Validation Study of Modelled Icing using Met Mast data and SCADA data

Marie Cecilie Pedersen, Tobias Ahsbahs and Morten Thøgersen
EMD International A/S

Winterwind 2022
April 19-21, Skellefteå, Sweden

windPRO

Validation Study – why?

Questions…

1. Do we model seasonal icing well?

2. Do we use good thresholds for identifying icing periods?

3. Estimation of production losses from the IEA Ice Class system?

Figure 1: Cup-anemometer on met mast boom.

Table 1: IEA Ice Classes [1].

IEA Ice-Class	Meteo. icing (% of year)	Instru. icing (% of year)	Production loss (% of AEP)
5	> 10.0	> 20.0	> 20.0
4	5.0 – 10.0	10.0 – 30.0	10.0 – 25.0
3	3.0 – 5.0	6.0 – 15.0	3.0 – 12.0
2	0.5 – 3.0	1.0 – 9.0	0.5 – 5.0
1	0.0 – 0.5	< 1.5	0.0 – 0.5

Modelling Chain: EMD-WRF On Demand ICING

The modelling chain relies on industry proven standards.

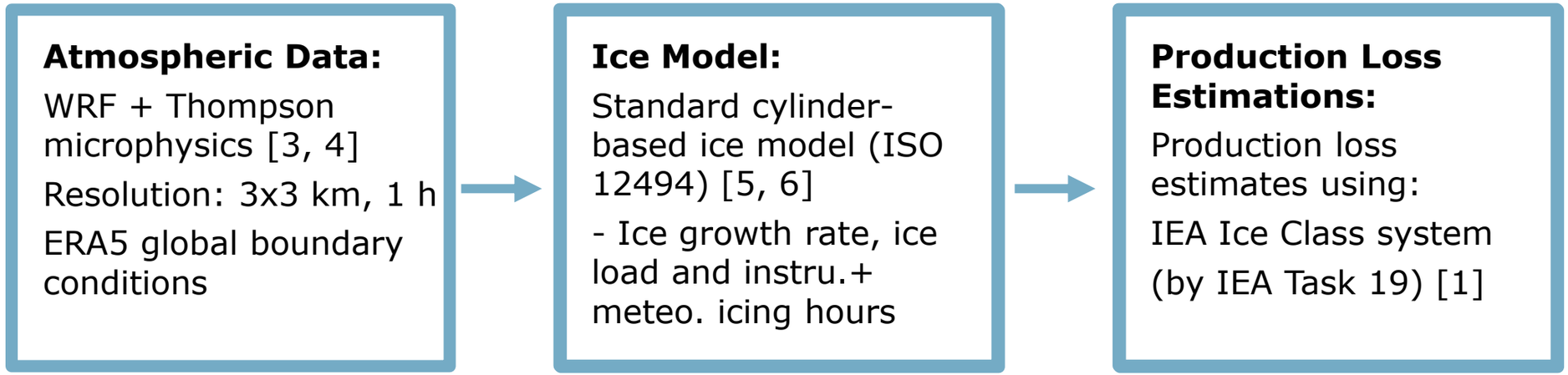


Figure 2: Sketch of EMD-WRF OD Icing modelling chain [2].

Do we model seasonal icing well?

Answer: Validate modelled instrumental icing

- Using *standard* meteorological masts
  - 29 met masts – from eight different countries

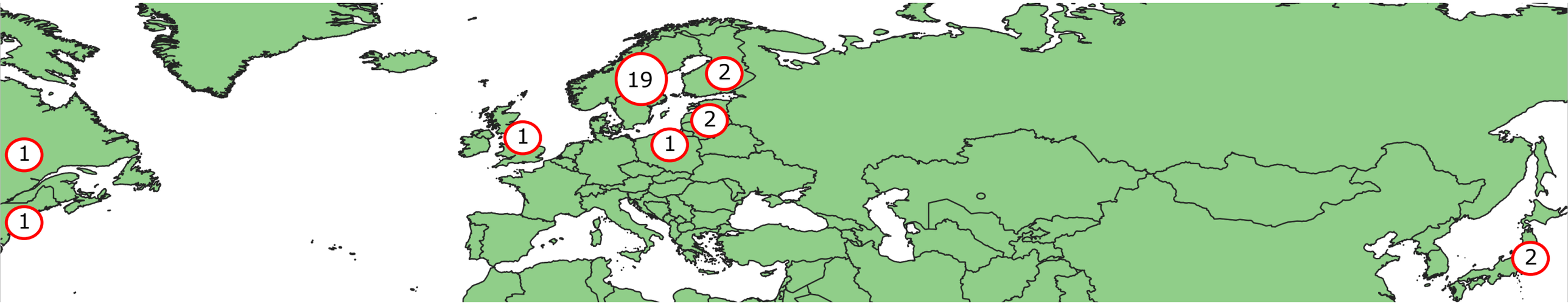


Figure 3: Masts shown as red dots. The total masts cover: 19 in Sweden, two in Finland, one in Poland, two in Lithuania, one in the United Kingdom, two in Japan, one in Canada and one in the USA

windPRO

Methodology

Met mast data prepared using **windPRO**

- Abnormalities in the data
  (wind vane, double anemometry, T<0ºC)
- Minimum 80% data availability
- Results:
  - 49 seasons of data available after filtering and cleaning
  - Filtered datasets of 1-4 seasons

