Effective validation for time series icing modelling using operational SCADA data

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Forming a collaboration

- **ABO Wind** develops renewable energy projects
- **Vortex** is a specialist in meteorological modelling
- A shared interest in time series icing modelling
- Our different areas of expertise make collaboration interesting

Motivation

For what applications can icing model time series be useful?

- More possibilities and flexibility
- A long-term view
- Impact of ice detection systems
- Impact of ice protection systems
- Ice throw assessment
- Ice load assessment
- Meteorological context for turbine performance assessment

Validation methodology

What metrics are useful for measuring model performance?

- Synchrony
- Amplitude
- Event cycle
- Variability
- Long-term icing class

Overview of the validation configuration

- Using SCADA data
- Central Europe and the Nordic region
- Projects with and without operational restrictions related to ice throw risk
- IEA Ice Classes 2 and 3
- Initially focus on ice accretion
- Simplified consideration of ice ablation
- Modelling and validation on a wind farm level
- **Validation as a tool to advance modelling**

Overview of the model

- The model uses WRF driven by ERA5 Reanalysis
- No on-site measurement data is needed as input
- In-cloud icing using the Thompson microphysics scheme
- Ice accretion using the Makkonen model

Test Case A – overview

- Central Europe
- High elevation, forested and complex terrain
- Public safety restrictions
- Rotor blade ice detection
- Automatic restart
- Temperature frequently around 0 ° C in winter
- Ice removal dominated by melting

Test Case A – contingency table statistics

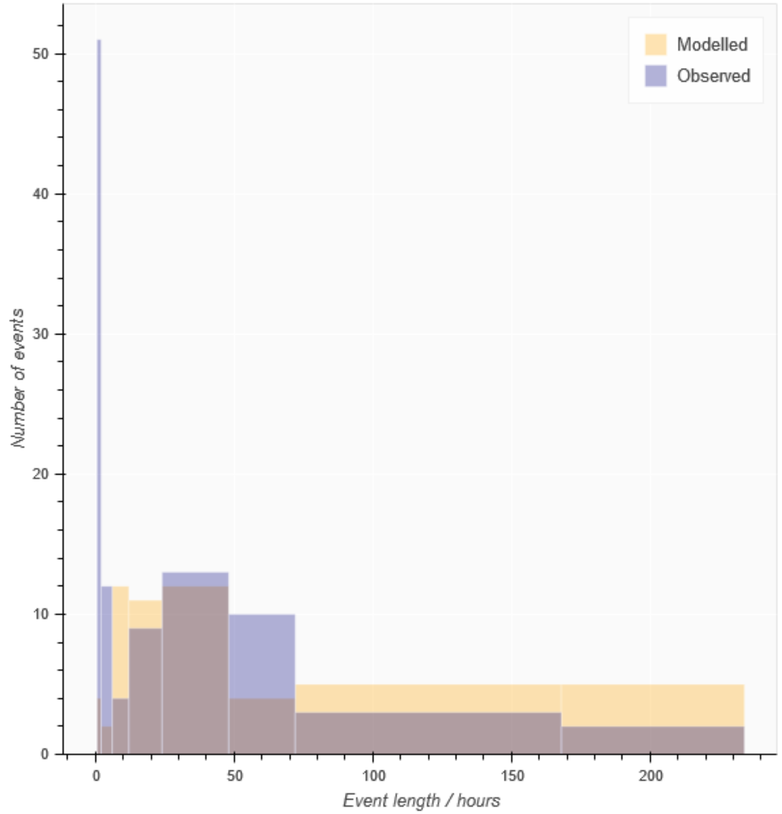
- Dichotomous (ice or no ice) prediction considering October to April for two years

		Observed		Total
		Ice	No ice	
Modelled	Ice	16%	9%	25%
	No ice	4%	71%	75%
Total		20%	80%	100%

