Validation of and findings from the IceLoss 2.0-project

Johannes Lindvall, Leon Lee, Øyvind Byrkjedal

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Validation of and findings from the IceLoss ~~2.0~~ 1.9-project

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The IceLoss 2.0 project

- **Overall goal:** To increase the knowledge of production losses due to icing and to develop a next generation IceLoss model that will provide wind power project stakeholders with better estimates of the production losses due to icing on the turbine blades
- Three working packages

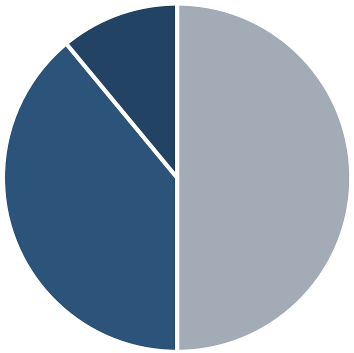
WP1: Icing climatology
Increase knowledge of icing conditions internally in wind farms

WP2: Ice accretion modeling
Improve calculation of ice build-up on turbine blades

NEXT TALK

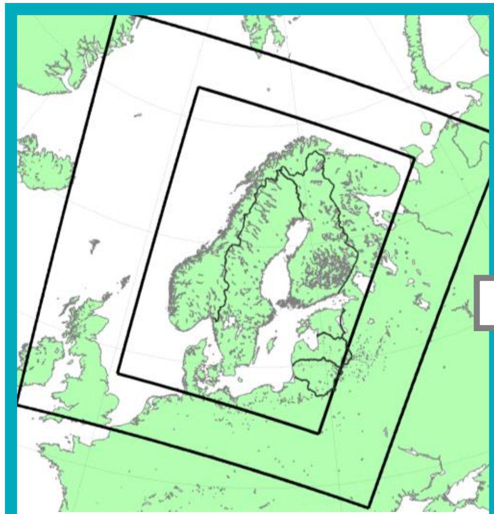
WP3: Next generation IceLoss
Integrate the results of WP1 and WP2 to the framework of the IceLoss model

- January 2018 – March 2020
- Total budget: 2.6 MSEK



- Swedish Energy Agency
- Kjeller
- Park owners

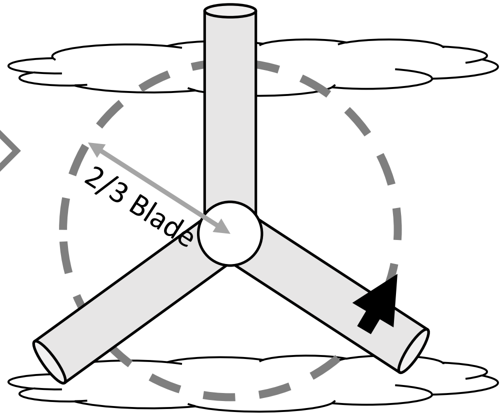
The IceLoss 2.0 development/model chain



KVT_NSF 3km dataset (ERA 5)

Downscaling

KVT Blade Cylinder Model



Timeseries of ice load and icing tendencies for individual WTGs

Ice reduction matrix
- Wind speed
- Ice load
- Icing tendency

Modelled ice losses on WTG level

SCADA database

Ice filtering following IEA-task 19 method

Observed Ice losses from SCADA

The IceLoss 2.0 development/model chain

KVT_NSF 3km dataset (ERA 5)

Downscaling

- Wind to 1 km resolution and adjusted for wakes
- Lifting of cloud variables to turbine elevation
- Cloud condensate sheltering effect

KVT Blade Cylinder Model

- Following Davis et al. (2014), Makkonen model is modified to mimic rotating turbine.
- Ice accretion/ablation caluclated at different heights of rotor swept area
- Turbine specific RPM-curves to determine relative air speed4

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IceLoss 2.0 SCADA ice loss database

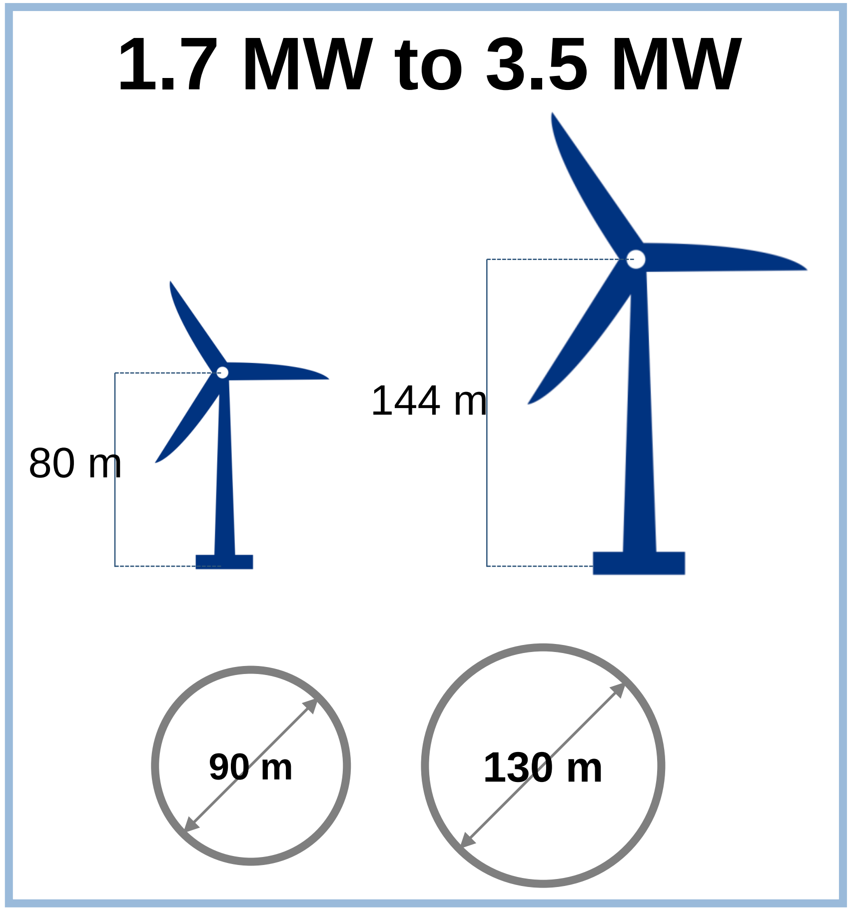
**24 Windfarms**
400 WTGs
2000 WTG years

