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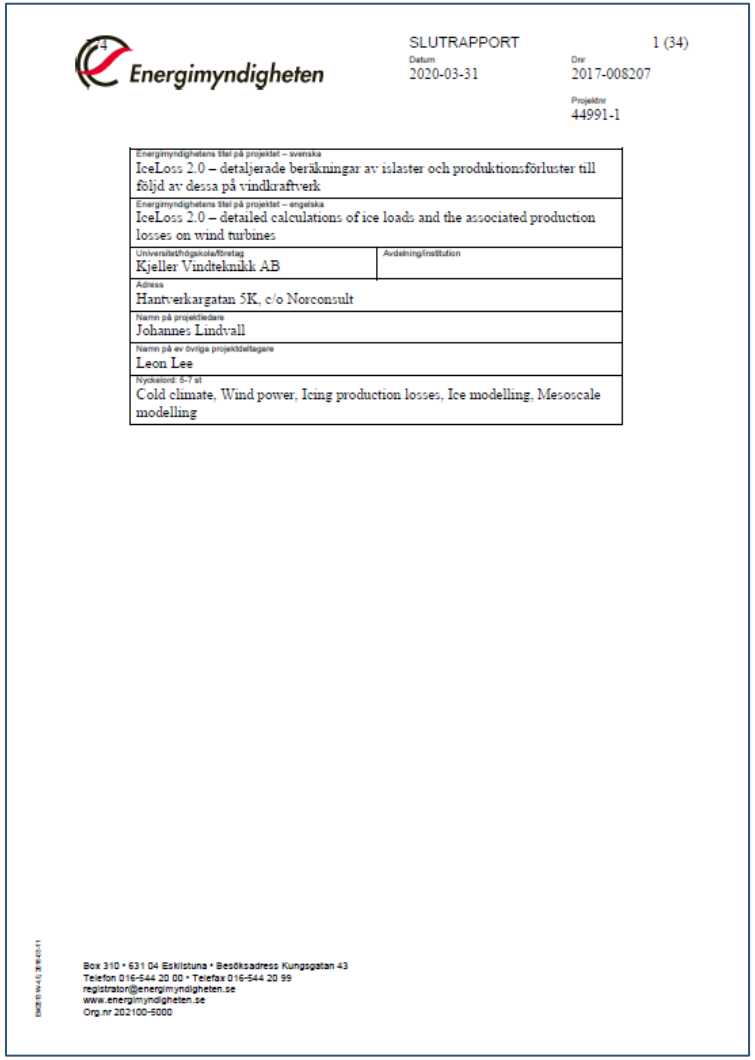
Development and calibration of state-of-the-art icing loss estimates using a new meteorological dataset.

Øyvind Byrkjedal, Johannes Lindvall, Leon Lee, Simo Rissanen

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
- **Total budget:** 2.6 MSEK
- **Funded by:** Swedish Energy Agency, Kjeller Vindteknikk, Park Owners
- January 2018 – March 2020
- Link to final report



Energimyndigheten

SLUTRAPPORT 1 (34)

Datum 2020-03-31

Dnr 2017-008207

Projektnr 44991-1

Energimyndighetens titel på projektet – svenska
IceLoss 2.0 – detaljerade beräkningar av islaster och produktionsförluster till följd av dessa på vindkraftverk

Energimyndighetens titel på projektet – engelska
IceLoss 2.0 – detailed calculations of ice loads and the associated production losses on wind turbines

Universitet/högskola/företag: Kjeller Vindteknikk AB
Avdelning/Institution:

Adress: Hantverkargatan 5K, c/o Norconsult

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Nyckelord: 5-7 st
Cold climate, Wind power, Icing production losses, Ice modelling, Mesoscale modelling

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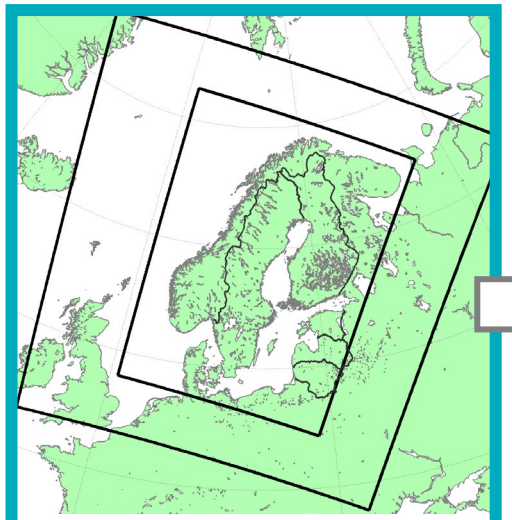
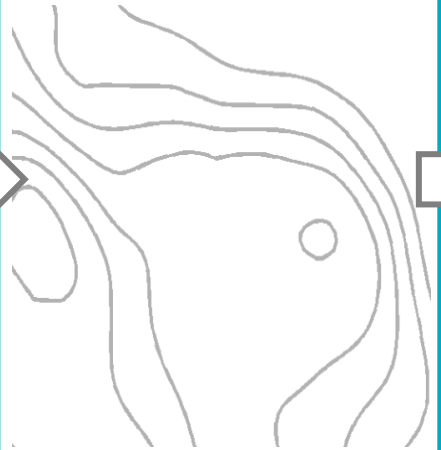
The IceLoss 2.0 development/model chain

