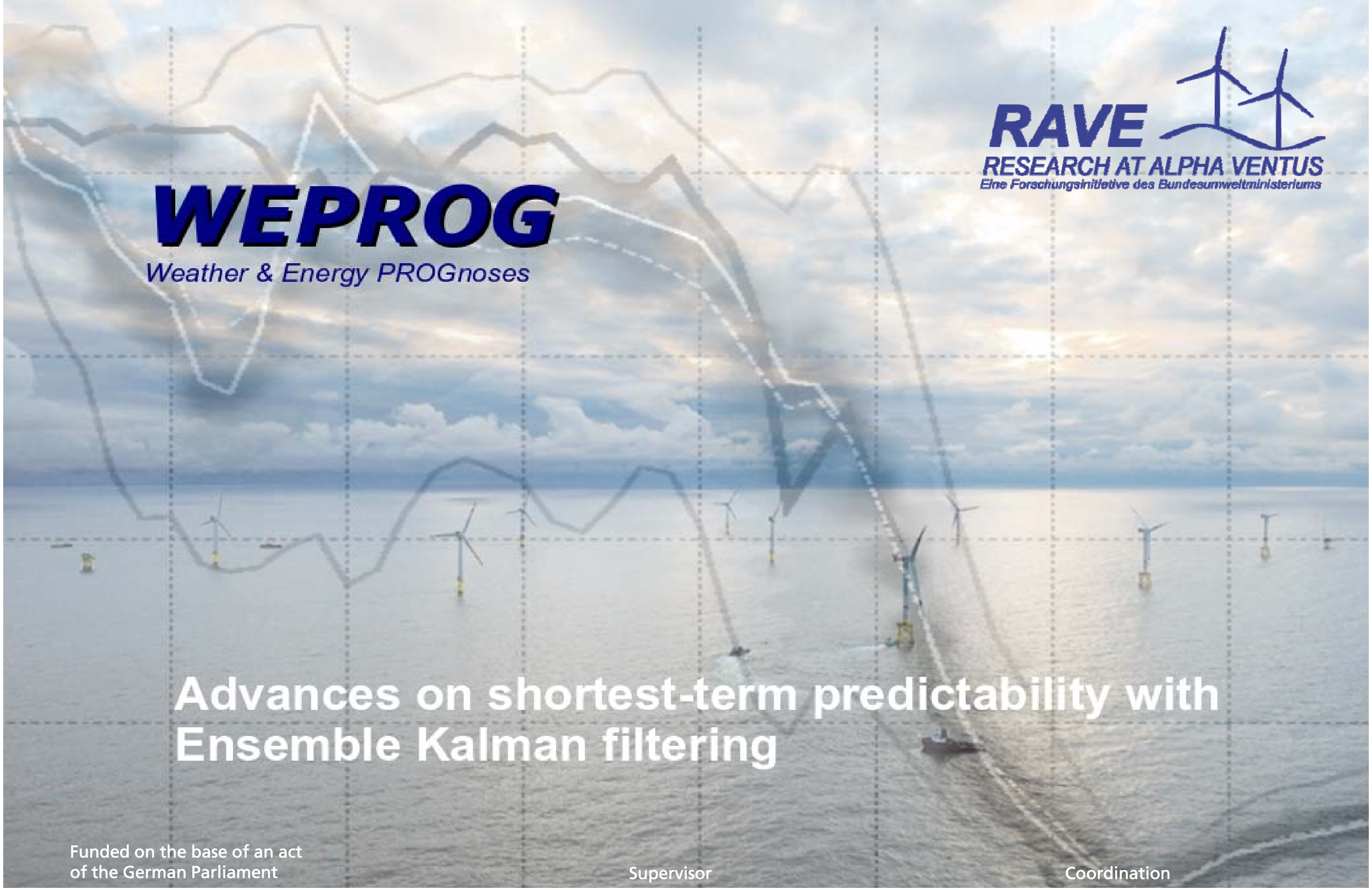


WEPROG
Weather & Energy PROGnoses

RAVE
RESEARCH AT ALPHA VENTUS
Eine Forschungsinitiative des Bundesumweltministeriums

Advances on shortest-term predictability with Ensemble Kalman filtering

Funded on the base of an act
of the German Parliament

Bundesministerium
für Umwelt, Naturschutz
und Reaktorsicherheit

Supervisor

PtJ
Projektträger Jülich
Forschungszentrum Jülich

Coordination

Fraunhofer
IWES

Table of Contents

Introduction to the Offshore forecasting problem

What characterizes offshore wind power:

>> high load factor (often between 40-50% of inst. capacity)

>> high variability of the wind power

What characterizes offshore wind power **forecasting**:

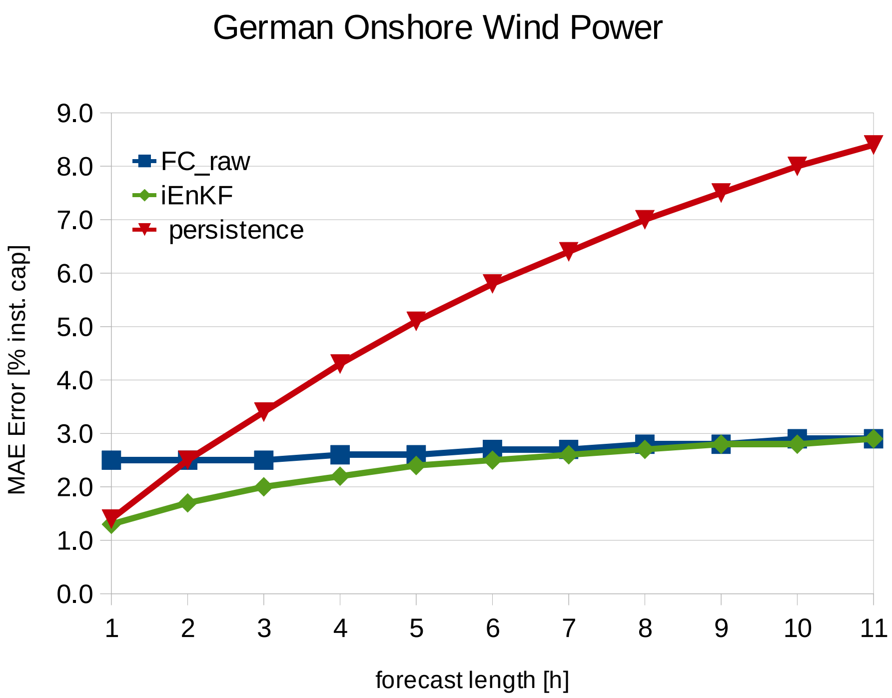
>> the forecast error is low relative to the generated power (~25% day-ahead)

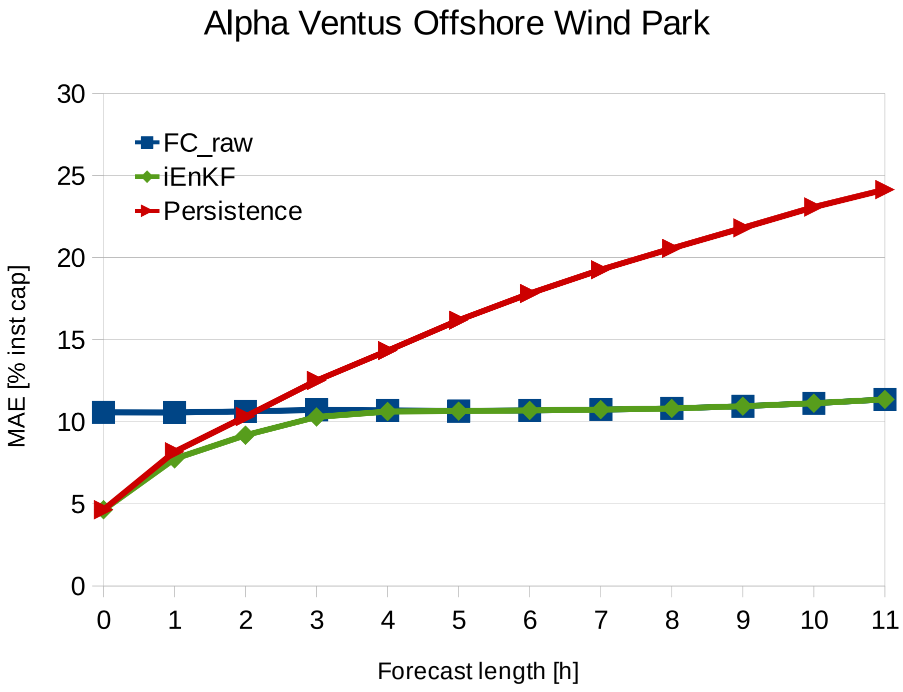
>> the forecast error is high relative to the installed capacity (~20% day-ahead)

>> the forecast error growth is higher than on land due to uncertainty in the weather forecast process !