Turbines from 4 OEMs

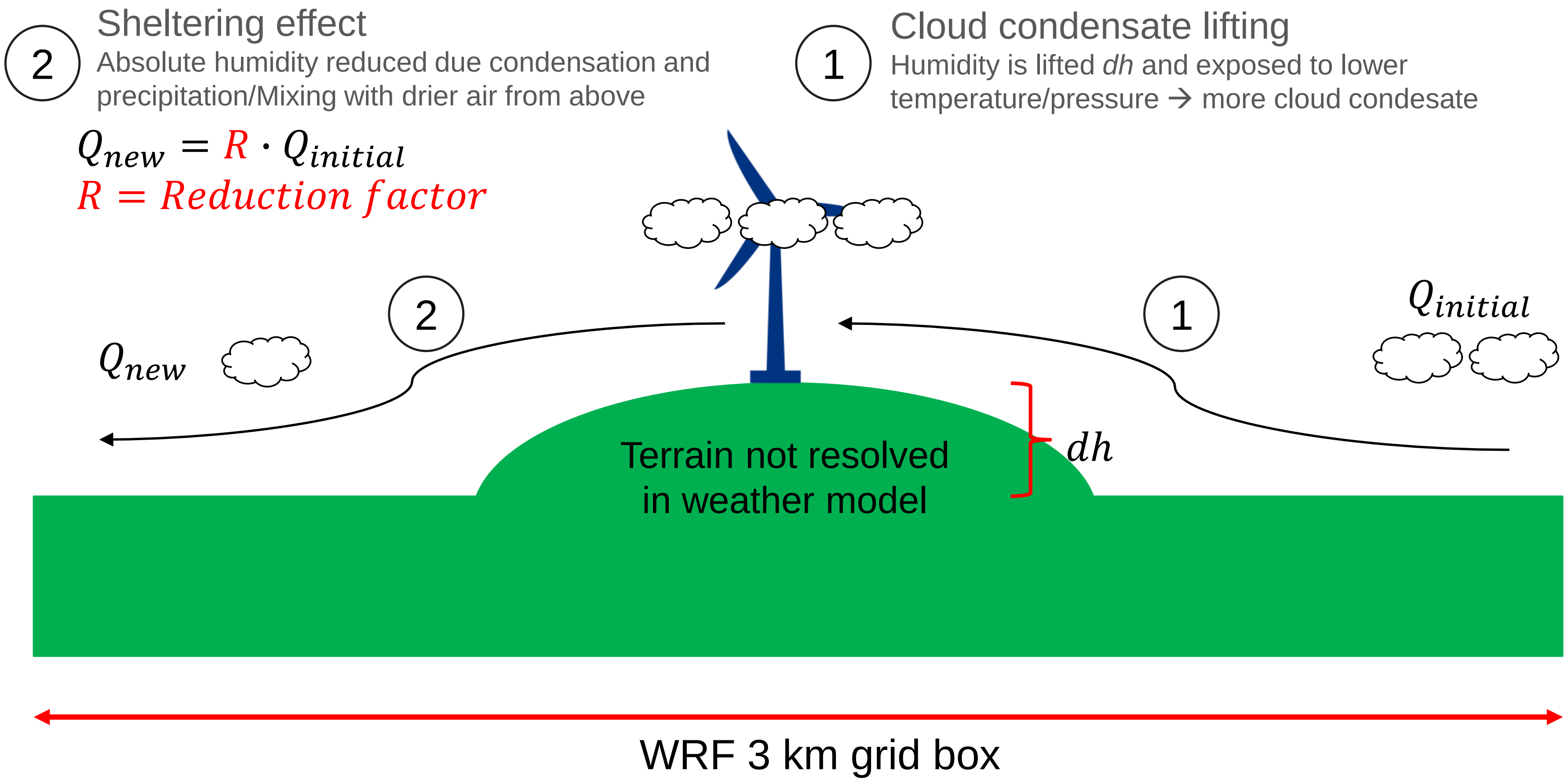
Sweden, Finland, Norway

No ice protection systems

Wind farms	Min	Median	Max
Elevation	0	250	600
Period analyzed [years]	1	4	8
# WTGs	1	17	>30
Historical annual ice hours	<200	600	>1400
Historical Ice loss [%]	< 1	3	> 10