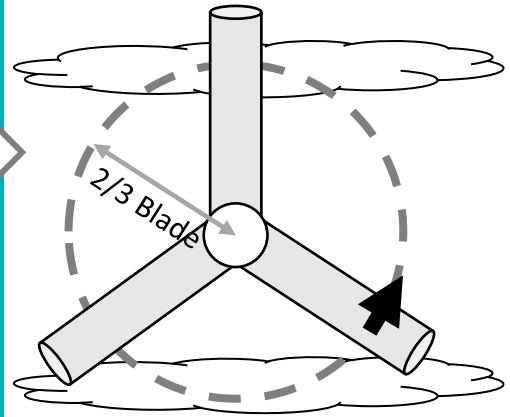


KVT_NSF 3km dataset (ERA 5)

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

Observed Ice losses from SCADA

SCADA database

Ice filtering following IEA-task 19 method

IceLoss 2.0 SCADA ice loss database

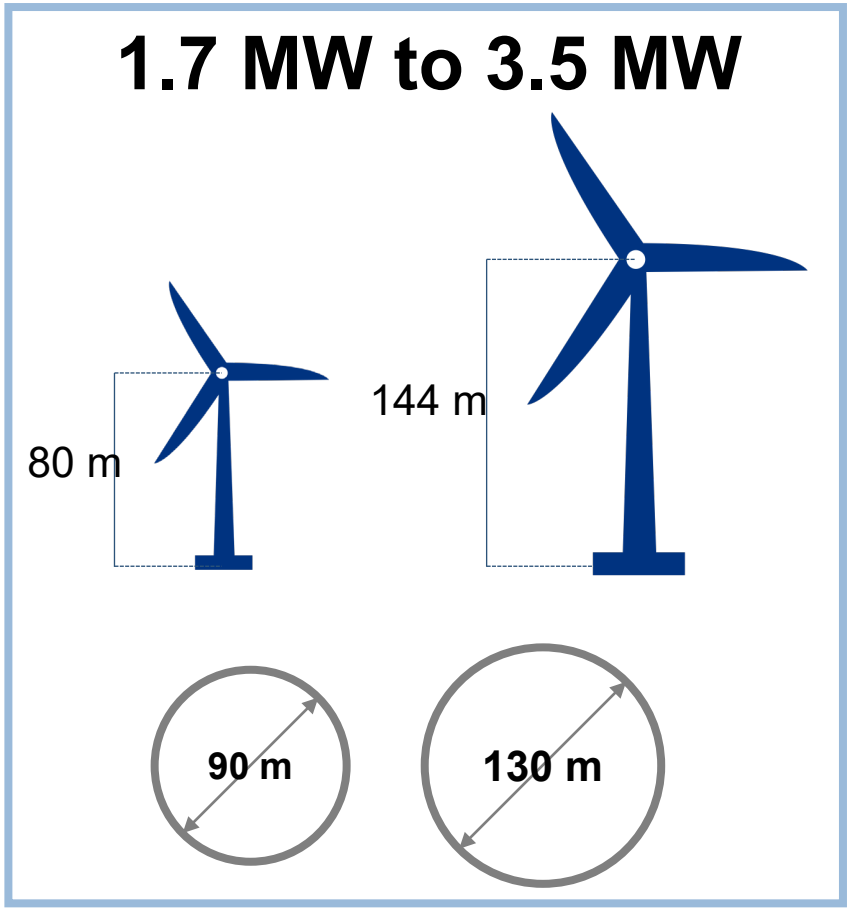
 # 24 Windfarms
400 WTGs
2000 WTG years

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



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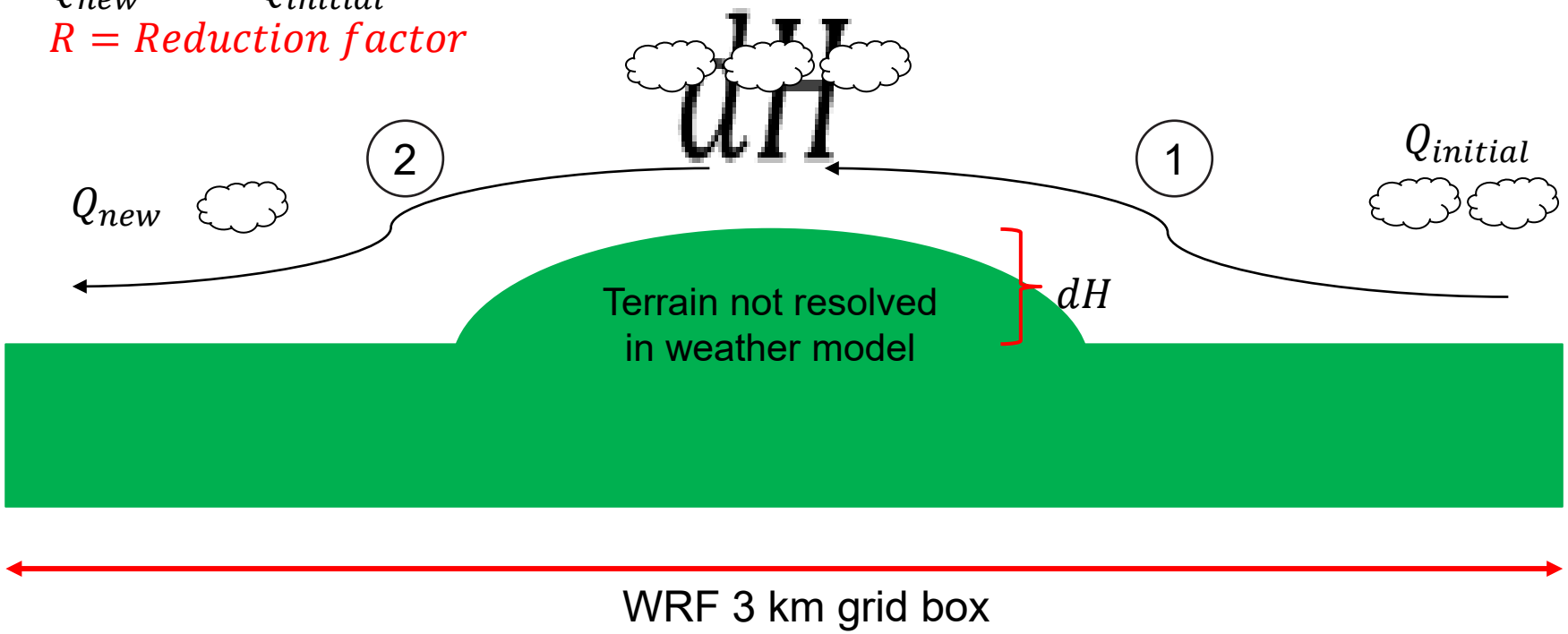
Cloud condensate lifting and sheltering effect