- Comparison of mast instrumental icing and modelled instrumental icing

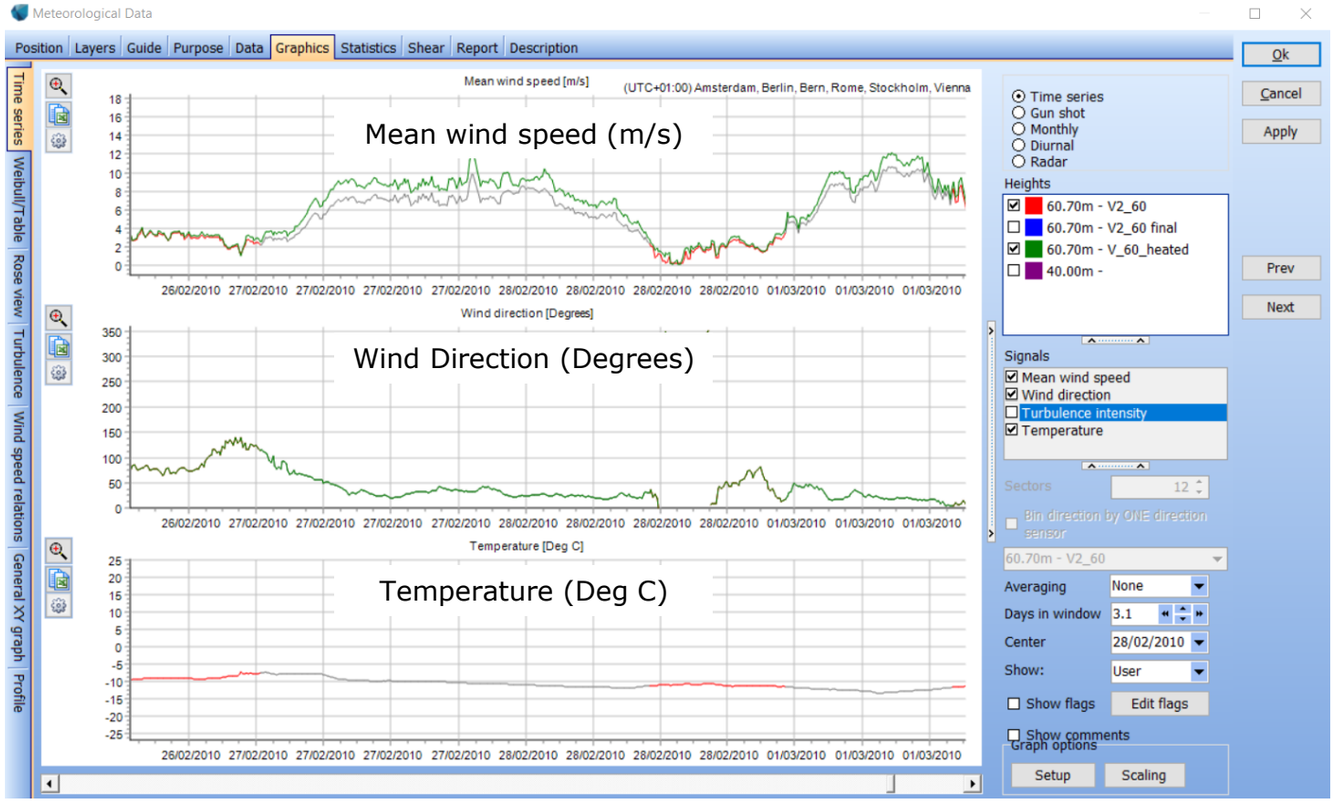
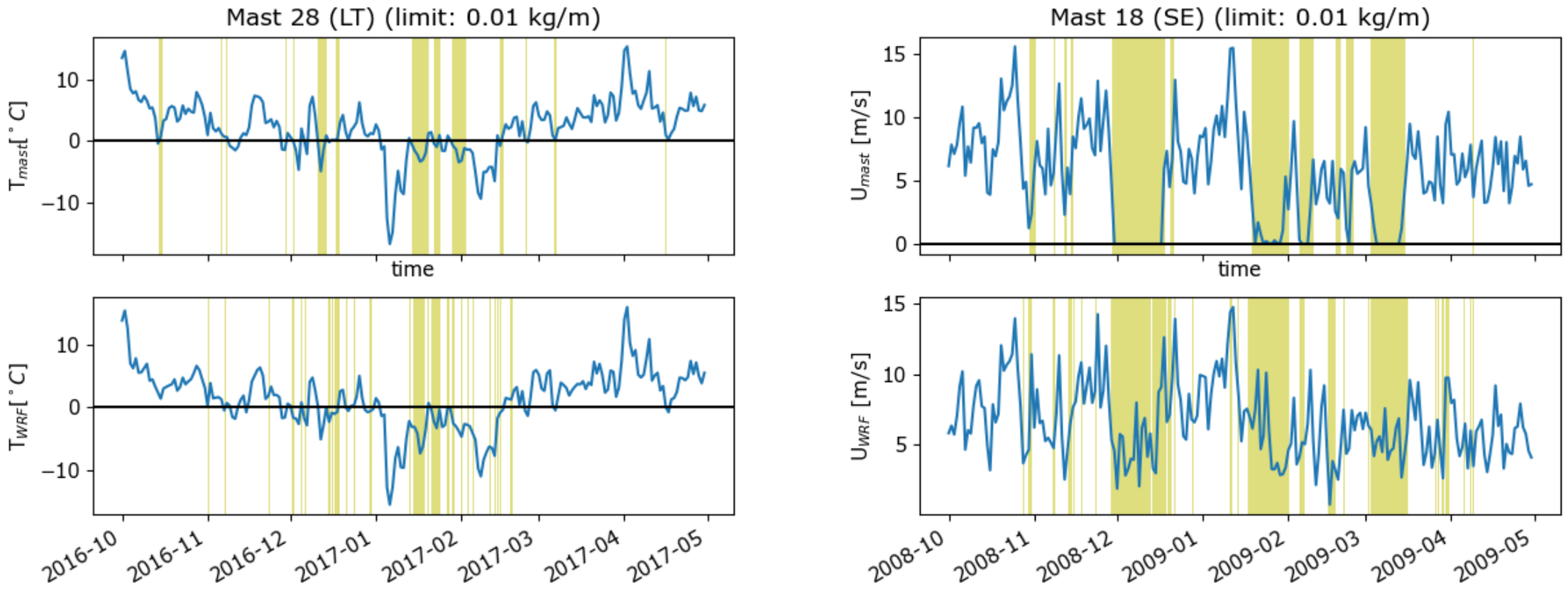


