Uncertainty forecasting practices for the next generation power system

Wind Integration Workshop 2017
Forecasting Session 6A

Berlin, 26th October 2017

iea wind

Task 36 WP3

Corinna Möhrlen, Ricardo J. Bessa, Gregor Giebel, Jess U. Jørgensen

WEPROG INESCTEC DTU WEPROG

Background of this investigation: IEA Task 36: Forecasting for Wind Energy

Task Objective is to encourage improvements in:
1) weather prediction
2) power conversion
3) use of forecasts

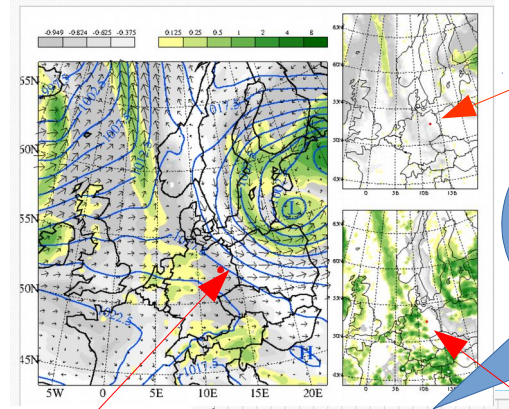
Task Organisation is to encourage international collaboration between:
- Research organisations and projects
- Forecast providers
- Policy Makers
- End-users and stakeholders

Task Work is divided into 3 work packages:
WP1: Weather Prediction Improvements inclusive data assimilation
WP2: Development of a benchmarking platform & best practice guidelines
WP3: Communication of best practice in the use of wind power forecasts

Follow us on our webpage: www.ieawindforecasting.dk

What is the purpose of uncertainty forecasts ?

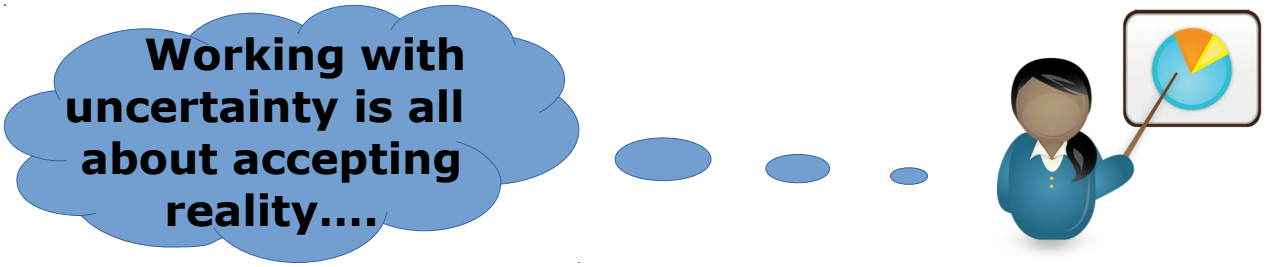
Cloudy with some splits of rain along...



Cloudy with 20% likelihood of some heavy rain in the afternoon and evening...

Do you take your umbrella with you in the morning or not ?

What is the purpose of uncertainty forecasts ?



.. if a forecaster issues a deterministic forecast the underlying uncertainty is still there, and **the forecaster has to make a best guess at the likely outcome**.

Unless the forecaster fully understands the decision that the user is going to make based on the forecast, and the impact of different outcomes,

the forecaster's best guess may not be well tuned to the real needs of the user .

Uncertainty forecasts make the unknown atmomspheric development visible, so we can take a decision based on a more realistic picture of the future...

How to define and understand Uncertainty

forecast error spread

confidence interval

forecast uncertainty

forecast interval

Forecast Error Spread

Definition:
Historically observed deviation of a forecast to its corresponding observation at a specific time.

An average error provided by an error metric, e.g. variance or standard deviation.

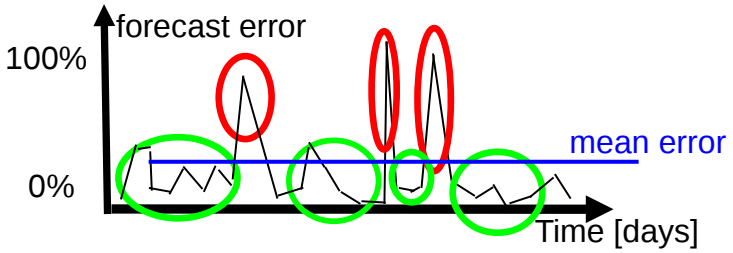
Confidence Intervals

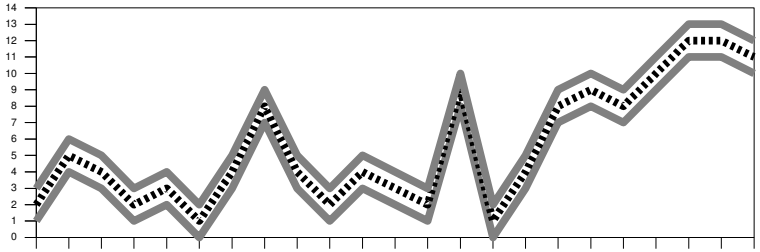
Definition: a confidence interval expresses the degree of uncertainty associated with a sample statistic and is an interval estimate combined with a probability statement.

Statistical confidence intervals in wind power represent a measure of the deviation to **climatology** and **do not** represent **uncertainty in space or time.**

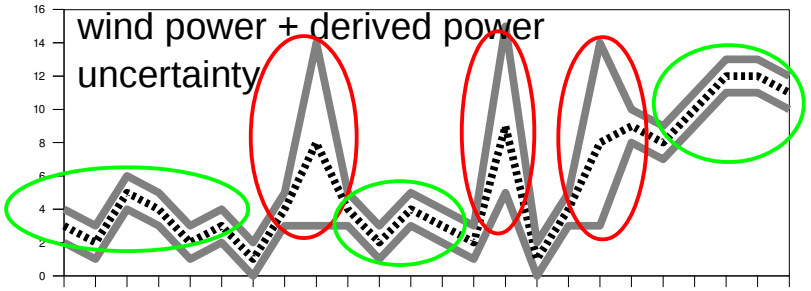
Physical ensemble generated confidence intervals represent **uncertainty in space and time**

Wrongly used formulation of confidence intervals from forecast error spread





wind speed + const. error band from past verification



Methodology in Wind Power:

Evaluation of errors in the past lead to a statistical mean error value in wind speed.

Error band from statistical test is fit around wind speed

Power curve conversion lead to an *apparently* changing uncertainty

Be aware of:

- no spatial- or temporal representation of the uncertainty
- does not relate to the physical character-istics of the modelled parameters
- does not work to detect extreme events

Forecast Uncertainty

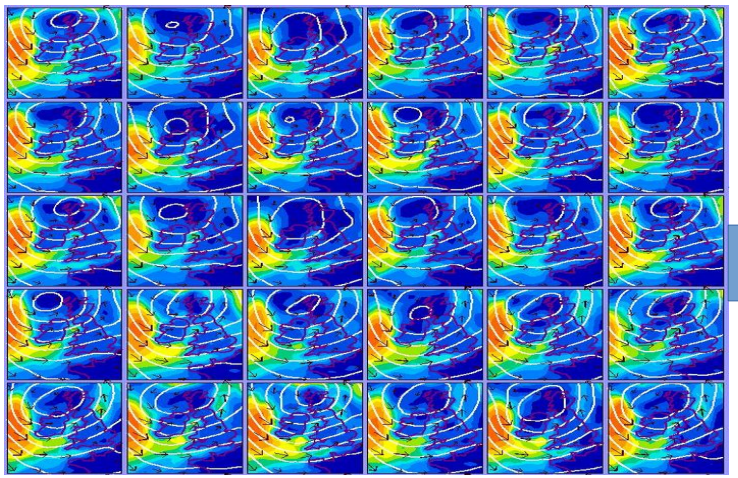
Definition: a possible range of forecast values in the future.

