Optimal Management of Storage Cascades with ensemble forecasts

RAVE International Workshop 2025, Berlin

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4cast

SWW wunsiedel wir bewegen

PtJ Projektträger Jülich Forschungszentrum Jülich

WEPROG

EnBW

SEtrade ENERGY REVOLUTION

Introduction of the Project

Introduction of the project

Motivation

Challenges

Current Solutions

Challenges		Current Solutions
Large forecasting errors	→	**Redispatch & retention of fossil capacity necessary**
„Too much“ energy	→	Redispatch
„too little“ energy	→	retention of fossil capacity necessary
2023: **25 TWh produced Offshore Energy**	→	**5,7 TWh could not be used due to grid congestion**

Beschleunigter Ausbau

Mehr Windenergie auf See

Mit dem Windenergie-auf See-Gesetz schafft die Bundesregierung die Voraussetzungen, um den Ausbau der Offshore-Windenergie voranzubringen. Bis zum Jahr 2030 soll die installierte Leistung von Offshore-Windenergie auf mindestens 30 Gigawatt und bis 2045 auf mindestens 70 Gigawatt steigen. Das Windenergie-auf-See-Gesetz ist zum 1. Januar in Kraft getreten.

Montag, 2. Januar 2023 · 2 Min. Lesedauer

Vom Aufbau einer Offshore-Windenergieindustrie können die strukturschwachen Küstenregionen über die maritime Wirtschaft hinaus profitieren.
Foto: Ulrich Baumgarten/Getty Images

Quelle: https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/windenergie-auf-see-gesetz-2022968

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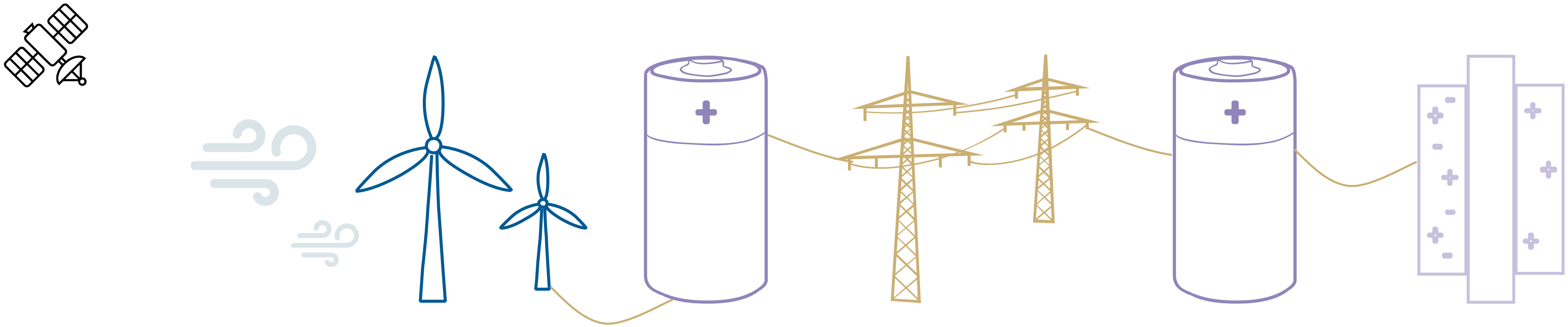
Introduction of the project

Project goal

Windpowerintegration:
From creating weather forecasts to smart wind power storage



Improvement of forecasting quality
- Satelite data
- Ensemble-forecasts

Optimization of storage use: *more buffering, less redispatch*
1. Shift from oversupply to times of undersupply
2. Optimized utilization of grids and existing renewable energy sources

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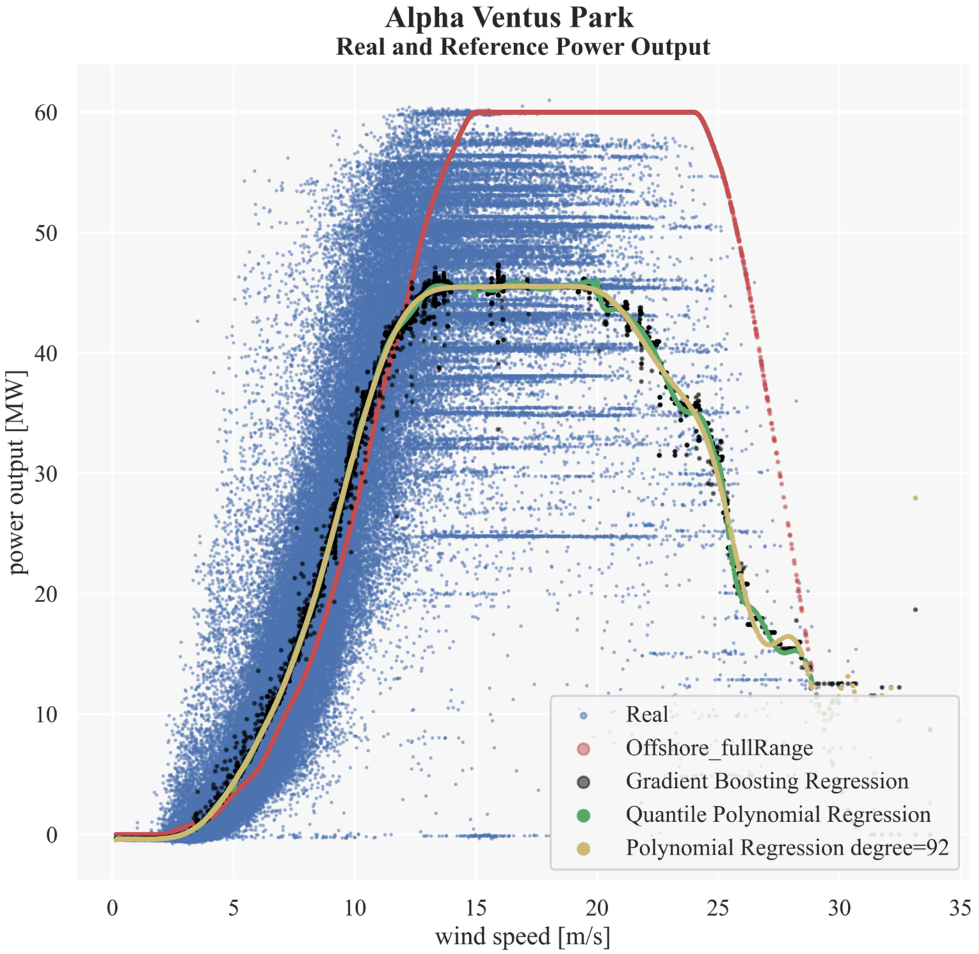
Analysis of RAVE data

