Winterwind
INTERNATIONAL WIND ENERGY CONFERENCE
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Part of Norconsult

Validation of day-ahead icing loss forecasts with SCADA data

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Increasing need for day-ahead icing forecasts

- The share of wind farms in electricity markets is increasing
  - ➢ The impacts of wind power on electricity prices and system dynamics is growing
- In the Nordics, icing losses are the second highest source of losses after wake losses
- Bigger turbines → More in-cloud icing in winter
- Capability to model icing loss for the next day, especially stops, would be crucial for the producer

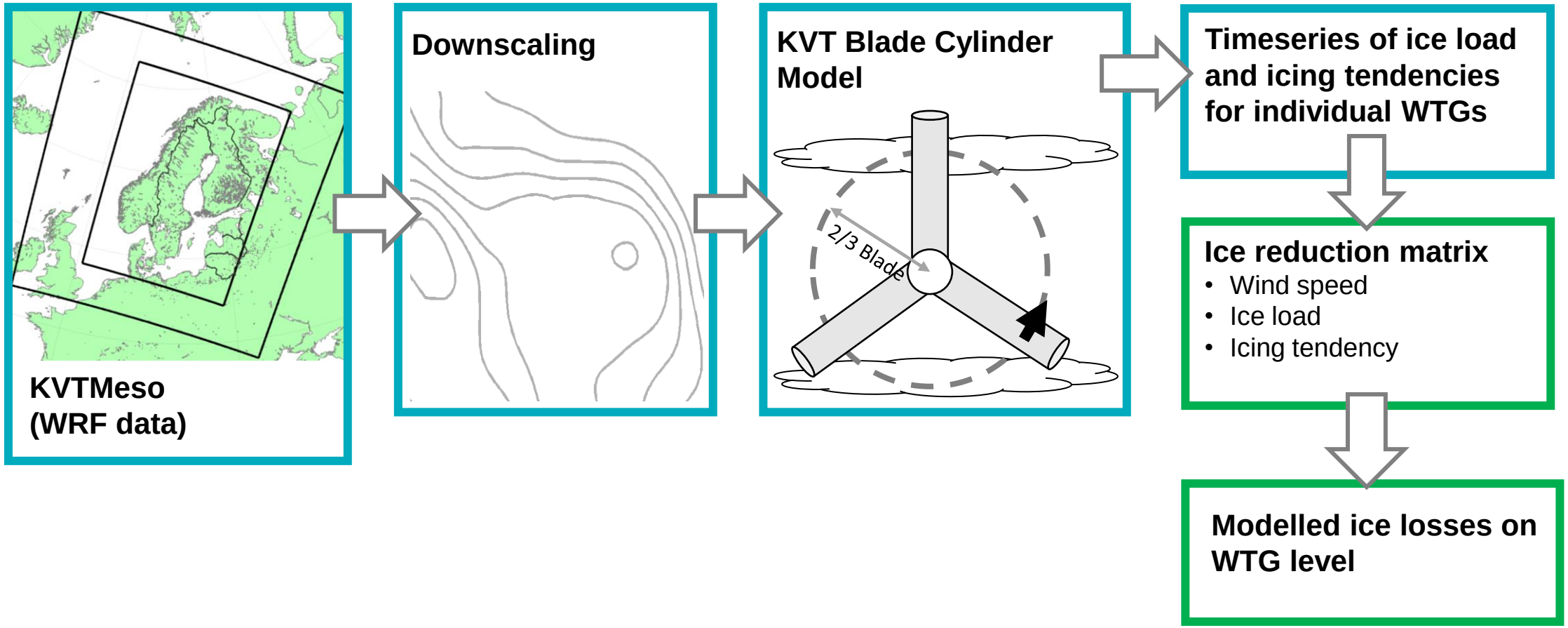
  - ➢ Day-ahead icing forecasts needed for electricity marketing pricing

Operational IceLossForecast 1.0 is being developed from the original IceLoss 2

- IceLoss 2.1 by Kjeller Vindteknikk
  - In-house model developed for years
  - Based on mesoscale weather model WRF combined with in-house post-processing scripts
  - Used extensively in the Nordics to assess the long-term average icing losses in pre-construction phase

- Operational IceLoss 2 for short-term forecasts (0-72 h) currently running as a prototype (IceLossForecast 1.0)
  - Preliminary probabilistic forecasts also included
  - Further development ongoing