In meteorology it is defined as a range of possible solutions of the atmospheric development in the future and is

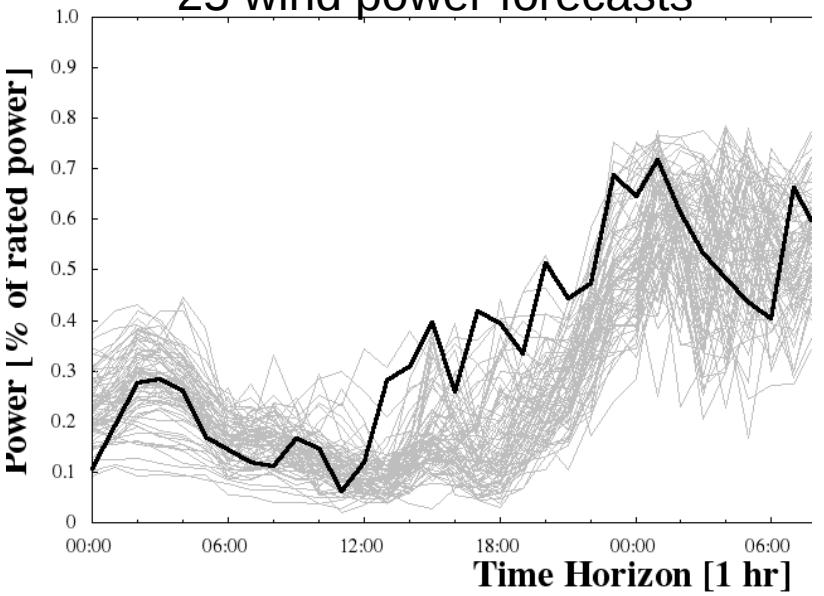
represented in ensemble forecasts by

- **perturbations to initial and boundary conditions**
- **expressing model physics differences**

25 weather forecasts



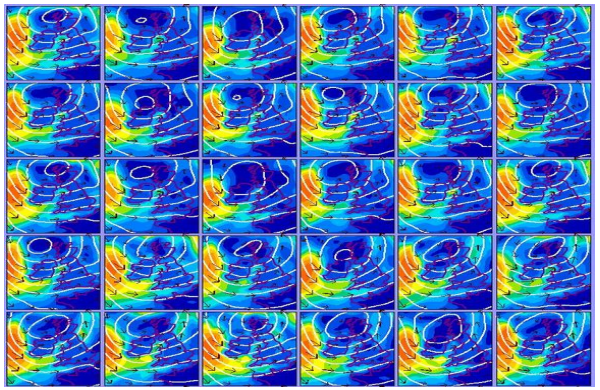
25 wind power forecasts

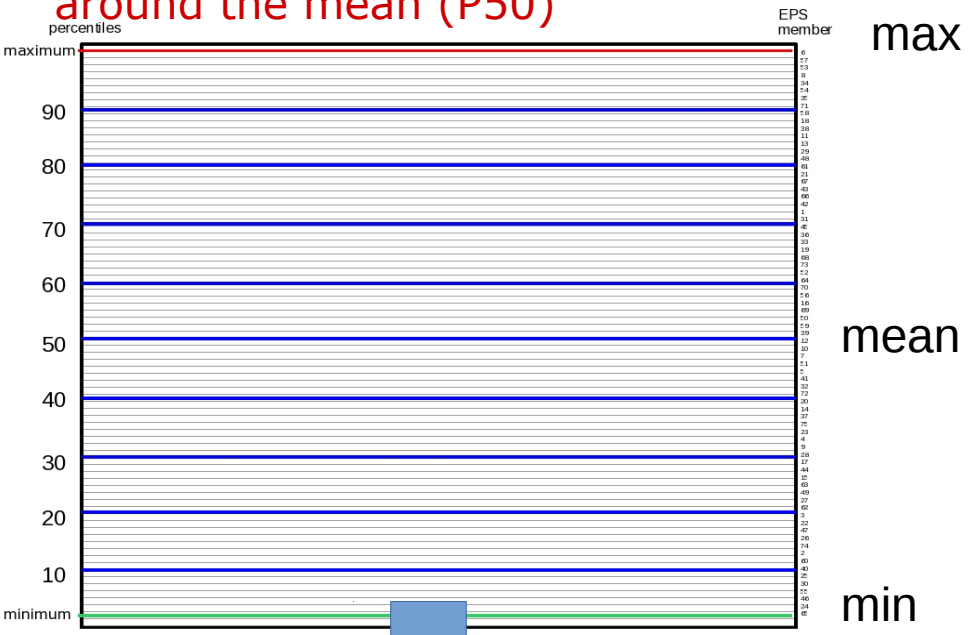


Forecast Uncertainty

Uncertainty range is between minimum and maximum forecast value, centered around the mean (P50)

