Modeling parameter uncertainty for atmospheric icing
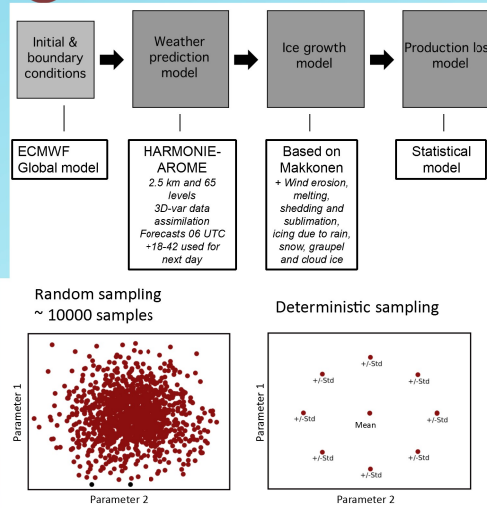
Jennie Molinder[1], Heiner Körnich[2], Esbjörn Olsson[2], Peter Hessling[3]

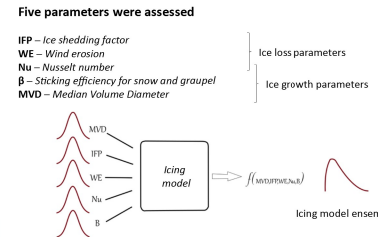[1]Uppsala Unviersity, [2]SMHI, [3]Kapernicus

UPPSALA UNIVERSITET

SMHI

1 Introduction

Next-day forecasts of icing and production losses due to icing on wind turbines are of great value for energy companies, but these forecasts are very uncertain. Uncertainties arise from the initial&boundary conditions of the NWP model, but also from the parametrizations in the different model components. In this work, we address the uncertainties in the icing model component with a Uncertainty Quantification method, namely Deterministic Sampling. With this method, we create an ensemble where the uncertainty of model parameters will be sampled in an optimized manner, allowing for very small ensemble sizes.
This method is verified against an ensemble with random sampling containing 10,000 members.

2 Modelling chain

Initial & boundary conditions → Weather prediction model → Ice growth model → Production loss model

ECMWF Global model

HARMONIE-AROME
2.5 km and 65 levels
3D-var data assimilation
Forecasts 06 UTC
+18-42 used for next day

Based on Makkonen
+ Wind erosion, melting, shedding and sublimation, icing due to rain, snow, graupel and cloud ice

Statistical model

Random sampling ~ 10000 samples

Deterministic sampling

+/-Std   +/-Std
+/-Std   Mean   +/-Std
+/-Std   +/-Std

Uncertain parameters in the icing model

Five parameters were assessed

IFP – Ice shedding factor
WE – Wind erosion   } Ice loss parameters
Nu – Nusselt number
β – Sticking efficiency for snow and graupel } Ice growth parameters
MVD – Median Volume Diameter

