Machine Learning Approach for Probabilistic Wind Power Forecasts with Discrete Probability Density Function

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Motivation

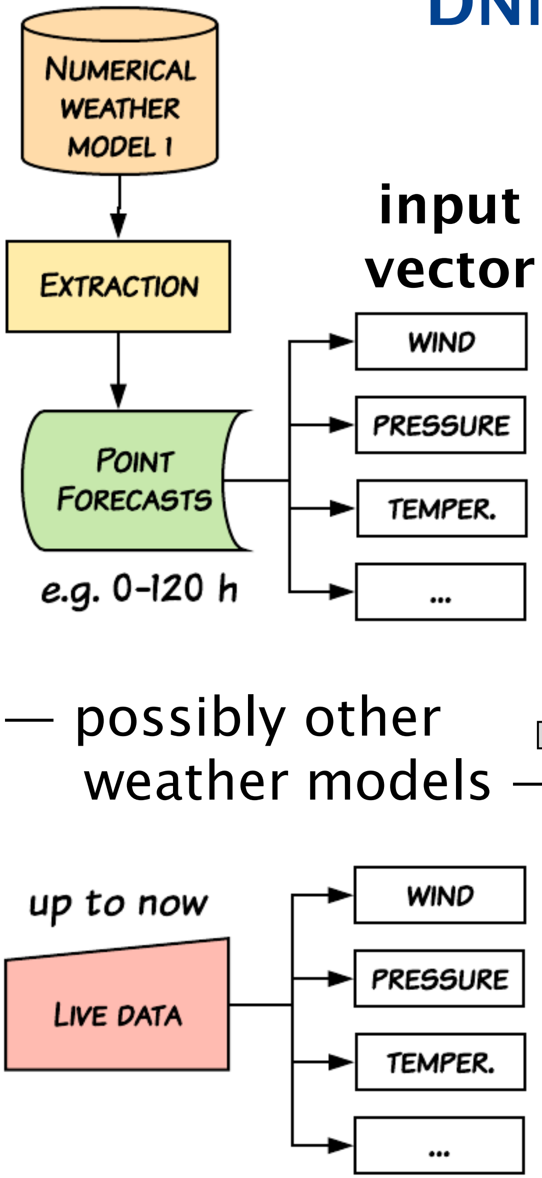
- Detailed power forecast error information often requested
- Our standard Deep Neural Network (DNN) based method provides only StD estimate
- Calibration of NWP ensemble models causes additional complexity
- Usage of NWP ensembles with DNN still unclear

But:

- Analog Ensemble (AnEn) method shows there is uncertainty information in the historical data record
- Different NWP models can be combined to provide additional uncertainty information

Question: → How can uncertainty information be presented to DNNs?

