
VALIDATION OF A WIND TURBINE ICING MODEL FOR SITE ASSESSMENT

Modeling & Detection of Icing



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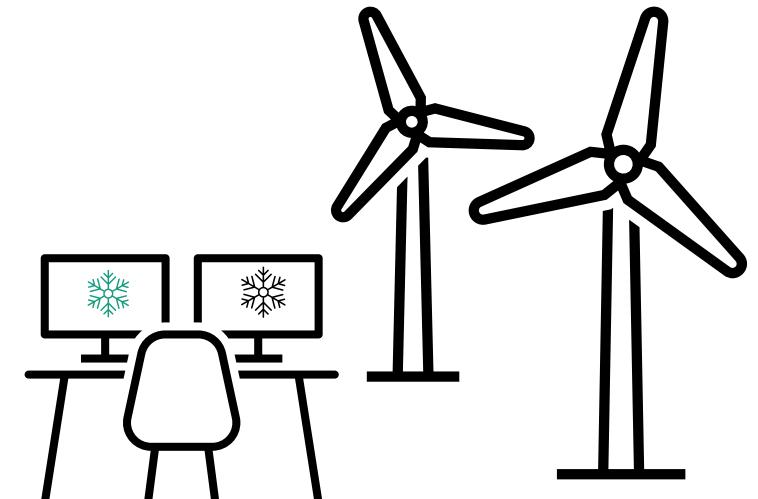
Winterwind

International Wind Energy Conference

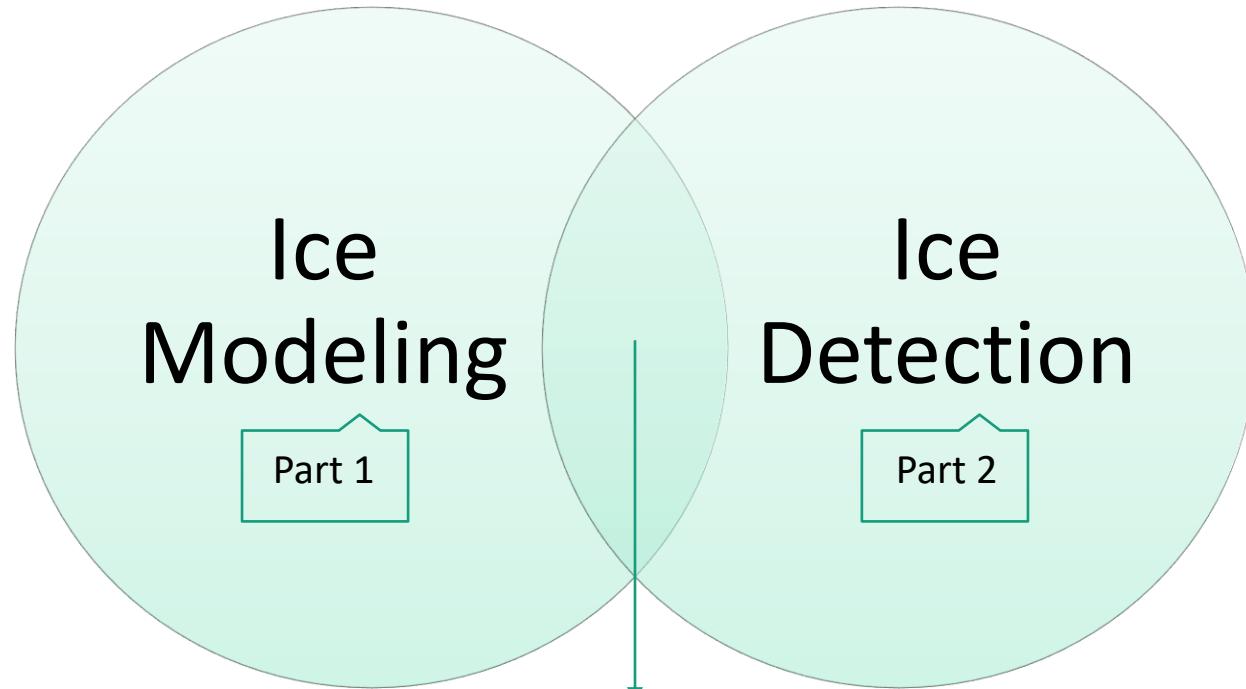
April 19 - 21, 2021 - Online

MOTIVATION

- Accurate site evaluation regarding icing is essential for wind farm planning
- Modeling of icing could become an important tool
- One modeling approach was developed at Fraunhofer IEE within the research project „Iceblades“
- The goal of this study is the evaluation of this icing model
 - In a large icing relevant wind farm with around 7,7 % AEP losses
 - With different weather models as input parameter
 - To determine the accuracy of the modeled icing hours



AGENDA

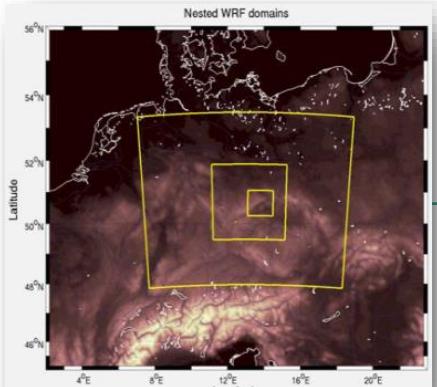


Part 3

Validation of a wind turbine icing model

Part 1: Ice Modeling Concept

1. Numerical Weather Model (Reanalyse Data)



- Temperature
- Liquid Water Content (LWC)
- Wind speed
-

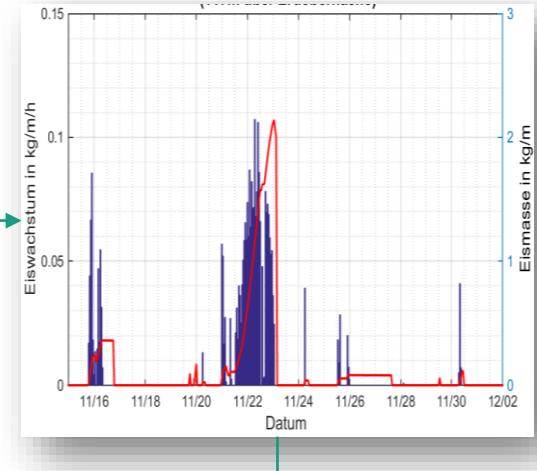
2. Fraunhofer Icing Model

Physical Model
Standard cylindrical body structure*

Model Extension
Reduction processes,
Turbine blades

* ISO 12494:2001 „Atmospheric Icing of structures“ [1]