MVD, IFP, WE, Nu, B → Icing model → $f_{(MVD,IFP,WE,Nu,B)}$ → Icing model ensemble
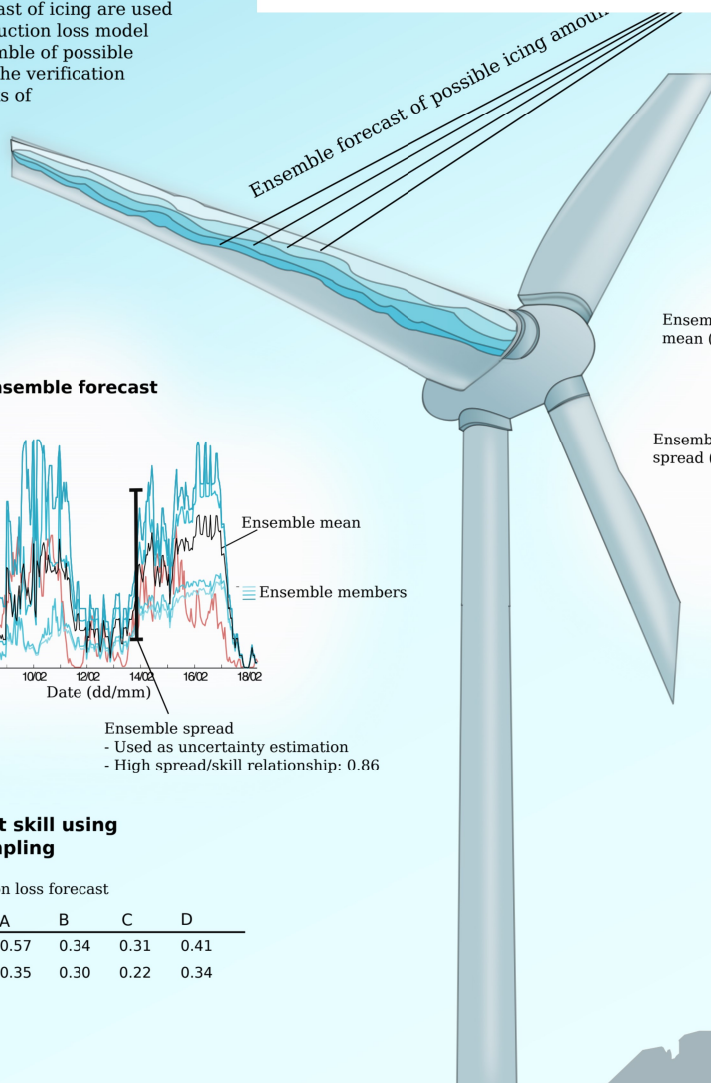
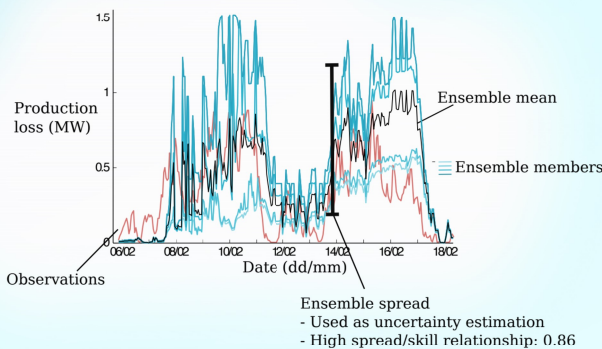**Deterministic sampling for 5 uncertain parameters**

- Ensemble members with **perturbation size** and **weights** for the control and perturbed members
- 9 member ensemble for 5 uncertain parameter
- To describe mean, standard deviation, skewness and kurtosis of uncertain parameters

Derivations are in Molinder et al. (2019)

3 Results

The ensemble forecast of icing are used as input to the production loss model generating an ensemble of possible production losses. The verification is based on 10 weeks of measurements from 4 sites.
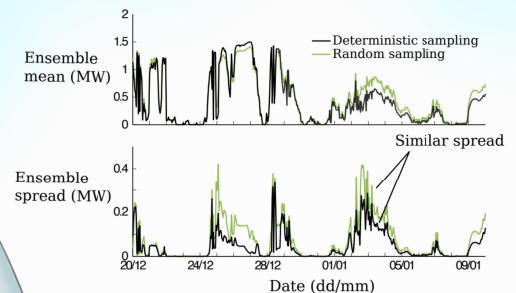
Ensemble forecast of possible icing amount

Example:
Production loss ensemble forecast

Production loss (MW)

Ensemble mean

Ensemble members

Observations

Ensemble spread
- Used as uncertainty estimation
- High spread/skill relationship: 0.86

Improved forecast skill using deterministic sampling

RMSE of production loss forecast

Site	A	B	C	D
Control	0.57	0.34	0.31	0.41
Ensemble mean	0.35	0.30	0.22	0.34

4 Evaluation of the method

Is deterministic sampling a reliable method?

Ensemble mean (MW)

Ensemble spread (MW)

Deterministic sampling
Random sampling

Similar spread

Yes - The spread and mean forecast of the deterministic sampling ensemble members is close to a 10000 random sampling ensemble.

Conclusions

Ensemble forecasting provide uncertainty estimations and improves the skill of icing forecasts and icing related production losses for wind turbines. With deterministic sampling the number of ensemble members can be optimized.

References: Makkonen, L.: Models for the growth of rime, glaze icicles and wet snow on structures, Philosophical Transactions of The Royal SocietyLond., 358, 2913–2039, https://

Molinder, J., H. Körnich, E. Olsson and P. Hessling, 2019: The use of uncertainty quantification for the empirical modeling of wind turbine icing. J. Appl. Meteorol. Climatol., vol. 58, 2019-2031.

Contact: heiner.kornich@smhi.se

Swedish Energy Agency