Validation of various approaches to forecasting production losses due to icing

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Introduction

- Growing need for accurate forecasts for icing related losses
- Wind energy production estimates for wind farms, traders, and national grid providers
- Predict energy imbalances and minimize economic costs in energy trading
- Time scales: intra-day and day-ahead

Methods

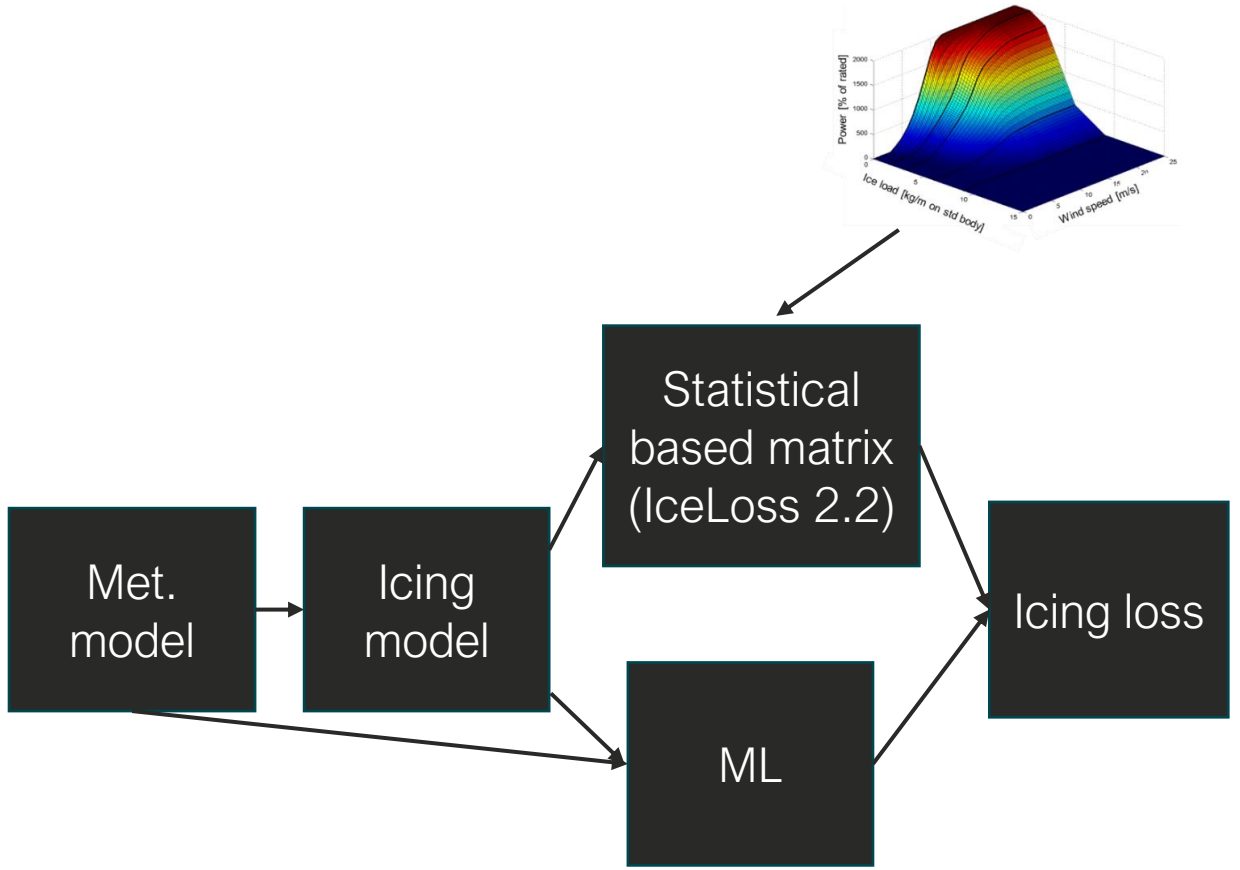
- Generating icing forecasts
  - Statistical based models (IceLoss 2.2)
  - Machine learning (ML) models

Data from high-resolution meteorological models is needed as input

We deliver:

Operational ice loss forecasts (hourly resolution, updated forecast every 6 hour)

SCADA-tuned forecasts (updated every hour)



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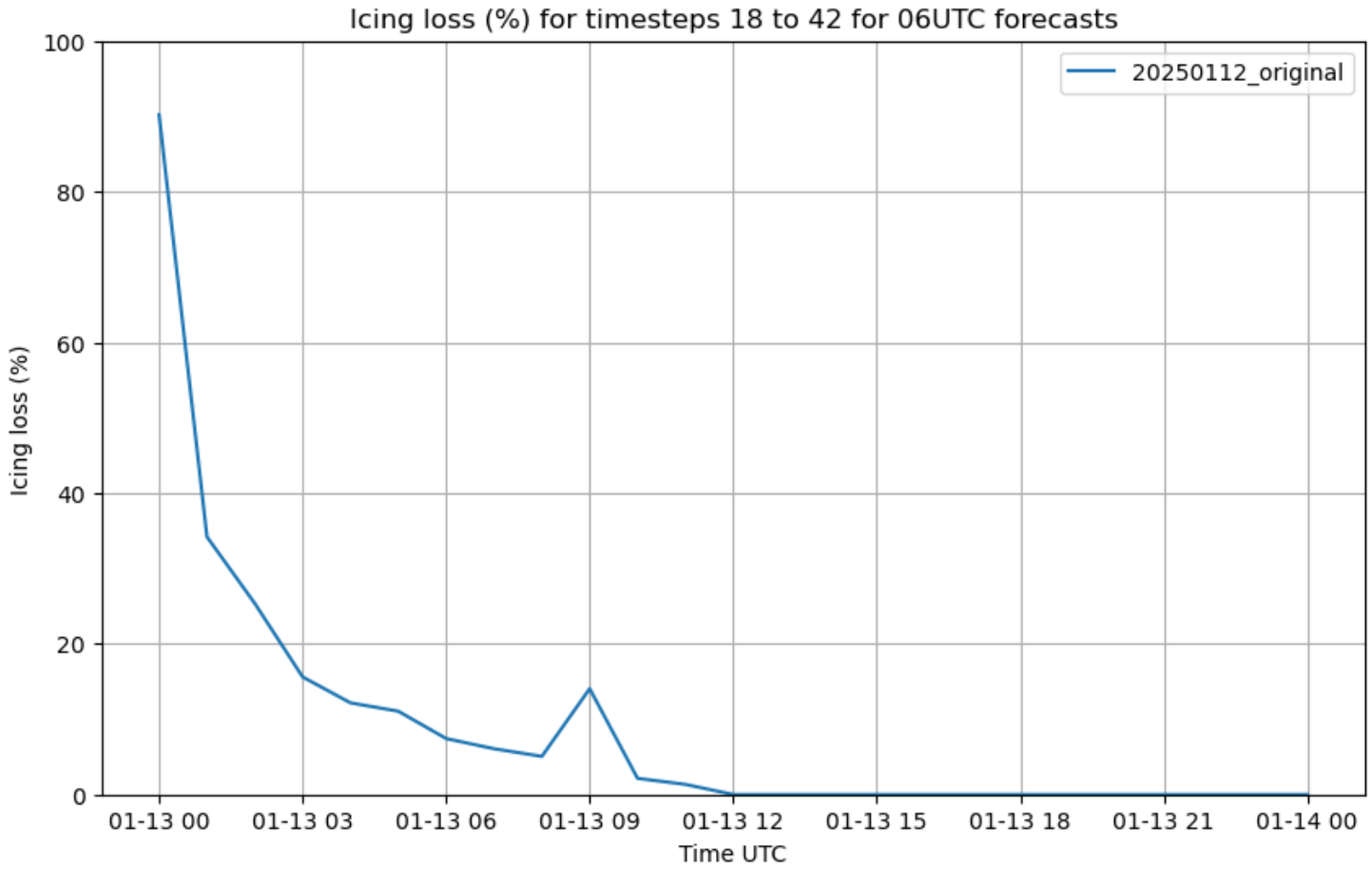
Methods – The model-based forecast

- Input data needed:
  - Turbine coordinates
  - Turbine base elevation
  - Turbine type, power and RPM curve