3. Icing Model Output

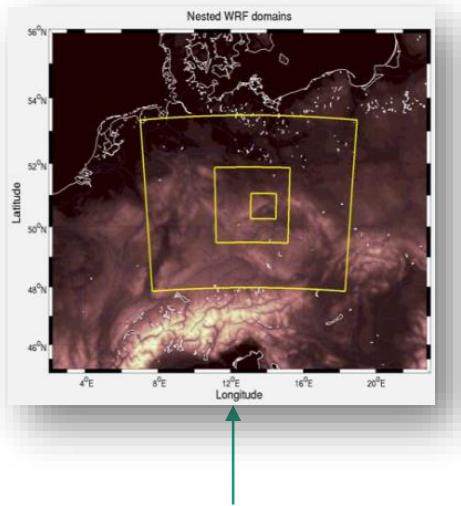


- Mass in kg/m
- Duration in h
- Intensity
- Types of Icing

Part 1: Ice Modeling Concept

1. Numerical Weather Model

(Reanalyse Data)



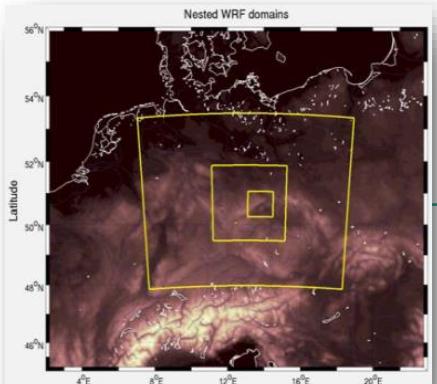
- Temperature
- Liquid Water Content (LWC)
- Wind speed
- Cloud water
- Rain water
- Cloud ice
- Snow content
- Graupel content
- Specific humidity
- Cloud cover

	COSMO DE	ERA5
Horizontal Resolution	2,8 km	30 km
Vertikale Resolution	50 Levels	37 Levels
Availability	Regional	Global

Part 1: Ice Modeling Concept

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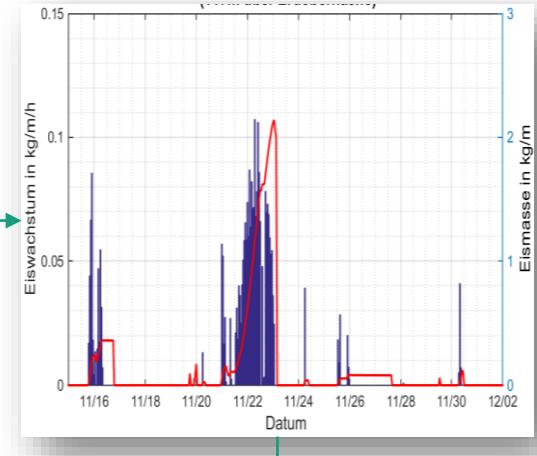
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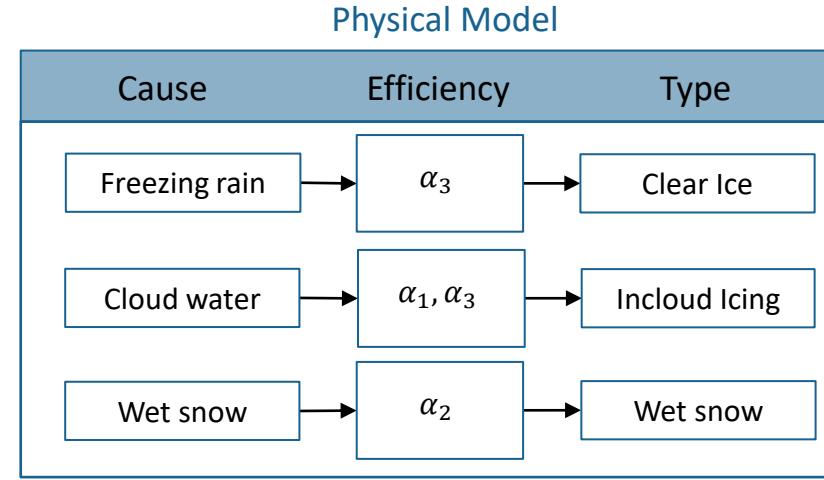
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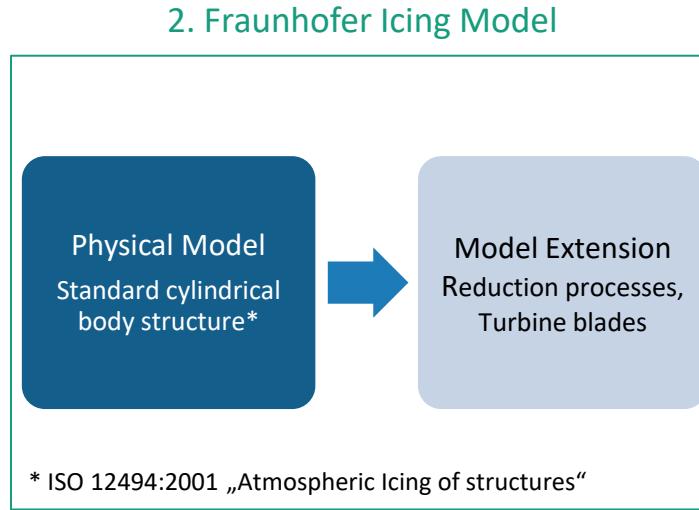
Concept – Fraunhofer Icing Model