Power Curve

Alpha Ventus PC Estimator and Reference Model



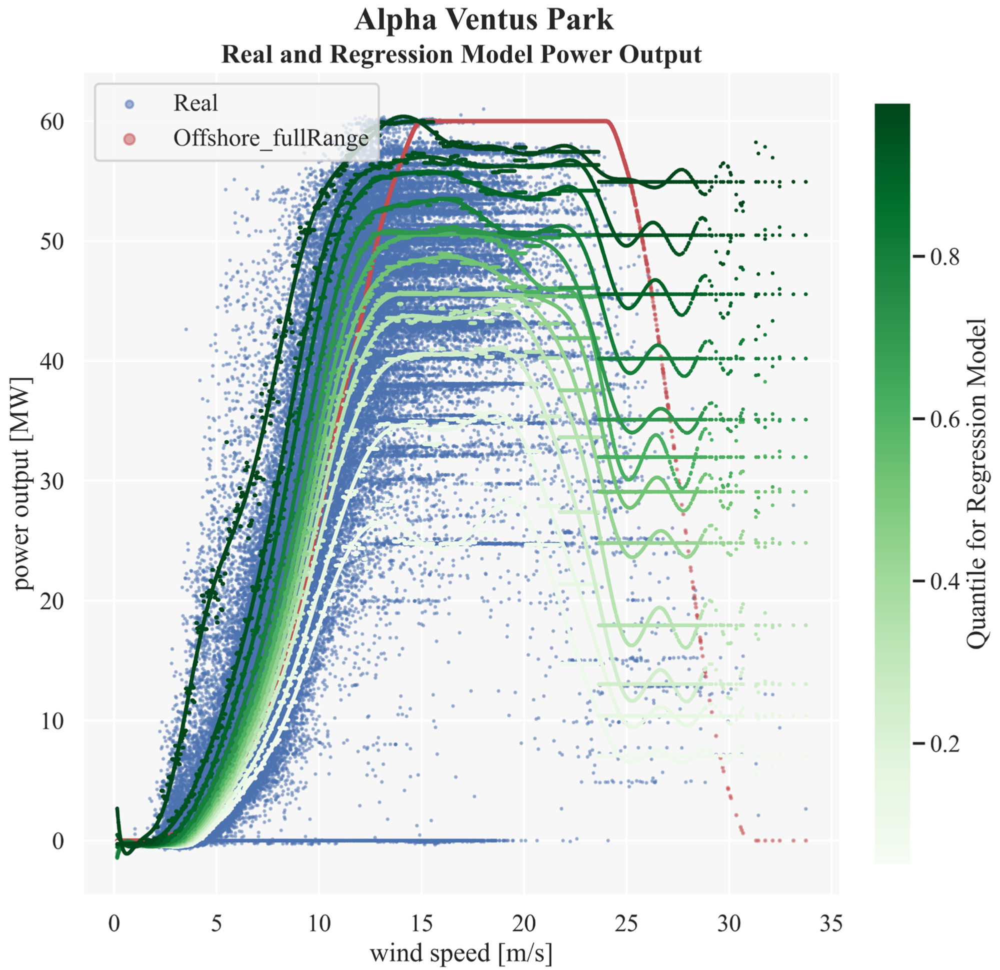
- Redispatch as horizontal lines

Metric:

- MSE: 59,32
- RMSE: 7,7
- R^2: 0,845

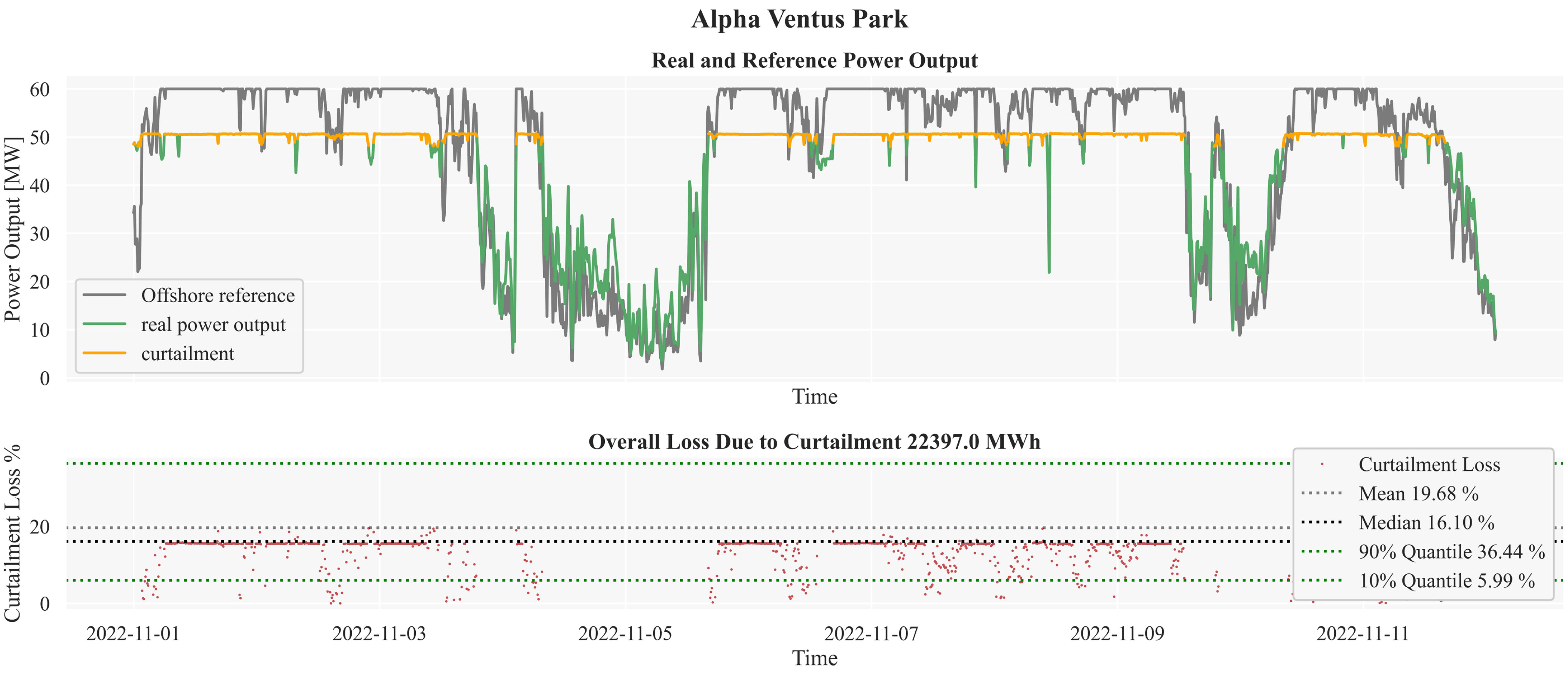
Research question:

- Effective curtailment detection: v>10m/s
- feature dimension>2

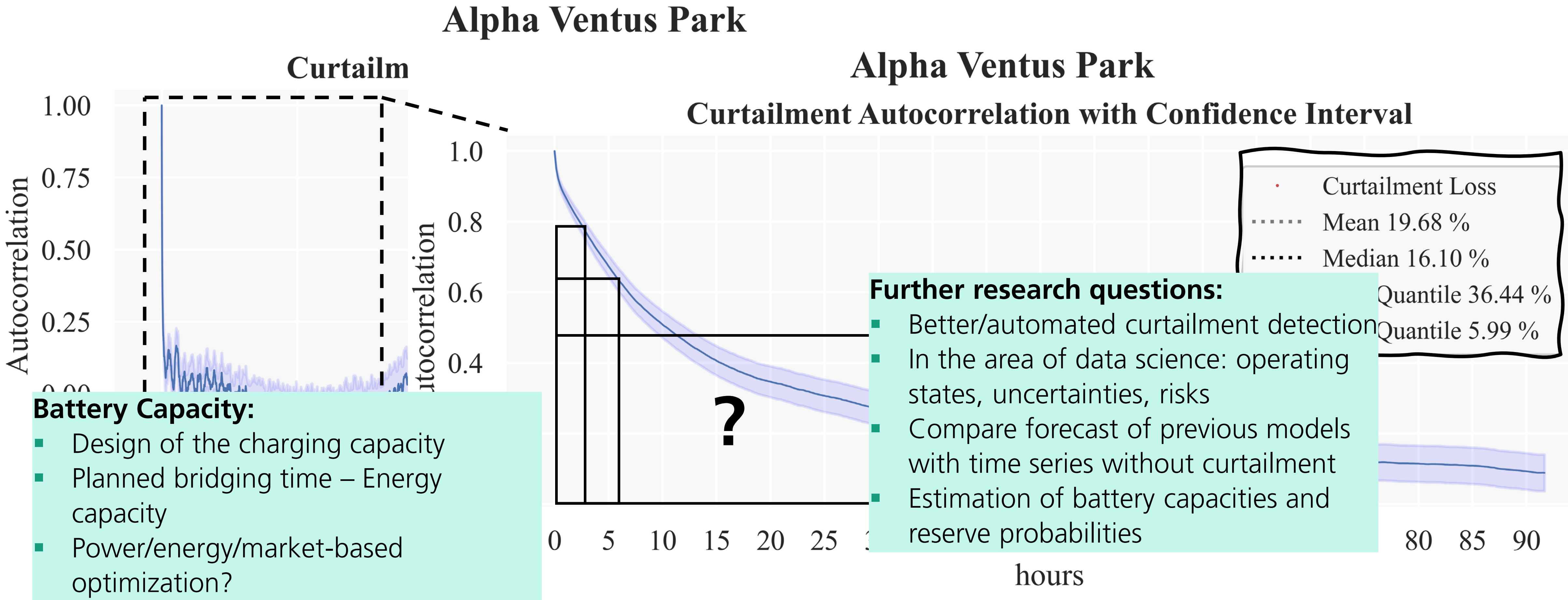


Reference model vs. Alpha Ventus

Redispatch loss estimation



Battery Capacity Planning



Battery Capacity:

- Design of the charging capacity
- Planned bridging time – Energy capacity
- Power/energy/market-based optimization?

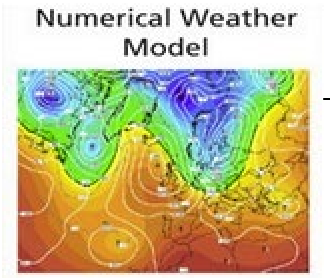
Further research questions:

- Better/automated curtailment detection
- In the area of data science: operating states, uncertainties, risks
- Compare forecast of previous models with time series without curtailment
- Estimation of battery capacities and reserve probabilities