The IceLoss 2.1 model chain



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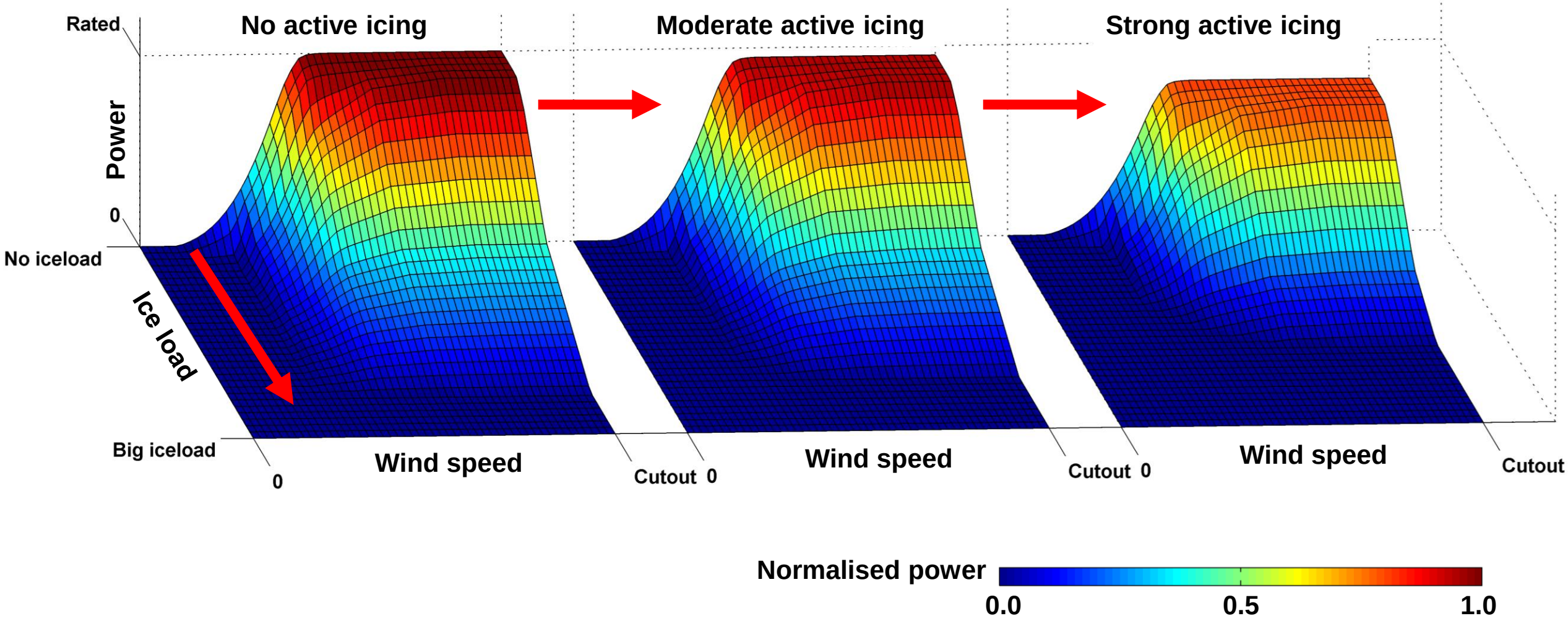

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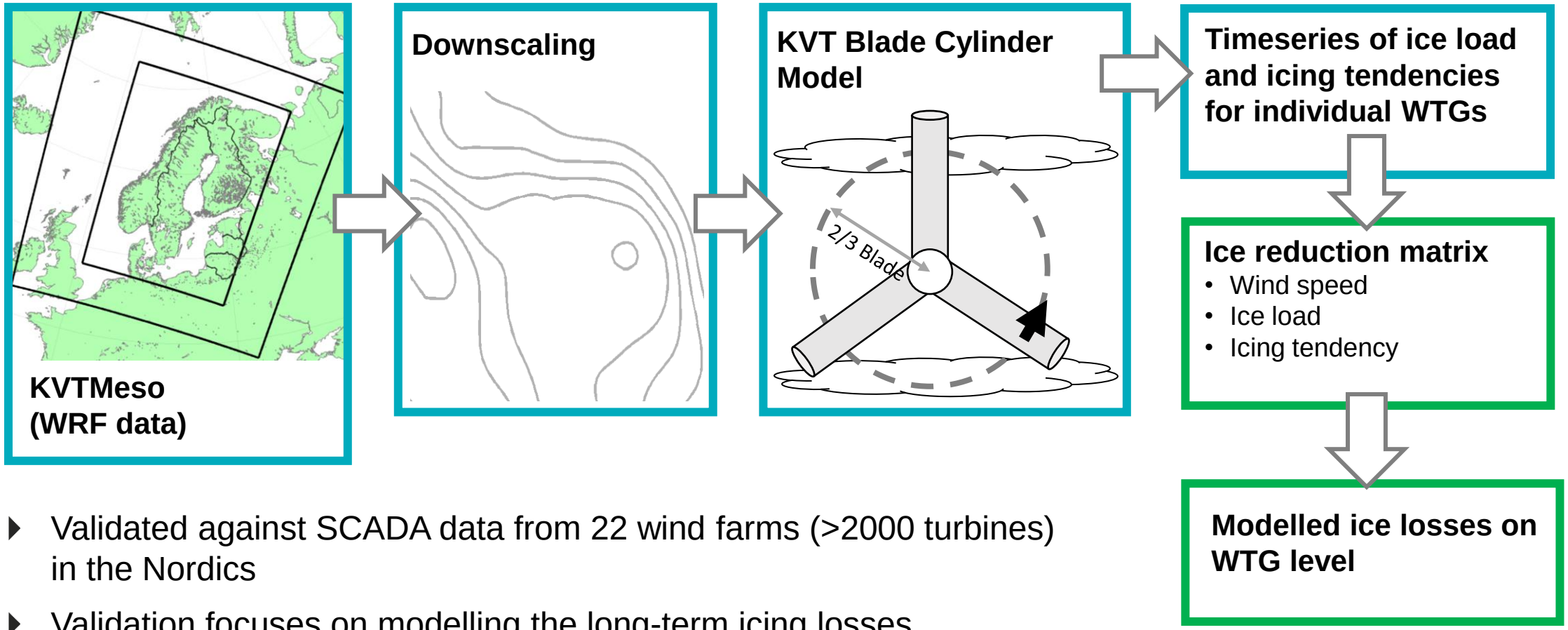