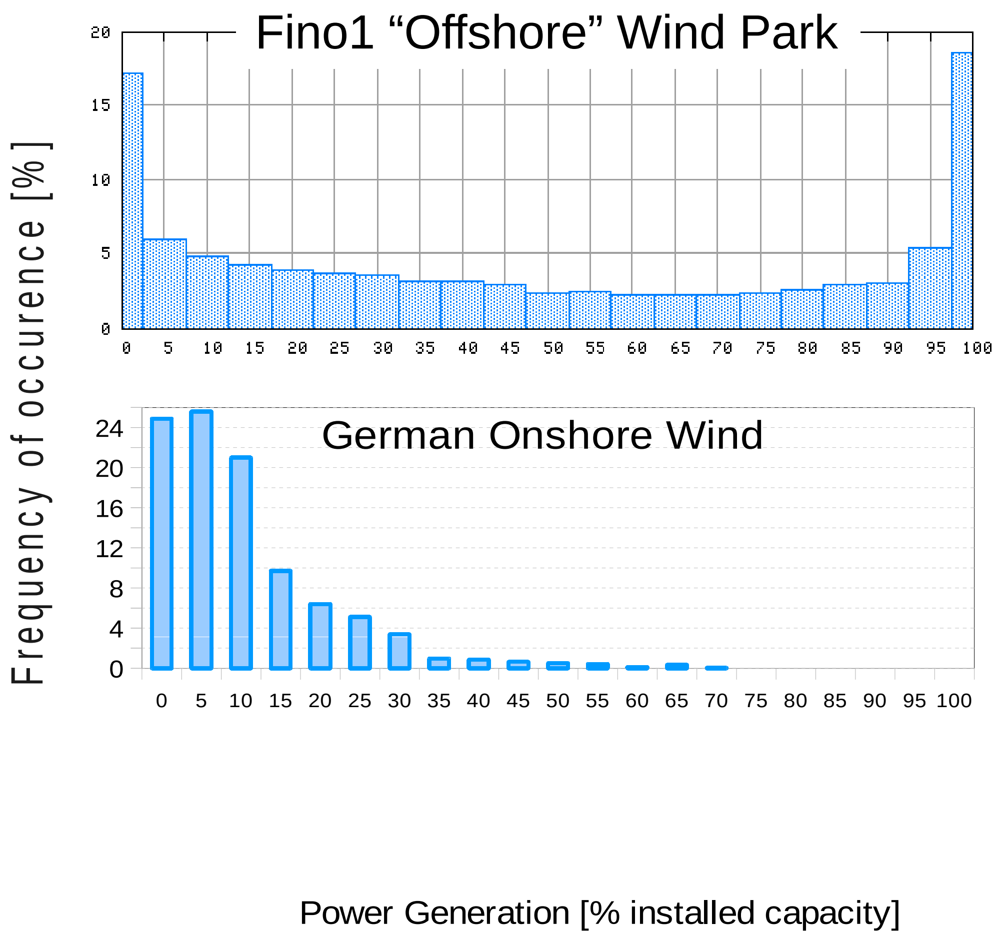
Statistics of short-term forecasting

Verification period: Jan 2011 – Dec 2011





Frequency distribution of power production



Main difference between Onshore and Offshore power production:
very different producation pattern

<u>Characterisitcs of offshore wind power:</u>

- many hours with full load
- high variability:
  many hours at the steep part of the power curve

<u>Advantage:</u>

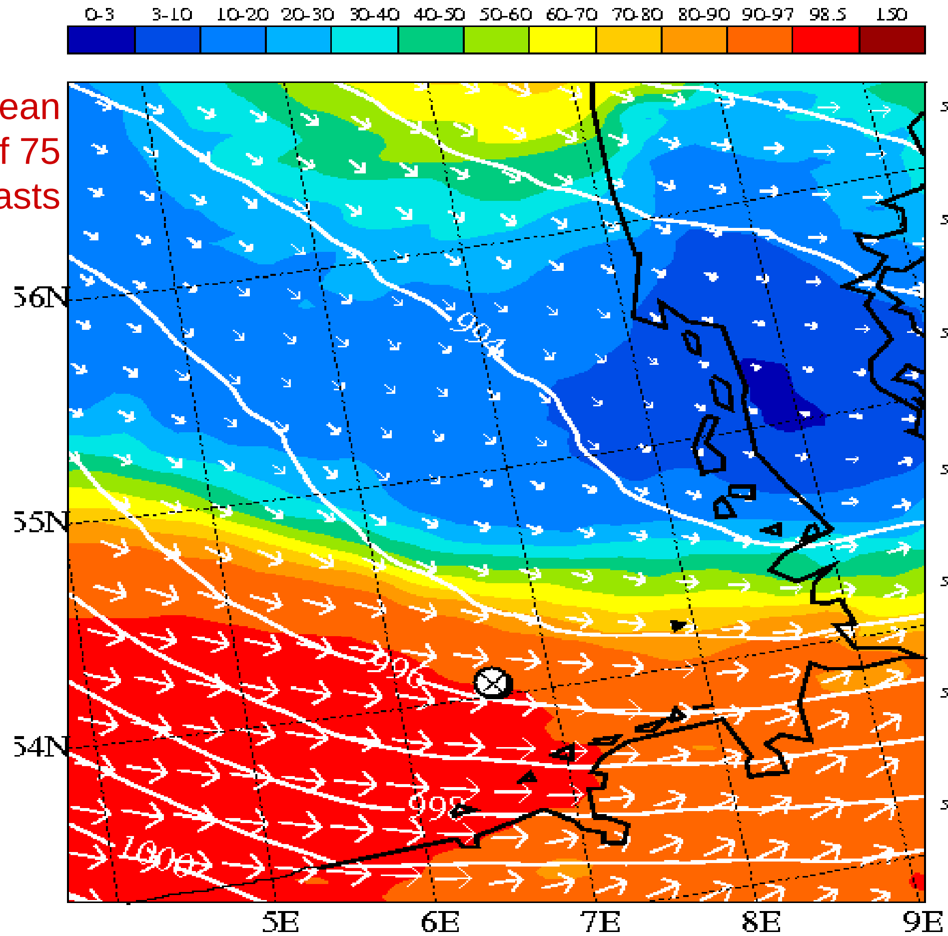
<u>Offshore power will change total power production to a more even distribution</u>