Day-ahead forecast for wind farm in northern Sweden



- Deterministic forecast

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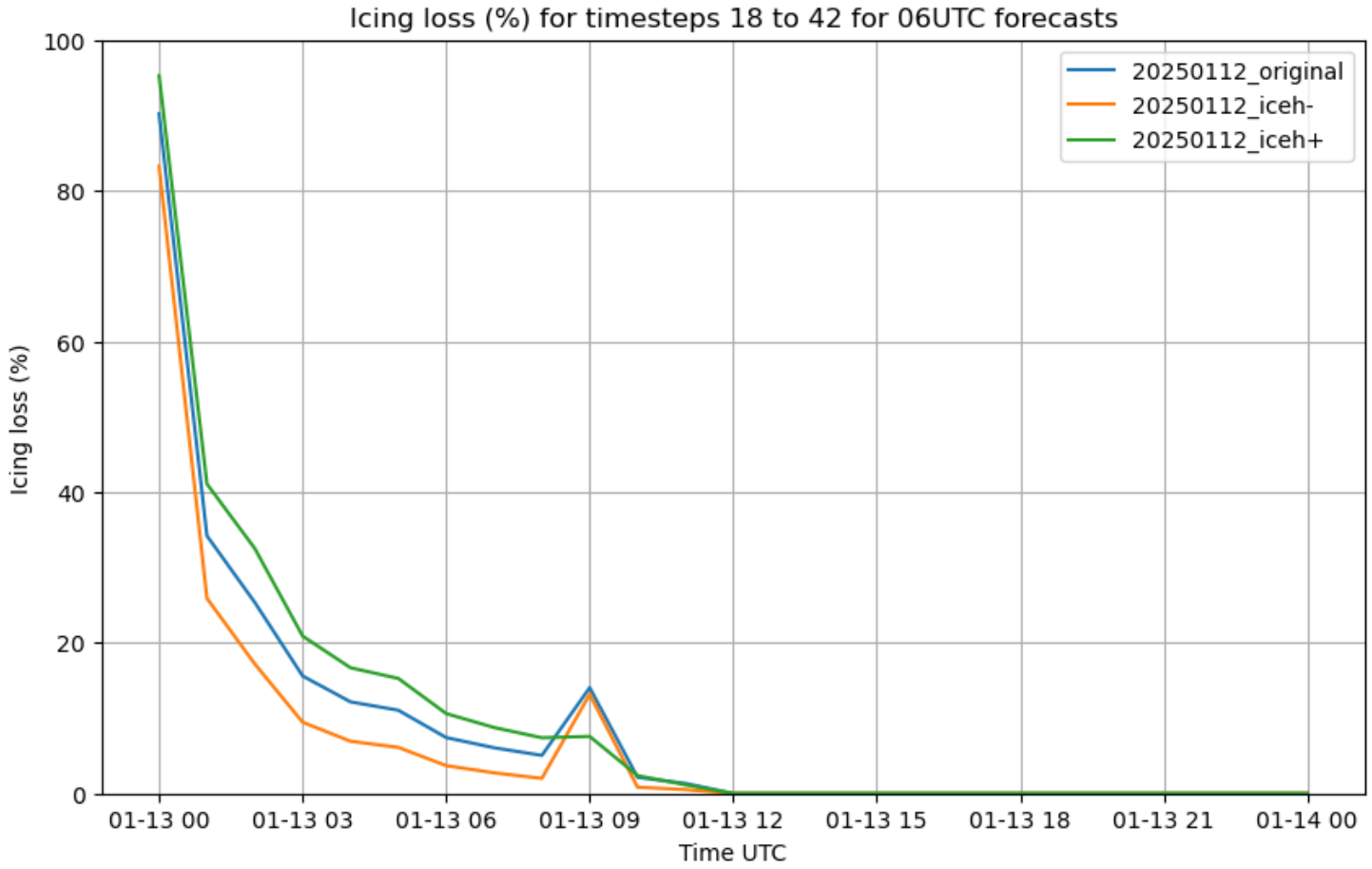

- Deterministic forecast
- Adding ensemble members to address forecast uncertainty

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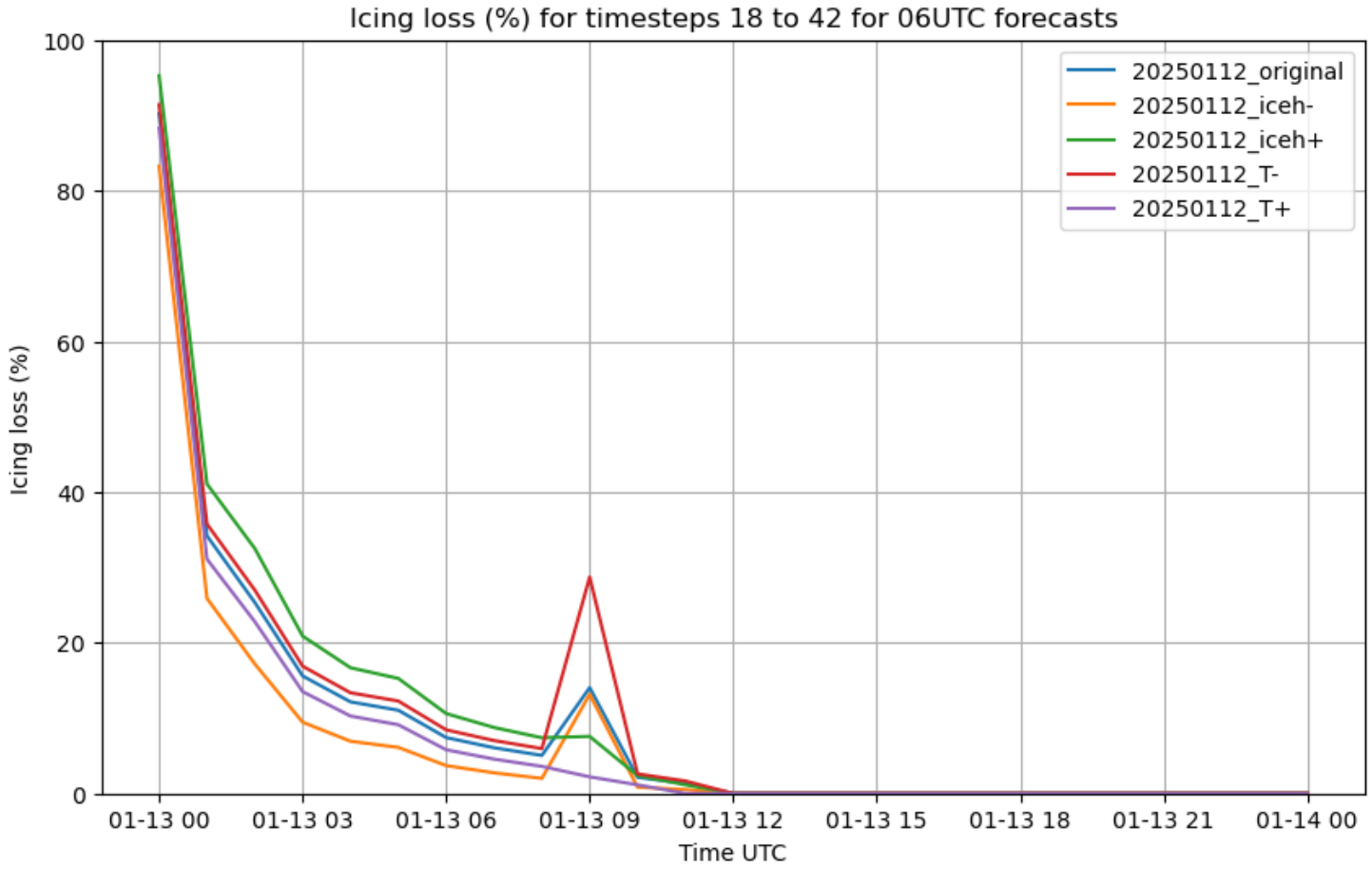

