Probabilistic forecasting of wind power production losses due to icing

presented at Winterwind 2019

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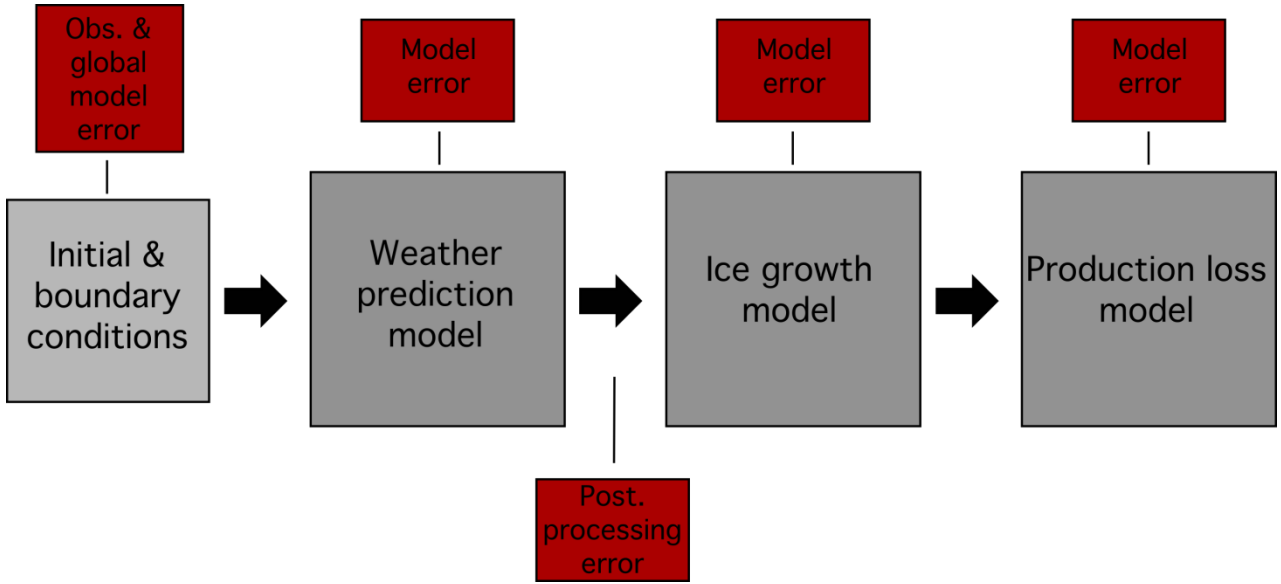
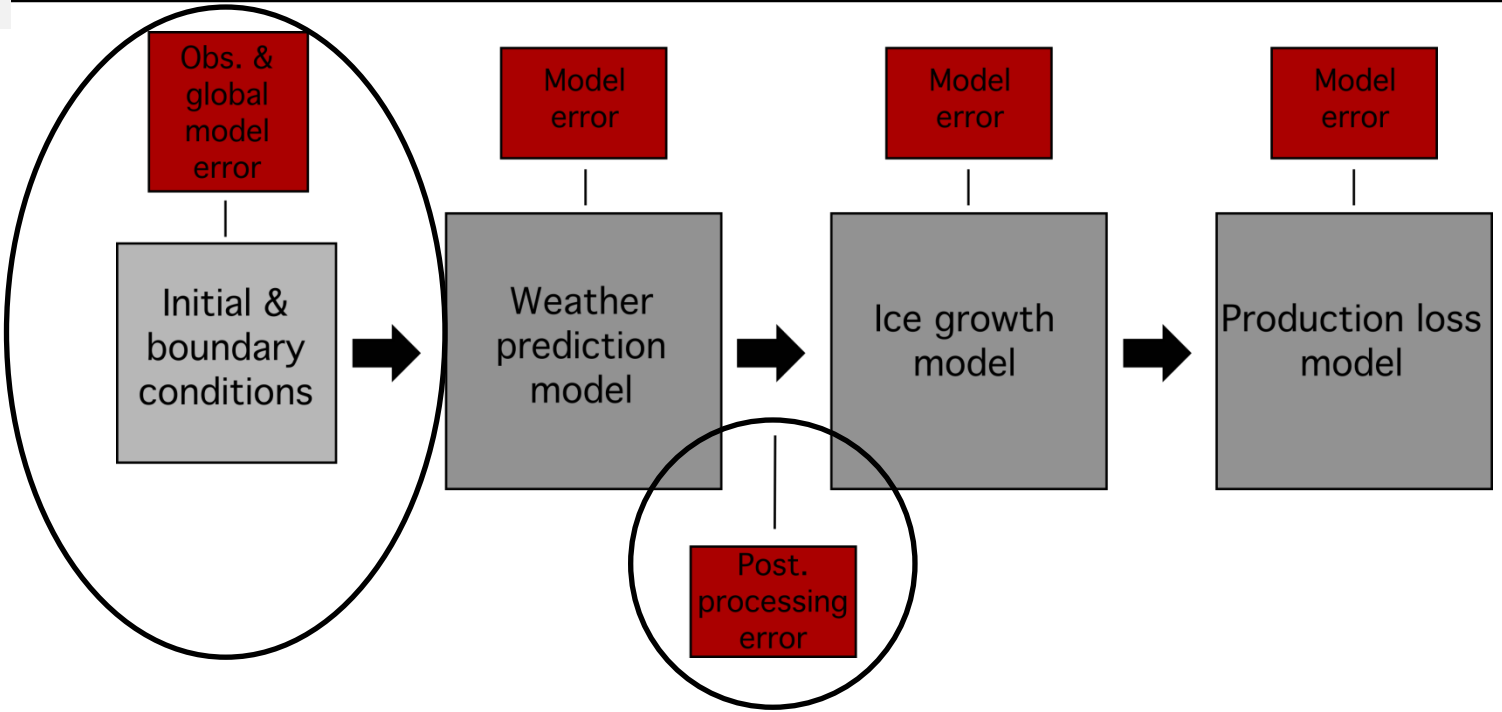
Uncertainties in the modelling chain