- Limitations: cylindrical body structure & simplified mass reduction processes

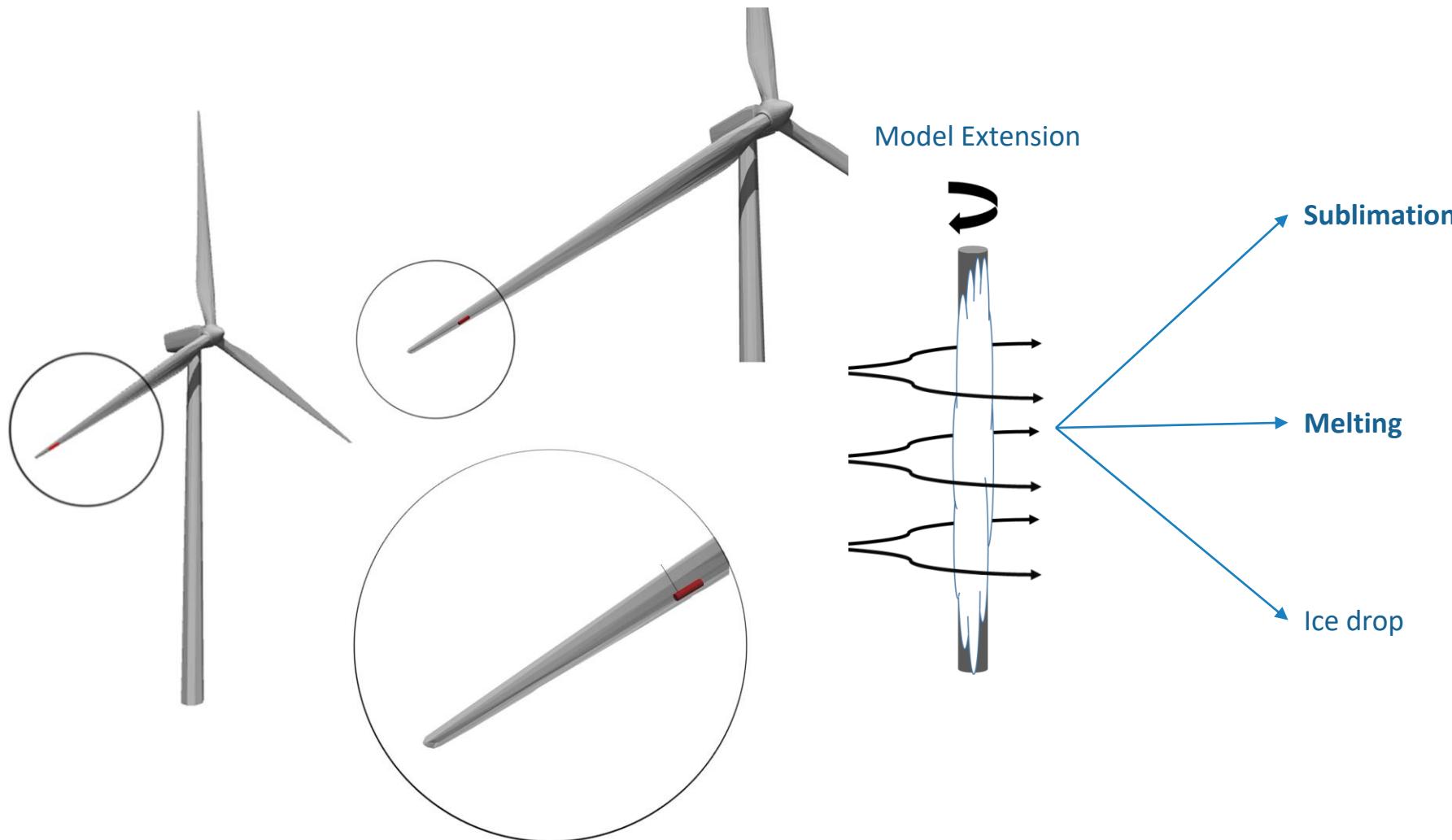
Part 1: Ice Modeling

Concept – Fraunhofer Icing Model



Part 1: Ice Modeling

Concept – Fraunhofer Icing Model Extension

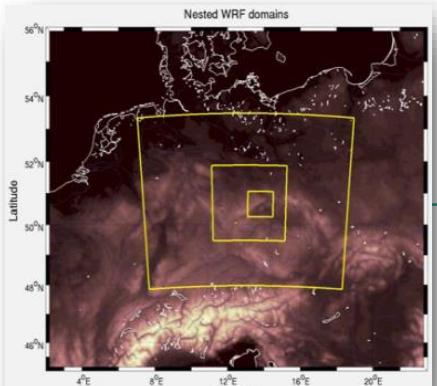


[2] Säger, Thomas; Iceblades

Part 1: Ice Modeling Concept

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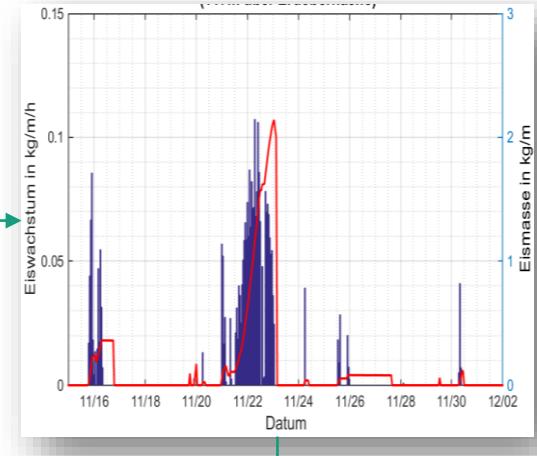
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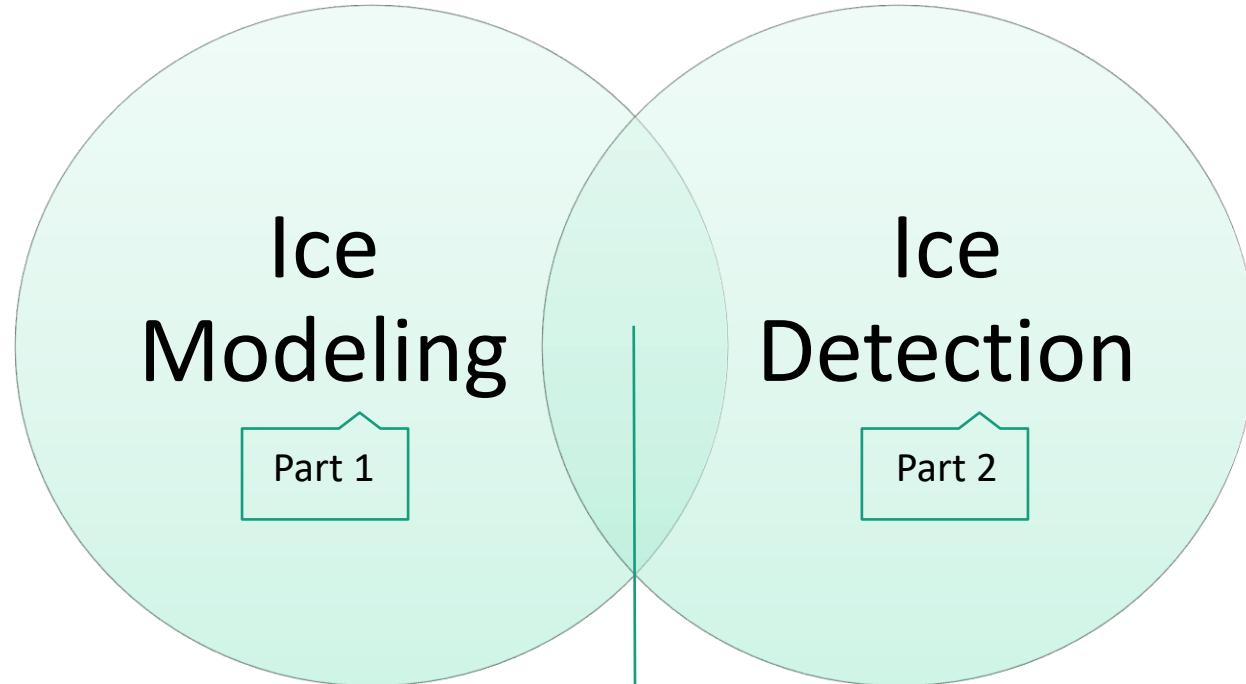
