Classification Based Approach for Icing Detection

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Outline

- The approach
- Analysis of icing events
- Input parameter selection
- Classification
  - Result presentation of two selected cases
  - Comparison of two methods
- Conclusions and outlook

Classification based approach

Icing detection

Why icing detection?

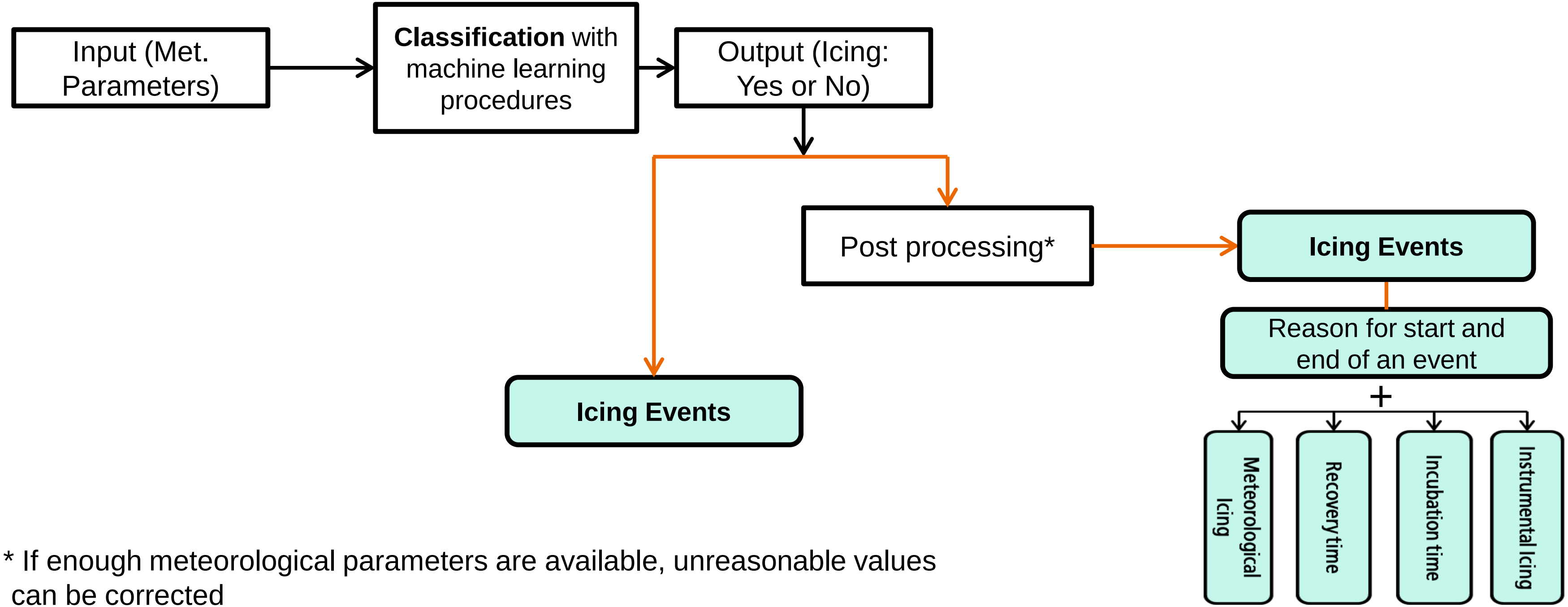
Essential issue during site assessment, project development and wind turbine operation

How?

- With instrumentation (directly):
  - Icing can be either detected or measured (thickness or weight)
  - Several ice sensors are available
  - Double anemometry and power curve control can be used
- Without instrumentation by using solely meteorological data **(BIG CHALLENGE!)**

Classification based approach

Methodology



* If enough meteorological parameters are available, unreasonable values can be corrected

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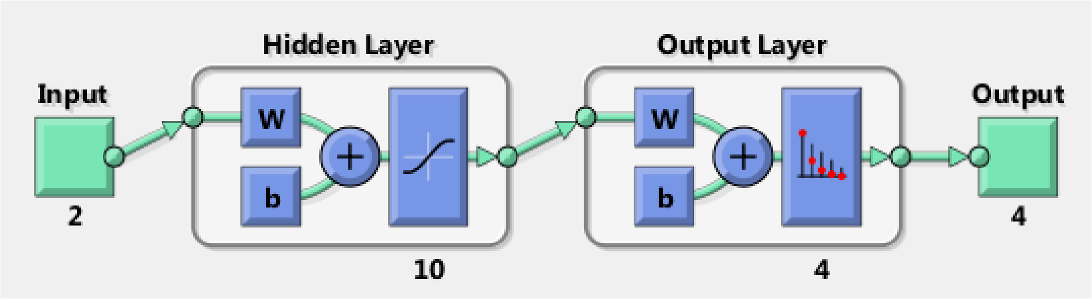
Classification based approach

