Increased wind power forecast skill due to improved NWP in the last decade

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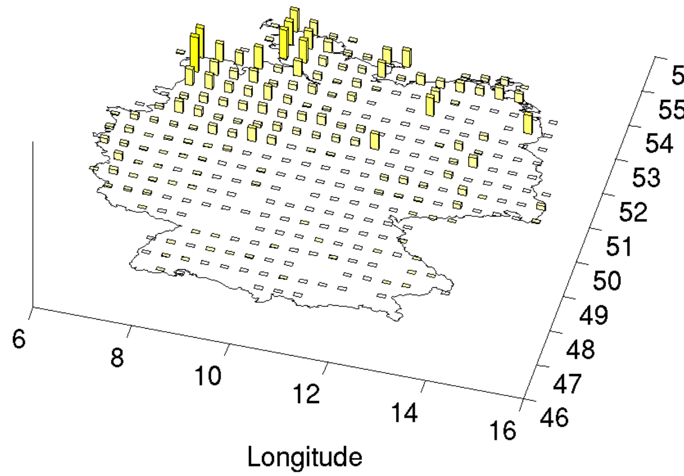
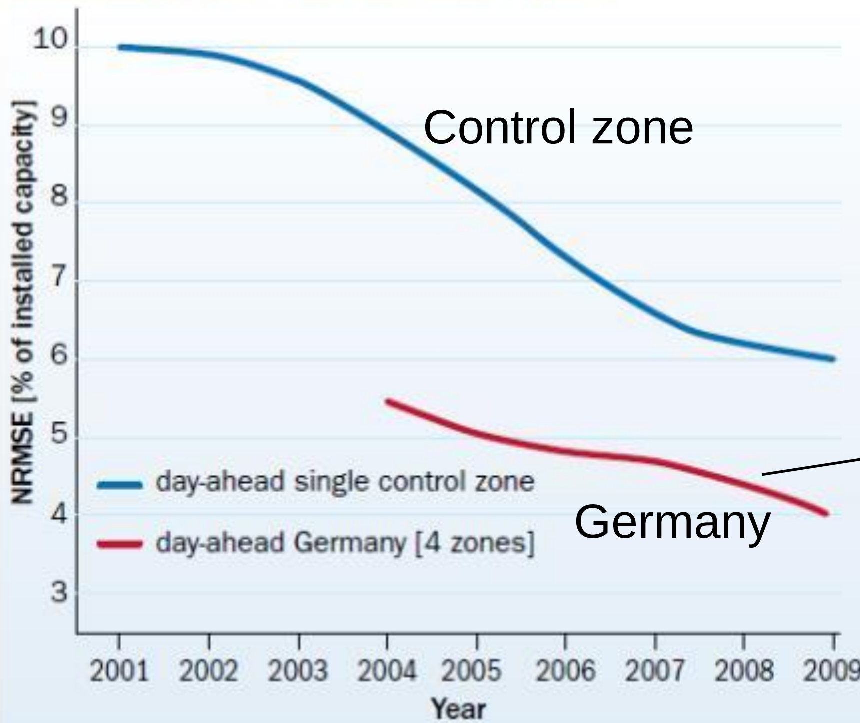


Outline

- Inspiration
- Complexity of „clean“ experiments for wind power
- Clean NWP impact on long term fc errors
- Issues not validating meteorological variables
- Saturated fc error smoothing (in Germany)
- Conclusions

Inspiration – what is the impact of each single factor for improved regional wind power forecast?

FIGURE 13: HISTORIC DEVELOPMENT OF THE AVERAGE FORECAST ERROR IN THE WHOLE OF GERMANY AND IN A SINGLE CONTROL ZONE IN THE LAST NINE YEARS



The improvements in accuracy are due to a combination of effects: better weather forecasts, increasing spatial distribution of installed capacity in Germany and advanced power forecast models, especially using combinations of NWPs and power forecast models [Tambke 2010].

overall improvement: 25%

- better NWP
- increased wind power capacity and more disperse distribution
- better WPP models & combination

Source: Powering Europe:
Wind energy and the electricity grid
EWEA, Nov 2010

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Diagnozing an impact factor in „clean“ experiments

- change only one component to pindown the impact of changes
- consistent individual verification data (at single sites) of constant quality
- long time series
- validate meteorological (model) variables
- variables are usually not spatially aggregated when verified

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Can be avoided by computing own verification data set !

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Simulation of wind power forecast improvement (in Germany)

ECMWF

- ECMWF model level winds from Jan 2001 – Dec 2012
- Forecasts up to +72h
- Analysis as verification data (6 hourly)
- Horizontal resolution has changed from T511 (~40 km) to T1279 (~16 km)

DWD

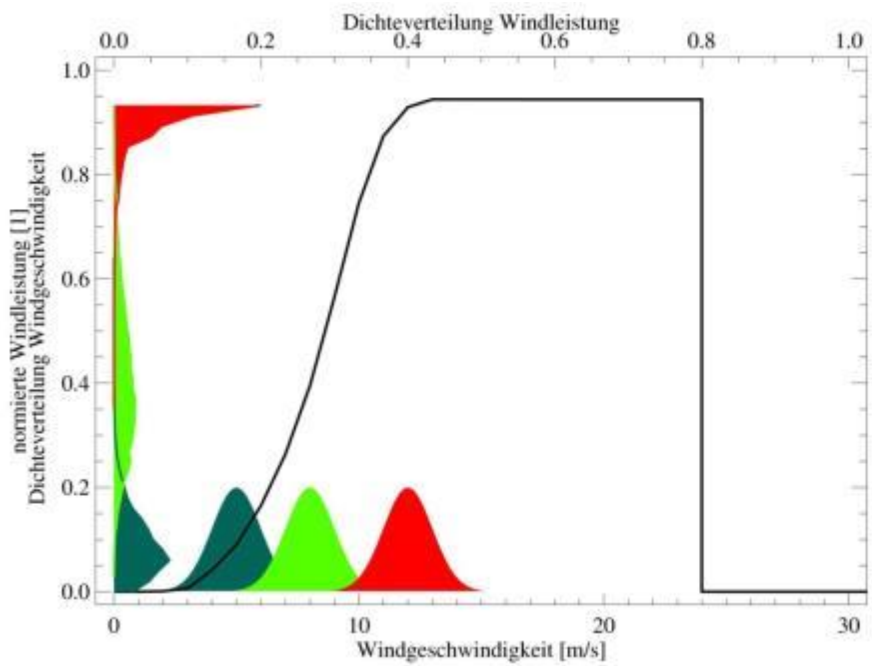
- model level winds from Jan 2007 – Dec 2012
- Forecasts up to +72h (hourly, but used 6 hourly when comparing with ECMWF)
- Analysis as verification data (hourly, but used 6 hourly)
- Constant horizontal resolution (7 km, 0.0625°)

- Simplified power curve model (TradeWind PC) for each grid box at (wind power weighted) average hub in each grid box

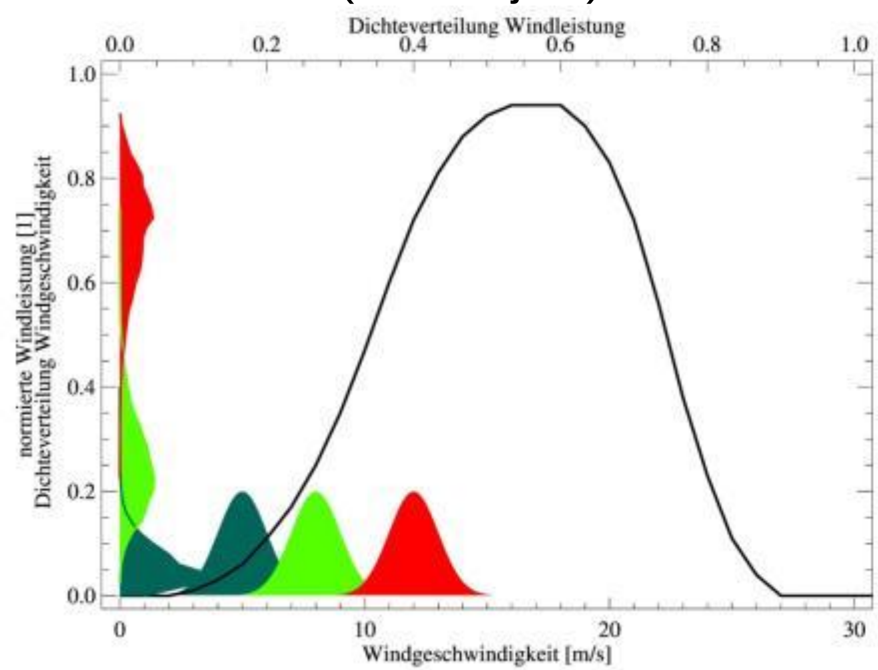
Transformation of wind speed distribution to power distribution by power curve

- Wind speed distribution with σ=1 m/s

Manufactor

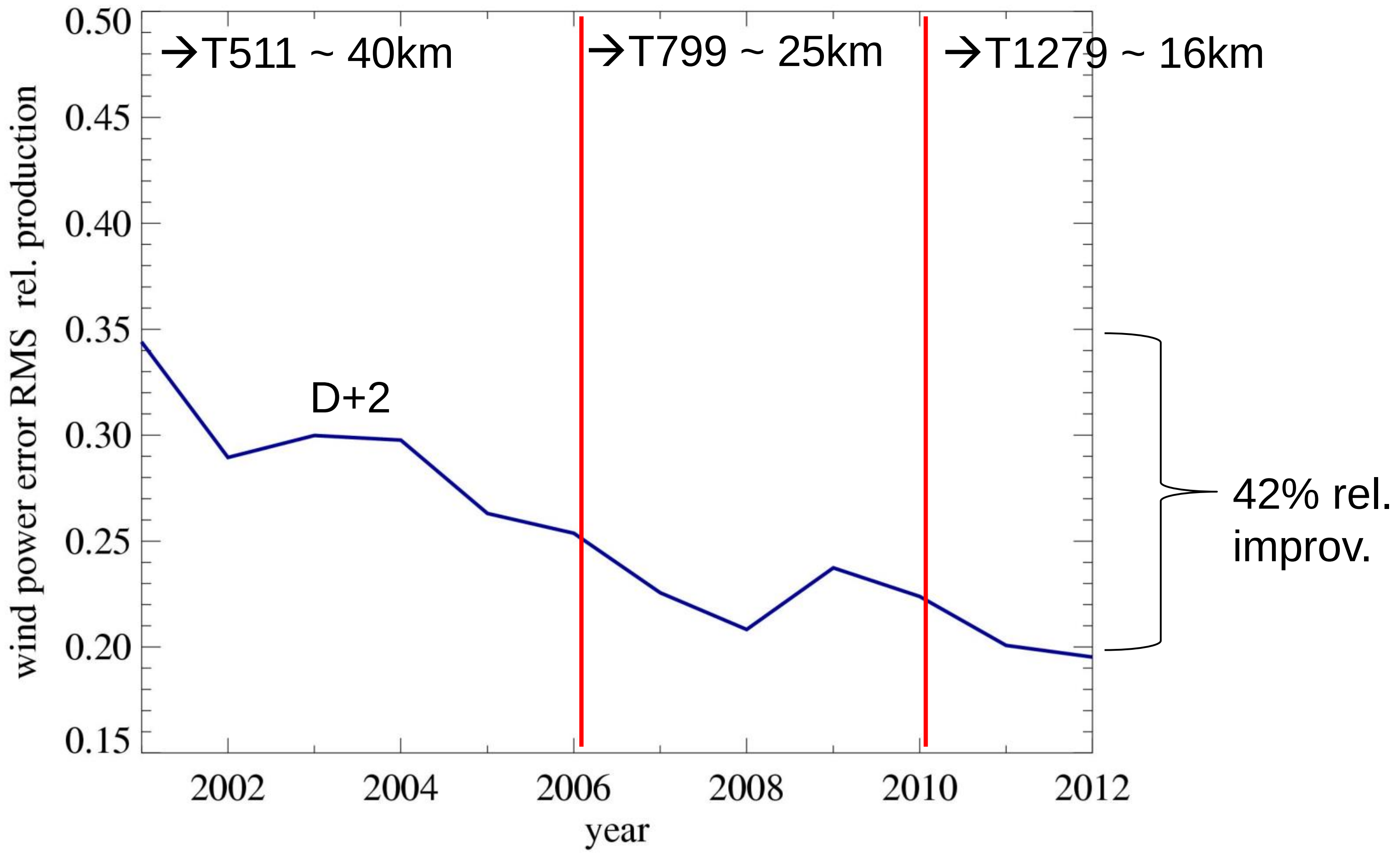


TradeWind (EU-Project)