Uncertain icing related production loss forecasts for wind turbines

$\Rightarrow$ Uncertain next-day production forecasts

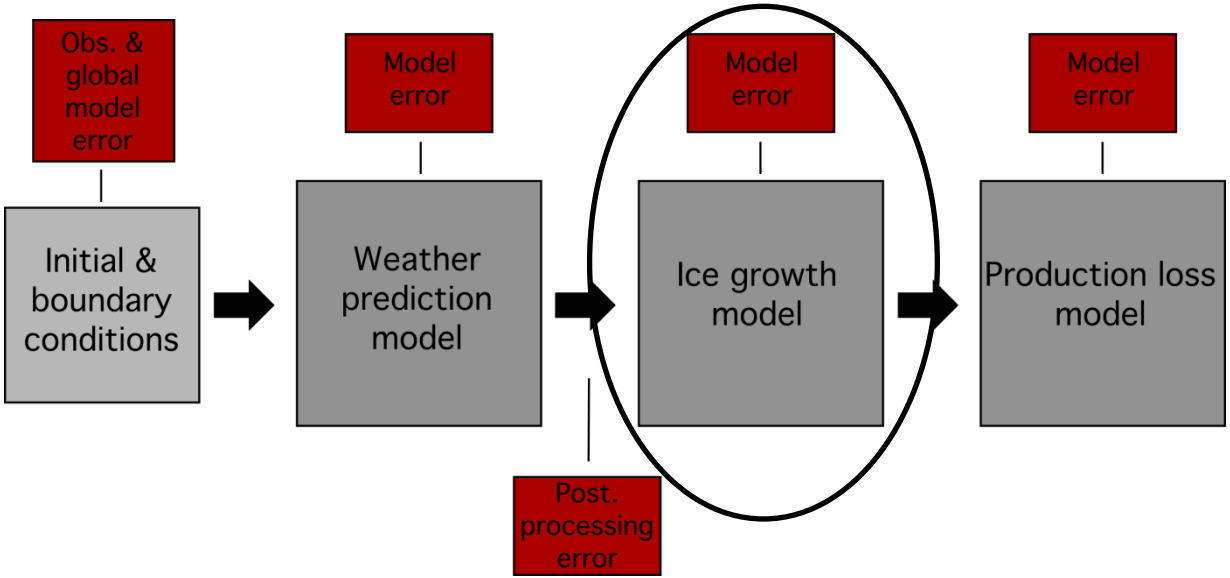
Uncertainties in the modelling chain



HarmonEPS with ECMWF ENS boundary conditions
Neighbourhood method

- Tested on a two-week period with icing

Uncertainties in the modelling chain

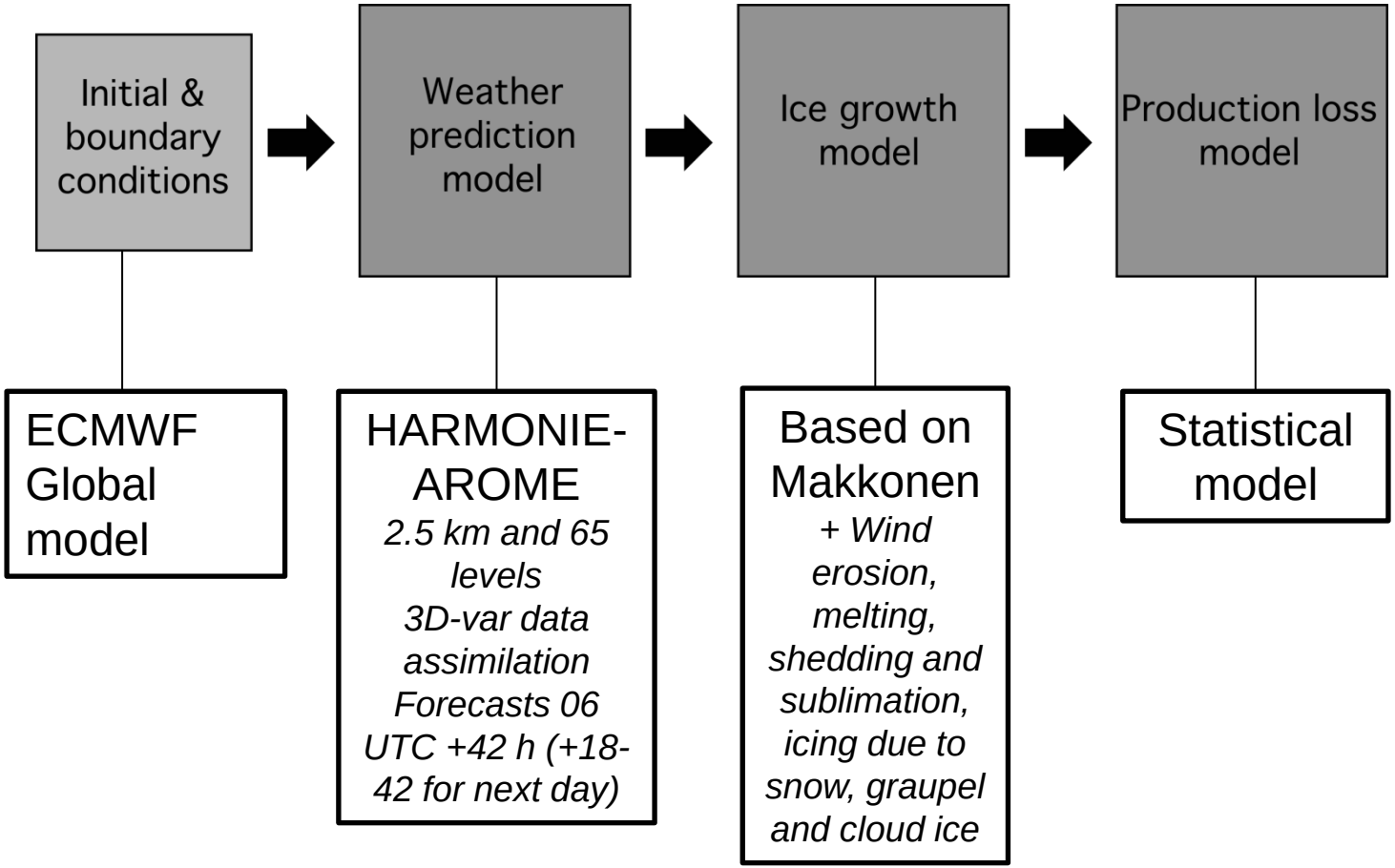


Ice model ensemble based on deterministic sampling

Tested on two periods:

- Dec 2013 to Feb 2014
- Sep 2014 to Jan 2015

Modelling chain



Initial condition NWP ensemble and Neighbourhood method

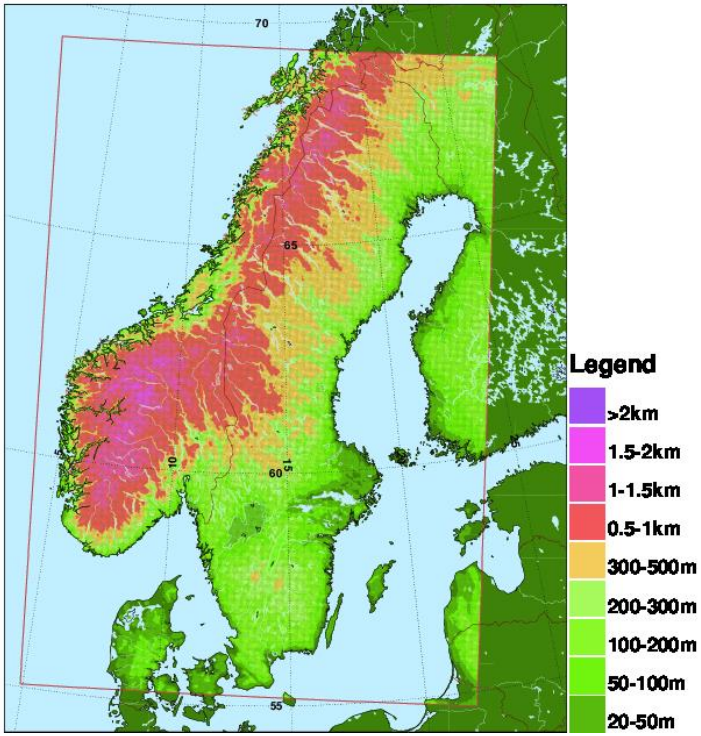
- Two-week period
- 10 sites with met. obs.
- 3 sites with production data

Icing model ensemble

- Two winter periods:
  1. December 2013 to February 2014
  2. September 2014 to January 2015
- 4 wind parks with production data

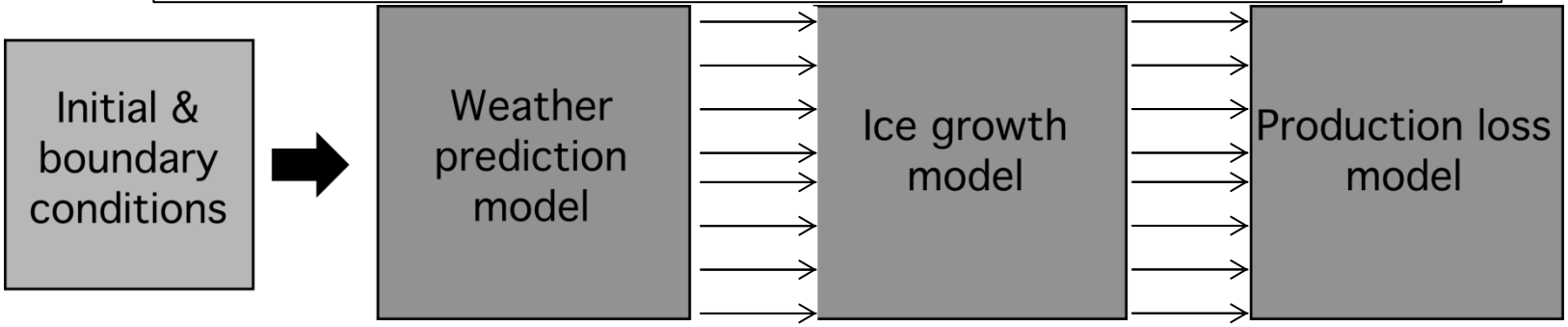
(Icing observations – not reliable)