Cloud condensate lifting and sheltering effect



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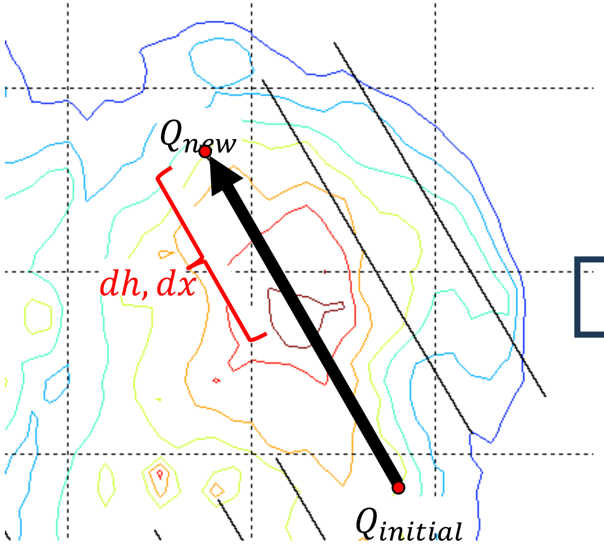
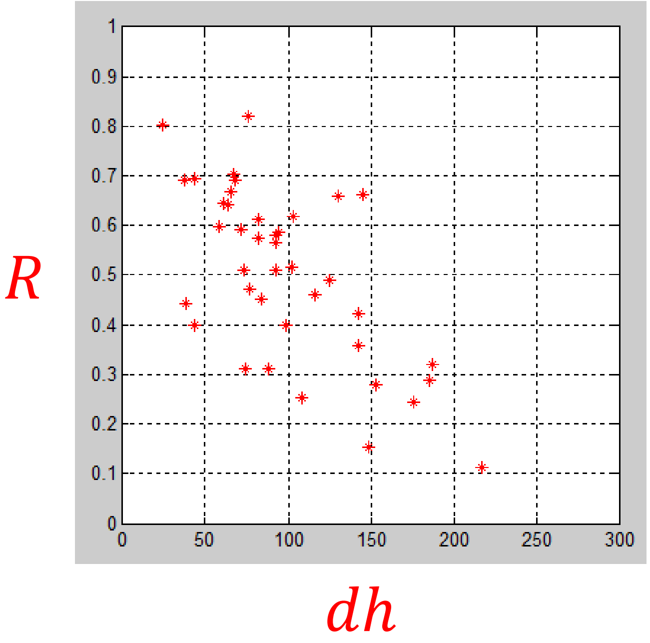
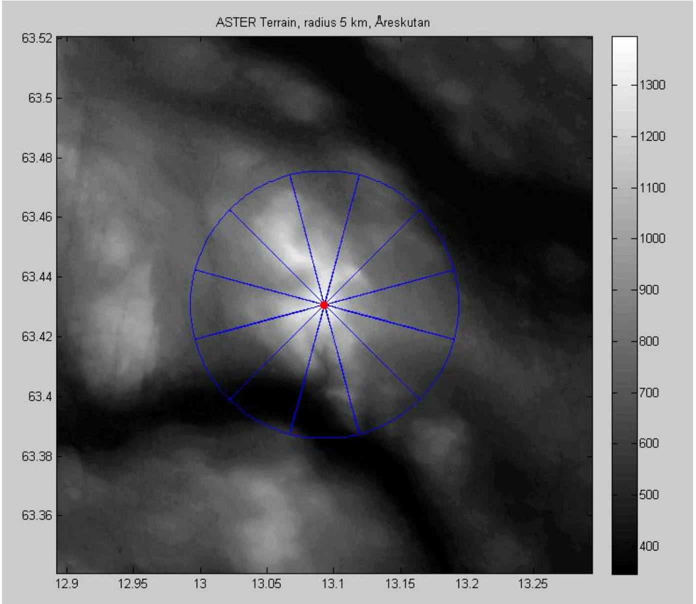
Cloud condensate sheltering effect







- Quantify cloud water reduction with hi-res WRF simulations (333 m).
- Multiple transect on different locations.

- A cloud water reduction function is made to correct for sheltering effect not resolved in the main weather model

- Cloud reduction factors for each WTG derived from WTG position and high-res topography data