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3. Icing Model Output



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Part 3

Validation of a wind turbine icing model

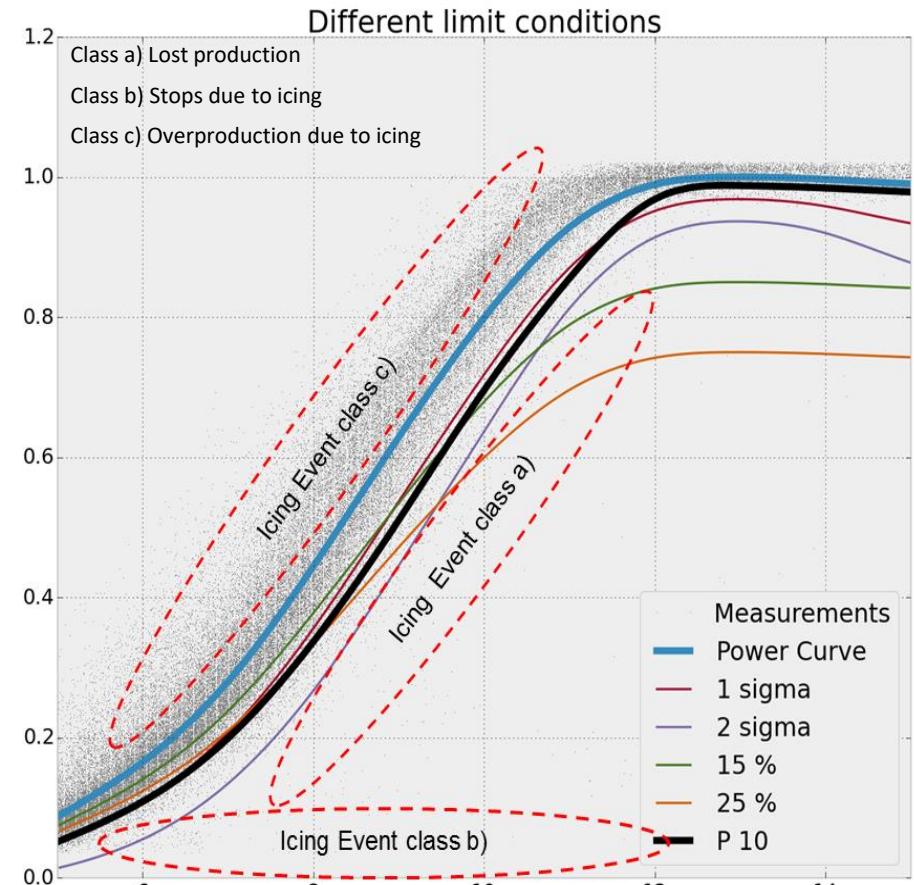
Part 2: Ice Detection

„T19IceLossMethod“ IEA-Task19

1. Calculation of a reference power curve (without icing)
2. Detection of start/stop times for the three icing classes
3. Calculation of production losses due to icing

Input-Parameter

- Meteorological data:
 - Temperature
 - Wind speed
- System data:
 - Blade orientation
 - Power
 - Status