- 80% hit rate
- +26% bias
- 87% accuracy
- 36% false alarm ratio

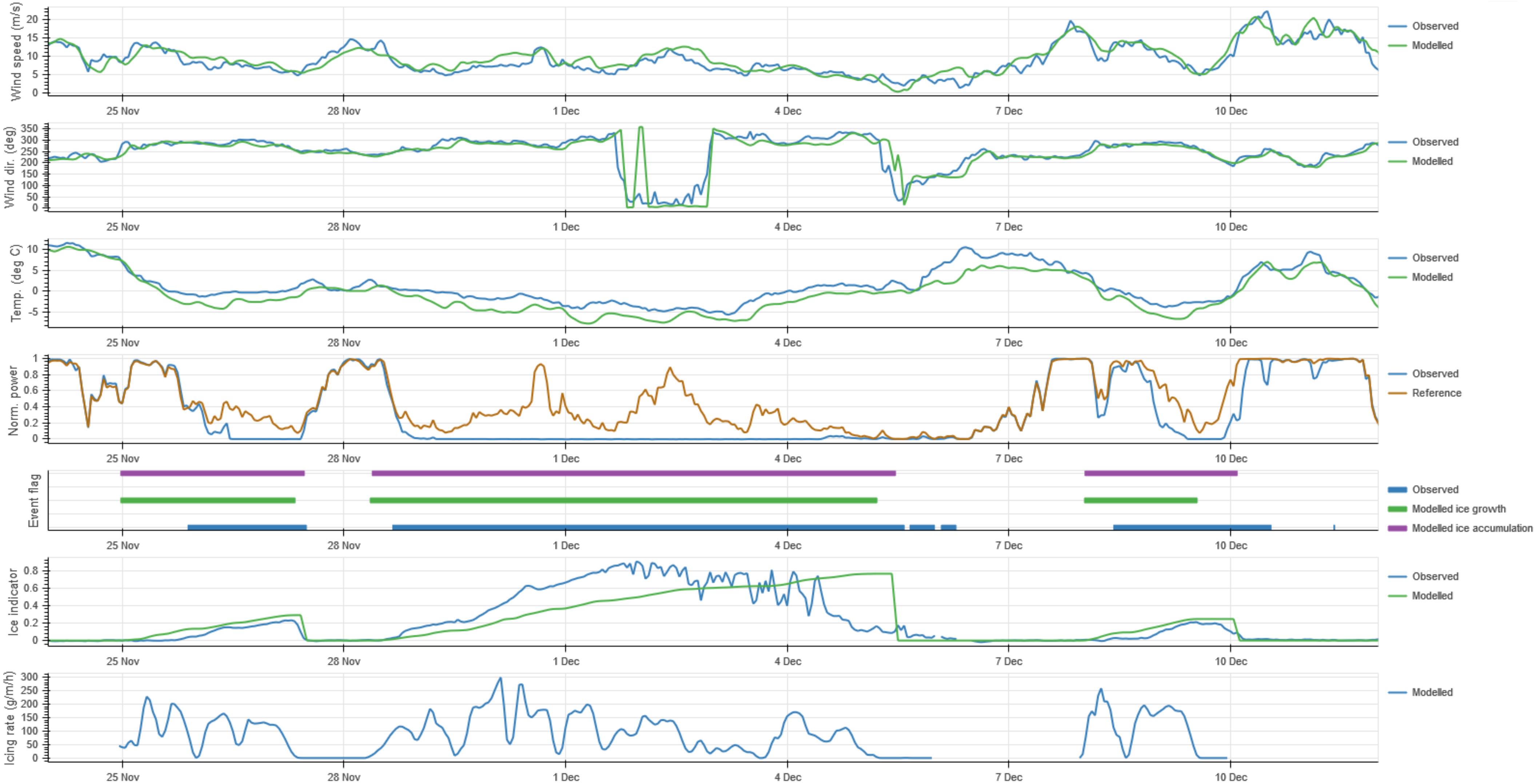
Test Case A – event length statistics

- More short events observed
- Short events challenging to capture with model
- The model predicts longer events
- Event distinction sometimes ambiguous



	Observed events	Modelled events	Hit rate	Bias
Total	104	55	80%	+26%
Below 6 h	63	8	1.4%	-71%
Above 6 h	41	47	82%	+30%
Above 24 h	28	25	82%	+27%