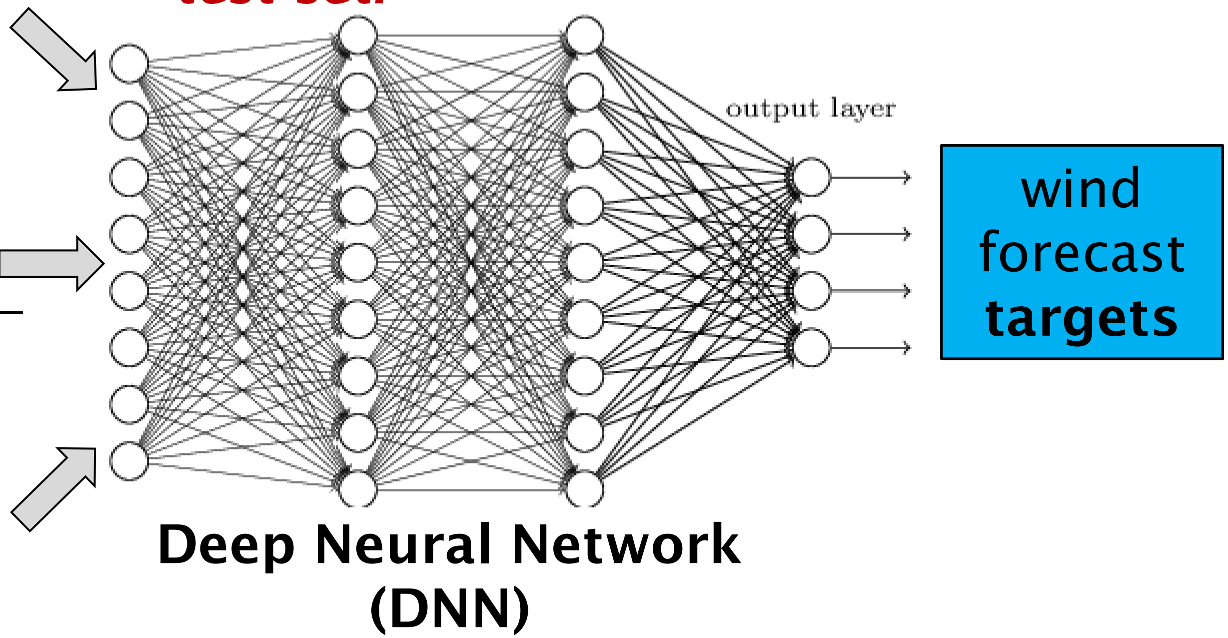
DNN Forecast Model Setup



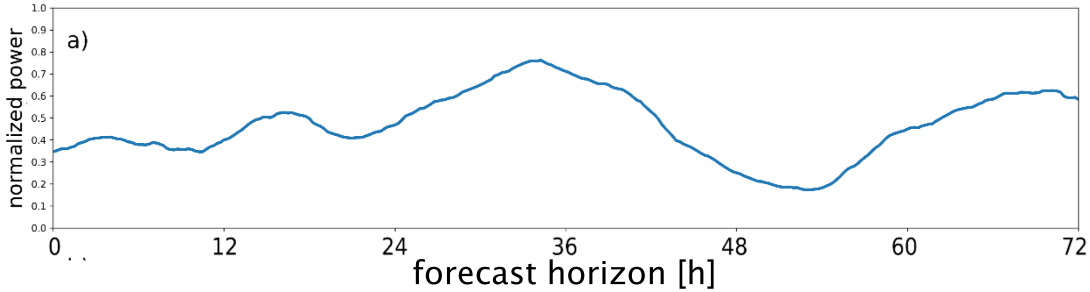
inputs + targets = 1 „pattern“

- split available patterns into training set and
- independent test set

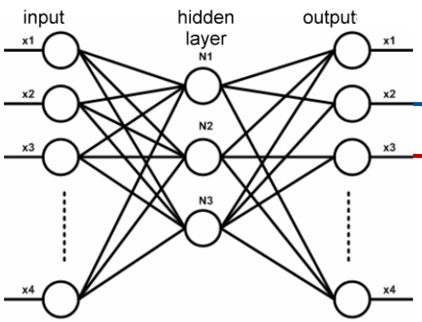
All results shown stem from the test set!



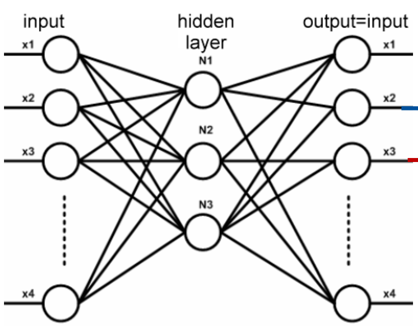
Target Encoding

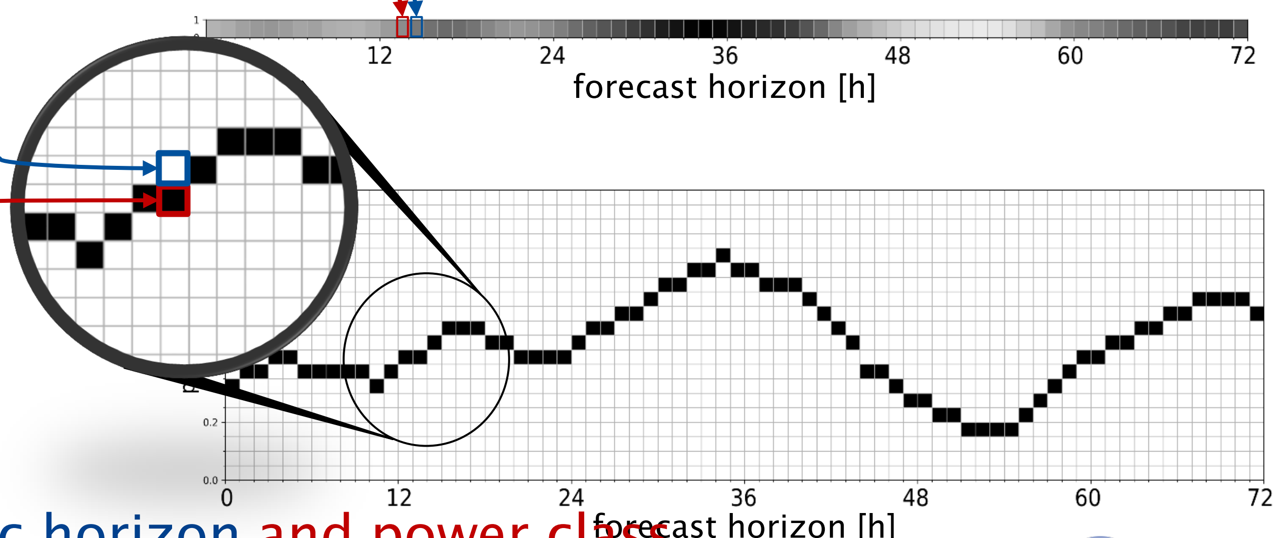


example targets:
historical obs for one forecast run



traditional encoding:
one neuron per forecast horizon





new encoding:
one neuron per fc horizon and power class

Input and Target Datasets

Target data:

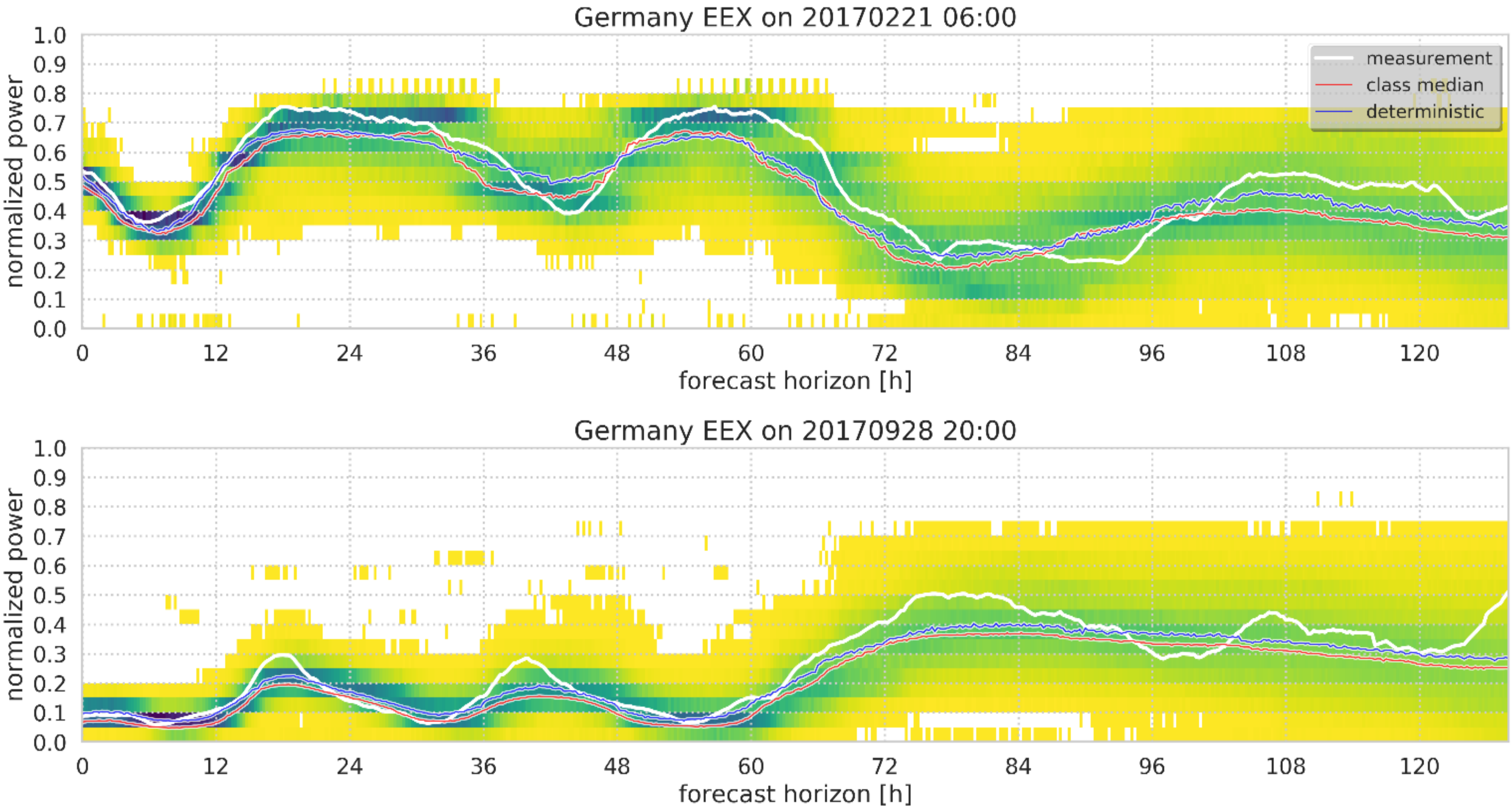
- Historical data from one wind farm in northern Germany
- EEX wind power data for Germany

Input data (=predictors):

- relevant fields from **GFS-4, IFS** and **HIRLAM** models
- live data (power measurements or EEX)

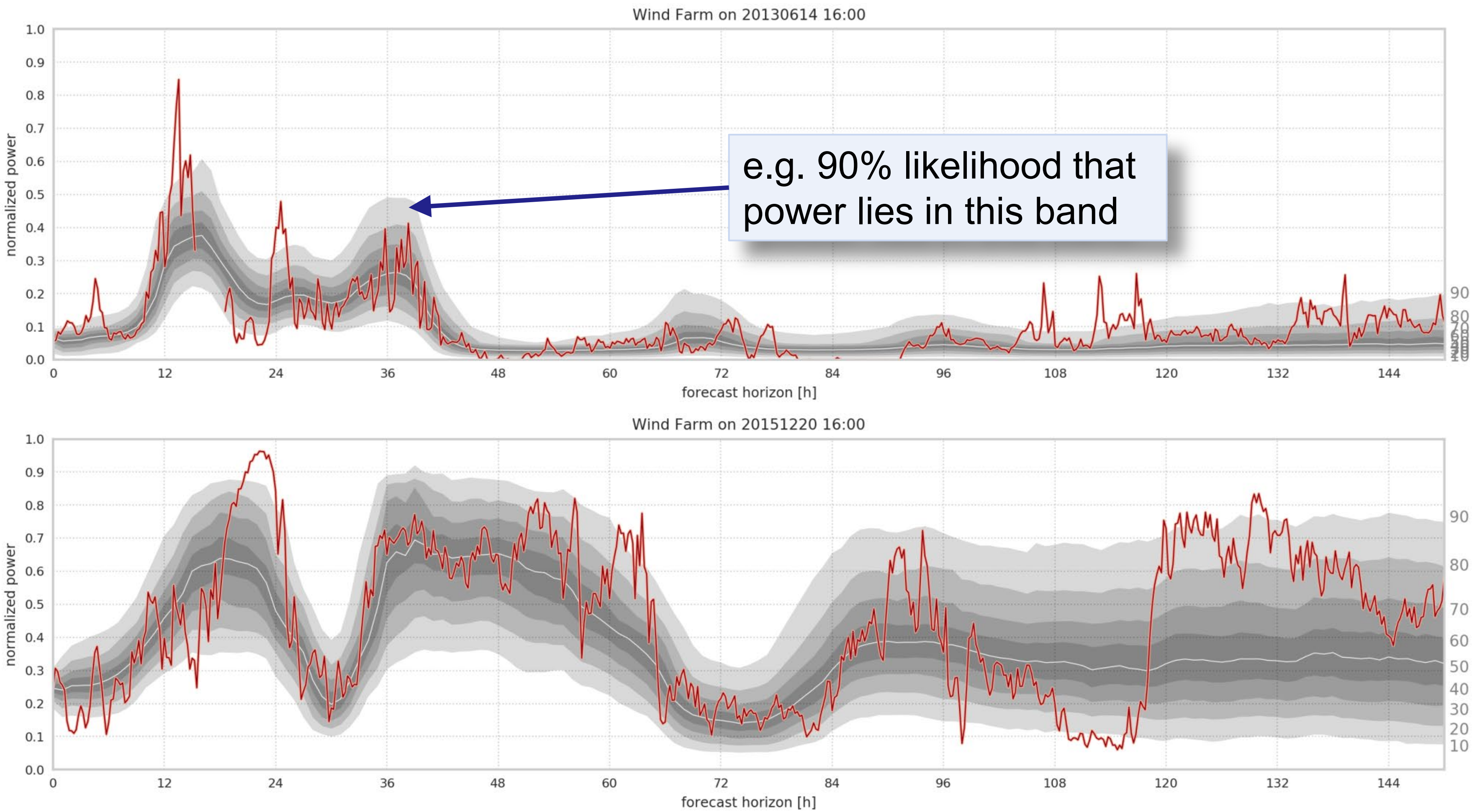
Data set	Time range	# of patterns	Test set
Wind farm	2013–2017	∼33000	12 months
EEX Germany	2015–2017	∼26000	2017

