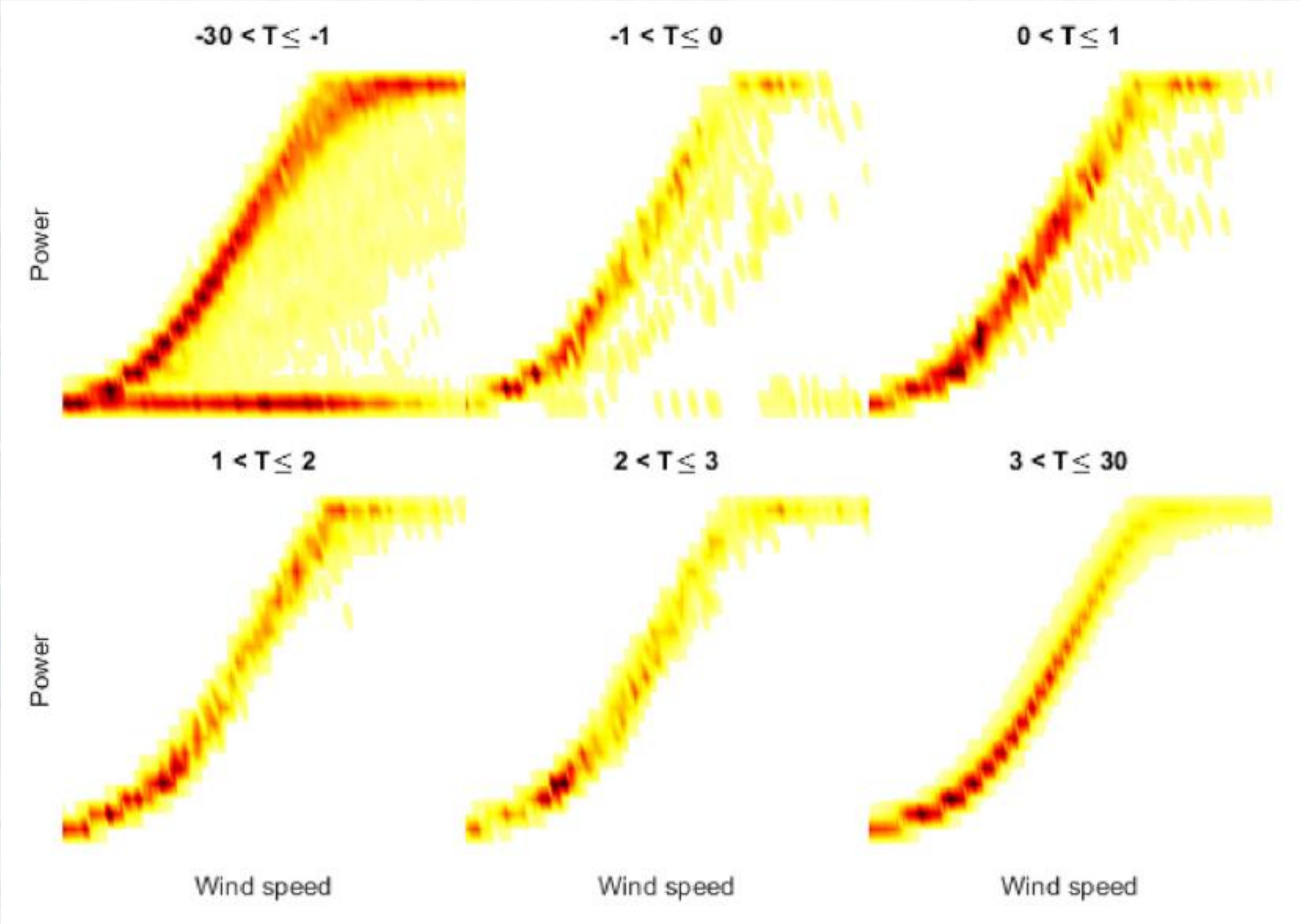
Myth #1: Investigation

- Still some points in the 2°C<T<3°C
- Effect of melting time?



Myth #1: Investigation

- Filtering by the minimal temperature in the past 2 hours
- Effect of melting time? YES
- Coherent witht he observed bias



Myth #1: Conclusion

A 3°C temperature threshold should be used for icing losses assessment?

- The 3°C bias cannot be generalized
- A value closer to 1°C was observed
- Best results achieved with minimal temperature in the last 2 h

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Myth #2

Nacelle based icing detection is inadequate

Myth #2 : Context

Is nacelle based icing detection inadequate

- Often seen in ice sensing reviews without a strong explanation
- 3 reasons:
  1. Difference in accretion rate
  2. Low clouds only affecting blade tips
  3. Larger volume swept

Myth #2 : Context

- 3 reasons:
  1. ~~Difference in accretion rate~~
  2. Low clouds only affecting blade tips
  3. ~~Larger volume swept~~
- Reasons 1 and 3 can be overcome with physical models[2]

Credit: WIcetec

2- Jolin, N., Bolduc, D., Swytink-Binnema, N., Rosso, G., Godreau, C., 2019. Wind turbine blade ice accretion: a correlation with nacelle ice accretion. Cold Reg. Sci. Technol. 157, 235–241.