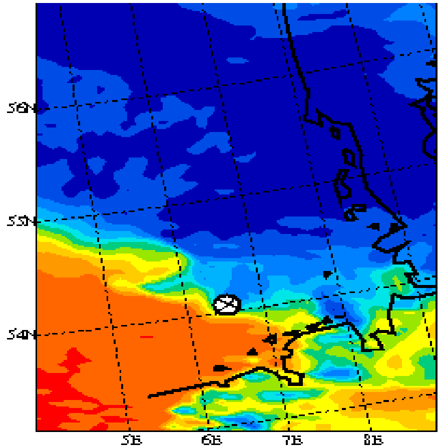
<u>=> requires that the grid can transport power away!</u>

Example of weather Uncertainty at Alpha Ventus

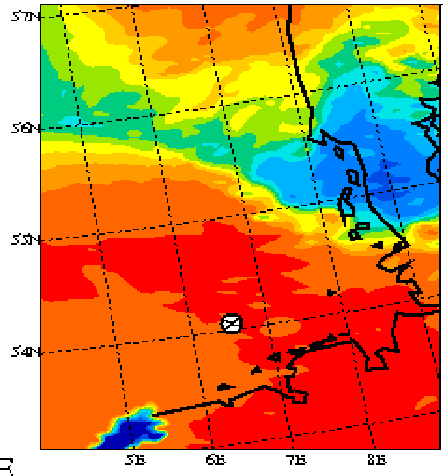
Mean, Maximum and Minimum of 75 forecasts as wind power potential