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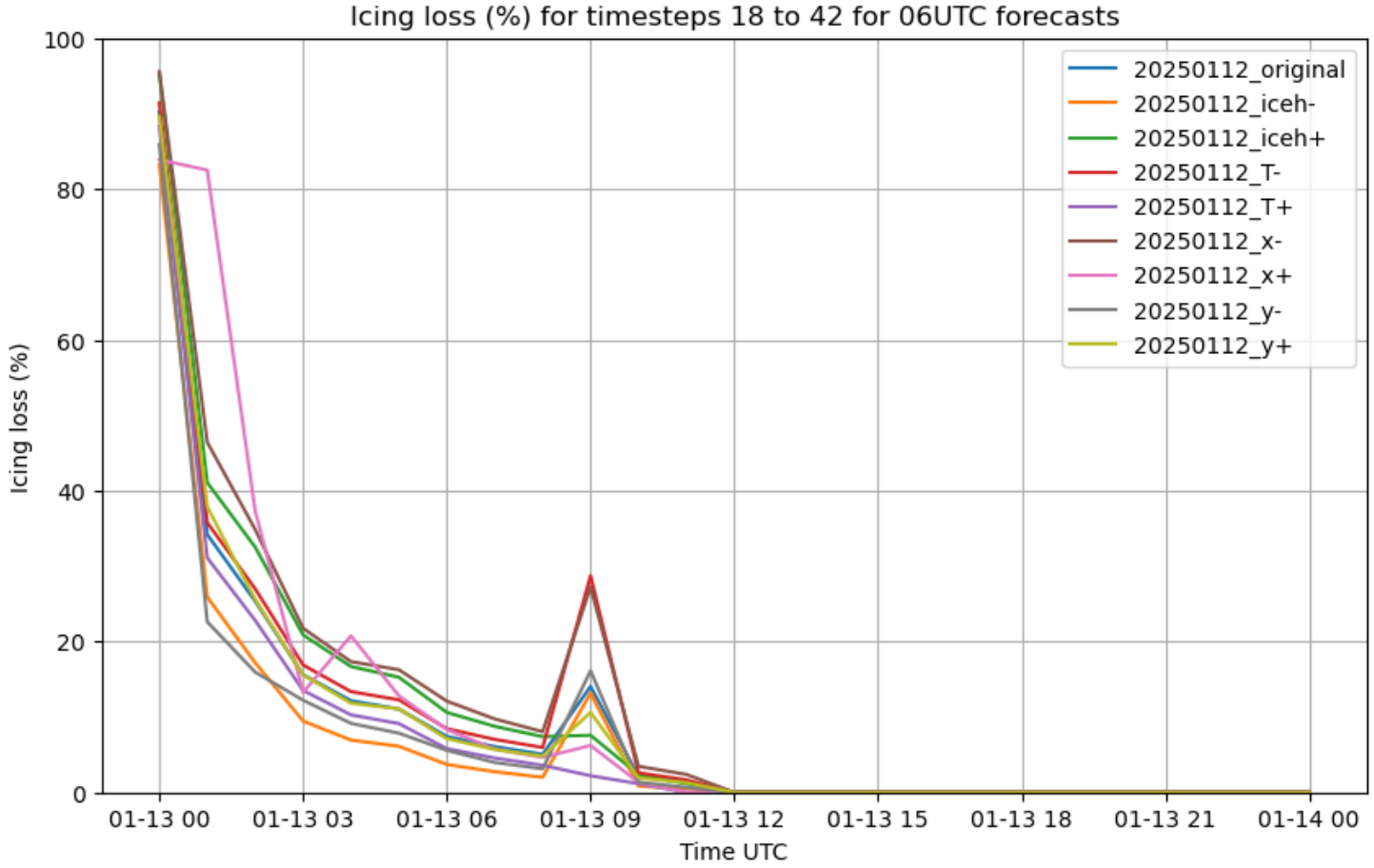

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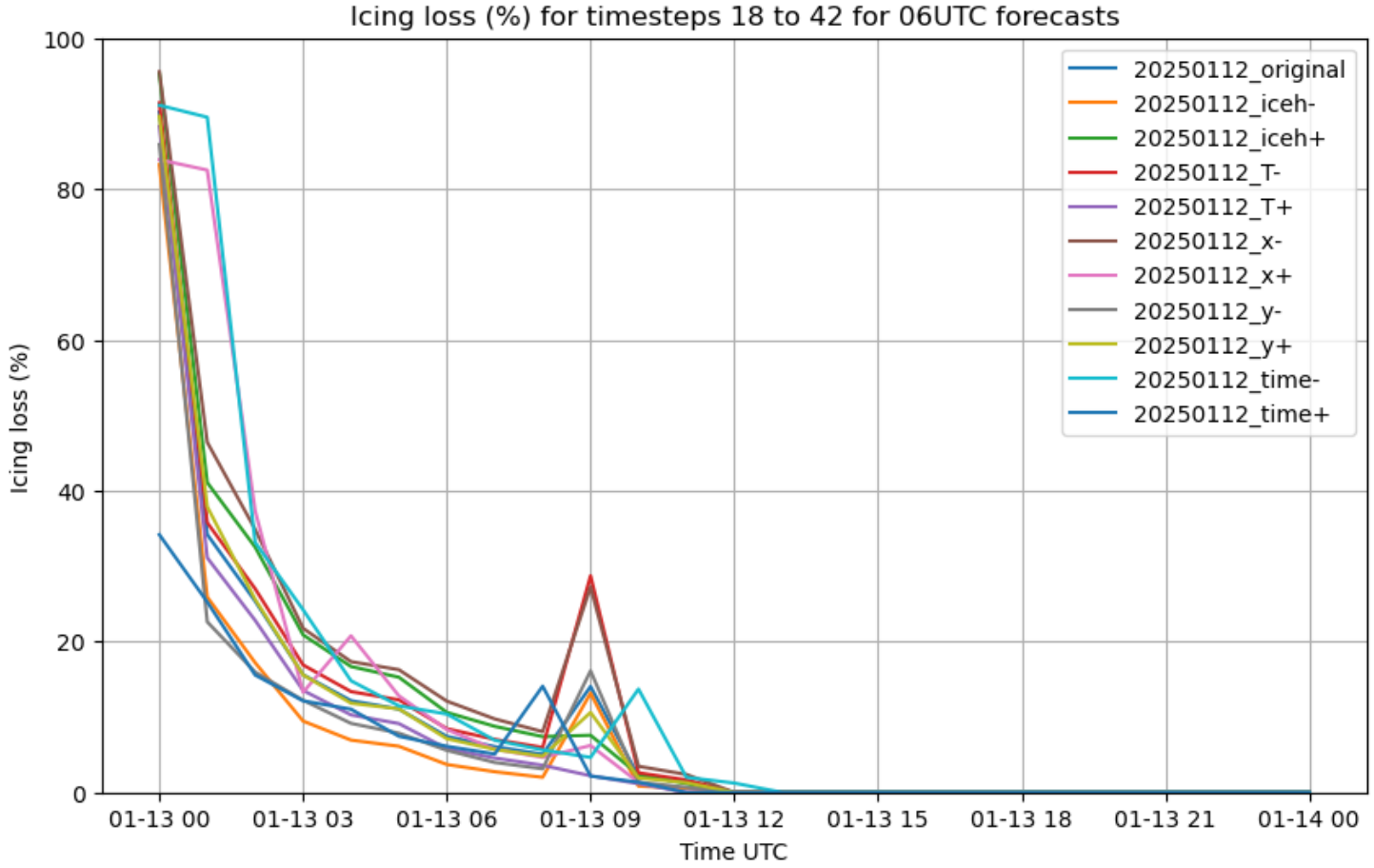

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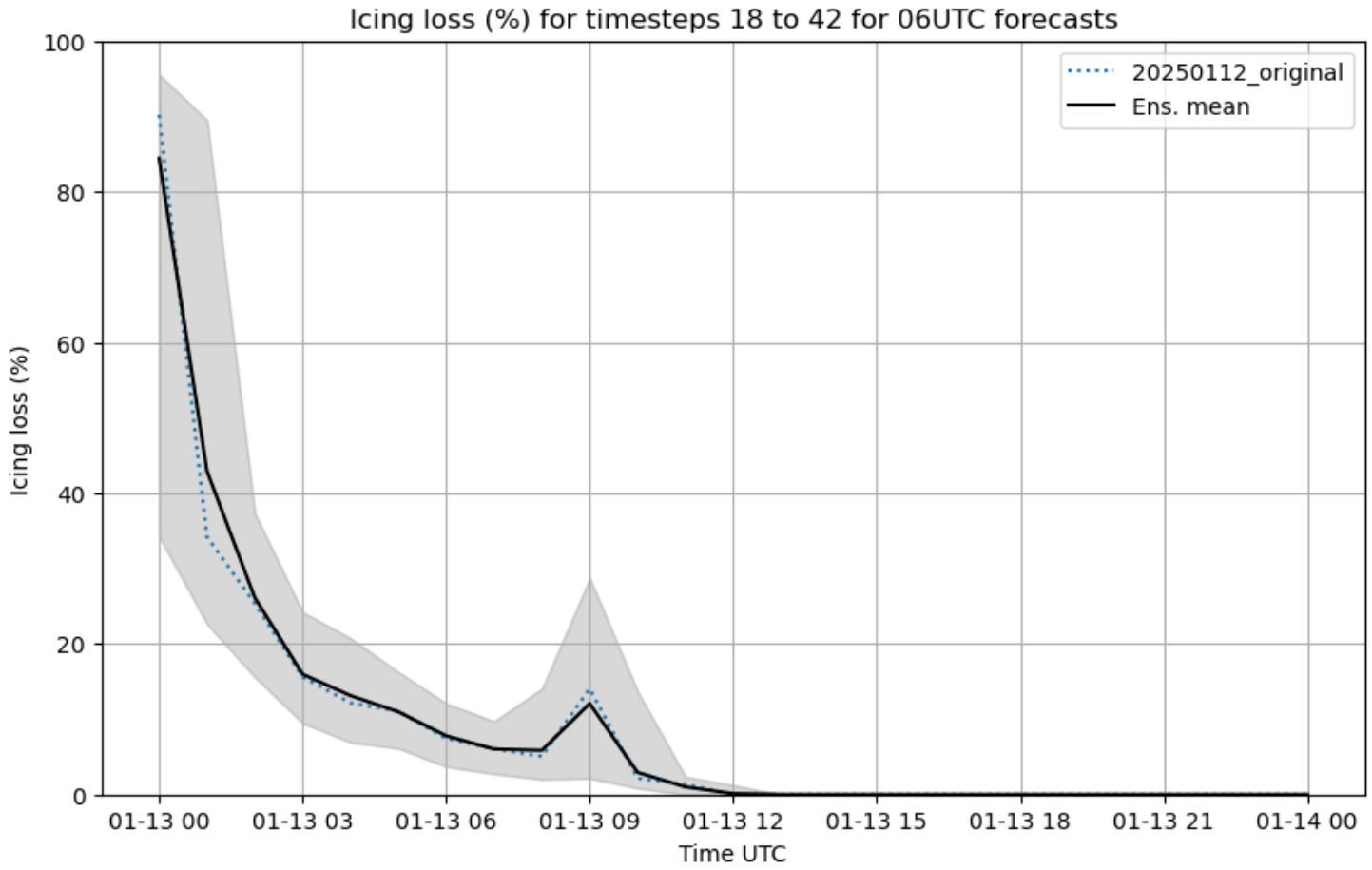