Probabilistic Forecast Results



- shading corresponds to probability density

Transforming into Percentiles



Case Study for Wind Park in Chile

Wind park Totoral:

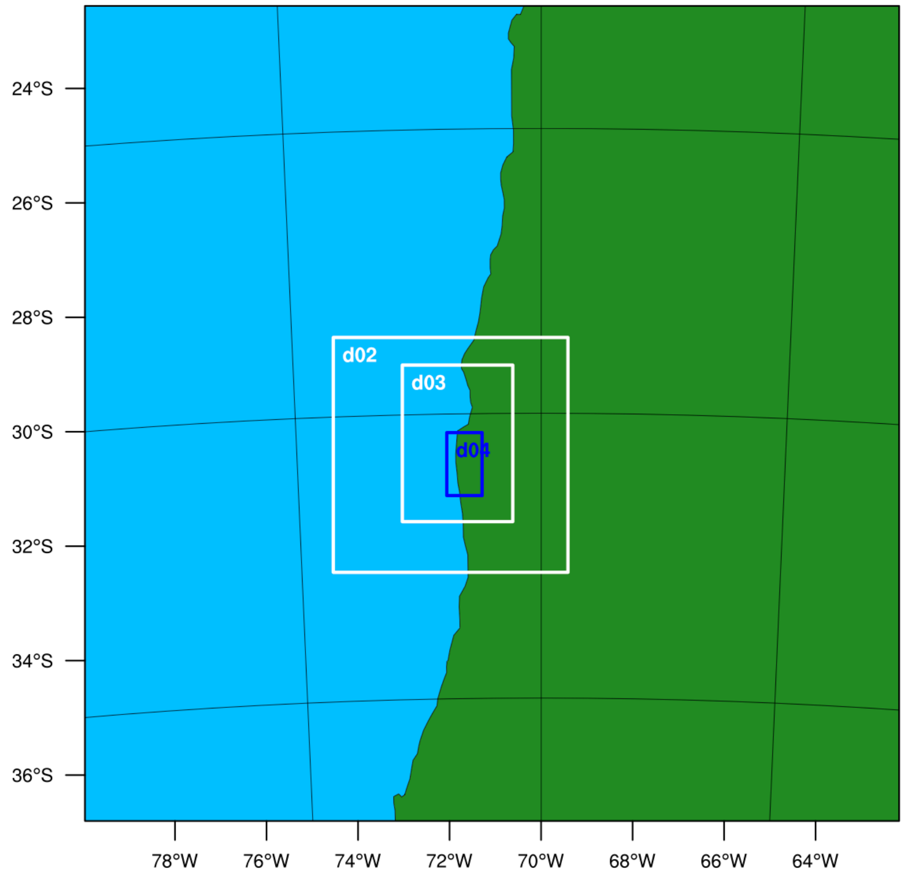
- 23 Vestas V90 2MW
- Close to the Pacific coast

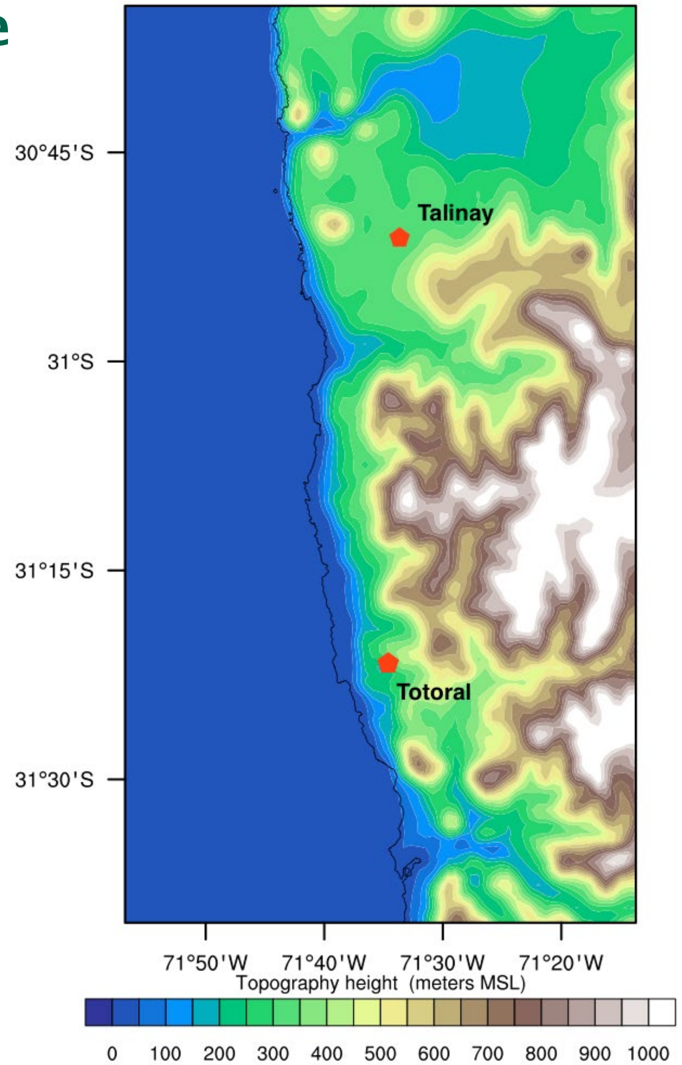
Input data (=predictors):