Myth #1 : Context

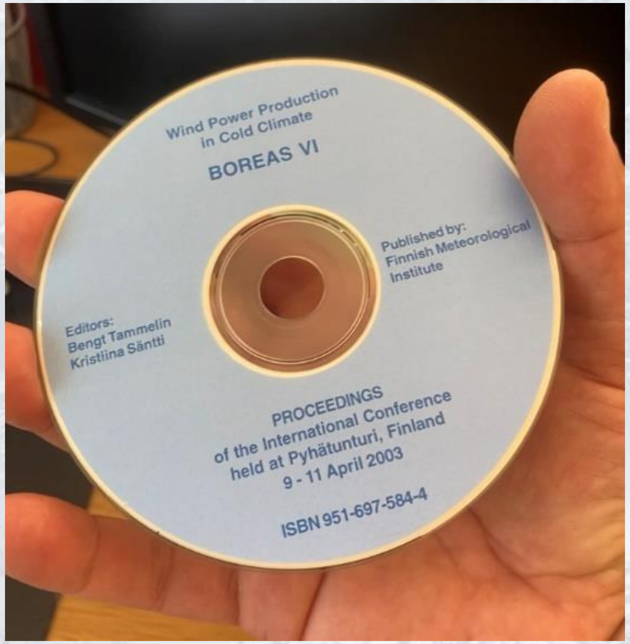
Low clouds only affecting blade tips

2003 study from BOREAS VI

“In-cloud icing periods at 84 m were 6 times more frequent compared to the number of periods observed at 62 m”

Myth #2 : Background

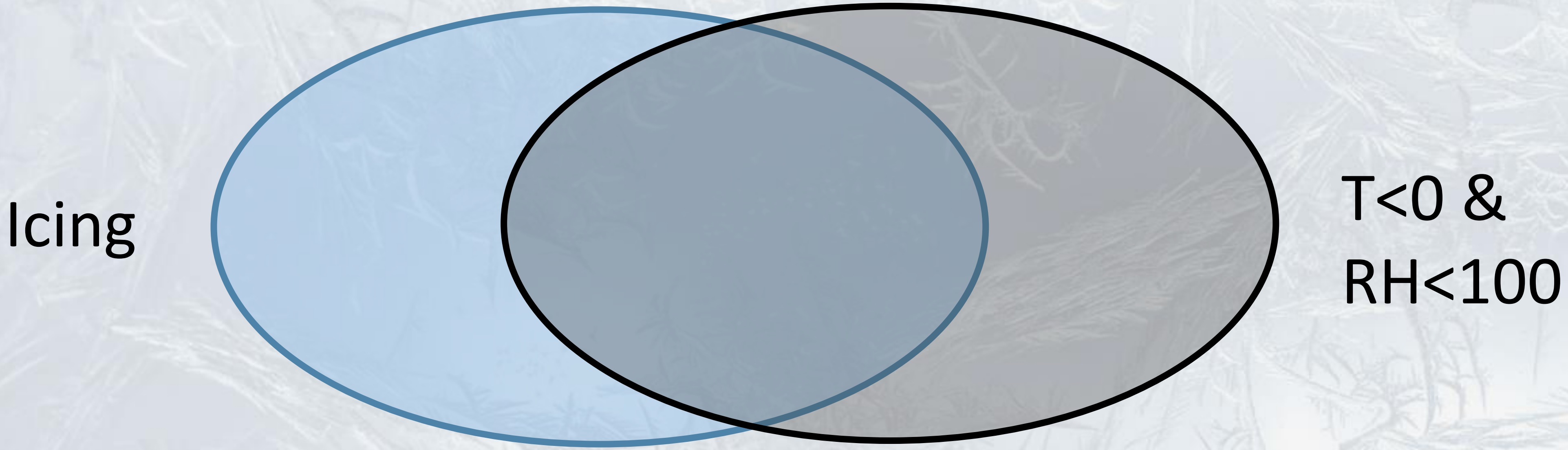
Finding the study



Myth #2 : Background

Low clouds only affecting blade tips

How? T<0°C and RH>100%



3- Säntti, K., Tammelin, B., Laakso, T., Peltola, E., 2003. Experience from measurements of atmospheric icing. In: Boreas VI Conference: Wind Energy Production in Cold Climates. Ilmatieteen laitos.