Methodology

Machine learning procedures for classification

- Pattern recognition with artificial neural network (ANN)

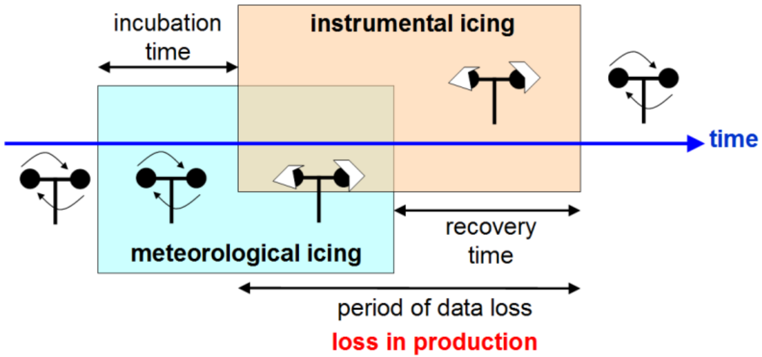


- Generalized Boosted Machines (GBM)

Analysis of icing events and input parameters

Analysis of all 4 icing phases

- Analysis of all icing events
  - Meteorological Icing
  - Instrumental Icing
  - Incubation period
  - Recovery period

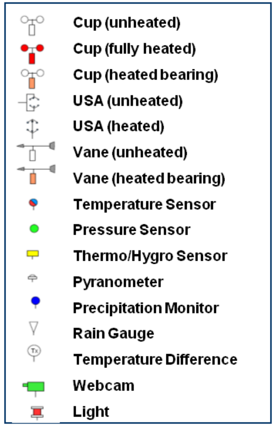


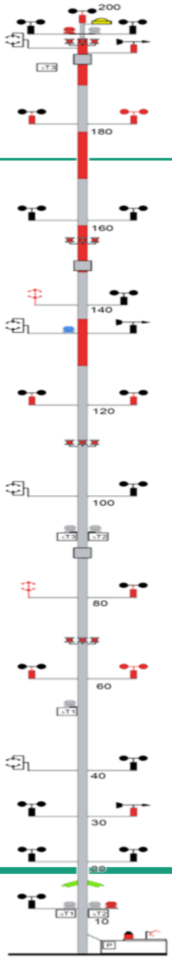
- Analysis of meteorological parameters with respect to each icing phase
  - Reason for start or end of an icing event

Analysis of icing events

Background of data (200m Mast)

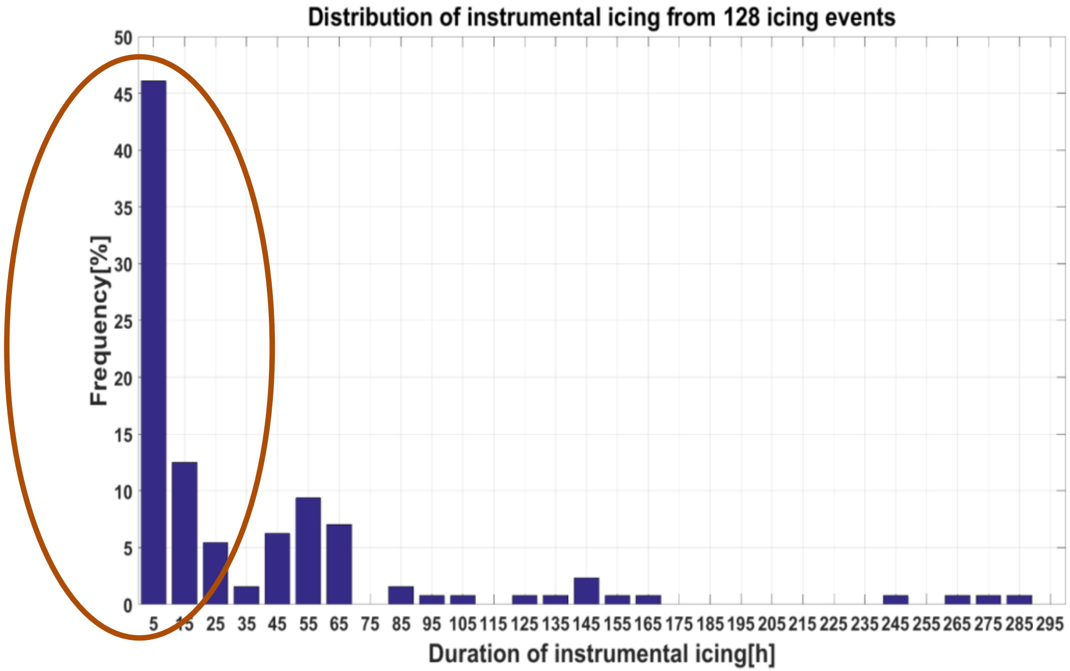
- Data of 200 m met-mast at an icing relevant site in Germany
- Three winter periods: from 2012 to 2015
- More than 128 icing events and 1200 hours of instrumental icing
- Several meteorological, wind and ice sensors
- Ceilometer and camera
- 10 min. averages