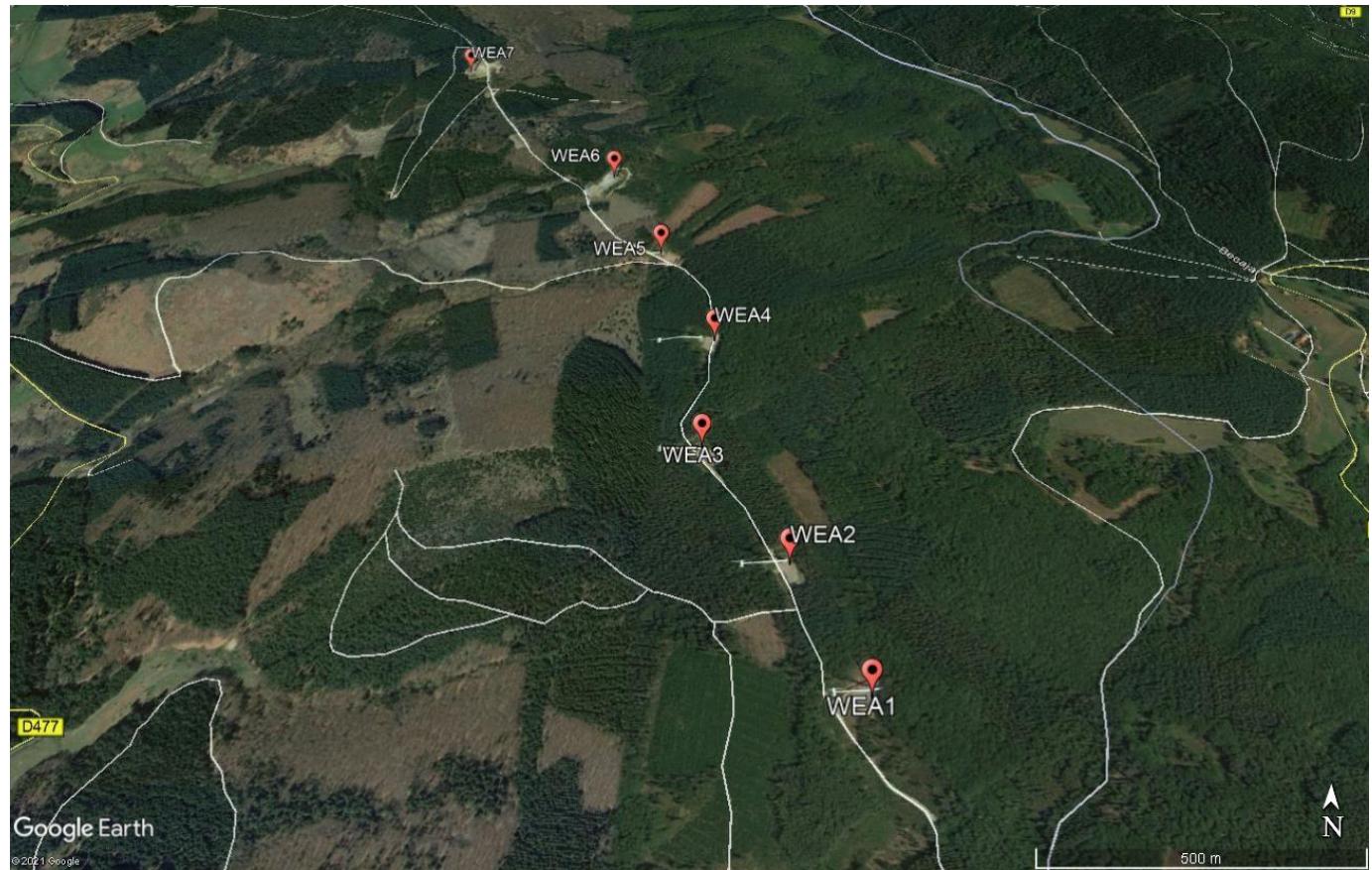


[3] <https://community.ieawind.org/task19/t19icelossmethod>

Part 2: Ice Detection

Wind farm

- Icing relevant location in France
- Height: ~1000 m
- IEA Class 3
 - 6 – 15 % Instrumental Icing
 - 3 – 12 % Production Loss
- 7 Wind turbines (WEA):
 - Nominal power: 2 MW
 - Turbine height: 105 m
 - No blade heating
 - Heated wind measurements