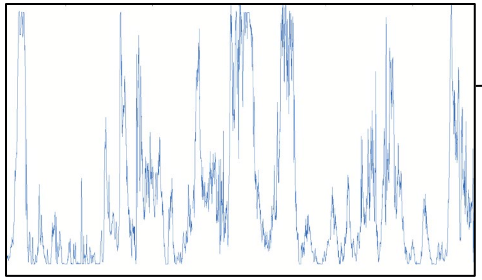
Ensemble Prognose

Ensemble Prognose

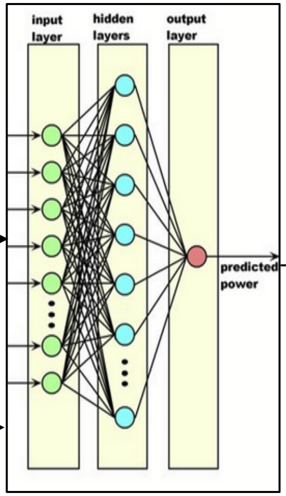
Prozesskette



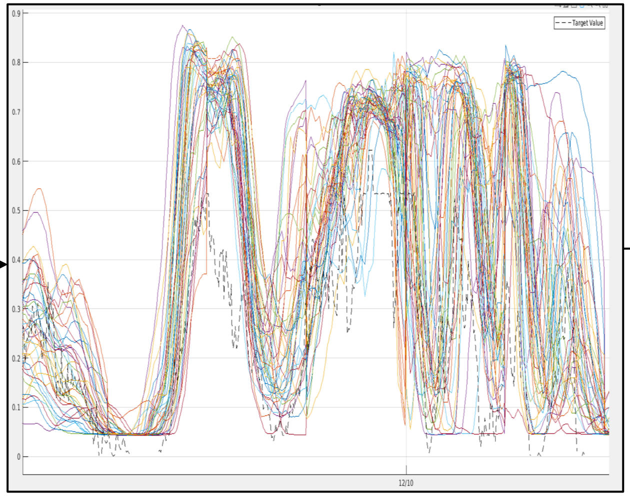
Weather Ensemble Forecast



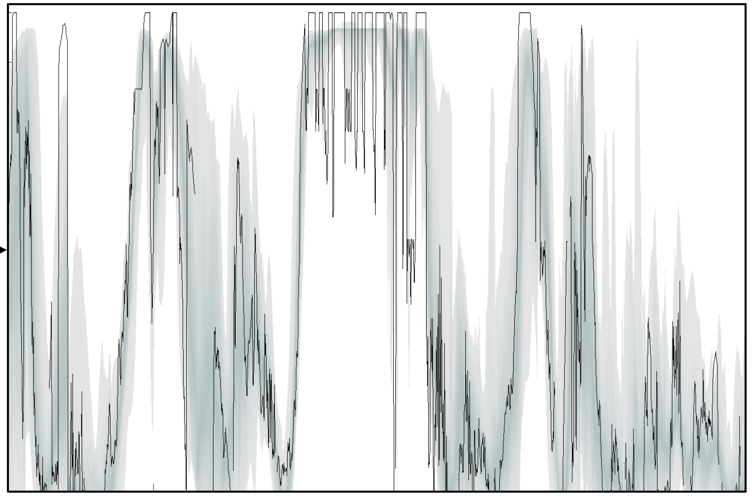
Measurement data



Multitasking –Machine Learning Model



Ensemble Forecasts



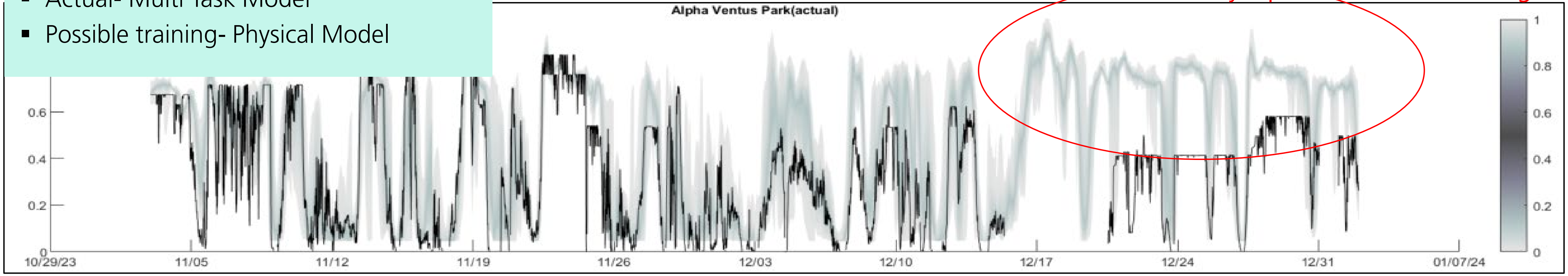
Ensemble quantile Forecast

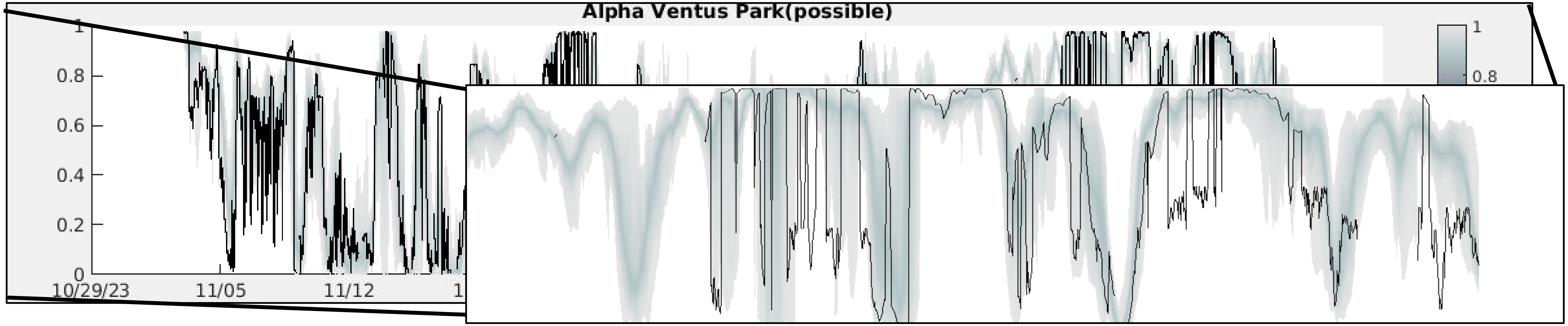
Ensemble Forecast Vs Measurements

Actual (with curtailment) und Possible (without curtailment) training

- Actual- Multi Task Model
- Possible training- Physical Model

Curtailments are not considered for Day ahead (DAF) forecasts
Probably input features are missing !



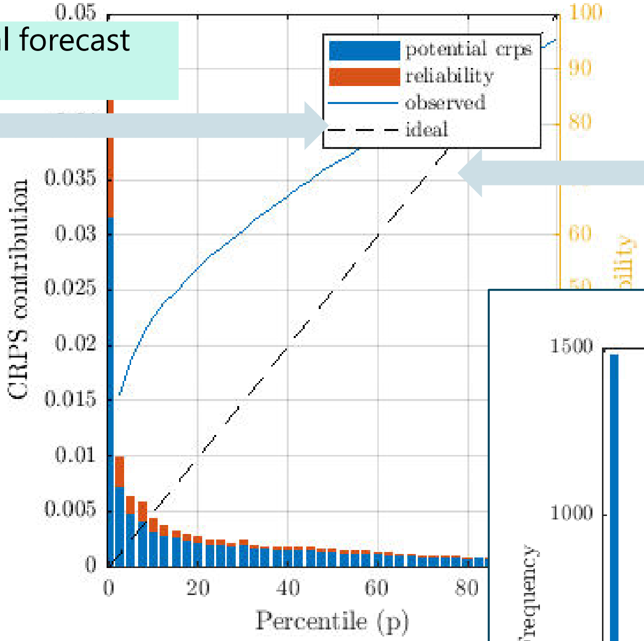


Verification

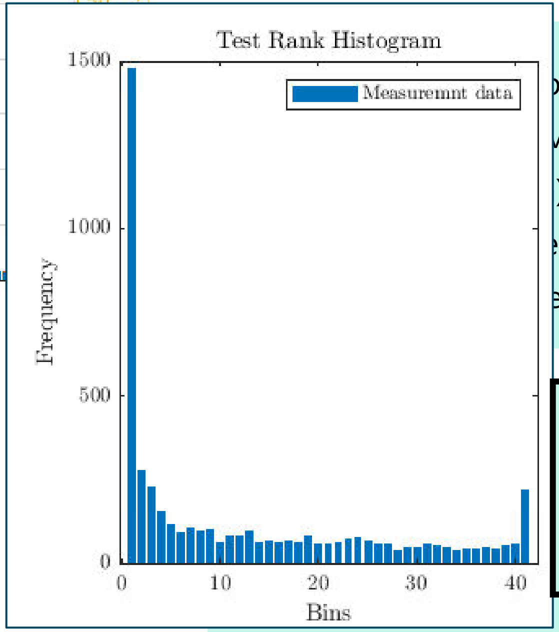
Continous Ranked Probability Score (CRPS) und Rank Histogram

Evaluation on Test Set (actual)

