WEPROG

Weather & wind Energy PROGnoses

EUROPEAN EXPERIENCE:

Large-scale forecasting with Ensemble Forecasts

Session 3: Large System Forecasting Status and Progress

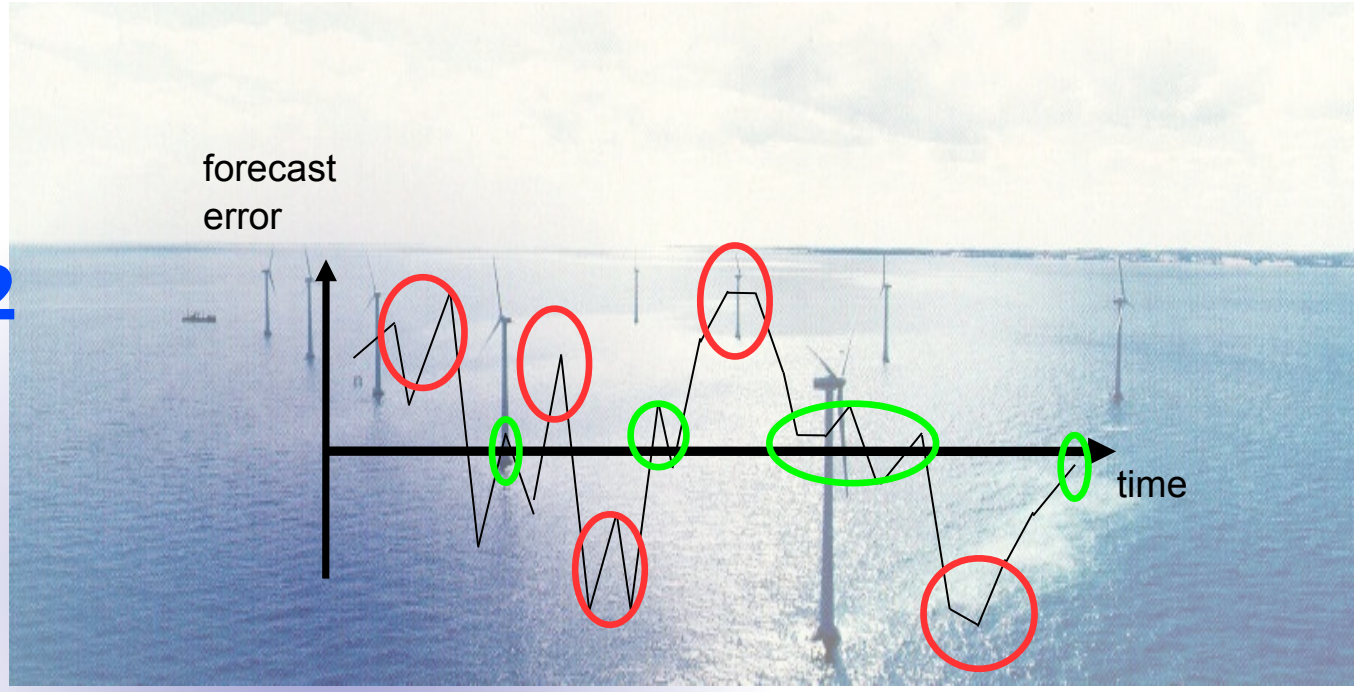
UVIG - Variable Generation Forecasting Workshop
Tucson, Arizona
February 2012

Including physical Uncertainty from Ensembles

TABLE OF CONTENTS

Daily Fluctuations of the Error

2002



The background

- the weather changes fast between predictable and less-predictable
- subjective methods are not sufficient to estimate predictability
- intermittent generation becomes less feasible with increased penetration

The solution

- Predict the expected forecast error

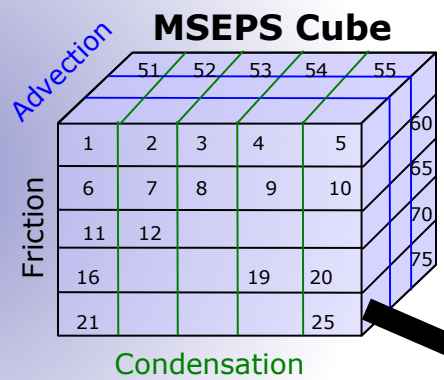
The method

- run a large number of different independent weather forecasts
- evaluate the uncertainty on the final power forecasts

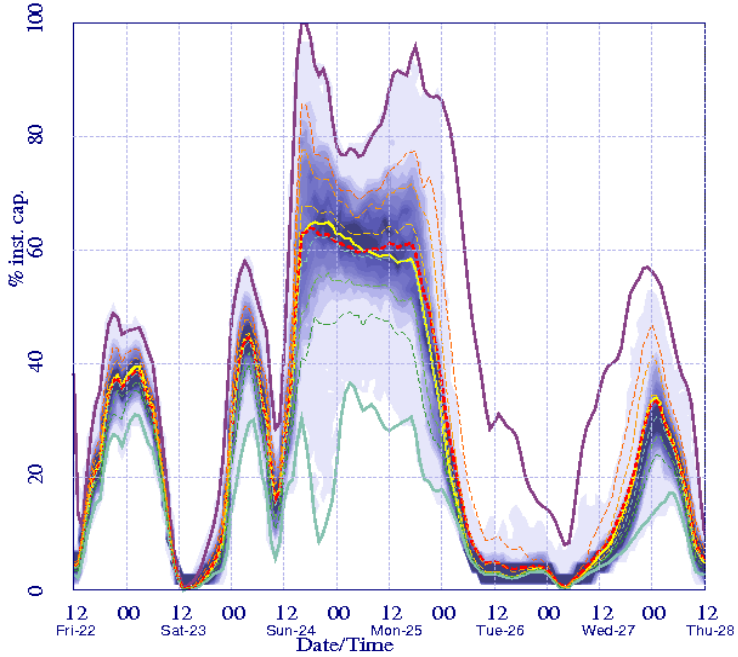
WEPROG's Multi-scheme Ensemble Prediction System (MSEPS)

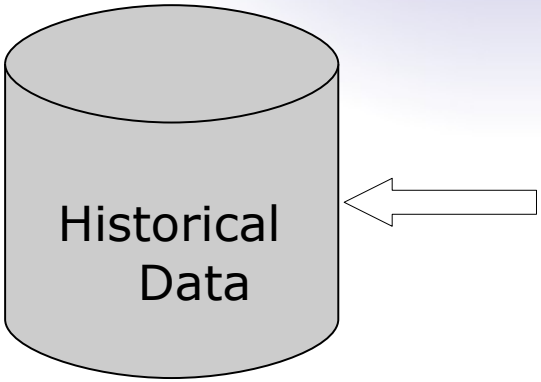
Global Analysis
(State Estimate)

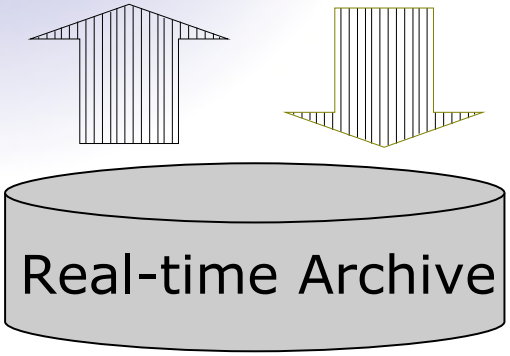
75 independent weather forecasts



Probabilistic
weather &
wind power forecast







From low resolution forecasting to high resolution forecasting...and from smaller areas to large areas