- Validated against SCADA data from 22 wind farms (>2000 turbines) in the Nordics
- Validation focuses on modelling the long-term icing losses

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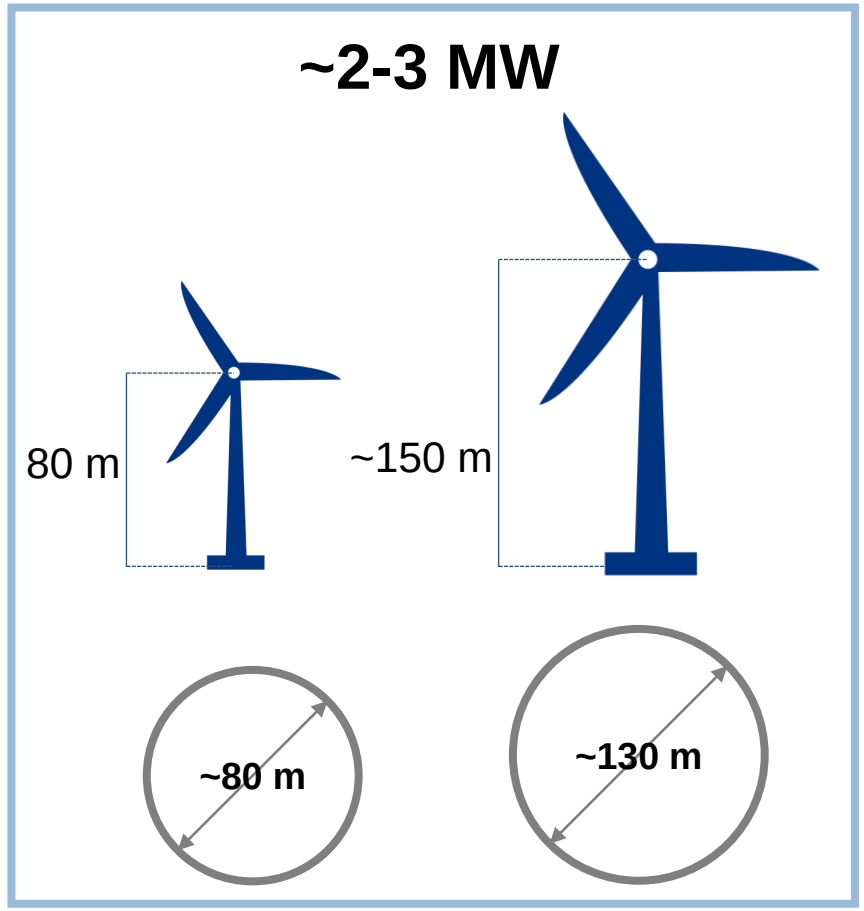
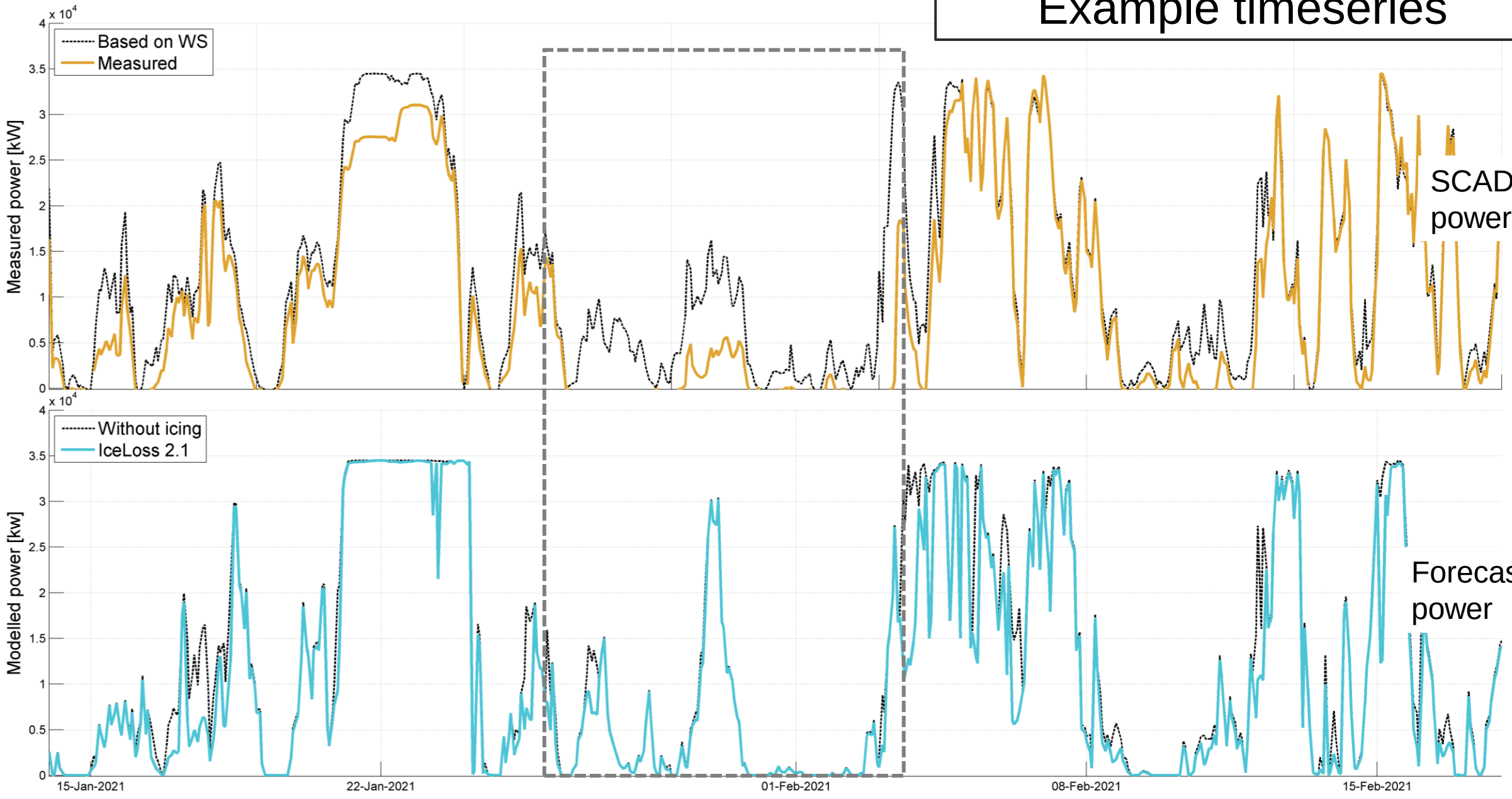
IceLossForecast 1.0 running at four wind farms in Finland