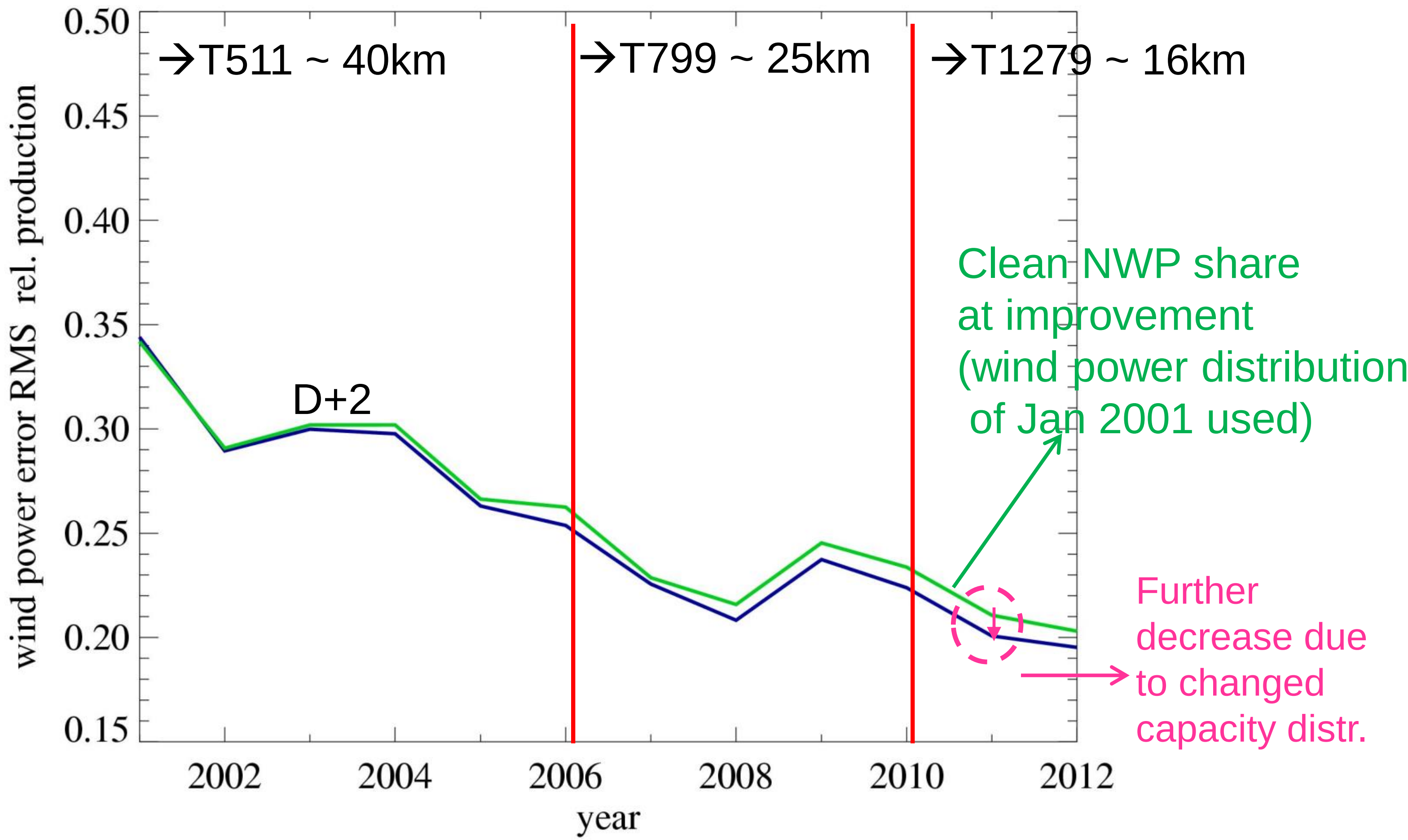
Simplify the effect of error amplification by power curves:
Use only one power curve (TradeWind)

Simulated day-ahead forecast root mean square error relative to produced power



What is required to „extract the clean impact“ due to NWP?

Simulated day-ahead forecast root mean square error (seperate clean NWP impact)



- Clean NWP improvement 40% between 2001 and 2012

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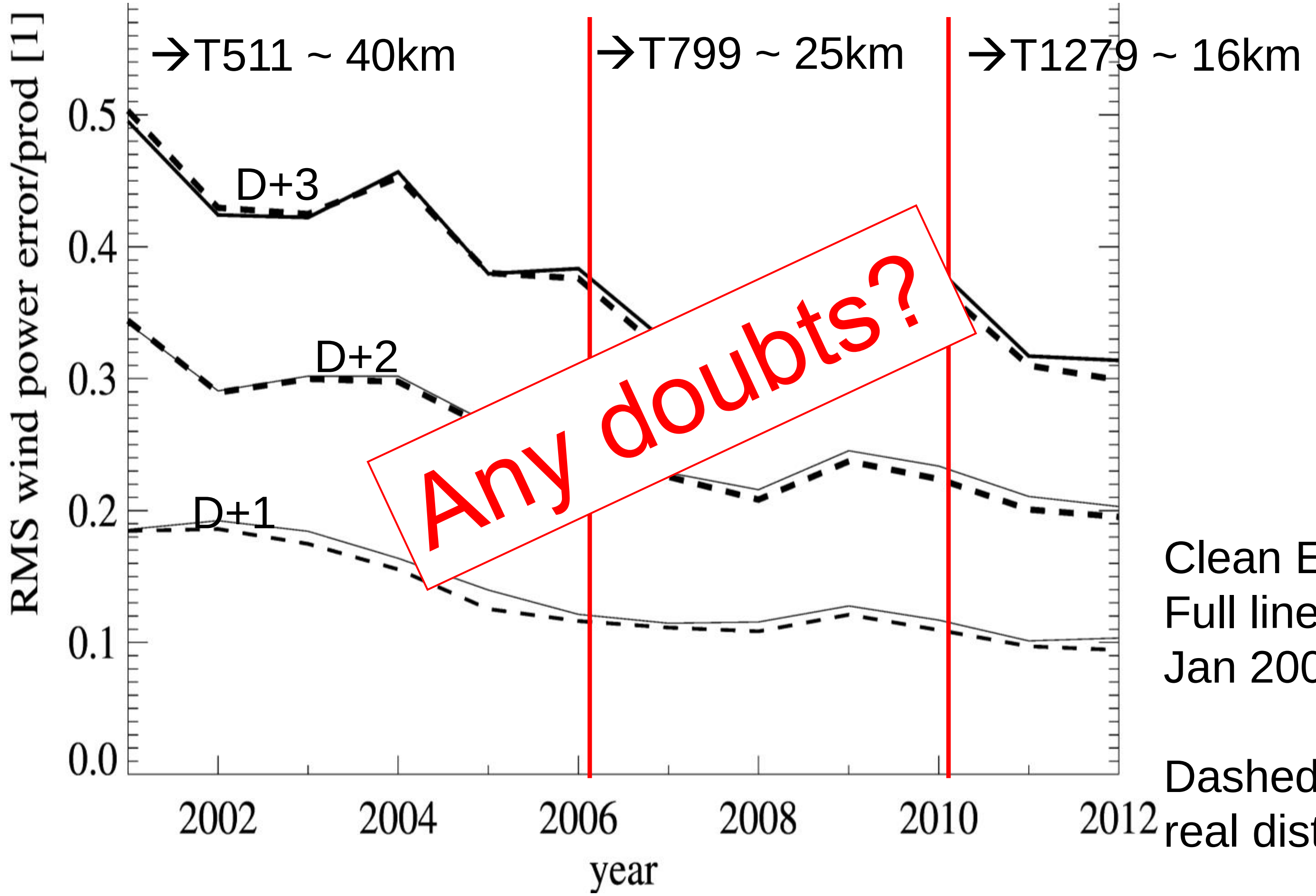
Simulated forecast root mean square error relative to produced power

➢



Clean Exp.
Full lines
Jan 2001distr.

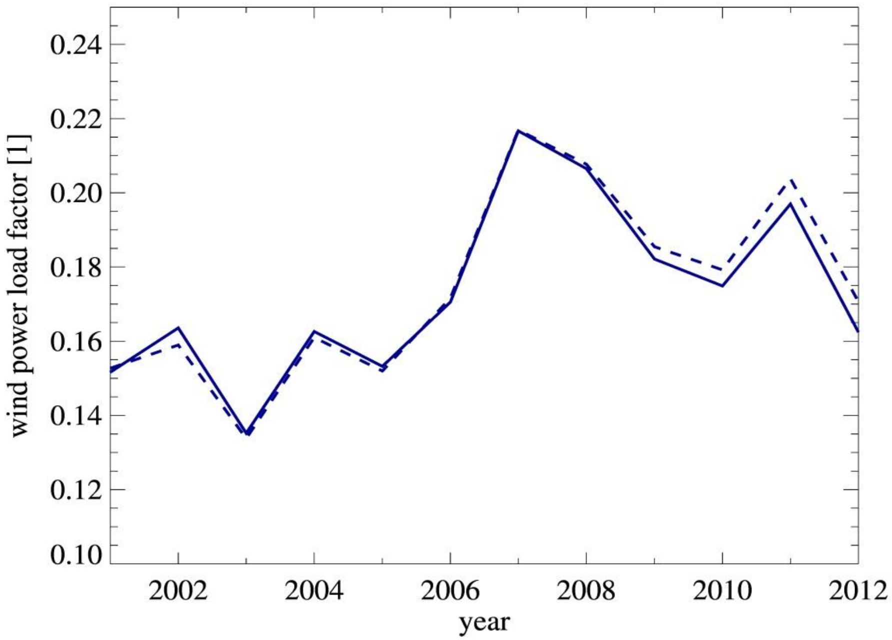
Dashed lines
real distribution

➢ Rel. improvement 42 % (D+1), 31 % (D+2), 27 % (D+3) in 10y (clean exp.)

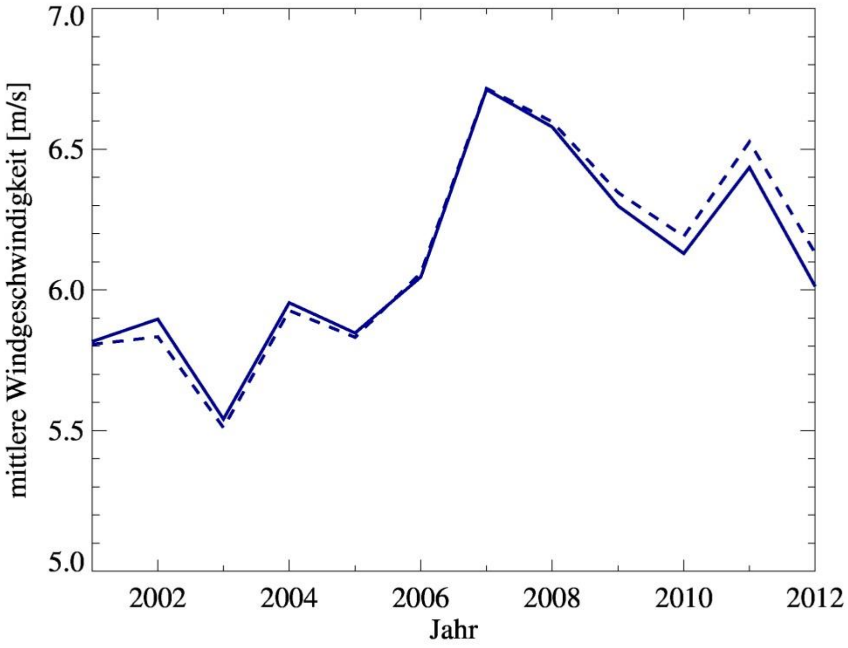
German load factor and hub height speed simulated by ECMWF

Dashed lines: real development
Full lines: capacity distribution frozen in Jan 2007