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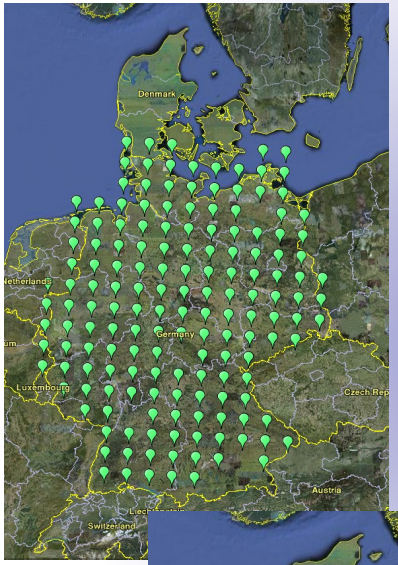
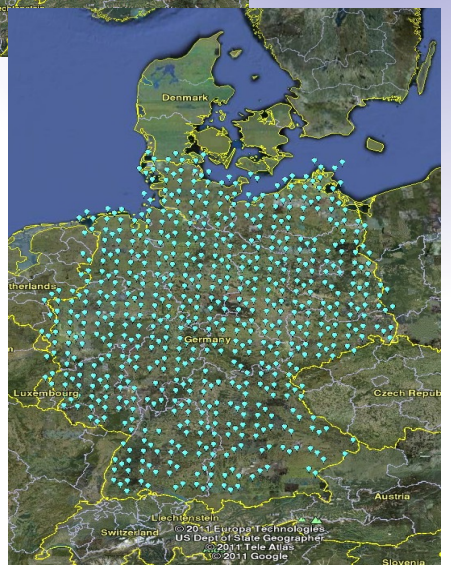
reducing the resolution to half the grid size
= 4 times the grid points & computations !