2 **Sheltering effect**
Absolute humidity reduced due condensation and precipitation/Mixing with drier air from above

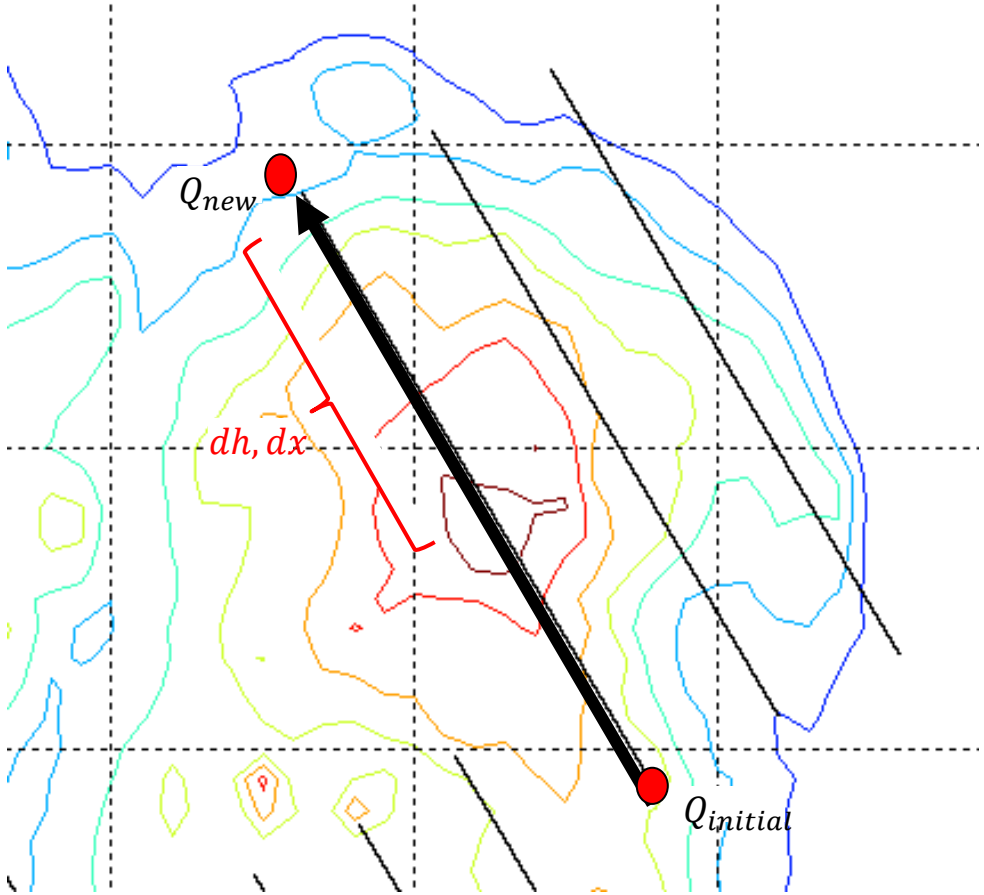
1 **Cloud condensate lifting**
Humidity is lifted *dh* and exposed to lower temperature/pressure → more cloud condesate