- Four WFs close to the northern shores of the Gulf of Bothnia
- ~10 turbines per WF
- Ground elevation <120 m ASL, internal variation <12 m
- No ice protection system

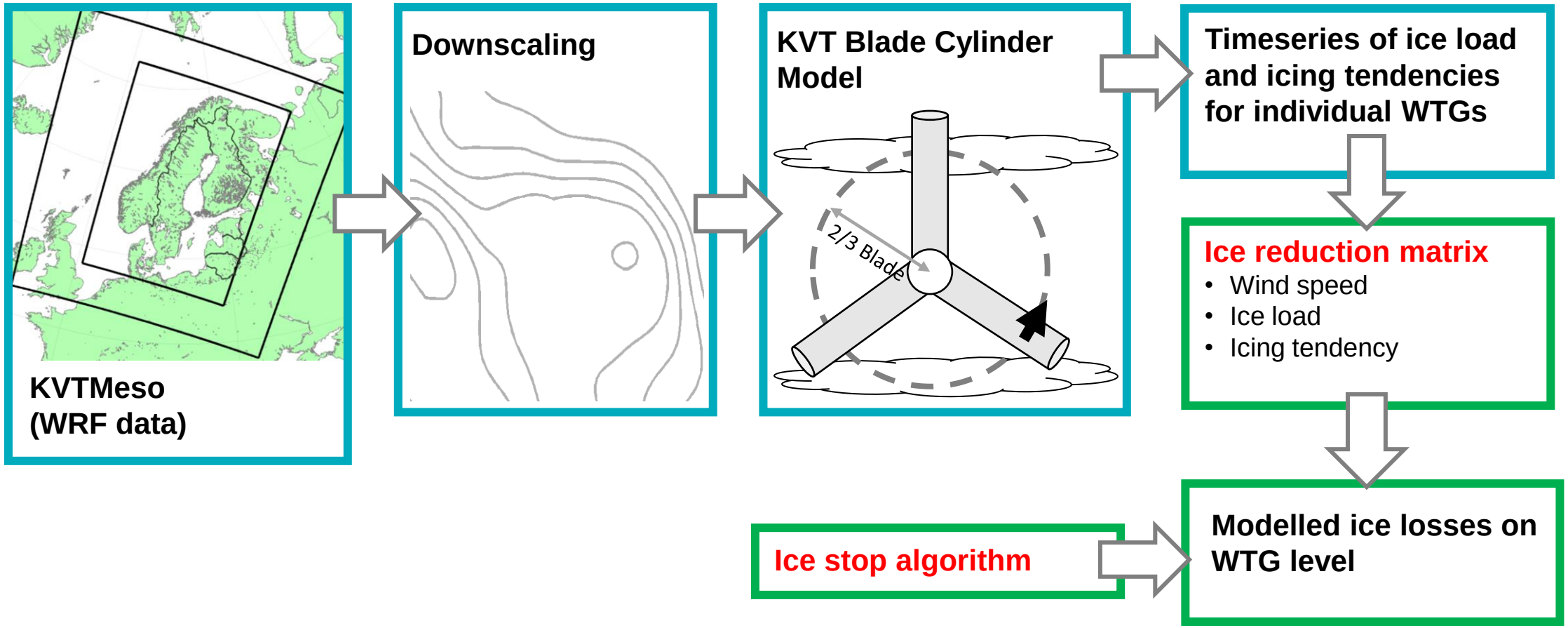
- Forecasts ongoing since 11/2019
- The client especially interested in day-ahead forecasts for <u>stops due to icing</u>