Reality-->actual forecast overesimates



CRPS=0.1320



Ideal---->Forecast=Observations

$$CRPS = \int_{-\infty}^{\infty} (P(y) - H(y-o))^2 dy$$

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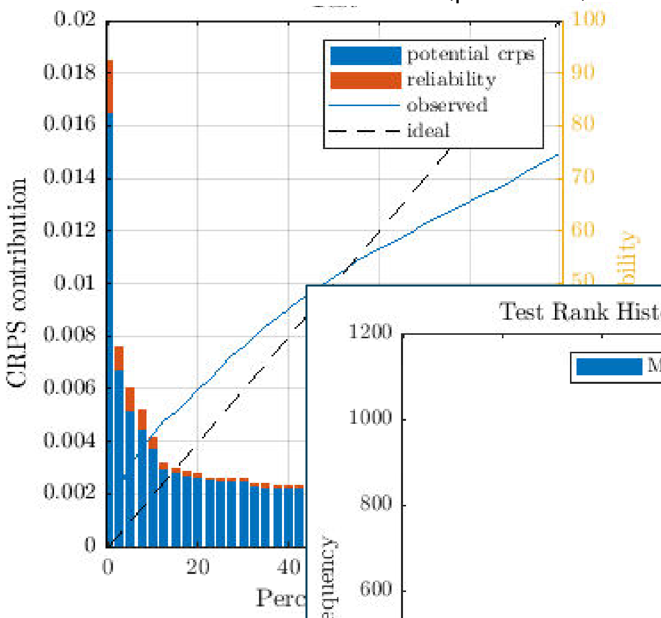
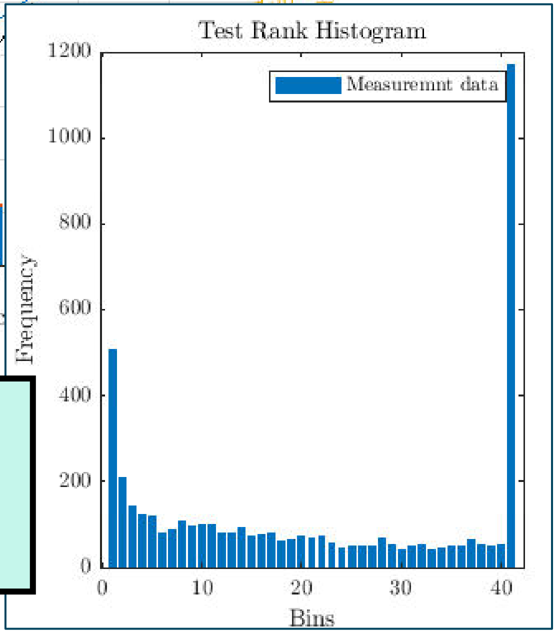
Evaluation on Test Set (possible)

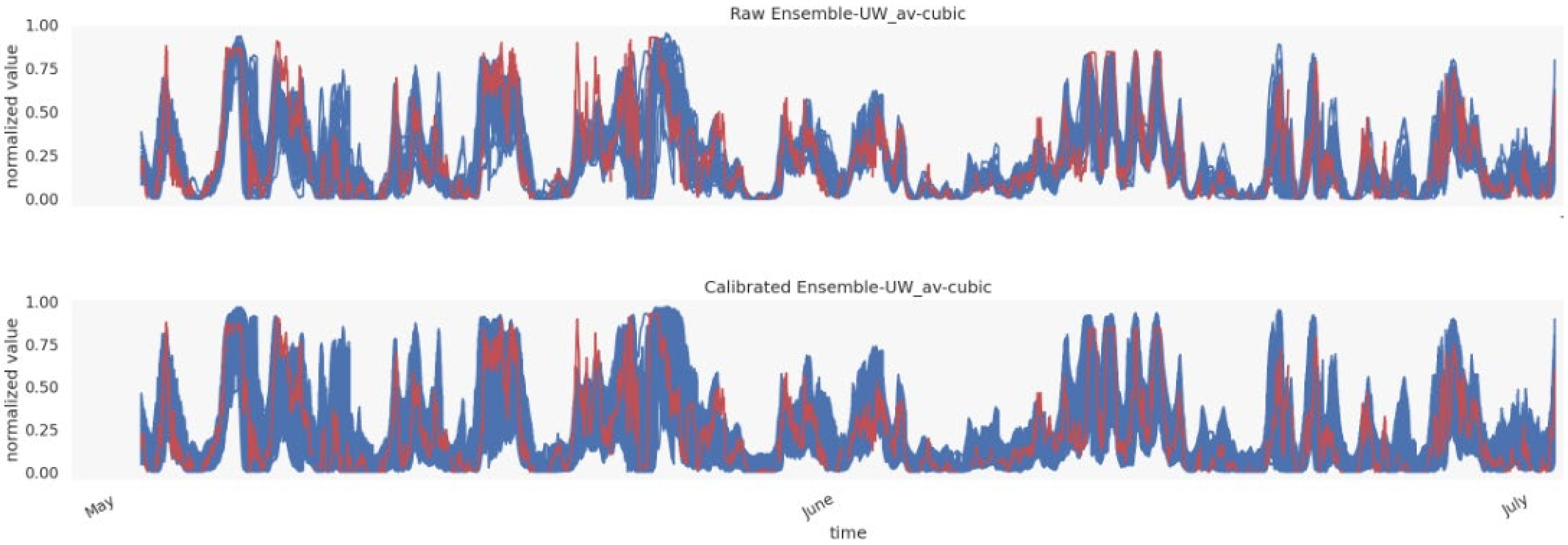




Motivation-Calibration with Ensemble Copula
 Coupling (ECC) to improve the forecasts