$$Q_{new} = R \cdot Q_{initial}$$
$$R = Reduction\ factor$$



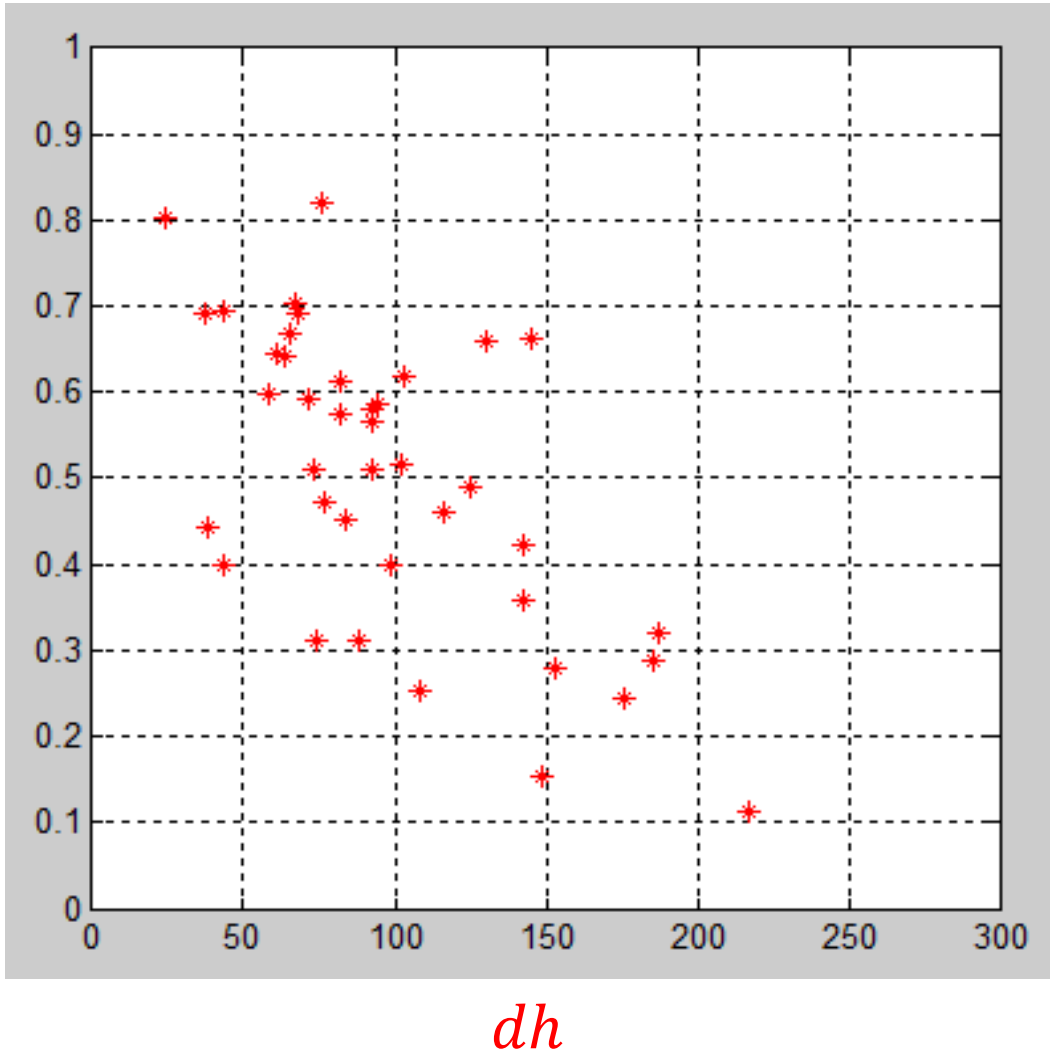
Cloud condensate sheltering effect

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



Cloud condensate sheltering effect

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



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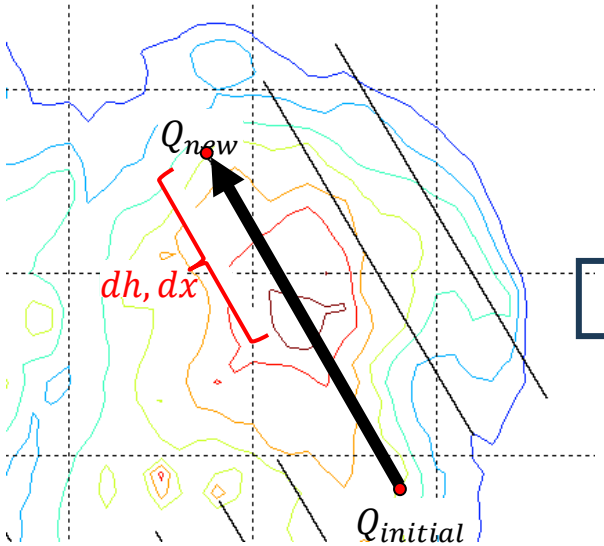

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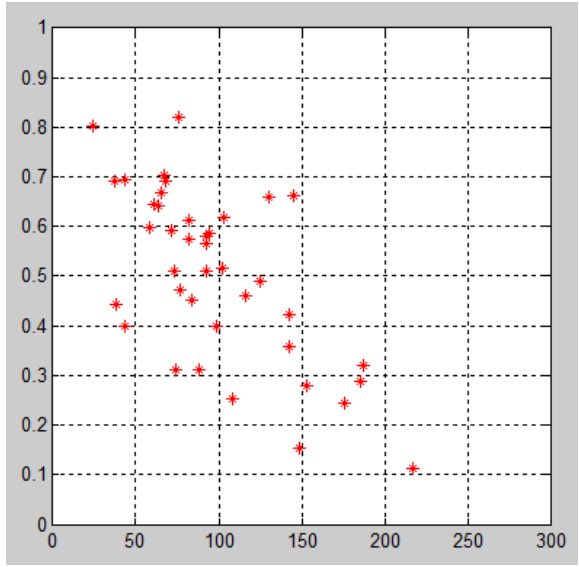
R



dh

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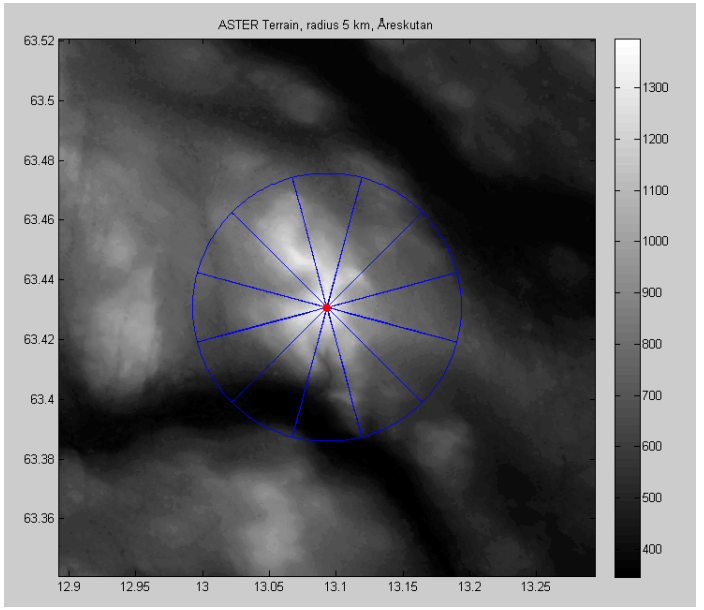