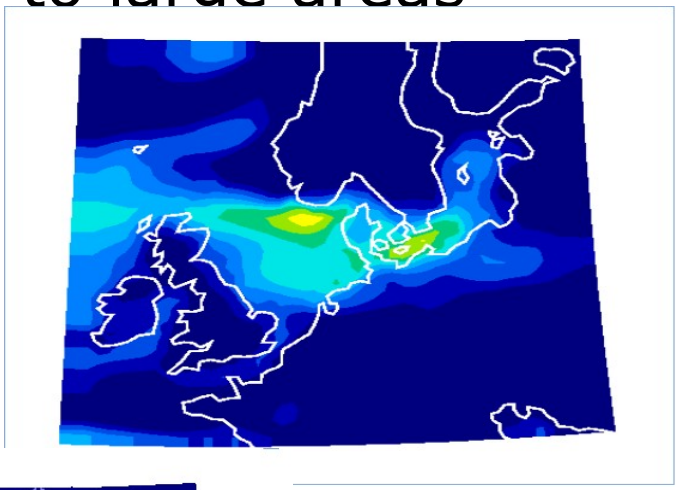
MSEPS-45km

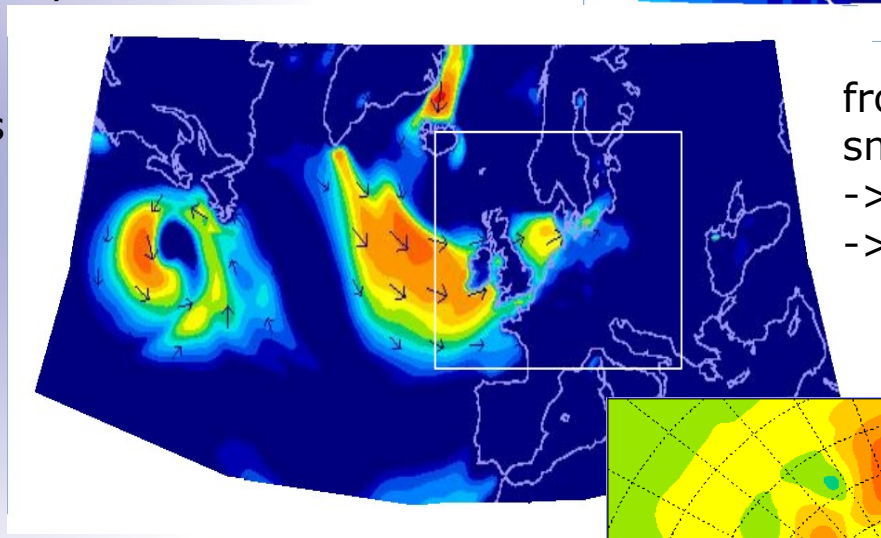


number of grid points over Germany for different resolutions

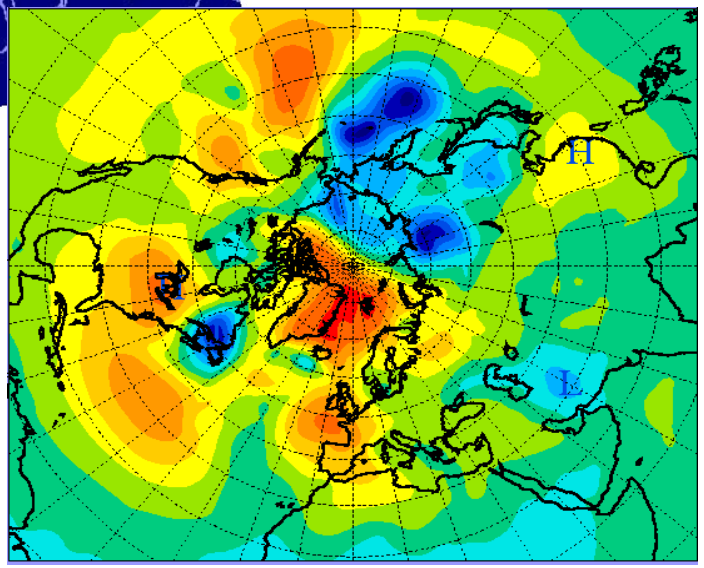
MSEPS -22km



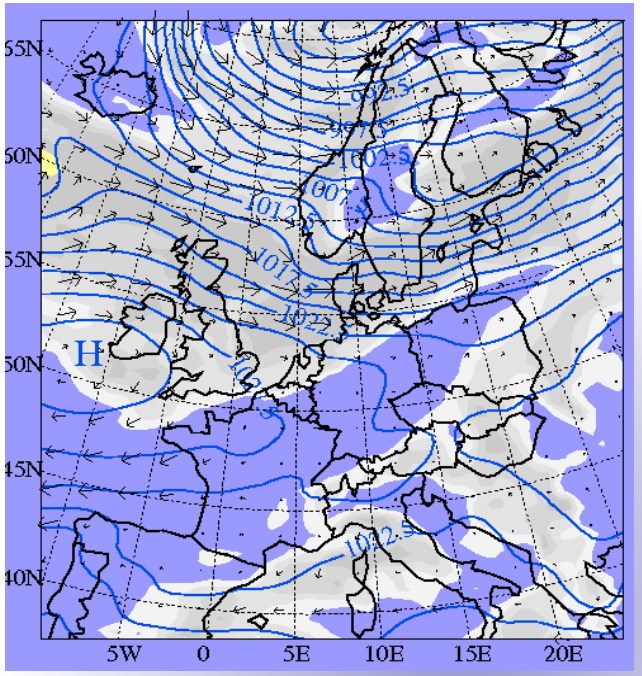


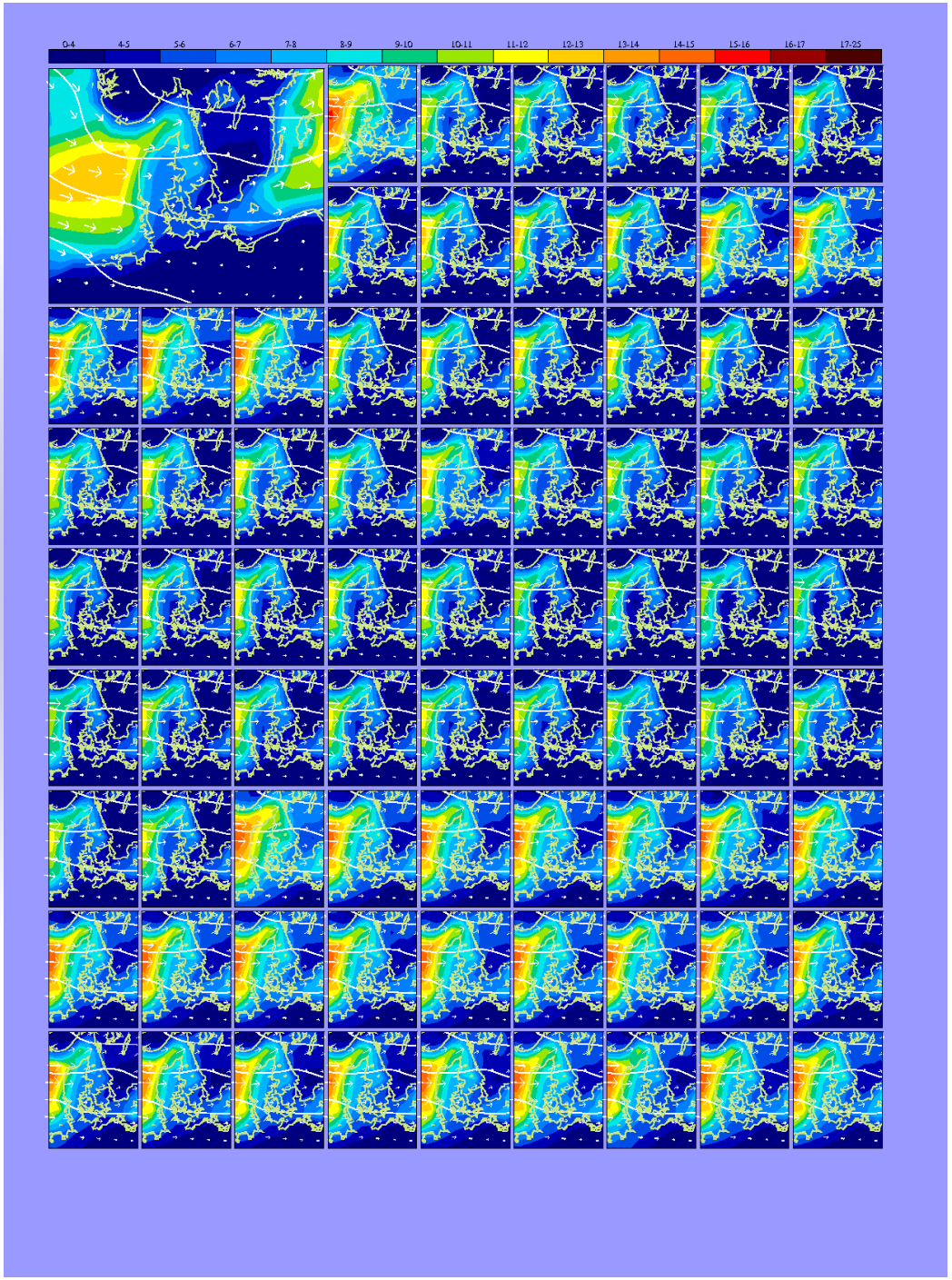


from
small regional areas
-> continents
-> hemispheric areas



Why are the forecasts wrong ?





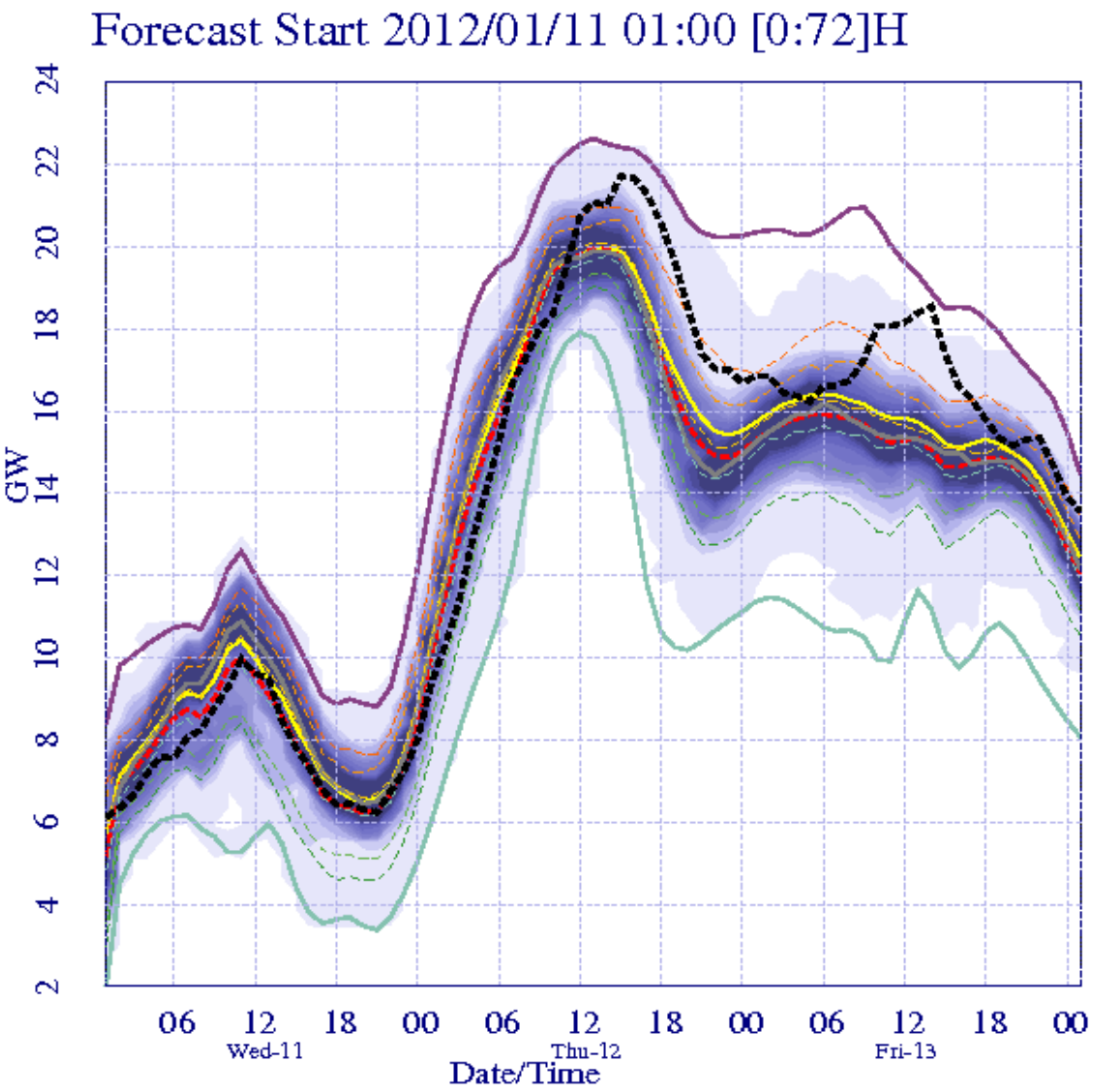
The weather development is often uncertain !