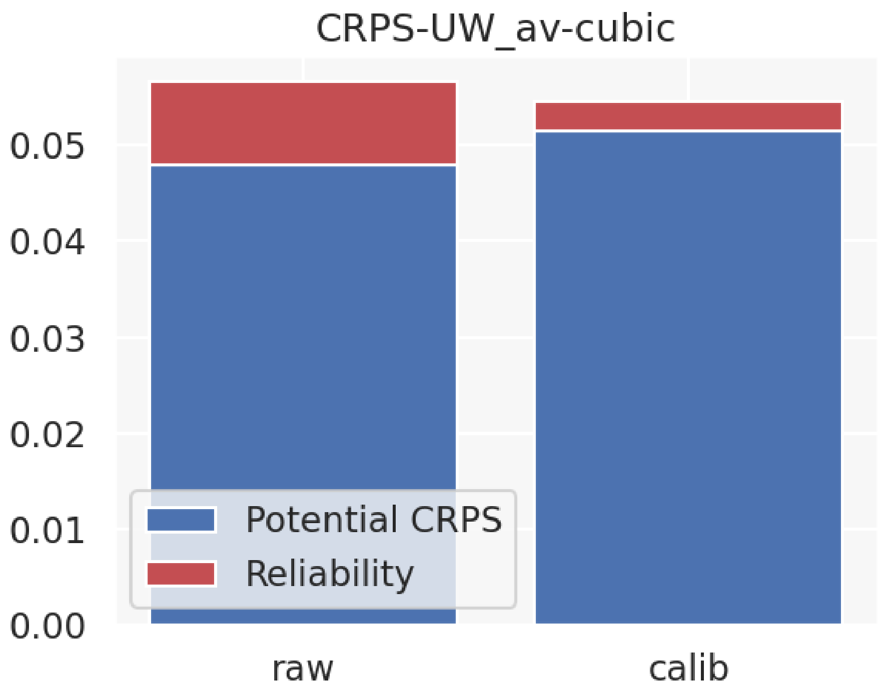
Calibration

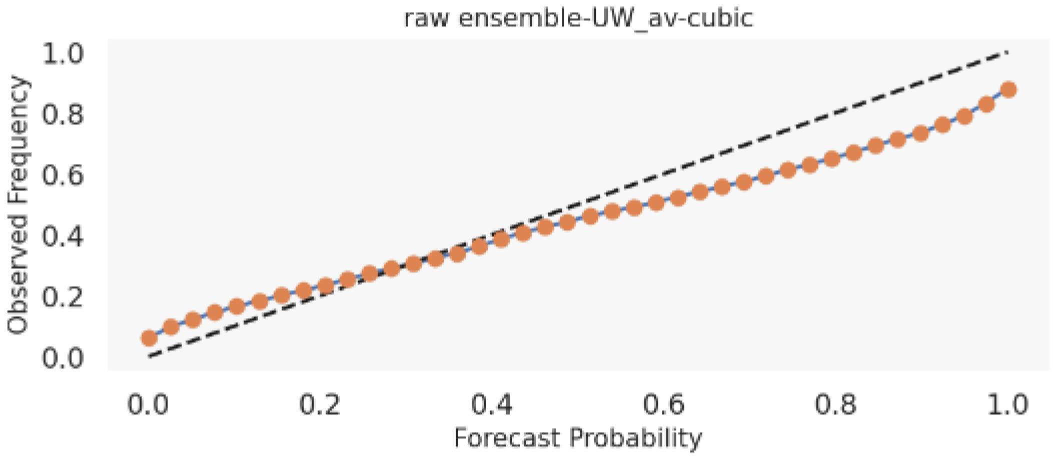
Raw Ensembles vs Calibrated Ensembles (May-July)

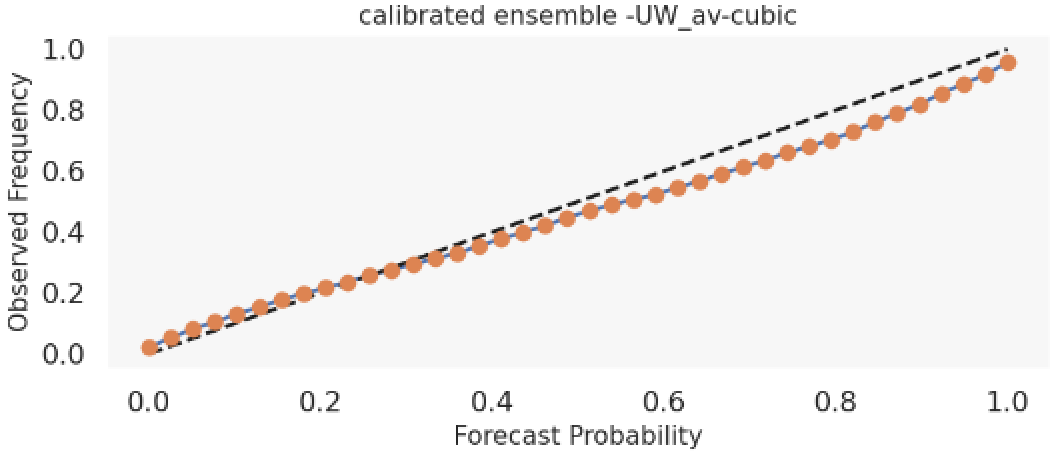


Calibration

Raw Ensembles vs Calibrated Ensembles (May-july)







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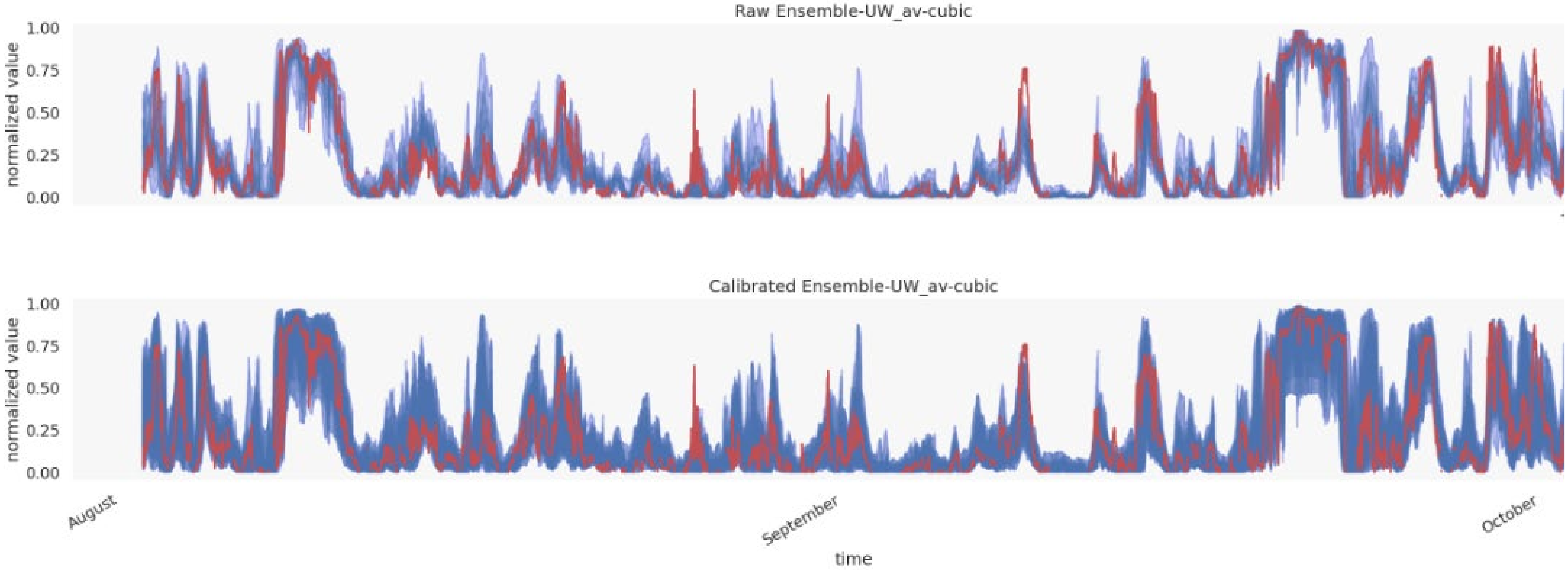
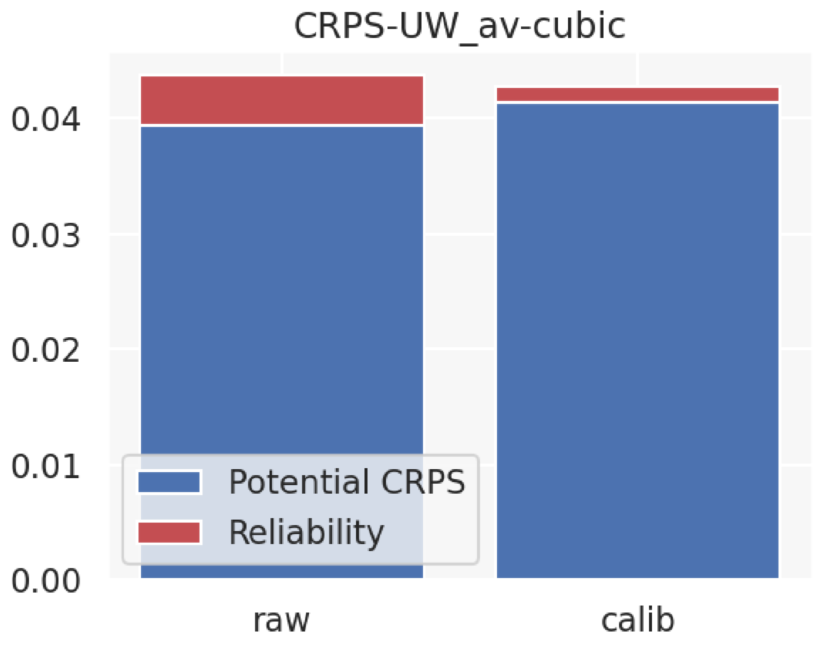
Calibration