- Cloud reduction factors for each WTG derived from WTG position and high-res topography data

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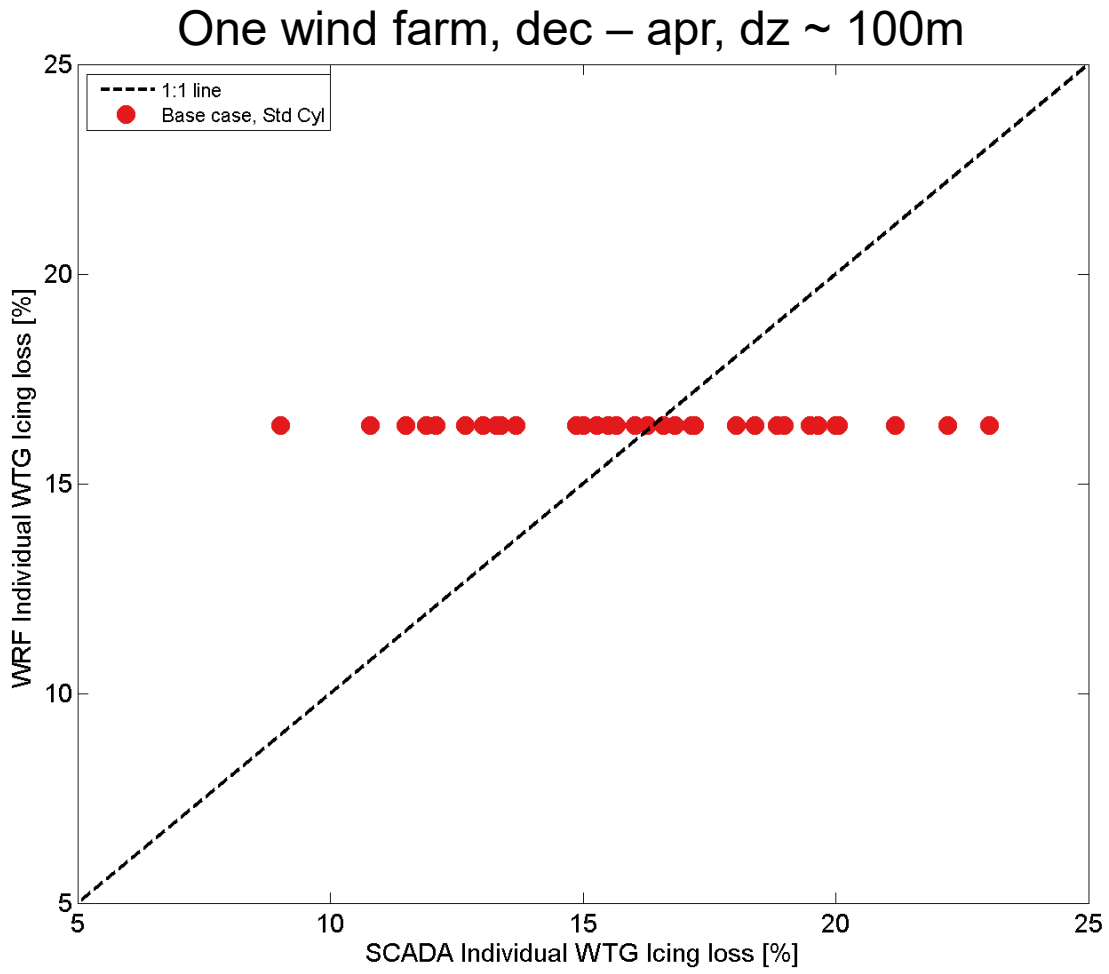
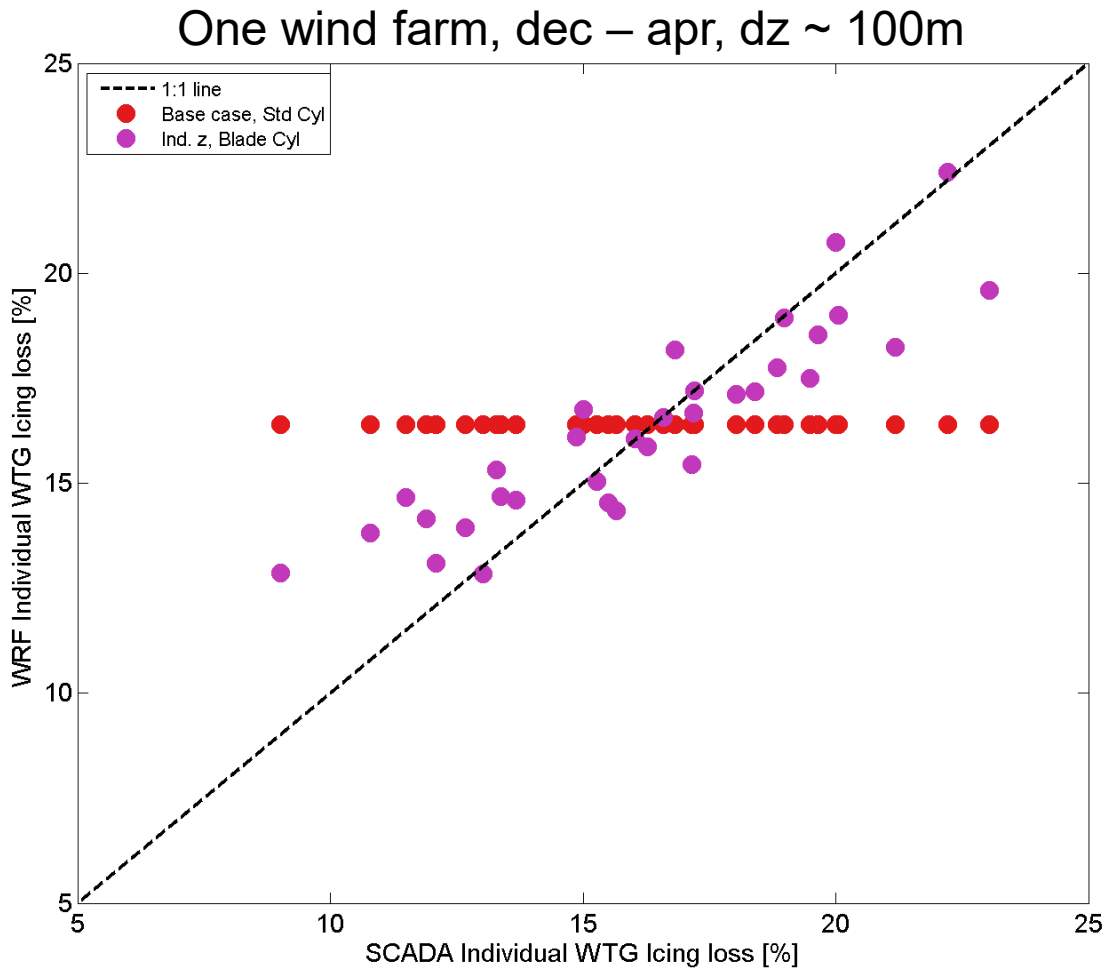
Wind farm internal variability of ice losses