Load factor



Average wind speed



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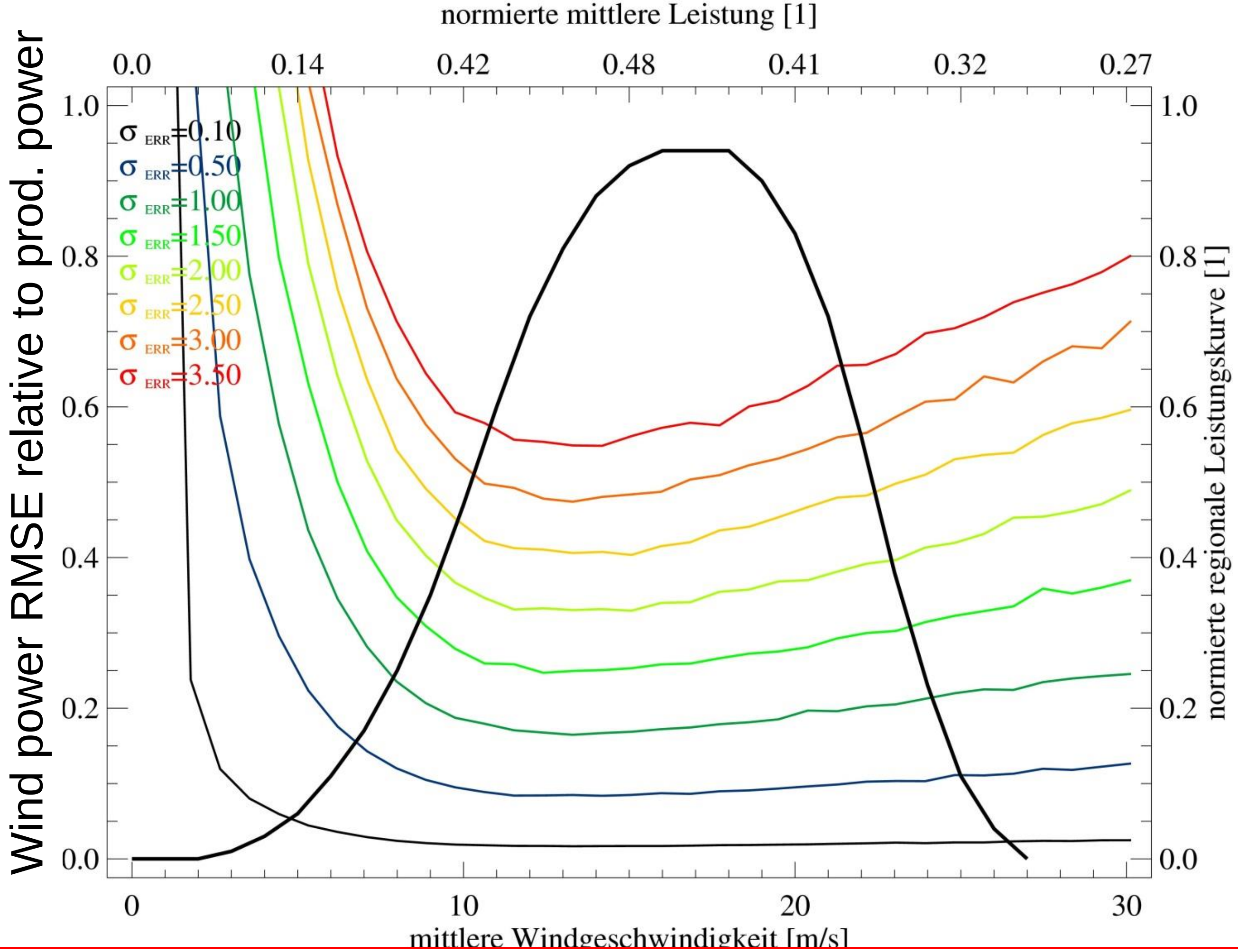
Dependence of wind power forecast error on mean wind speed and wind Gaussian speed error normalized with produced power

Weibull distribution at each wind speed class/bin (shape factor=2)

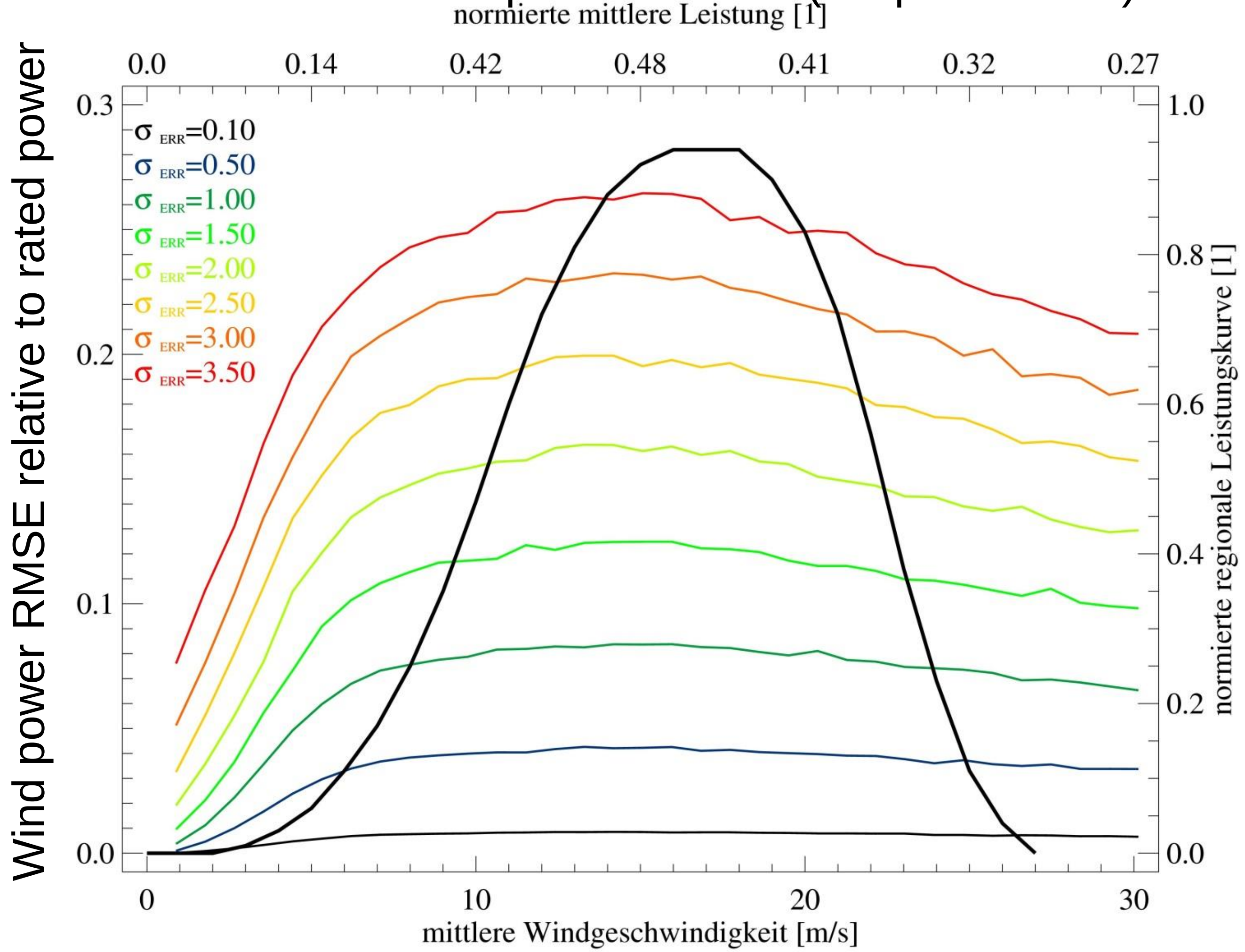


(13)

- ➢ Decrease of wind power error with average wind speed (~0.1 per m/s)

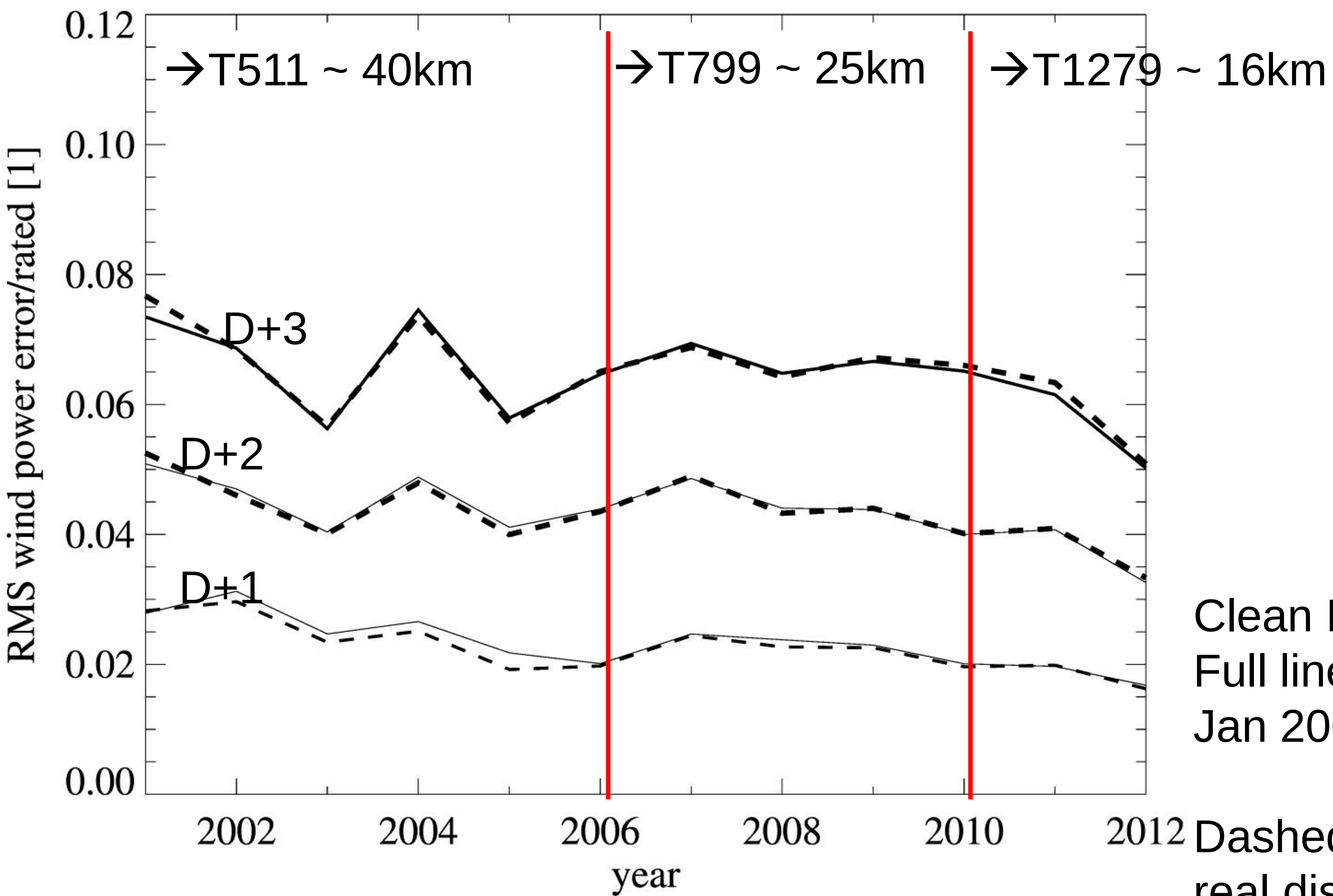
Dependence of wind power forecast error on mean wind speed and wind Gaussian speed error normalized with installed power

Weibull distribution at each wind speed class/bin (shape factor=2)



➢ Increase of wind power error with average wind speed (~+0.015 per m/s)

Simulated forecast root mean square error relative to rated power



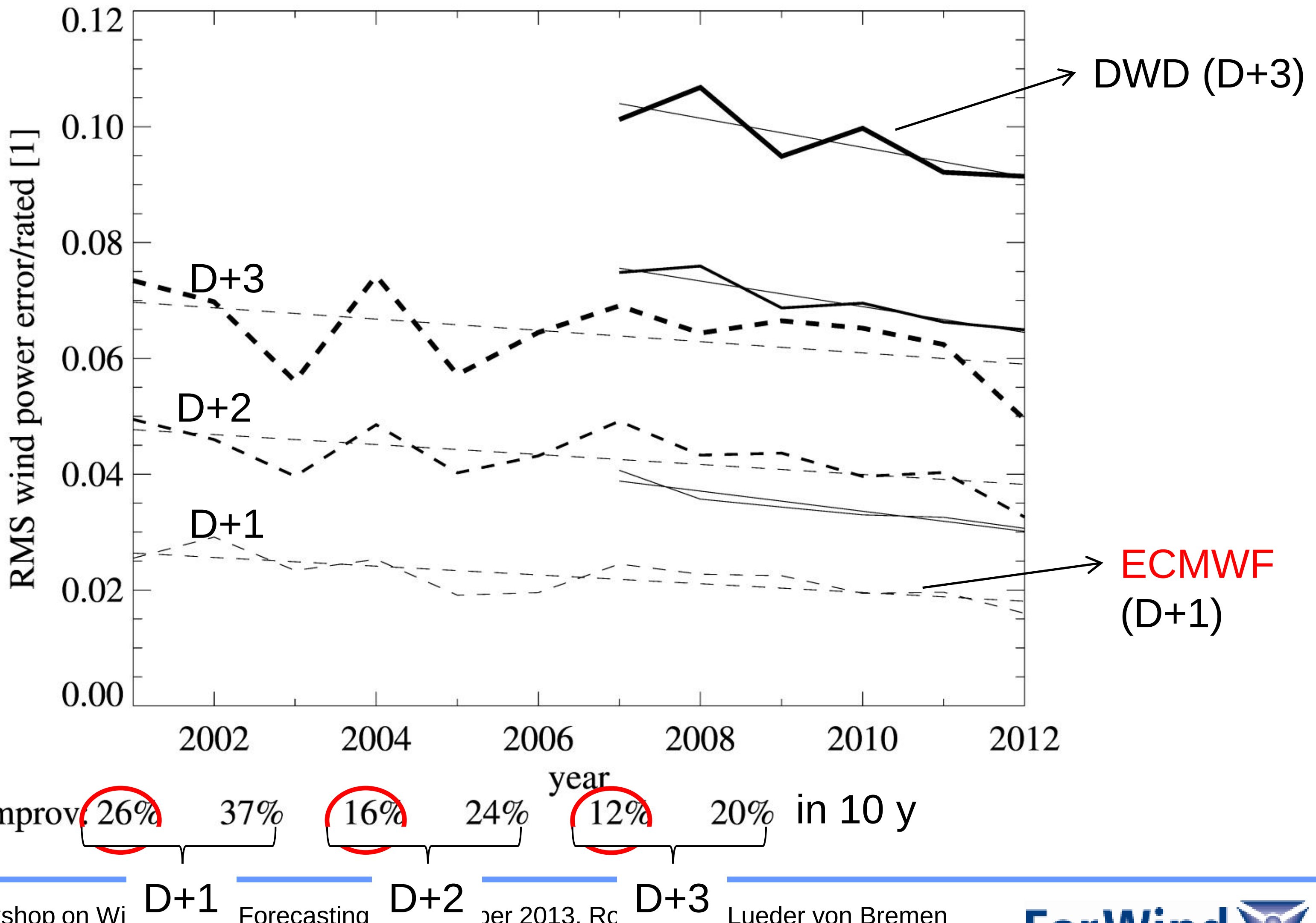
Clean Exp.
Full lines
Jan 2001distr.