"Butterfly-effect":
Small differences can have large impact in
- space
- time

The measured power generation varies almost randomly within the ensemble spread

It is non-trivial to find the best forecast some hours ahead !!!

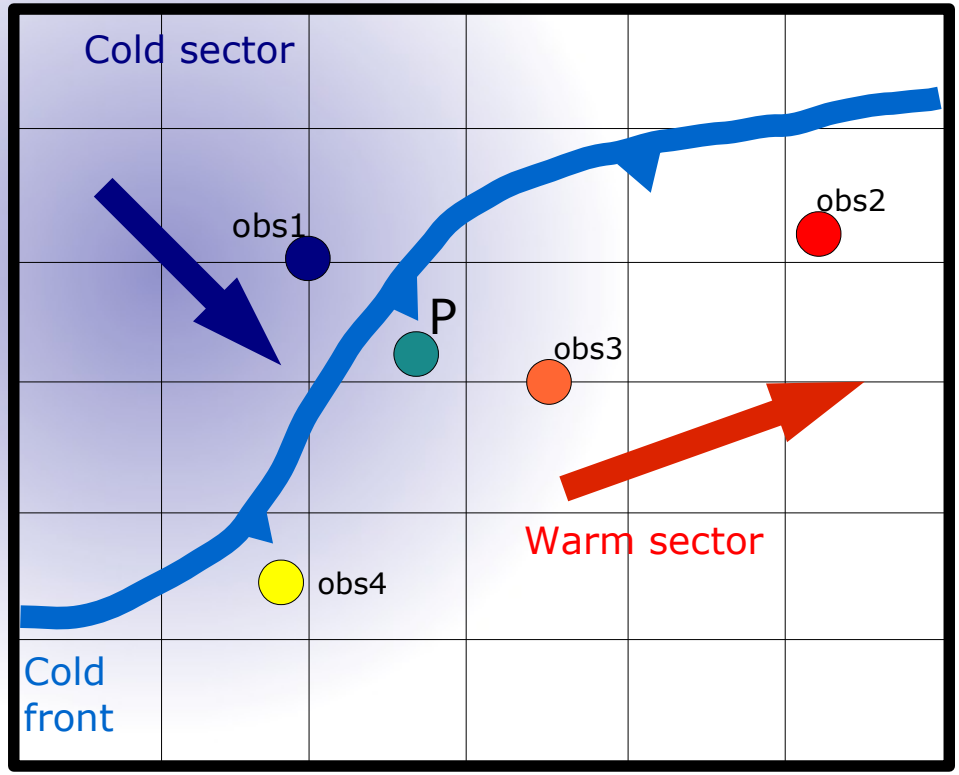
An intelligent algorithm is required to translate influence of measurements to:
- other locations
- forward in time



Influence of measurements in short-term forecasts and up-scaling is not static

...but weather dependent

$$P = \int p_{fc} + \sum_{obs} w_{dist+weather} (p^*_{obs} - p_{fc}) \, dA$$



What we need is a translation of weather information into "power" space and distribution of information in → time and → space

Solving the weather dependency in the short-term forecasts with an inverted Ensemble Kalman Filter technique

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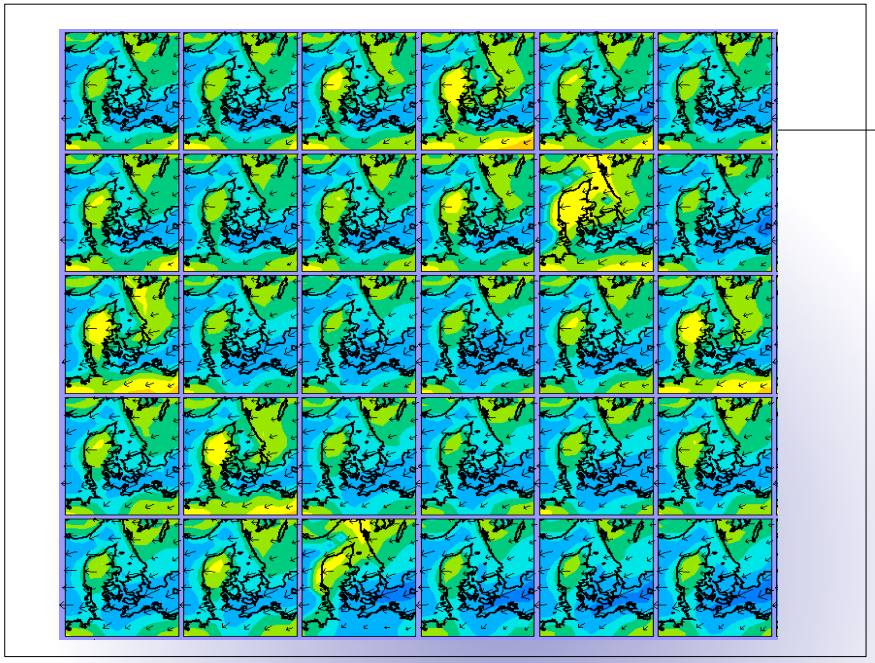
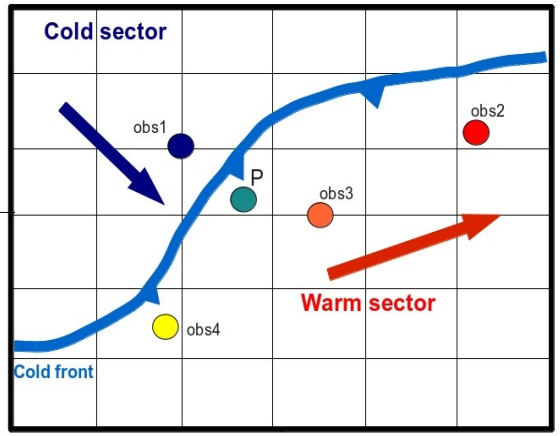
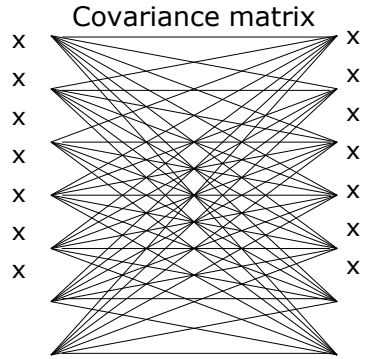
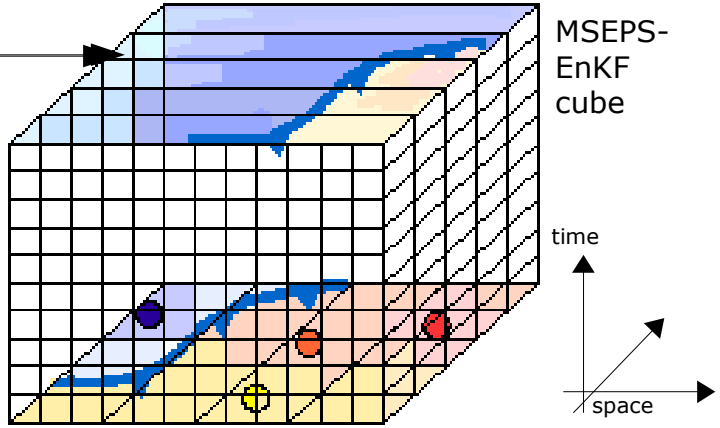


