Forecastability of Wind Farm Power Production

DEWEK 2012

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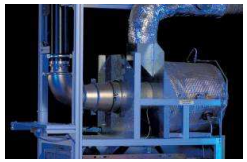


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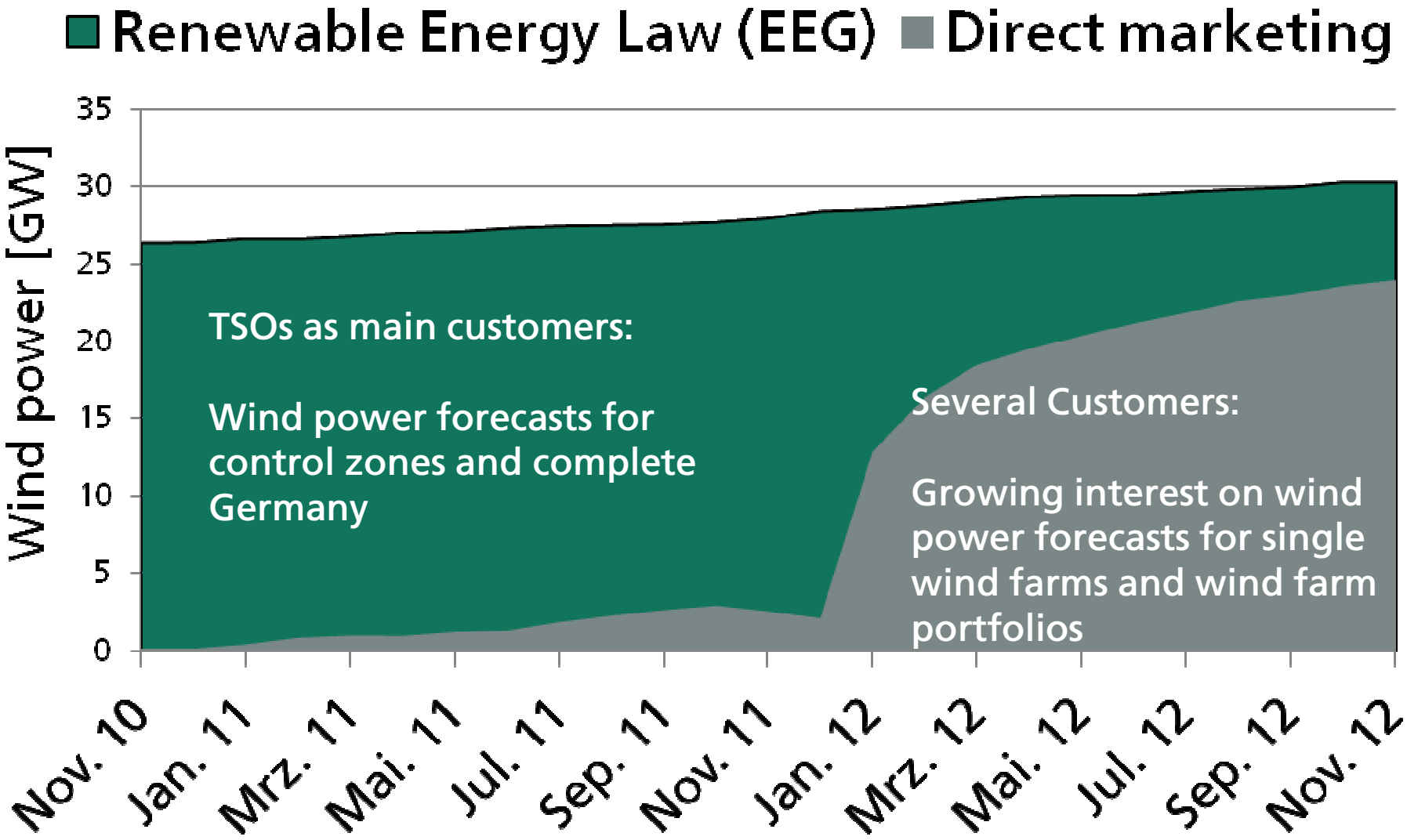
AGENDA

- Motivation & objective of this study
- Power and forecast data set
- First results & model development
- Model evaluation
- Summary

Motivation



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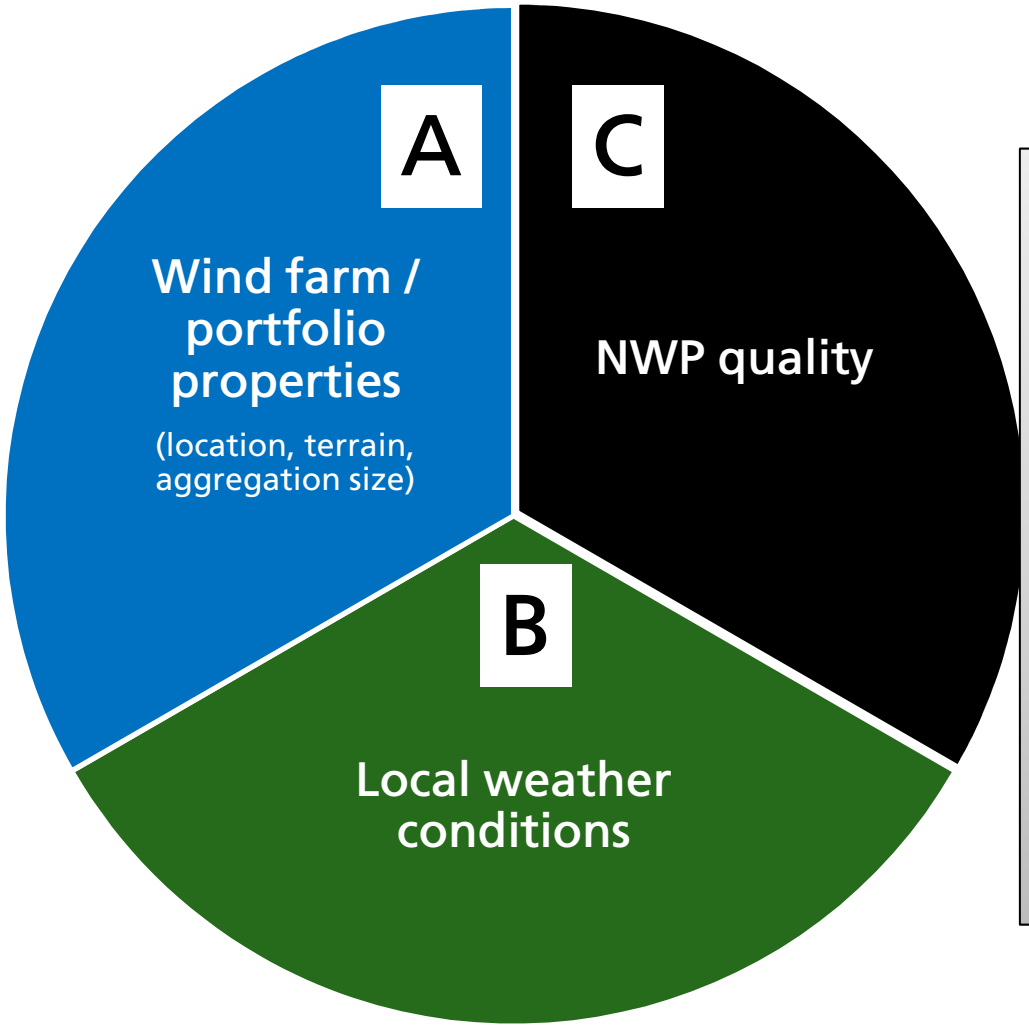
Motivation

Regarding the new customers new questions come up, like:

- What will be the forecast accuracy of my wind farm / wind farm portfolio ?
- How to conclude if a forecast is of high/poor quality ?
- What is to consider when pooling wind farms with respect to forecast quality ?