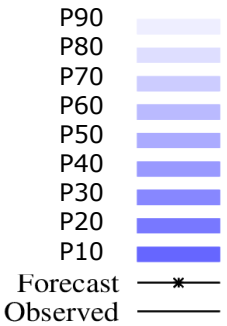
Wether Ensemble

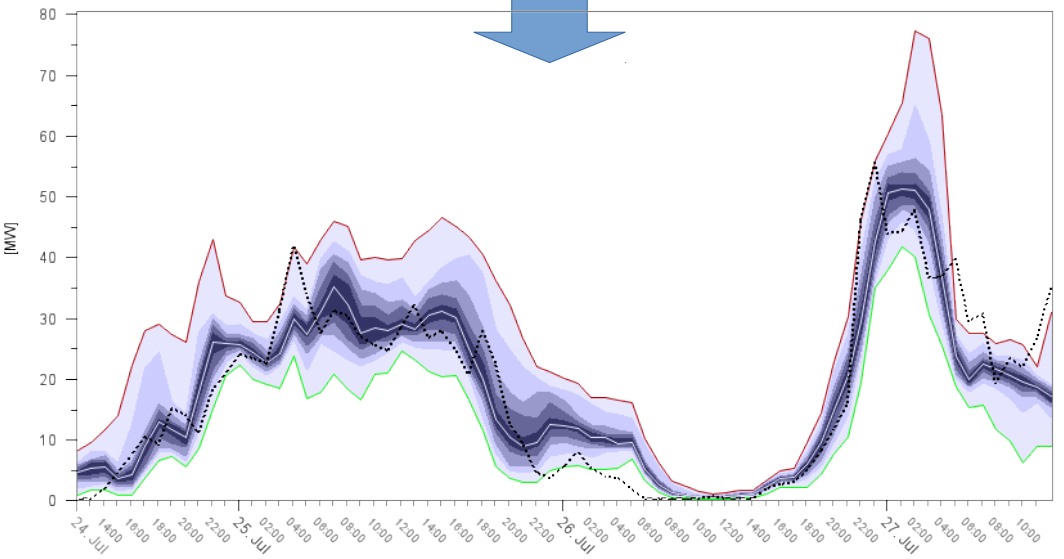




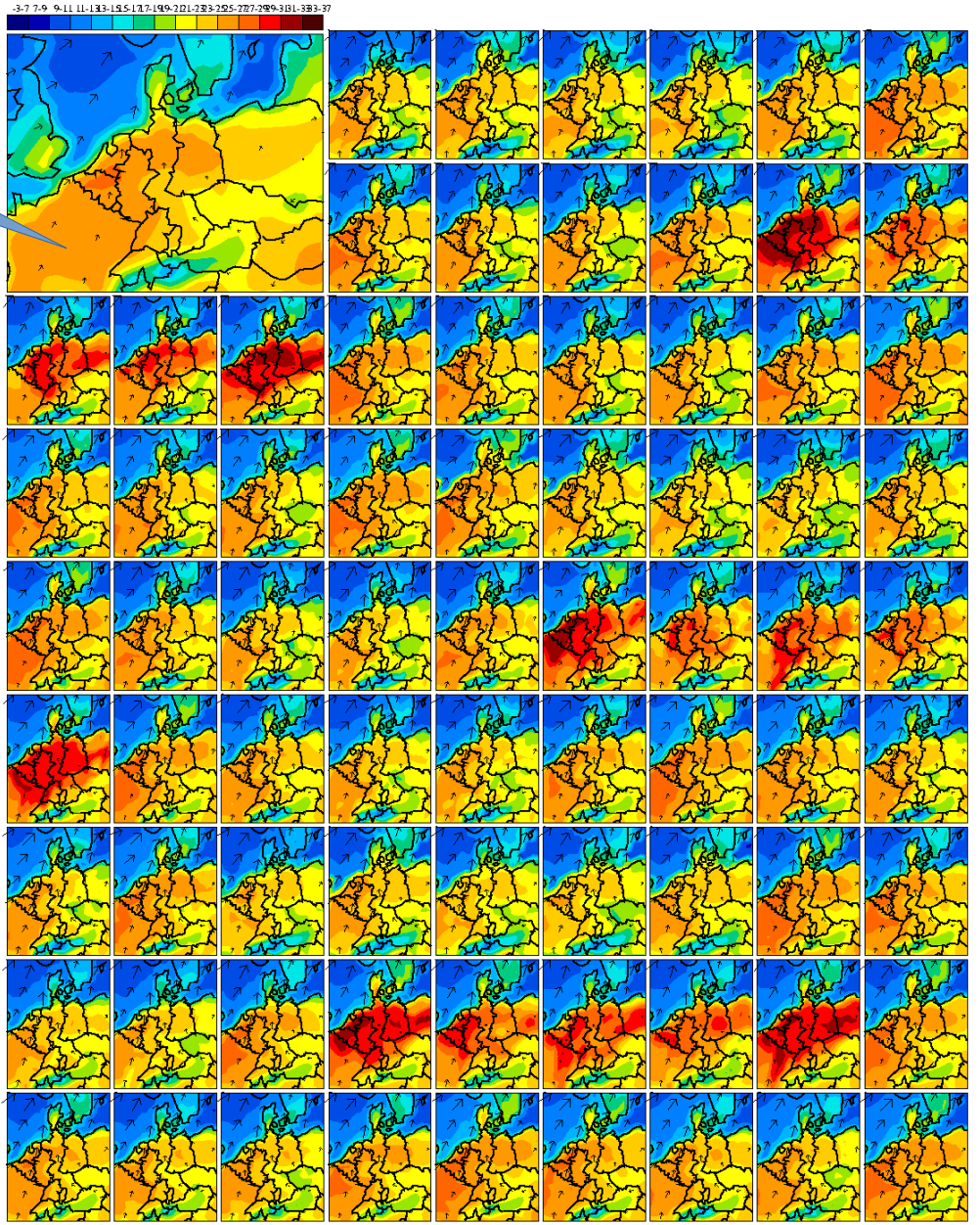
Example: 68 members:
=> 90% probability/confidence
=> percentile 90

the intervals are generated in that way for every time step of the forecast





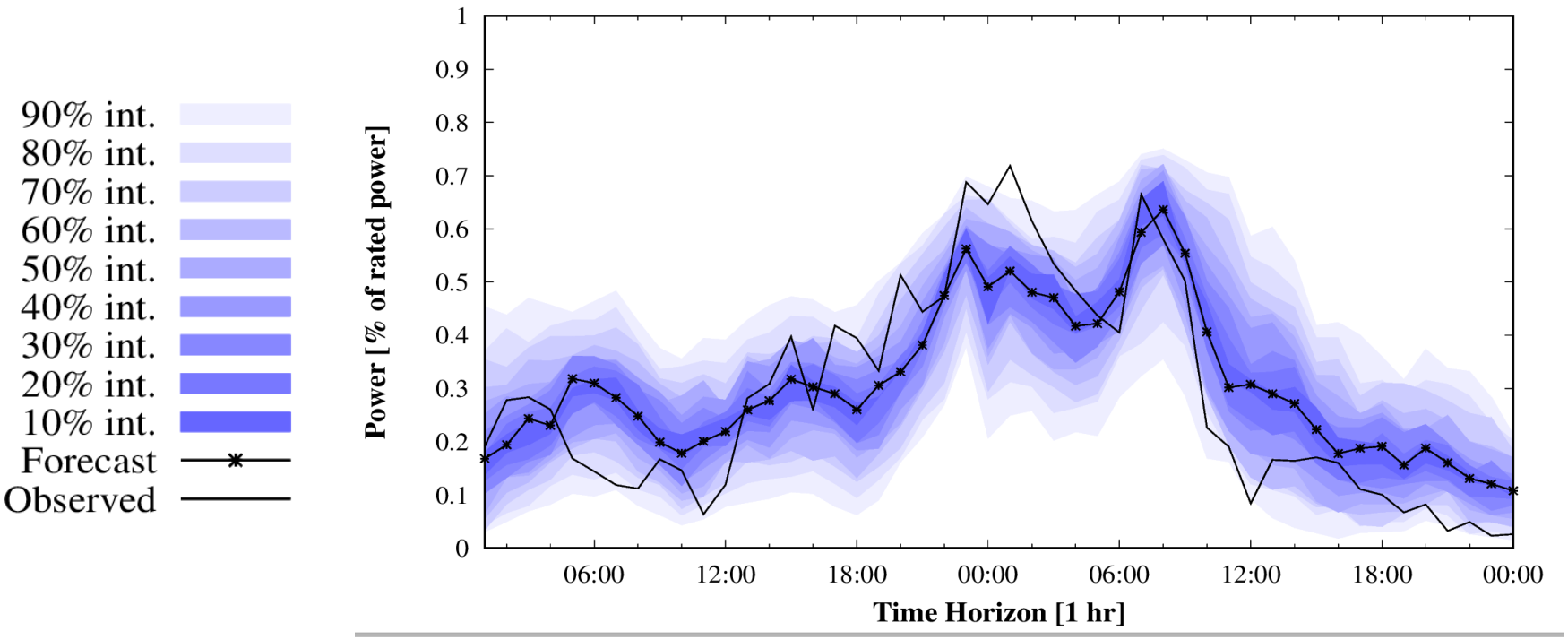
Forecast Uncertainty



In a weather ensemble with physical parameterization differences, the mean is a “real” weather forecast

