Renewable Energy Analytics

WICE 2.0 – The new generation of ice loss models

Stefan Söderberg, Jon Collins, Till Beckford, and Carla Ribeiro

Winterwind 2019, Umeå

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Part 1: Introduction and Methodology

Introduction

- In September 2018 DNV GL joined forces with WeatherTech.

DNV GL joins forces with Swedish cold climate experts WeatherTech

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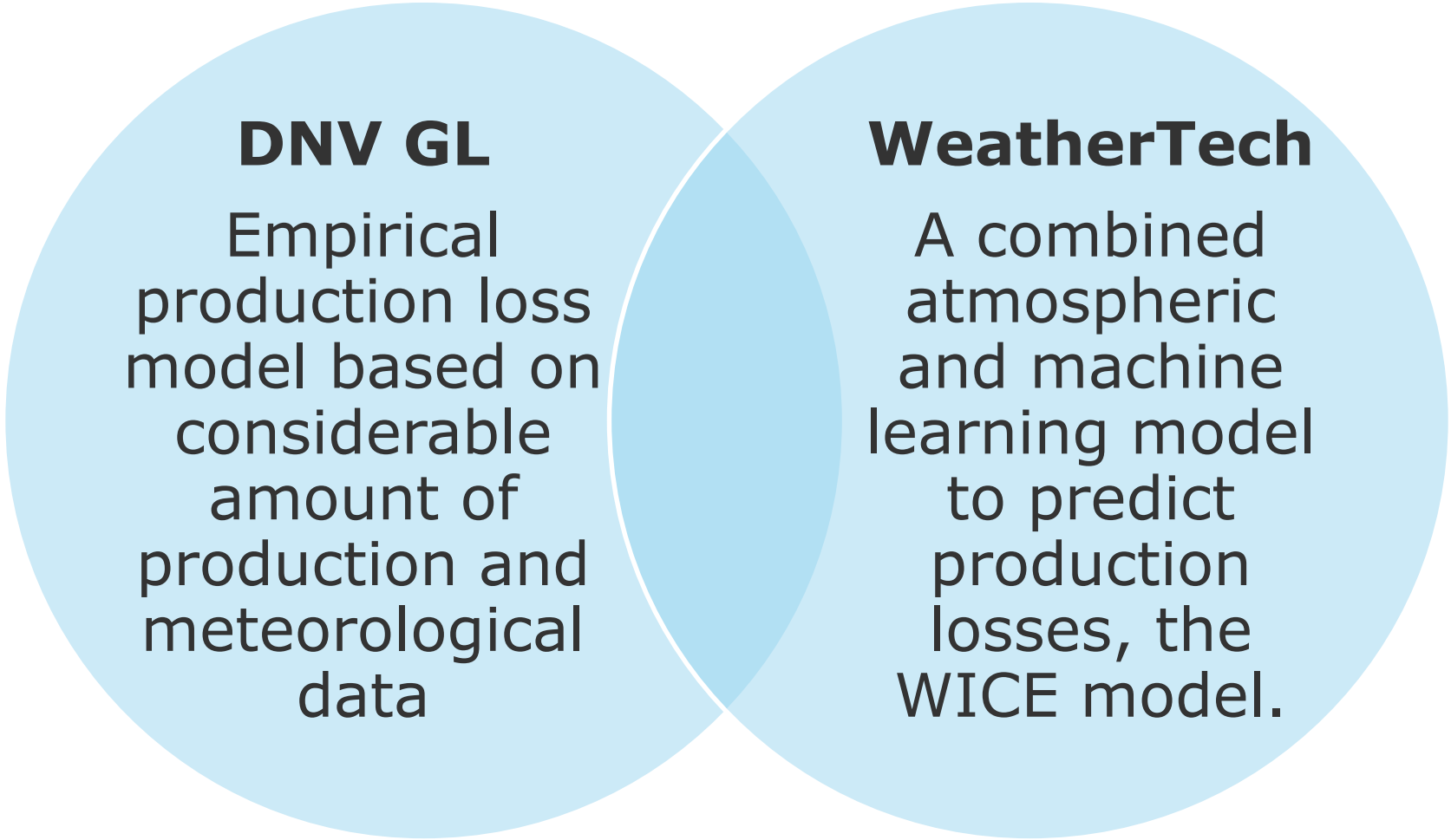
The combined expertise of DNV GL and WeatherTech will enable the development of an innovative new icing model, which can be applied globally to better predict the performance of wind turbines in cold climates

Published: 13 September 2018 **Author:** Mona Ghobadi **Keywords:** Wind energy, Power and renewables

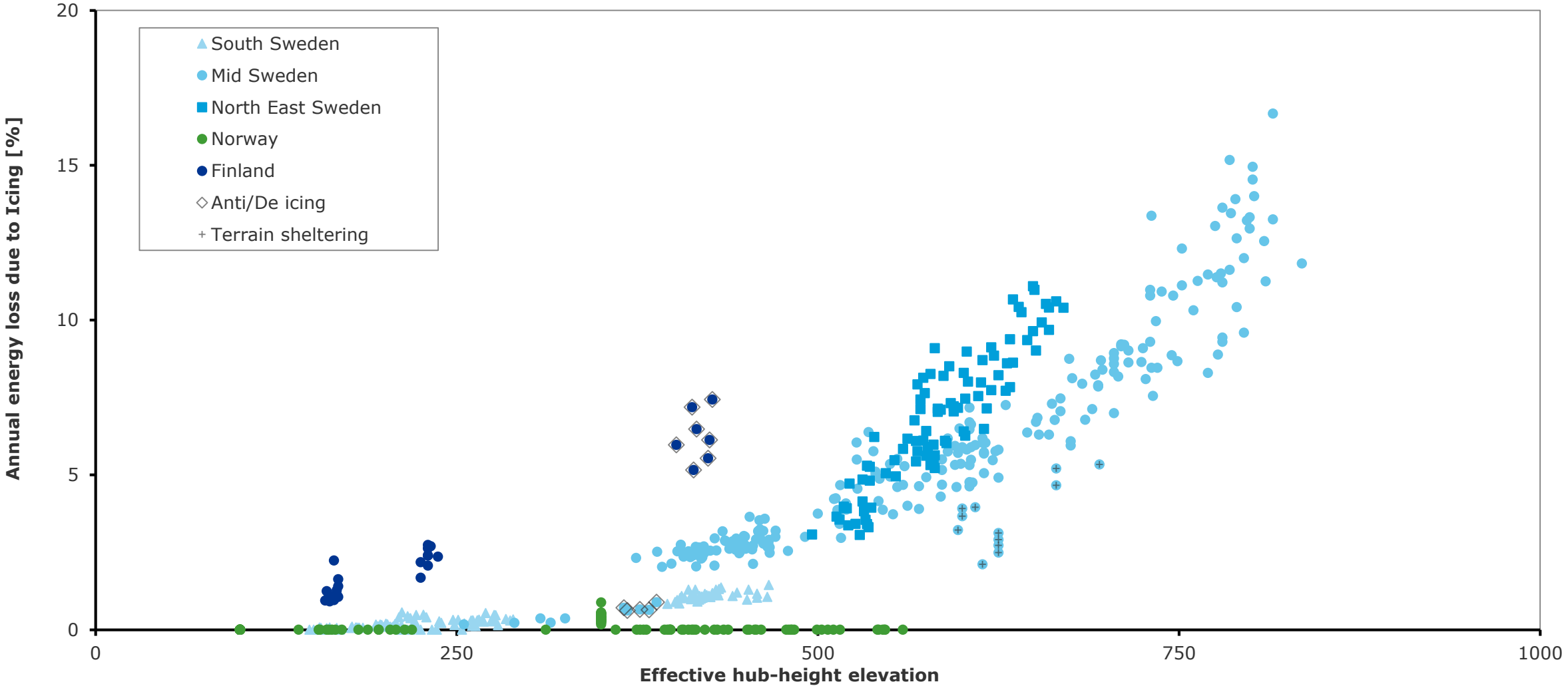
Contact: Prajeev Rasiah *Regional Manager, Energy-North West Europe, Middle East & Africa*