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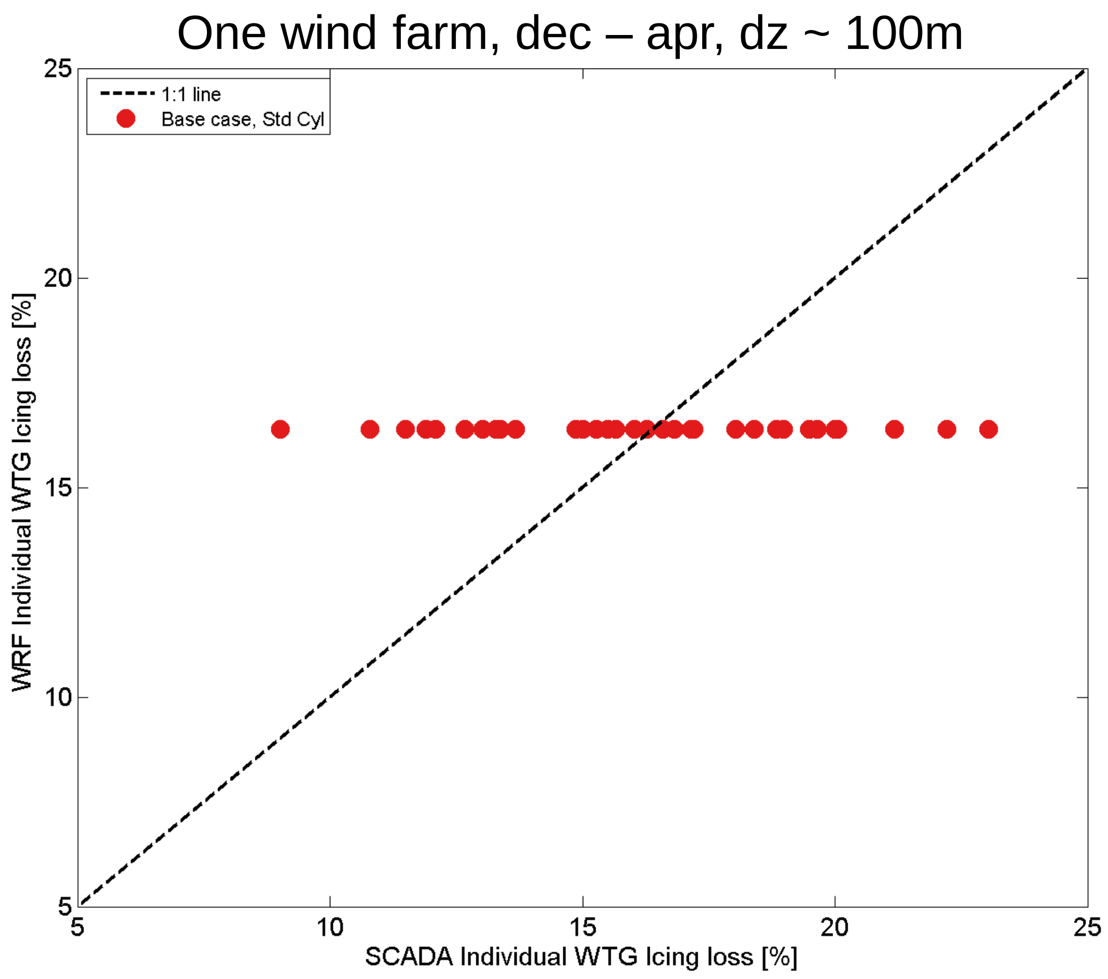
Wind farm internal variability of ice losses



BIAS CORRECTED METRICS

	Intern. std [%]	r	RMSE
SCADA, 16.4 % loss	3.51		
Base case, Standard Cyl.			3.48

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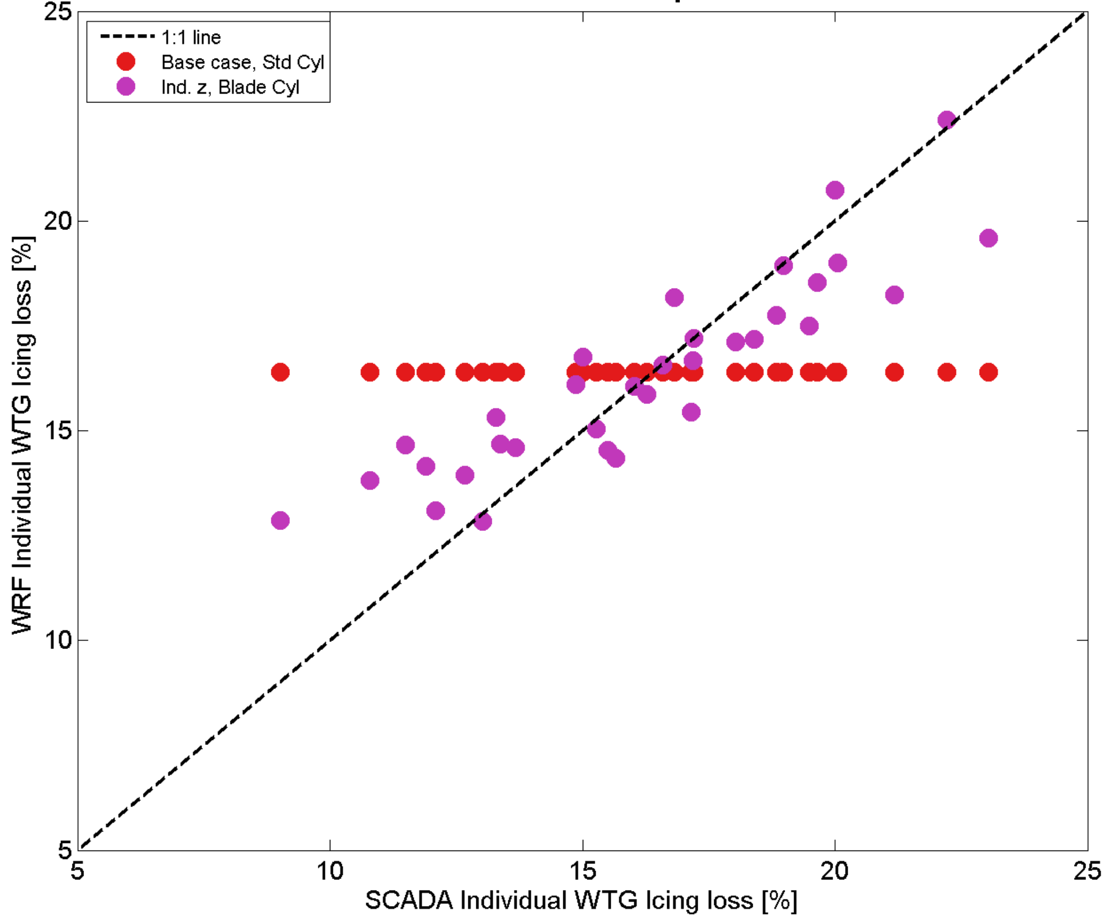
Wind farm internal variability of ice losses