Figure 4: Example of filtering/cleaning data in windPRO.

Do we model seasonal icing well ?

When does instrumental icing start?

- Ice mass over cylinder > 10 g for a 1-m-high standard cylinder [7] ?

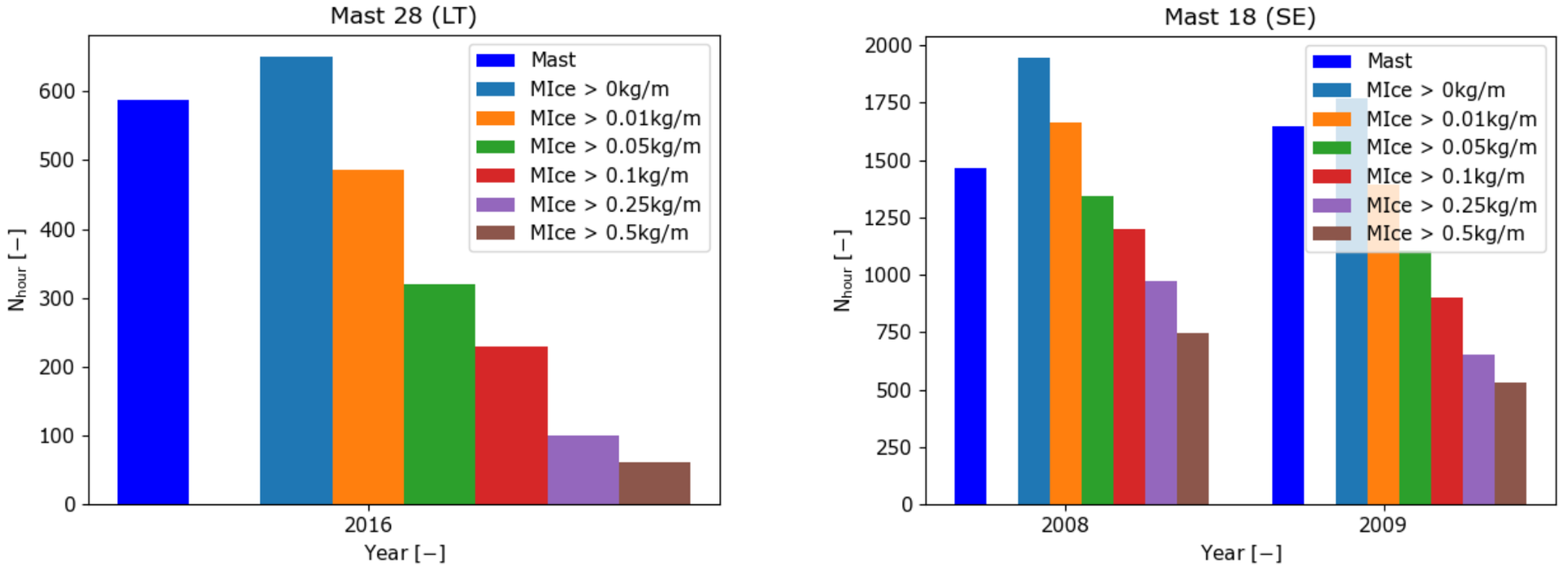


Figures 5-6: Hourly comparison of mast instrumental icing and modelled instrumental for Mast 28 (LT) and Mast 18 (SE).