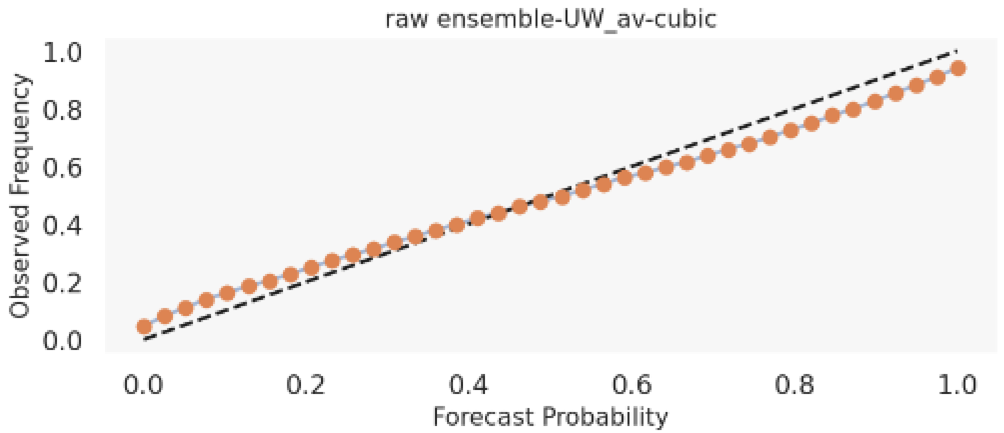
Raw Ensembles vs Calibrated Ensembles (Aug-Oct)

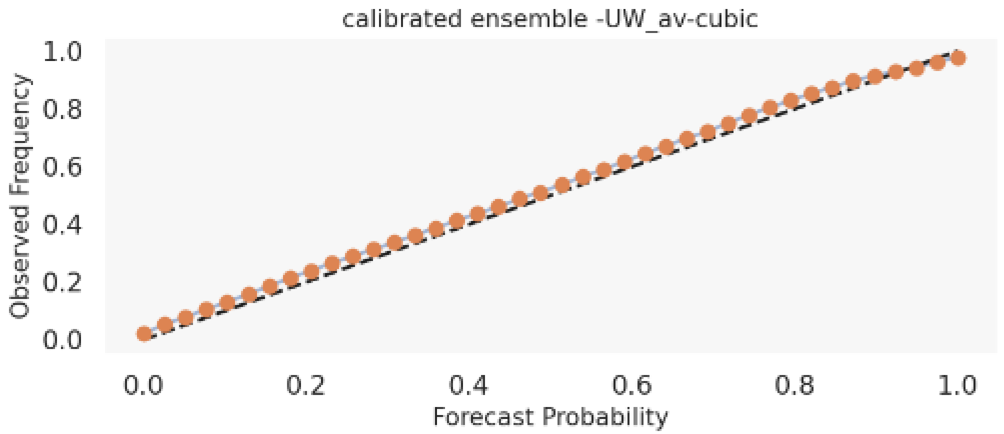


Calibration

Raw Ensembles vs Calibrated Ensembles (Aug-oct)