Dashed lines
real distribution

- Rel. improvement 29 % (D+1), 17 % (D+2), 12 % (D+3) in 10y (clean exp.)

Simulated forecast root mean square error relative to rated power

- DWD: 6y, ECMWF: 12y using Jan 2007 distribution



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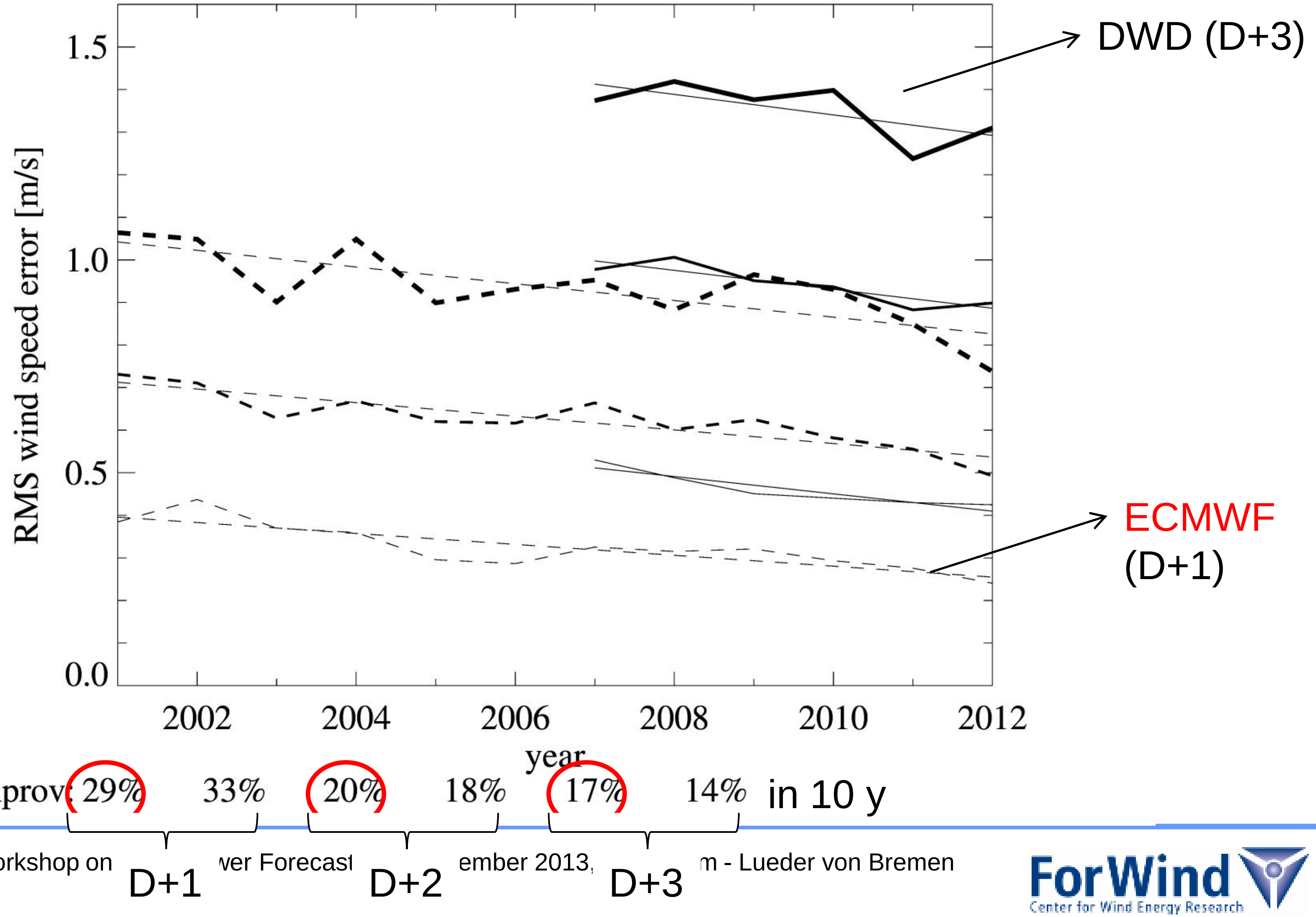
How to properly assess how much the skill in wind power forecasts has improved?

➢ Possible solution:
evaluate wind speed (here: weighted with Jan 2007 wind power distribution)



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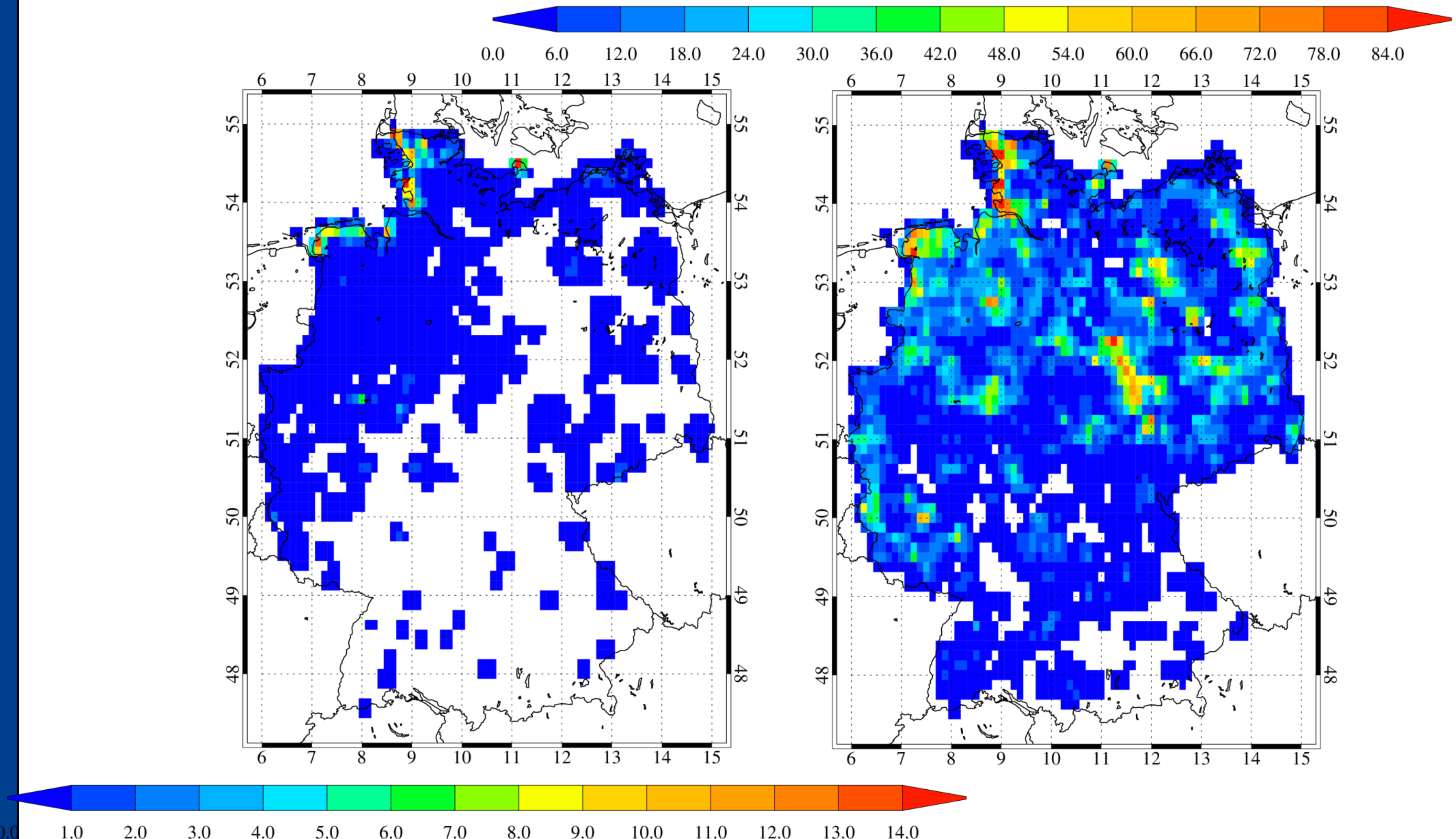
Change in wind power capacity [MW/160km^2] from Jan 1995 to Dec 2011



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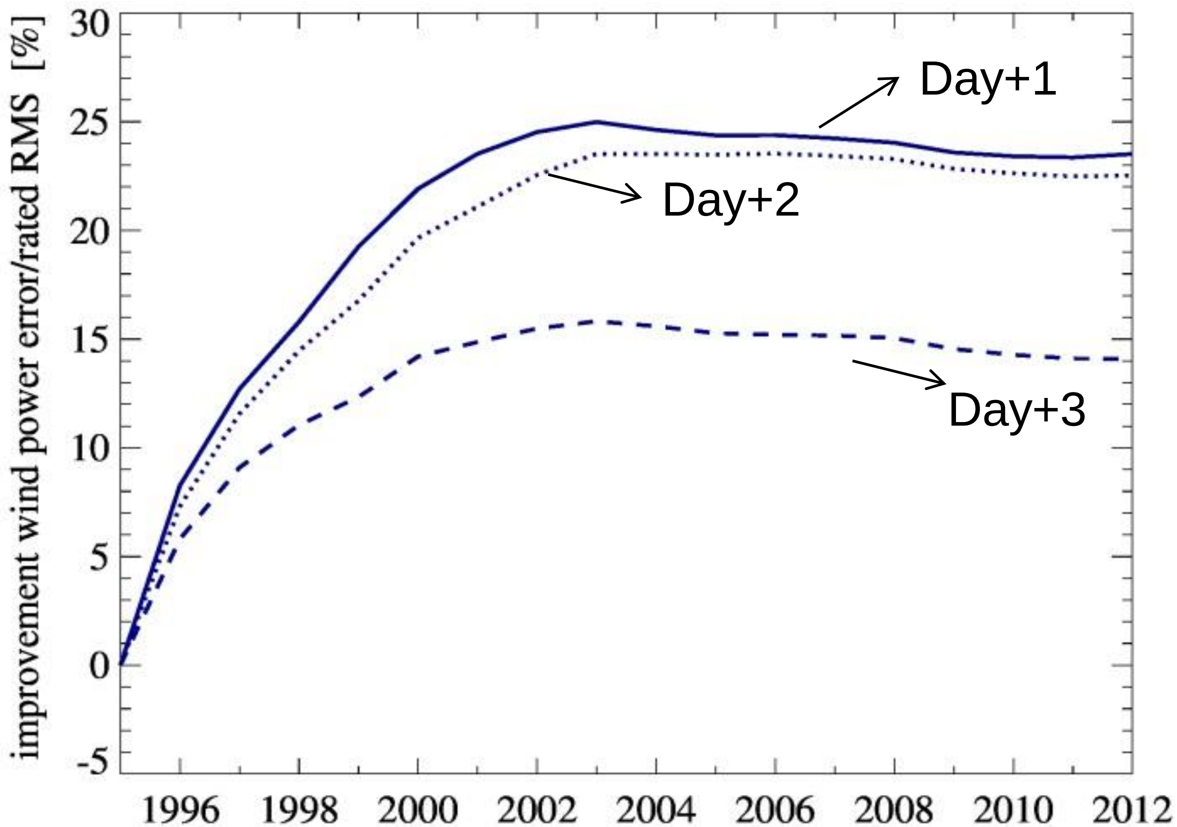
Skill improvement by enhanced spatial forecast error smoothing (ECMWF)

NWP year= 2011
normalized with rated power



- Saturation reached with respect to rated power in 2001/2002

Conclusions

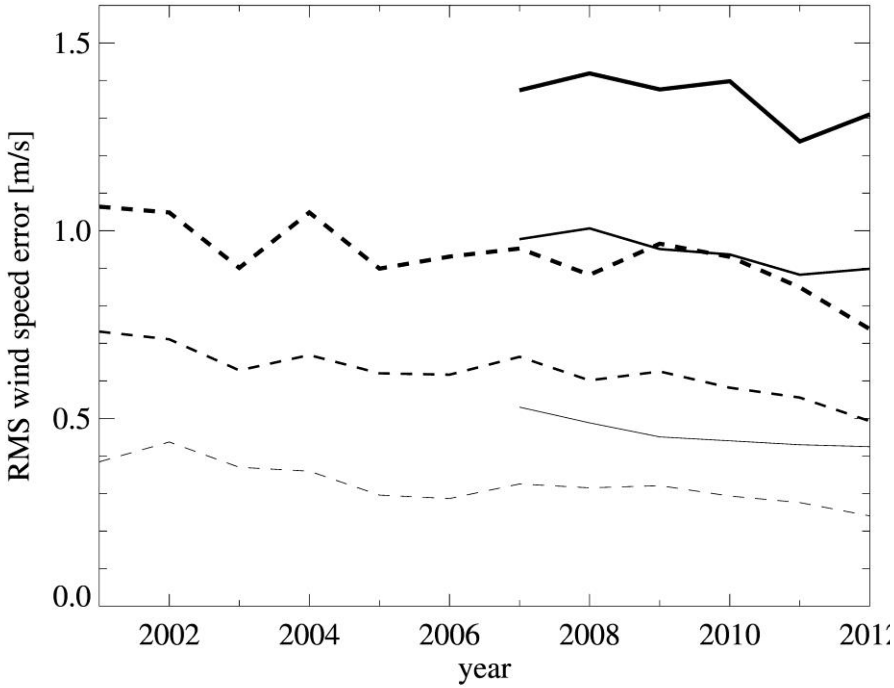
Thank you for your attention

- Wind power fc error improvement depends on used error metric
- Normalization with rated power yields similar results as improvements in wind speed
- NWP (ECMWF) rel. improvement alone is 16 % (12 %) in 10y for D+2 (D+3) (normalized with rated power) (DWD: 24 % (20 %))
- Saturation for fc error smoothing was reached in 2001/2002 (relative to rated capacity)→ However, there is still potential for further wind power fc error smoothing (combine with offshore)
- Outlook: How to assess the impact of NWP improvements using real wind power data? Consistent time series of wind power are required!