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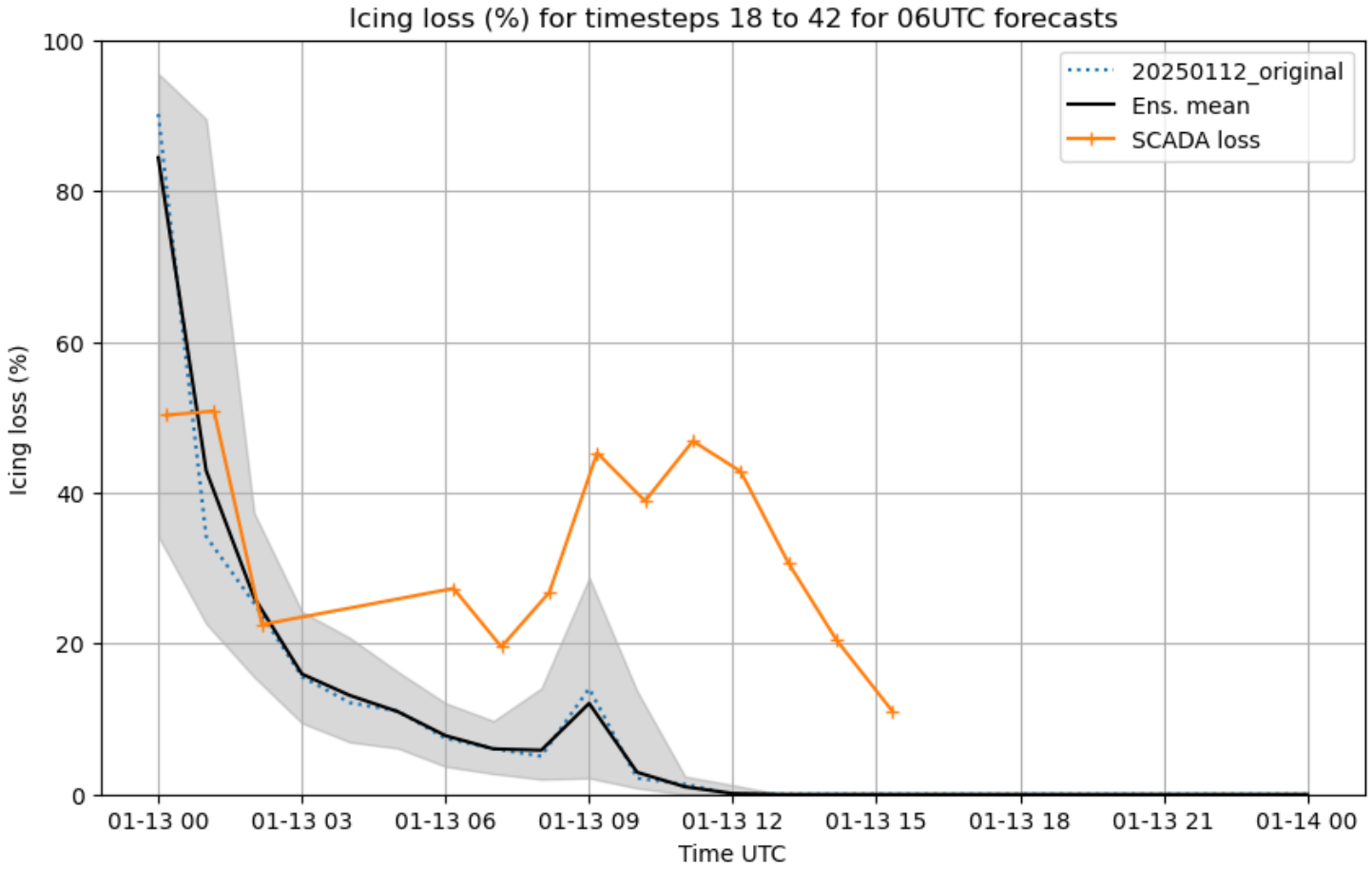

- Deterministic forecast
- Adding ensemble members to address forecast uncertainty
- Reality: SCADA

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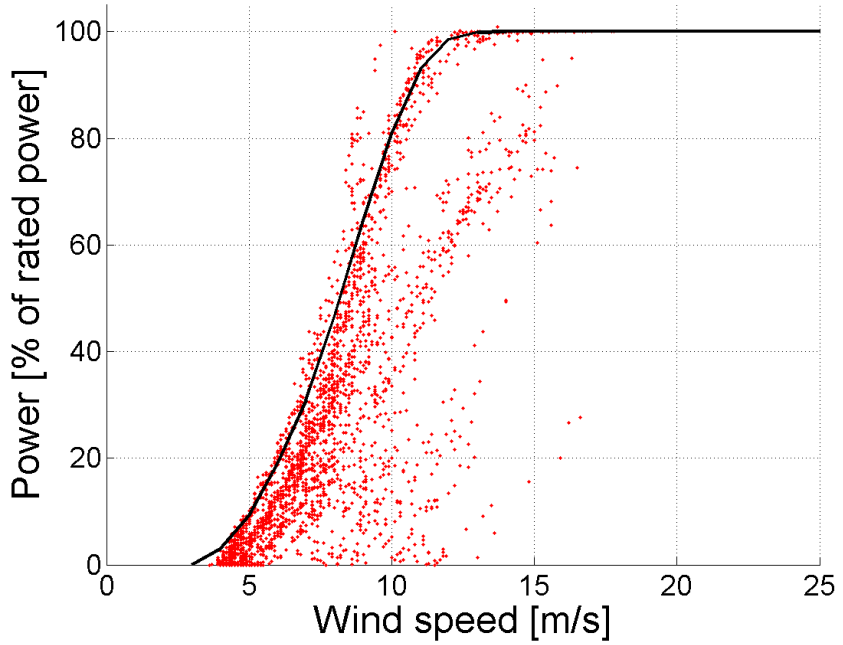
Methods – The SCADA-tuned forecast

- Input data needed:
  - Turbine coordinates
  - Turbine base elevation
  - Turbine type and RPM curve
  - Historical SCADA data
  - For nowcast - access to current production, wind speed, temperature, alarms and warnings from each turbine
- Using turbine specific power curves