Myth #2 : Background

Low clouds only affecting blade tips

With RH>100%: $Icing_{84m}$ = 600% $Icing_{62m}$

With RH>95% : $Icing_{84m}$ = 125% $Icing_{62m}$

With RH>90% : $Icing_{84m}$ = 95% $Icing_{62m}$

3- Säntti, K., Tammelin, B., Laakso, T., Peltola, E., 2003. Experience from measurements of atmospheric icing. In: Boreas VI Conference: Wind Energy Production in Cold Climates. Ilmatieteen laitos.

Myth #2 : Background

L

H

V

V

V

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Inconclusive evidence

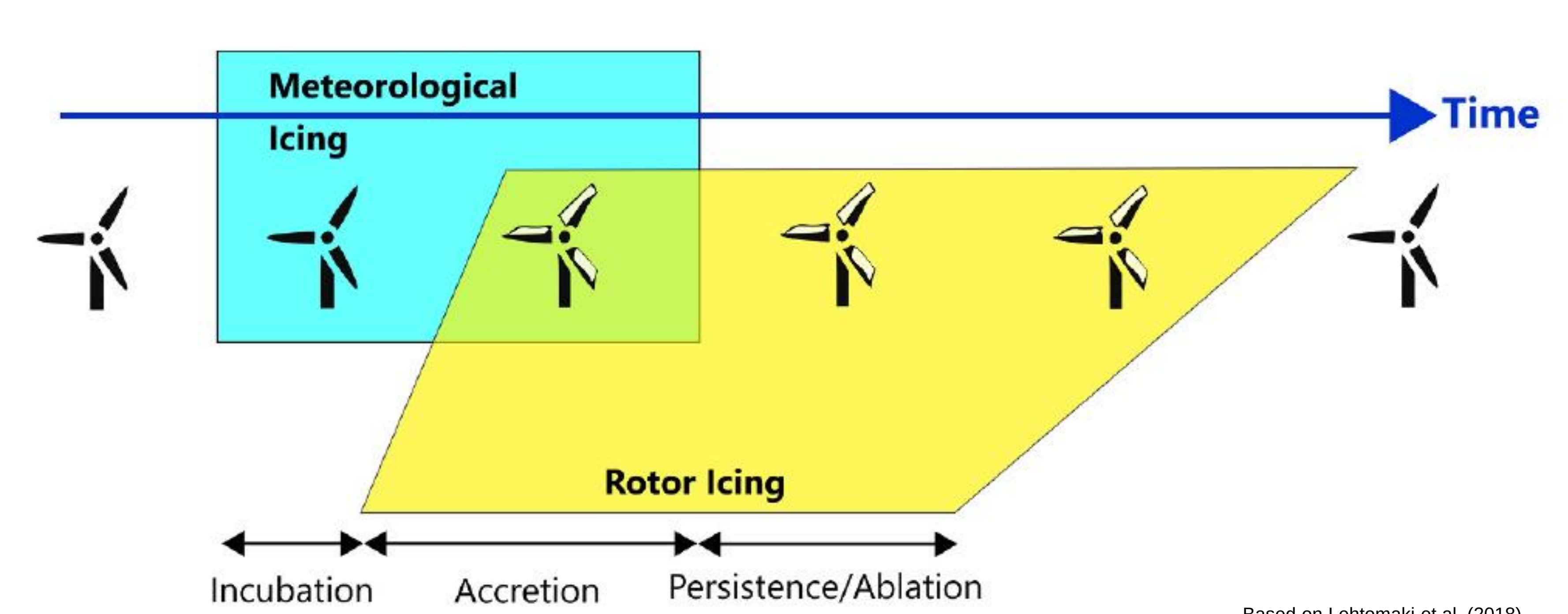
3-

m

Production in Cold Climates. Ilmatieteen laitos.