Example timeseries



The IceLoss 2.1 model chain



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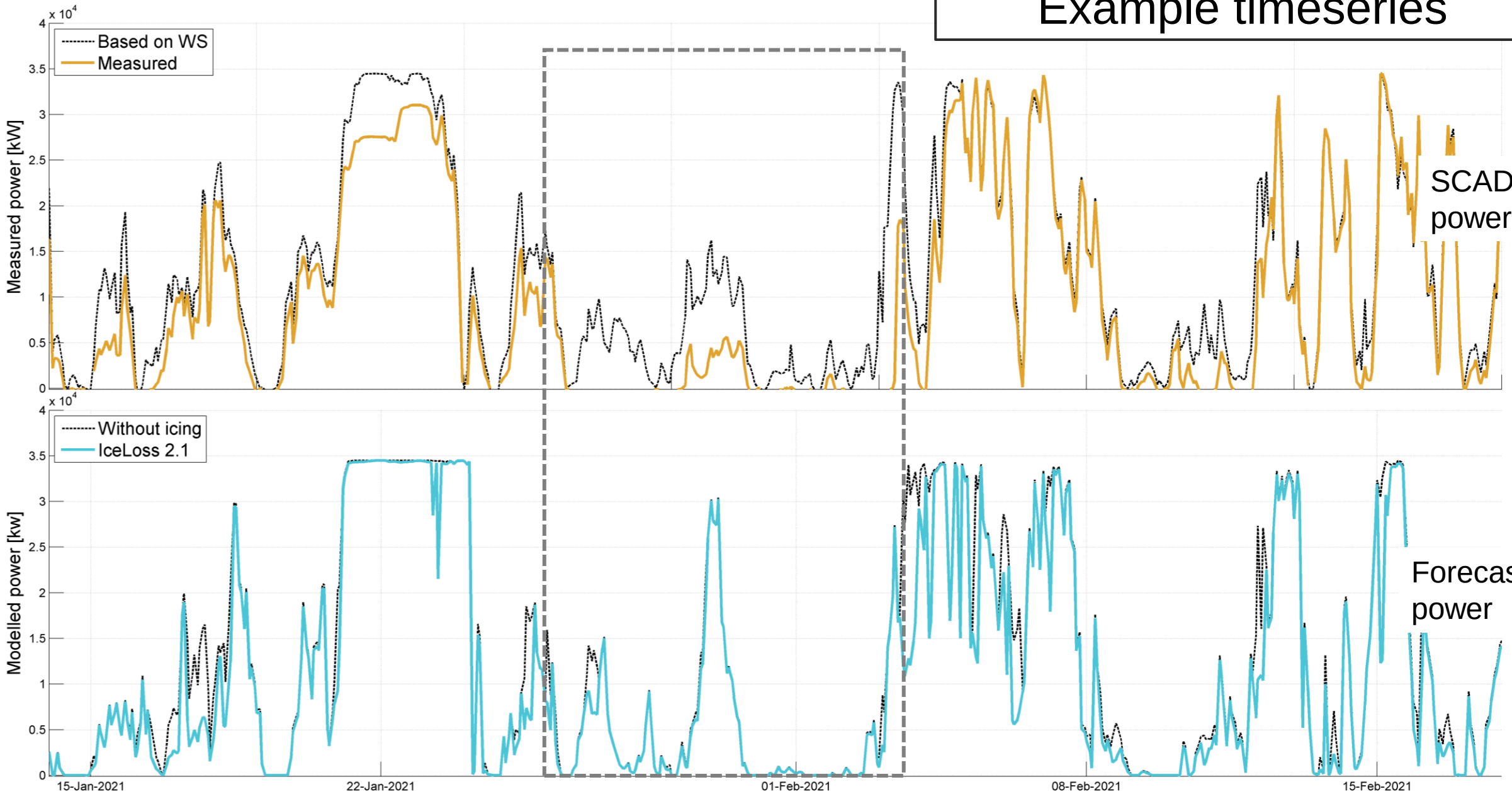
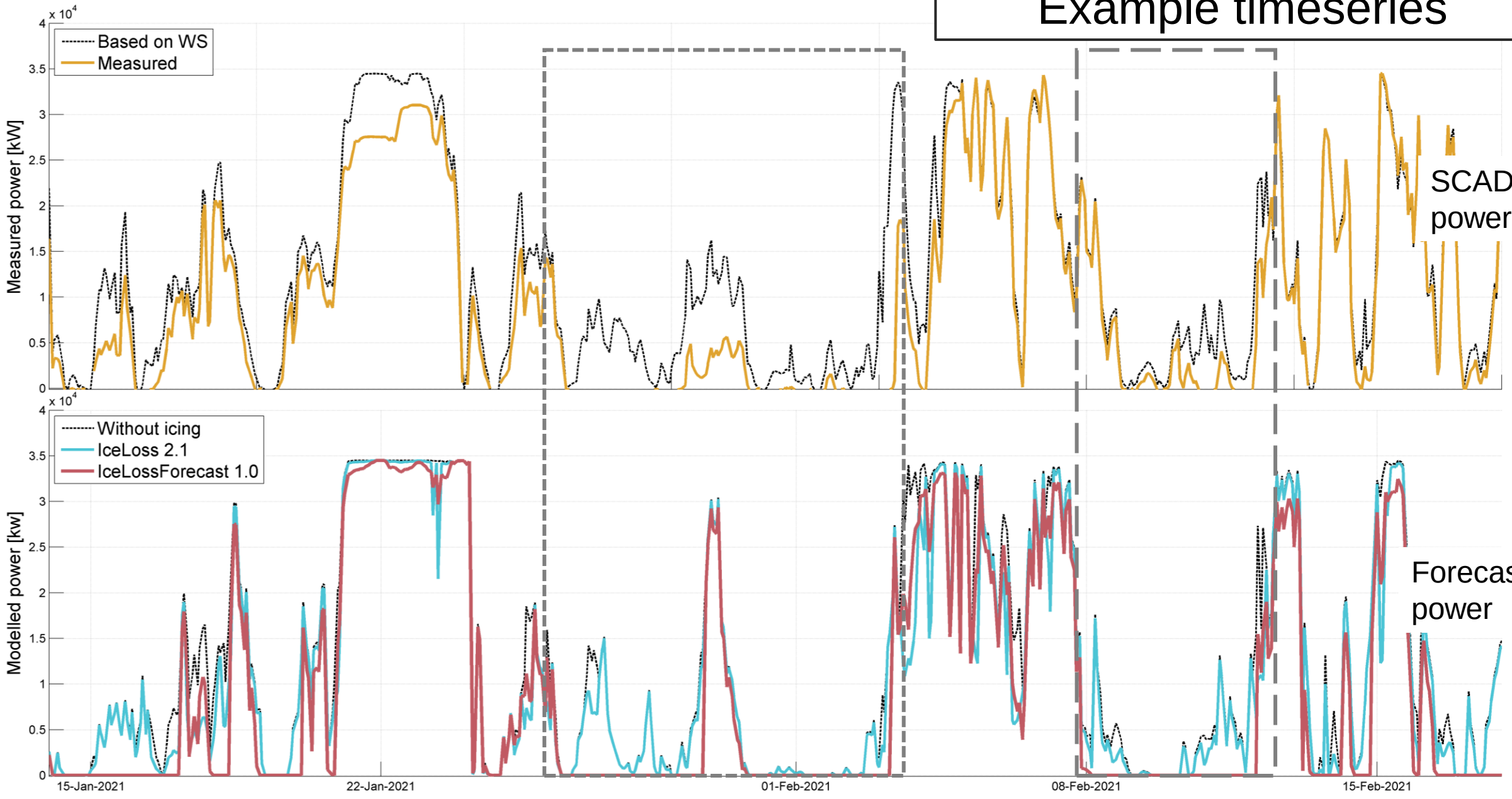
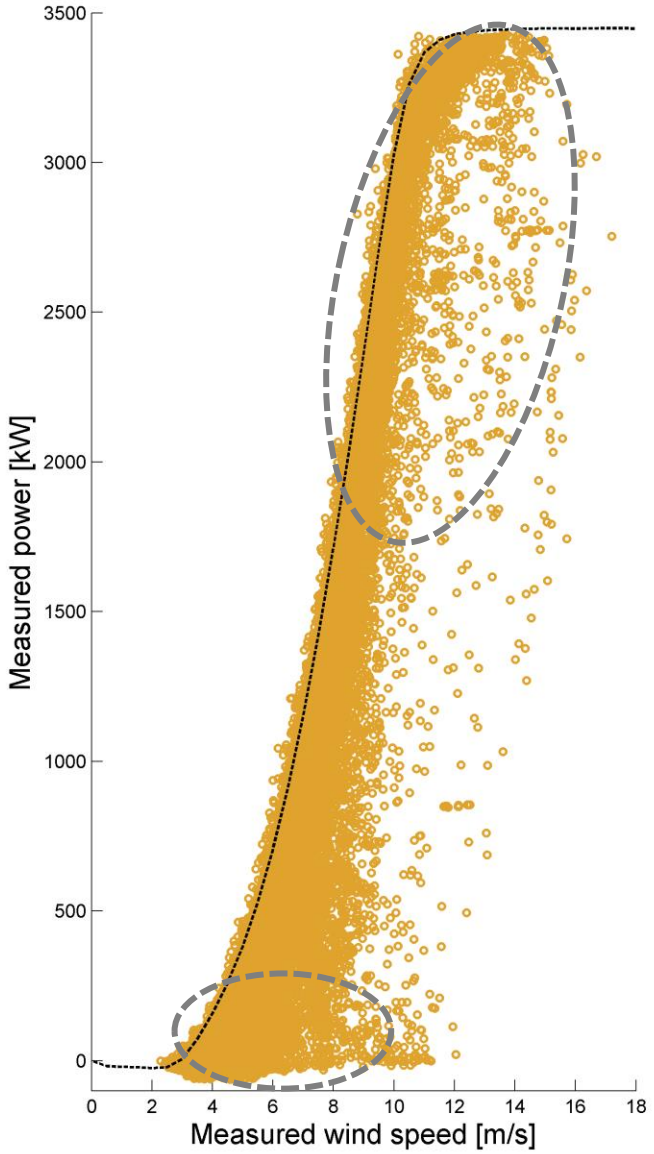
Example timeseries