STOCKHOLM, Sweden - 13 September 2018 - DNV GL, the world's largest resource of independent energy experts and certification body, today announced that it has joined forces with Swedish atmospheric science experts, WeatherTech. The combined expertise of both companies will enable the development of the most advanced icing model for wind turbines available on the market, allowing customers to better predict the performance of turbines in cold climates.

Combined expertise



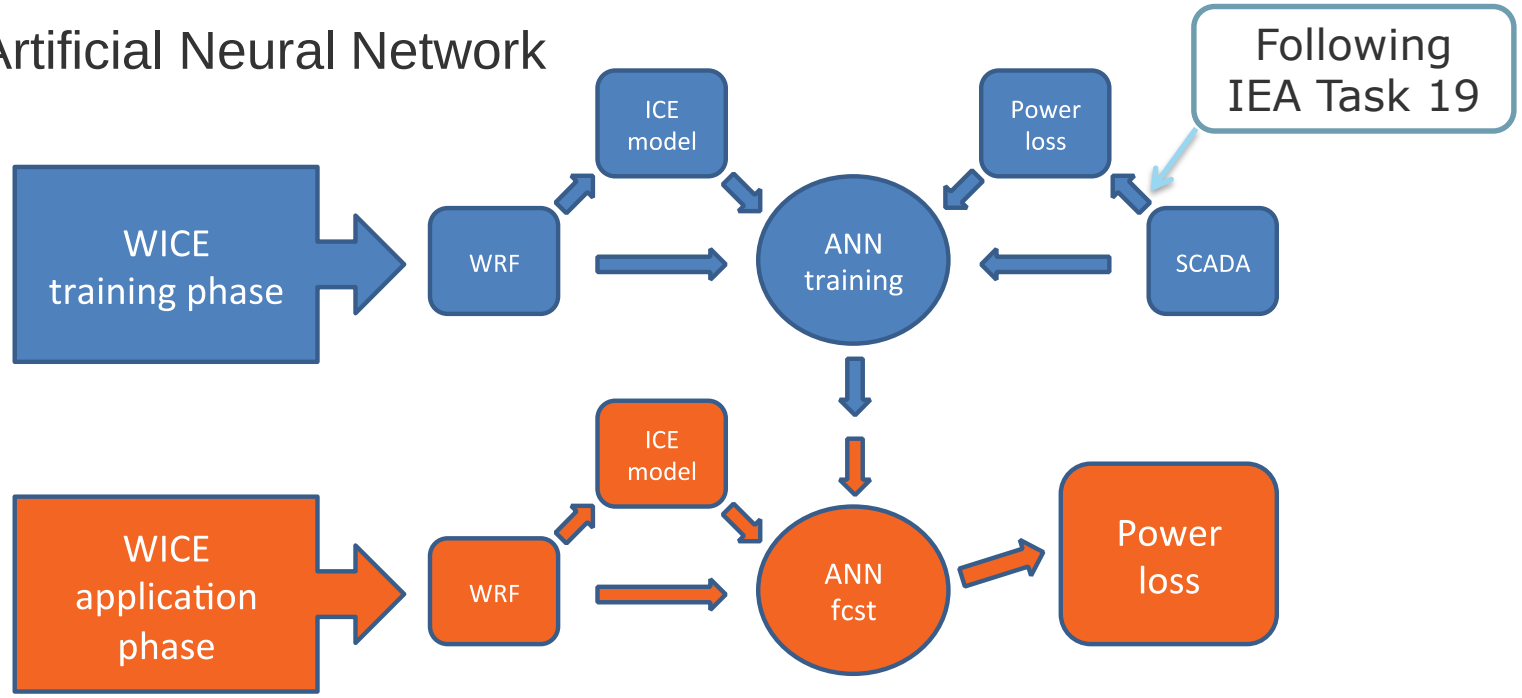
Nordic operational data – Icing vs Elevation



Production loss model - WICE

A combination of physical and statistical modelling

ANN – Artificial Neural Network



WICE model chain

NWP	Ice model	Production loss	Long term
• WRF model • High resolution • Microphysics	• Makkonen • Turbine blade • IPS	• WICE • SCADA	• 30yrs • Condensates
2013 2016	2013 2014 2018	EWEA 2013 VIENNA 2013	2012 2015 2017