Do we use good thresholds for identifying icing periods?

When does instrumental icing start?

- Ice mass over cylinder > 0.0g, 10g, 50g, 100g, 250g, 500g?
  (for a 1-m-high standard cylinder)



Figures 7-8: Comparison of *seasonal* mast instrumental icing and modelled instrumental for Mast 28 (LT) and Mast 18 (SE). Mice is the ice mass.

Results – Mast vs Model

- 1:1 correlations of mast and model

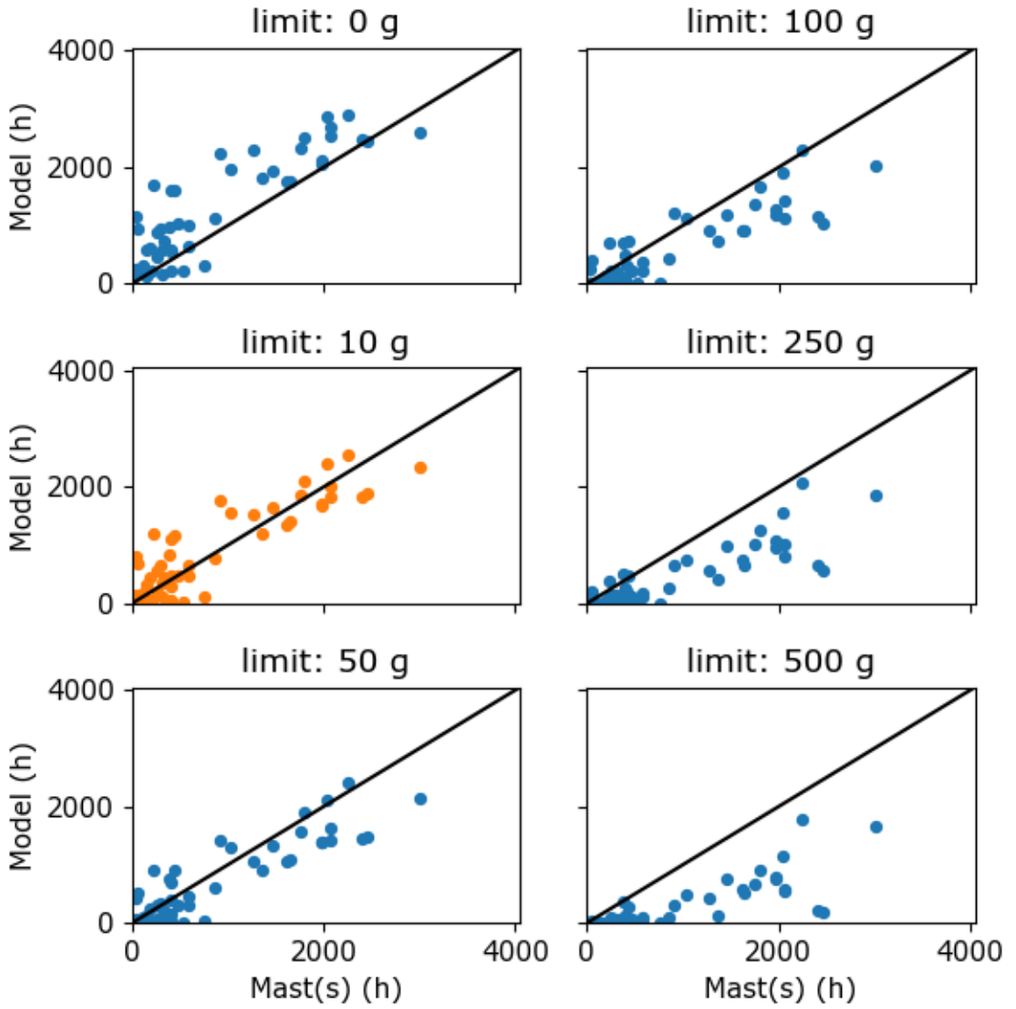
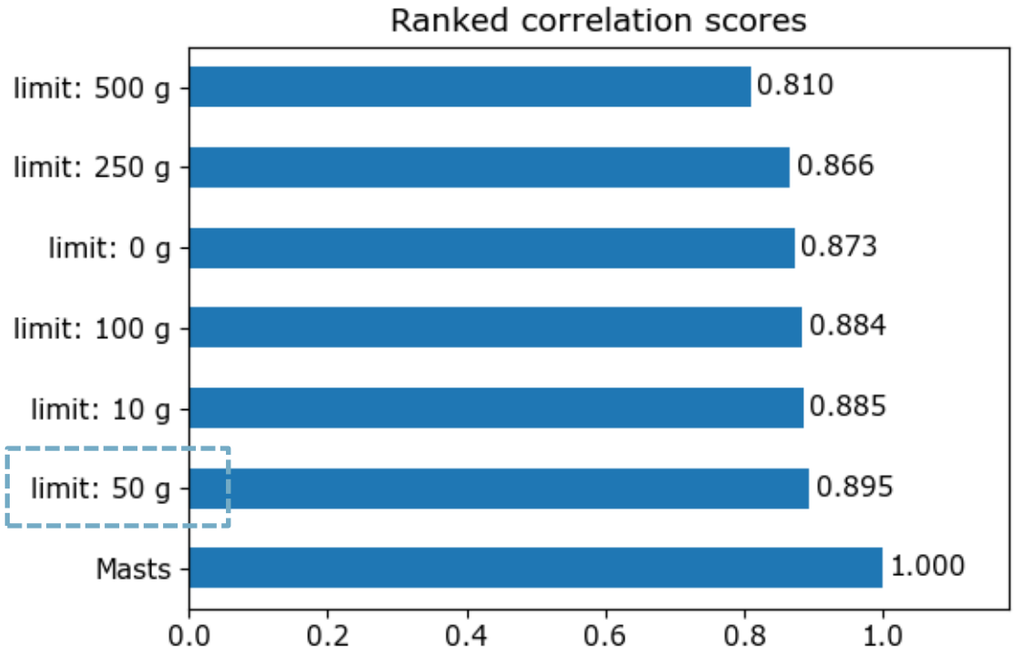