Model domain

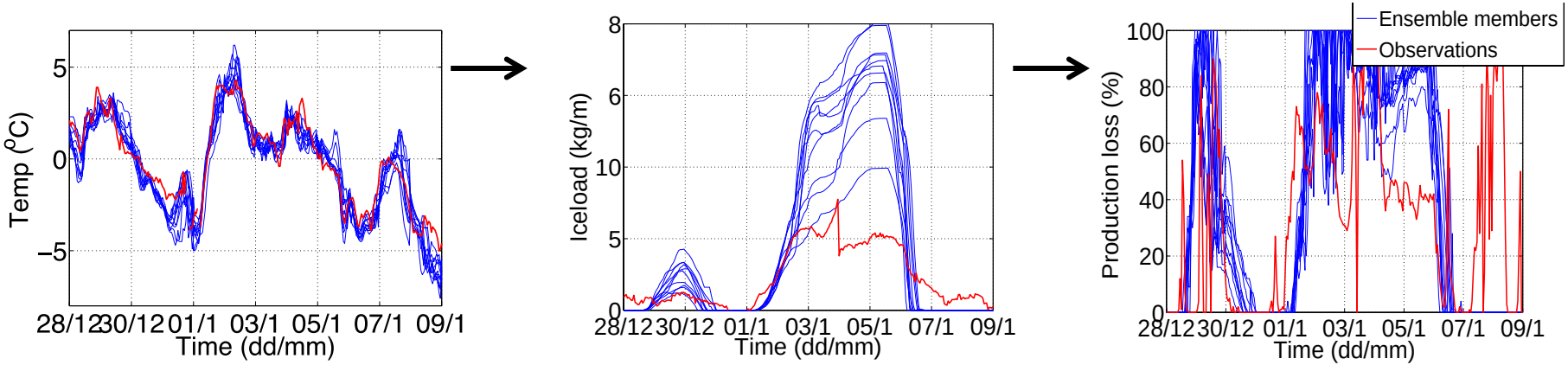


Method: Ensemble forecasting

Forecast 06 +18-42 hours generates a forecast for the next day



Two week period, 2011-2012, Site B



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Neighbourhood method

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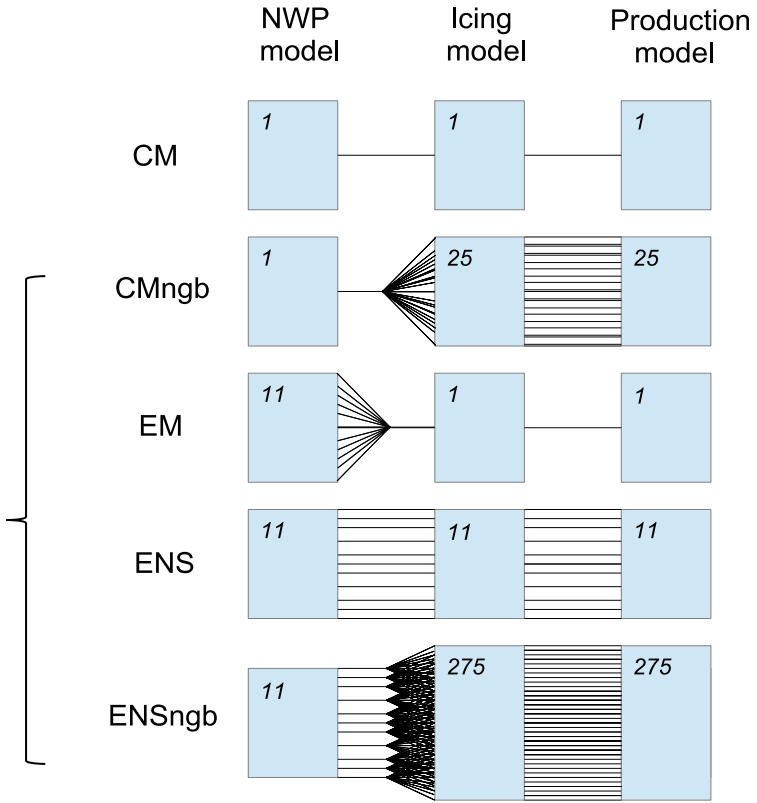
- An approach to take representation uncertainties in to account
- Treats neighbouring grid points (5x5, 25 grid points) as equally likely forecasts