Part 2: Validation of WICE model chain

Validation

- 10 sites
- Chosen to cover different regions

SCADA

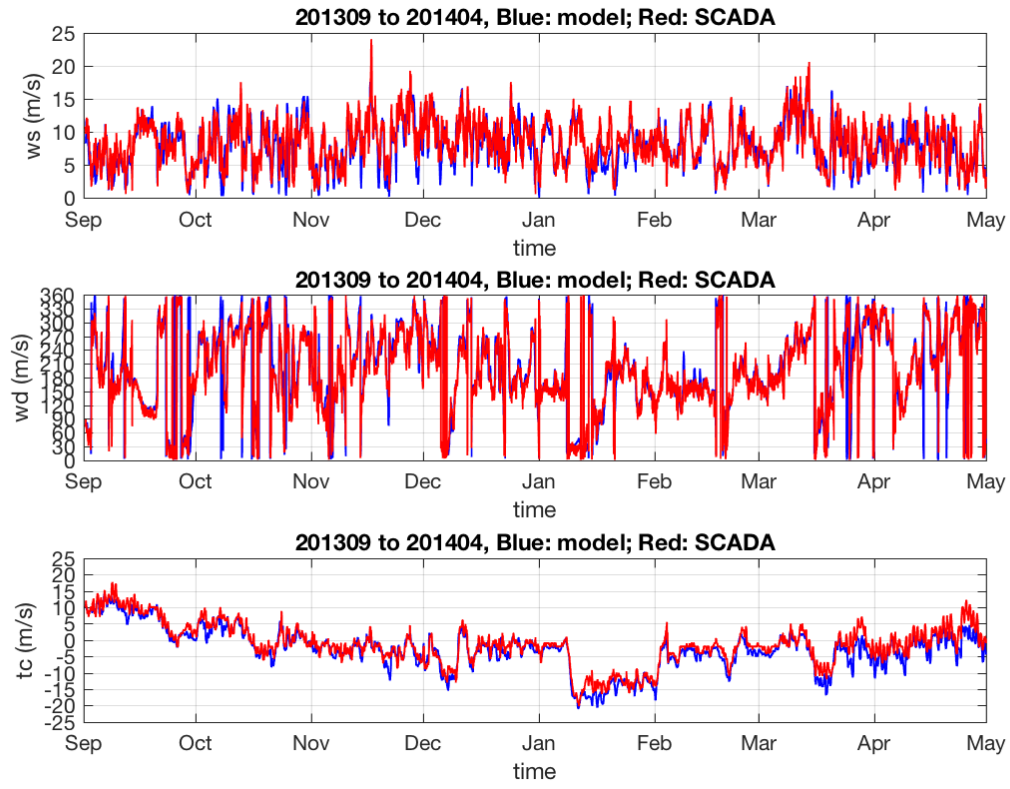
- 1-7 years of operational data
- 263 turbines

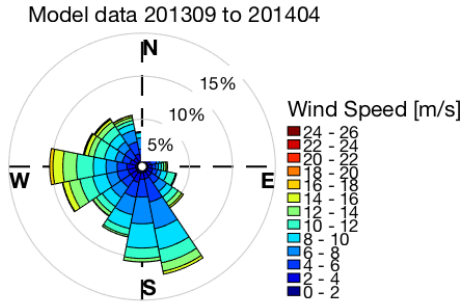
Weather modelling

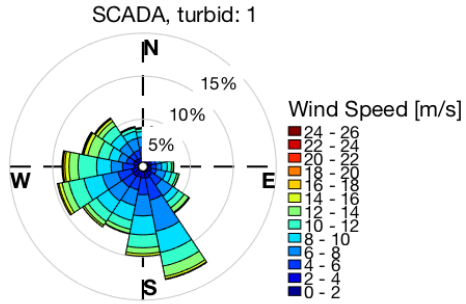
- WRF
- In-house setup
- 1000m / 333m model grid resolution

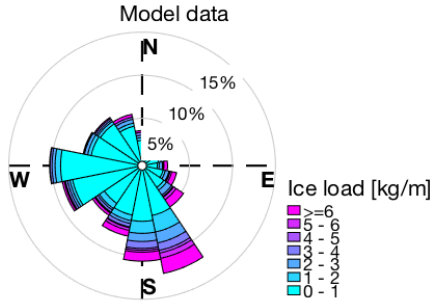
Validation – weather modelling

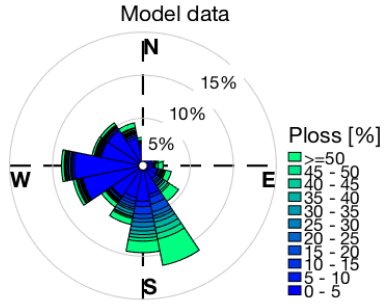
- Time series and statistics have been analysed
  - In general a good agreement