One wind farm, dec – apr, dz ~ 100m



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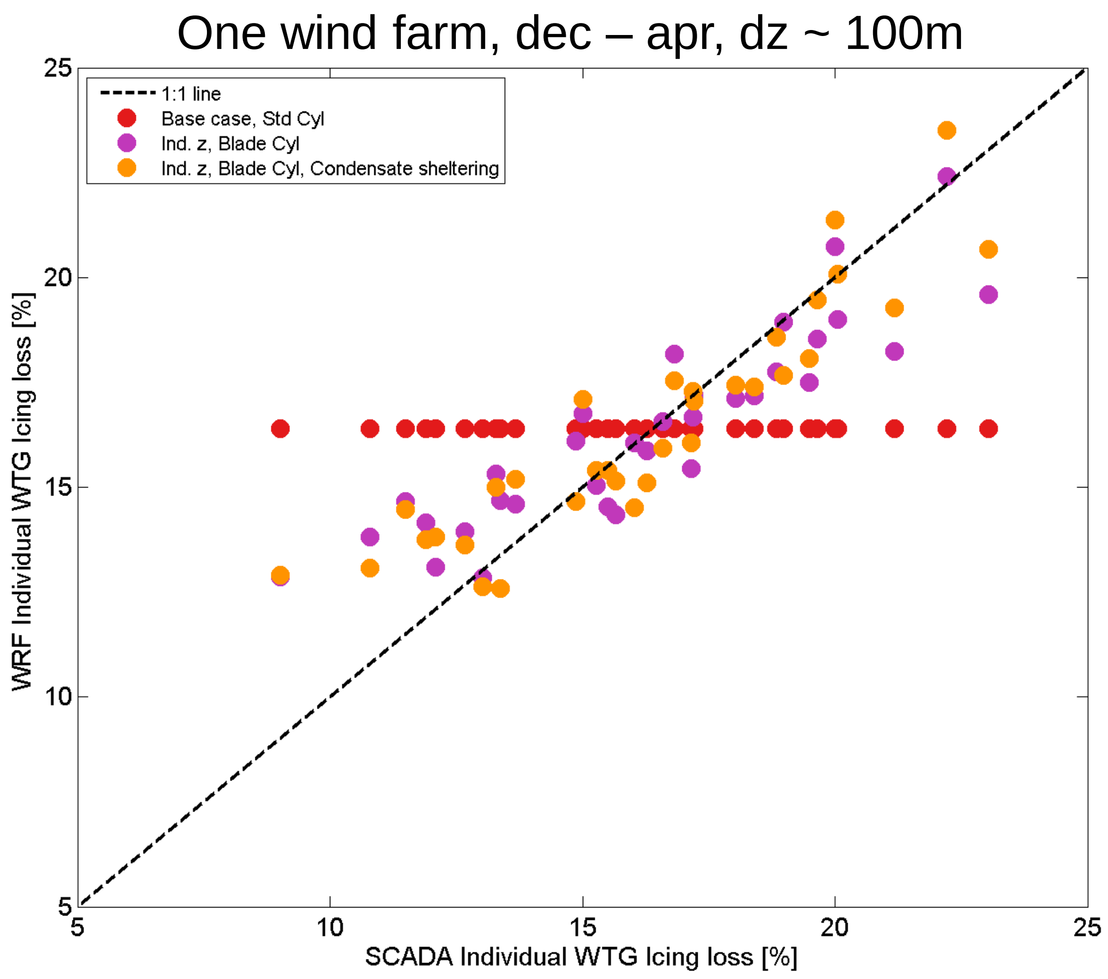

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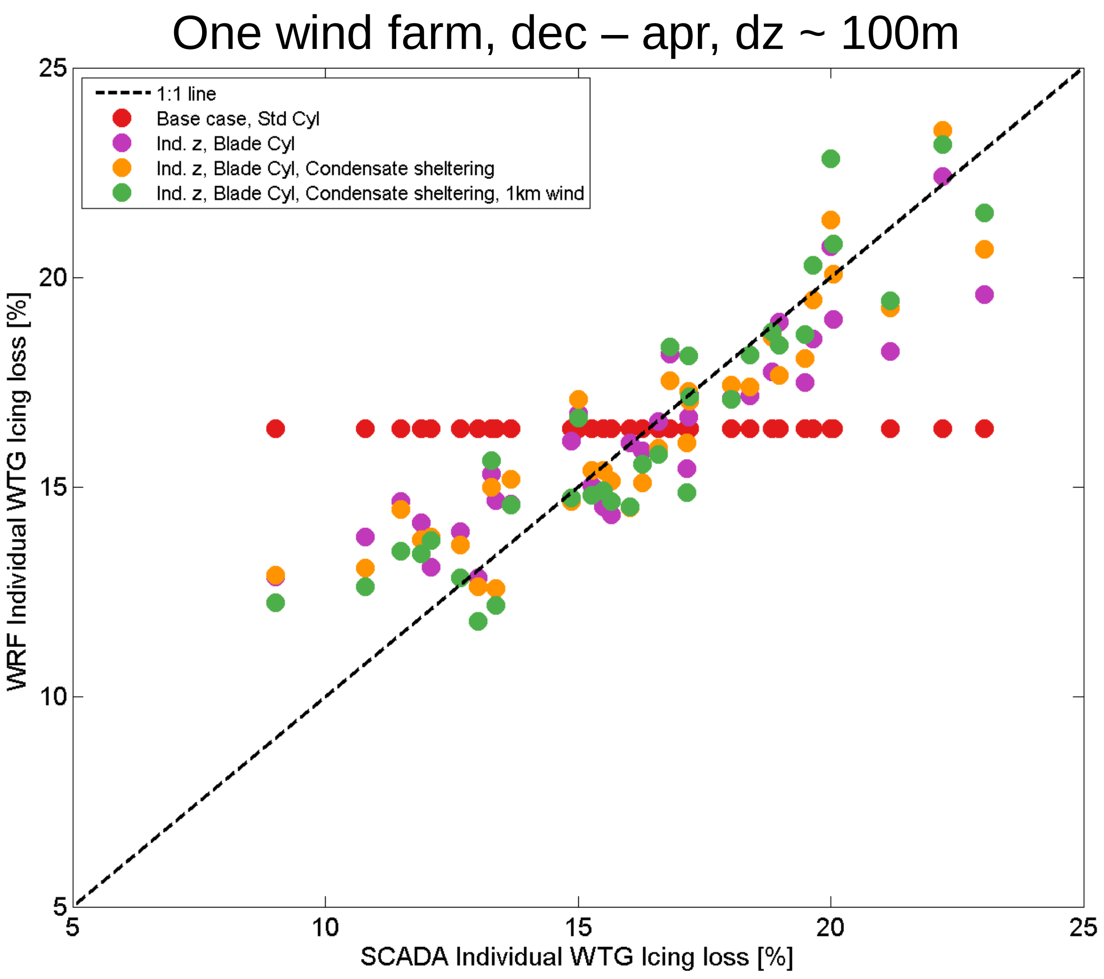