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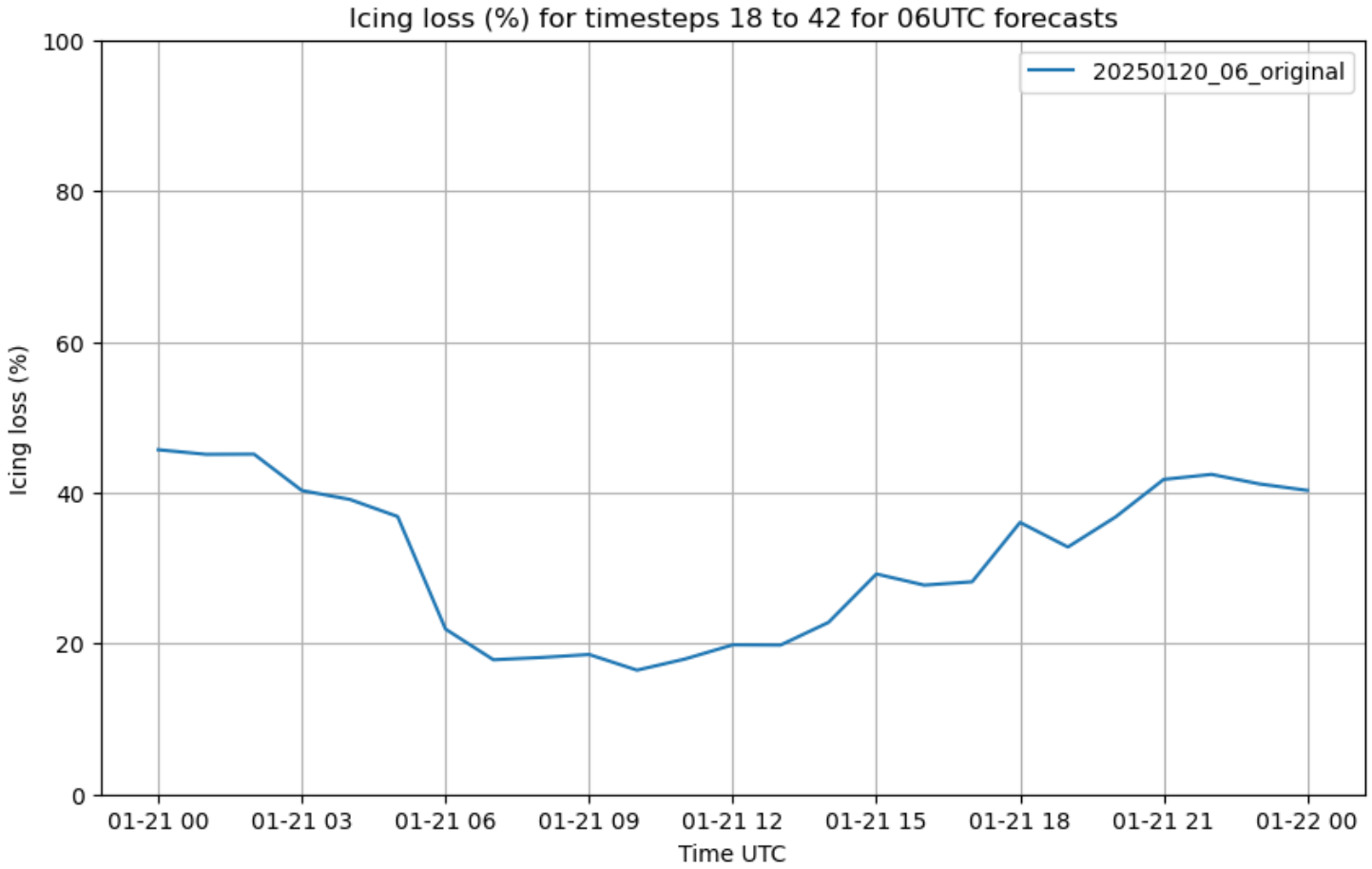

- Deterministic only model-based forecast

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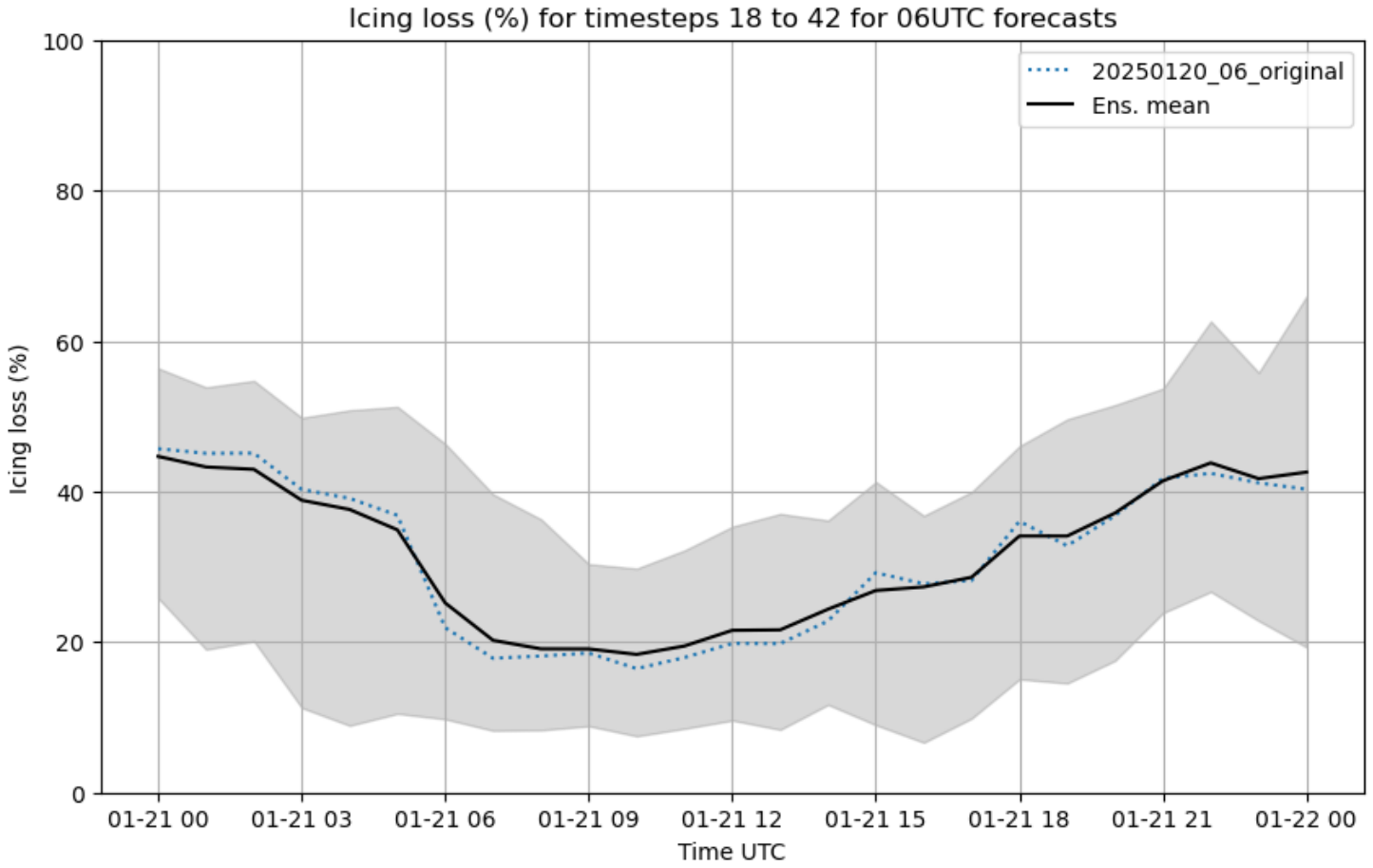

- Deterministic only model-based forecast
- Adding ensemble members to address forecast uncertainty