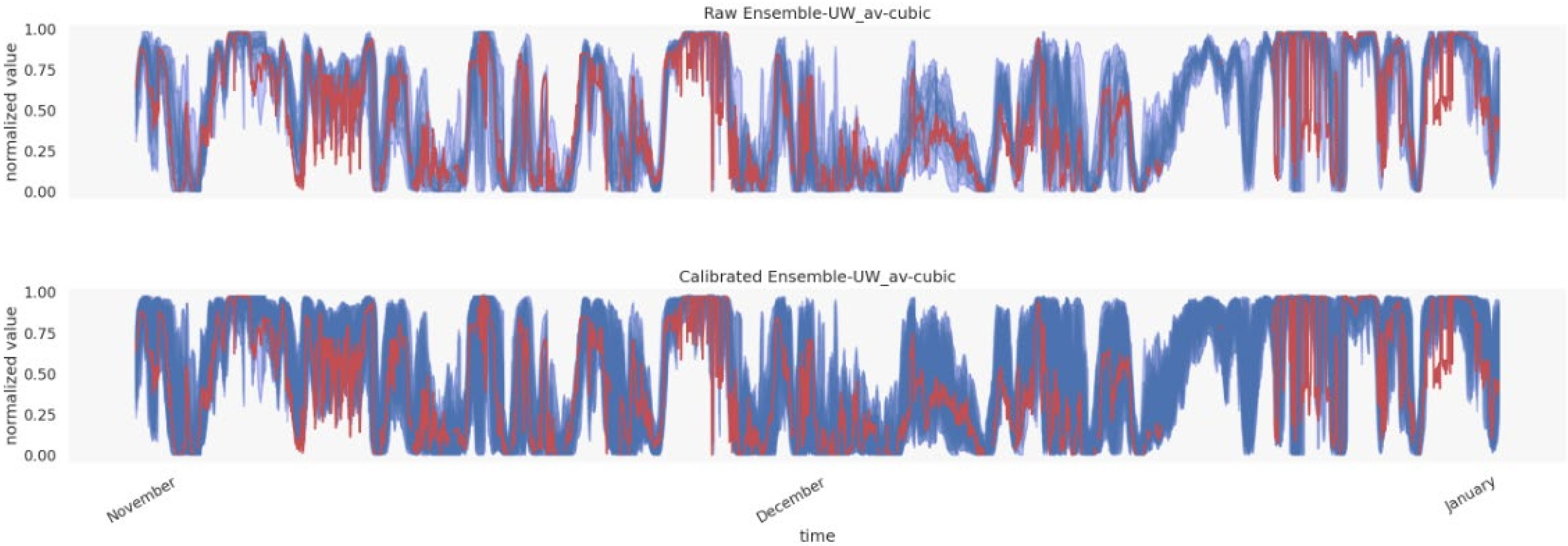






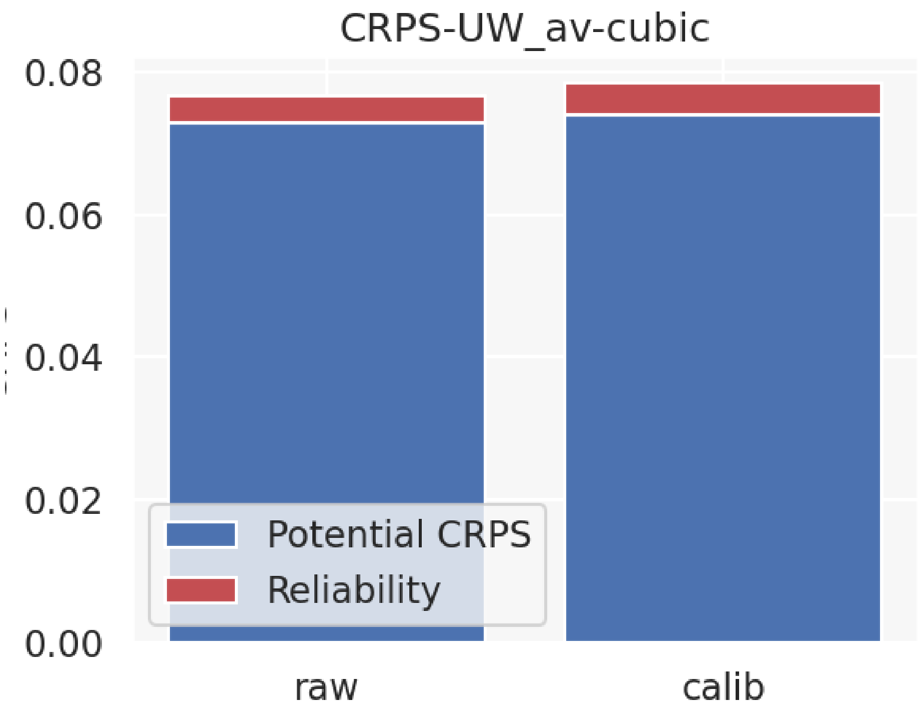
Calibration

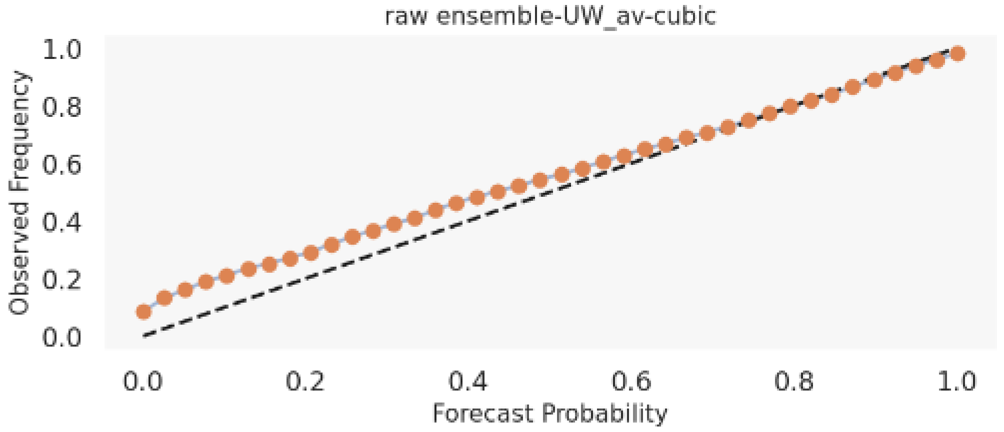
Raw Ensembles vs Calibrated Ensembles (Nov-Jan)

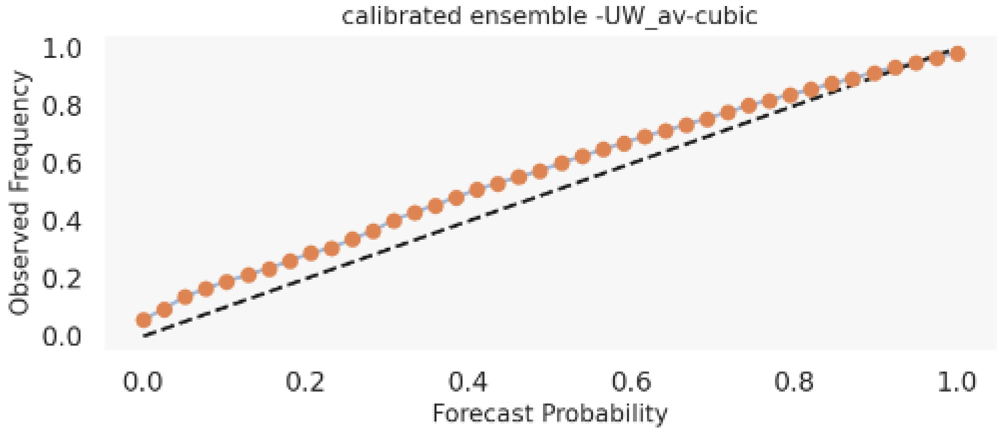


Calibration

Raw Ensembles vs Calibrated Ensembles (Nov-jan)







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Optimization model

First Optimization Steps
Cases

R1: What **concrete added value** do **probabilistic** forecasts offer compared to **deterministic forecasts** in the control of **battery storage systems** in **offshore wind farm** applications?

1. Deterministic Forecast and Energy Storage :
   - Deterministic forecast
   - Single battery storage
   - Linear Program
2. Probabilistic Forecast and Energy Storage:
   - Probabilistic forecasts
   - Single battery storage
   - Stochastic program
3. Reference Status-quo:
   - Measurement data
   - Single battery storage
   - Rule-based control

Cost Function:

- Maximum possible feed-in quantity of the wind farm (Battery without charging loss)
- As few reserve power plants as possible need to start up for consumers; CO_2 savings

Starting with 3 simple cases and finally to detailed, complicated scenarios

R2: To what extent can the **predictive operation** of **battery storage systems** reduce the need for **redispatch** measures at **offshore wind farms**, and what **quantitative savings (Money/Energy/CO_2)** can be realized?

- Battery Cascade
- Day-Ahead Market
- Multiple Energy consumers/producers

Thank you for your attention!
Any further Questions?