- relevant fields from **GFS-4, Env. Canada, WRF** models
- live data (SCADA power measurements)

Case Study for Wind Park in Chile

Wind park Totoral: Local WRF mode

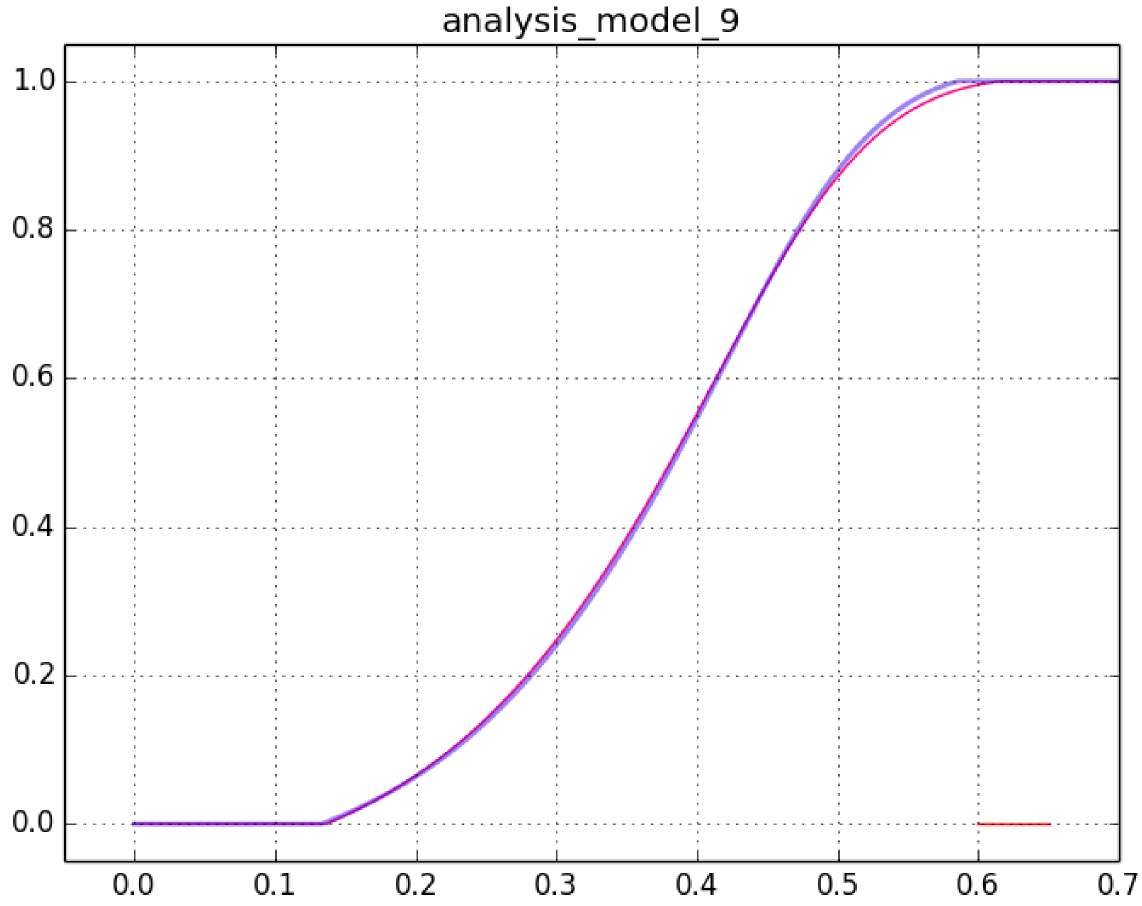




[source: Universidad de Valpariso]