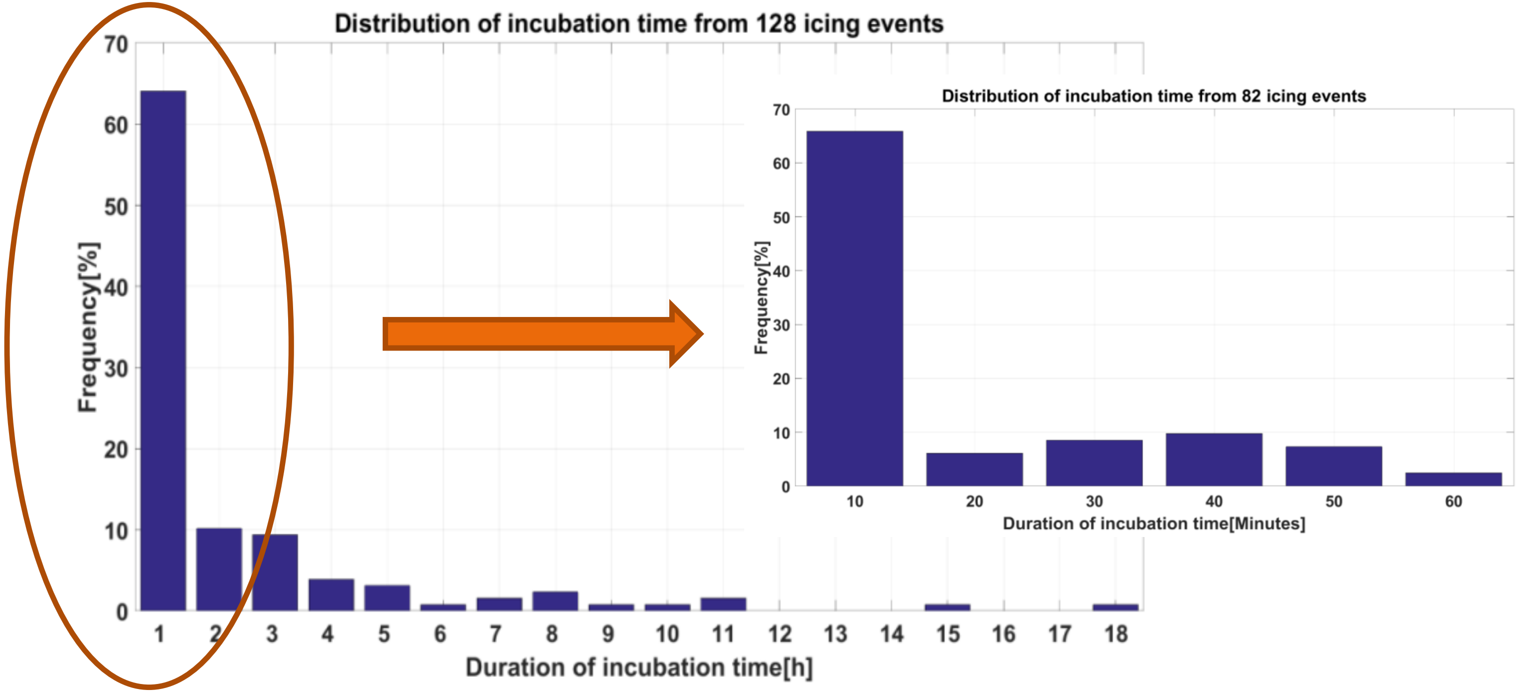
Analysis of icing events and input parameters