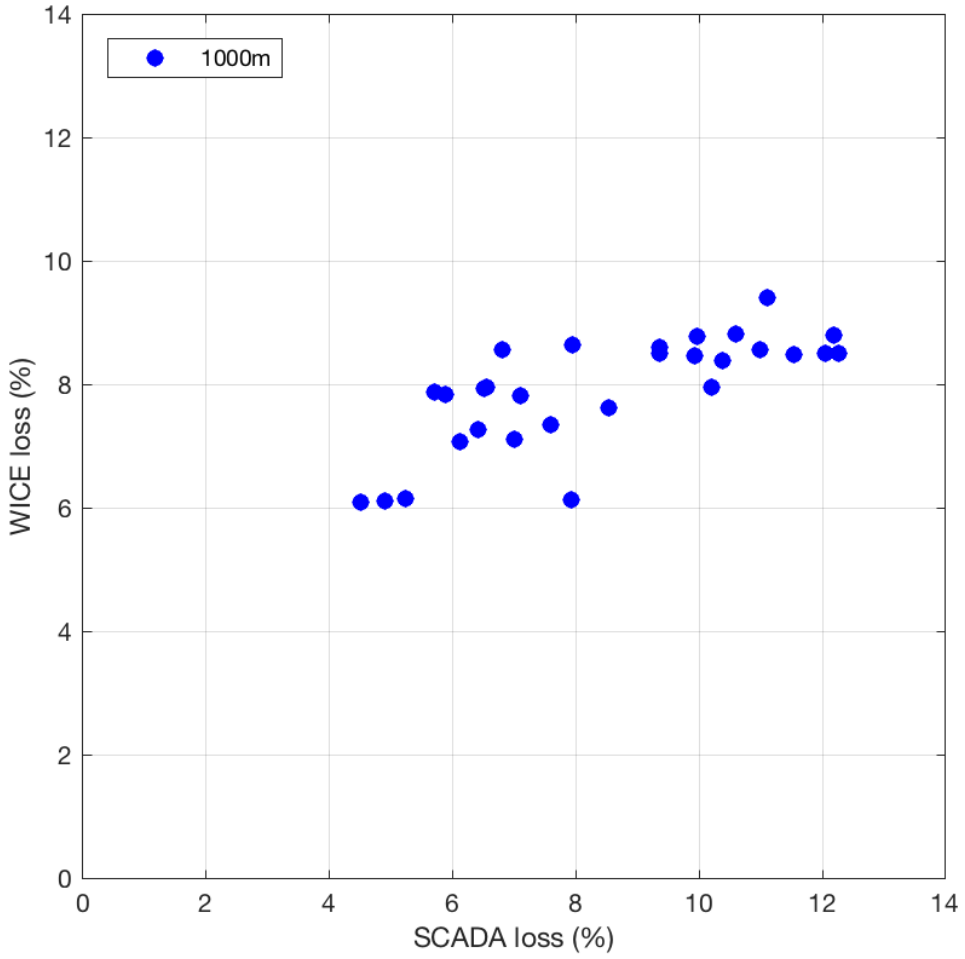






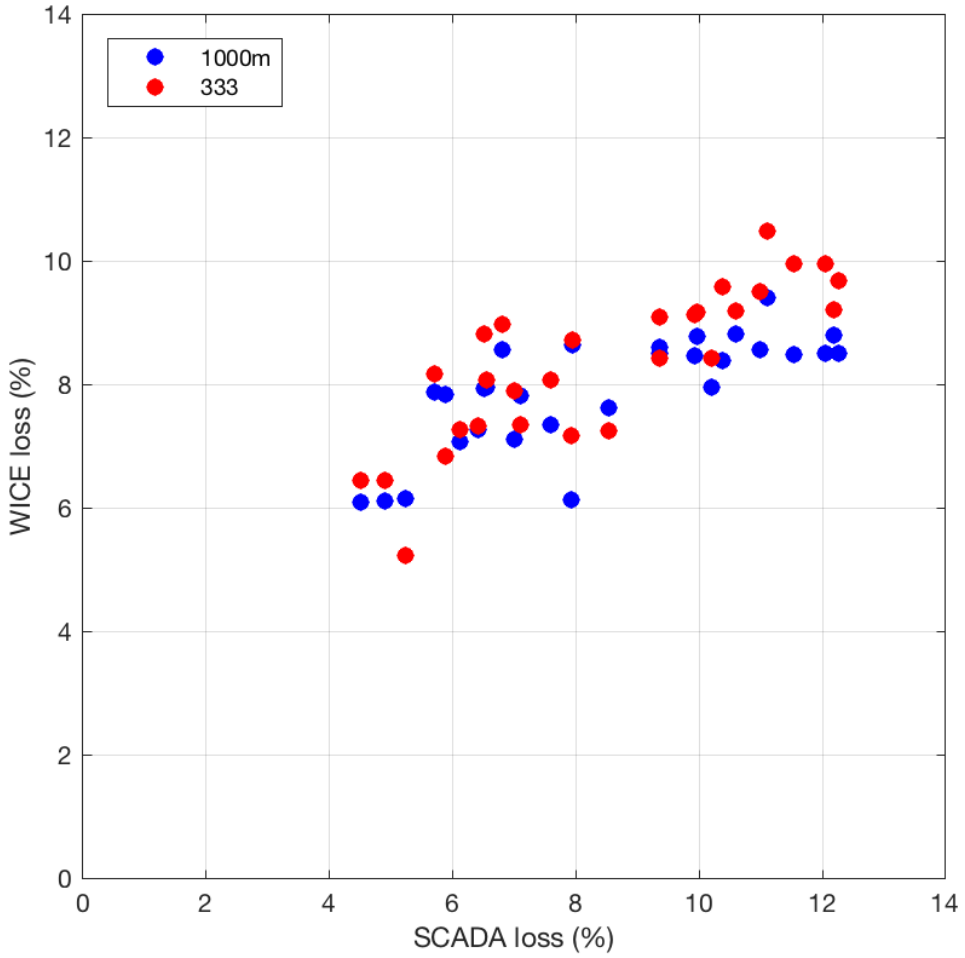
Validation – WICE model chain: intra-farm variability

- Individual WTG losses
- SCADA vs WICE 1000m grid resolution



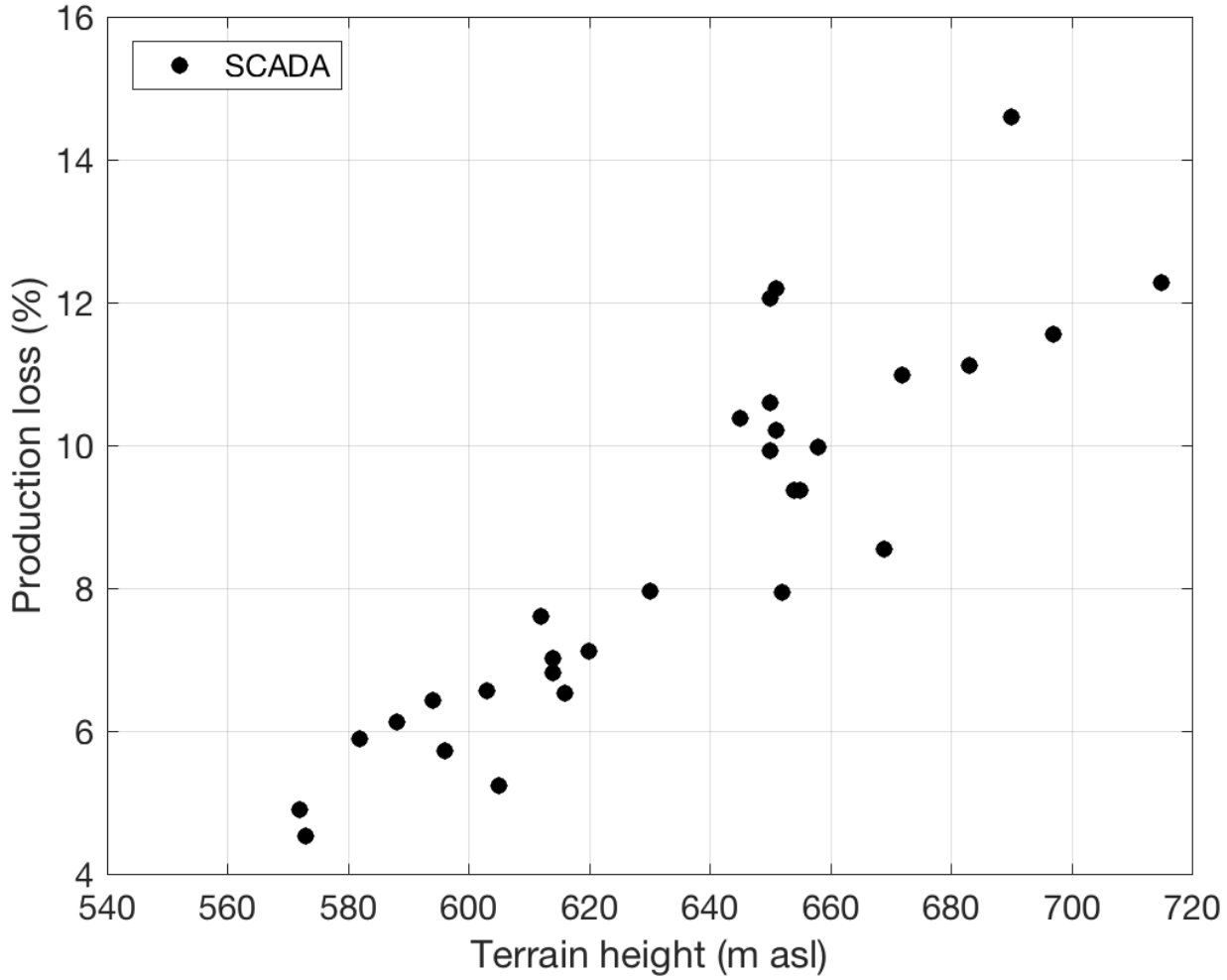
Validation – WICE model chain: intra-farm variability