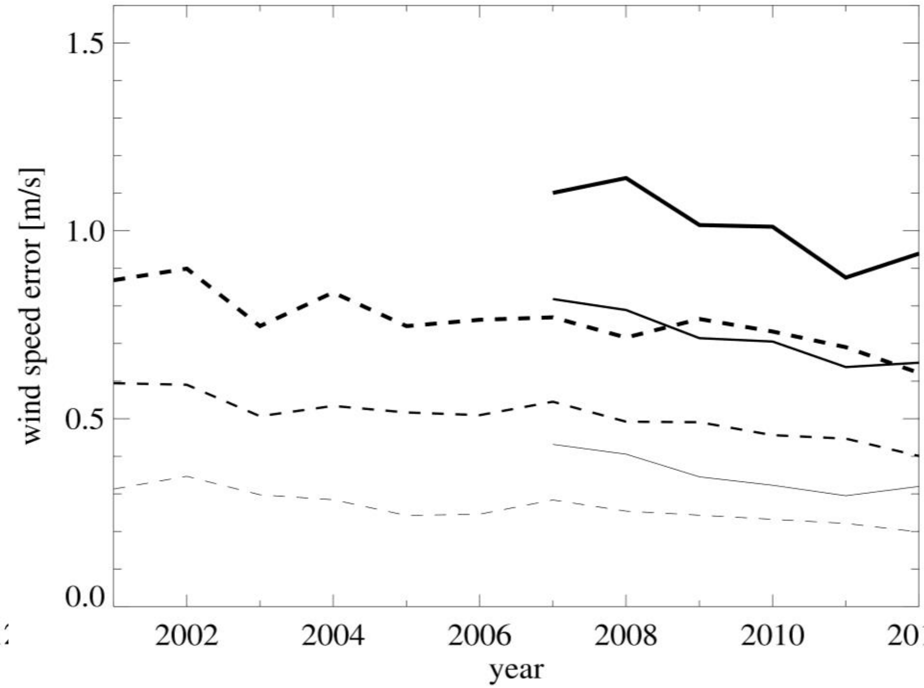
Acknowledgement: This work was supported by the Federal Ministry for Science and Culture of Lower Saxony. Contact: lueder.von.bremen@forwind.de

Skill in average German wind speed

Jan 2007 wind power distribution



all German grid points (incl. offshore)

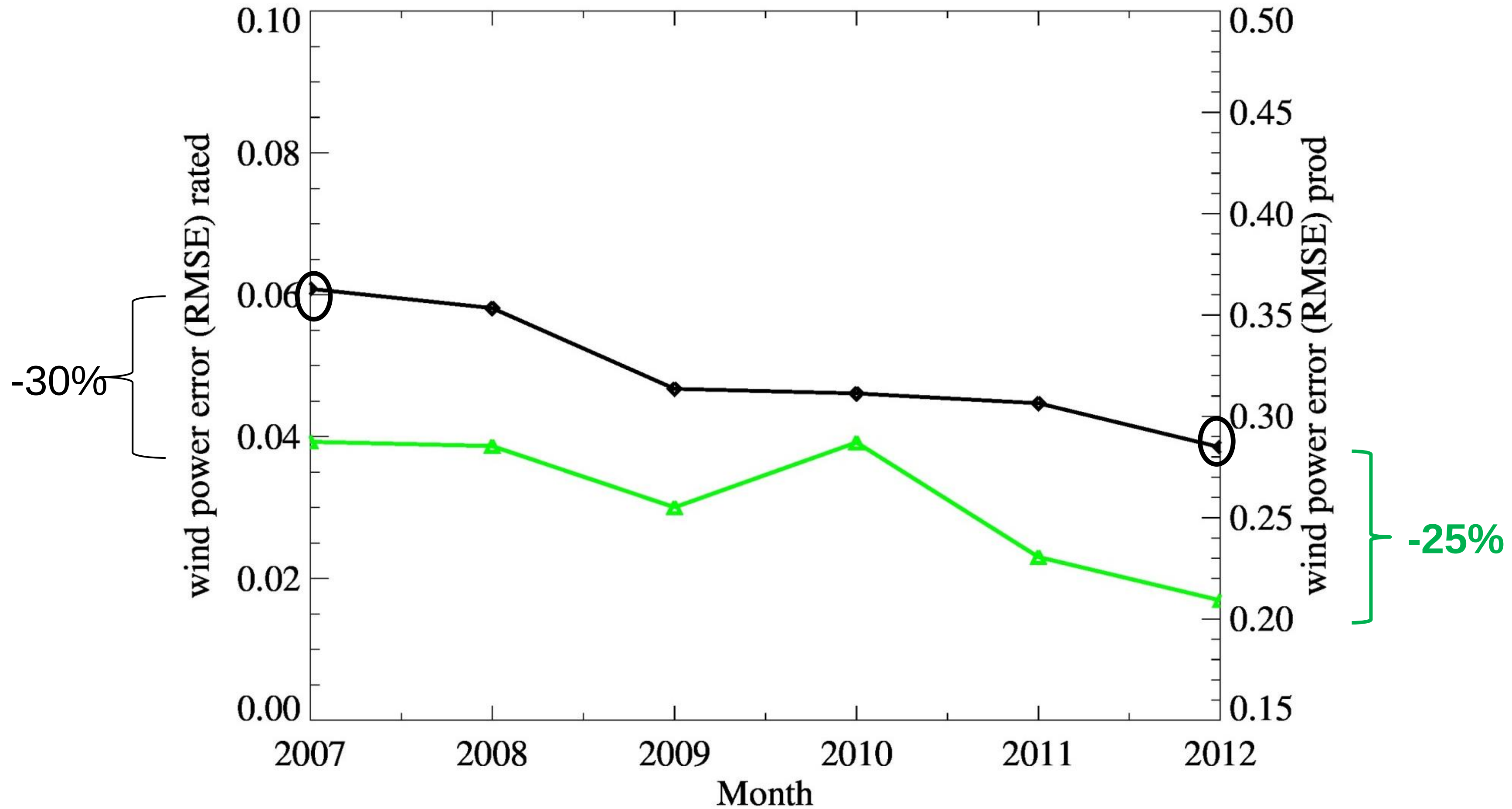


- Still potential for enhanced wind fc error smoothing in Germany

day-ahead wind power forecast error in Germany (Meta-Forecast by TSOs)

Normalized with rated capacity

Normalized with prod. wind power



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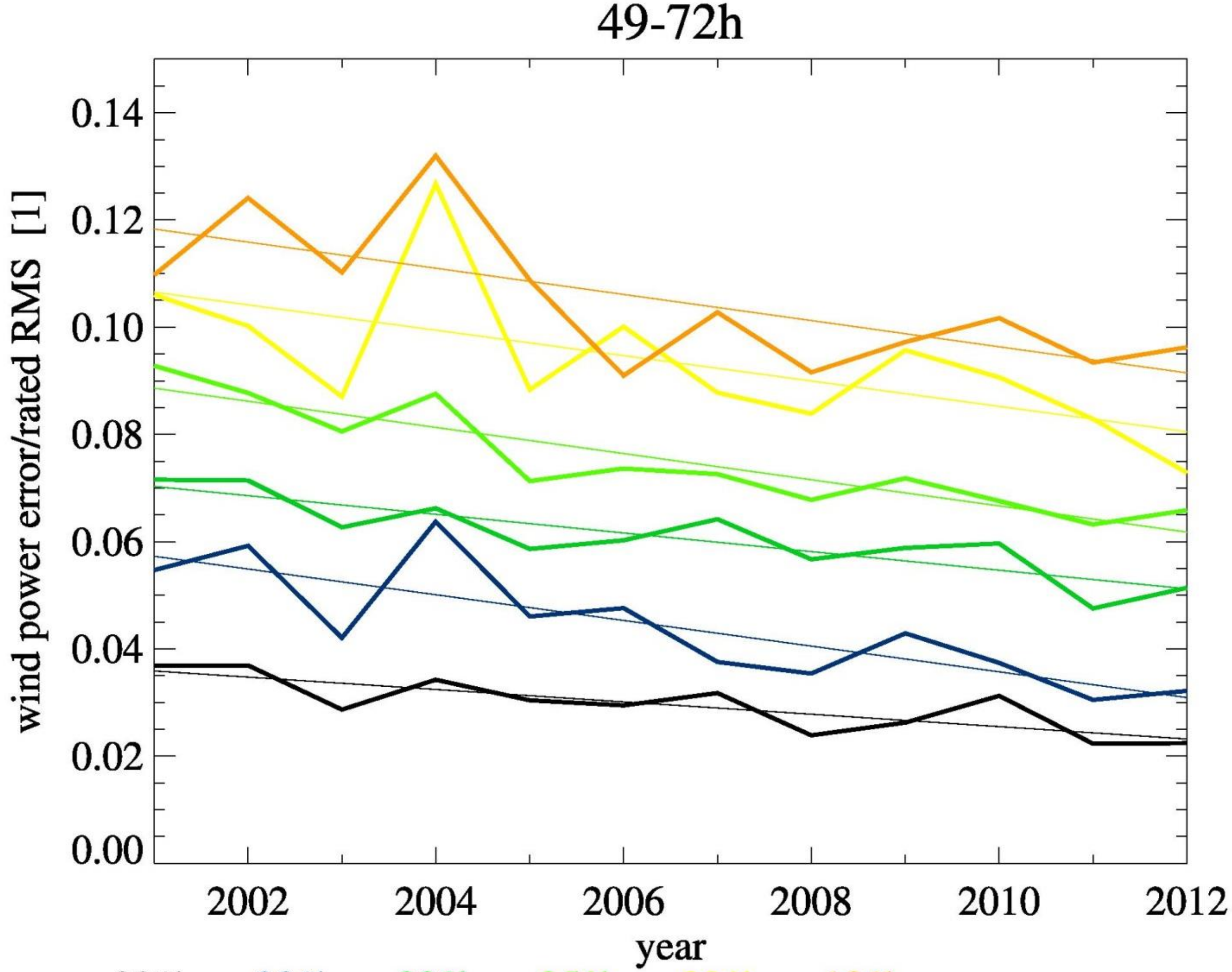
Average yearly speed and load factor stratified by wind speed class

Fig mean speed and power should be flat (real av. Speed and load factor also in t
.idl is prepared