Ensemble weather forecasts

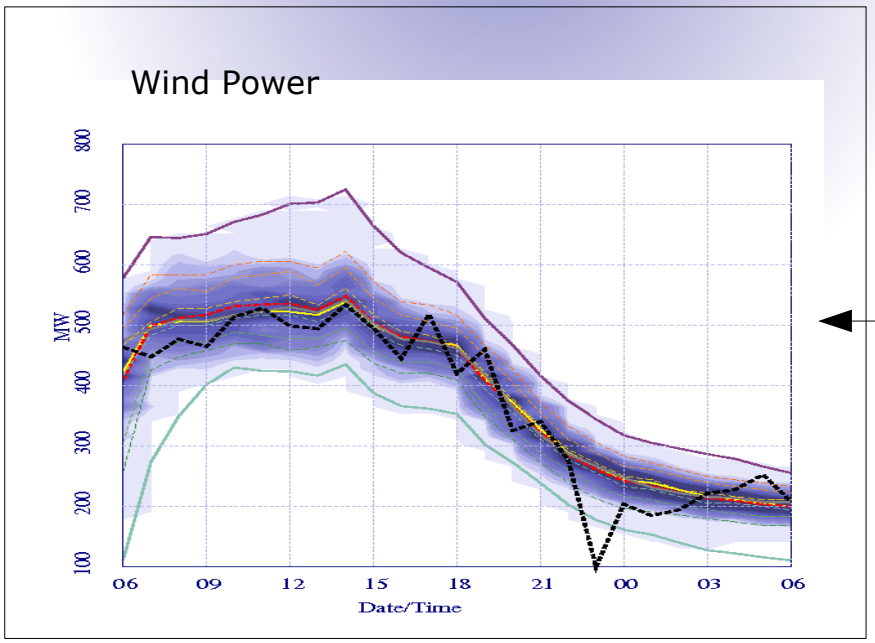
translation of measurements







Wind power forecasts



The inverted Ensemble Kalman Filter (iEnKF) solves the problem of using any type of measurement and translating it to POWER

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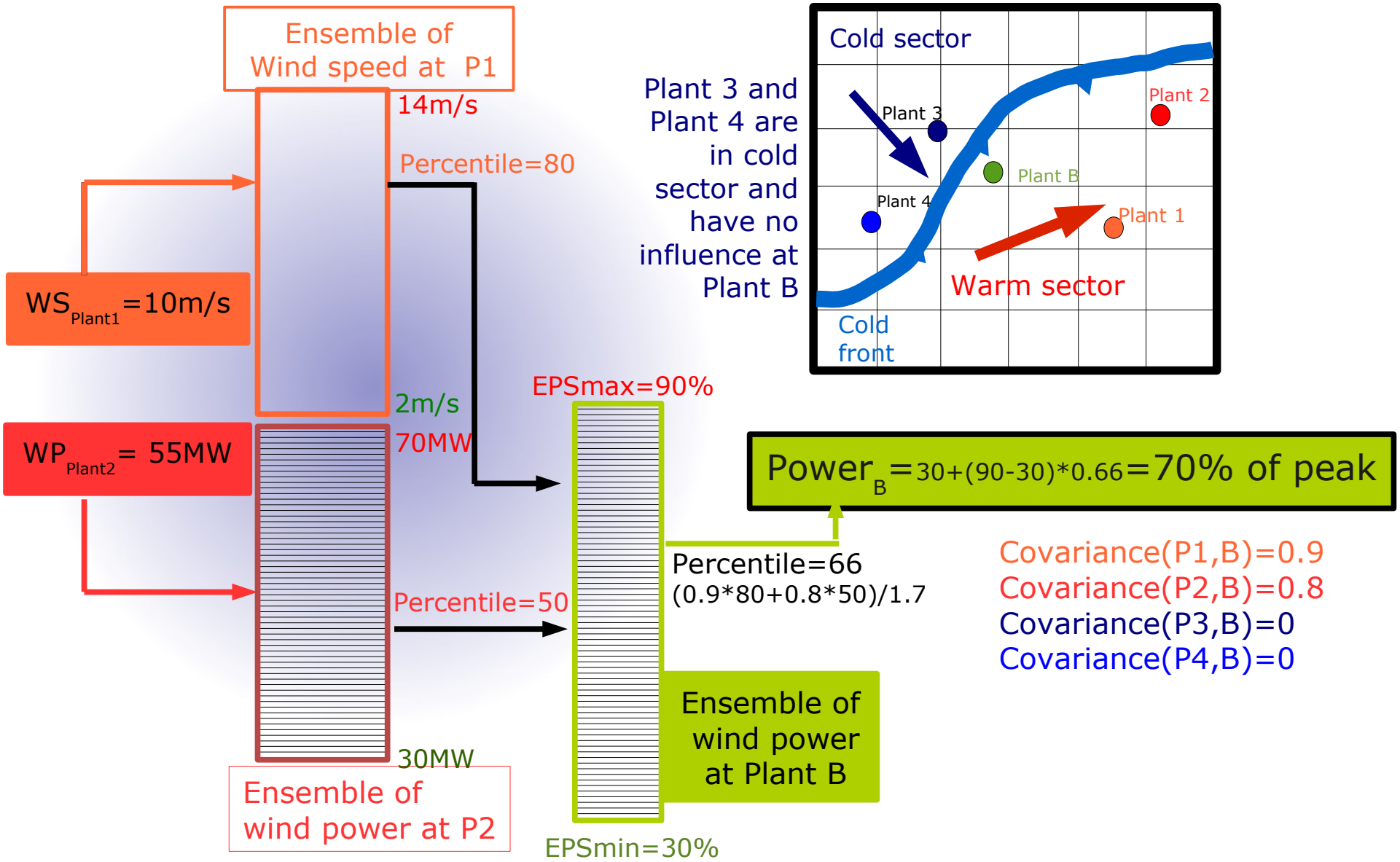