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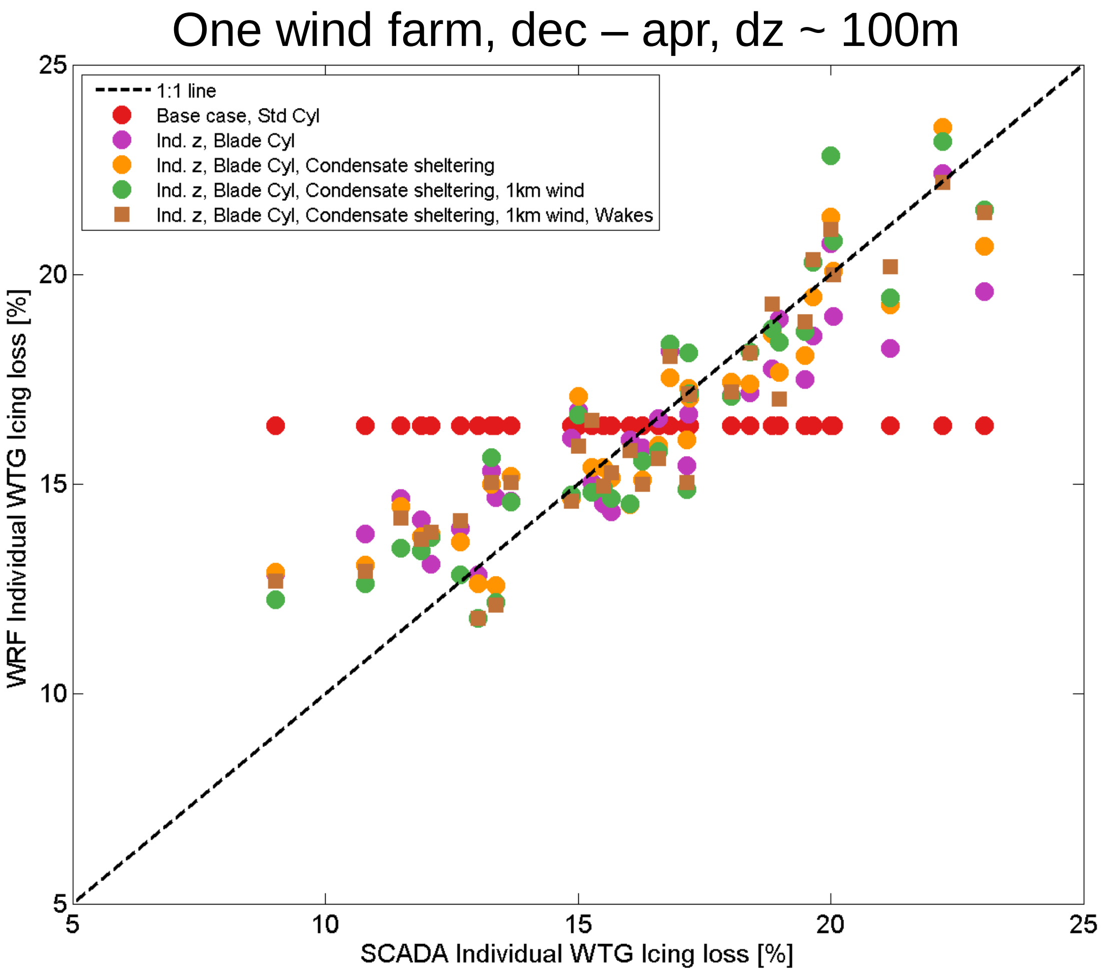
Ind z, Blade Cyl, condensate sheltering, 1km wind	2.95	0.89	1.60