- Individual WTG losses
- SCADA vs WICE 1000m and 333m grid resolution



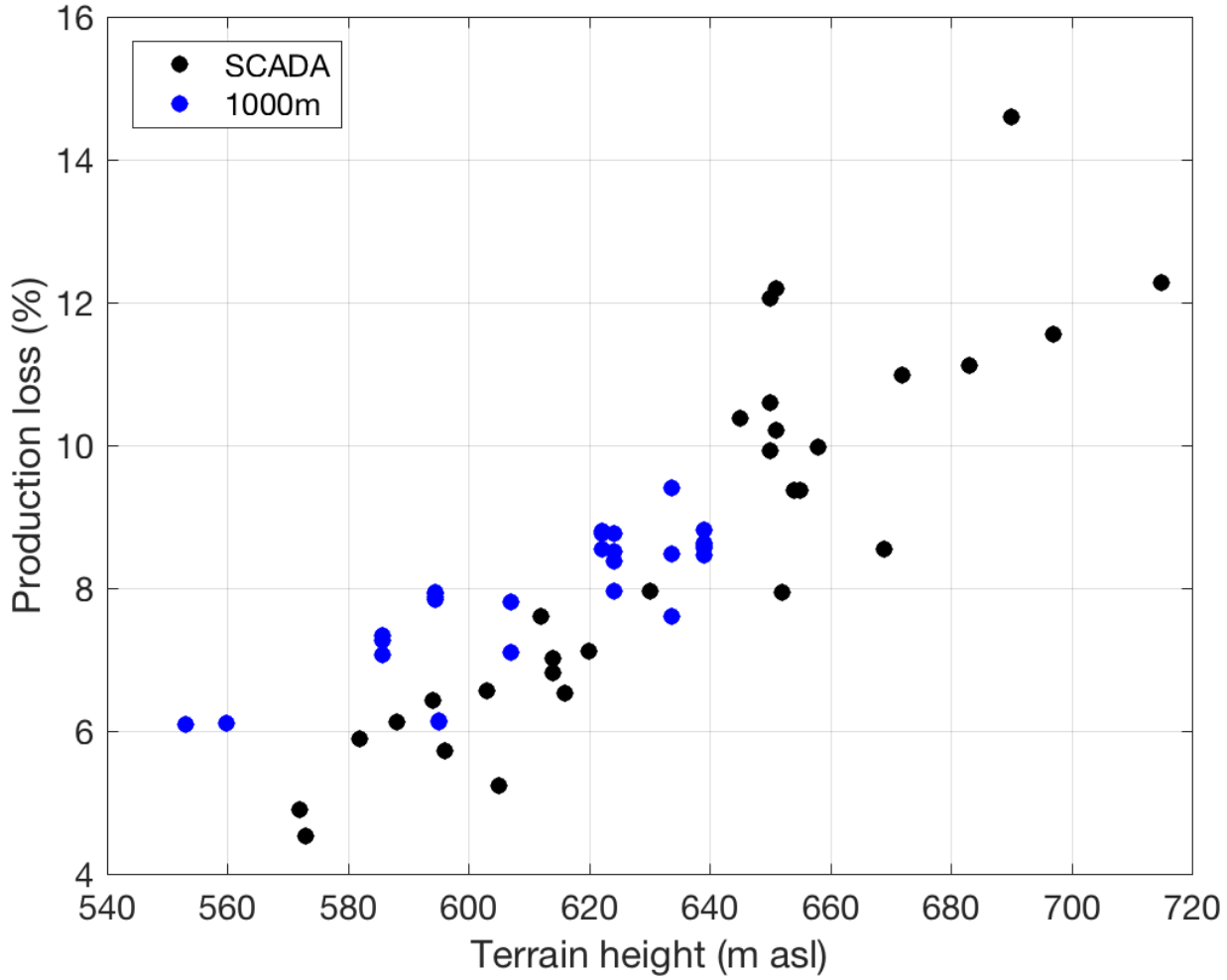
Validation – WICE model chain: intra-farm variability