Example Pilot Project in Alberta

- Q4 RMSE statistics of the 9 model set-ups in the forecasting Test-bed -

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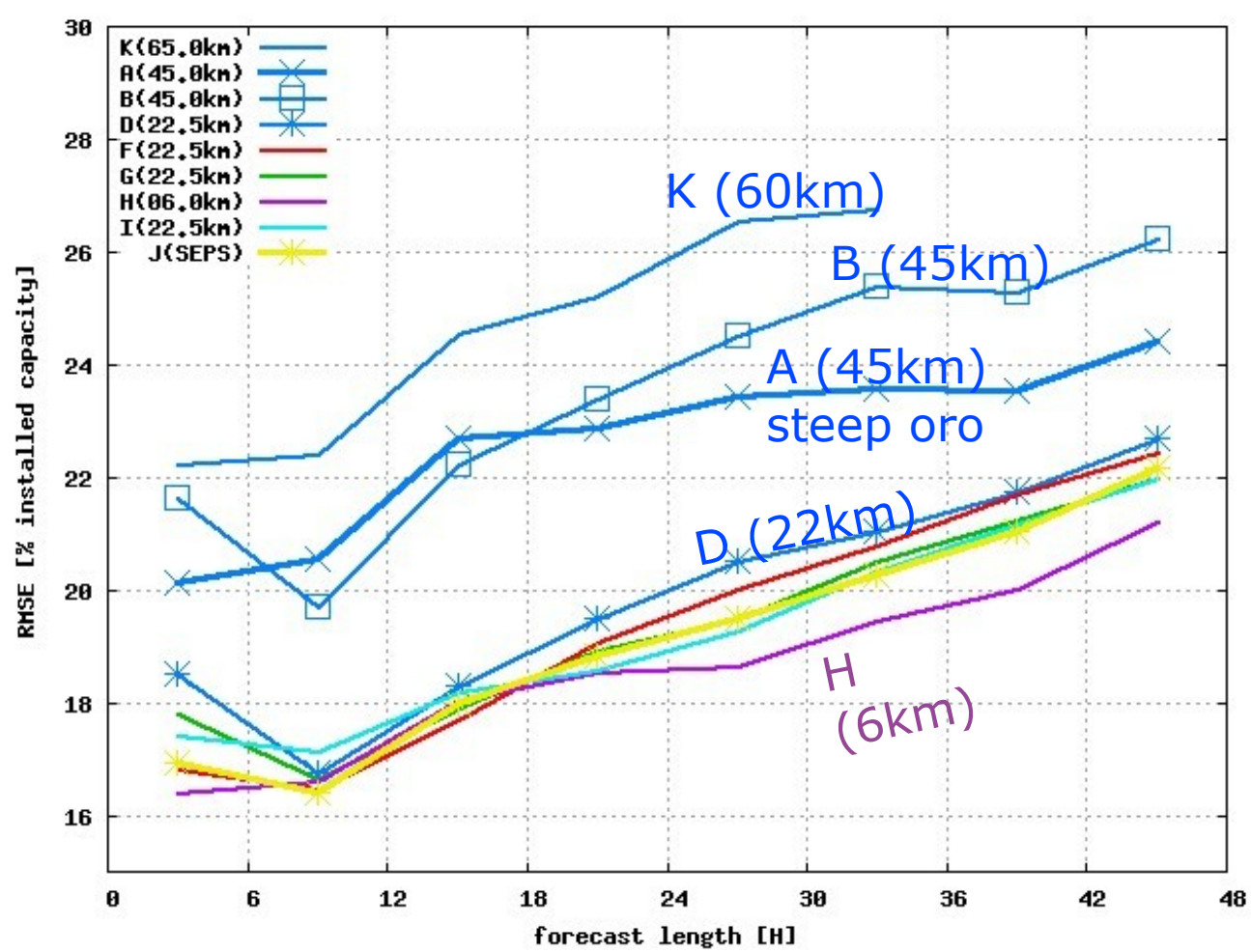
CONCLUSION was:

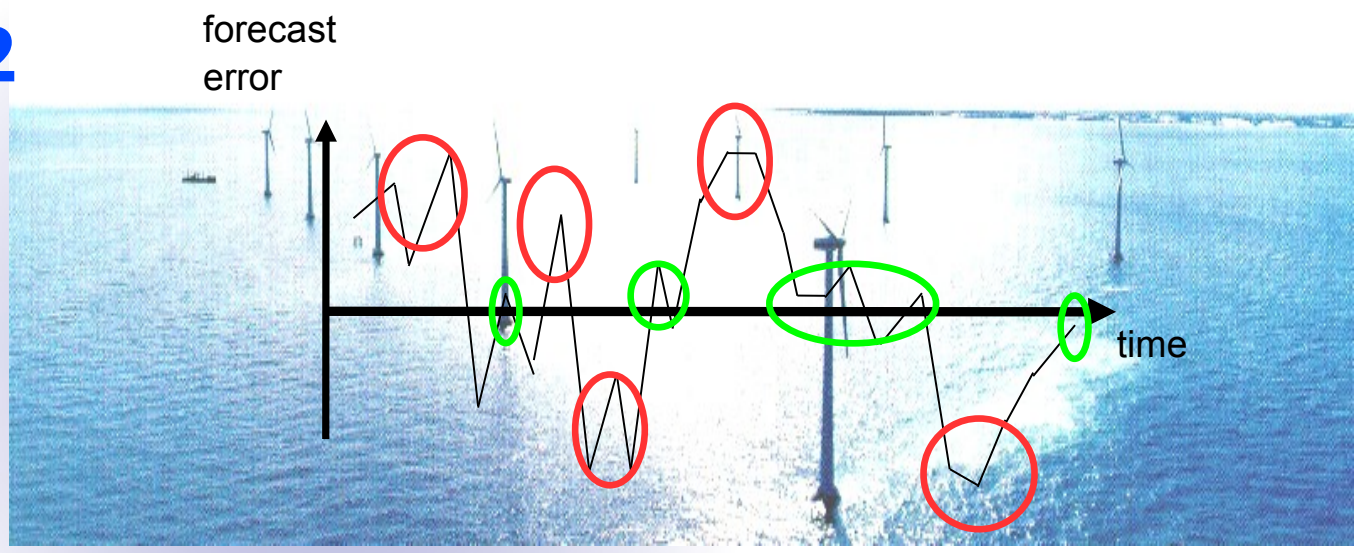
Forecast accuracy is very **sensitive** to:

- Spatial resolution
- Type of orography
- Initial conditions
- Lat. boundary data



The forecast error is as variable as the wind itself..no matter how large the area and how "good" the forecast in average!

2012 ... 10 years later



PREDICTABILITY

- the weather changes fast between predictable and less-predictable
- Smoothing effects do not change this pattern !

Have there been any surprises ?

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Yes...

- predictability and accuracy is dependent on many different aspects and it's non-trivial to proof "improvements"
  Forecasters have **improved forecasts** a lot, BUT can we really quantify it ?
  => more variable power on the grid
  => different dispersion level
  ===> **the "reference" has also changed!**

- forecast accuracy is a relative measure: a good forecast measured with a RMSE/MAE error is not necessarily a good forecast in "cost space"
  ==> **market principles need to be considered as well**

- **offshore forecasting is as difficult as onshore** ! (see publications of offshore projects e.g. www.hrensemble.net, www. rave.de)

- **data handling: "size matters"**
  (e.g. Germany: over 1mio renewable power plants in 2011,
  ca. 29000 Turbines, over 900.000 solar plants !)

- market integration of variable energy sources requires restructuring and more liquidity!

What are the challenges to come ?

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Wind and Solar energy have to follow market principles at some stage....

Denmark:
2003: 600MW => 17% of inst. cap
2011: 3100MW => **75% of inst. cap**

Germany:
2009: 34MW => 0.1% of inst. cap
2011: 2049MW => 7.3% of inst. cap.
2012: 16280MW => **57% of inst. cap**

This will have most impact on:

- <u>forecasting principles</u>: its no longer the forecast that has the lowest RMSE that is required, but the forecast that fits the production best into the market !!!

- <u>data handling:</u> forecasting measurement handling and training of many (small) individual plant
  ---> especially solar plant are very small !
  (Germany: 2012=1mio solar plants!

===> new forecast products are required to take market principles into account

Marketing of variable energy can lead to negative prices and become expensive !