Mean
of 75
forecasts



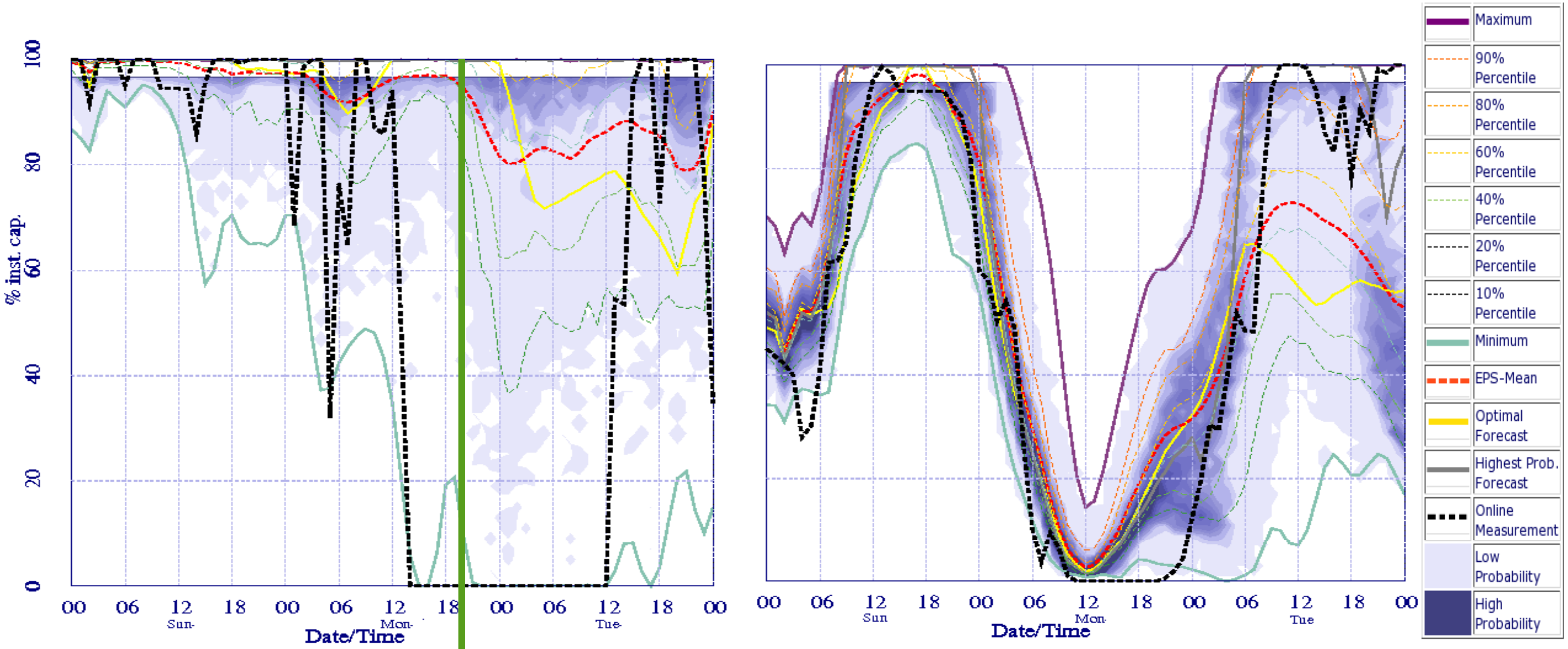


Minimum
of 75
forecasts



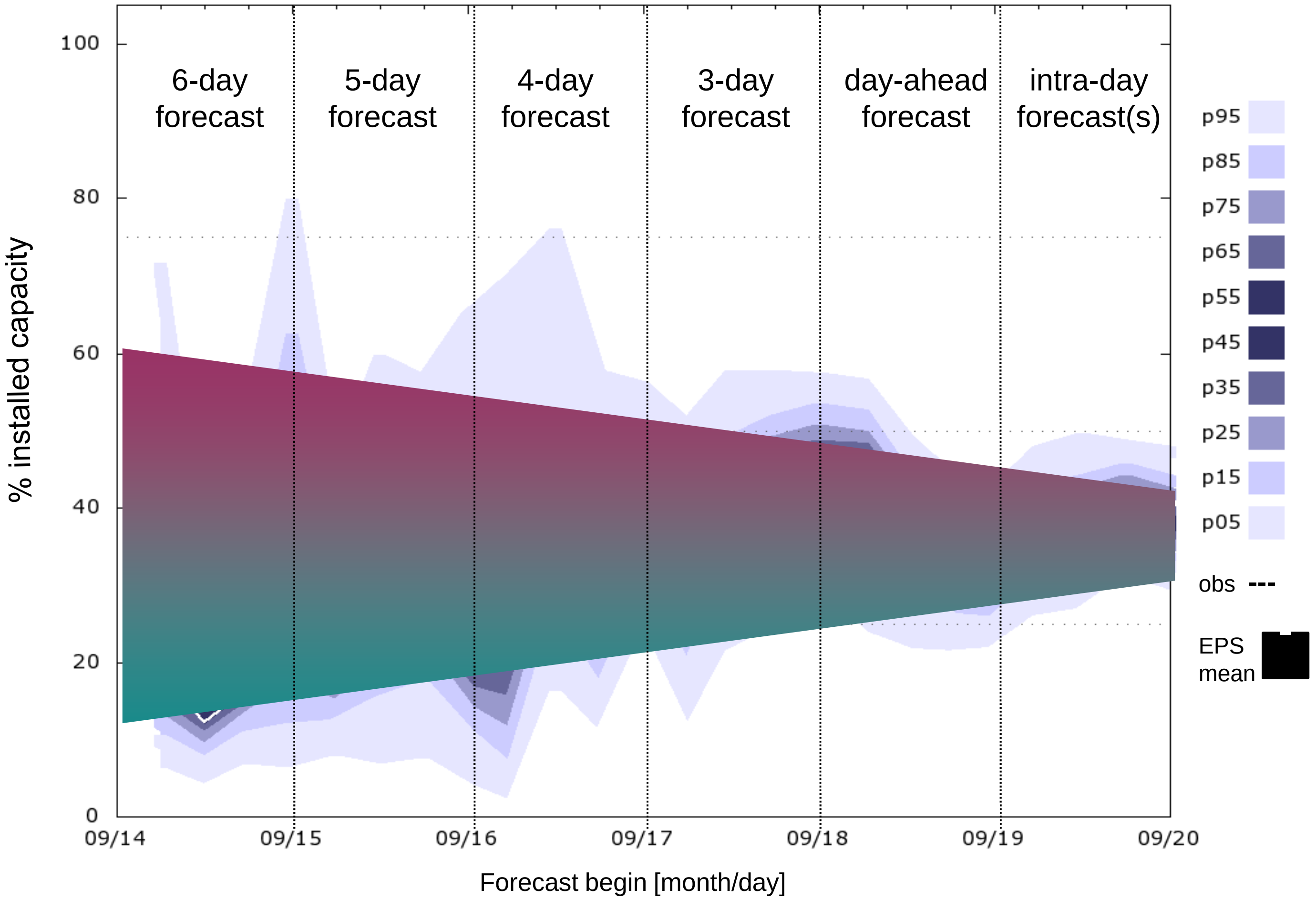
Maximum
of 75
forecasts

2 Examples of typical Uncertainty at Alpha Ventus



Time of power forecast from previous slide

Changes of Forecast Quality over 6 days



Schematic depiction of the change in uncertainty spread for different forecast horizons.

Forecast starting with 144 hours in 6 hour intervals, up to the point in time when the forecast is valid. (2011/09/20 at 3:00UTC).

The black dashed line depicts the measurements at 2011/09/20 at 3:00UTC, the white line is the so called optimum forecast, the blue shaded areas are percentiles