- Individual WTG losses
  - Terrain elevation vs SCADA



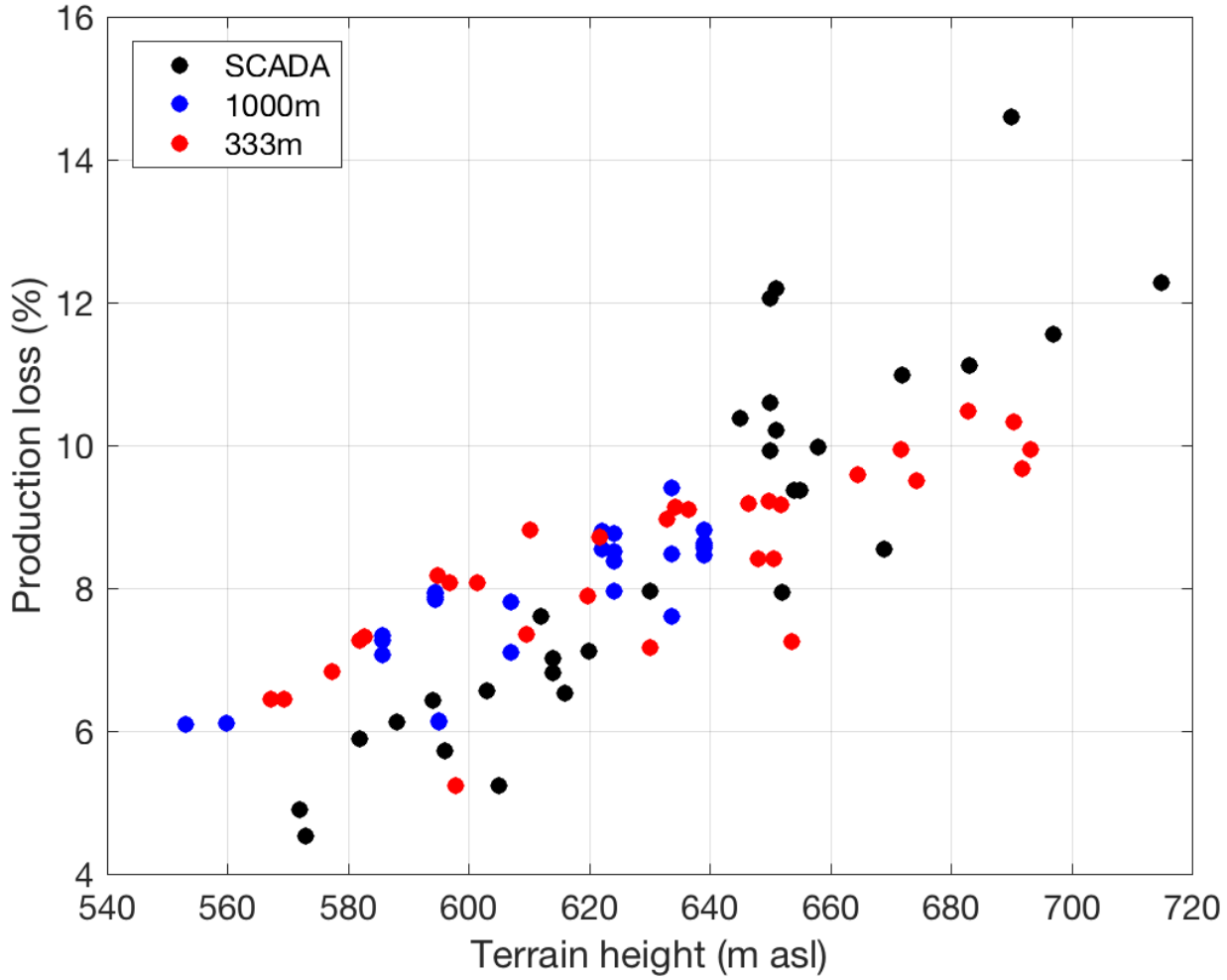
Validation – WICE model chain: intra-farm variability

- Individual WTG losses
  - Terrain elevation vs SCADA and WICE 1000m grid resolution



Validation – WICE model chain: intra-farm variability

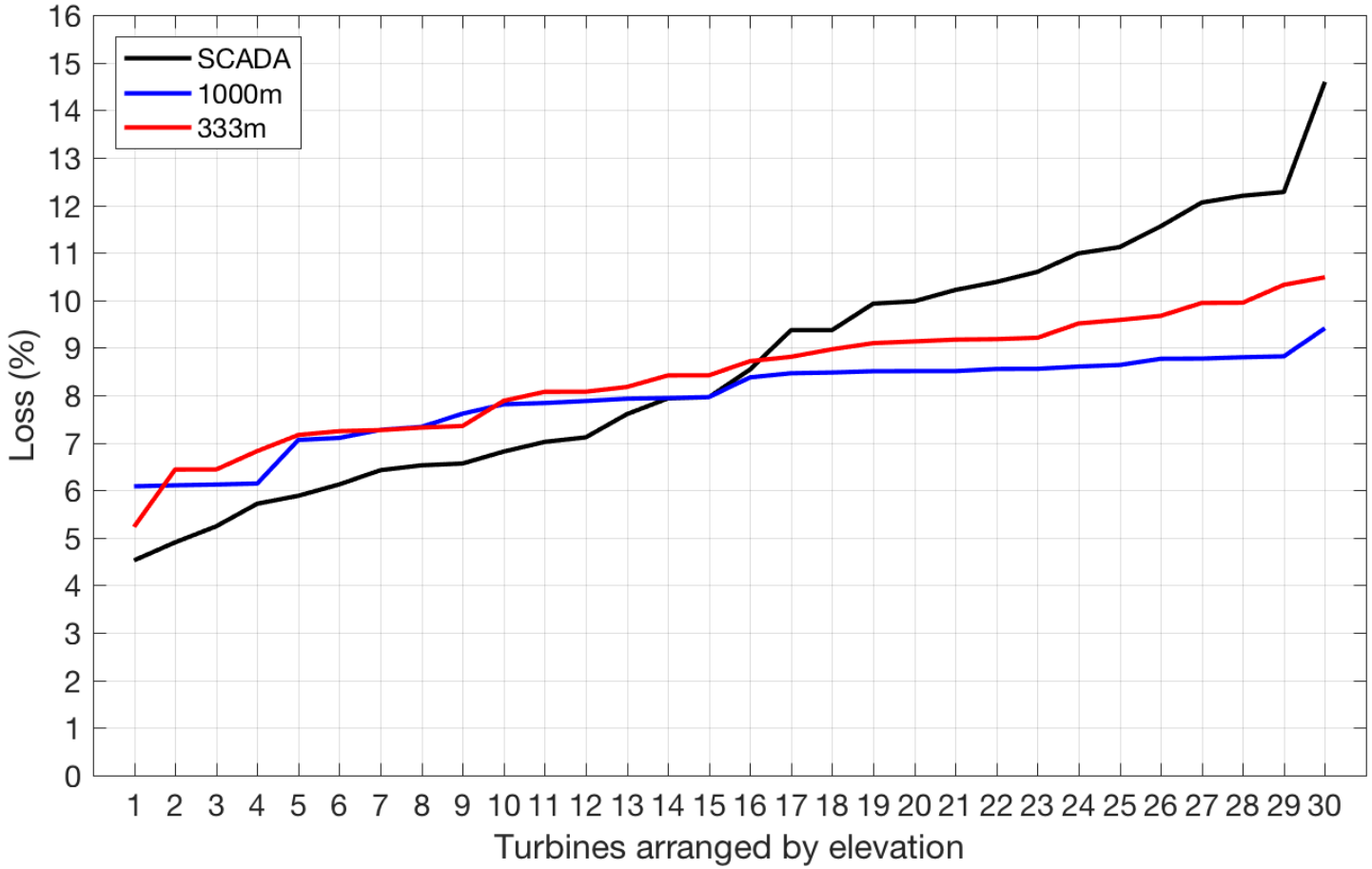
- Individual WTG losses
  - Terrain elevation vs SCADA, WICE 1000m and 333 grid resolution