Figure 9: Variation in correlation of the met mast instrumental icing to the modelled instrumental icing for the six thresholds.

Results - Correlation Scores

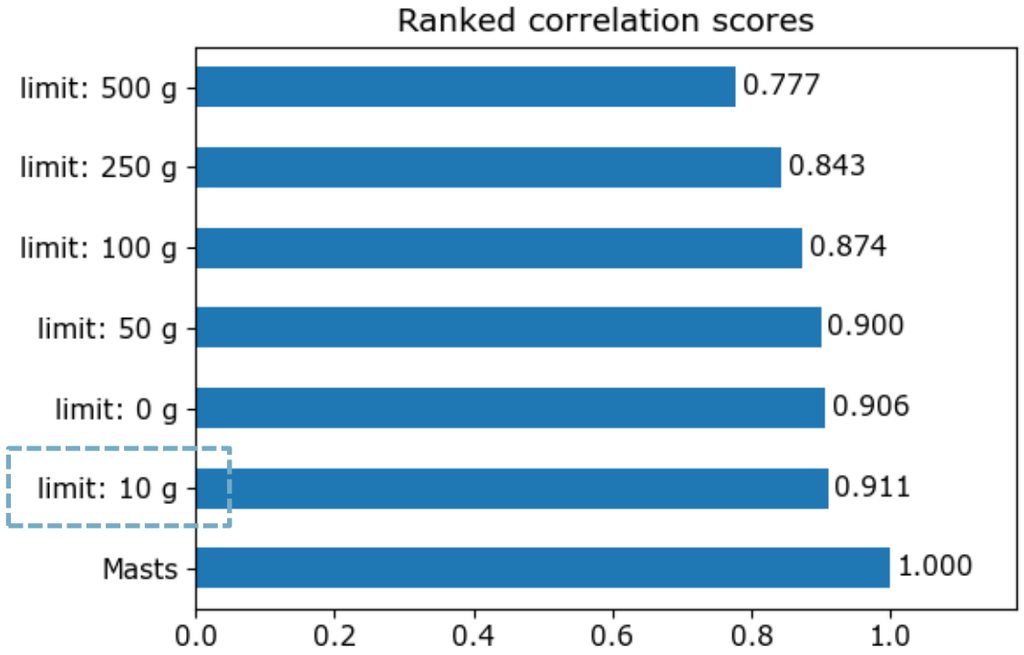
All Masts

- 50 g – best correlation
- Thresholds > 100 g – poor correlation



Sweden only

- 10 g – best correlation
- -



Figures 10-11: Pearson correlation for all masts left and right for Sweden masts only

Summary Question 1+2

- 50 g best general limit for all met masts
- 10 g best limit for Sweden met mast

- EMD-WRF OD ICING modelling chain is capable of modelling seasonal instrumental icing very well