Wind power error D+3 for various wind speed classes

Normalized with rated power (capacity distribution Jan 2007)
Wind speed classes: 3-4, 4-5, 5-6, 6-7, 7-8, 8-9 m/s



relative improv: 29% 38% 22% 25% 20% 18%

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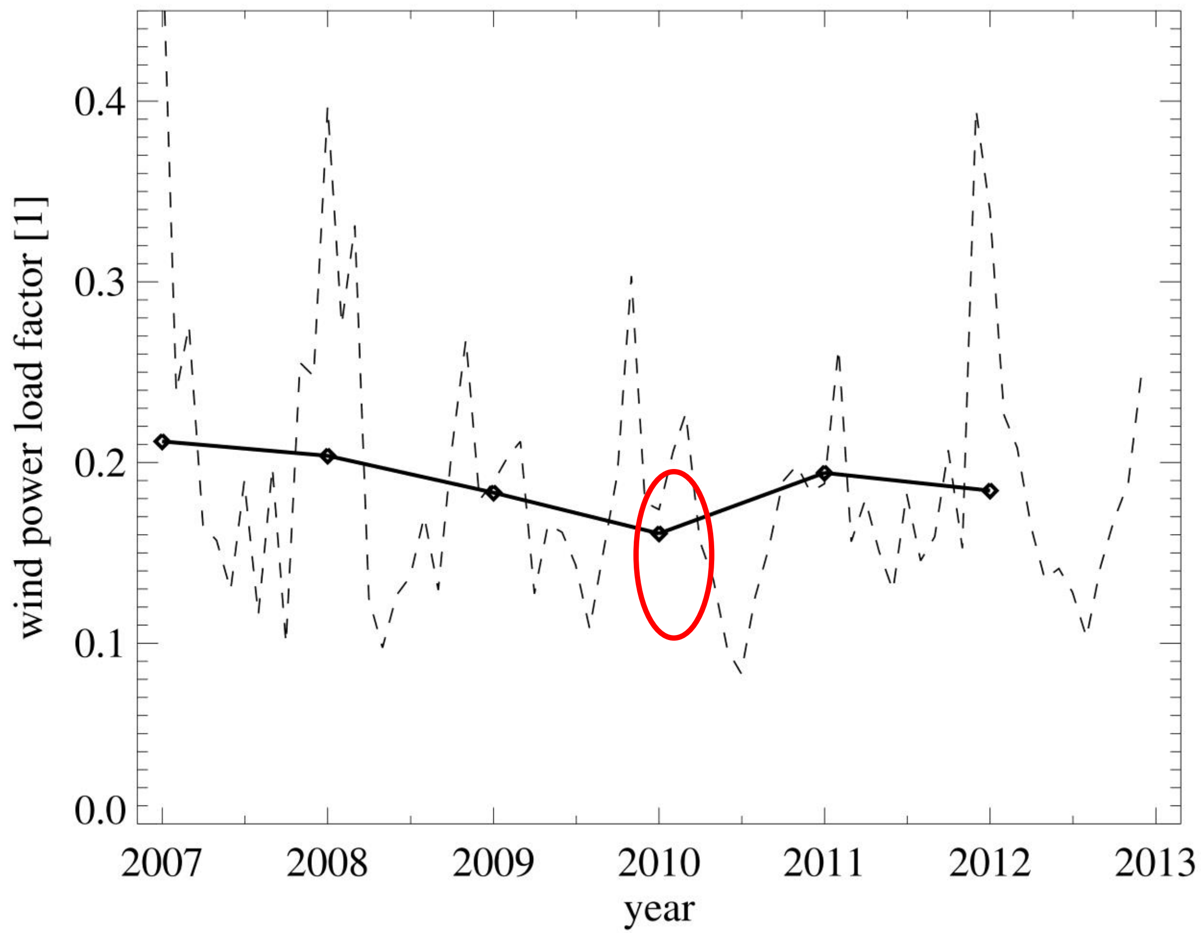
Load factor in Germany

Data from TSO-Websites



day-ahead wind power forecast error in Germany (Meta-Forecast by TSOs)

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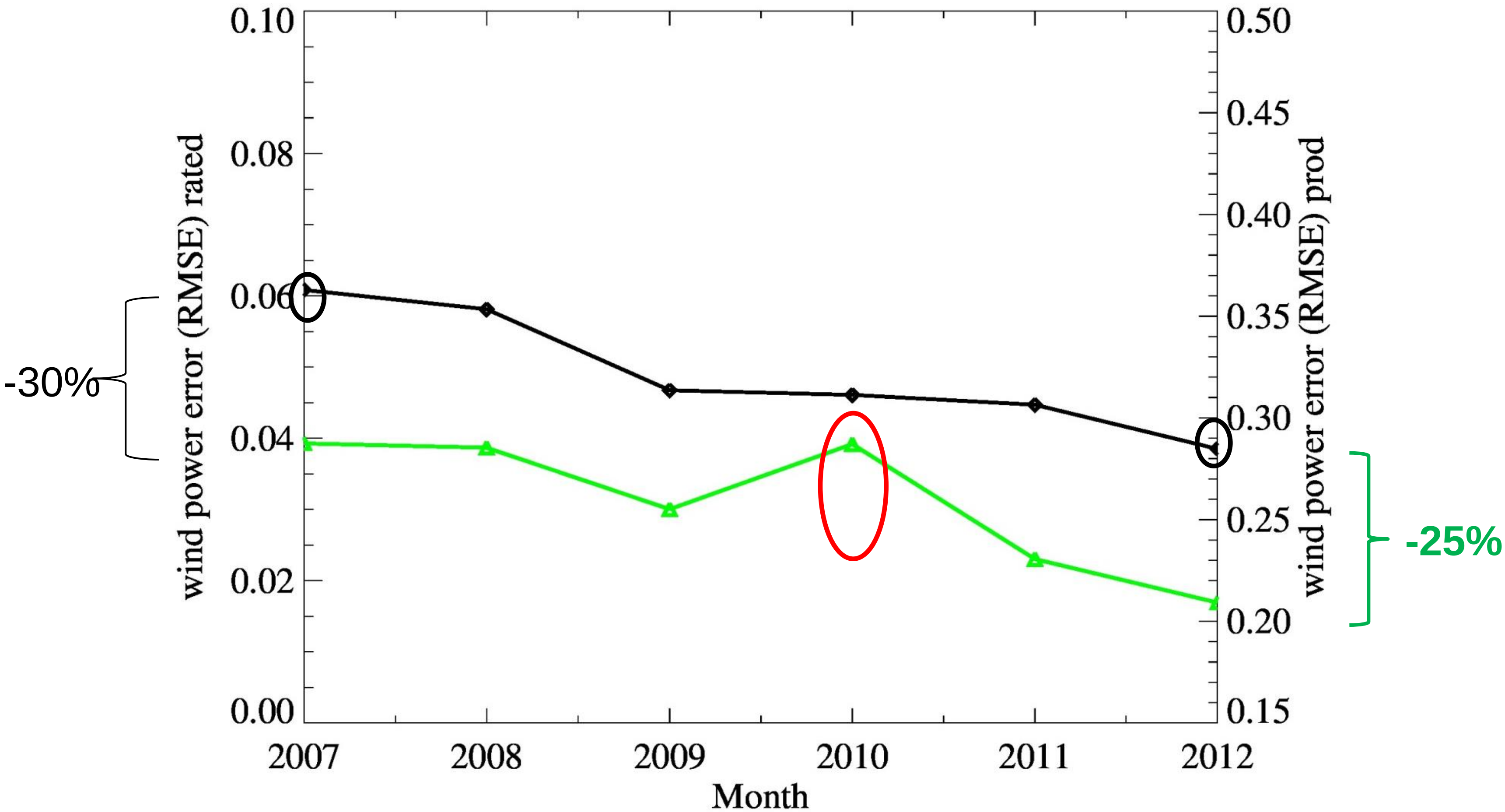
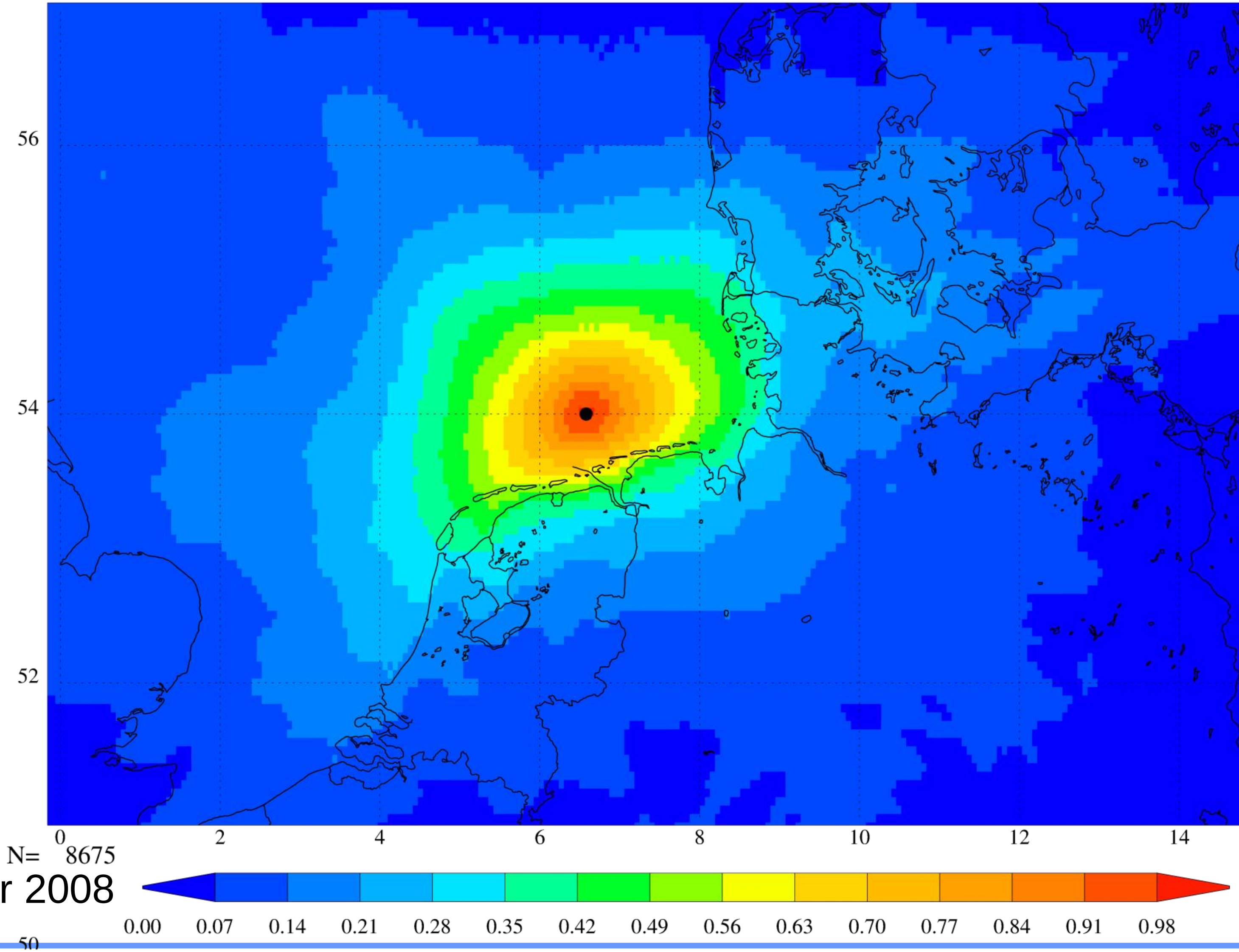


What is fc error smoothing?

➢ Cross-Correlation of forecast error (D+2) at FINO1



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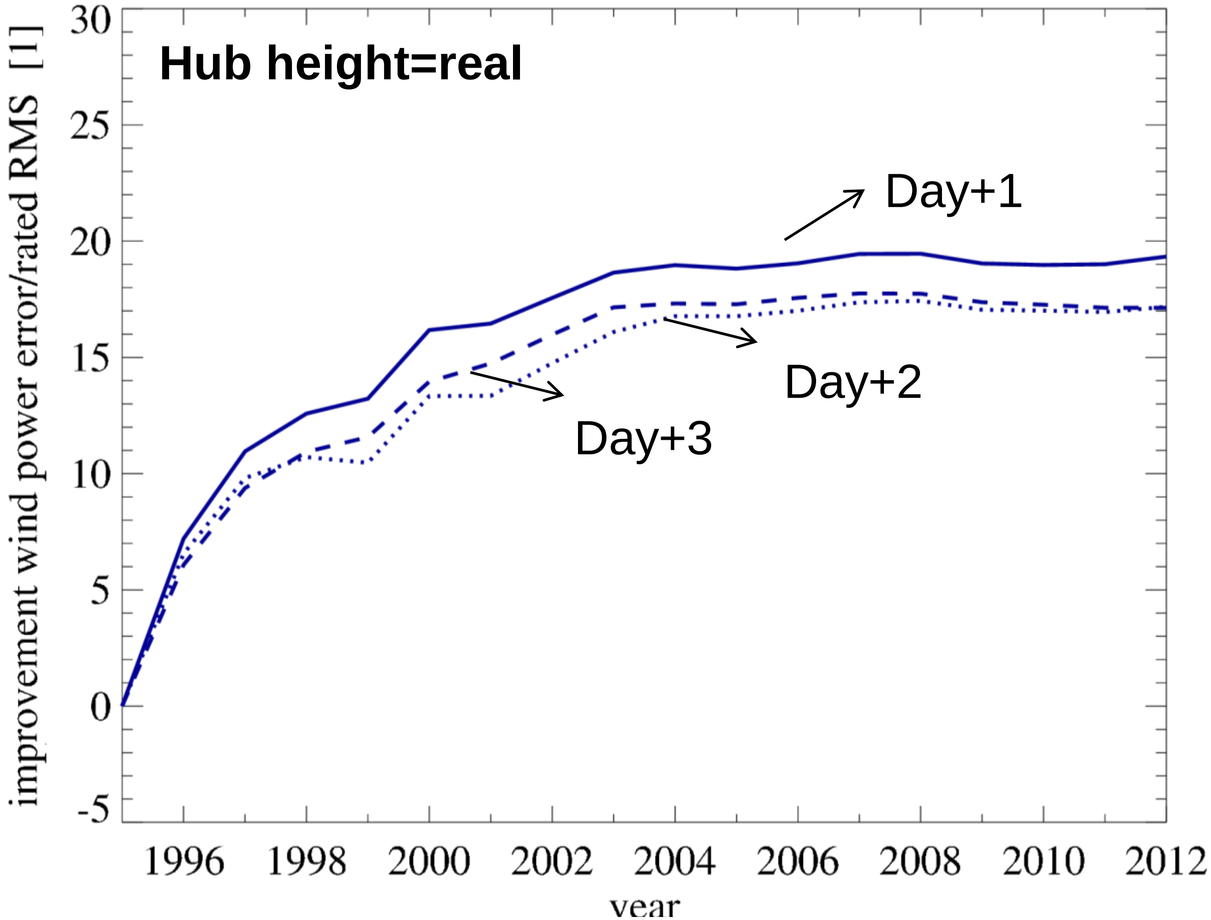
Impact of spatial forecast error smoothing (DWD)