Different approaches

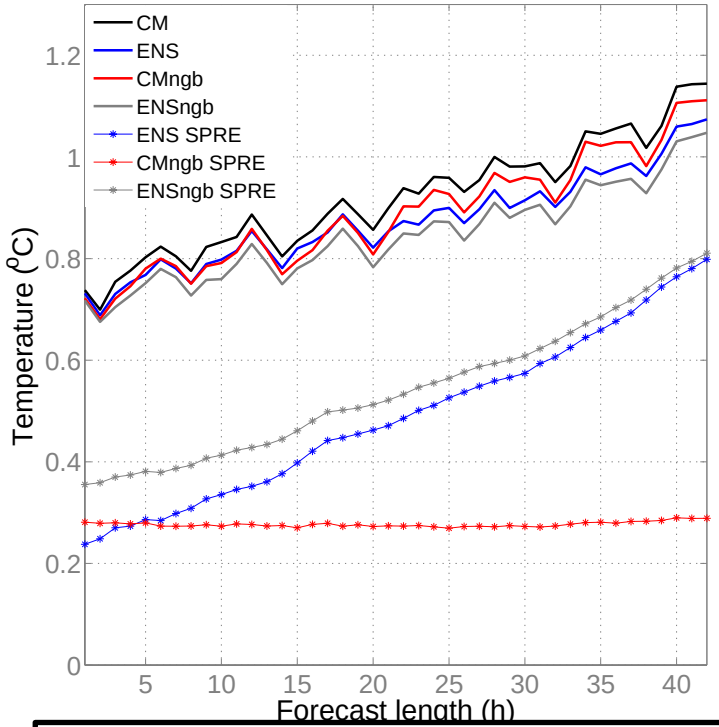
Deterministic forecast

Probabilistic approaches



ENS and Neighbourhood method

- Improved forecast



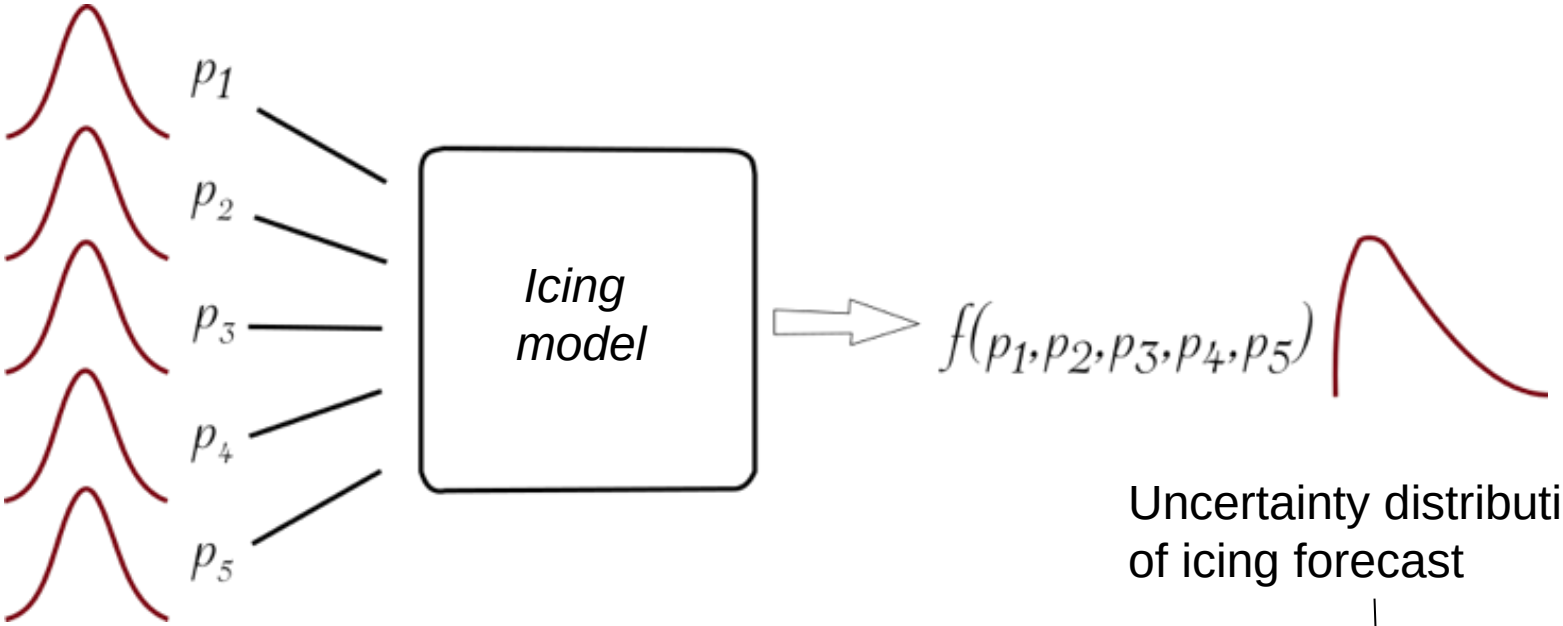
Reduced unbiased RMSE for forecasted met. parameters