Forecast Intervals

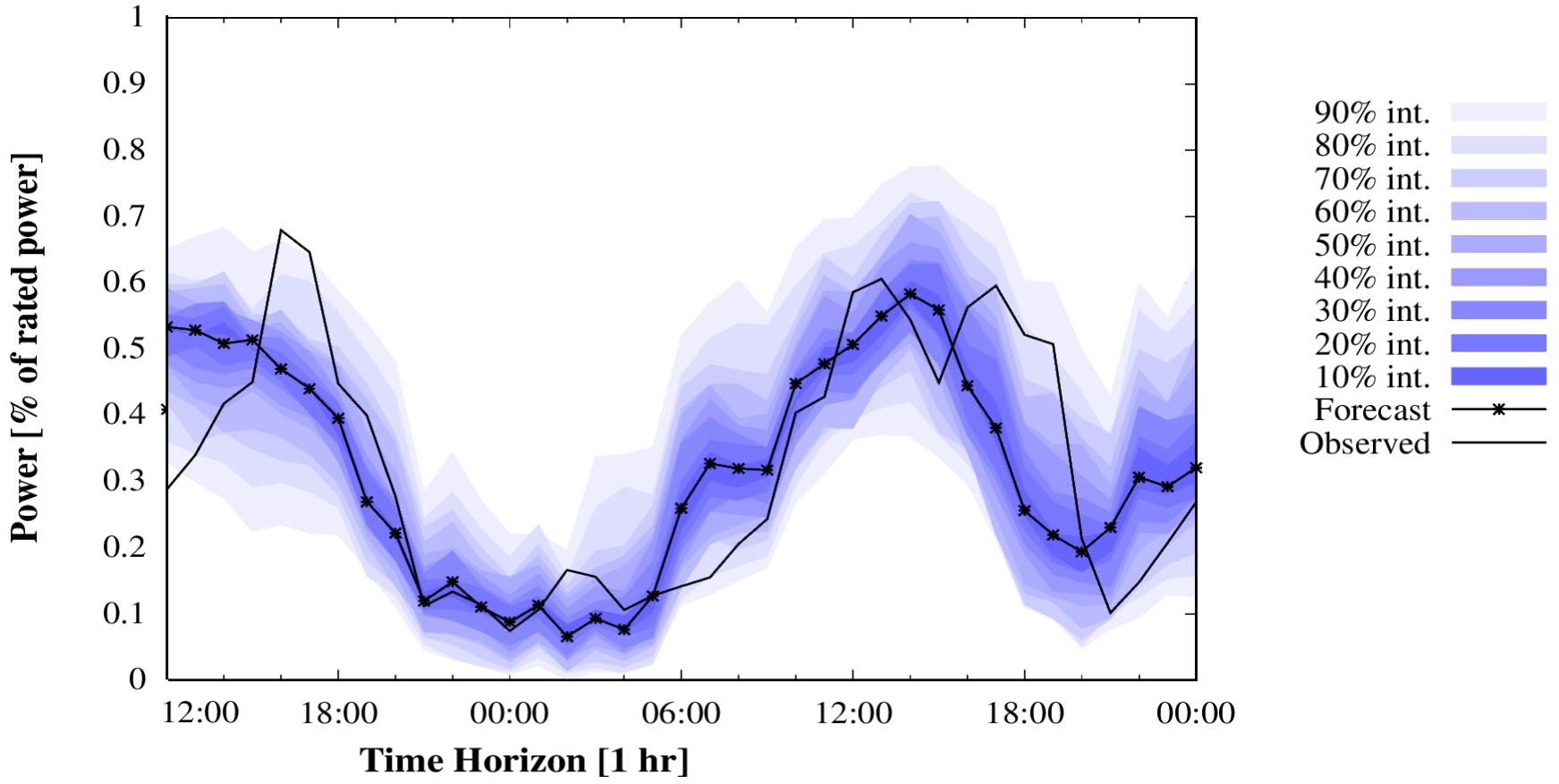
Definition: Forecast intervals are the coverage rate that corresponds to the probability of having the observed value inside the forecast interval



Note: when constructing prediction intervals, it is a standard convention that the interval is **centered on the median, in terms of probability**. Such forecast intervals provide likelihood at one specific time

Visualisation of Uncertanty

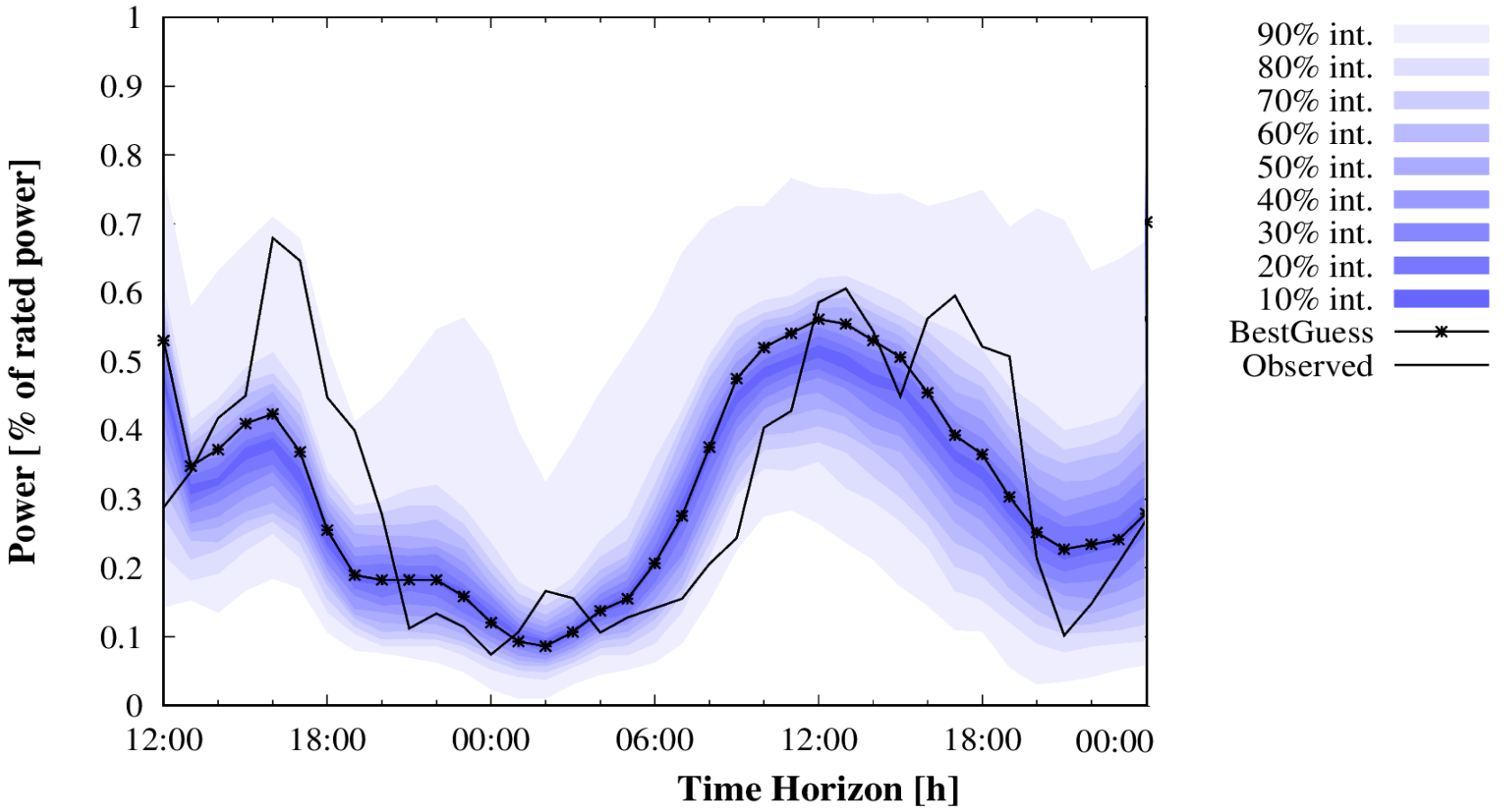
Quantile plot with statistically derived **forecast intervals**