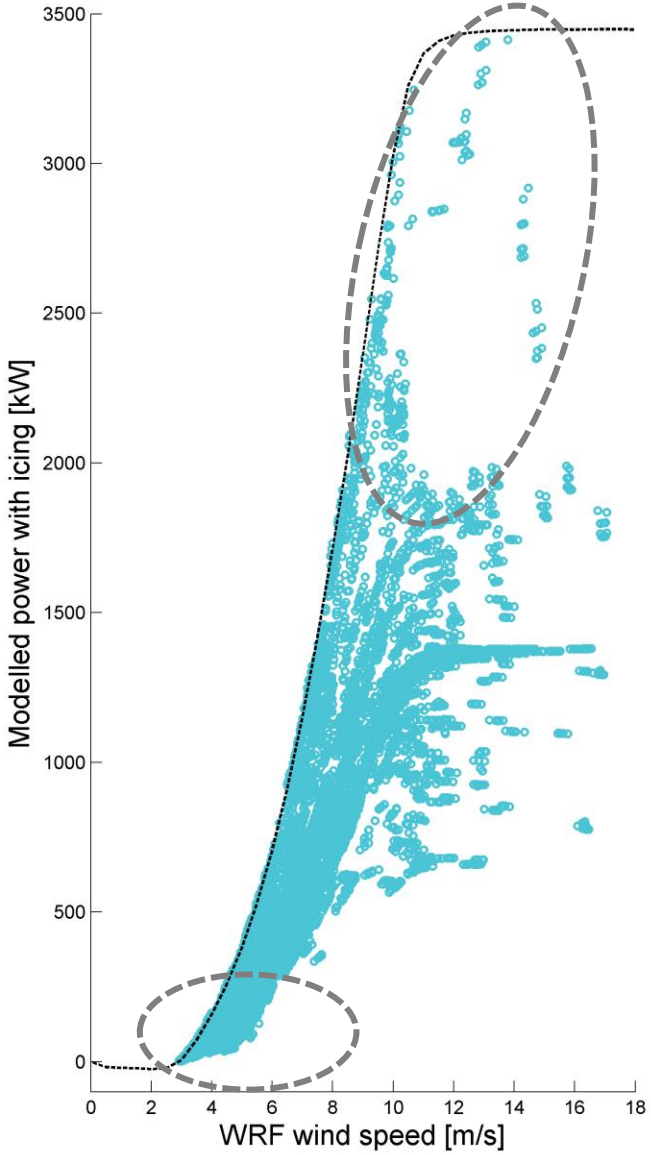
Example timeseries



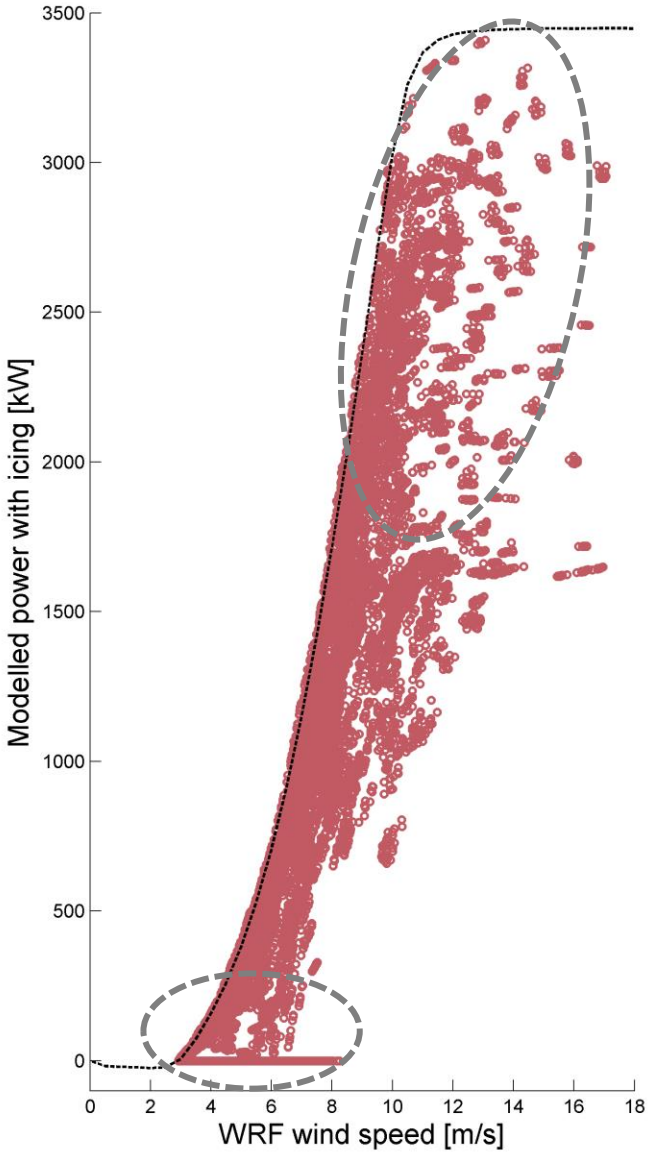
SCADA



Original



IceLossForecast 1.0



Hit rate for stops improved, but false alarms increase

	Stops due to icing		Total loss due icing	
Site	Hit rate	False alarm rate	Measured	Modelled
WF1	0% → 41.0%	0% → 4.1%	3.0%	3.6% → 4.2%
WF2	0% → 22.9%	0% → 2.2%	1.8%	1.9% → 2.0%
WF3	0% → 30.2%	0% → 2.7%	1.5%	1.0% → 1.8%
WF4	0% → 31.7%	0% → 3.1%	3.6%	2.6% → 3.4%

Improved
Worsened

		Observation	
		Stop	No stop
Model	Stop	a	b
	No stop	c	d

- Hit rate: a/(a+c)
- False alarm rate: b/(b+d)

Some observations and ideas for improvement

- Choose the correct metrics / cost functions in model optimization
  - MAE of total loss **vs.** hit rate for stops
- Parametrisations for long-term icing losses ≠ parametrisations for short-term icing losses
  - Especially stops
- Incorporating SCADA data to the modelling to improve timing issues
- Machine learning based model:
  Option for a physical model?
  - Using WRF output as the model input

Summary

- Day-ahead icing forecasts are crucial for electricity marketing pricing
- A prototype of an operational icing forecast model (IceLossForecast 1.0) is currently running at 4 wind farms in Finland
- Further development is ongoing
  - Tuning the IceLoss model parametrisations (ice reduction matrix)
  - Introducing a separate algorithm for stops
    - Found to improve the forecast already significantly
  - Incorporating real-time SCADA data in modelling → IceLossForecast 2.0

Thank you!

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