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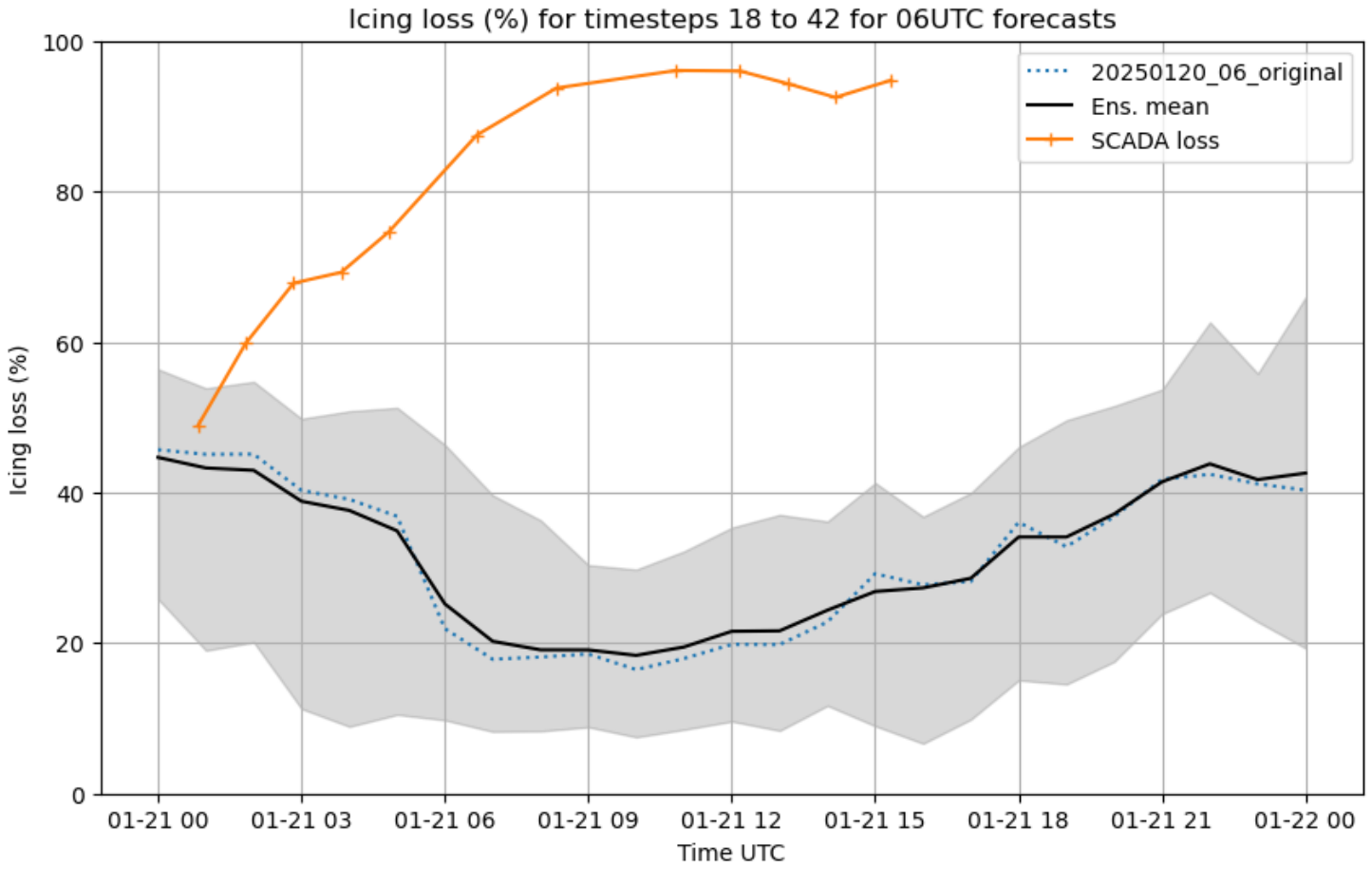

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- Reality: SCADA

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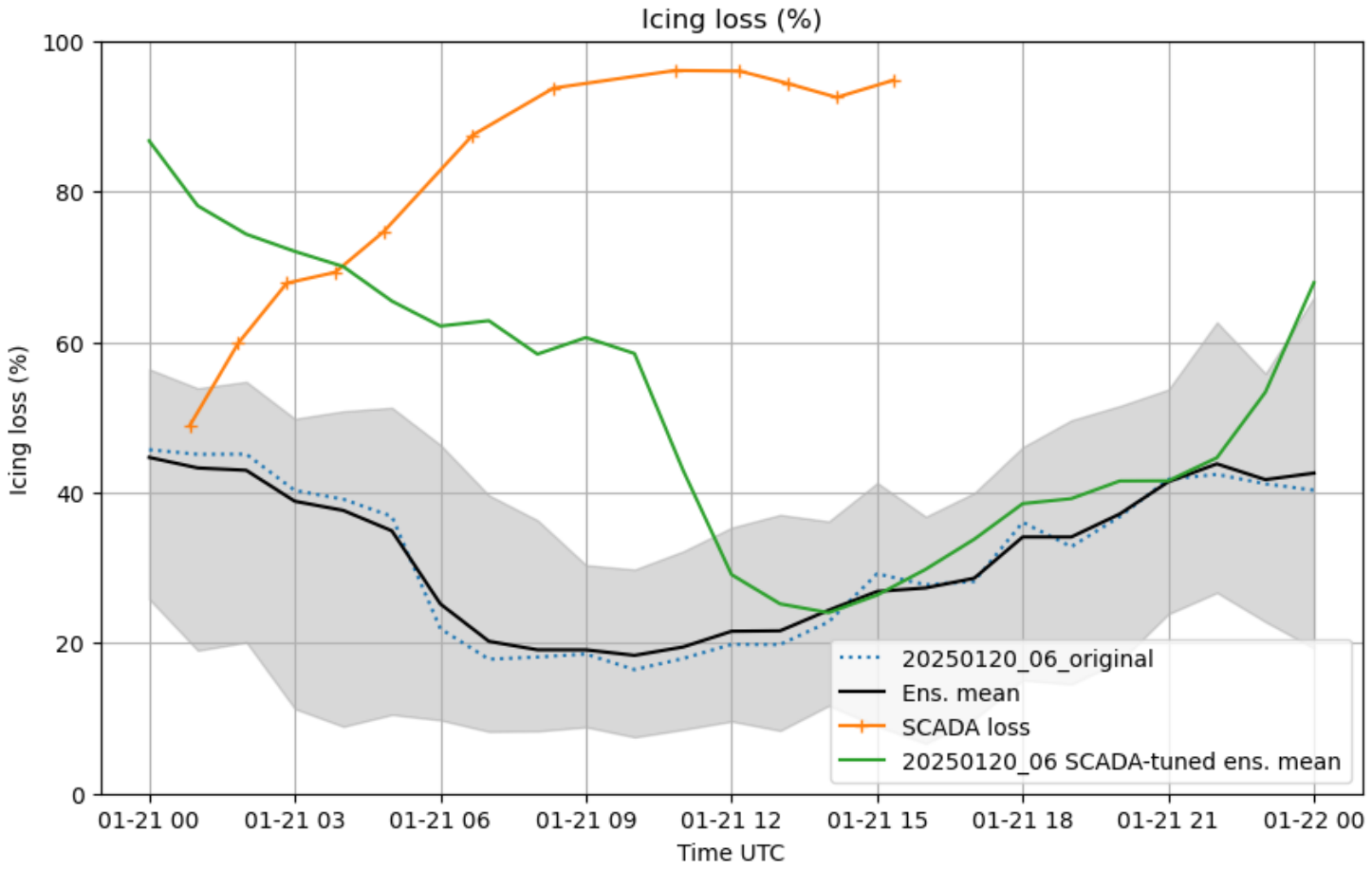

- Deterministic only model-based forecast
- Adding ensemble members to address forecast uncertainty
- Reality: SCADA
- The SCADA-tuned forecast performs better

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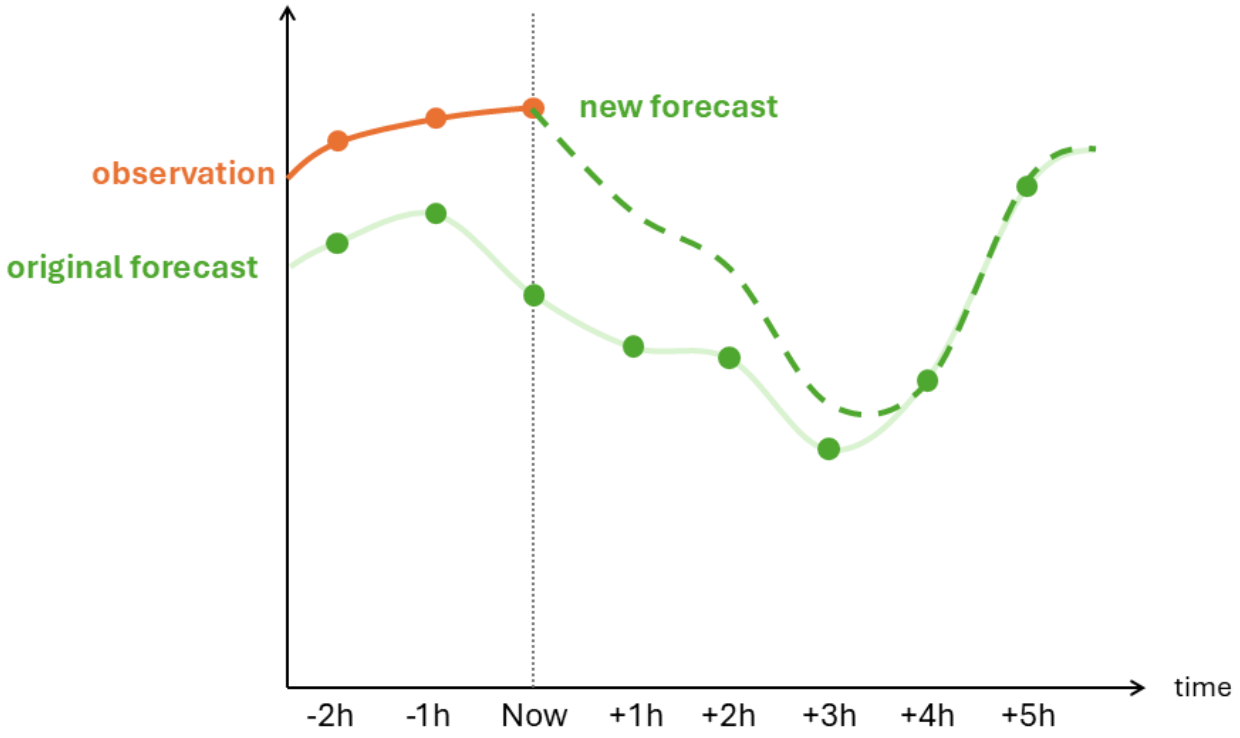
Methods – Real-time SCADA-tuned forecast for intra-day