NWP year= 2011
normalized with rated power



- ➢ Saturation level much lower compared to ECMWF
- ➢ smoothing stronger at Day 3 than at Day 2

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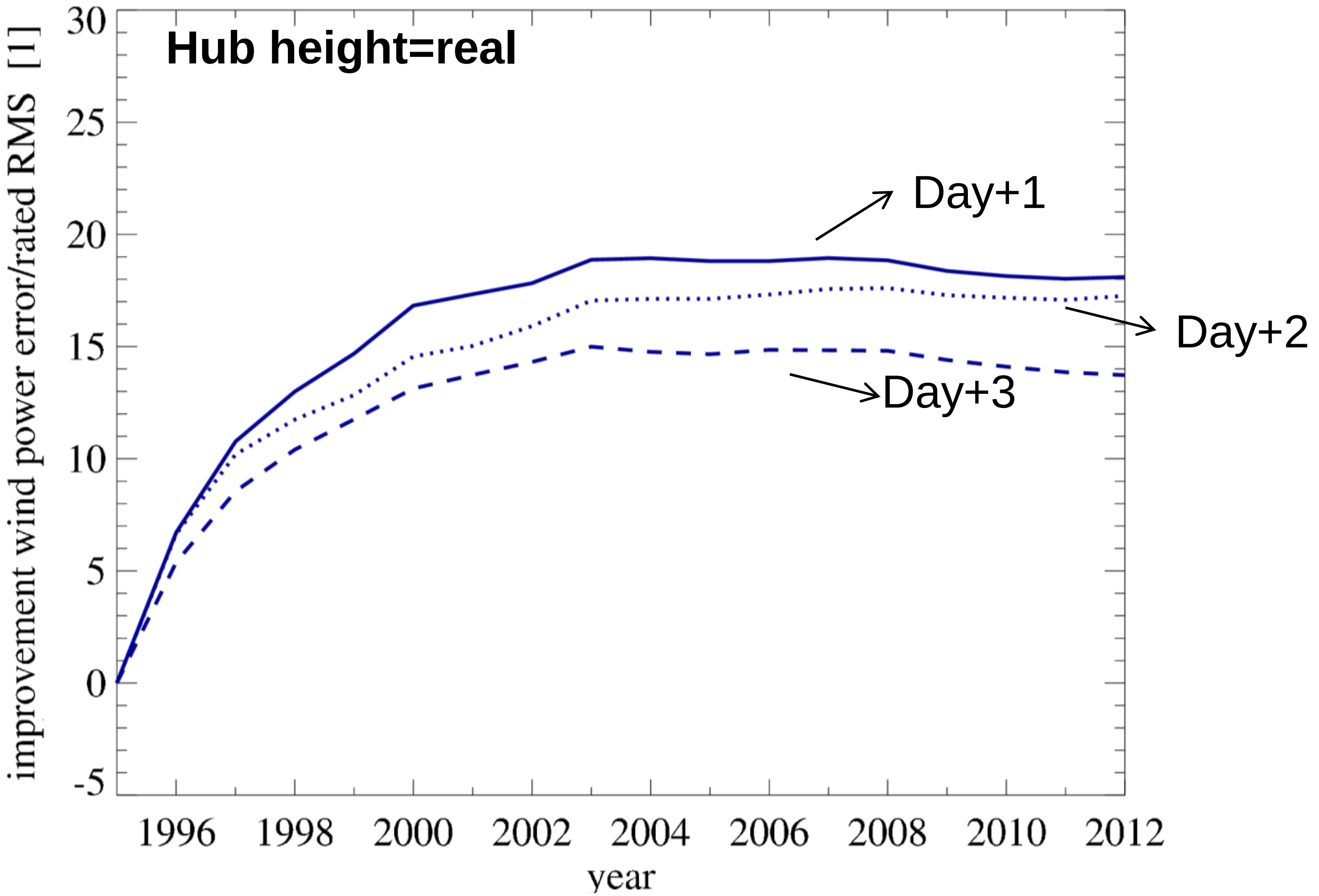
Impact of spatial forecast error smoothing (DWD)

NWP year= 2012
normalized with rated power



➢ Now smoothing at Day 3 is weakest (as expected)

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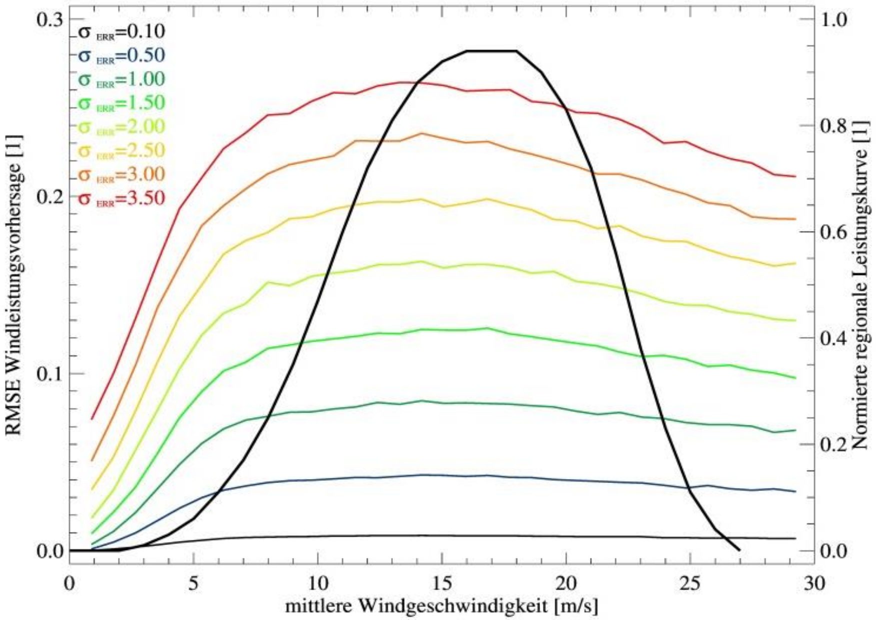
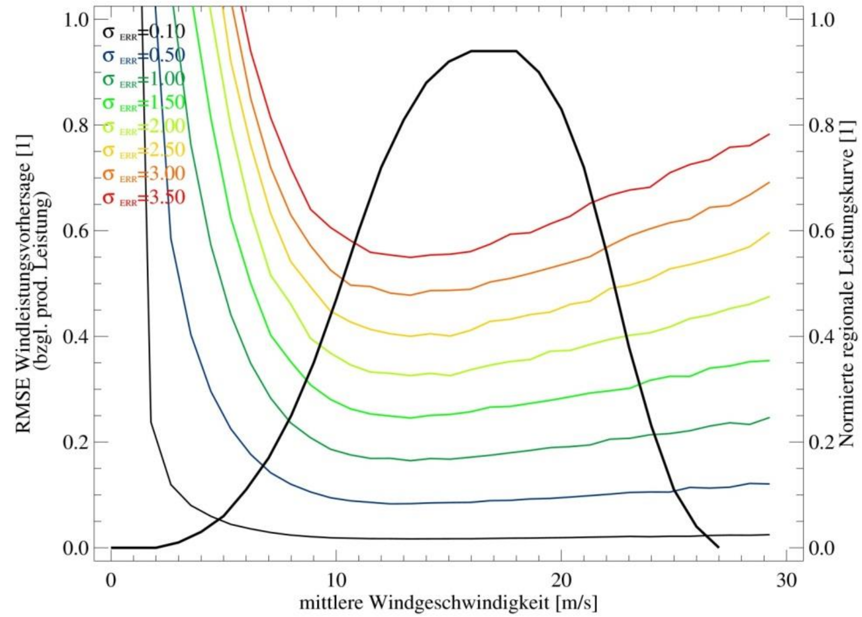
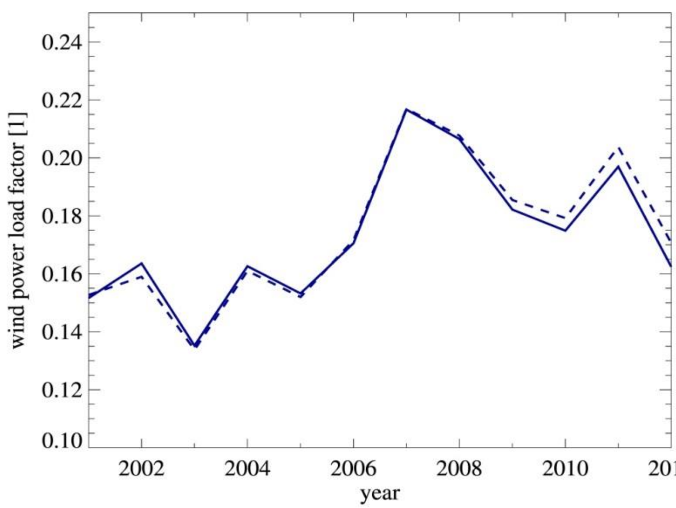
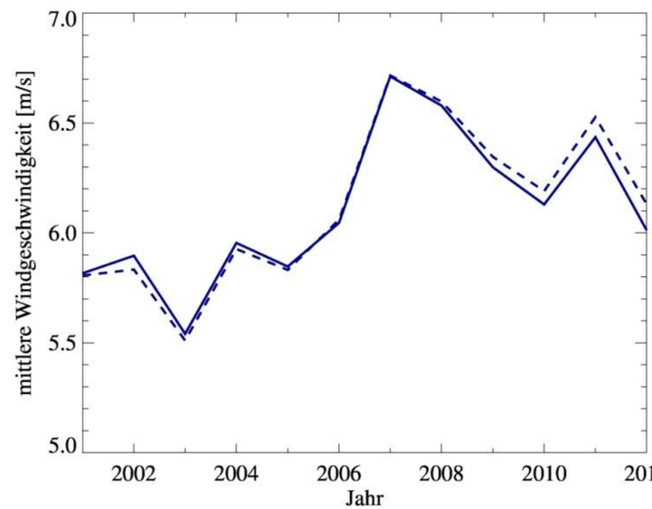
How to assess varying mean wind speed in evaluation of long term WPP skill properly?



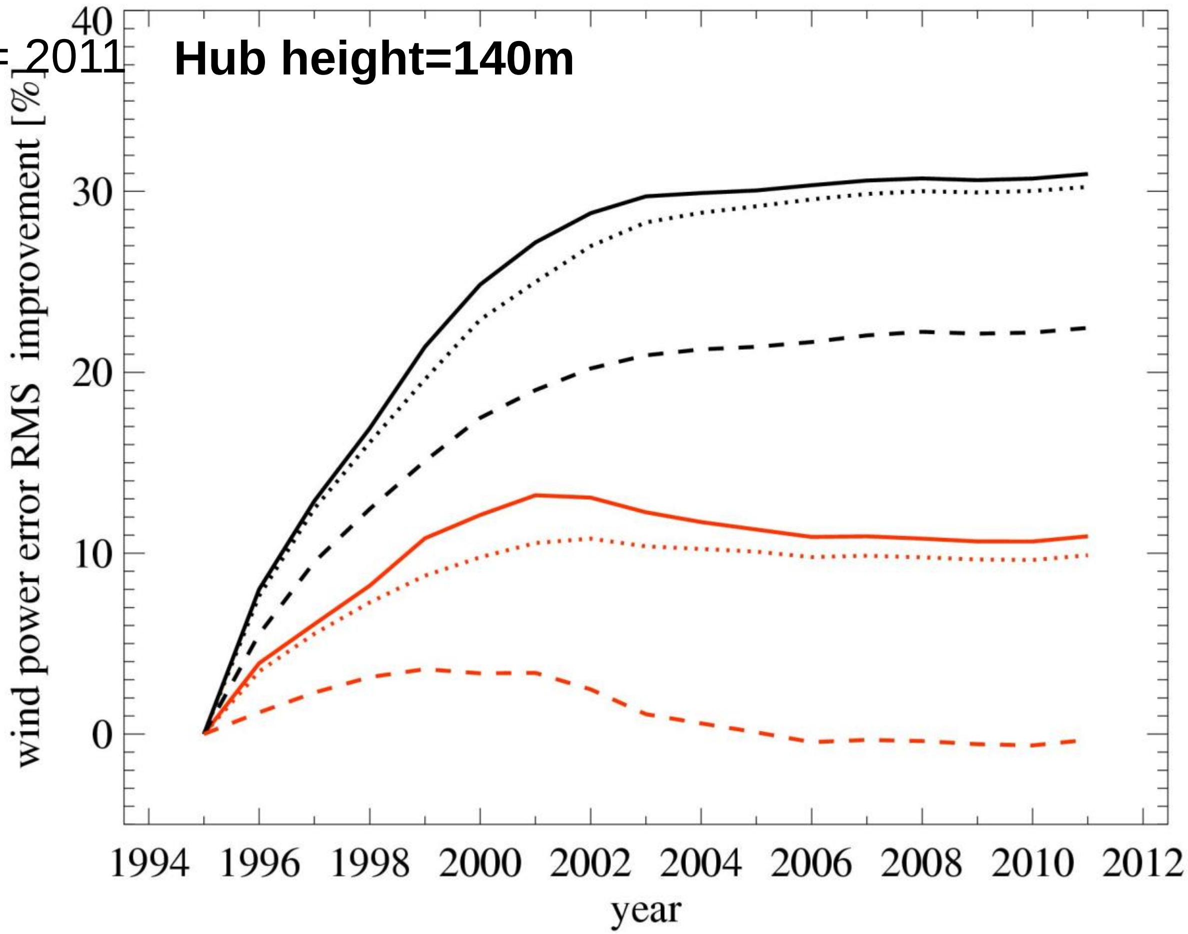






What is the perspecitve for future spatial forecast error smoothing, e.g. hub height of 140m?