Validation – WICE model chain: intra-farm variability

- Individual WTG losses
  - Turbines arranged by elevation.

	SCADA	WICE 1000m	WICE 333m
Mean	8.7	7.9	8.4
Max	14.6	9.4	10.5
Min	4.5	6.1	5.2



Validation – WICE model chain: long term correction

- Long term correction approach
  - One year with high resolution model data.
  - Long term reference modelled with coarser model grid resolution.

- Question:
  - How sensitive is the estimated long term production loss to which year that is modelled with high resolution?

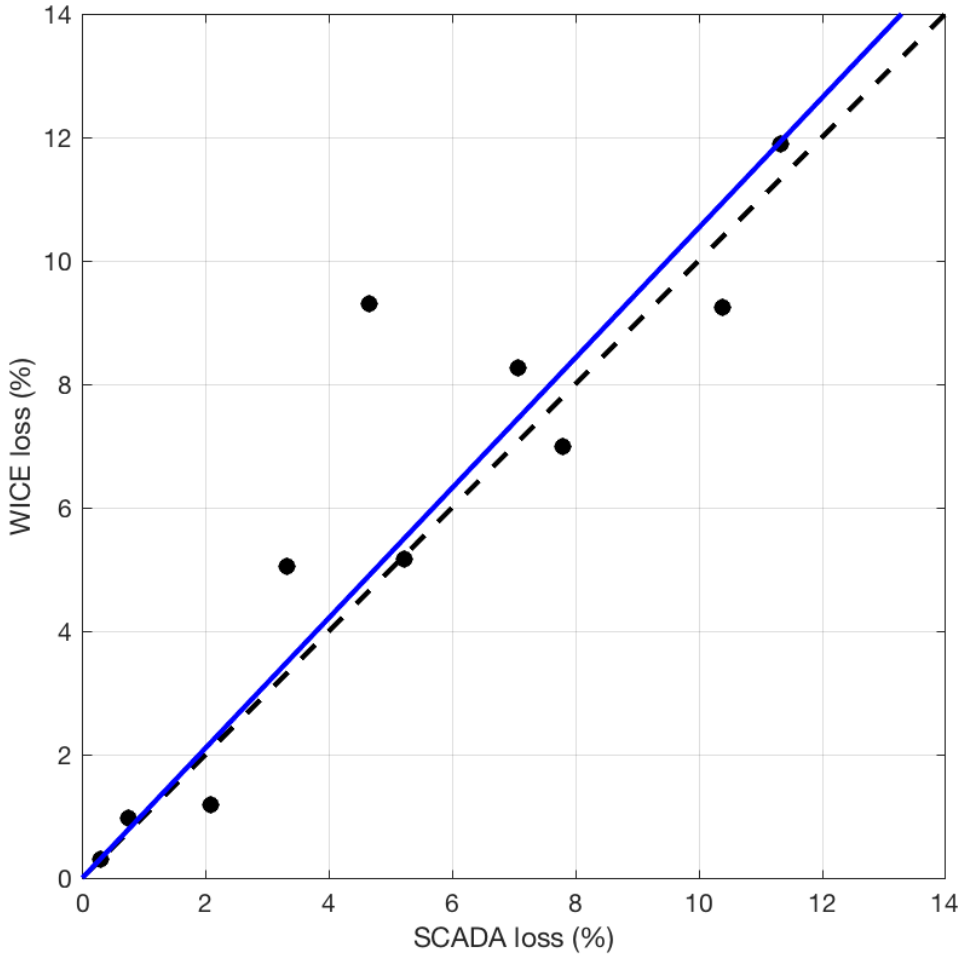
Validation – WICE model chain: long term correction

- 4 years of WRF 1km and long term reference data
- Long term correction one season at a time

Year	1	2	3	4	Loss (%)
LT ref					
High res					
LT corr					7.1
High res					
LT corr					6.6
High res					
LT corr					6.1
High res					
LT corr					6.0
High res					6.2