Analysis of all 4 icing phases – Instrumental icing



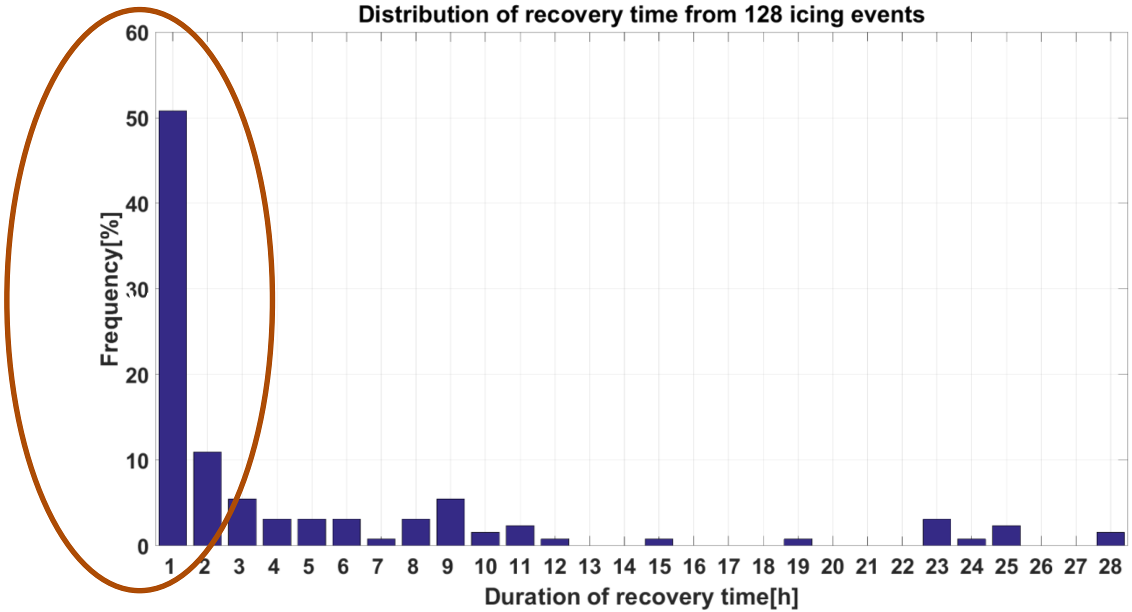
Analysis of icing events and input parameters

Analysis of all 4 icing phases – Incubation time



Analysis of icing events and input parameters

Analysis of all 4 icing phases – Recovery time



Analysis of icing events and input parameters

Selection of Input parameters and case definition

Case 1

Input parameters for training and test data										Target /Output
T(t)	VW(t)	RH(t)	LWC (t)	T(t-3)	LWC (t-3)	T(t-6)	LWC (t-6)	T(t-7)	LWC(t-7)	“Icing” “no Icing”

Case 2

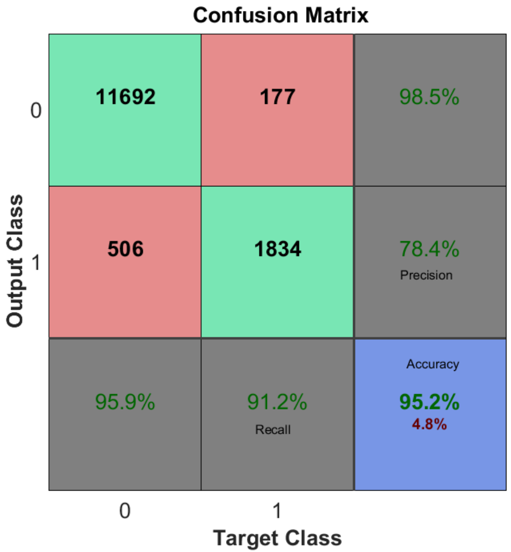
Input parameters for training and test data						Target /Output
T(t)	VW(t)	RH(t)	T(t-3)	T(t-6)	T(t-7)	“Icing” “no Icing”