Reduced unbiased RMSE production loss forecast

Combination	Prod. loss (%)
CM	26
ENS	21
CMngb	23
ENSngb	21

Spread/skill relationships production loss forecast:
ENS: 0.5
ENSngb: 0.7

Multi-physics icing model ensemble



Uncertain parameters
of the model with estimated
uncertainty distribution

Uncertainty distribution
of icing forecast

Production loss forecast

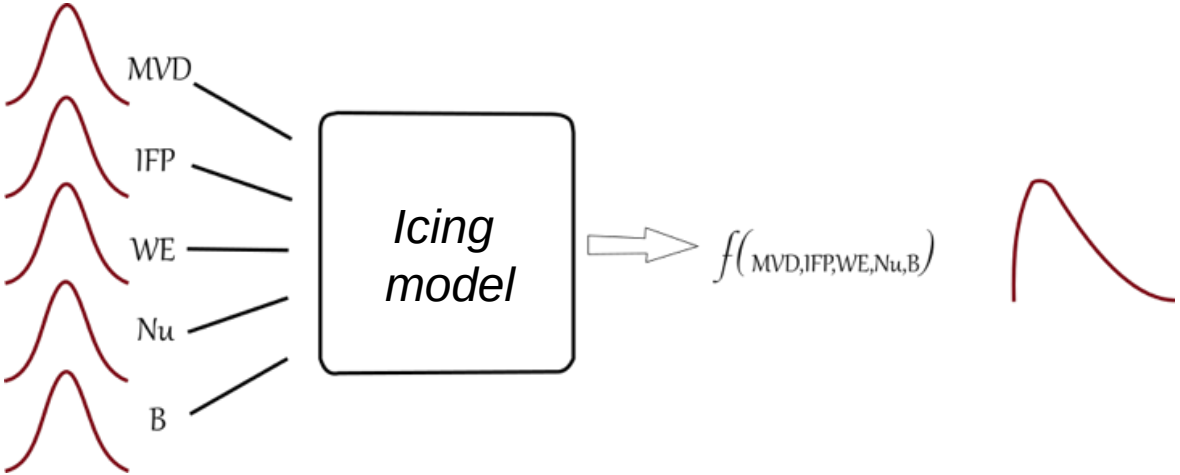
Uncertain parameters in the icing model

Five parameters based on literature studies

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

Ice loss parameters

Ice growth parameters

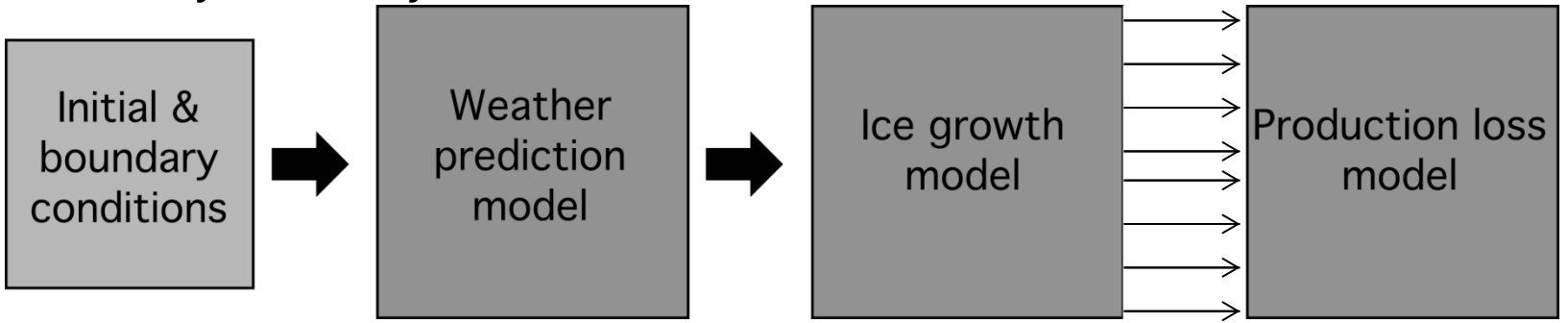


Using deterministic sampling instead of random sampling

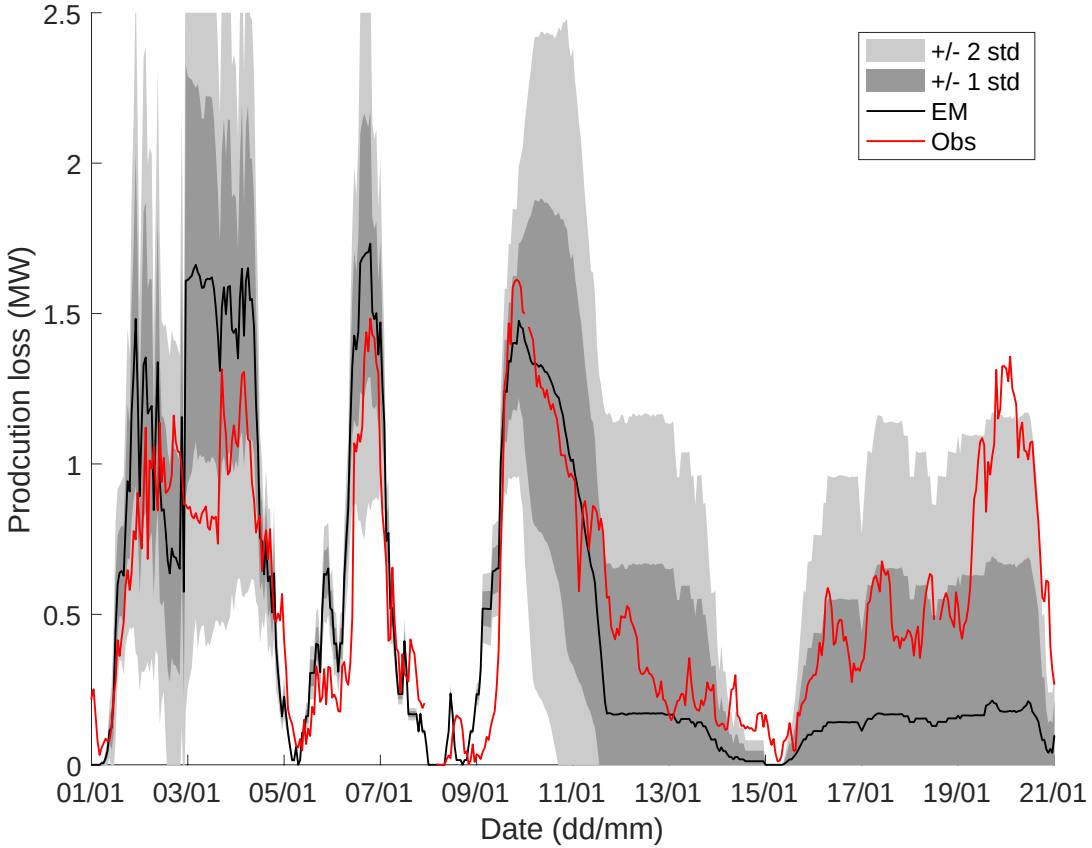
Deterministic sampling for 5 uncertain parameters

- Specific sampling points from the uncertainty distribution are derived
- 9 member ensemble (compared to ~10000 req. using random sampling)
  - Less computational cost
  - Easy sensitivity tests

Random sampling and deterministic sampling results in similar ensemble mean and mean spread



Results – Probabilistic forecast



The uncertainty for each forecast step can be presented using ensemble std/spread

Results – Reduced forecast error

RMSE production loss (MW)