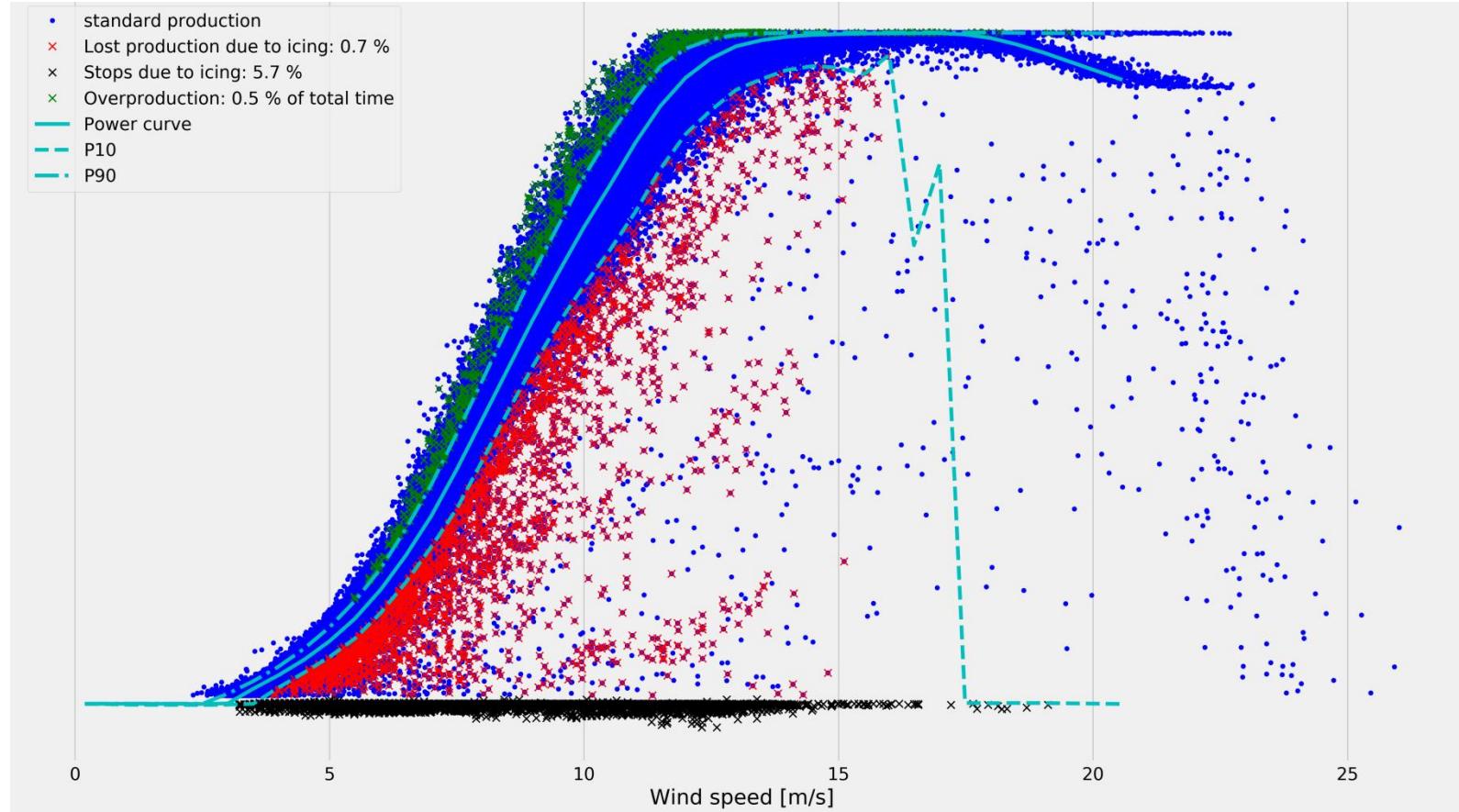


Part 2: Ice Detection

Results Wind turbine 2

Output of the IEA-Task19 IceLossMethod: Detection results for one wind turbine

18/01/2015 – 01/06/2018



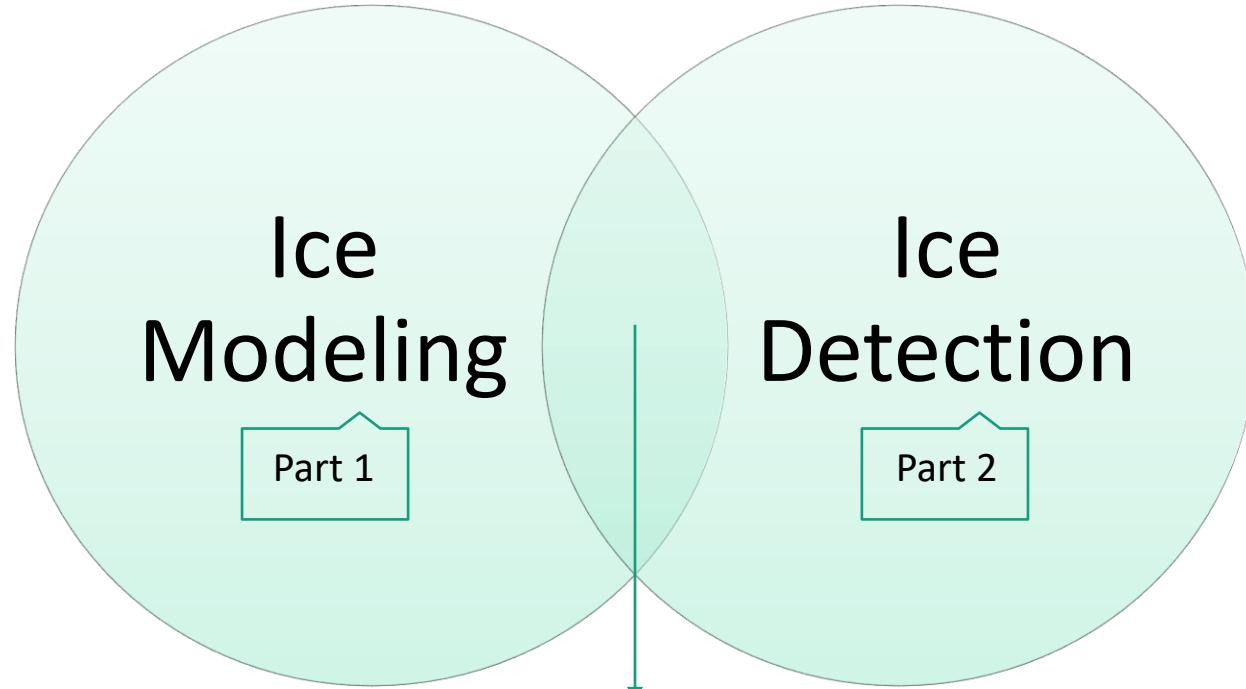
Part 2: Ice Detection

Results Wind farm

2015 - 2018	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Turbine 6	Turbine 7
Class a) Lost production in MWh	164 (0,9 %)	141 (0,7 %)	191 (0,9 %)	159 (0,7 %)	94 (0,4 %)	177 (0,8 %)	148 (0,7 %)
Class b) Stops due to Icing in MWh	1294 (6,7 %)	1165 (5,7 %)	1615 (7,4 %)	1789 (8 %)	1502 (7,2 %)	1446 (6,7 %)	1491 (7,5 %)
Icing hours in h	2092	2186	2586	2757	2451	2373	2530

- Average loss over 3 years: **7,7 % due to icing**
- Average icing hours over 3 years: **2425 h**
- Average icing hours each winter: **692 h**