T: Temperature – VW: velocity of wind – RH: relative Humidity – LWC: Existence of Liquid water content (yes or no - based on sky condition index from ceilometer measurements)

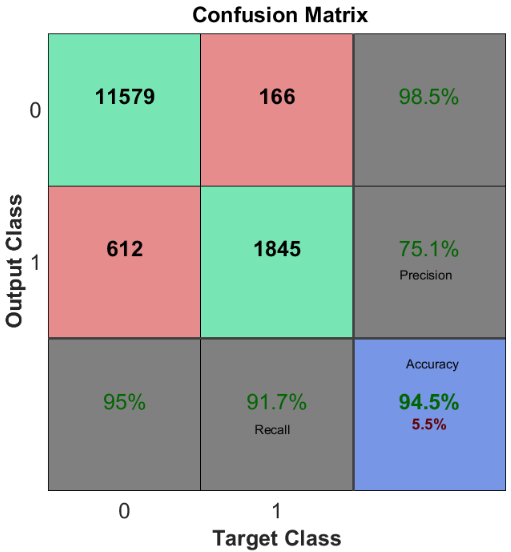
Results

Case 1(with LWC) – good accuracy of detection

ANN



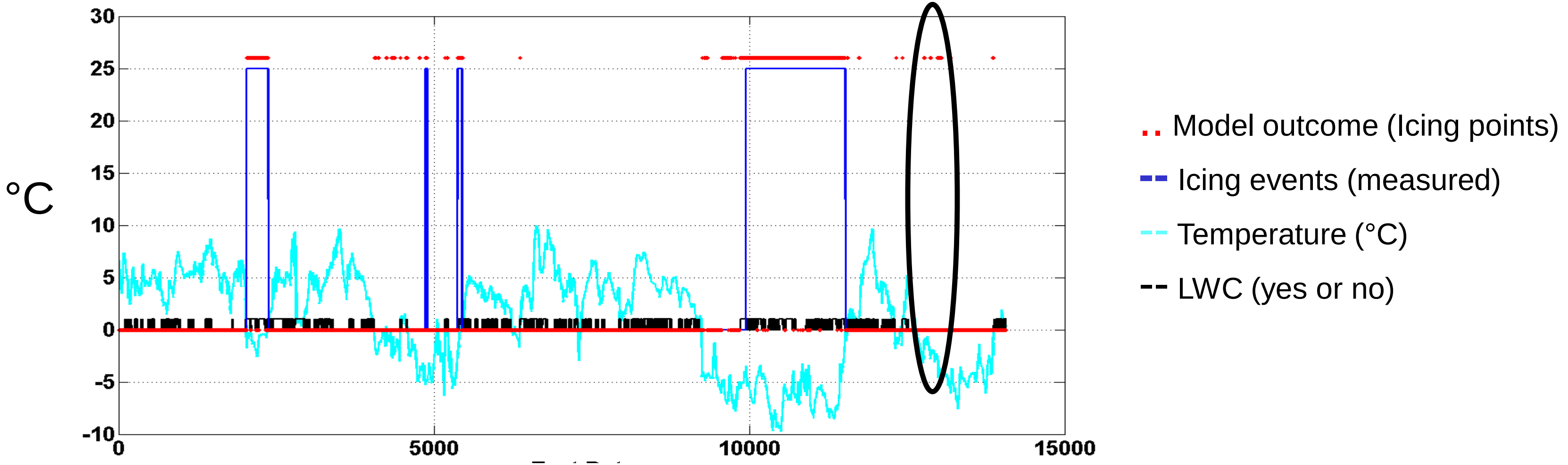
GBM



0 = no icing
1 = icing

Results

Case 1: Post processing – correction of unreasonable values



Results

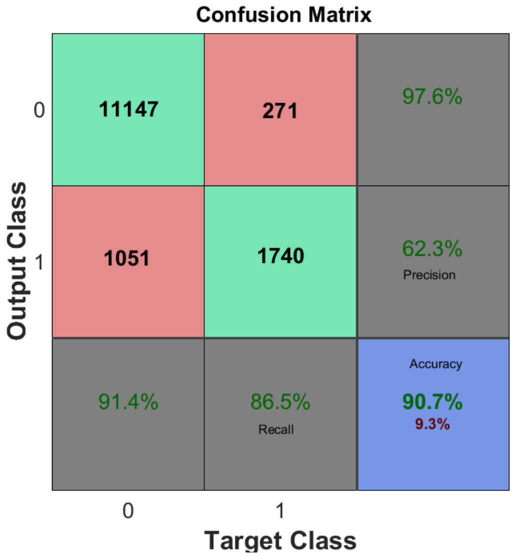
Case 1 after post processing – very good accuracy