Objective of this study

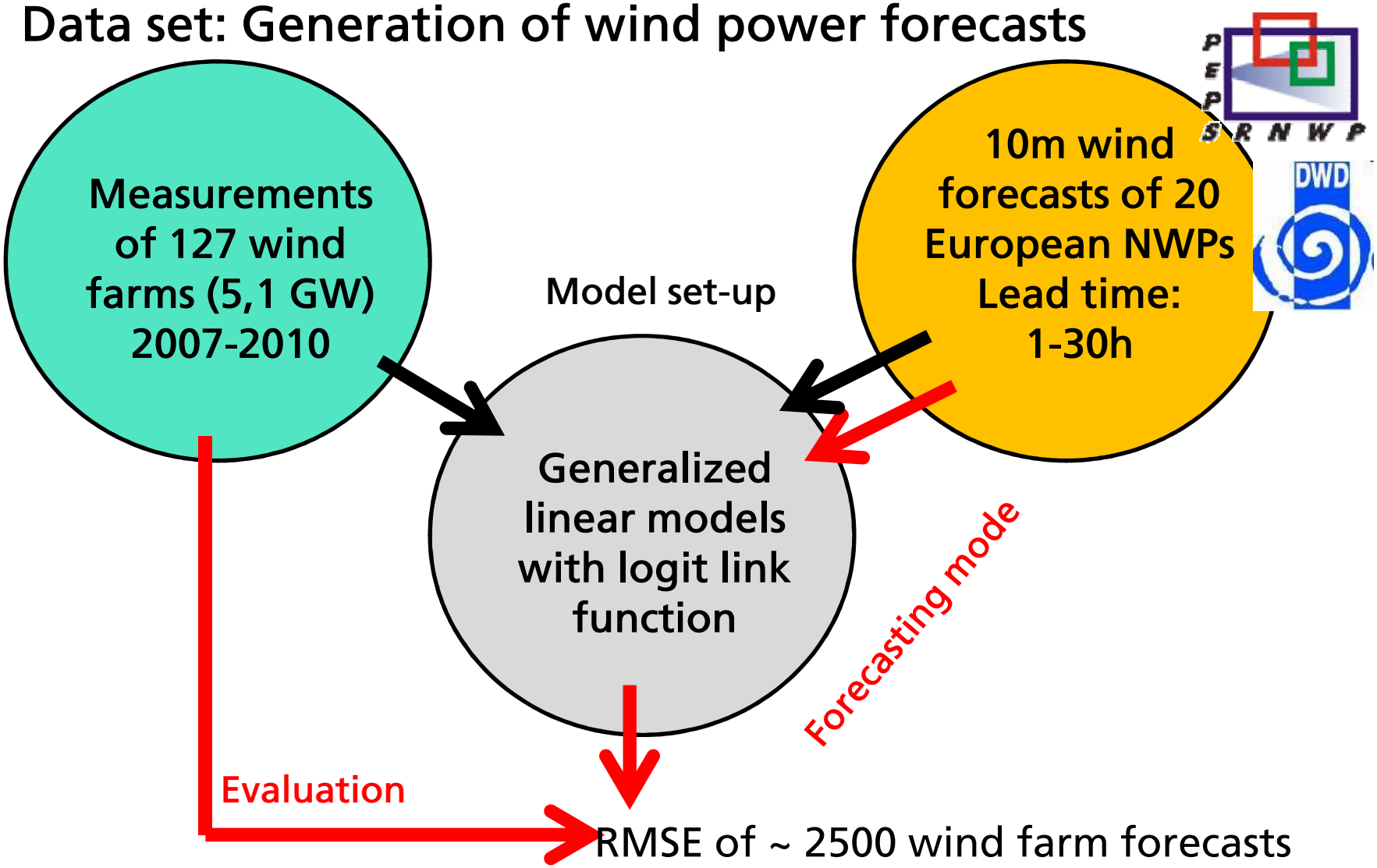


1) Investigation of the main drivers of forecast quality

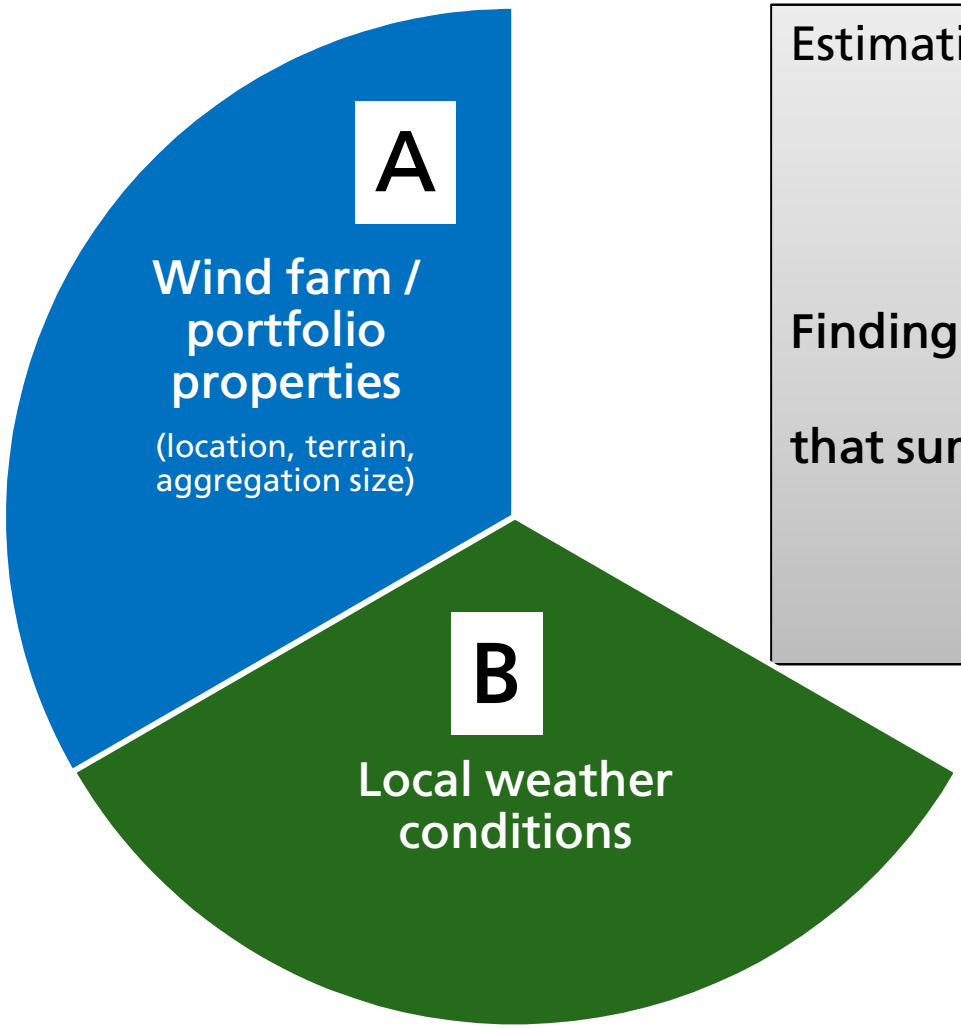
2) Estimation of an equation:
Forecast Quality = fct(A,B,C)

… based on a large-scale onshore wind power forecast analysis.

Data set: Generation of wind power forecasts



Results → Model development I:



Estimation of an equation:

RMSE= fct(A,B)

Finding a measurable parameter X,

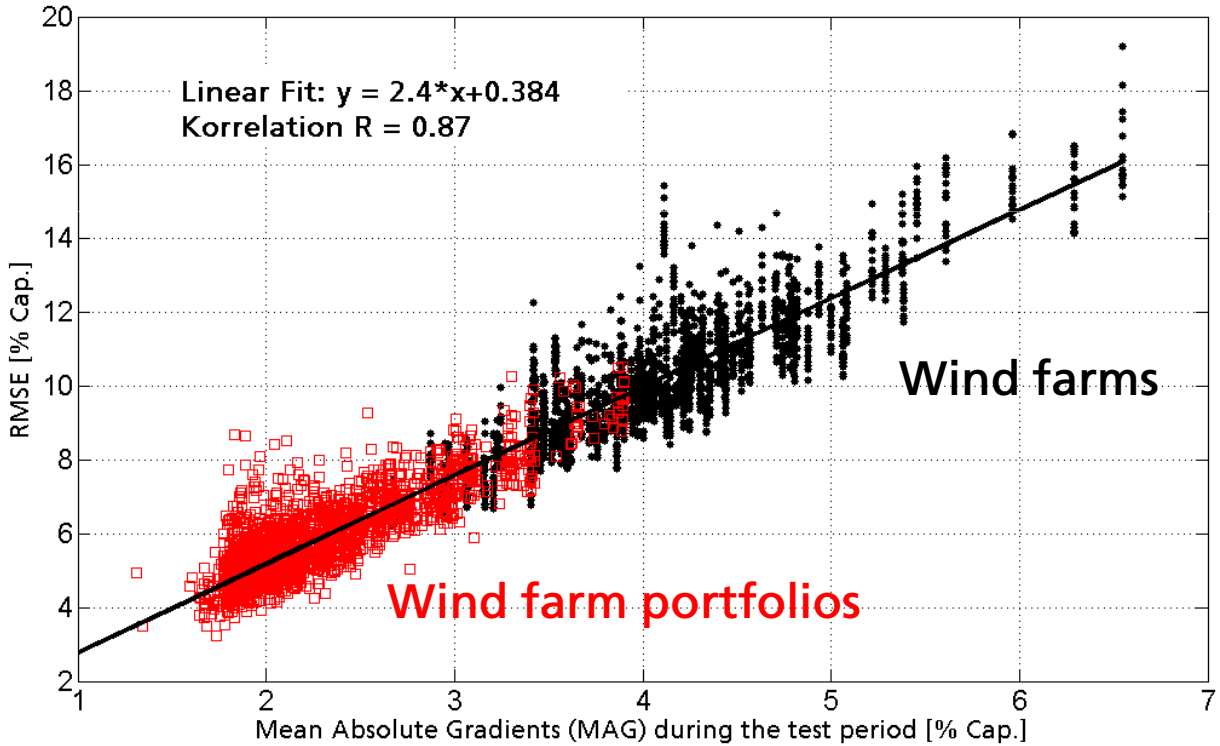
that summarizes the impacts of A and B

Power Fluctuations

Results: Forecast Quality vs Power Fluctuations

…in terms of the **Mean Absolute Gradients (MAG)** of the measured 1h-power time series