Forecast challenges and requirements

* Offshore wind farms show higher variability and lower predictability

--> Many wind farms of similar size reduce the high variability

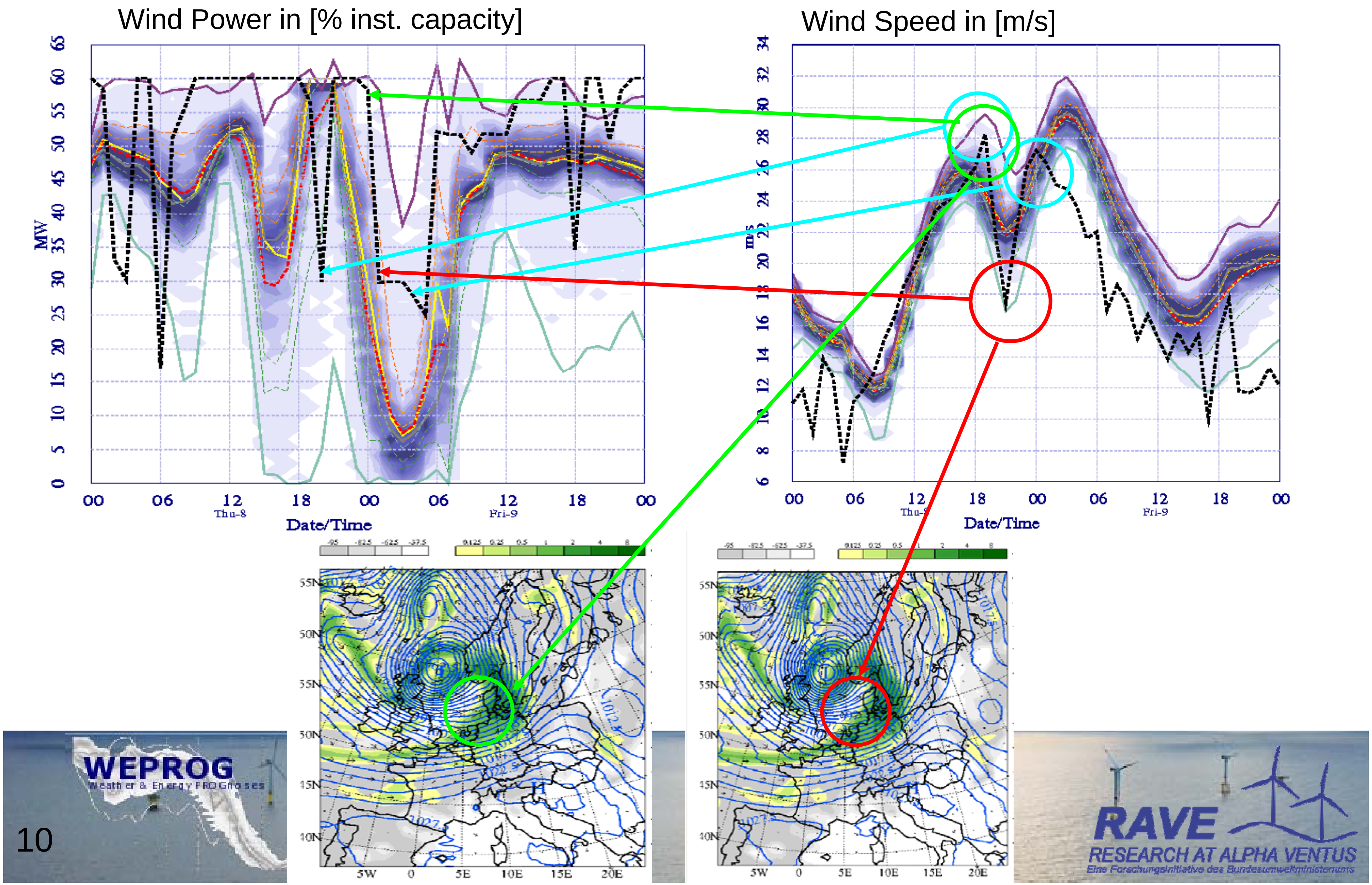
--> But, there will always be need for some automatic frequency control
- errors will always exist !

In order to guarantee a safe and economically feasible operation we need:

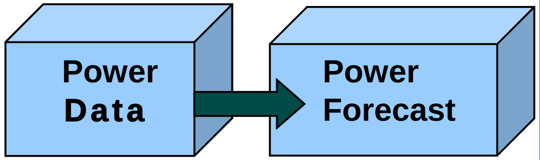
Weather dependent short-term forecasts

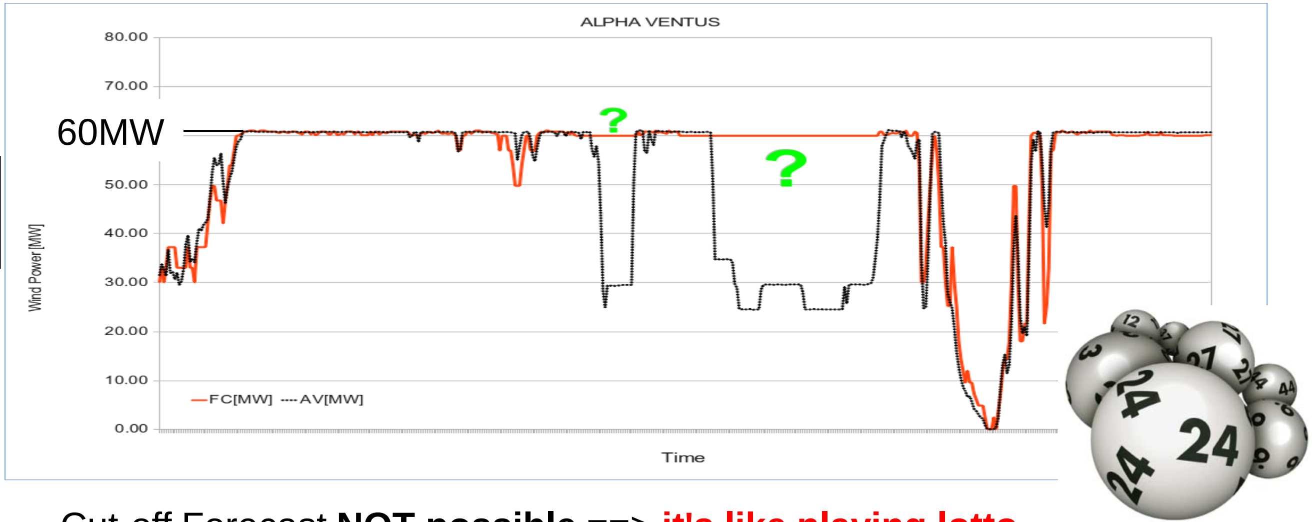
Uncertainty forecasts

Example computation of the iEnKF algorithm at a site with wind and power measurements

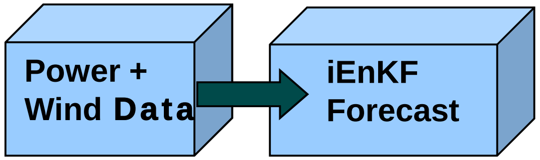


Forecast comparison for Offshore wind parks

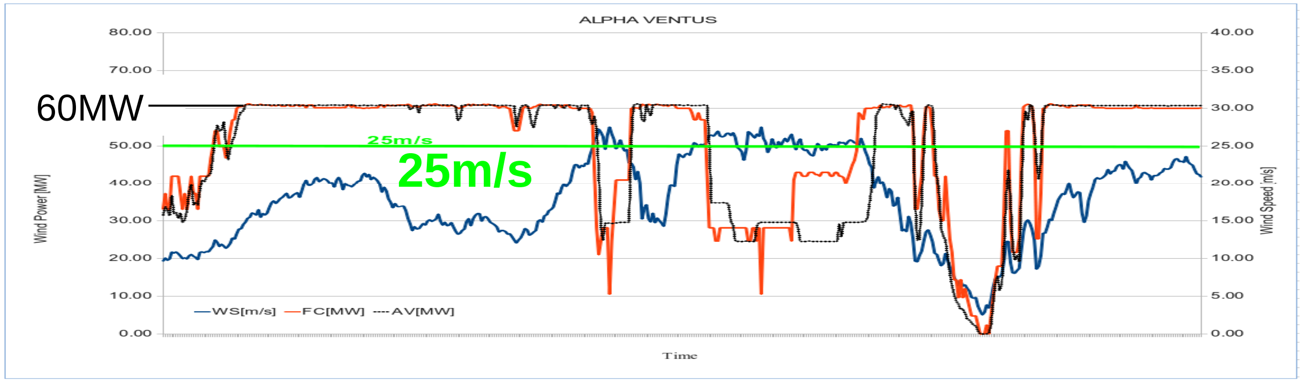




Cut-off Forecast **NOT possible** ==> **it's like playing lotto**



Forecasts with
windspeed influence
(machine adaptation)



Cut-offs prediction **possible** ==> **no gambling required:**
wind speed measurement clearly indicates risk of cutoff

iEnKF Forecast

Short-term Forecasting with an *inverted Ensemble Kalman Filter (iEnKF)*

- Generation of independent ensemble data with a multi-scheme ensemble approach
- Matrix is based on forecasts, not errors („inverted“ problem solver)
- Covariance Matrix incorporates the current weather condition into the power forecast

Remember: Offshore wind farms have many full load hours, where power measurement alone is insuffcent to estimate risk of cut-offs

iEnKF is: - a **weather dependent** data assimilation

- is the first **physically consistent method**, where ensemble forecasts provide the framework for the distribution of observational influence

- can use wind speed & wind power measurements and has an inherent uncertainty estimate

But: Powerful forecasts need full <u>data delivery</u> to TSO + Trading party
=> we need <u>an obligation for data transfer</u>
– of MET & Power measurements from large on & offshore wind farms

Predictability of high-variable and uncertain Offshore power for Trading purposes

PREDICTABILITY OF ERRORS can be computed with an Ensemble:

predictability of errors = correlation (MAE,Ensemble Spread)

Predictability measured over 1 year:

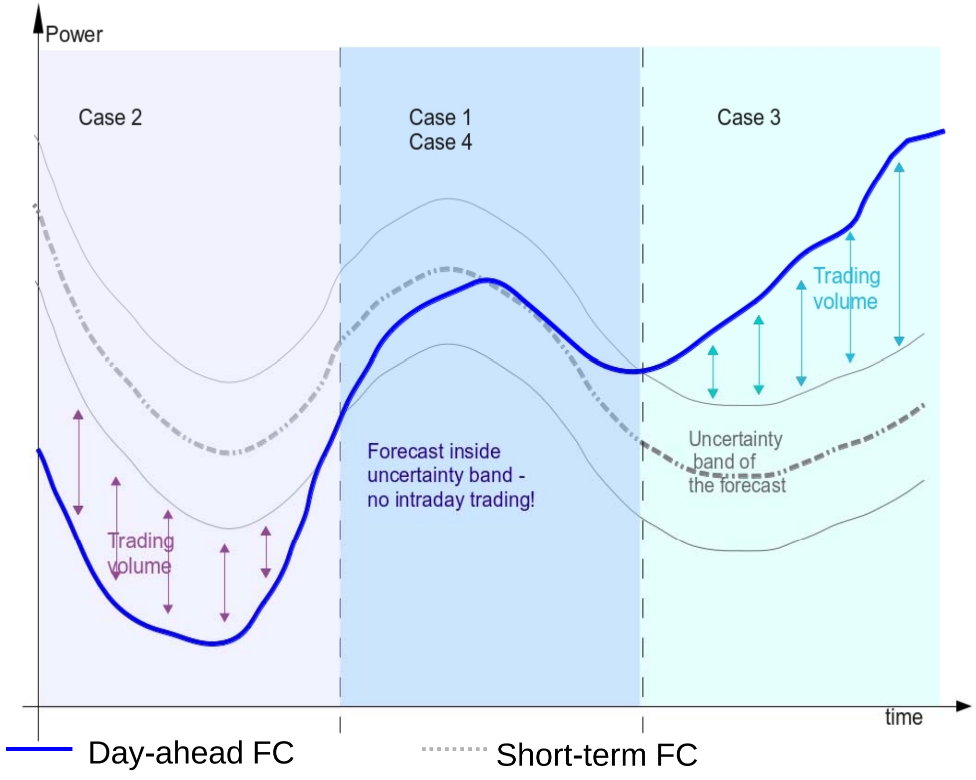
Short-term FC error predictability **day-ahead** is 0.43
Short-term FC error predictability **2h in advance** is 0.53

Conclusions:

=> 47% of the error is random uncertainty, only partially weather related !

=> trading of the error in the intra-day requires uncertainty estimate to prevent DOUBLE TRADING !

Use of Uncertainty for intra-day forecasting



The "magic formula":
Computation of the balancing volume for the correction of the day-ahead forecast in the intra-day:

$$CFc = a * SFC + b * PFU - c * DFC$$

where
SFC is short-term forecast,
DFC is the Day-ahead Forecast
PFU is the "power forecast uncertainty"

Expected Balance: EB = SFC - DFC
Absolute Balance: AB = |SFC – DFC| - PFU

CASE	EB	AB	FUP	a,b,c
1	<0	<0	DFC	0,0,0
2	>=0	>0	SFC-PFU	1,-1,1
3	<0	>0	SFC+PFU	1,1,1
4	>=0	<0	DFC	0,0,0

Consequences of new optimisation requirements...

PARADIGM SHIFT:

Not the forecast with the lowest RMSE is desirable,
but the forecast that:

- **creates the <u>least costs</u> and generates the <u>highest revenue</u>**
- **provides <u>highest grid security</u>**
- **follows market principles**
- **is a <u>reliable energy source</u> in a dynamic market**

CONSEQUENCE

Forecast optimisation and evaluation has to happen in accordance with the market rules in the future, that is in “cost space”

Conclusions

Offshore power delivers **more efficient power** with many more full load hours

Offshore power has a **higher variablity** and hence **lower predictability**

wind measurements + uncertainty estimates are required to estimate cut-offs

trading of offshore power requires **uncertainty estimates** to prevent double trading

Powerful forecasting requires that **MET & PWR Data** is available **ONLINE**

=> we need an <obligation for delivery> in the law not only a <making it available> !

Ensemble Forecasts & the iEnKF short-term algorithm have proven to be crucial tools to solve many forecasting challenges of offshoe wind power

Thanks for your attention!

Contact:
Corinna Möhrlen
com@weprog.com

More information about the studies can be found at our web-page:
www.weprog.com -> Information -> Publications

or directly by following these links:

inverted Ensemble Kalman Filter:
http://download.weprog.com/public_paper_WIW11_032_joergensen_et_al.pdf
http://download.weprog.com/presentation_WIW11_032_joergensen_et_al.pdf
http://download.weprog.com/moehrlen_dewek2010_s10_p4.pdf
http://download.weprog.com/moehrlen_presentation_dewek2010_s10_p4.pdf

Uncertainty estimates and trading strategies:
english:
http://download.weprog.com/WEPROG_Trading_strategies_EEG2012_ZEFE_71-2012-01_en.pdf
german:
http://download.weprog.com/WEPROG_Handelsstrategien_EEG2012_ZEFE_71-2012-01.pdf

Other Offshore related Research Project Publications:
Final Report: High-Resolution Ensemble for Horns Rev
http://www.hrensemble.net/public/pdf/HRensembleHR_finalreport_2010.pdf
http://www.hrensemble.net/public/pdf/HRensembleHR_finalreport_2010_summary.pdf

WEPROG GmbH Germany
Eschenweg 8
71155 Altdorf
Tel. +49 (0)7031 414279
Fax. +49(0)7031 414280

WEPROG ApS Denmark
Aahaven 5
5631 Ebberup
Tel. +45 64 71 17 63
Fax: +45 6471 2094

Email: info@weprog.com
Web: www.weprog.com