0 = no icing
1 = icing

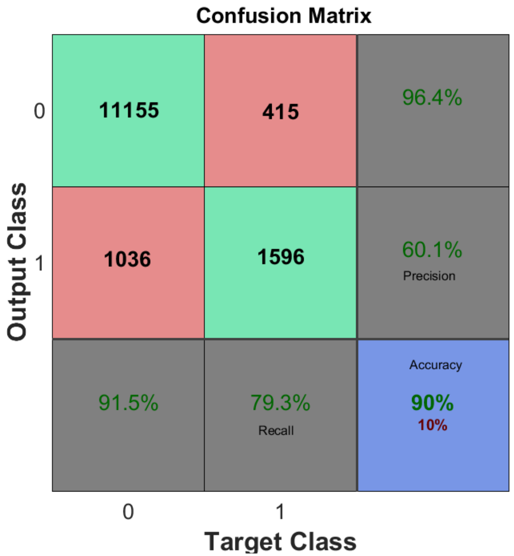
Results

Case 2 (without LWC) – less accuracy than case 1

ANN



GBM

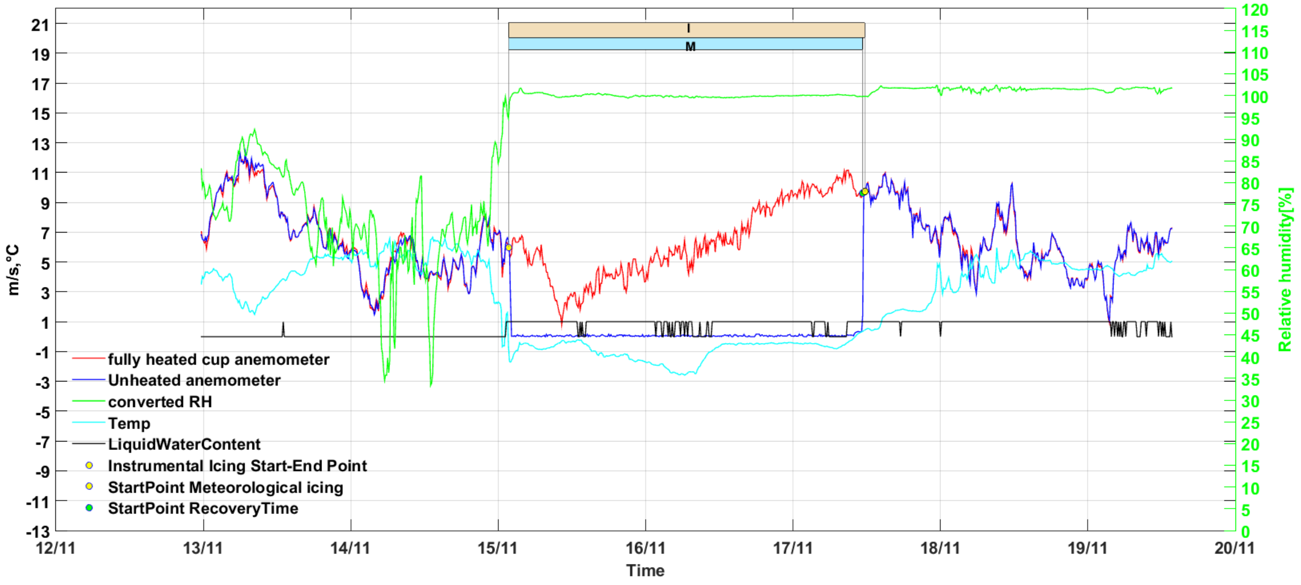


0 = no icing
1 = icing

Results

Example of one detected icing event

I : Instrumental icing – M: Meteorological icing



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Conclusions and Outlook

Conclusions

- Promising results of icing detection with the presented approach
- Very good detection with “temperature”, “wind speed”, “rel. humidity” and “LWC” (after post processing)
- Good detection with “temperature”, “wind speed ” and “rel. humidity”
- Similar results of ANN and GBM

Outlook

- Method can be used for site specific icing detection
- Test with more data and with data of other location

Thank you for your attention!

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