$$\overline{|P(t)-P(t+1h)|} \quad \forall t$$



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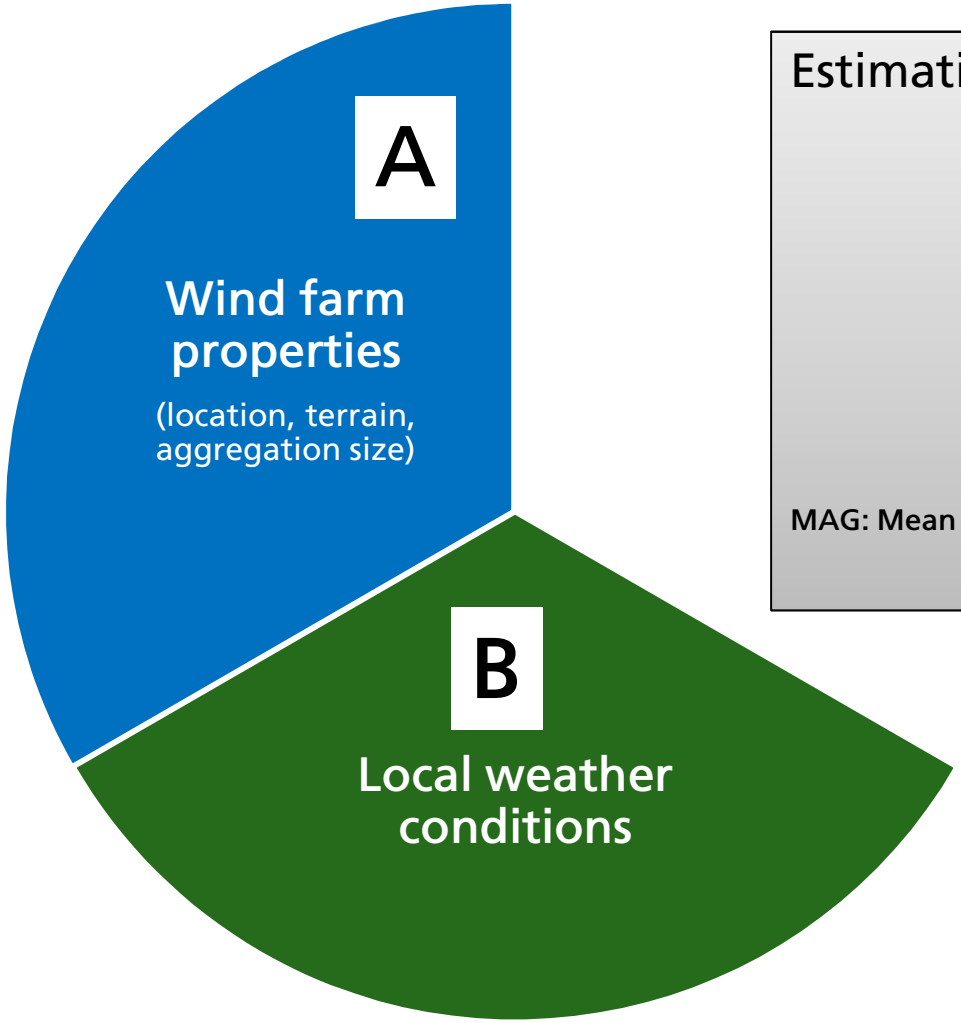
Results → Model development I:



Estimation of an equation:

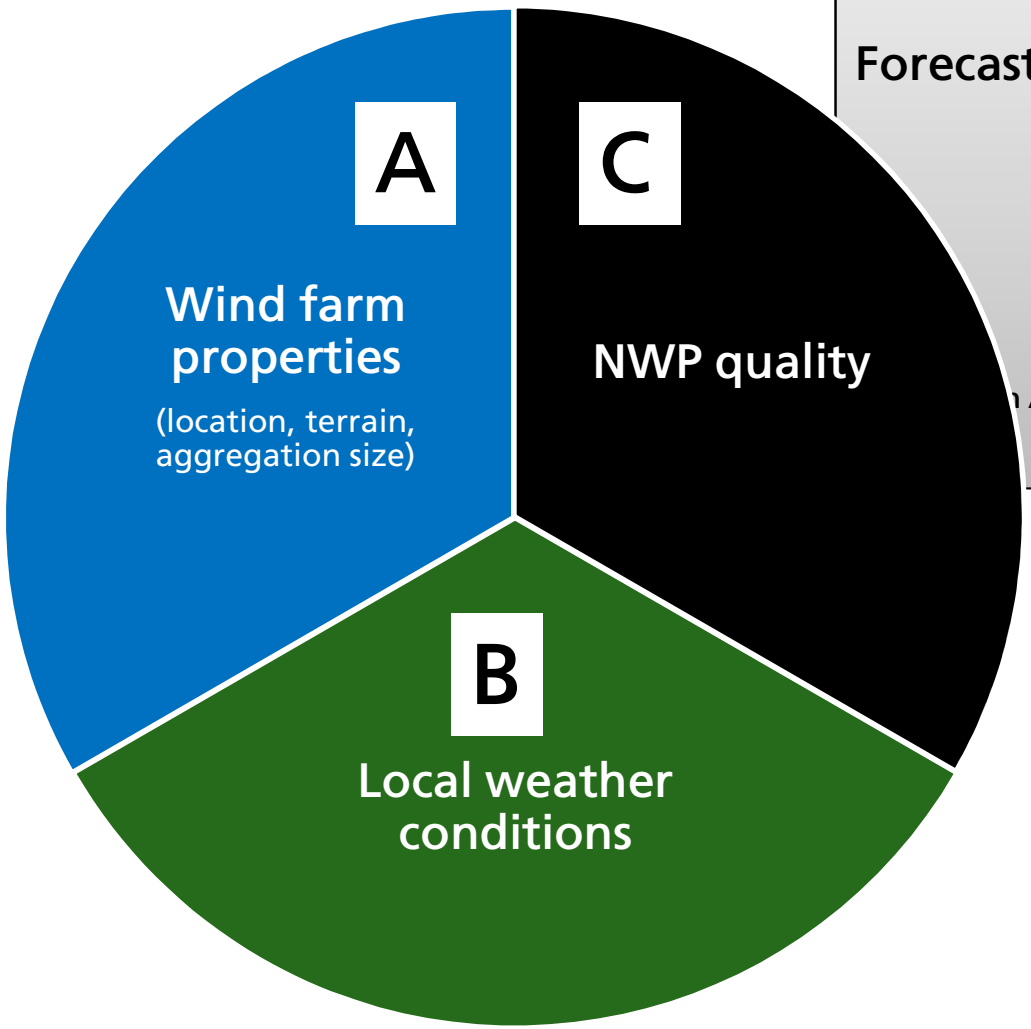
$$RMSE = fct(A,B)$$

$$\Downarrow$$

$$RMSE = 2.4 * MAG + 0.384$$

MAG: Mean Absolute 1h-Gradients of the measured power time series

Objective of this study:



Estimation of an equation:

Forecast Quality = fct(A,B)

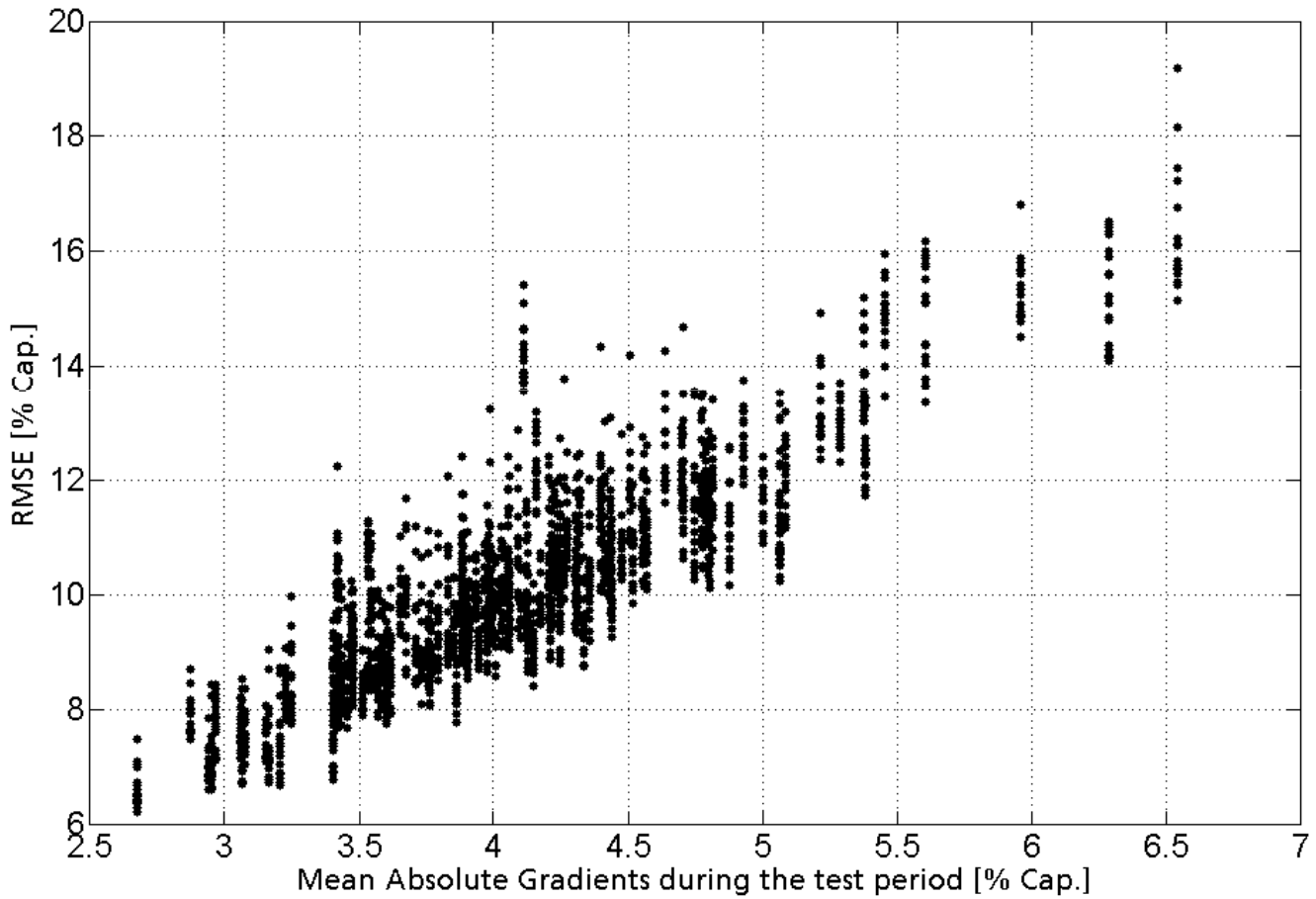
RMSE = 2.4 * MAG + 0.384

Absolute 1h-Gradients of the measured power time series

And what is the impact of the numerical weather prediction (NWP)?