BIAS CORRECTED METRICS

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

Wind farm internal variability of ice losses



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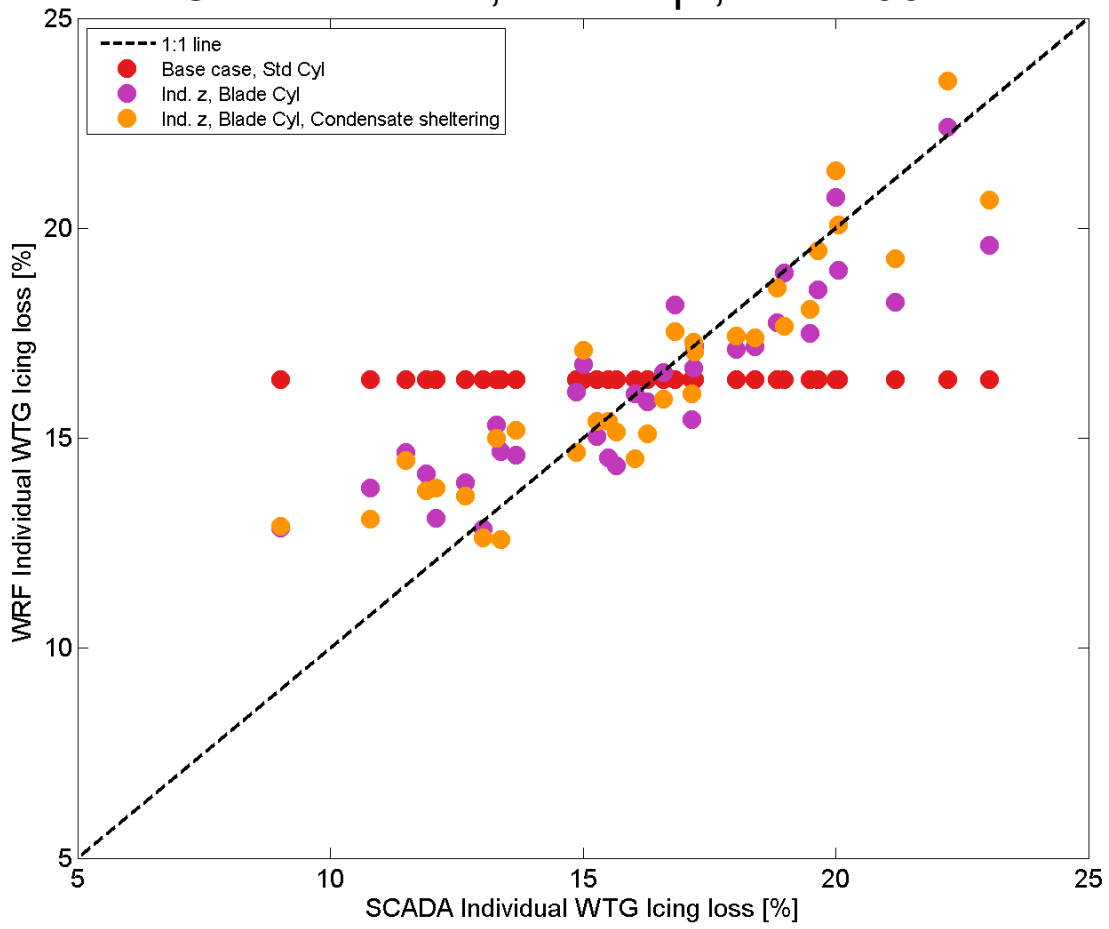
Individual z, Blade Cyl	2.22	0.88	1.86