Wind farm internal variability of ice losses



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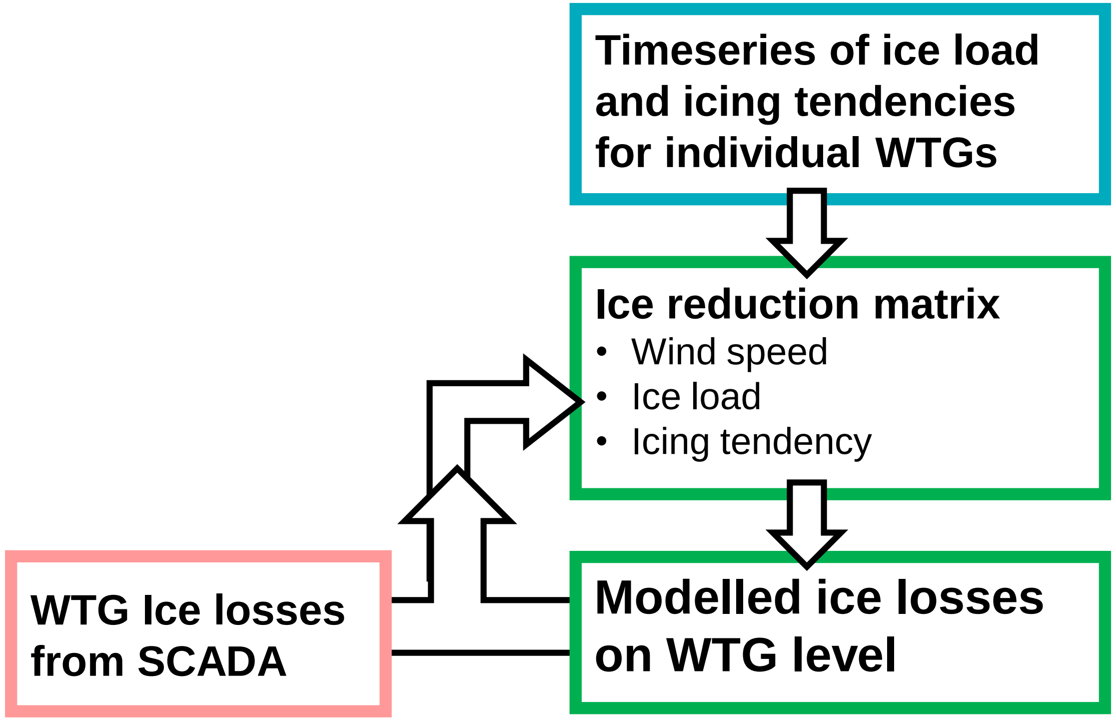
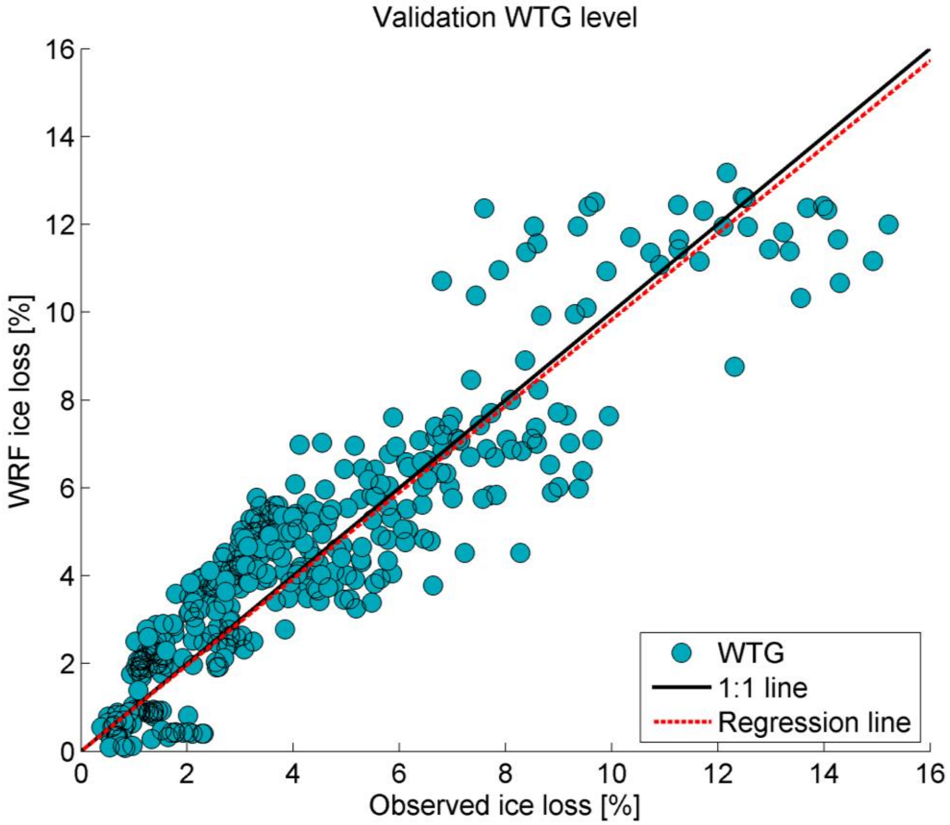
Ind z, Blade Cyl, condensate sheltering	2.53	0.90	1.65
Ind z, Blade Cyl, condensate sheltering, 1km wind	2.95	0.89	1.60
Ind z, Blade Cyl, condensate sheltering, 1km wind, wakes	2.67	0.88	1.68