Myth #2 : Investigation

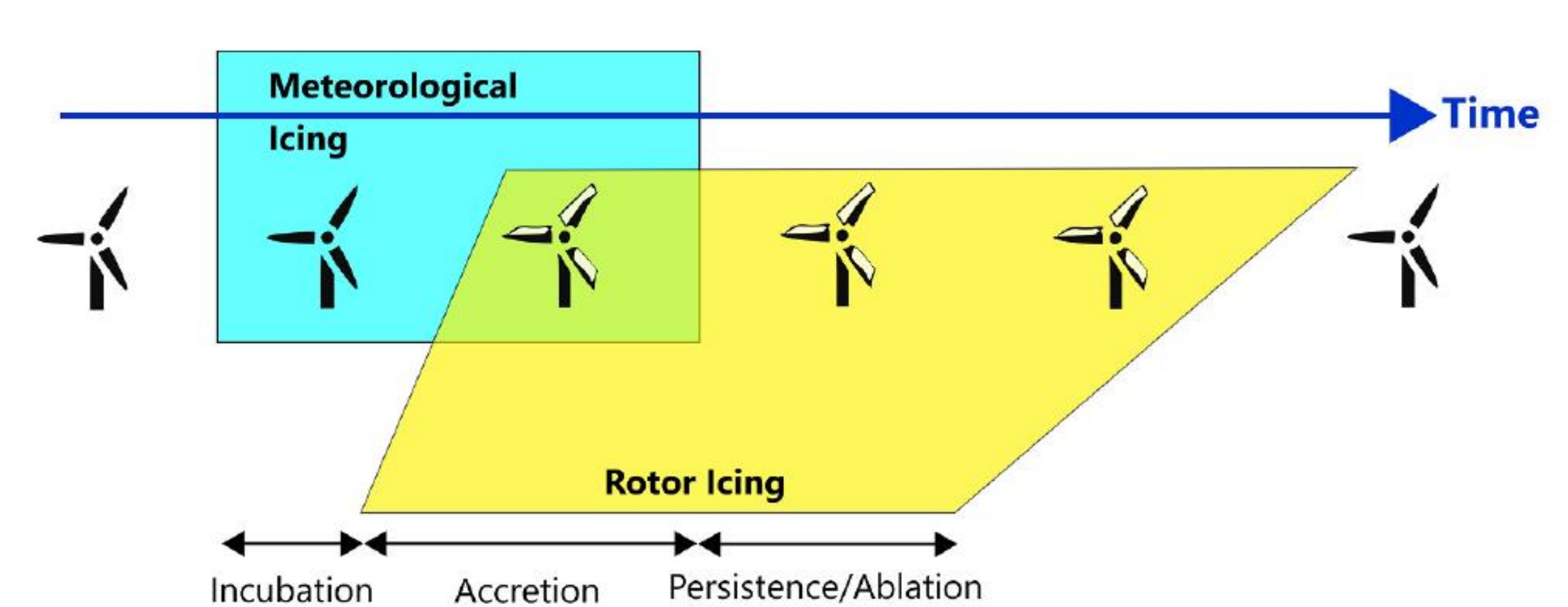
- Reference? Turbine performance
- Comparing Rotor Icing to Meteorological Icing
- Start of Rotor icing overlaps with Met. Icing



Based on Lehtomaki et al. (2018)

Myth #2 : Investigation

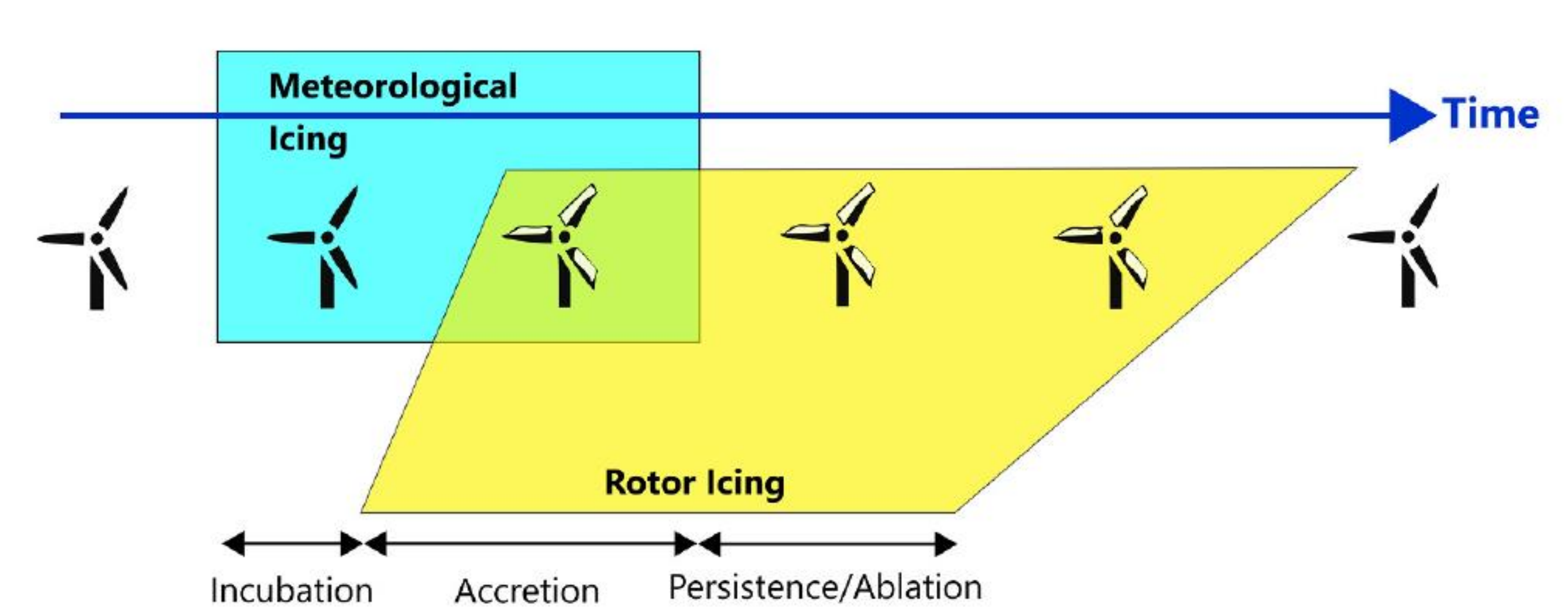
- 3 wind farms, total of 74 icing events
- Algorithm identifying icing events
- Criteria: Met. Icing in a two hour window of the start of rotor icing