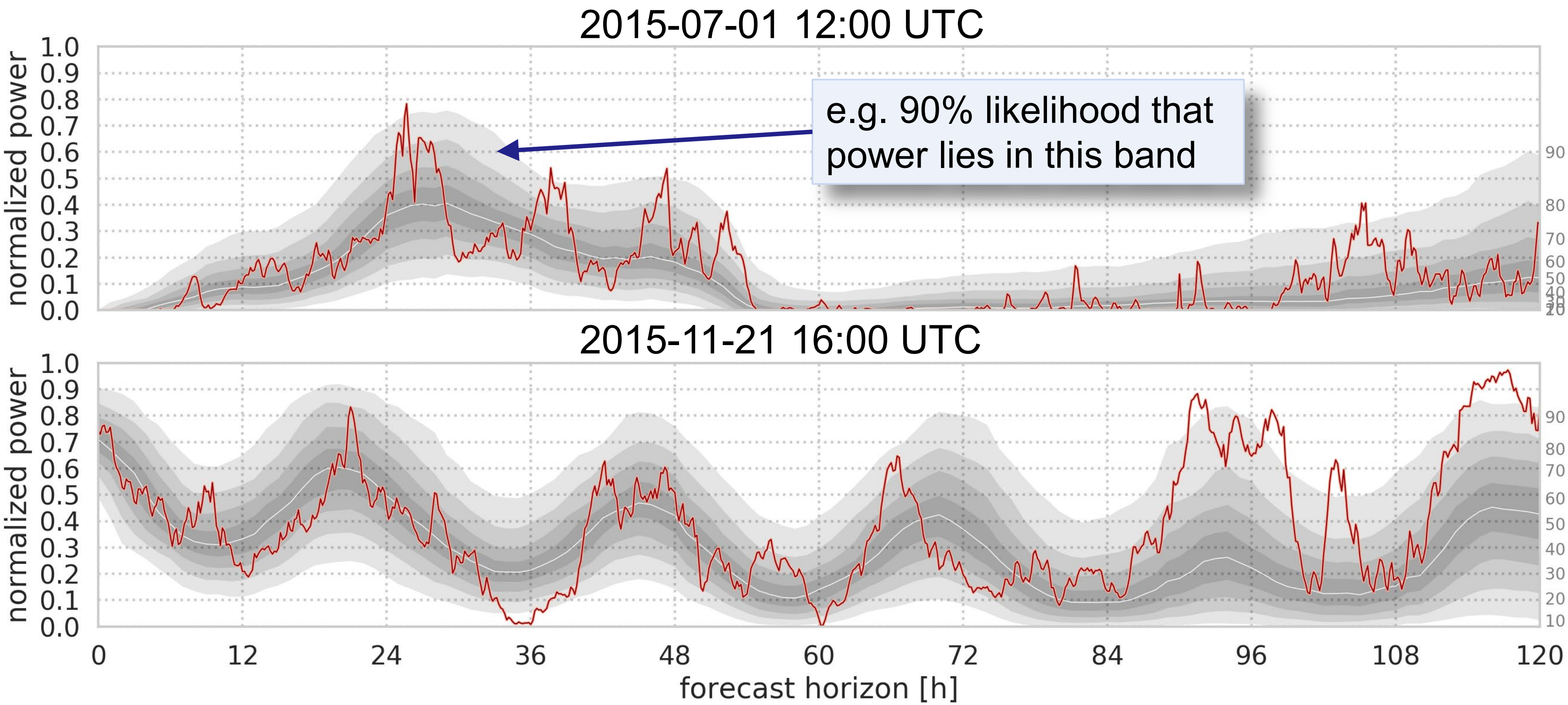
Case Study for Wind Park in Chile

Dependence of Power Curve from wind direction

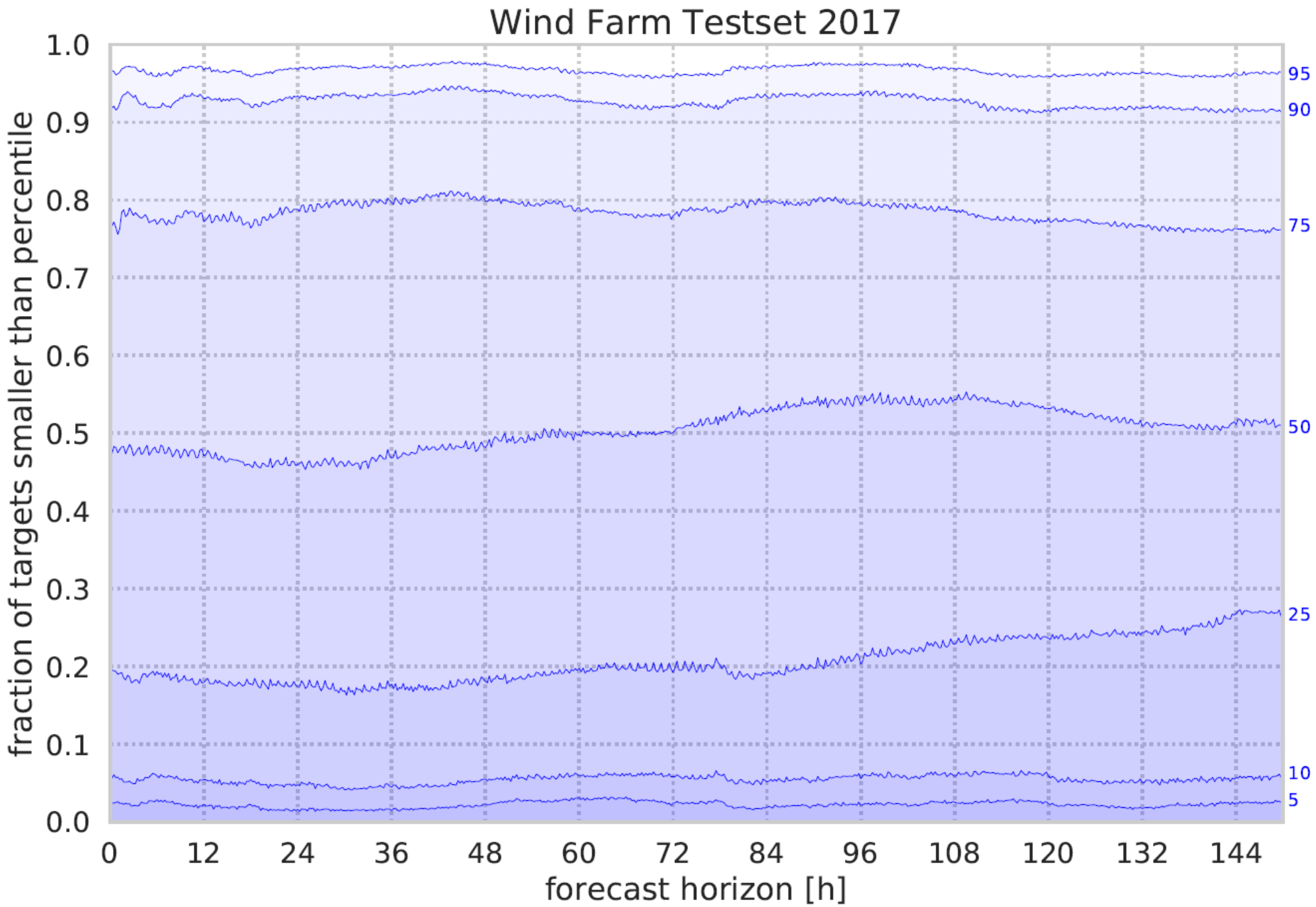


Percentiles for Wind Park in Chile

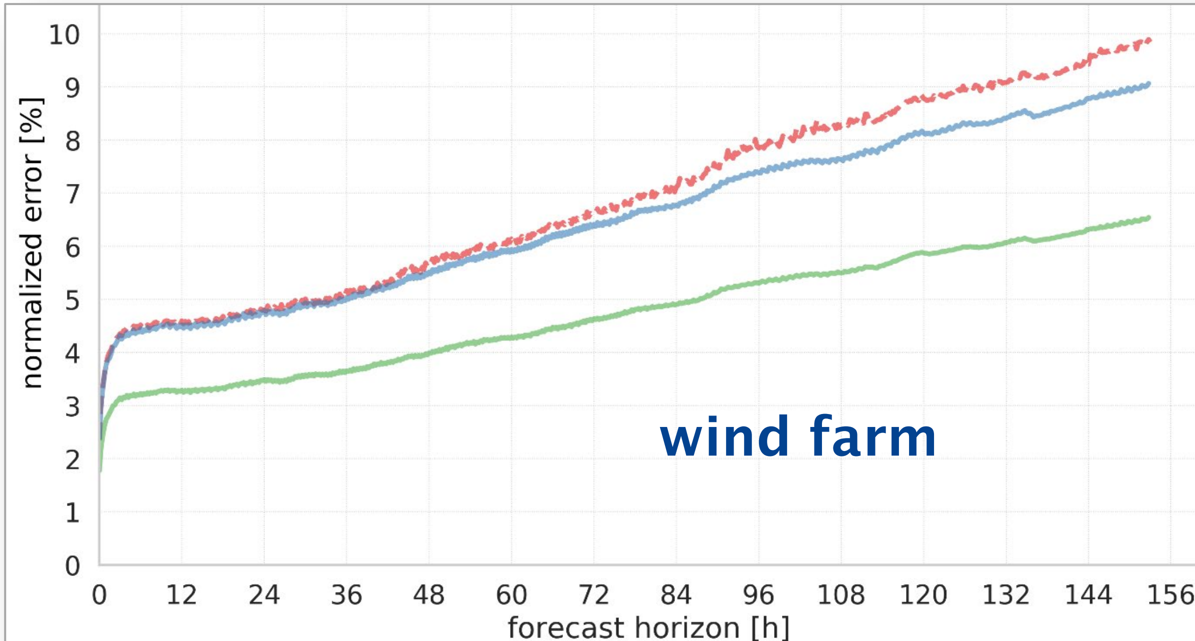
Totoral Wind Park

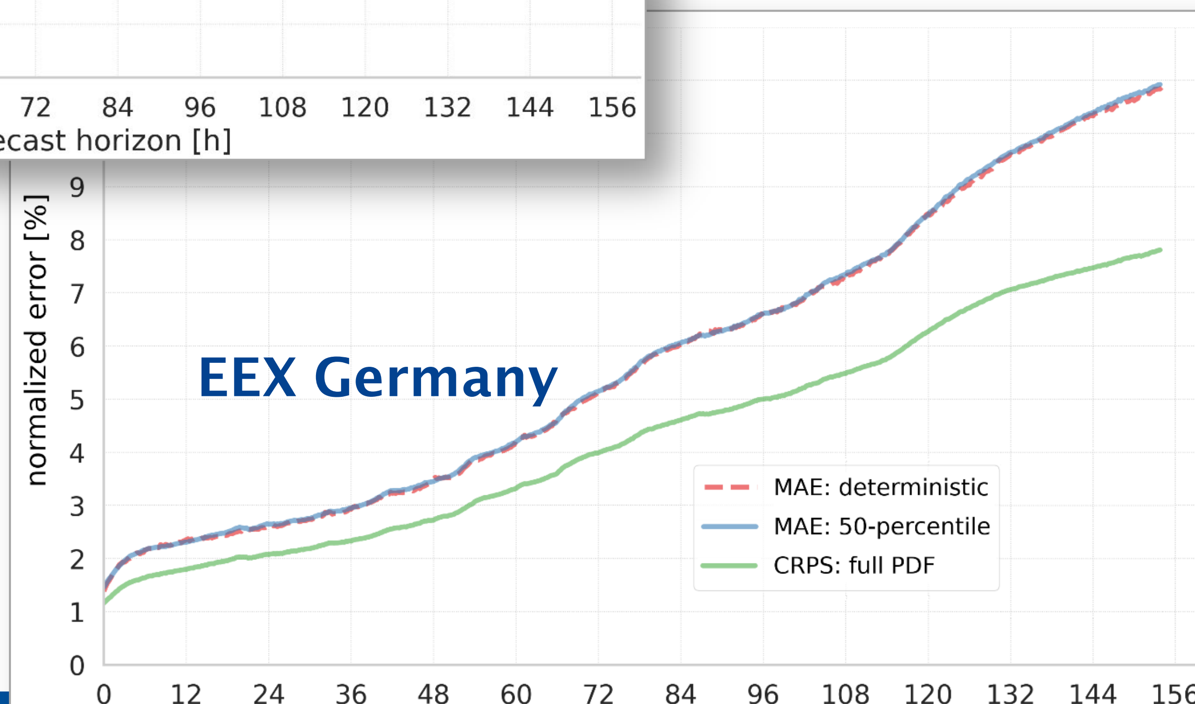


Precentiles Validation



Forecast Errors