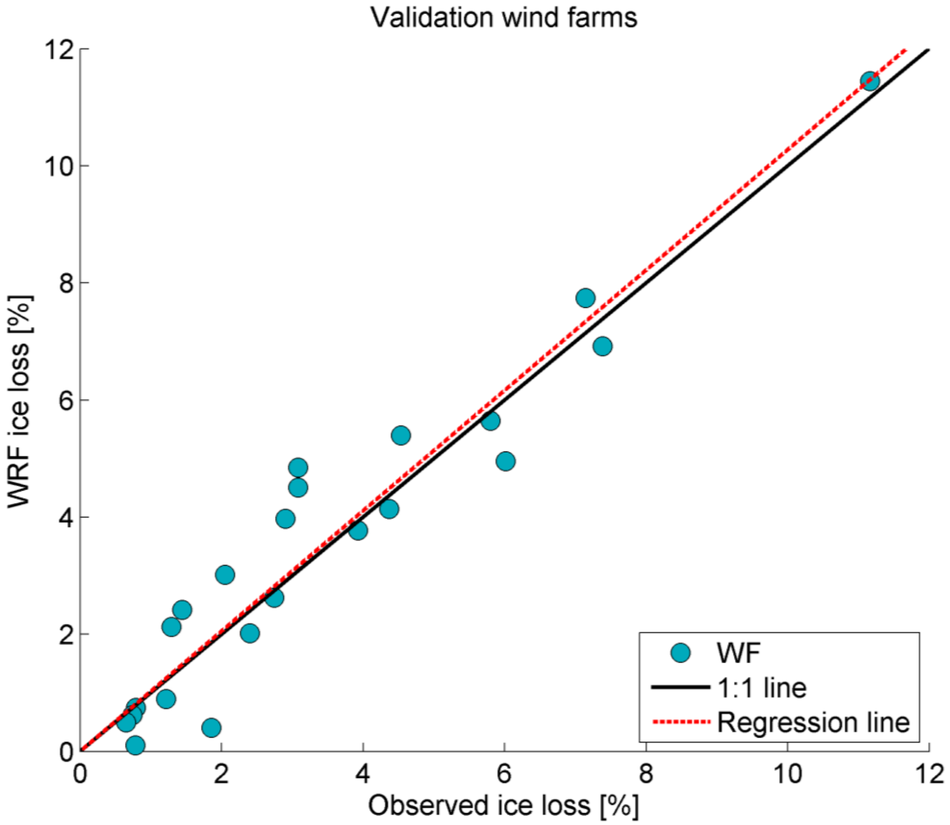
Calibration process

- Prior to calibration two windfarms are excluded from the SCADA ice loss database. Adjacent to industrial area and stopped occasionally for safety reasons
- Optimization on RMSE of individual WTGs' ice losses.
- To make maximum use of database but keep validation independant from calibration. Optimized power reduction matrix derived for each wind farm based the on remaining wind farms



IceLoss 1.9 validation

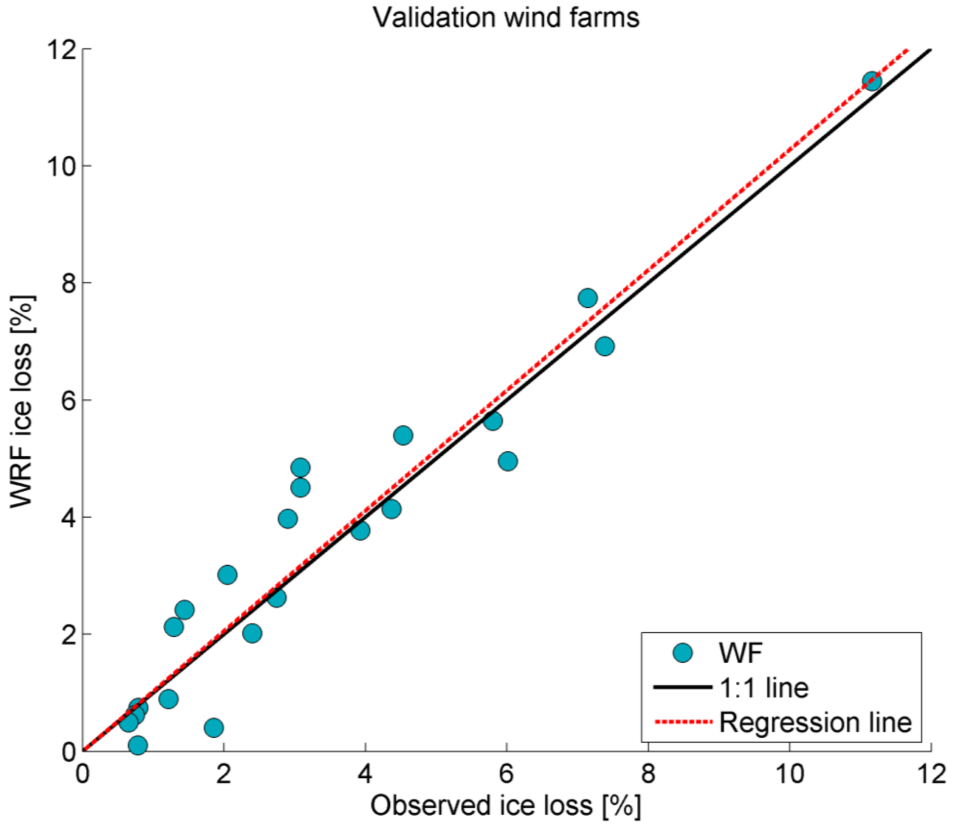




	WTG	WF
Bias [%]	0.2	0.2
Corr	0.92	0.96
Std [%]	1.3	0.8
MAE [%]	1.0	0.6
Slope	0.98	1.03

Summary

- Important to include cloud condensate sheltering effects of non-resolved topography to describe internal wind farm variability of icing losses.
- IceLoss 2 will have substantially reduced uncertainties in the modeled ice loss compared to earlier vesions



	WF
Bias [%]	0.2
Corr	0.96
Std [%]	0.8
MAE [%]	0.6
Slope	1.03

Report on the IceLoss 2 project to be submitted to the Swedish Energy Agency in late March and eventually available through there homepage.

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