- Forecast updated hourly
- Initial production loss based on observed icing losses last hours



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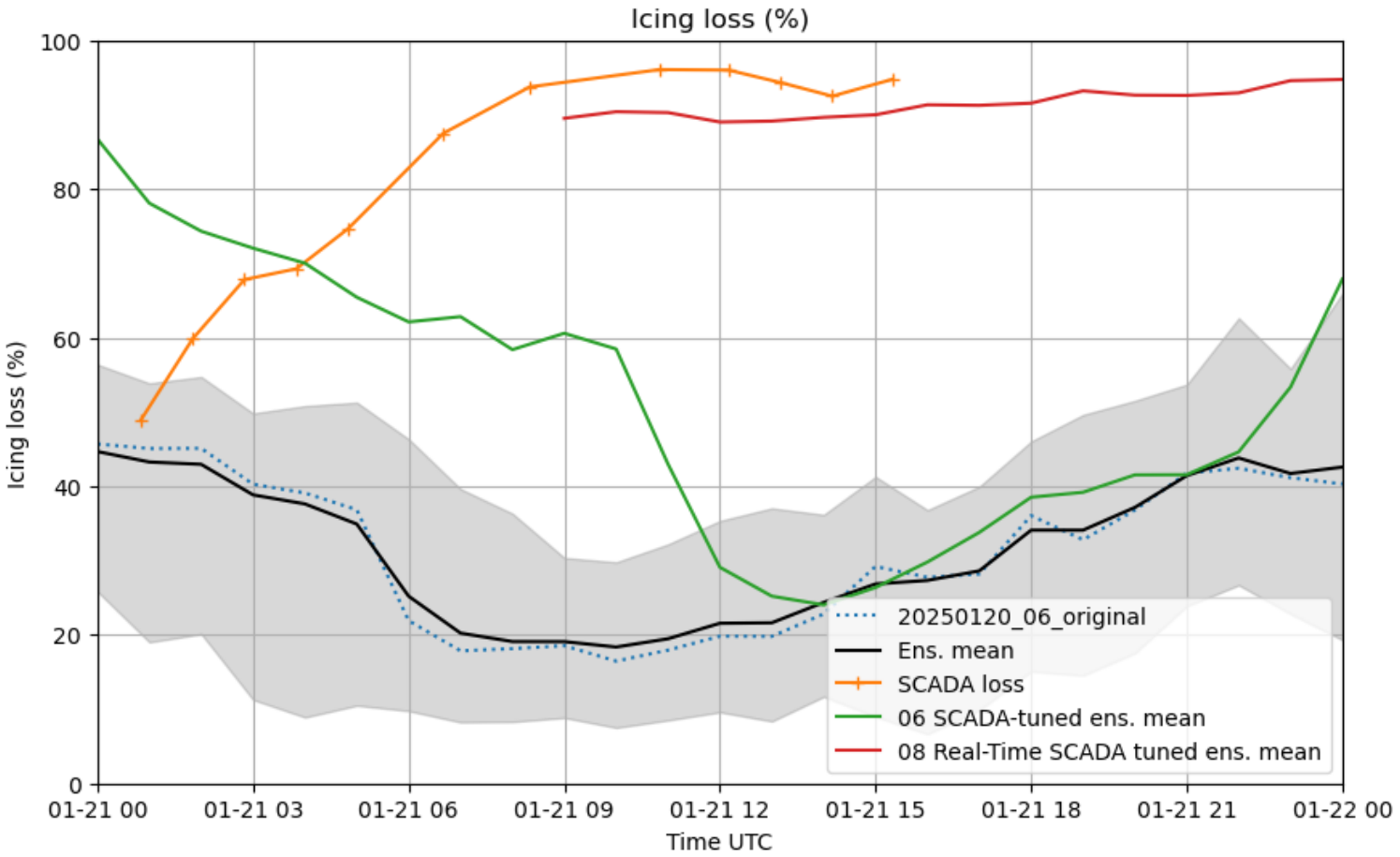
Intra-day forecast for wind farm in northern Sweden



- Deterministic forecast
- Adding ensemble members to address forecast uncertainty
- Reality: SCADA
- Using real-time SCADA, forecasts can be improved for intra-day trading

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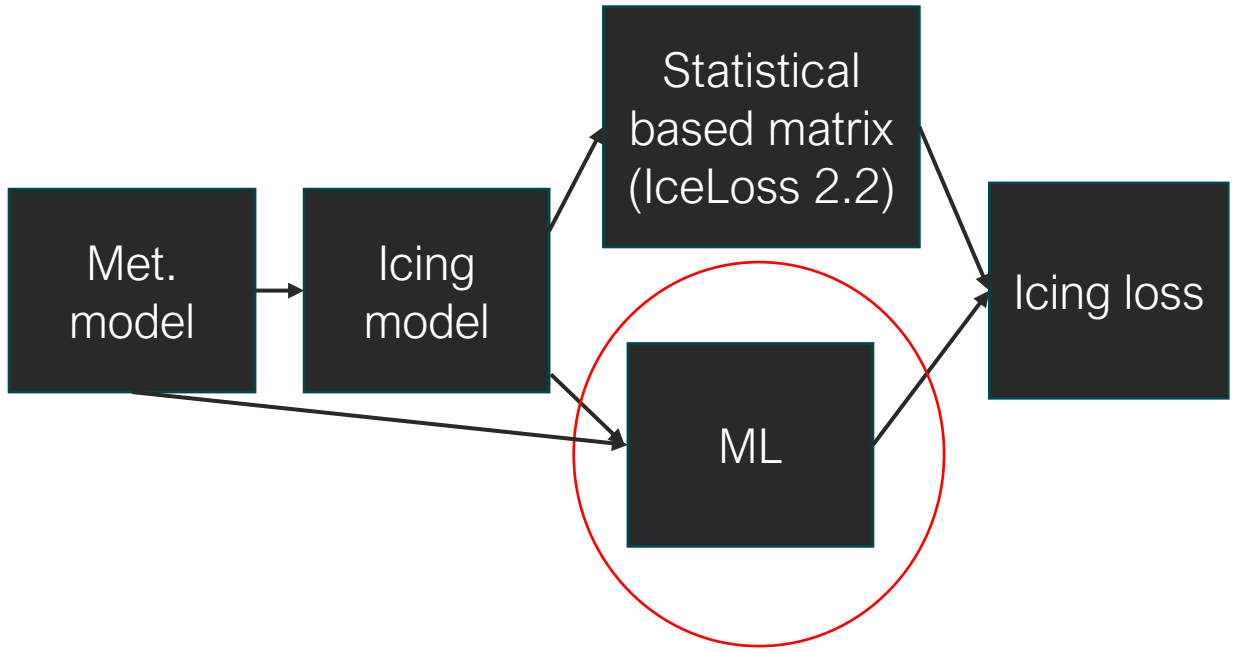
Methods – Machine Learning based forecast

- Trained on data from both meteorological model and the icing model
- KVT standard **IceLoss** optimized for long-term average loss
- In **IceLossForecast** hourly correlation and performance is the most important