AGENDA

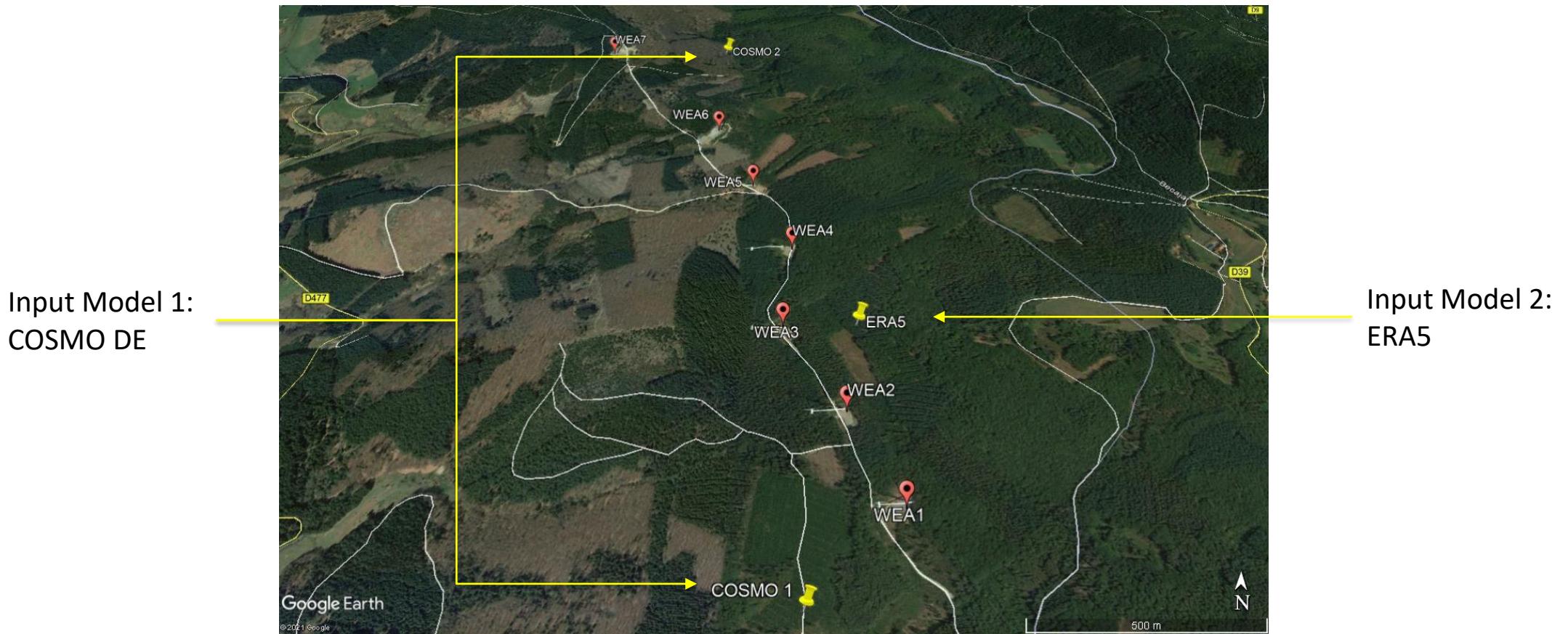


Part 3

Validation of a wind turbine icing model

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Wind farm and Input Model



Part 3: Validation of a wind turbine icing model

Comparison Input Model

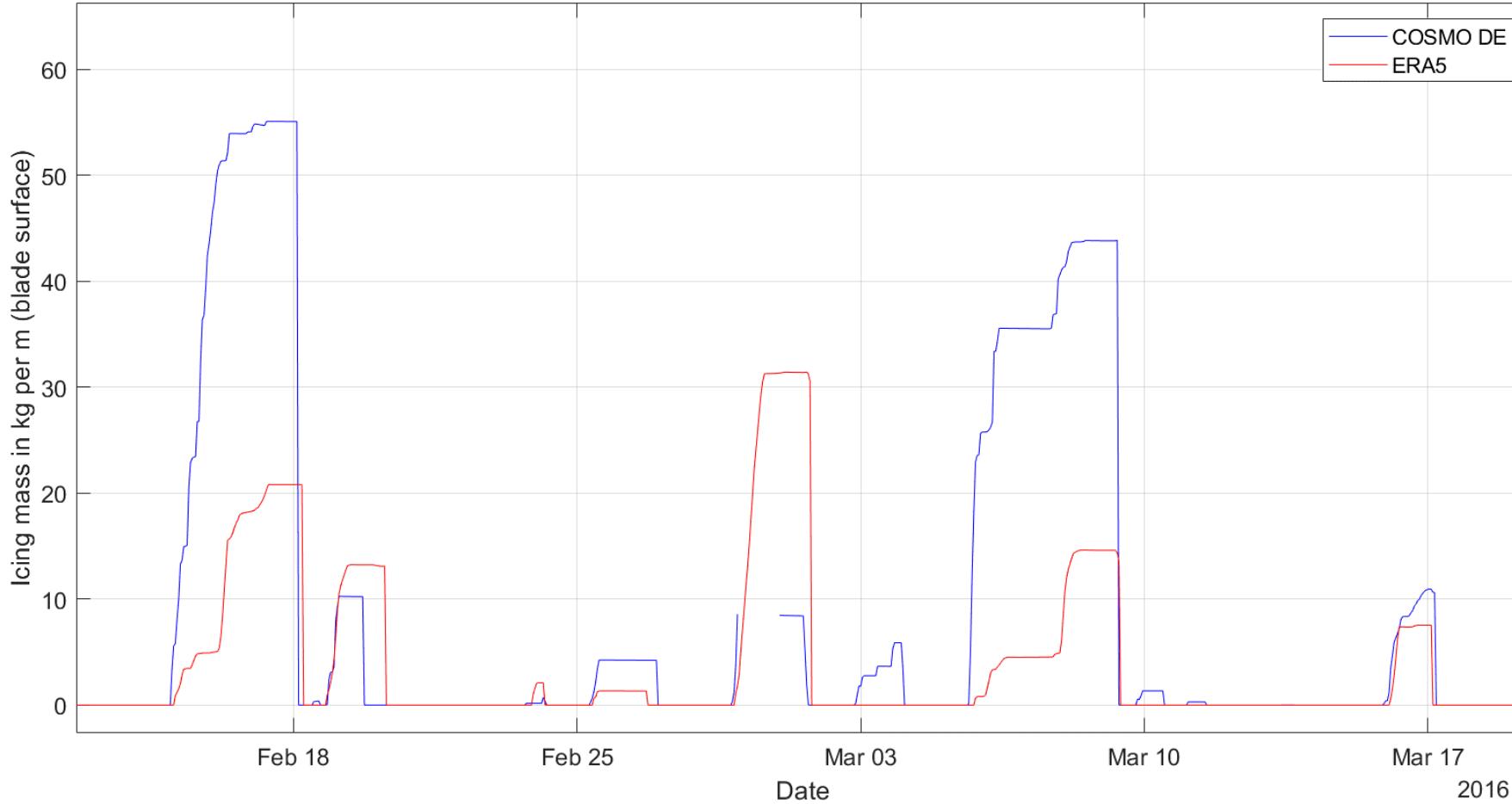
Turbine 2	Winter 2	Winter 3	Winter 4	Ø/Winter	2015 - 2018
Modeling* in h COSMO DE	607	669	1009	761	2285
Modeling* in h ERA5	724	544	822	696	2090
Δh	117	125	187	65	195