Period 1, 2013-2014

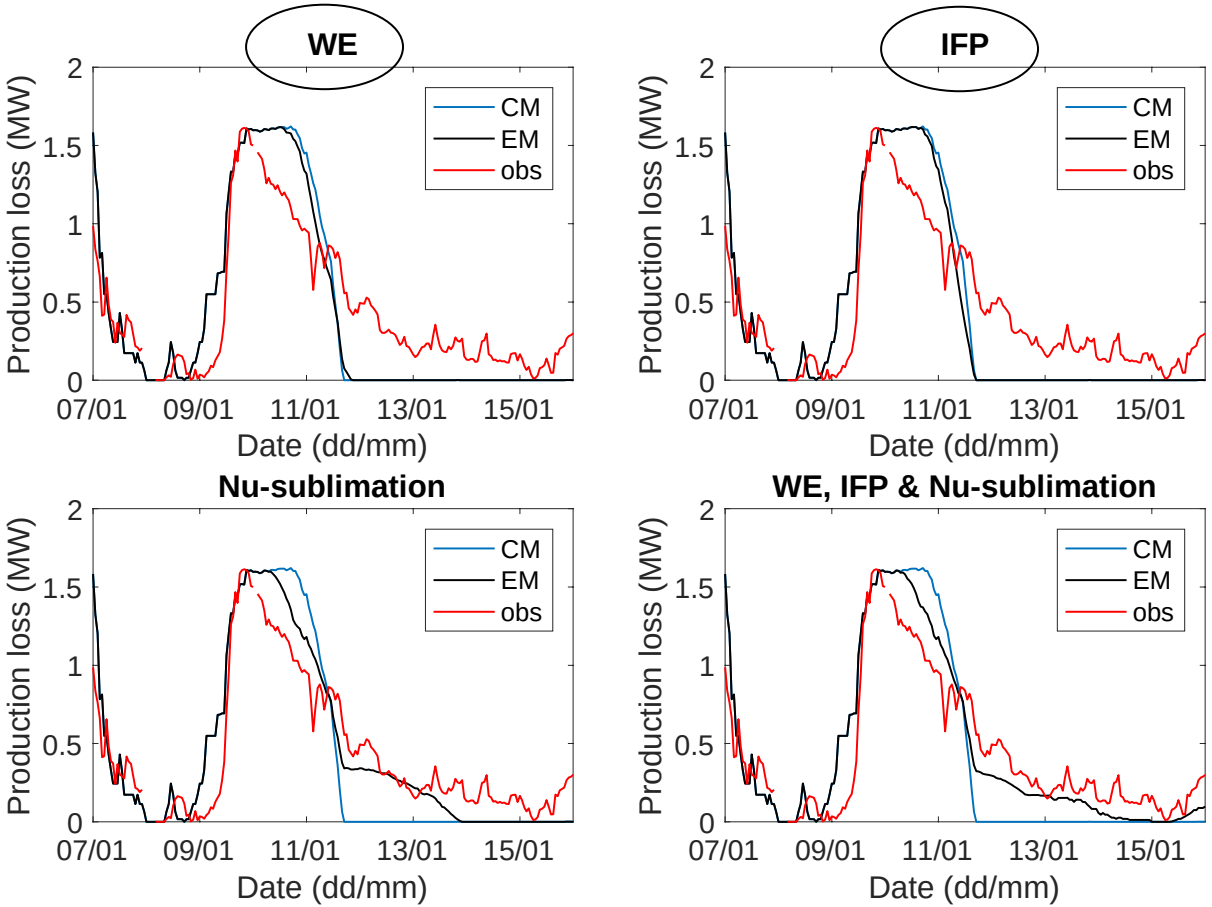
Site	A	B	C	D
CM	0.52	0.48	0.33	0.44
Det. sampling (Ensemble mean)	0.42	0.45	0.29	0.42

Period 2, 2014-2015

Site	A	B	C	D
CM	0.44	0.38	0.40	0.42
Det. sampling (Ensemble mean)	0.33	0.31	0.31	0.32

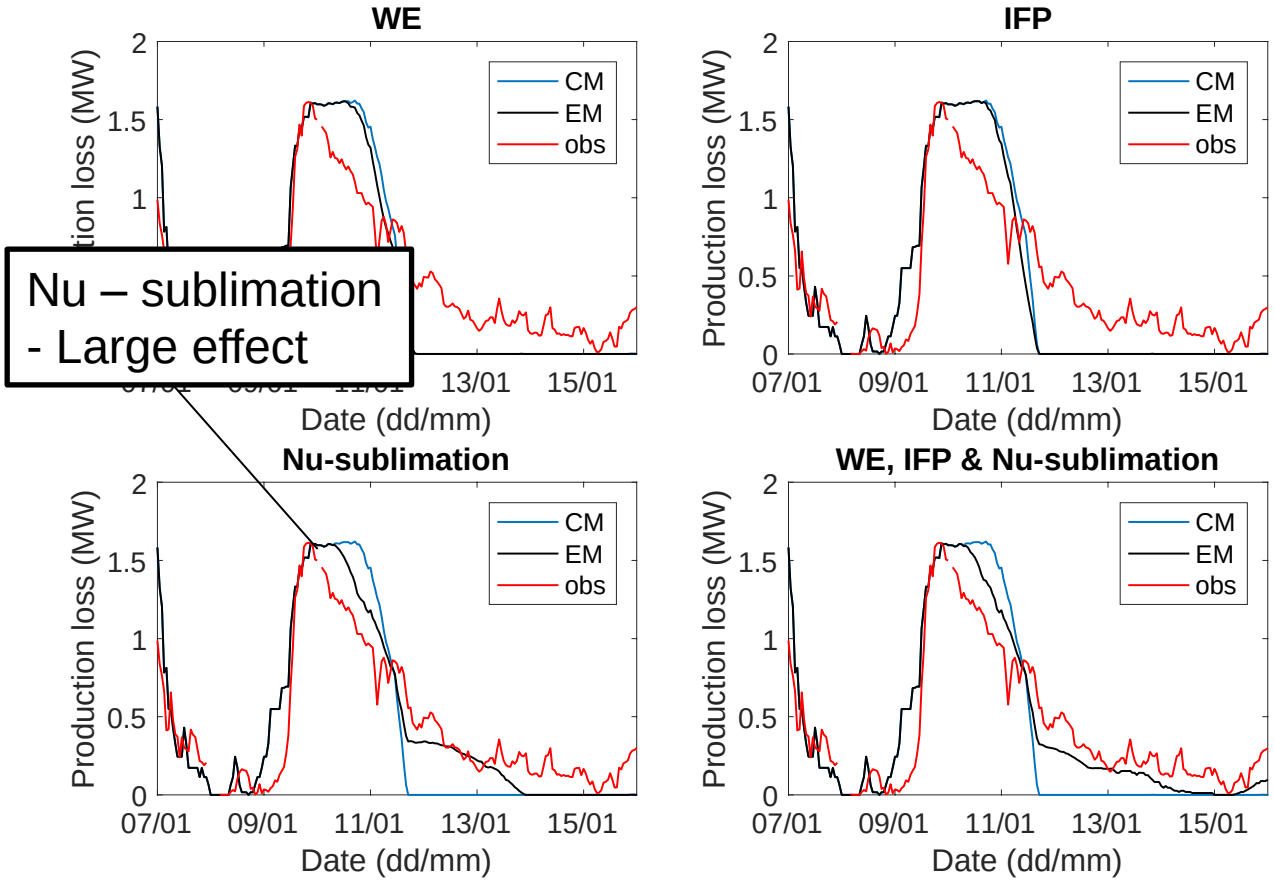
RMSE on average reduced between 5 and 25%