Validation – WICE model chain: production losses

- Total wind farm losses
  - slope:1.0533
  - std dev: 1.7064
  - corr:0.9062

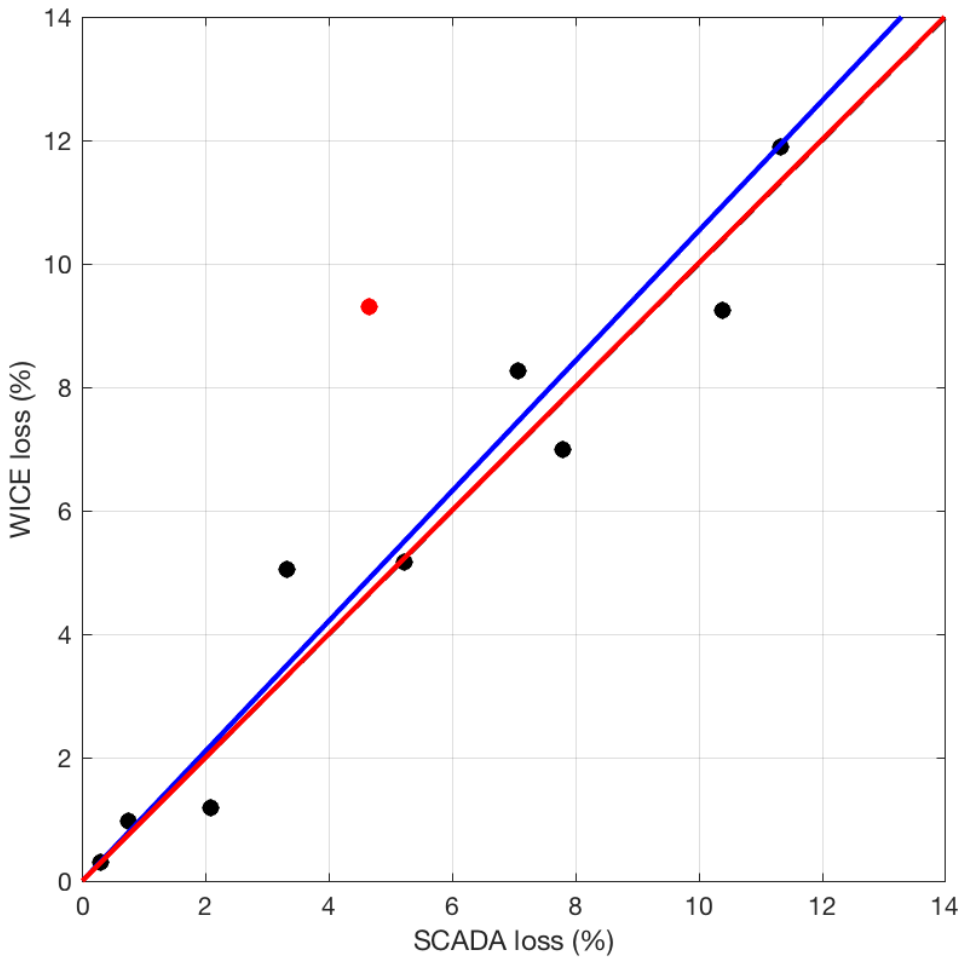


Validation – WICE model chain: production losses

- Total wind farm losses
  - slope:1.0533
  - std dev: 1.7064
  - corr:0.9062

Without outlier:

  - slope:1.0008
  - std dev: 0.9667
  - corr:0.9716



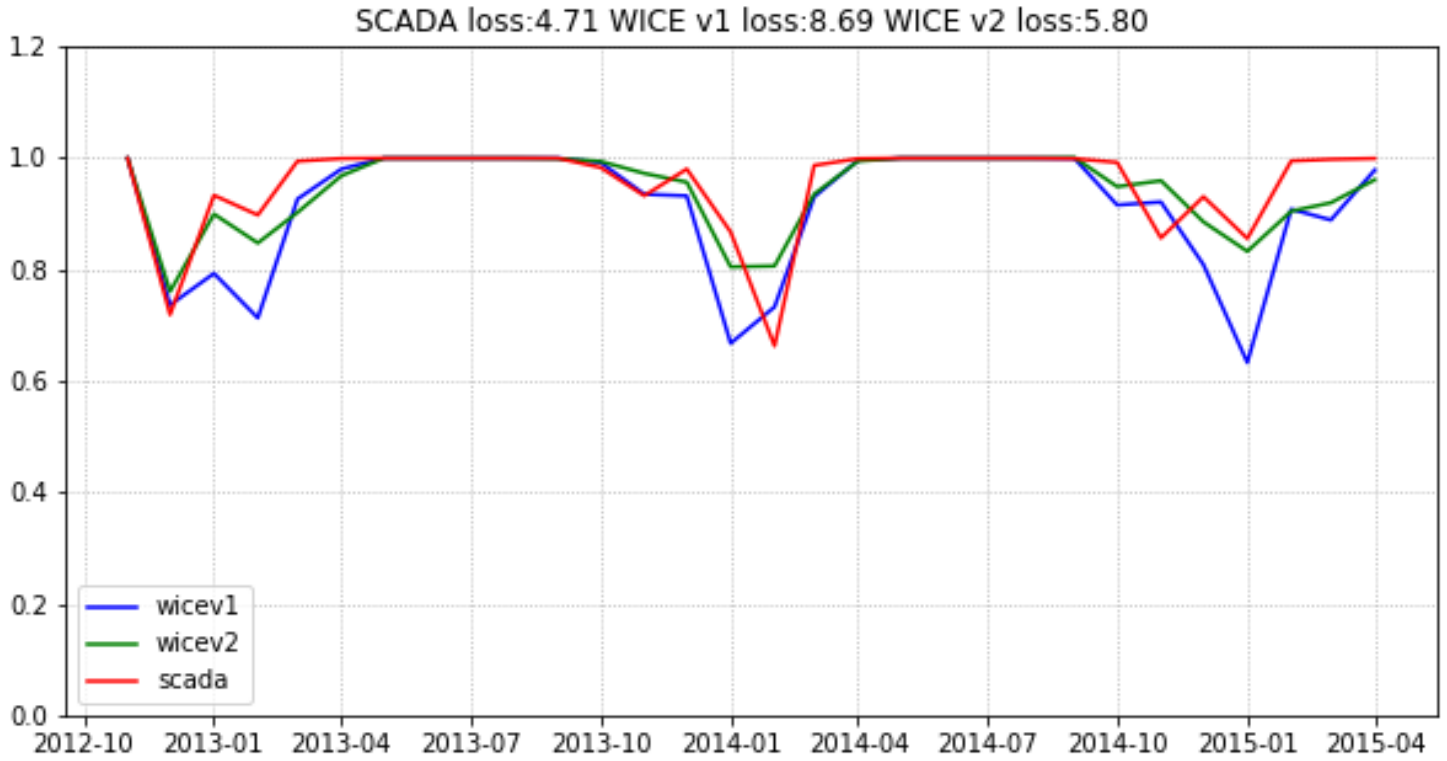
Part 3: Improvements – WICE2.0

WICE 2.0

- What is new
  - Training data from new sites (and more coming soon)
  - Machine learning improvements:
    - ”Extreme Gradient Boosting” (XGBoost) – a tree-based model that typically performs better than neural networks on this kind of multi-dimensional regression problem
    - Refinements to feature selection and feature engineering
  - Updated long term correction method

WICE 2.0

- Icing losses estimated by WICE2.0 are in line with previous DNV GL models
  - Outliers are better represented



Conclusions

Conclusions

- In general a good agreement between modelled and observed wind and temperature
- Capture intra-farm variability quite well
  - a higher model grid resolution is recommended for sites with complex terrain
- Estimated long term losses agree well with observed losses
- Icing losses estimated by WICE2.0 are in line with previous DNV GL models

Thanks for listening

Stefan Söderberg
stefan.soderberg@dnvgl.com

www.dnvgl.com

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