Note: the intervals are generated with historical information and **do not represent current weather uncertainty**

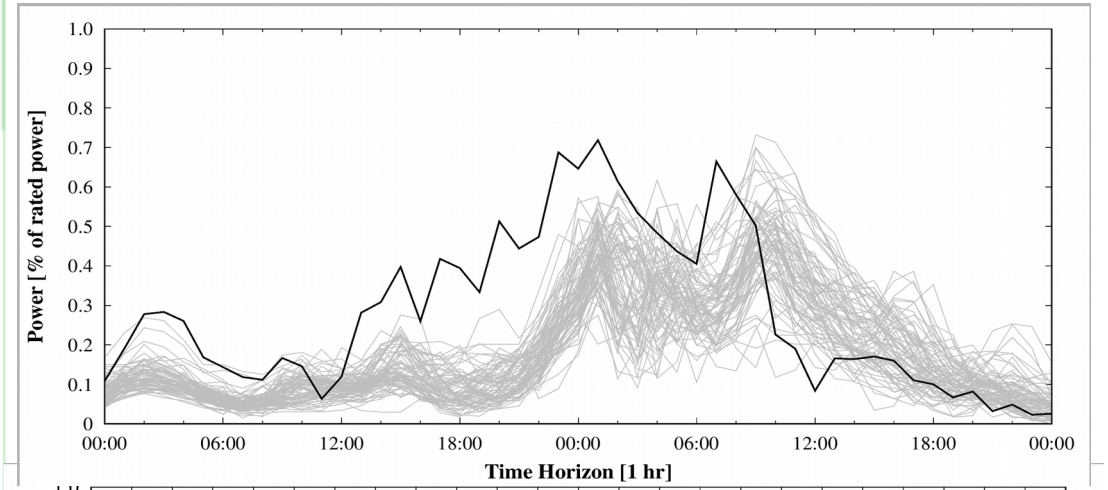
Visualisation of Uncertainty with "fan charts"

Quantile plot from a multi-scheme **ensemble prediction system**

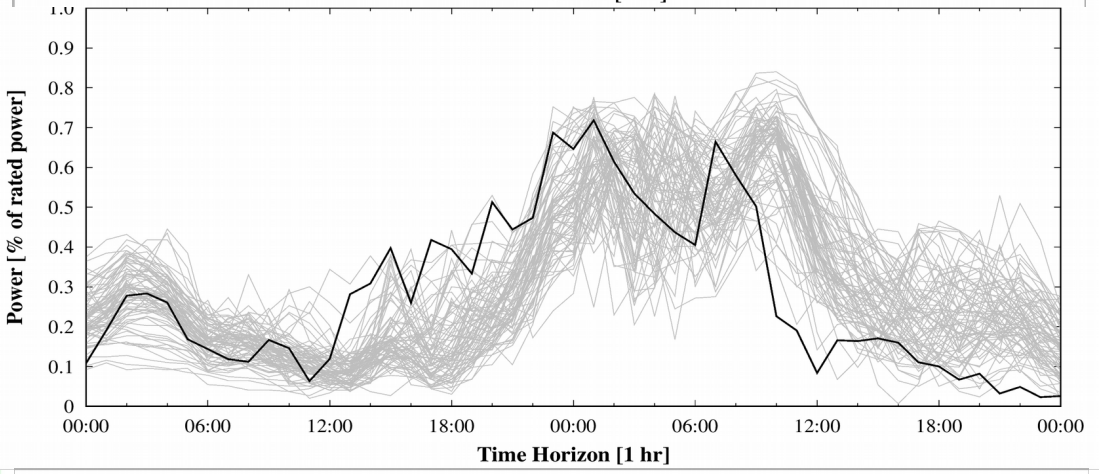


Note: The weather ensemble has a large 90% interval – for the extreme hours 14-16 on day 1 the few members represent reality and contain the observations. **The ensemble represents current weather uncertainty in space and time.**

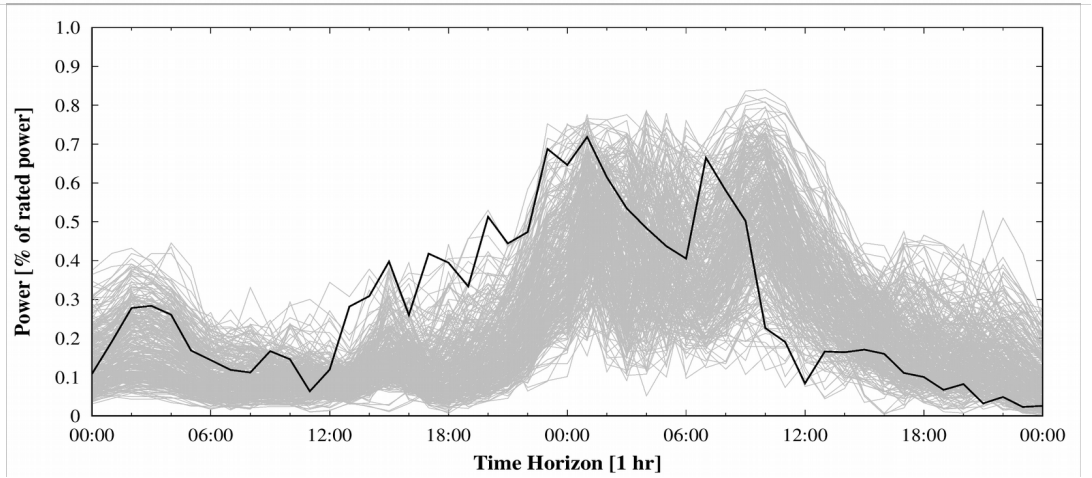
Visualisation of Uncertainty with "spaghetti plots"



75 wind power forecasts at 40m from a 75 member multi-scheme ensemble prediction system (MSEPS) at a wind farm in Spain