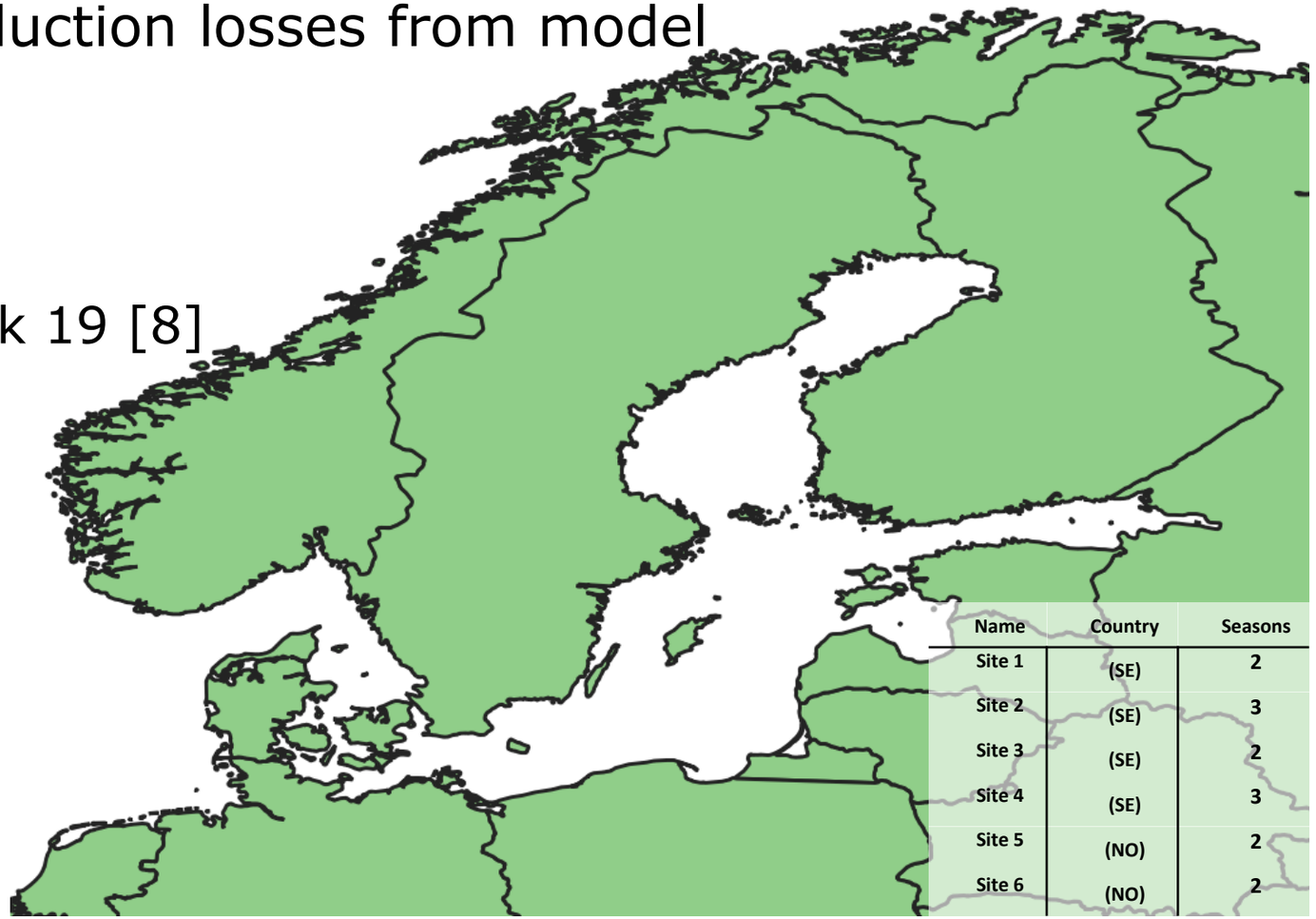
More met masts will continuously be added to the validation framework

- More masts outside Scandinavia
- Masts from the southern hemisphere are in the pipeline

Production losses from the IEA Ice Class system?

Answer: Validate estimated production losses from model

- SCADA from six wind farms
- T19 Ice Loss Method by IEA Task 19 [8]



Name	Country	Seasons
Site 1	(SE)	2
Site 2	(SE)	3
Site 3	(SE)	2
Site 4	(SE)	3
Site 5	(NO)	2
Site 6	(NO)	2

- Comparison of SCADA losses and modelled losses

Figure 12: SCADA data from 6 windfarms: 4 in Sweden and 2 in Norway. Locations are anonymous.

windPRO

Results – SCADA Loss vs Modelled IEA Loss

- Mean seasonal losses due to icing
- IEA loss by instrumental icing overestimates (almost) consistently