* Ice mass > 0,5 kg/m²

- Modeled icing hours varies by **195 hours** depending on the input model

Part 3: Validation of a wind turbine icing model

Comparison Input Model



Part 3: Validation of a wind turbine icing model

Comparison with Detection

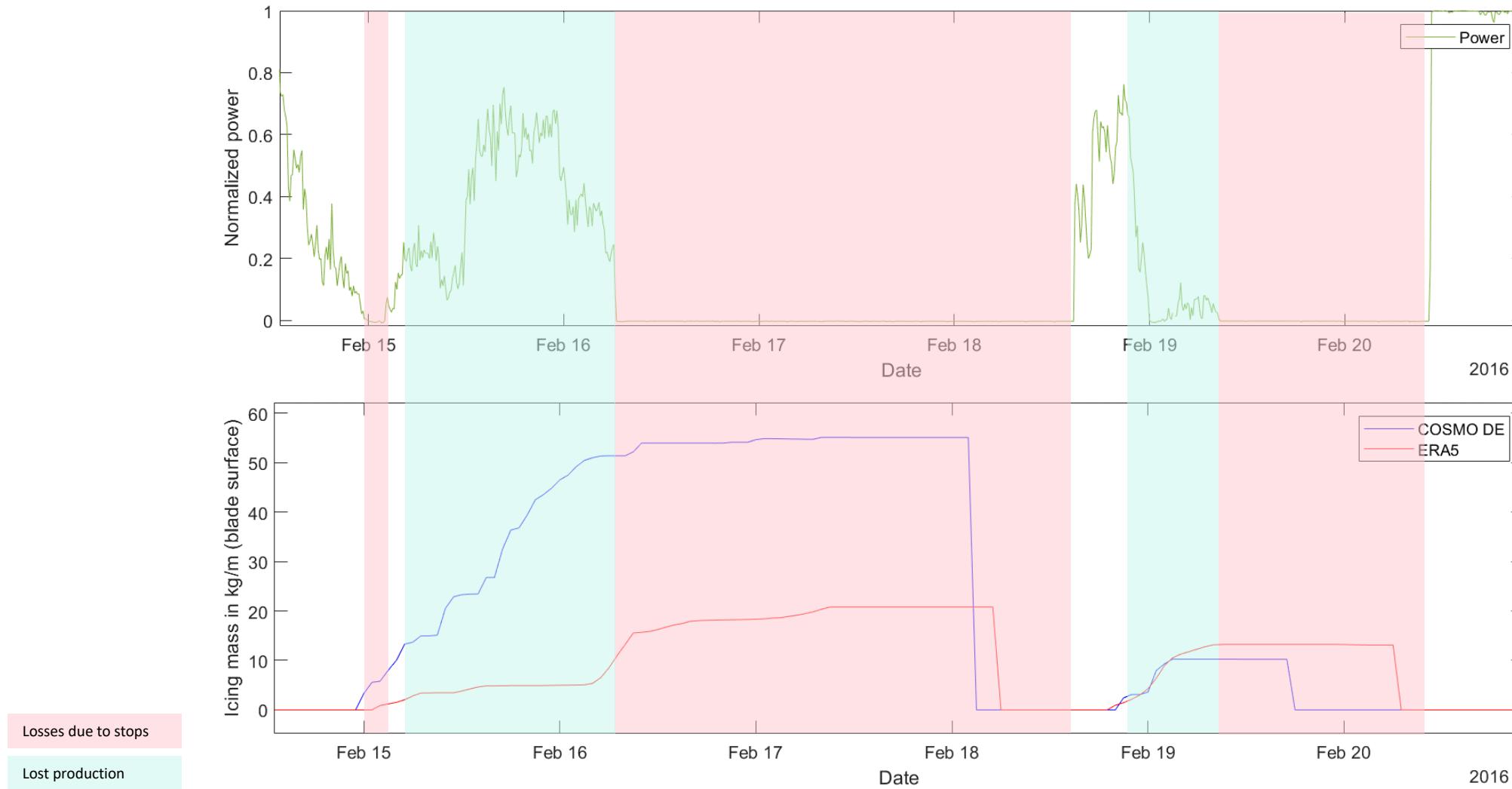
Turbine 2	Winter 2	Winter 3	Winter 4	Ø/Winter	2015 - 2018	Δh
Detection in h	581	627	1028	745	2236	
Modeling* in h COSMO DE	607	669	1009	761	2285	49
Modeling* in h ERA5	724	544	822	696	2090	146

* Ice mass > 0,5 kg/m²

- 98 % icing hours accuracy (49 h total difference) with the COSMO DE model
- 93 % icing hours accuracy (146 h total difference) with the ERA5 model

Part 3: Validation of a wind turbine icing model

Comparison with Detection



Conclusion

- The Fraunhofer icing model can be used on a regional scale (COSMO DE) as well as on a global scale (ERA5)
 - The differences between COSMO DE und ERA5 are **195 h**
 - Between detection and modeling the differences over 3 years:
 - **49 h** with COSMO DE data (**98 % icing hours accuracy**)
 - **146 h** with ERA5 data (**93 % icing hours accuracy**)
- Fraunhofer icing model can provide accurate results for this first site assessment
- Possible future work can be the validation in other locations and in regard to other parameters (e.g., ice mass)

THANK YOU! FEEL FREE TO CONTACT US!



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REFERENCE LIST

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- [1] ISO 12494:2001 „Atmospheric Icing of structures“
 - [2] Final report „IcedBlades“ Project 2017; <https://doi.org/10.2314/GBV:887592554>
 - [3] IEA wind; <https://community.ieawind.org/task19/t19icelossmethod>