Wind farm internal variability of ice losses

One wind farm, dec – apr, dz ~ 100m



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SCADA, 16.4 % loss	3.51		
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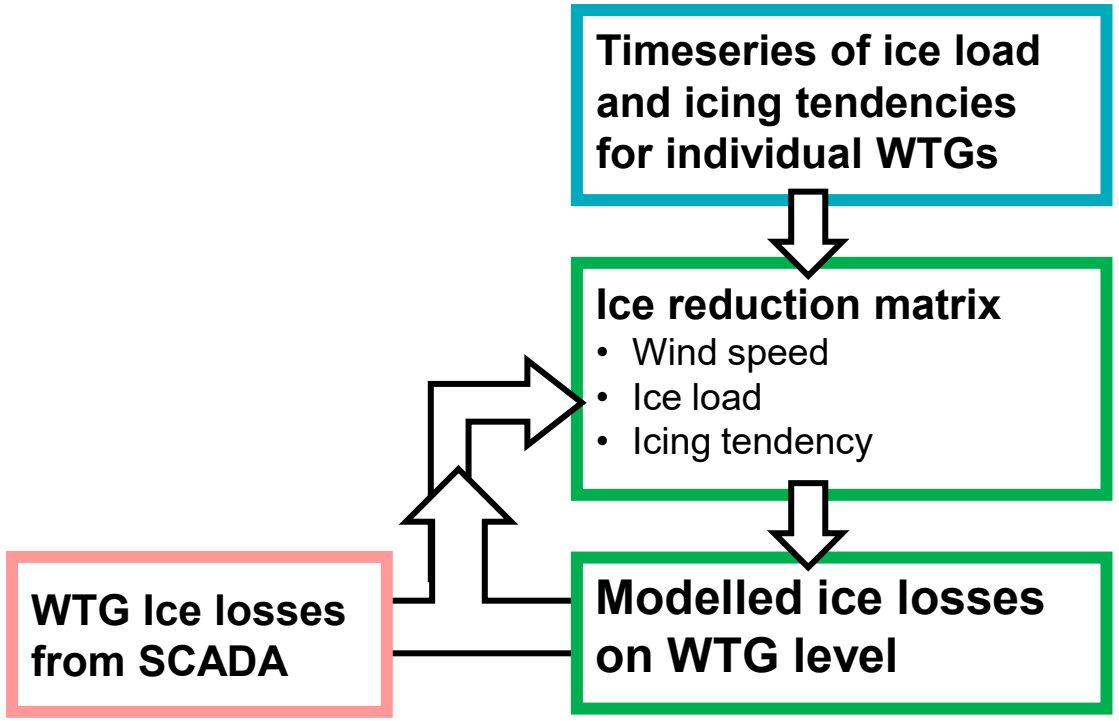
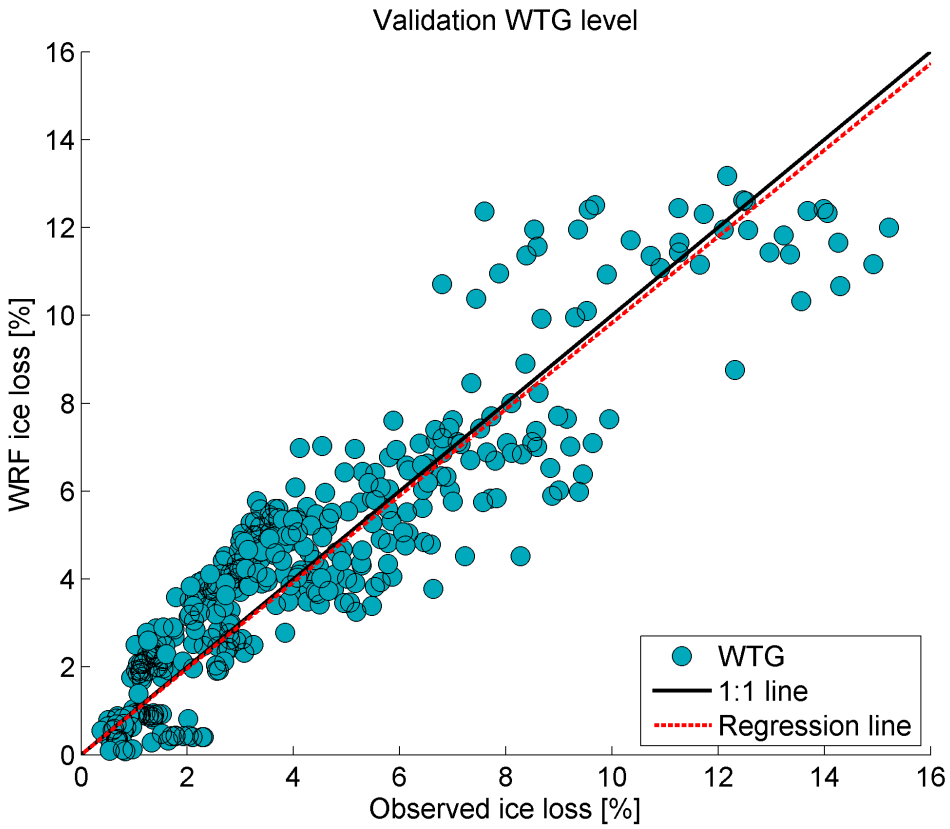
Individual z, Blade Cyl	2.22	0.88	1.86
Ind z, Blade Cyl, condensate sheltering	2.53	0.90	1.65