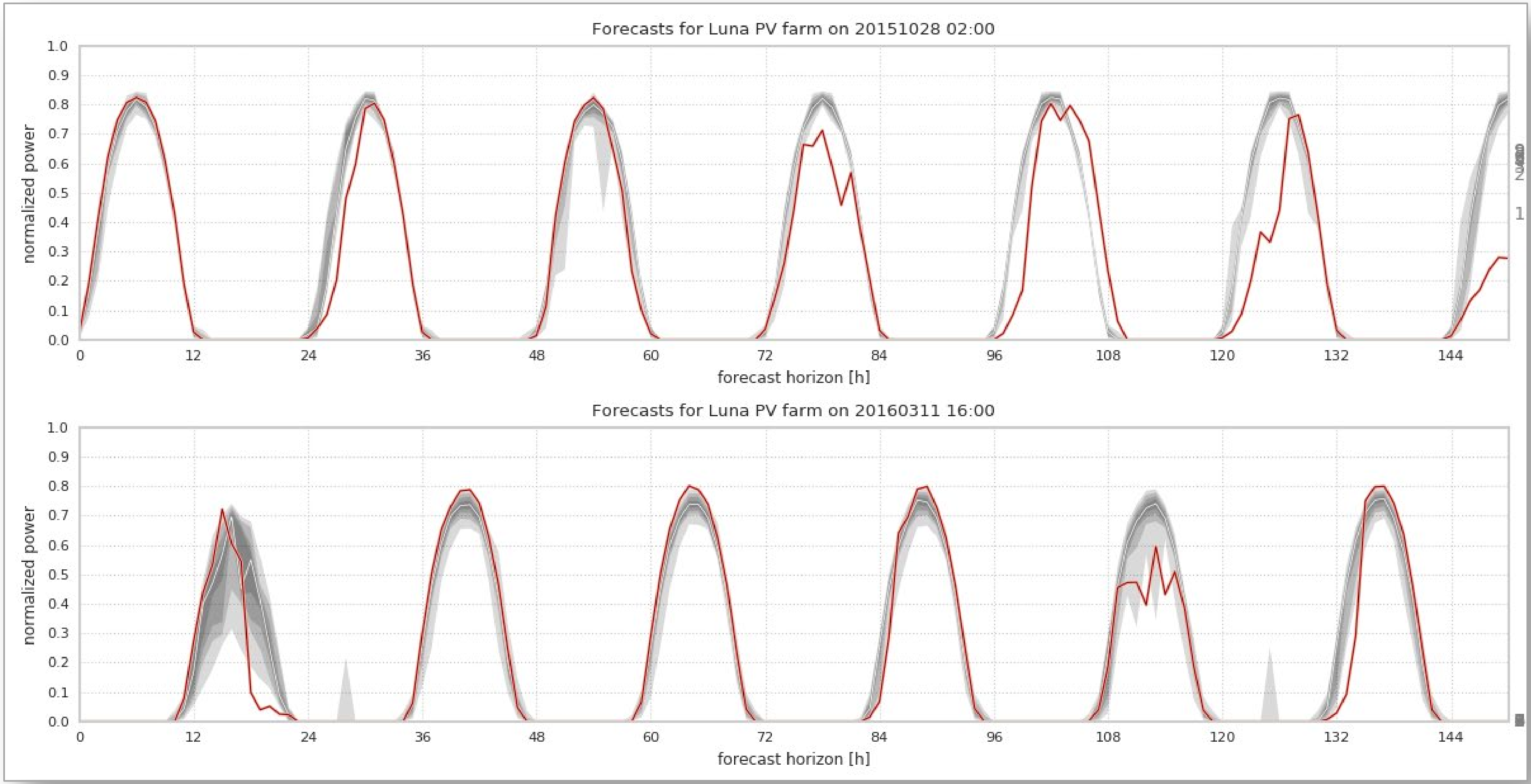




CRPS:
Continuous Ranked Probability Score

Same Story for PV Power Forecast

Example: PV farm in Chile (1 h target resolution)



Conclusions

- Simple method for producing **PDF forecasts** introduced
  - needs only discrete target encoding and some postprocessing
  - applicable for wind and PV power forecast
- Neural networks (DN) use **historical uncertainty** info
  - similar to Analog Ensemble method
  - plus uncertainty from (small) number of different NWP models
- Improved method in preparation for **operational application**

// Energy with a future

// Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)

Thank you for your attention!

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