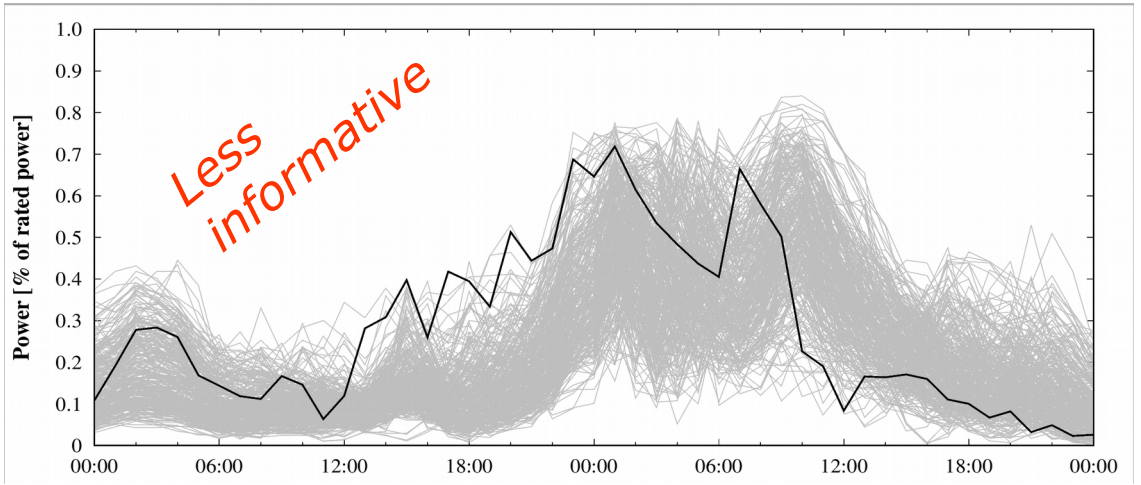
As on 1st figure, but this time with 75 wind power forecasts at 150m height



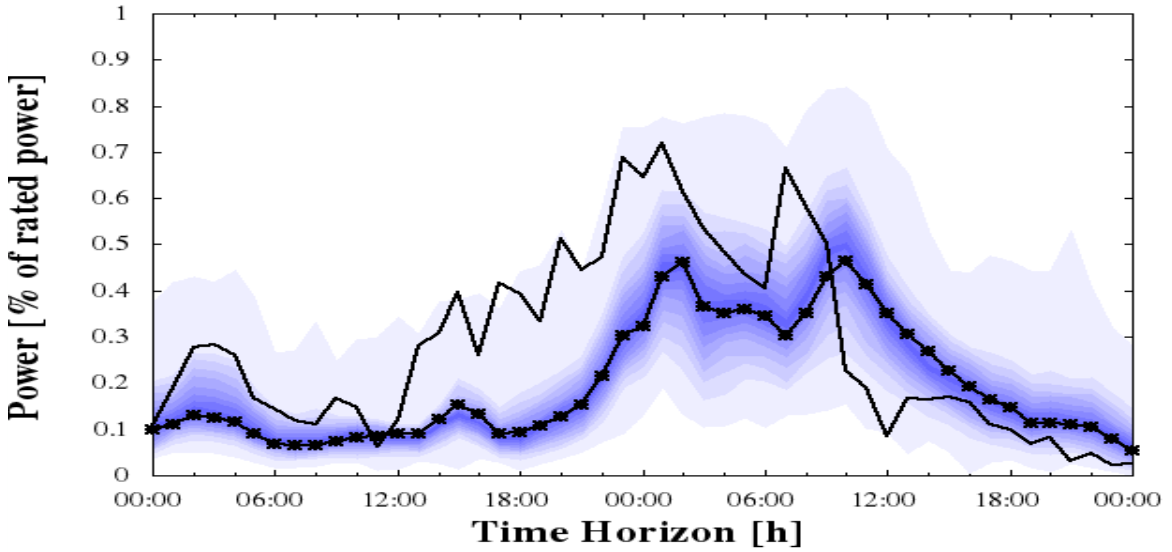
As on 1st figure, but this time with 300 wind power forecasts at 10,40,100,150m height

Be aware: when calling an ensemble "underdispersive", it can sometimes be due to the wrong choice of parameters – e.g. height of wind speed !

Visualisation of Uncertainty Forecasts

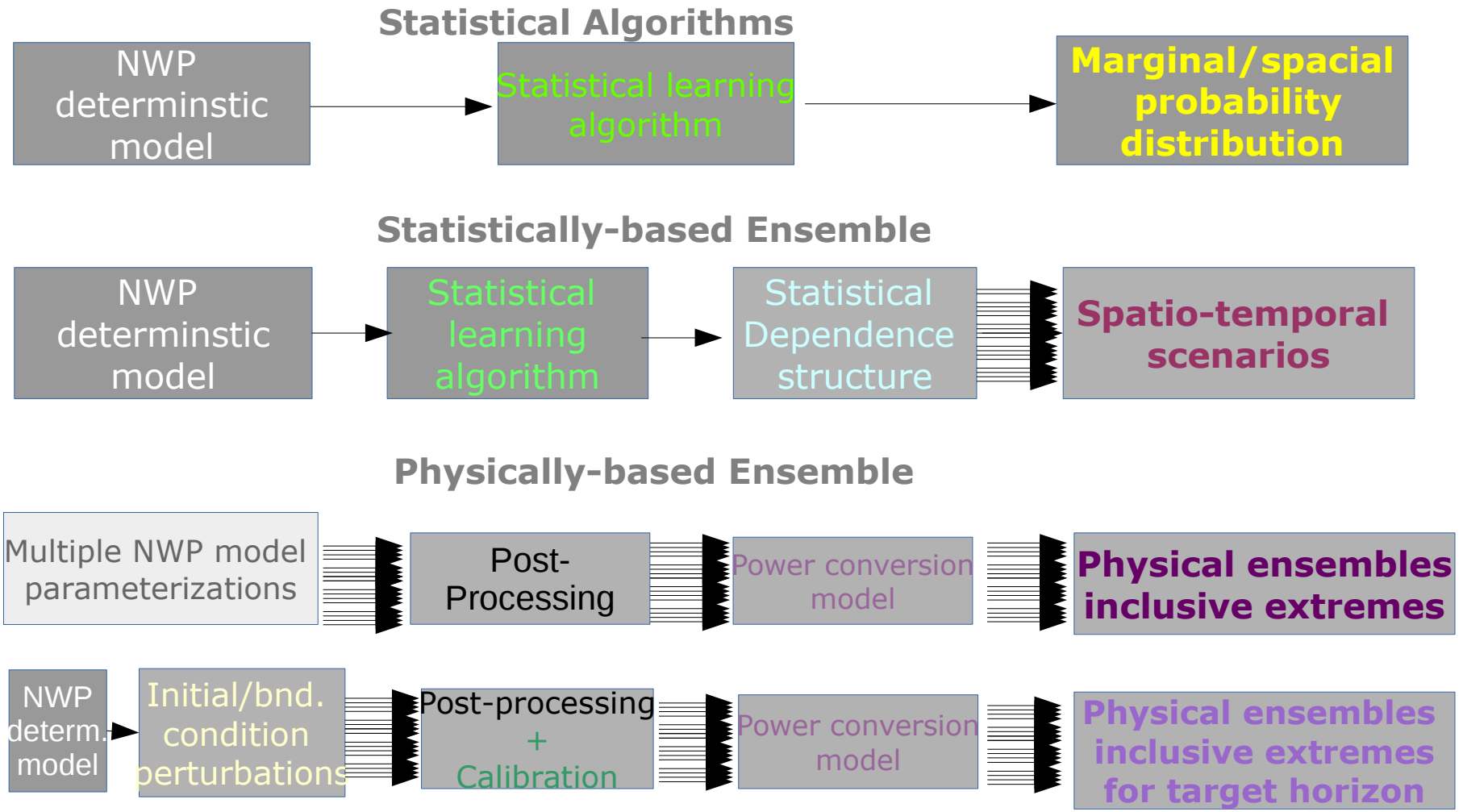


Spaghetti plot of 300 wind power forecasts from a 75 member multi-scheme ensemble prediction system (MSEPS)



Quantiles Fan Chart with Quantiles from a 75 member multi-scheme ensemble prediction system (MSEPS)