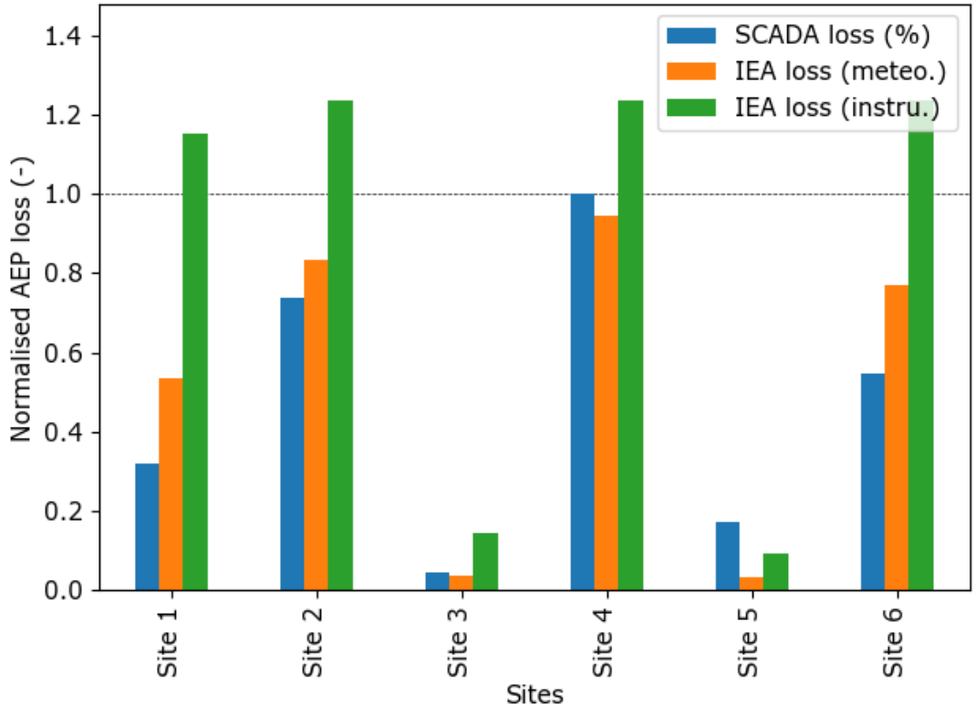


Figure 13: Comparison of SCADA losses and modelled losses for the six sites. The losses have been normalized by Site 4.

Table 1: IEA Ice Classes.

IEA Ice-Class	Meteo. icing (% of year)	Instru. icing (% of year)	Production loss (% of AEP)
5	> 10.0	> 20.0	> 20.0
4	5.0 – 10.0	10.0 – 30.0	10.0 – 25.0
3	3.0 – 5.0	6.0 – 15.0	3.0 – 12.0
2	0.5 – 3.0	1.0 – 9.0	0.5 – 5.0
1	0.0 – 0.5	< 1.5	0.0 – 0.5

Results – SCADA Loss vs IEA Ice Class Loss

- Understand conversion using IEA ice Class Table
- Contradictory results → weak conversion for instrumental icing

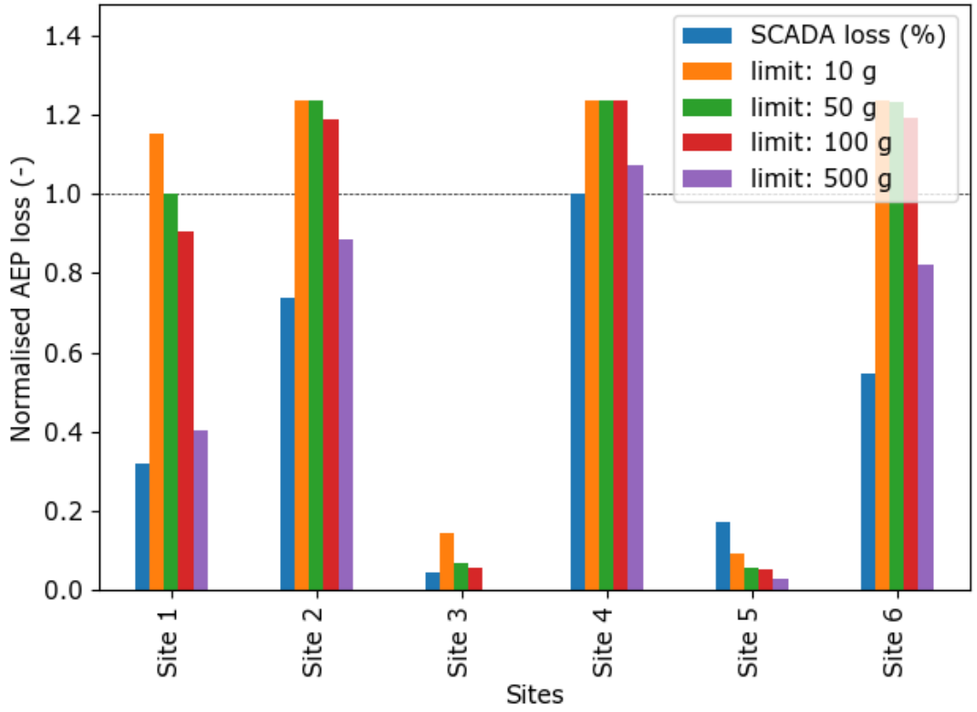


Figure 14: Comparison of SCADA losses and modelled losses varying the threshold.

windPRO

Results – SCADA Loss vs IEA Ice Class Loss

- IEA ice Class Table + instru. icing **too conservative**
- IEA ice Class Table + meteo. icing **good consistency!**

- Question 3: EMD-WRF OD ICING chain and IEA Ice Class system, able to model site production losses (% AEP)