Forecast Quality = fct(A,B,C)

Results: Forecast Quality vs Power Fluctuations



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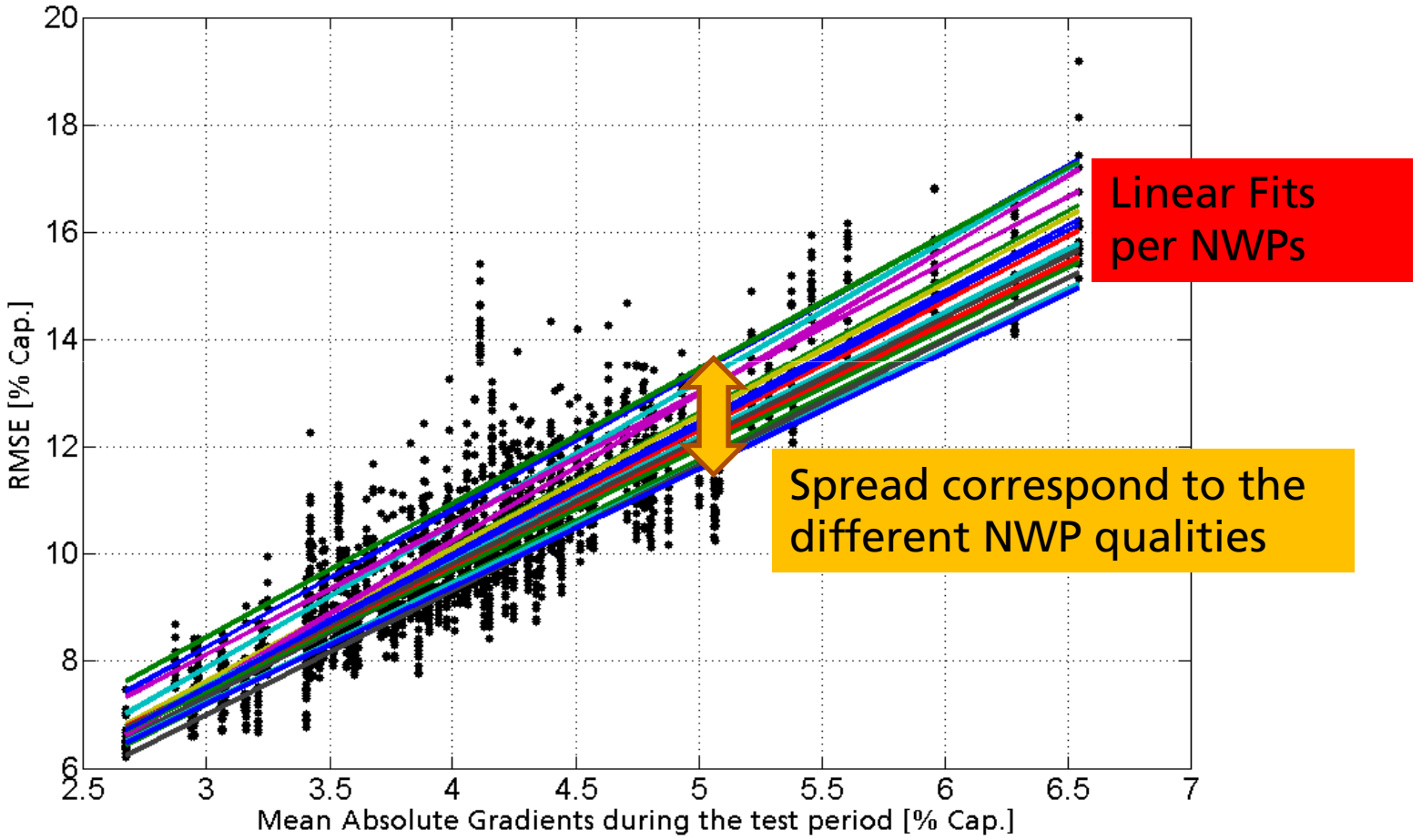
Results: Forecast Quality vs Power Fluctuations



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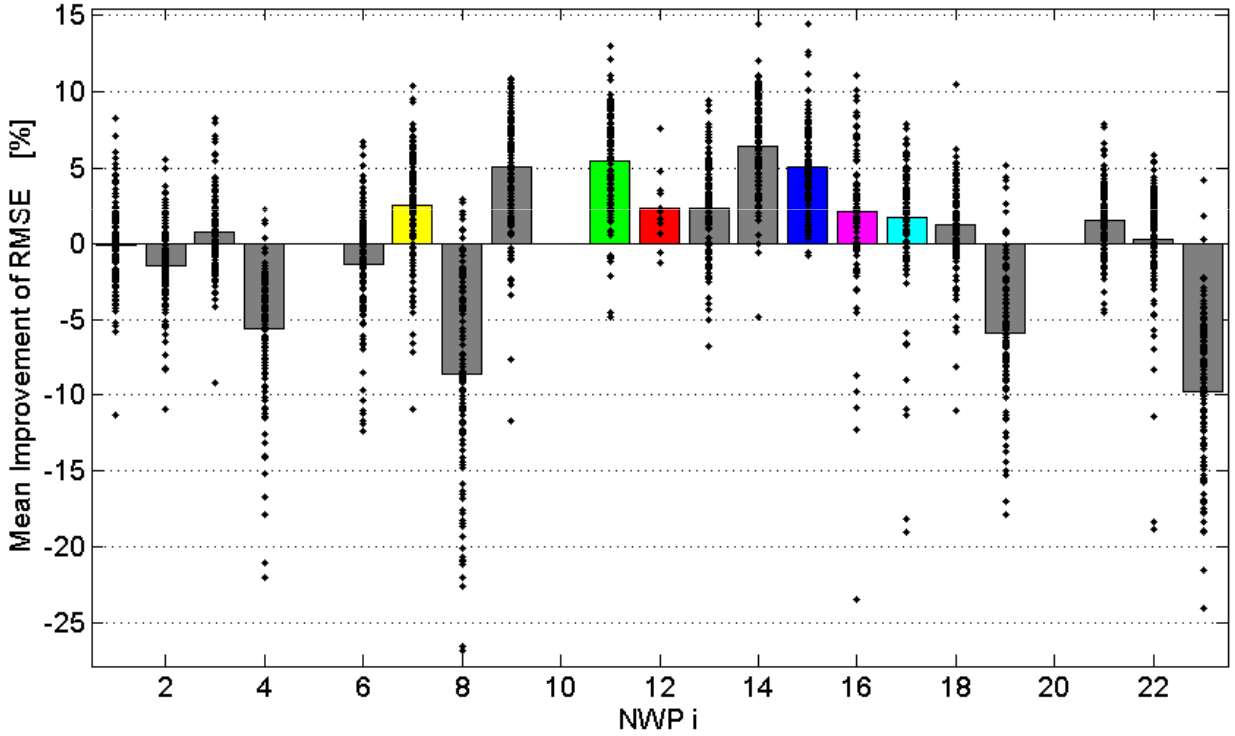
Results: Mean improvement of the RMSE using NWP i compared to the average RMSE of all NWP

$$IMP_i = \frac{\overline{rmse_{WP}} - rmse_{WPi}}{\overline{rmse_{WP}}} [\%]$$



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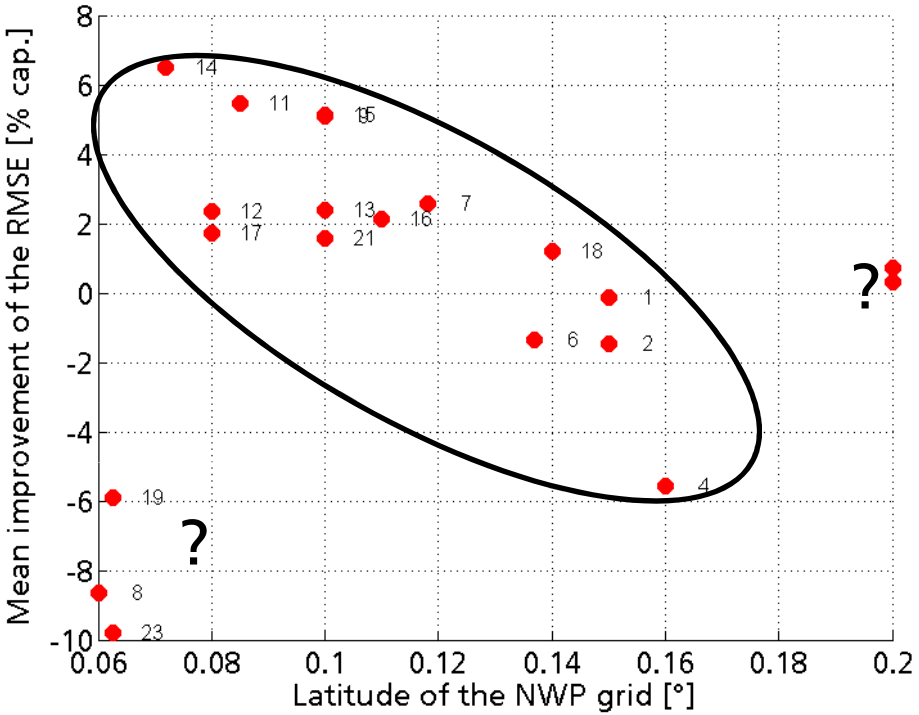
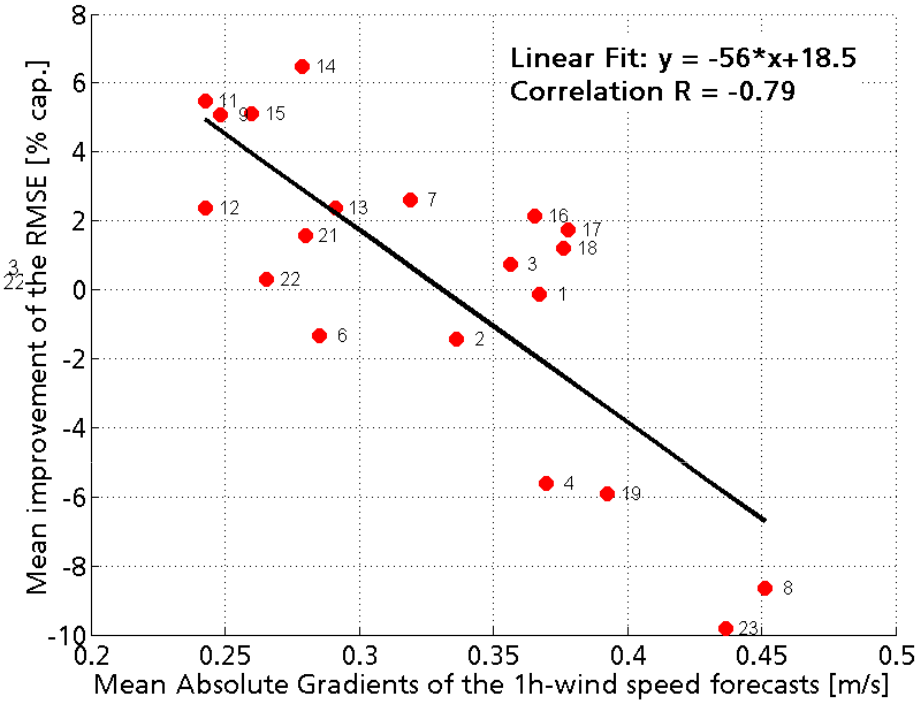
Results: Wind Power Forecast Quality depending on NWP characteristics





Not the NWP grid resolution but the wind speed fluctuations show the most significant relation to the wind power forecast quality !!