Based on Lehtomaki et al. (2018)

Myth #2 : Investigation

- Met. Icing was detected on the nacelle in 71 of the 74 events
- The remaining 3 events were minor and inconclusive



Based on Lehtomaki et al. (2018)

Myth #2: Conclusion

Is nacelle based icing detection inadequate?

- Met. Icing was detected on the nacelle in 71 of the 74 events
- The remaining 3 events were minor and inconclusive

Conclusion and perspectives

- 1°C threshold on the minimal temperature in the last 2 hours
- Nacelle based sensors are suitable
- Do you have ideas on other myths?

- Roberge, P., Lemay, J., Ruel, J., & Bégin-Drolet, A. (2022). Evaluation of meteorological measurements made on the nacelle of wind turbines in cold climate. Cold Regions Science and Technology, 203, 103658.

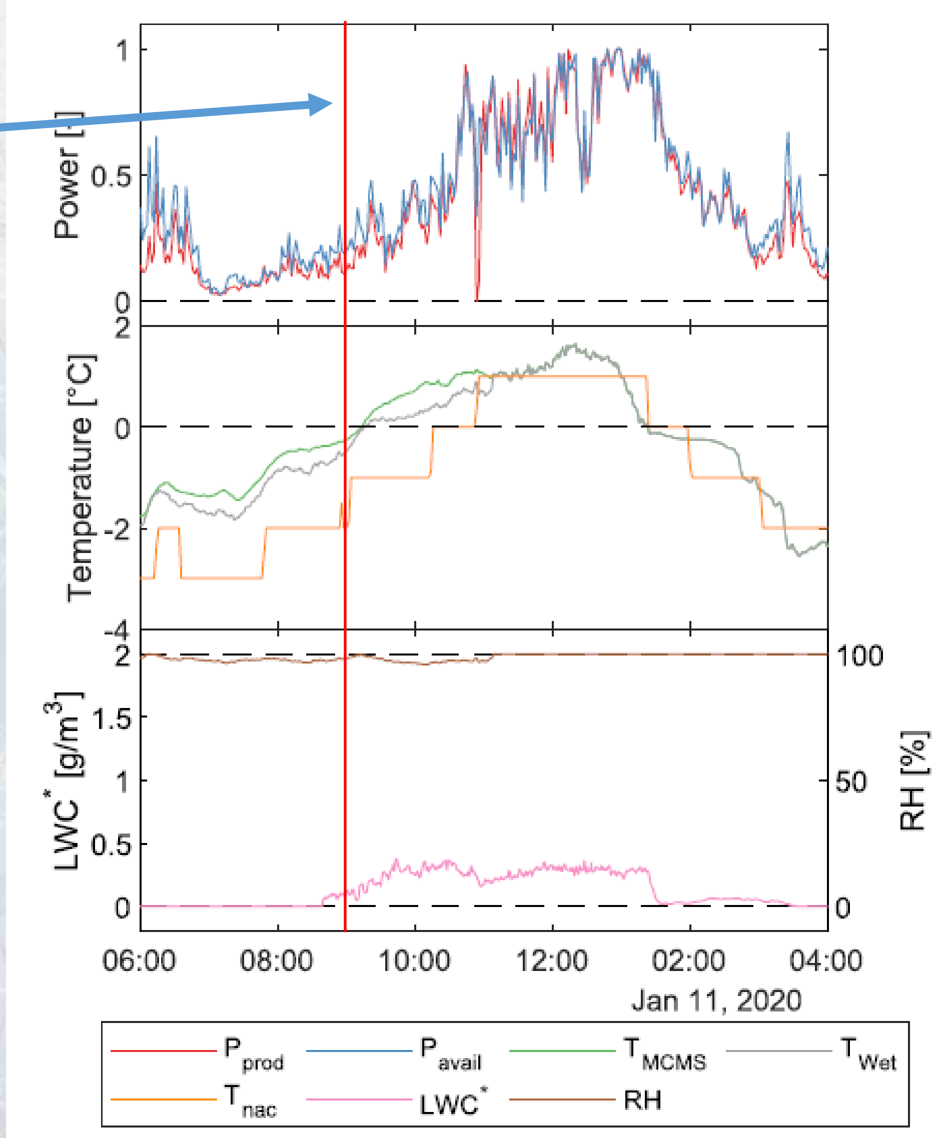
- Contact : Patrice.roberge.2@ulaval.ca

Myth #1: Background

Who	Value	Why?	Context
Homola et al., 2009	2°C	No explanation	Sort summer and winter data sets
Säntti et al., 2003; Laakso et al., 2003; Cattin et al., 2008;	0°C	Water freezing point	Combined with RH to infer icing
Davis, 2014	3°C	Bias in turbine temperature measurement	Filter for icing losses
Canovas Lotthagen, 2020	0°C, 3°C and 6°C	Evaluate the influence of the threshold	Filter for icing losses
Yang et al., 2015	2°C FR 0°C IC	Based on a study on freezing rain (FR)	Validate weather models