- NWP year= 2011



normalized with rated power

normalized with prod. power

- Saturation level is a bit higher (~30 % for rated power)

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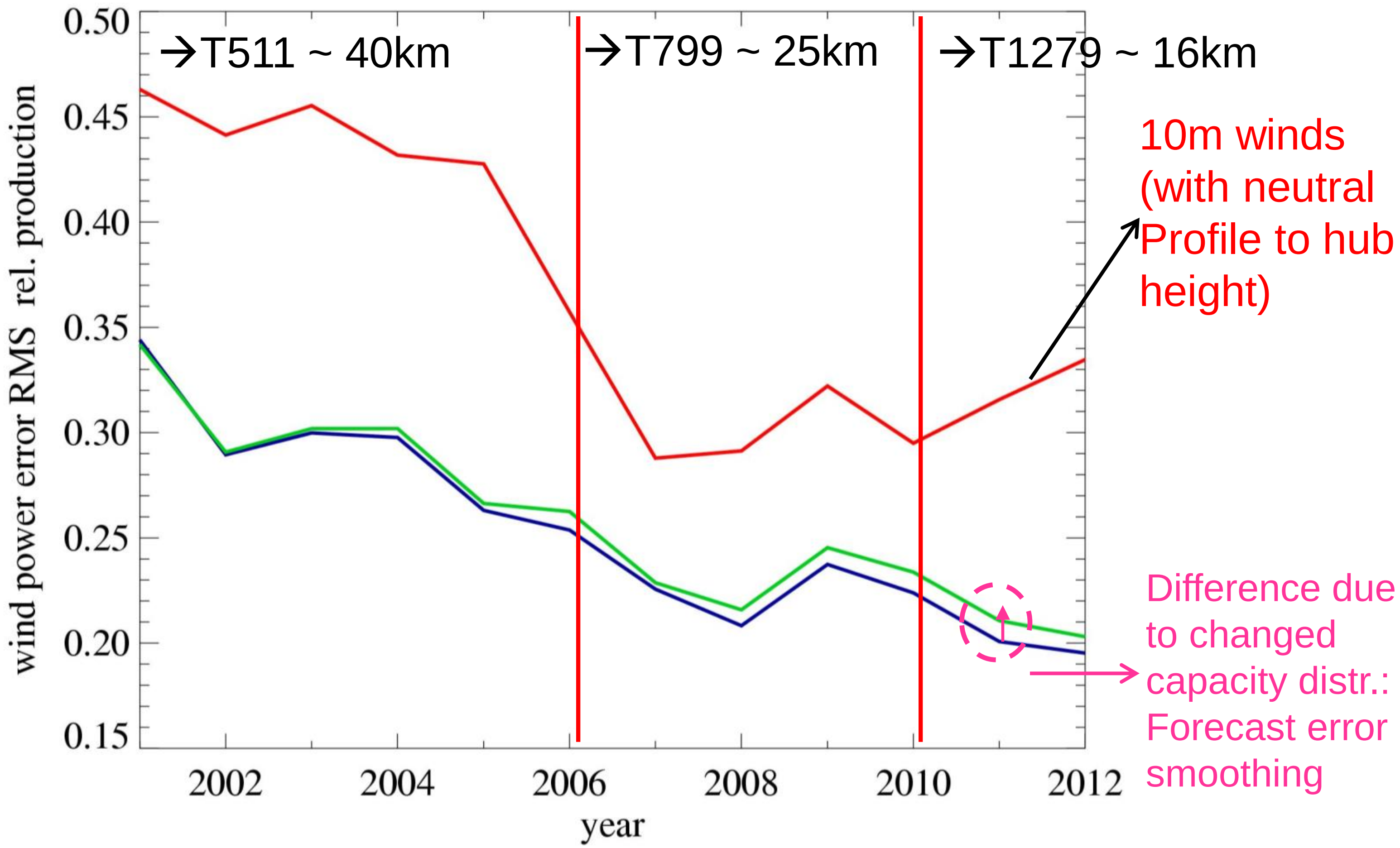
Simulated day-ahead forecast root mean square error (seperate clean NWP impact)

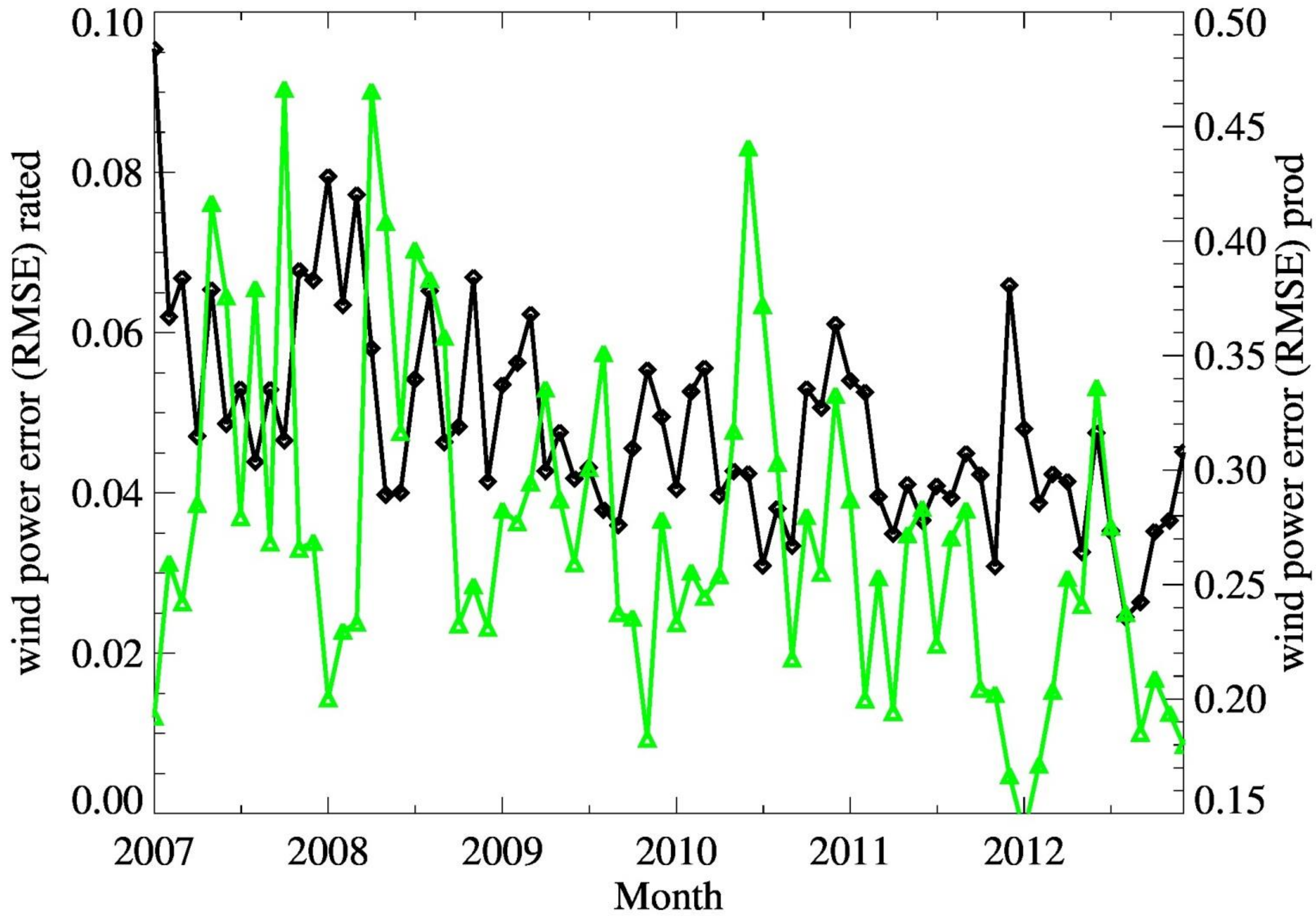


- 10 m winds are no option at all!

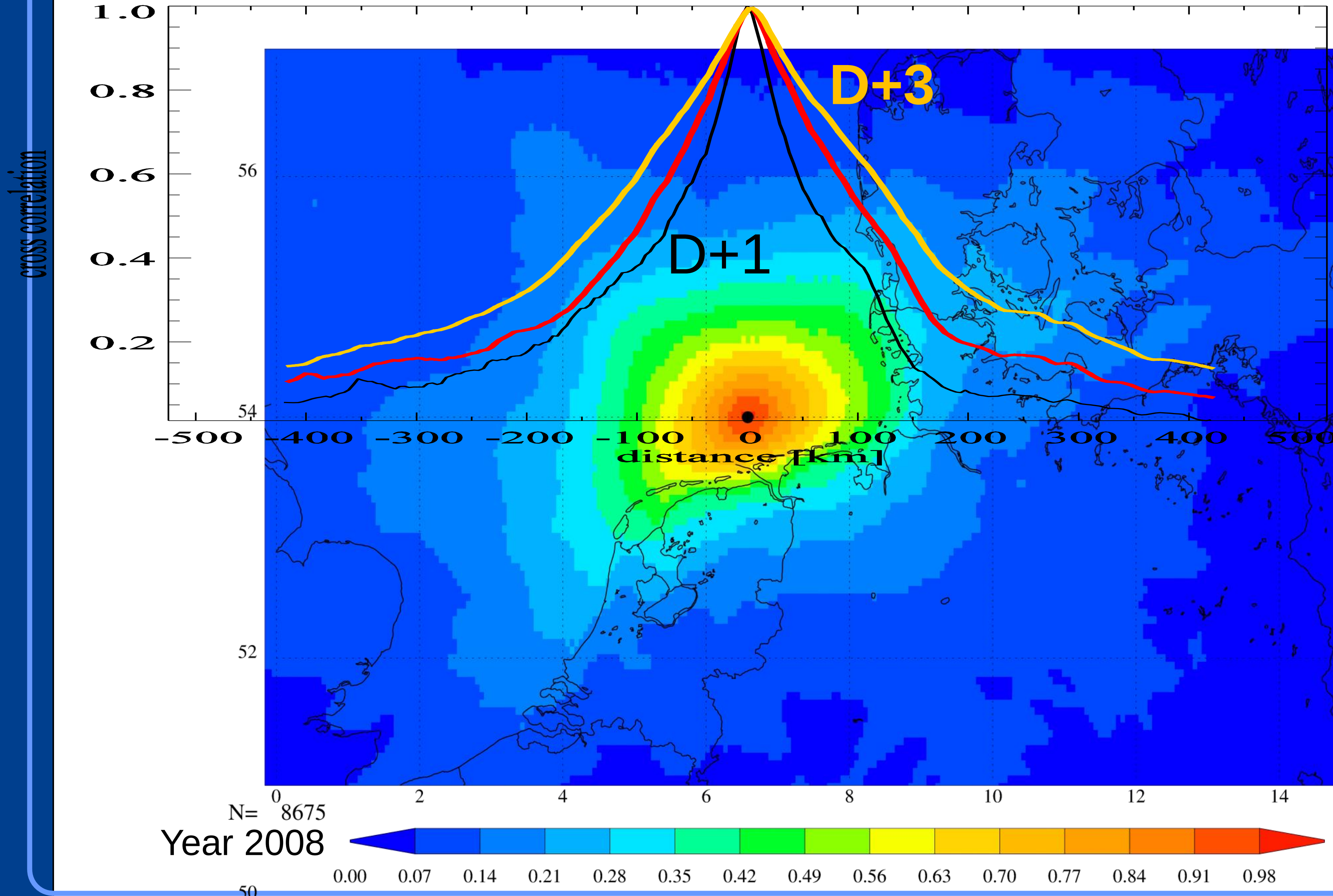
Published day-ahead wind power forecast error

Normalized with rated capacity

Normalized with prod. wind power



Cross-Correlation of forecast error (D+2) at FINO1



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Cross-Correlation of forecast error (D+2) at FINO1

➢ Reduction of RMSE