Improvement of RMSE = -56*MAGws+18.5

With MAGws: Mean Absolute 1h-Gradients of the wind speed forecasts

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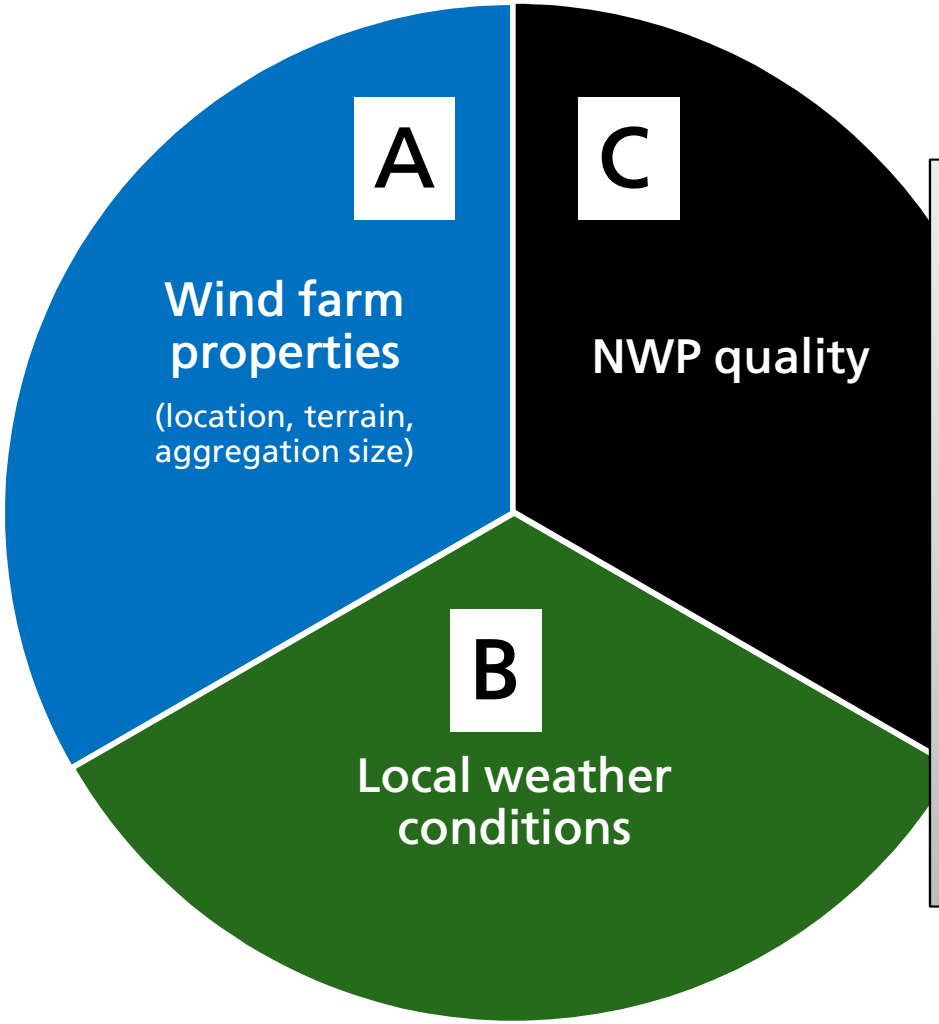
Results → Model development II



Estimation of an equation:

Forecast Quality = fct(A,B, C)

RMSE = (2.4 * MAG + 0.384)(100-Imp)/100

With Imp = -56*MAGws +18.5

MAG: Mean Absolute 1h-Gradients of the measured power time series
MAGws: Mean Absolute 1h-Gradients of the wind speed forecasts

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Model evaluation:
Forecasting the RMSE of 50 wind farms using different NWP models

Approaches:

1. $RMSE_{WPi}$ = Average RMSE of all analyzed wind power forecasts

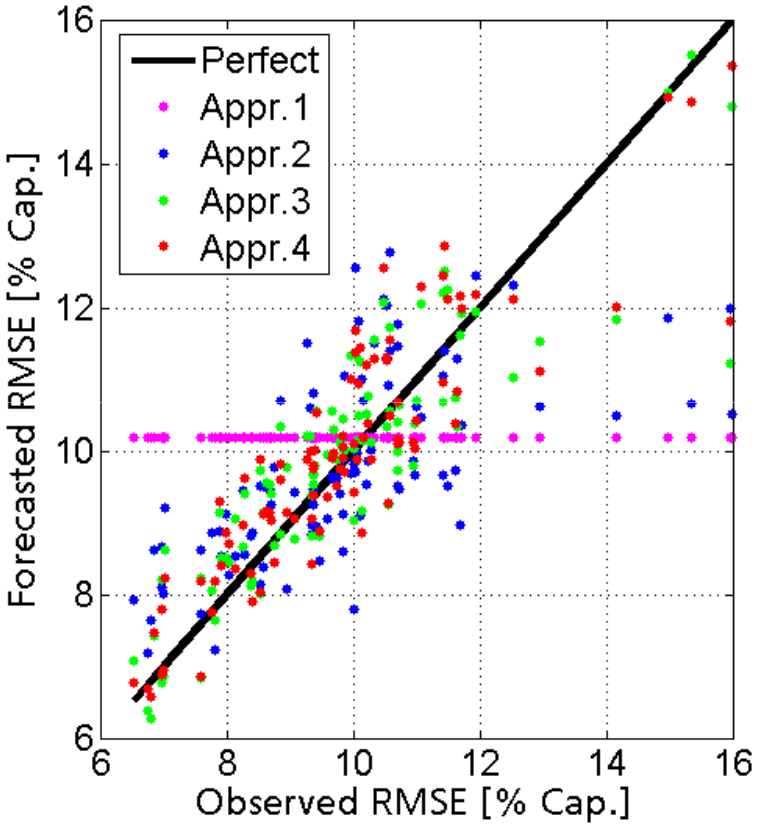
2. $RMSE_{WPi} = 0.27 * \mathbf{CapacityFactor}_{WPi} + 4.78$

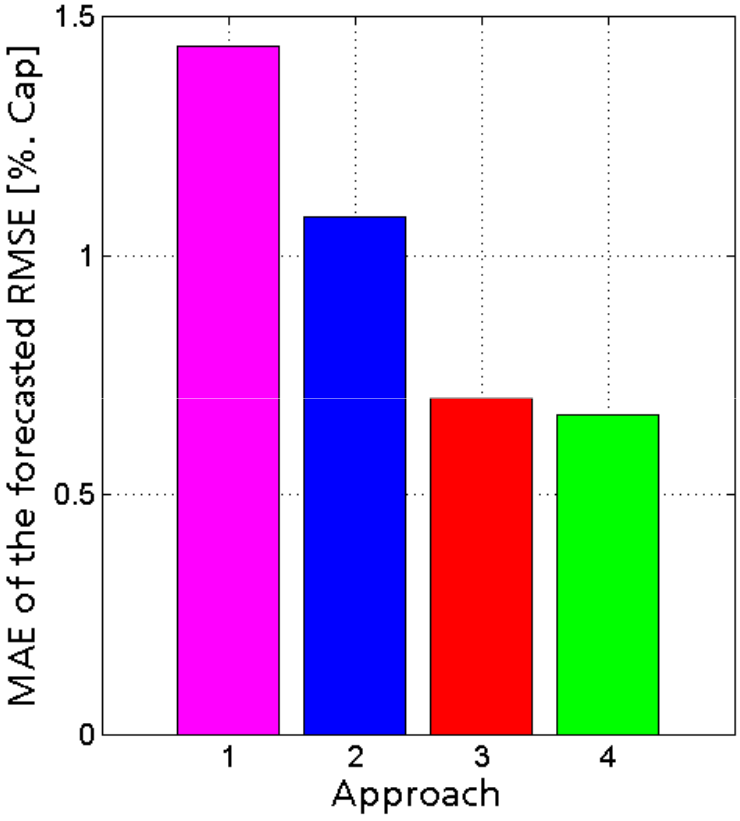
3. $RMSE_{WPi} = 2.4 * \mathbf{MAG}_{WPi} + 0.384$

4. $RMSE_{WPi} = (2.4 * \mathbf{MAG}_{WPi} + 0.384) * (100 - Imp)/100$
   with $IMP = -56 * \mathbf{MAGws}(i) + 18.5$

Model evaluation:

Forecasting the RMSE of 50 wind farms using different NWP models





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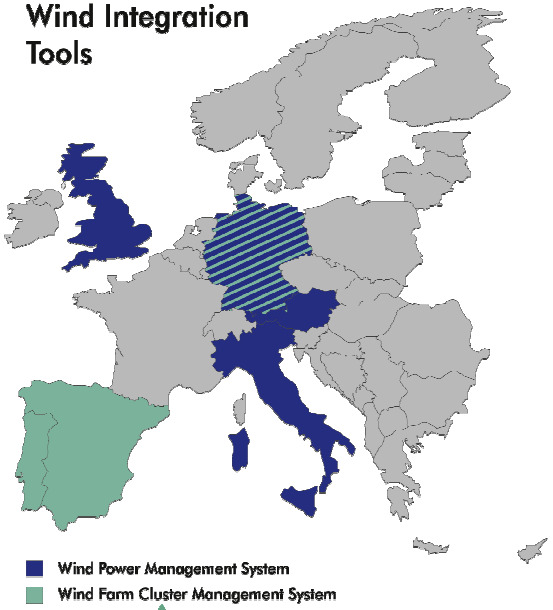
Summary:

→Linear dependency between the RMSE of wind farm/portfolio power forecasts and the mean absolute 1h-gradients of the power time series

→ „Linear“ dependency between the quality of an NWP re wind power forecast quality and the mean absolute 1h-gradients of the wind speed forecasts

An equation has been estimated that allows to forecast the RMSE of a wind park/portfolio power forecast with a lead time of 1-30h



Acknowledgement: The study is based on results obtained during the research activities for the IWES Wind Power Management System (WPMS) operated by

50hertz amprion TenneT Taking power further

Thank you for your attention

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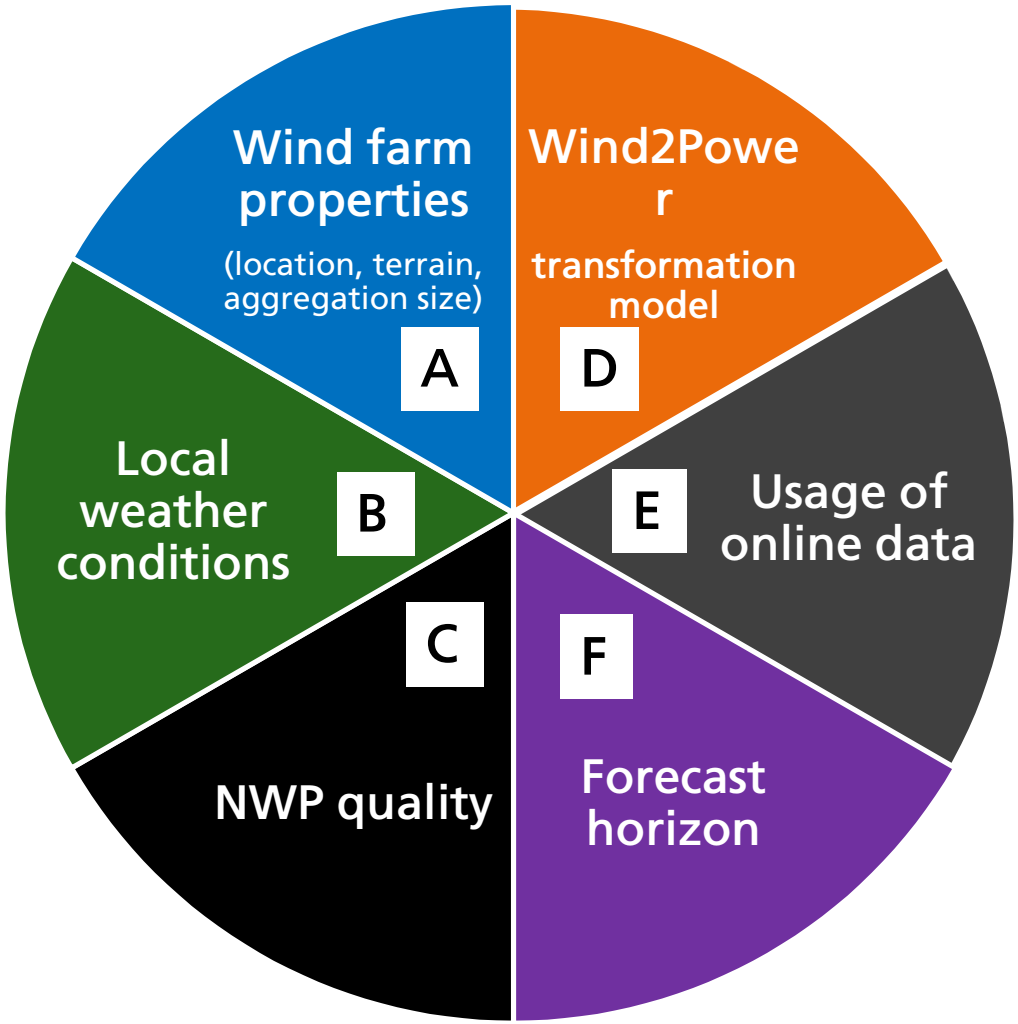
BACKUP

Motivation:
Main Drivers of Wind Farm Power Forecast Quality



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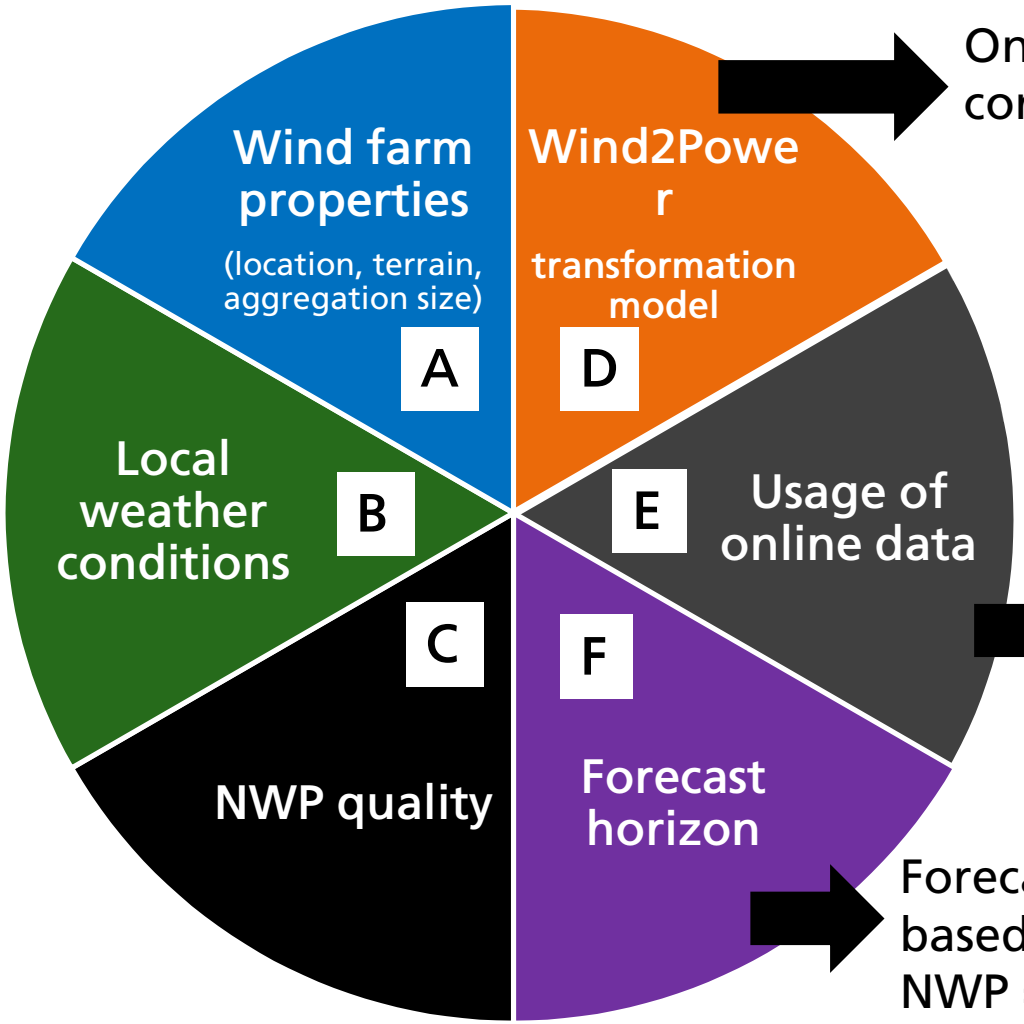
Motivation:
Main Drivers of Wind Farm Power Forecast Quality



Only one approach considered !!

No online data considered !!

Forecast horizon based on available NWP = 1-30h

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Former Studies: Terrain complexity

Wind farm properties

(location, terrain, aggregation size)