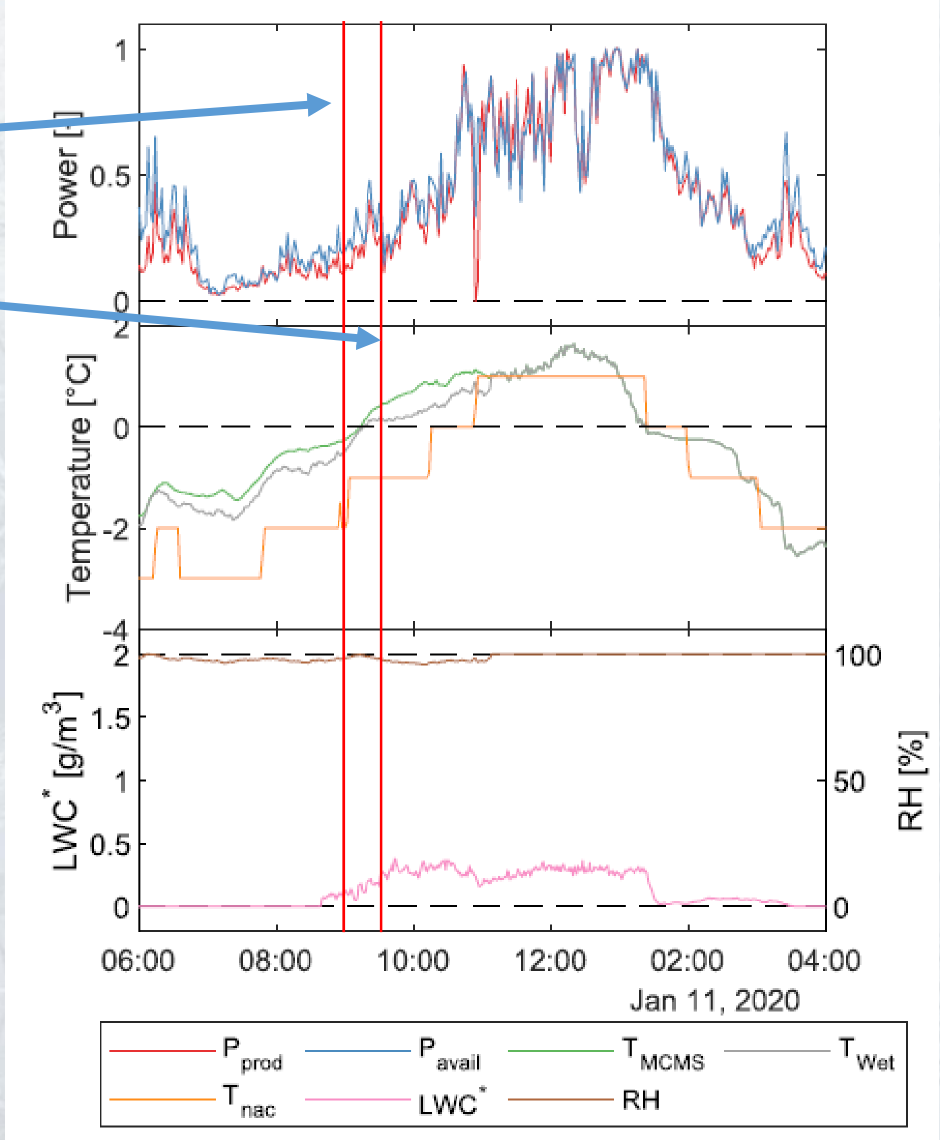
Myth #1: Investigation

1. 08:45 - Ice thickness on the nacelle started to increase.