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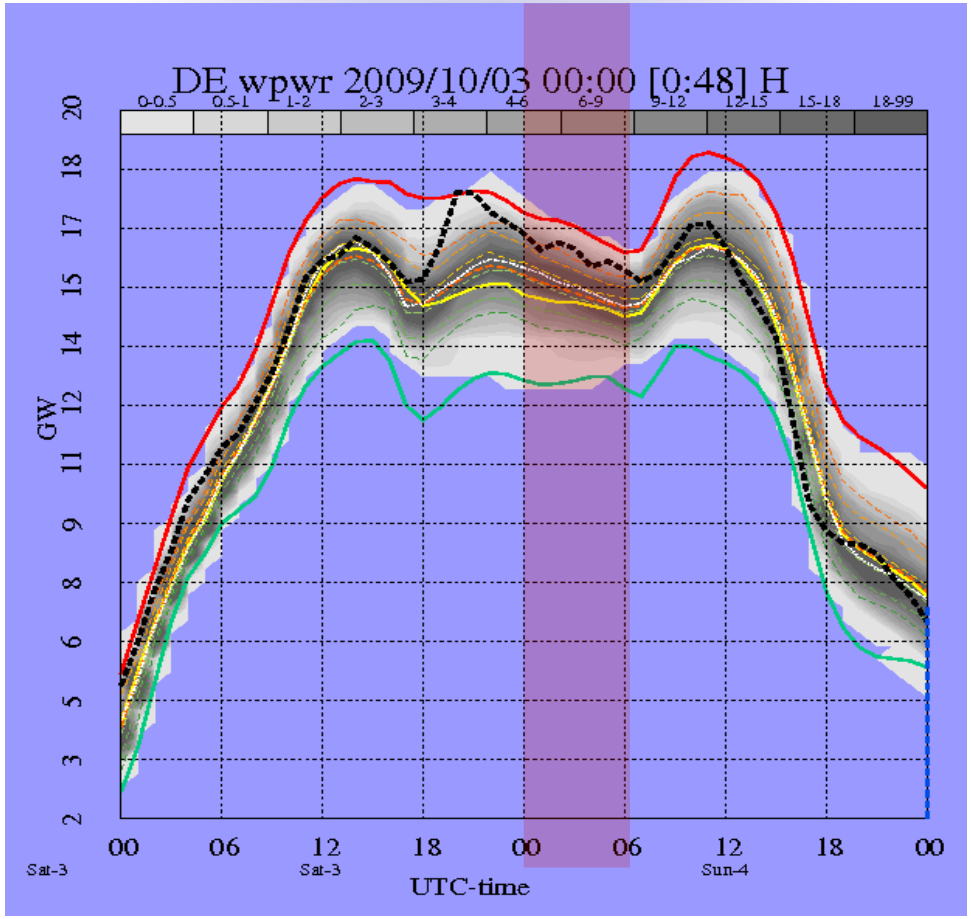
An example of an "expensive" (Sun)day for wind power in Germany

Day-ahead market:
7mio US$ loss in 1 hour
11.2mio US$ loss over 5 hours



		So, 04.10.	Mo, 05.10.	Di, 06.10.
00-01	€/MWh	0,05	26,63	36,05
	MWh	17.414,0	14.900,0	13.761,8
01-02	€/MWh	-105,76	20,10	30,39
	MWh	18.042,7	15.406,5	14.427,1
02-03	€/MWh	-500,02	14,01	26,88
	MWh	17.620,6	15.499,4	15.178,5
03-04	€/MWh	-100,09	5,65	23,18
	MWh	18.176,4	15.297,2	16.000,6
04-05	€/MWh	-60,09	8,35	24,89
	MWh	18.176,7	14.765,6	15.917,4
05-06	€/MWh	-25,04	26,00	28,95
	MWh	18.222,6	13.180,2	14.657,5
06-07	€/MWh	0,00	48,75	69,34
07-08				
	MWh	18.158,8	15.481,2	17.384,6
08-09	€/MWh	24,89	64,78	107,95

Day-ahead market

	Low €/MWh	Average €/MWh	High €/MWh	Last €/MWh	Volume MWh
00-01	-1.499,00	-335,42	10,00	-1.499,00	1.415,10
01-02	-950,00	-648,62	-55,00	-950,00	957,00
02-03	-800,00	-580,20	-205,00	-800,00	673,90
03-04	-500,00	-351,36	-65,00	-295,00	924,00
04-05	-600,00	-295,94	-30,00	-60,00	1.528,00
05-06	-490,00	-280,07	-10,00	-10,00	1.647,00
06-07	-190,00	-130,10	5,00	-150,00	1.688,00
07-08	-190,00	-87,34	9,00	-150,00	1.610,20
08-09	-5,00	-0,32	24,00	2,00	1.379,00
09-10	1,00	12,69	25,00	1,00	1.671,50
10-11	5,50	15,38	31,00	6,50	1.443,00
11-12	9,50	18,33	55,00	9,50	1.525,40
12-13					1.611,00
13-14	-1				1.635,00
14-15	-299,00	-37,98	6,00	-250,00	1.872,00
15-16	-750,00	-95,20	6,00	-750,00	1.799,00
16-17	-200,00	-37,59	17,50	-200,00	1.877,00

Intra-day market

Intra-day market:
1.7mio US$ loss in 1 hour !
4.1mio US$ loss over 9 hours

Solution: Early intra-day prediction with help of ensemble forecasts

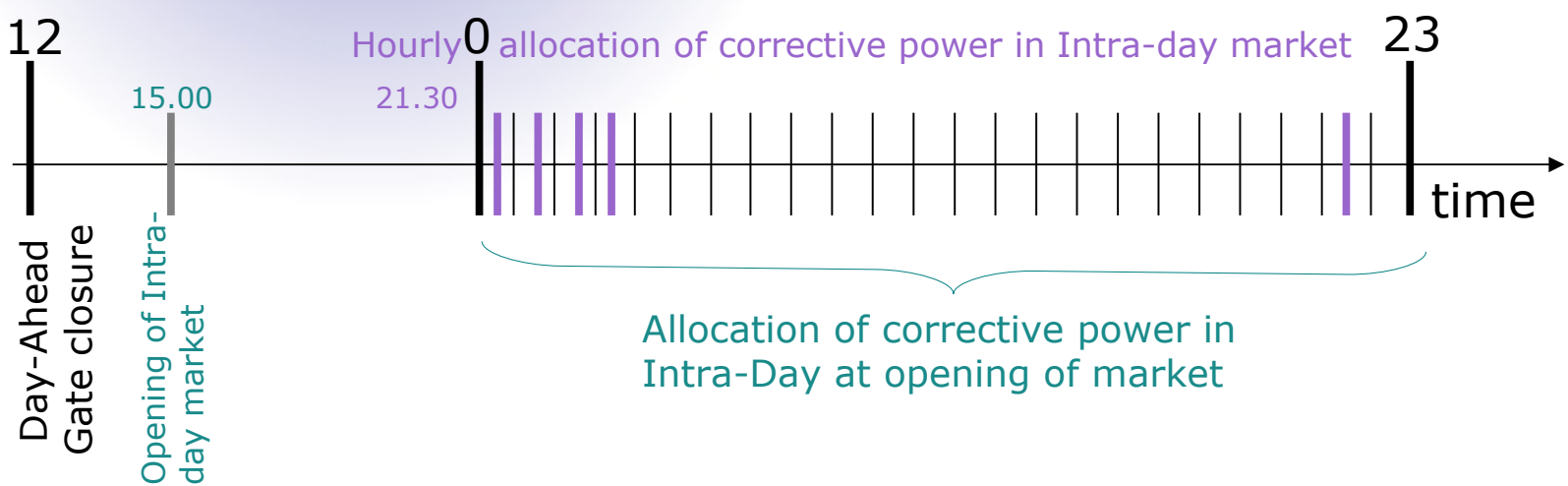
PREDICTABILITY OF ERRORS

predictability of errors = correlation (MAE,Ensemble Spread)