Main Methods to generate Uncertanty Forecasts



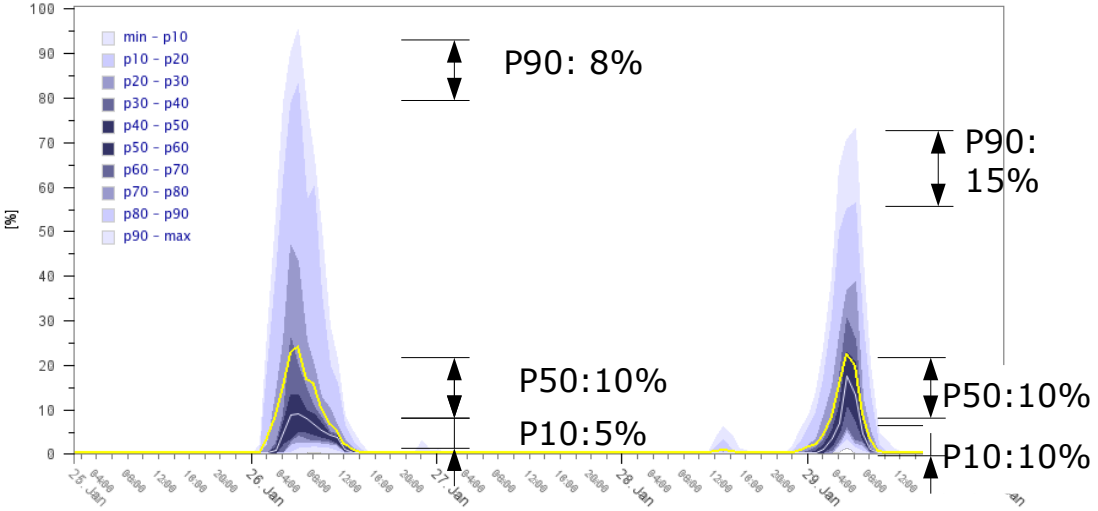
Be aware of the differences for your applications!!!

Most common Applications in the Power Industry

1) Balancing/trading of wind/solar power
2) **Probabilistic reserve setting**
3) Situational awareness
4) Flexibility management in smart power grids
5) **High-Speed shut down warning system**

Application Example: High-speed Shut-down using Ensemble Forecasts

High-speed shut down index



Index:

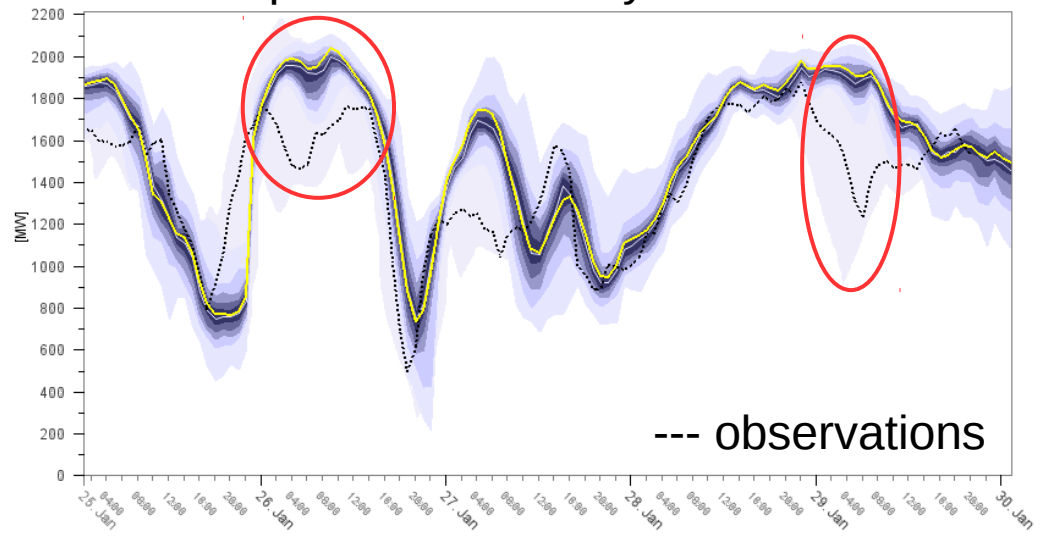
Case 1 at 26. January:

- *8% probability of 90% shutdown*
- *10% probability of 50% shutdown*
- *90% probability of 5% shutdown*

Case 2 on 31. January:

- *15% probability of 90% shutdown*
- *10% probability of 50% shutdown*
- *90% probability of 10% shutdown*

Wind power uncertainty in MW



Result:
Case 1: 35% HS-shutdown
Case 2: 45% HS-shutdown

Note: interpretation of the risk is very individual and requires threshold values from the end-user

Application Example: High-speed Shut-down using Ensemble Forecasts

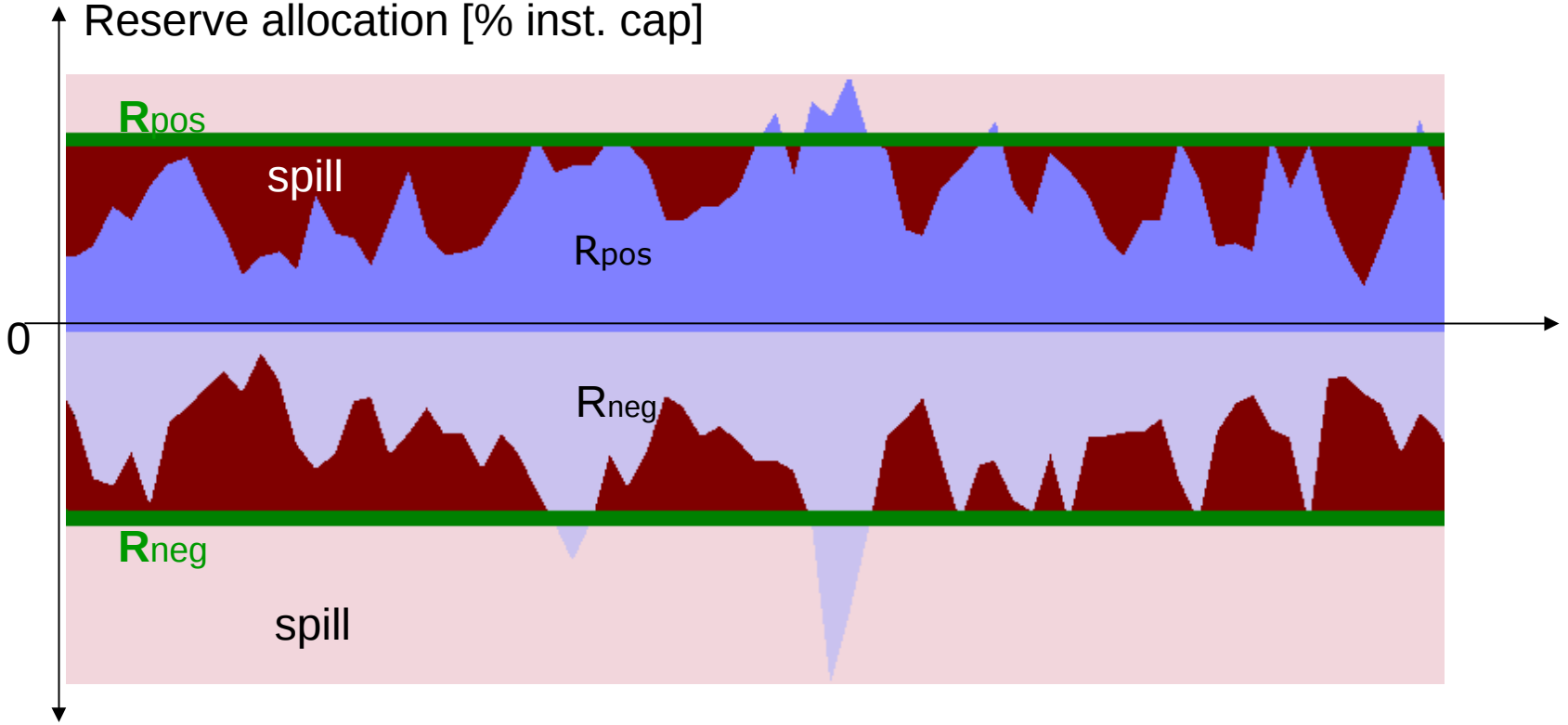
Example assumptions on some thesholds:

wind speed in 100m	index value
0 - 22.5 m/s	0.00%
22.5 - 24.5 m/s	0 -> 100%
24.5 m/s ->	100.00%

Be aware of: necessary defitions for an alarm system

(a) lead time of the alert
(b) change of severity level since previous alert
(c) initial and valid week day and time of the day
(d) severity of the event computed from a ramp-rate perspective and required actions
(e) the need and possibility to call back and/or revert actions

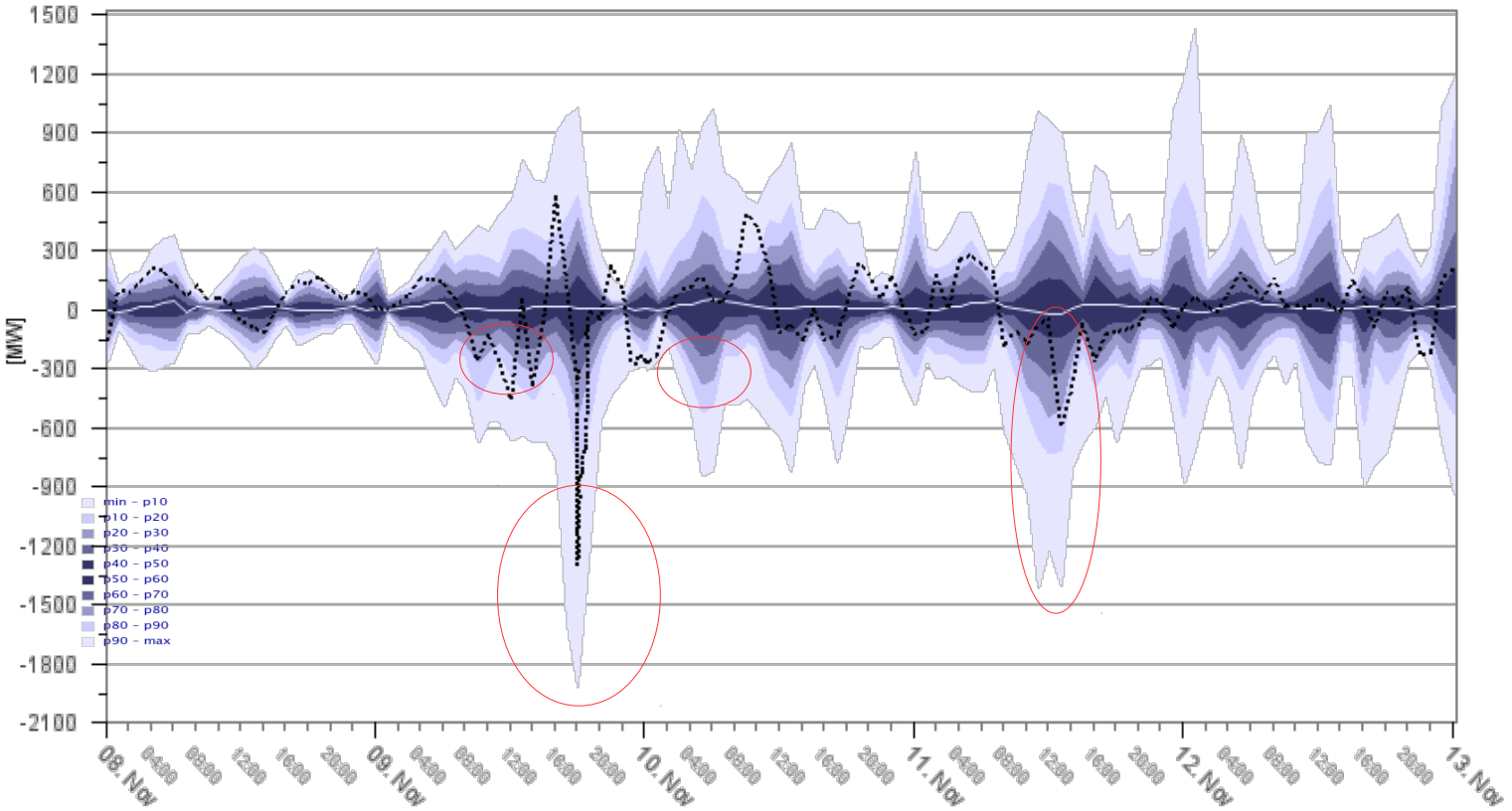
Reserve Predictions using Ensemble Forecasts



Be ware of:
Only by being able to predict the forecast error can we predict reserve !

In in a well-calibrated ensemble forecast, the forecast error is contained in the ensemble member spead at all times

Reserve Predictions using Ensemble Forecasts



Static reserve allocation generates a lot of spill and still does not cover outliers

Using **reserve foreast intervals reduce the amount of reserve significantly**

But…do not forget the outliers and how to setup warnings for them!!!

Lessons Learnt for Reserve Forecasting

When setting up reserve forecast it is important to:

have the correct type of probabilistic forecast data input

- Physical or statistical ensemble approach
- deterministic or statistic algorithmns do not provide uncertainty
- it is the weather uncertainty that generates the errors

define the forecast objective very clearly

- which types of errors are critical
- what type of reserve fits to my objective:
  typical scenarios are: static, security or dynamic/economic

set the time scales that needs to be forecasted

- required ramping capabilities

use aggregated forecasts of all weather dependent sources & sinks

- built the uncertainty term on load+wind+solar

define a "noise term" to handle the non-local imbalances

- imbalances from interconnections
  (small system <-> large system)

Wrap up:
Using Applications based on the Uncertainty Forecasts

means, we deal with:

- **High information level**
- **Wide application level**
- **Applicable using Linear Algebra and Numerical methods**
- **Suitable for automatic processes**

Leading to:

→ End-user tailored simplified solutions
→ Increased productivity
→ Economic growth

Intelligence is contained in the uncertainty data
=>
Applications are much simplified!

Thank you for your attention !

Follow us:

Project webpage

http://www.ieawindforecasting.dk/

Task-page:

http://www.ieawindforecasting.dk/topics/workpackage-3/task-3-1

http://www.ieawindforecasting.dk/topics/workpackage-3/task-3-5

Contact:

Coordinator:
Dr. Gregor Giebel: **grgi@dtu.dk**

Task Leaders

Dr. Corinna Möhrlen: **com@weprog.com**

Dr. Ricardo Bessa: **rbessa@inescporto.pt**