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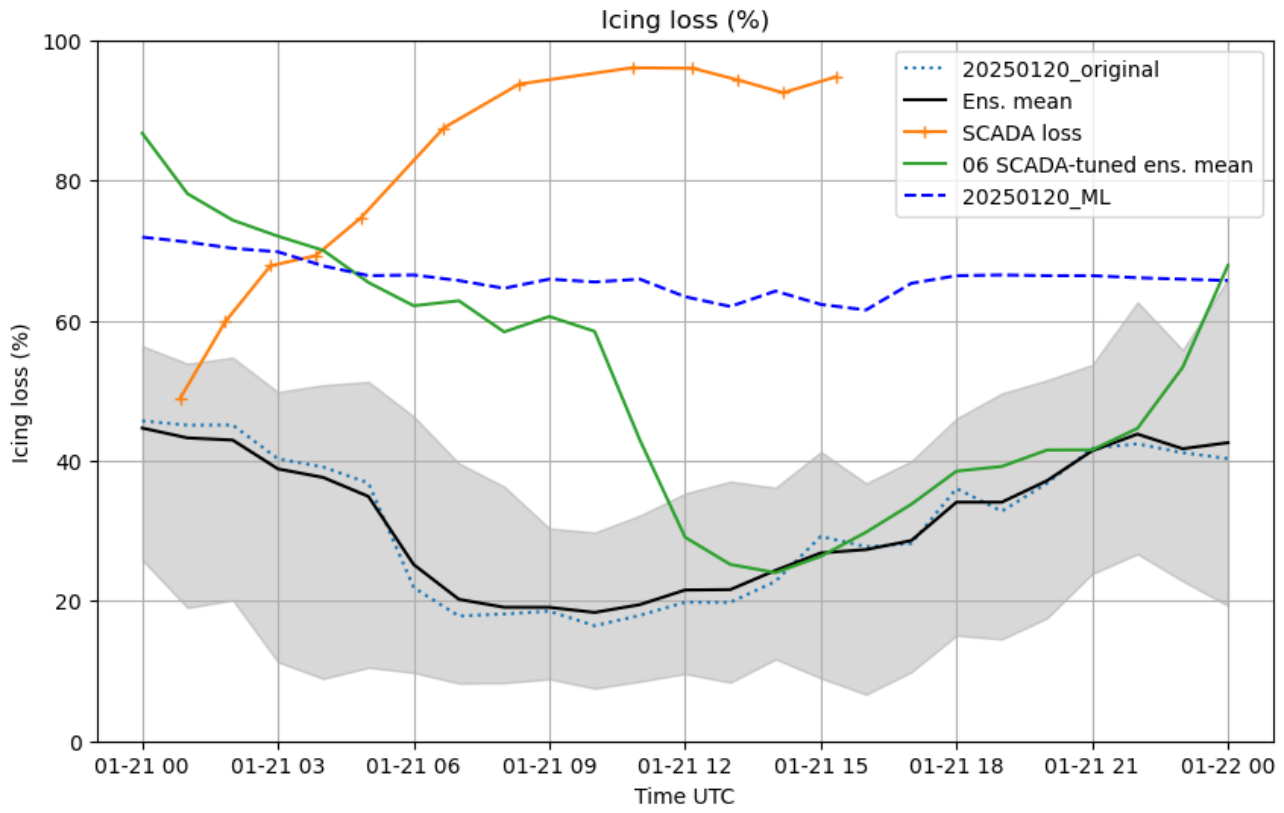
Day-ahead ML based forecast



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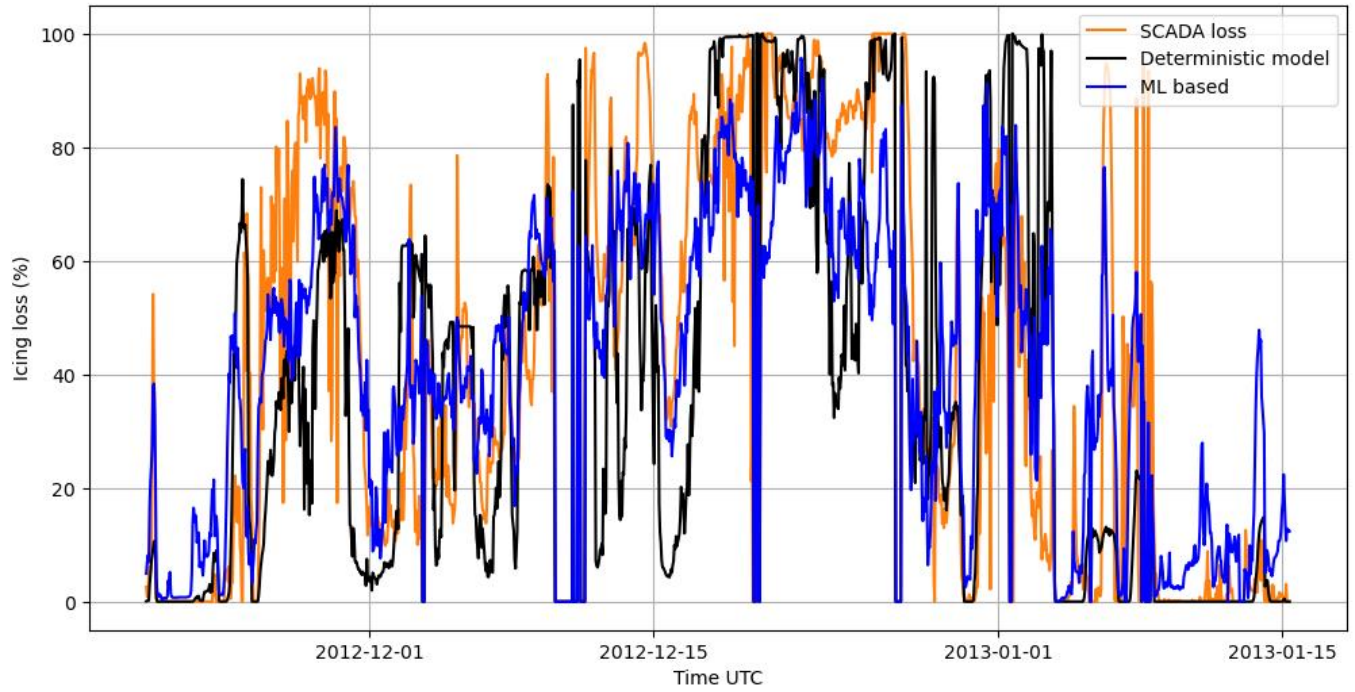
Day-ahead ML based forecast

- ML based capture several events better than standard deterministic model
- Deterministic model still better in some cases



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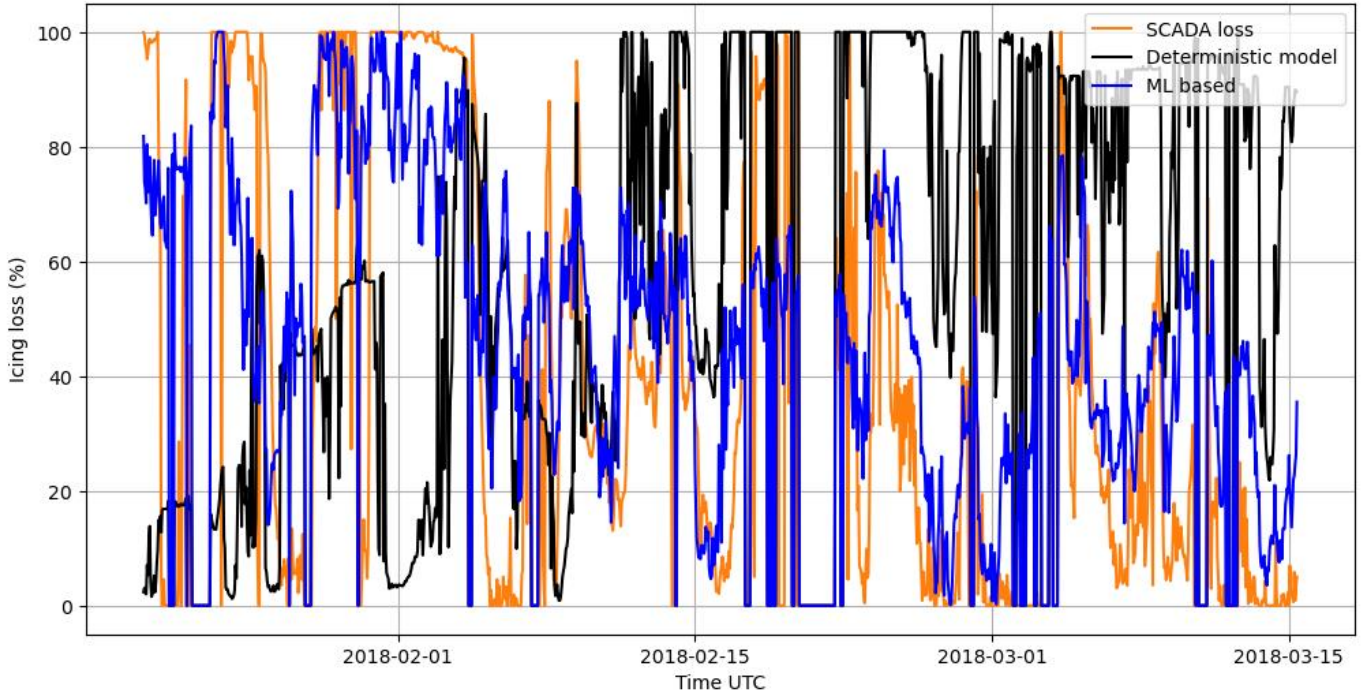
Day-ahead ML based forecast

- Total loss for the period is better captured by the deterministic model
- Hourly correlation much better in ML based

Extreme case



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Day-ahead ML based forecast

ML based

- Increased hourly correlation compared statistical IceLoss
- Increased forecast skill on an hourly basis
- Even higher skill in some cases when trained only on specific site data
- Sensitive to quality of SCADA data

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