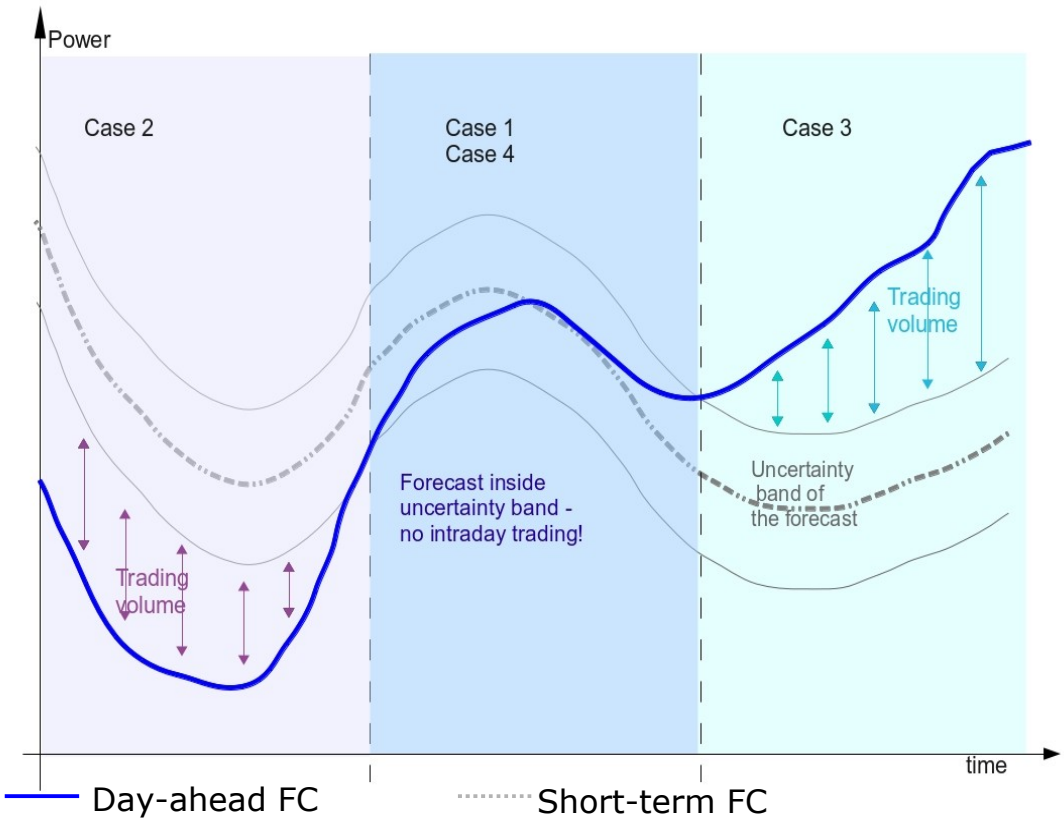
- Predictability of **Short-term FC** error **day-ahead** is 0.43
  => almost half of the error is predictable one day in advance

- Predictability of **Short-term FC 2h in advance** only increases to 0.53
  => 0.47 is random uncertainty, not weather related ! (+10%)

==> almost half of the error can be predicted day-ahead and hence large errors and missing liquidity in the market can be avoided



Intra-day forecasting strategy



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

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

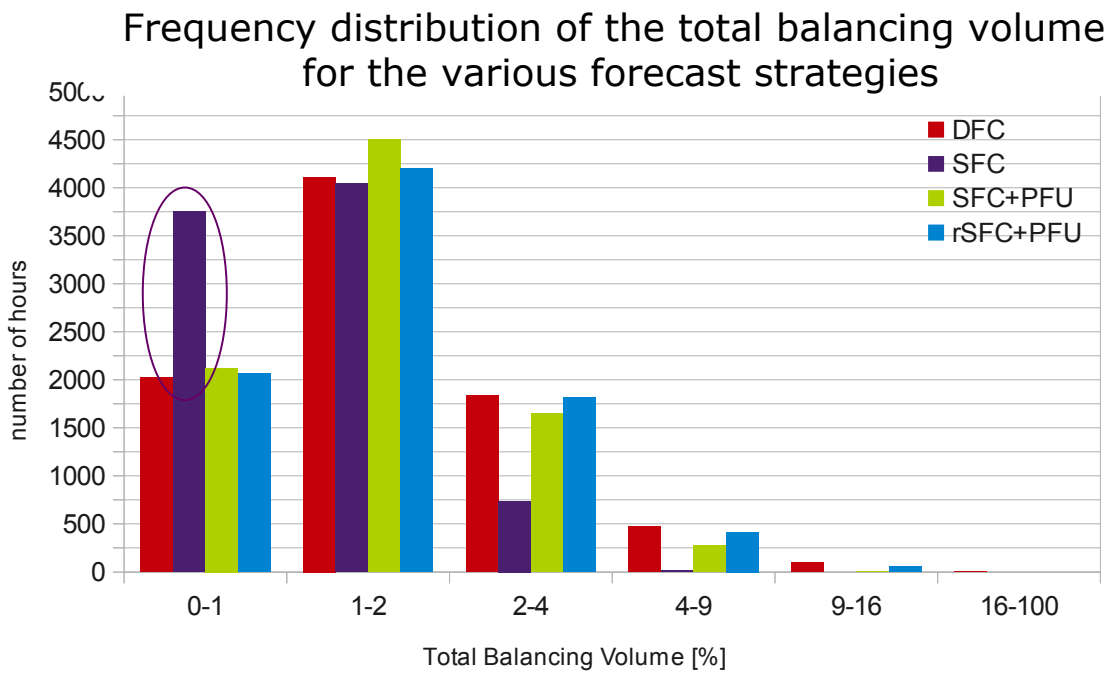
Expected Balance: EB = SFC - DFC

where SFC is short-term forecast,
DFC is the Day-ahead Forecast

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

where PFU is the "power forecast uncertainty"

Results illustrating "error distribution" for different trading strategies



Study: 1-year simulation of a coupled Danish and German market

- RMSE > 4% only 0.6% of time <===> RMSE < 2% found in 92% of time
  => **50% errors < 2% help the system!**

- RMSE(DFC,OBS)-RMSE(SFC,OBS)=2.5%, but RMSE(DFC,SFC) is 3.8%
  ==> **with permanent trading, 35-50% of the corrections are in the wrong direction and impose unnecessary costs !**

Summary of the recent advances in forecasting and managing wind and solar power in Europe

- ➔ **If all differences** between Day-ahead FC and Short-term FC **are traded** in the intra-day market, there is a risk that **too much erroneous volume is traded !**

- ➔ With applying **uncertainty forecasts** only **the large errors** of the day-ahead forecast are corrected and there is **NO double trading** !

- ➔ The **uncertainty forecast gains** from the fact that **a large amount of the small errors help the total system** and hence **reduce costs!**

- ➔ A **large portion of the forecast error is predictable** well in advance with Ensemble forecasts and:
  - **provide savings**, if used to pre-allocate reserves day-ahead!
  - trigger **higher liquidity in the short-term market**
  - will be important, if wind power error reaches reserve limit

- ➔ **RMSE error does not provide a measure for the costs** of the integration and hence will be **insufficient to optimise and evaluate forecasts** in the future!

Conclusions of the recent advances in forecasting and managing wind and solar power in Europe

Paradigm shift:

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

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

CONCLUSION:

Forecast optimisation and evaluation has to happen in accordance with the market rules in the future , i.e. in "cost space"

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Thank you for your attention !

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http://download.weprog.com/WEPROG_Trading_strategies_EEG2012_ZEFE_71-2012-01_en.pdf

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