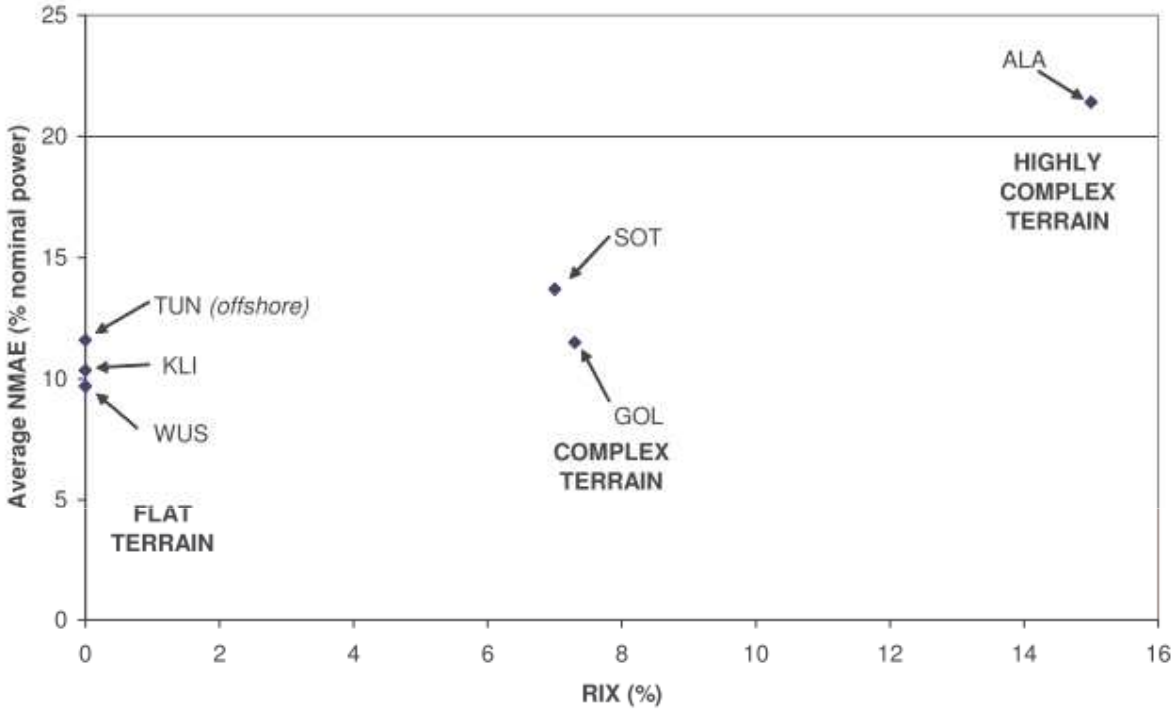


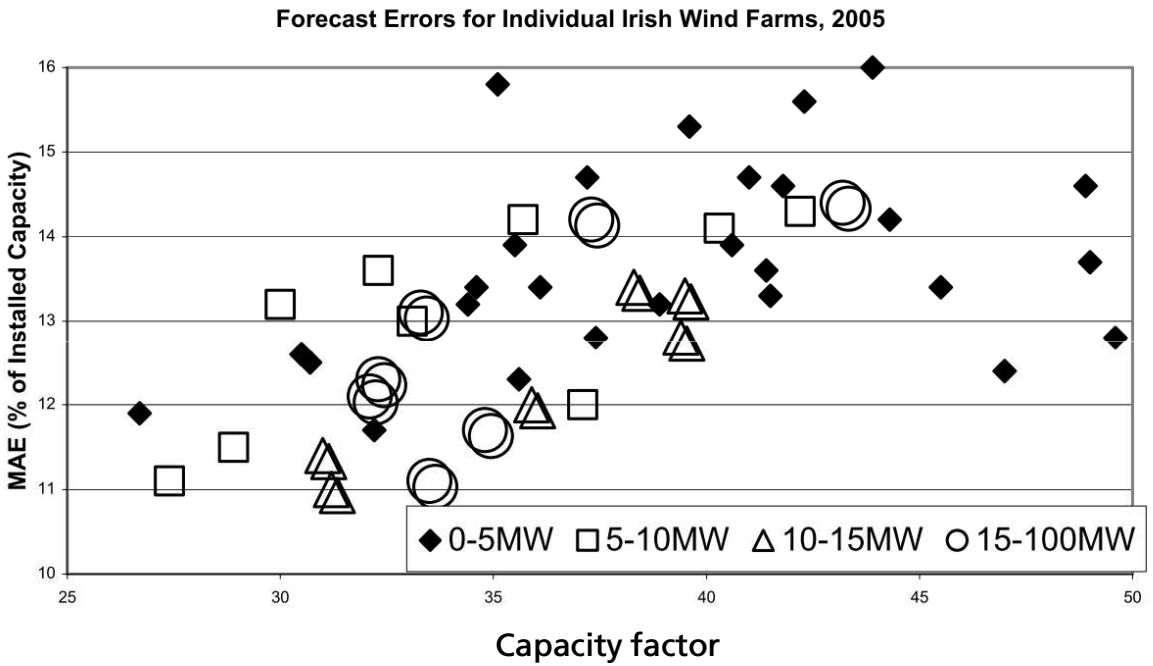
Figure 5: *Average NMAE for 12 hours forecast horizon vs RIX at each test case. Qualitative comparison.*

Source: Martí et al.: „Evaluation of Advanced Wind Power Forecasting Models – Results of the Anemos Project", in Proceedings European Wind Energy Conference, EWEC 2006, Athènes, Greece, 2006

Former Studies: Local wind conditions

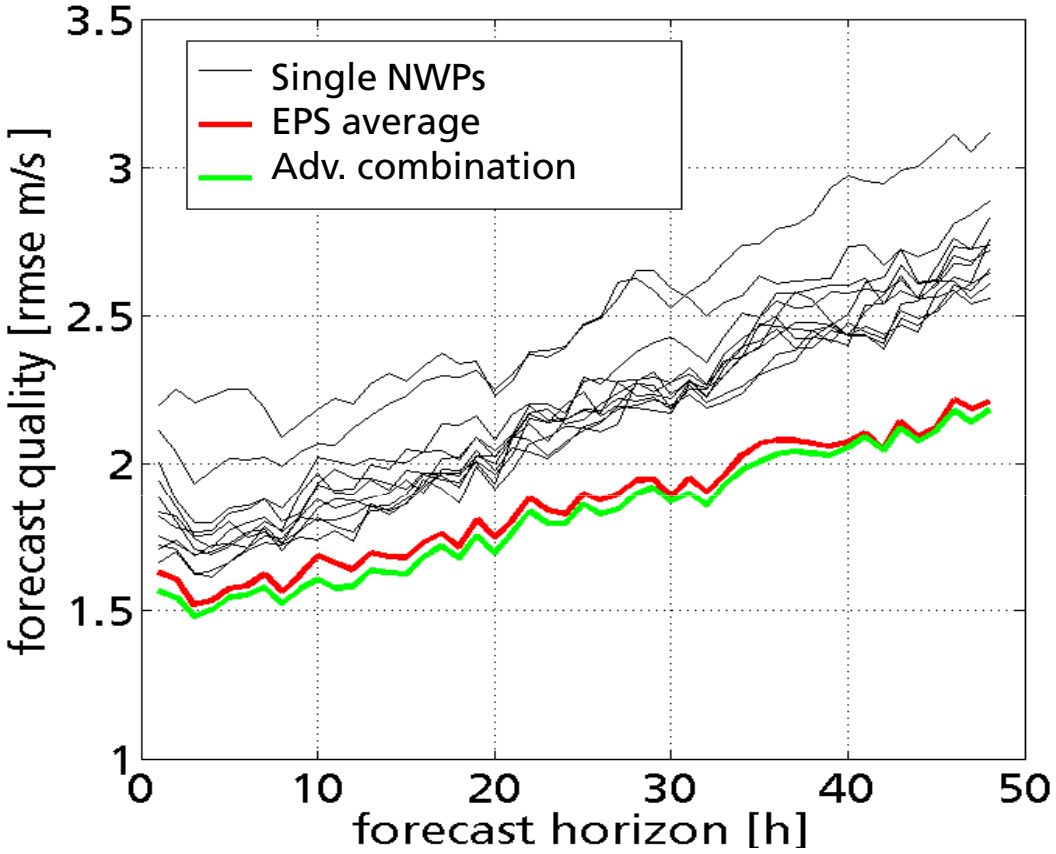
Local weather conditions

Fig. 3 - Forecast Errors Normalised to Installed Capacity



Source: Lang et al.: „Forecasting Total Wind Power Generation on the Republic of Ireland Grid with a Multi-Scheme Ensemble Prediction System“, in Proceedings Global Windpower 2006, Adelaide, Australia, 2006

Former Studies: NWP selection and combination



NWP quality

Source: Dobschinski et al.: "How to construct a reliable ensemble forecast?", 0th German Wind Energy Conference (DEWEK) 2010, Bremen, Germany, 2010

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Former Studies: Wind2Power Transformation Model Selection