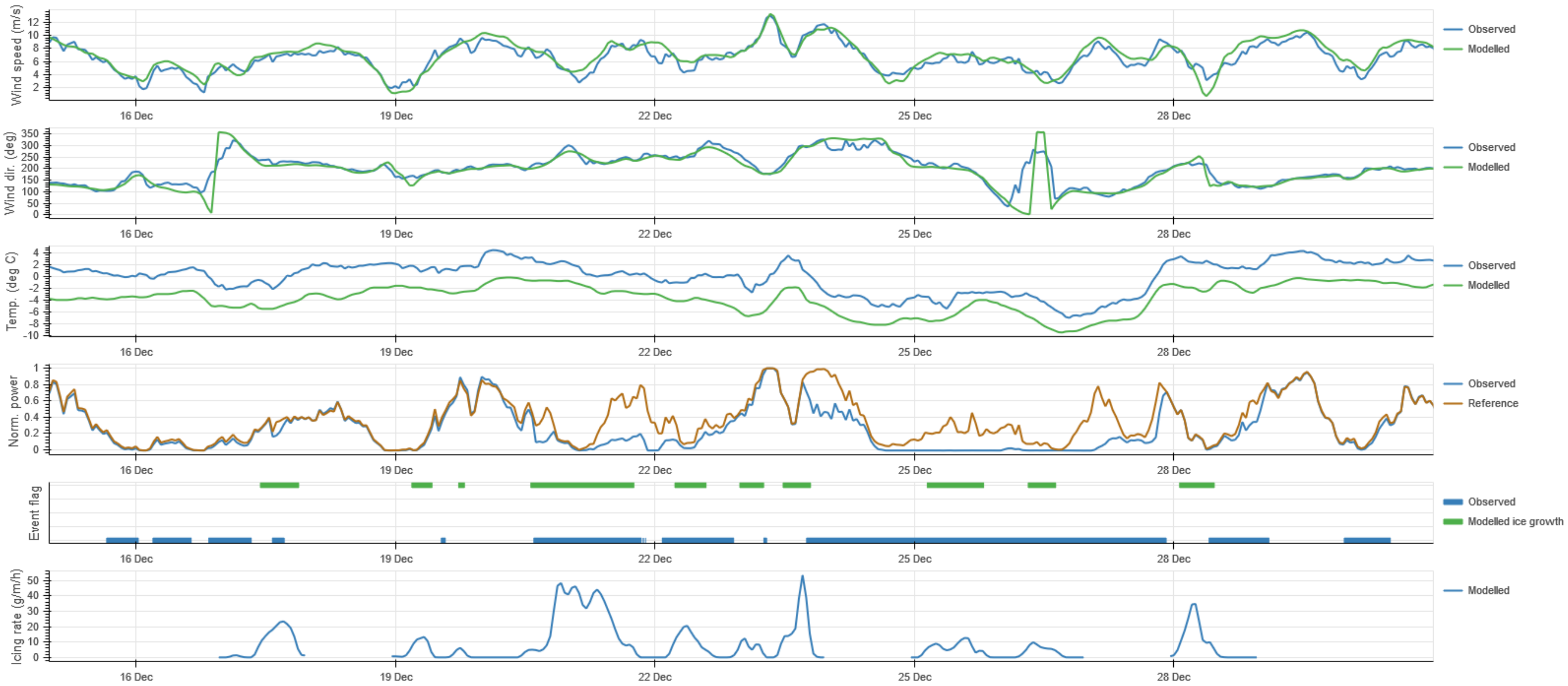
Test Case A – example time series



Test Case B – overview

- Nordic region
- Forested and simple terrain
- No operational restrictions related to ice throw
- No dedicated ice detection sensors
- Icing assessed using T19IceLossMethod
- Temperatures often below 0 ° C for long periods in winter
- Sublimation and wind erosion important for removal in addition to melting
- Aim was to capture start of icing events

Test Case B – example time series



Test Case B – findings

- Challenging interpretation
- Ambiguous event distinction
- Impact on turbines depends on wind speed
- Turbines susceptible during start-up
- Sublimation and wind erosion important
- Detailed assessment of operational characteristics needed
- Model results appear largely plausible from qualitative evaluation
- Some periods fit well, others less well

Test Case C – summary

- Central Europe
- Similar to Test Case A, but much less icing conditions
- During two winters, only one severe event of long duration
- Model captures this, but estimates much more icing
- Possibly due to cold bias in model
- Preliminary and under further investigation

Conclusions and future outlook

- Encouraging start
- Detailed time series assessment give useful insights
- Different challenges for different types of sites
- Extend and refine validation framework based on initial findings
- Full modelling of ice ablation for colder sites
- Include turbine performance modelling and analysis
- Apply performance metrics on larger datasets to evaluate uncertainty drivers

Thank you for your interest – any questions?

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