Sensitivity analysis

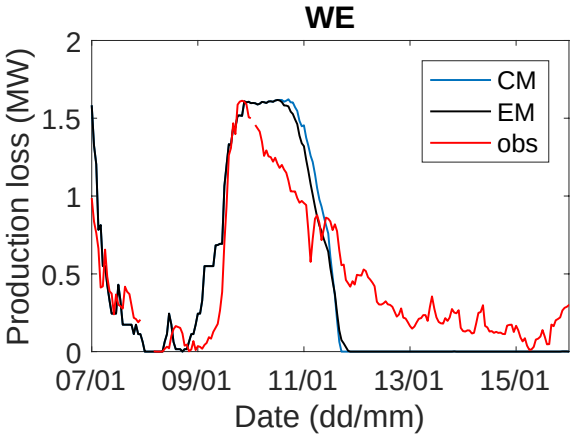


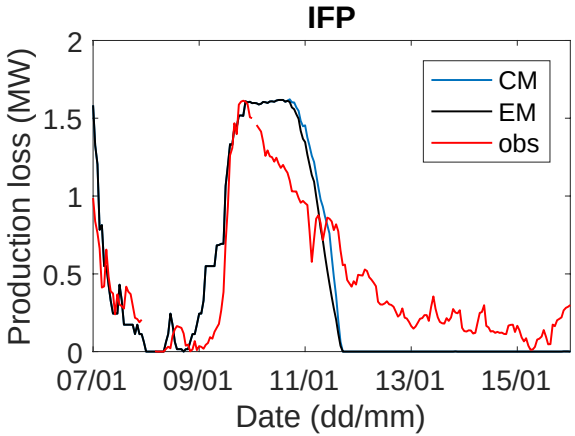
IFP & WE
- Small effect

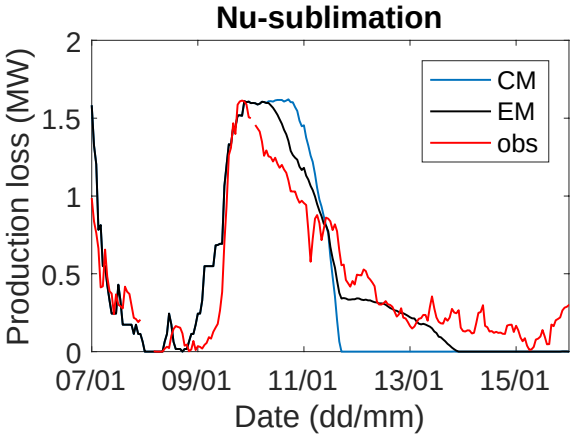
Sensitivity analysis

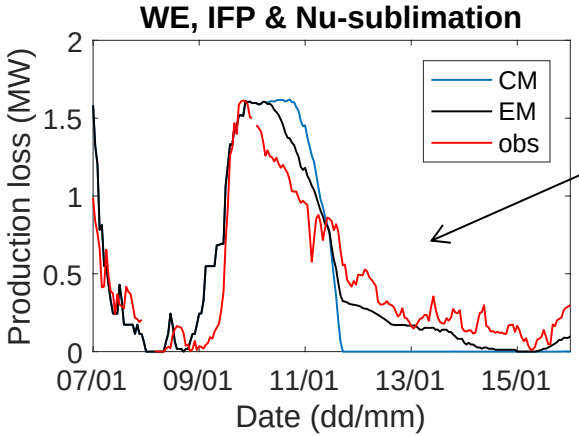


Sensitivity analysis









Best forecast when all parameters are included in the ensemble

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Summary and conclusions

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- Probabilistic forecast can be used to lower the forecast error for wind energy production in cold climates
- Three uncertainty quantification methods where tested - Initial condition NWP ensemble, a Neighbourhood method, and an Icing model ensemble
- The resulting ensemble mean forecasts improves forecast skill
- The forecast spread can be used as an estimation of forecast uncertainty
- Best results when including all uncertain parameters in the icing model ensemble forecast