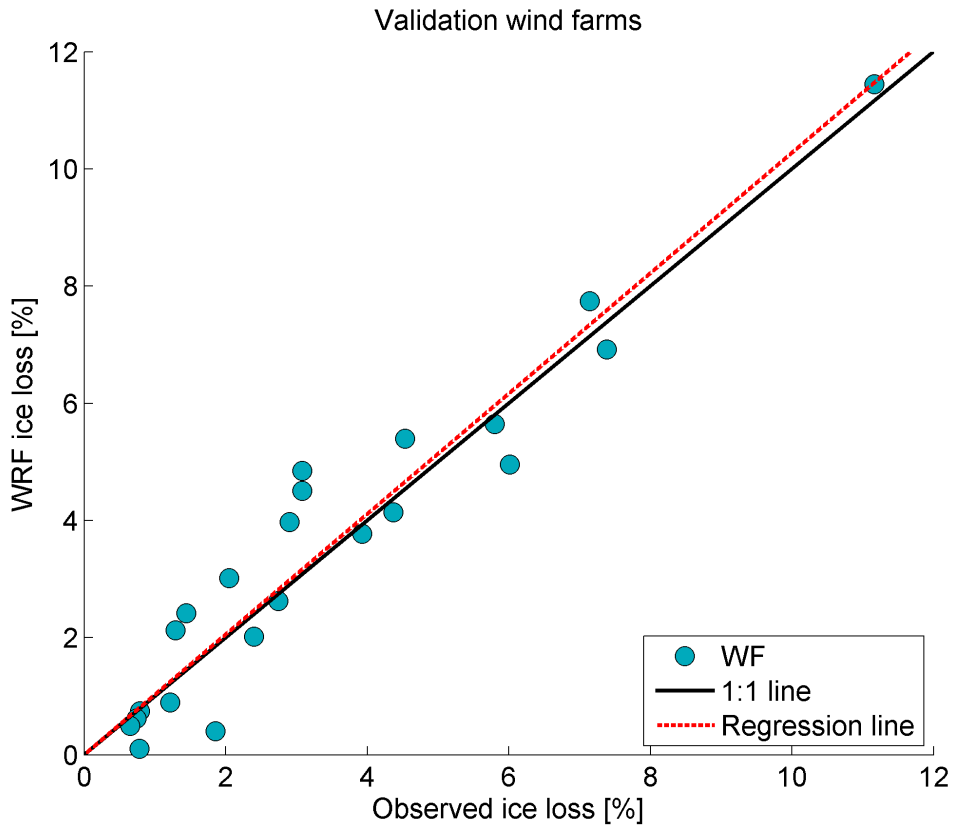
Calibration process

- 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.
- **Leave-one-out cross validation:** 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 validation

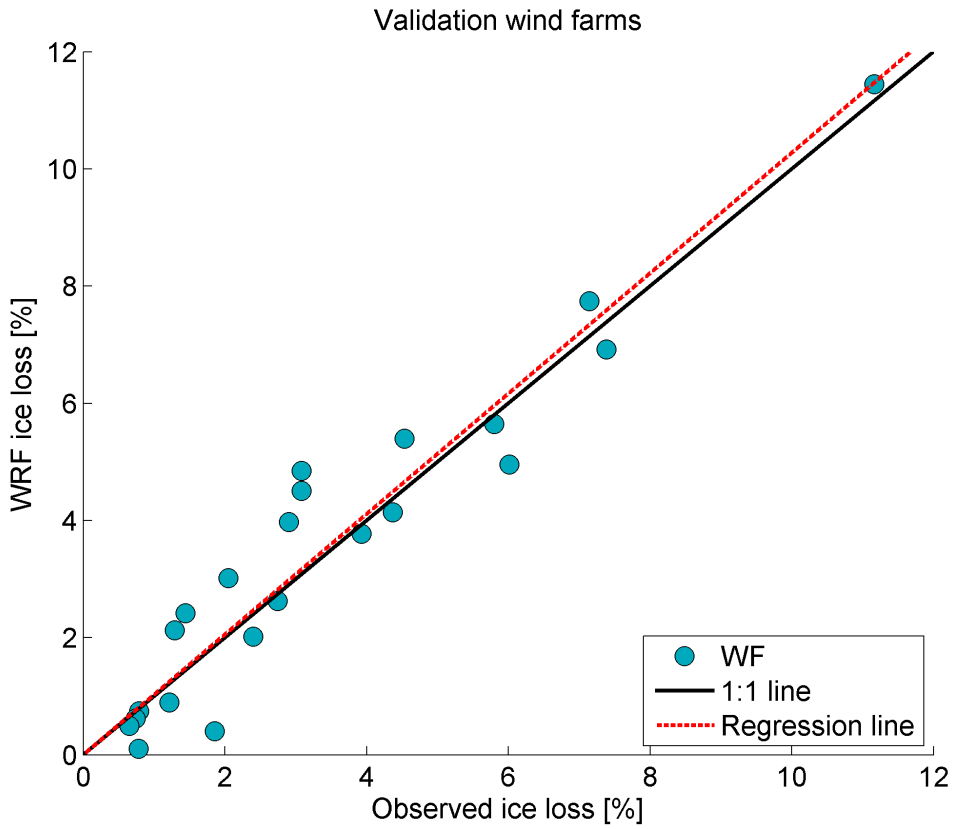




	WTG	WF
Bias [%]	0.2	0.2
Corr	0.92	0.96
Std [%]	1.3	0.8
MAE [%]	1.0	0.6
Slope	0.98	1.03

Summary

- Local topography influence is important for the correct description of icing conditions. Both sheltering and exposure effects.
- Ongoing work to calibrate the model with new WRF dataset.



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KJELLER VINDTEKNIKK
Part of Norconsult

- Science based wind energy consulting
- Established 1998
- 31 employees
- Main office in Lillestrøm close to Oslo
- Other offices: Espoo, Stockholm, Stavanger and Kópavogur
- Main markets: Norway, Sweden and Finland

- Since 2019 a part of Norconsult

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