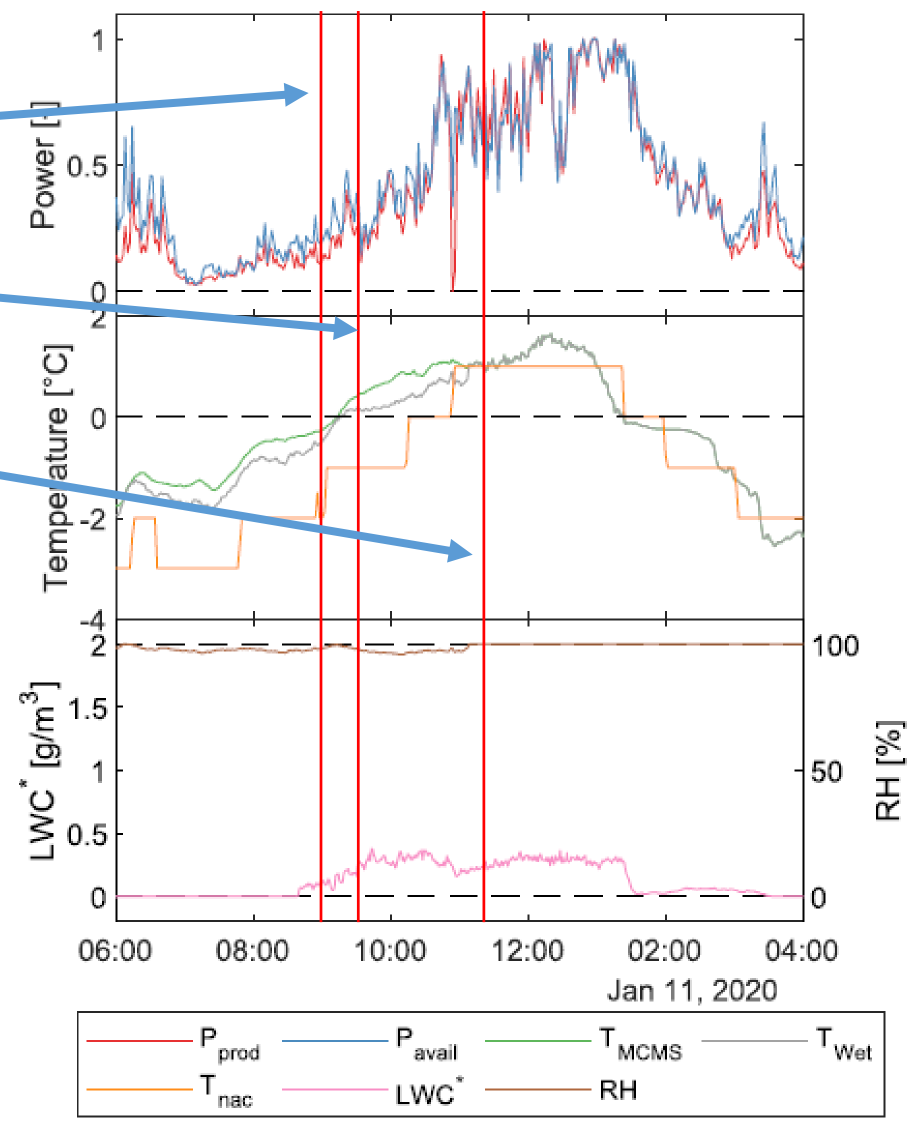
Myth #1: Investigation

1. 08:45 - Ice thickness on the nacelle started to increase.
2. 09:30 - First chunk of ice shed from the structures of the nacelle.