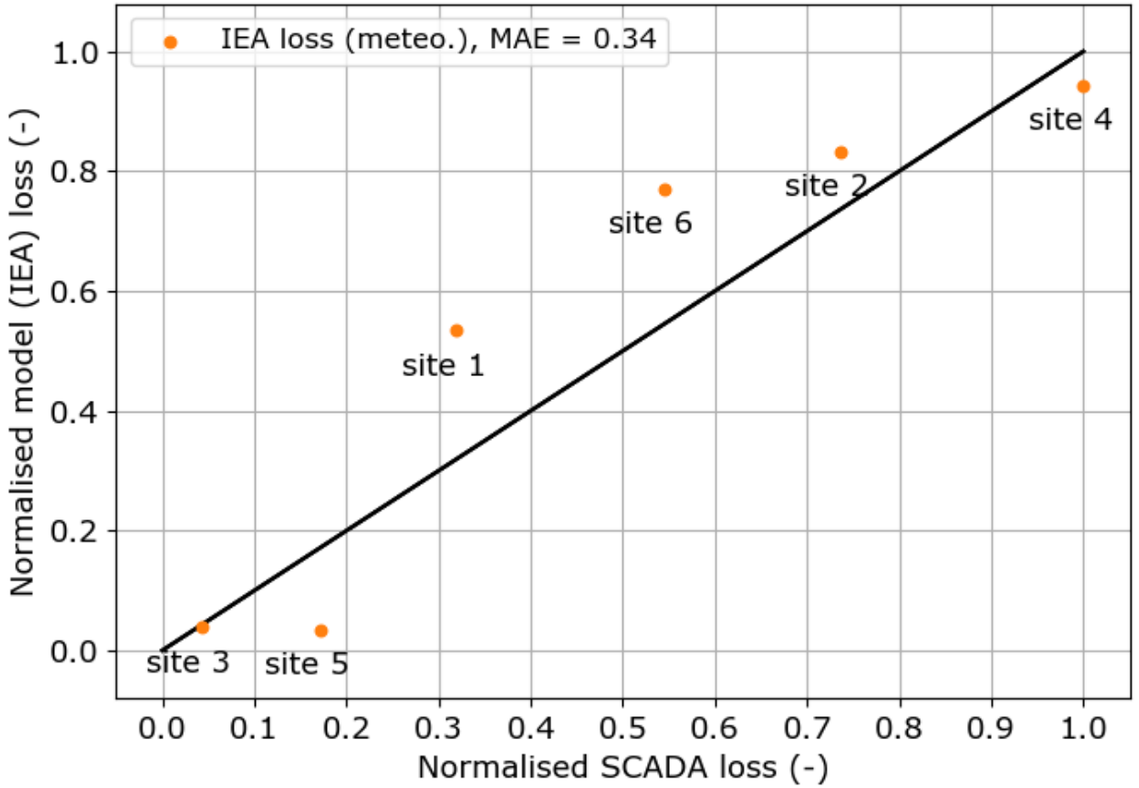


Figure 14: Comparison, 1:1 plot of SCADA losses and modelled losses.

Conclusions

- EMD-WRF OD ICING modelling chain validated:
  - Models icing satisfying
  - Best threshold 50 g/m for all masts used
  - IEA Ice Class system using modelled meteorological icing performs very well!

- We continuously add more met mast data and SCADA data to the validation framework!

References

[1] I. Baring-Gould, R. Cattin, M. Durstewitz, M. Hulkkonen, A. Krenn, T. Laakso, A. Lacroix, E. Peltola, G. Ronsten, L. Tallhaug and W. T., "*13 Wind Energy Projects in Cold Climate,*" IEA Wind, http://ieawind.org, 2011.

[2] https://help.emd.dk/mediawiki/index.php?title=EMD-WRF_On-Demand_ICING

[3] G. Thompson, P. R. Field, R. M. Rasmussen and W. D. Hall, "Explicit Forecasts of Winter Precipitation Using an Improved Bulk Microphysics Scheme. Part II: Implementation of a New Snow Parameterization," American Meteorological Society, vol. 136, no. Monthly Weather review, pp. 5095-5115, 2008.

[4] G. Thompson, B. E. Nygaard, L. Makkonen and S. Dierer, "Using the Weather Research and Forecasting (WRF) model to predict ground/structural icing," in International Workshop on Atmospheric Icing on Structures (IWAIS), 2009.

[5] ISO, "*DS/ISO 12494:2017 Atmospheric icing on structures,*" Danish Standard Association, København, 2017.

[6] L. Makkonen, "*Models for the Growth of Rime Glaze Icicles and Wet Snow on Structures*," Royal Society, vol. 1776, no. Ice and Snow Accretion on Structures, pp. 2913 - 2939, 2000.

[7] K. Hämäläinen and S. Niemelä, "Production of a Numerical Icing Atlas for Finland," Wind Energy, vol. 20, pp. 171-189, 2017.

[8] https://iea-wind.org/task19/t19icelossmethod/

windPRO