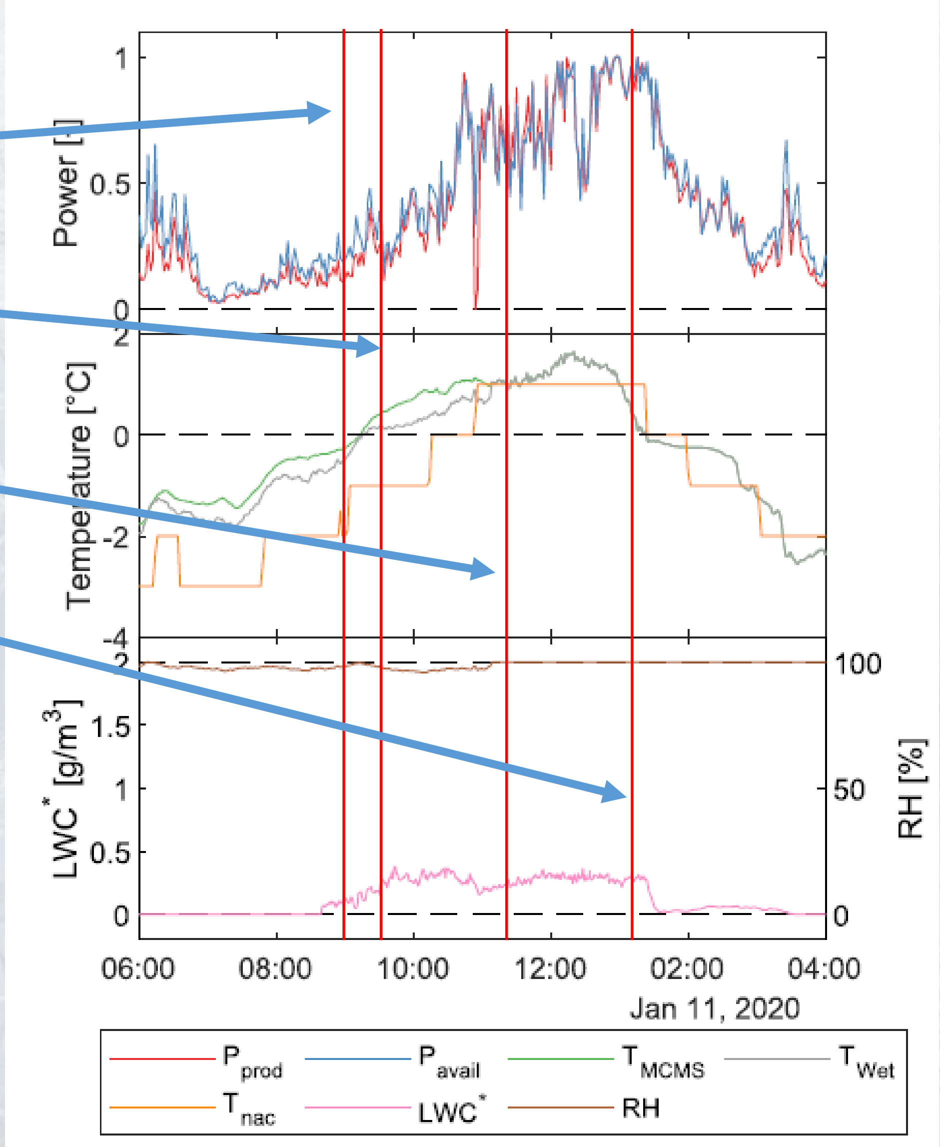
Myth #1: Investigation

1. 08:45 - Ice thickness on the nacelle started to increase.
2. 09:30 - First chunk of ice shed from the structures of the nacelle.
3. 11:30 - Ice fully shed from the structures on the nacelle.



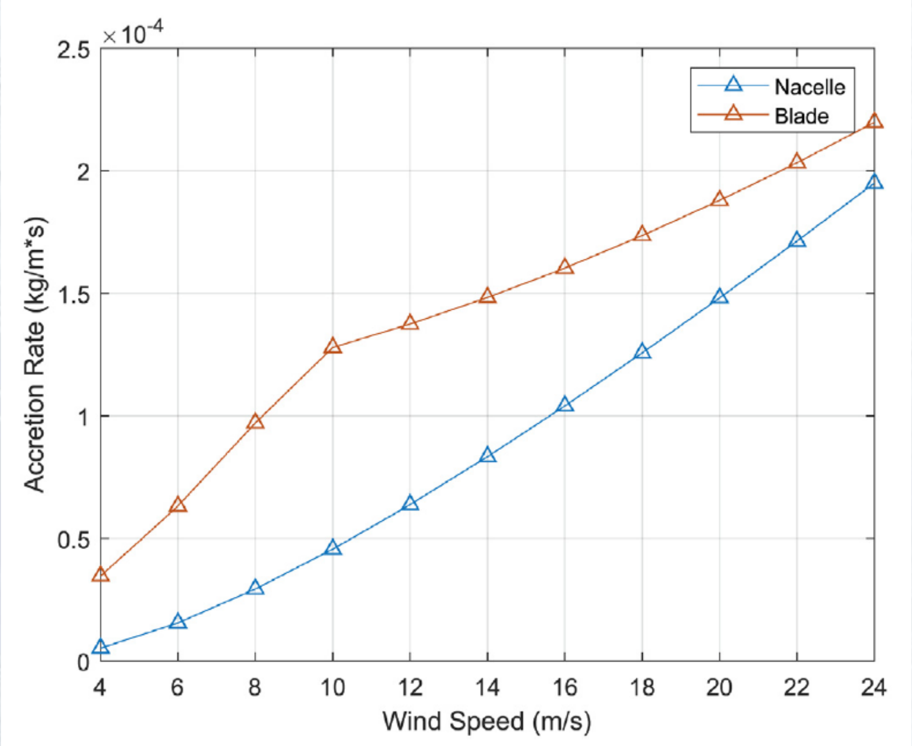
Myth #1: Investigation

1. 08:45 - Ice thickness on the nacelle started to increase.
2. 09:30 - First chunk of ice shed from the structures of the nacelle.
3. 11:30 - Ice fully shed from the structures on the nacelle.
4. 13:15 - Ice started to form on the structures of the nacelle.



Myth #2 : Context

- 3 reasons:
  1. ~~Difference in accretion rate~~
  2. Low clouds only affecting blade tips
  3. ~~Larger volume swept~~
- Reasons 1 and 3 can be overcome with physical models (see figure)[2]



2- Jolin, N., Bolduc, D., Swytink-Binnema, N., Rosso, G., Godreau, C., 2019. Wind turbine blade ice accretion: a correlation with nacelle ice accretion. Cold Reg. Sci. Technol. 157, 235–241.