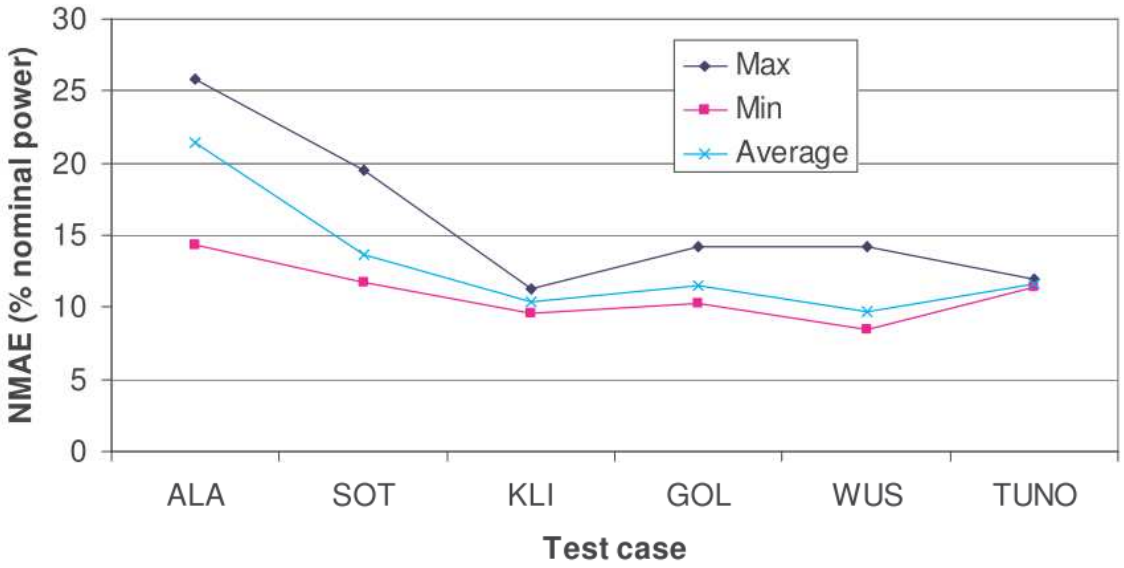
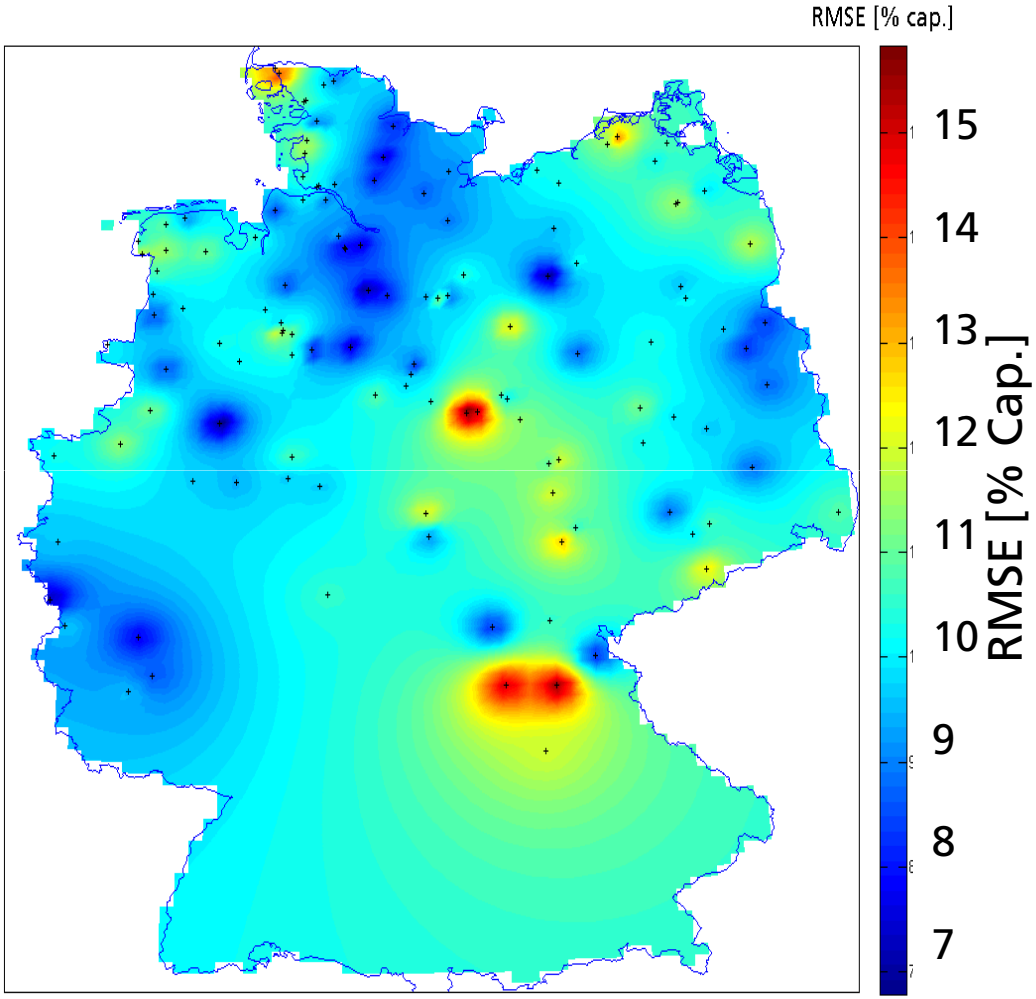


Figure 6: *Average NMAE for 12 hours forecast horizon vs RIX at each test case ordered by RIX value. Qualitative comparison.*

Wind2Power transformation model

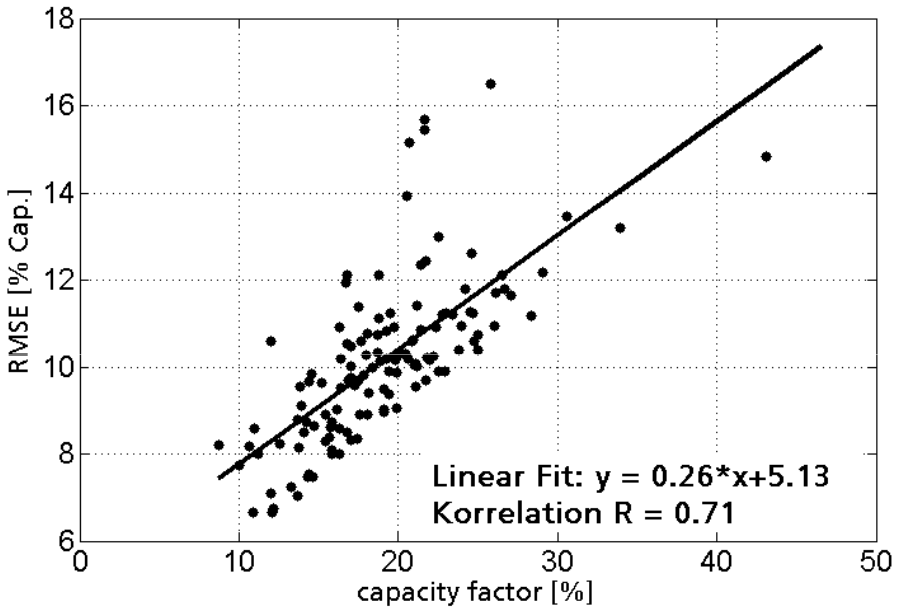
Source: Martí et al.: „Evaluation of Advanced Wind Power Forecasting Models – Results of the Anemos Project", in Proceedings European Wind Energy Conference, EWEC 2006, Athènes, Greece, 2006

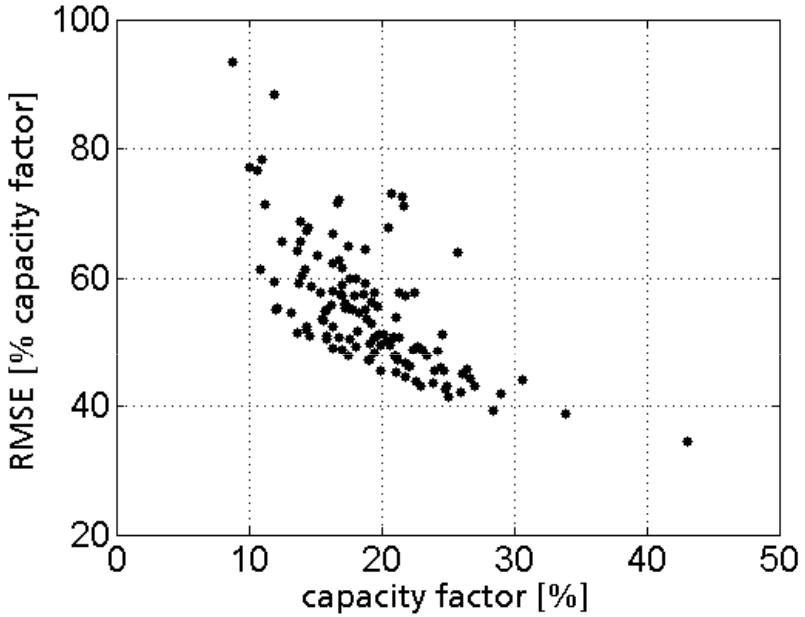
Results: Terrain complexity (using power forecasts based on NWP 1)



No clear relation between forecast quality and location!

Results: Local wind conditions : Capacity Factor = mean generated power





Clear correlations!

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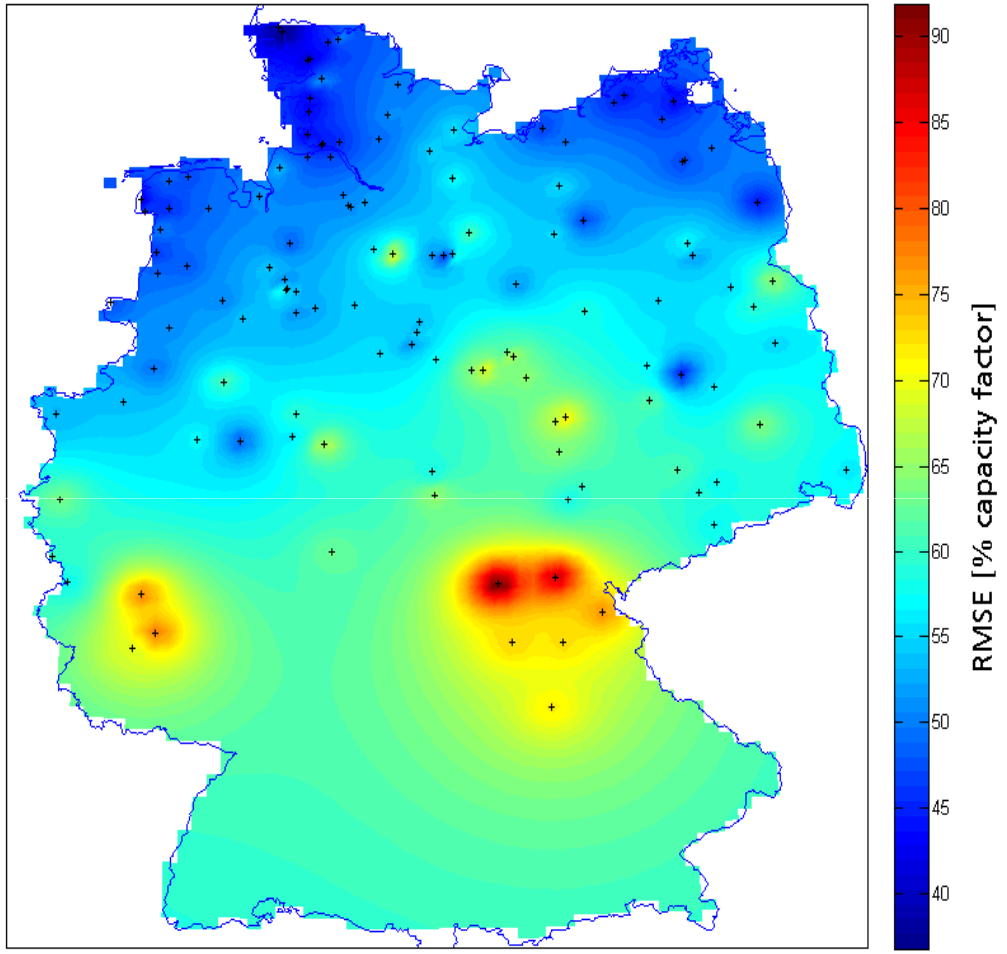
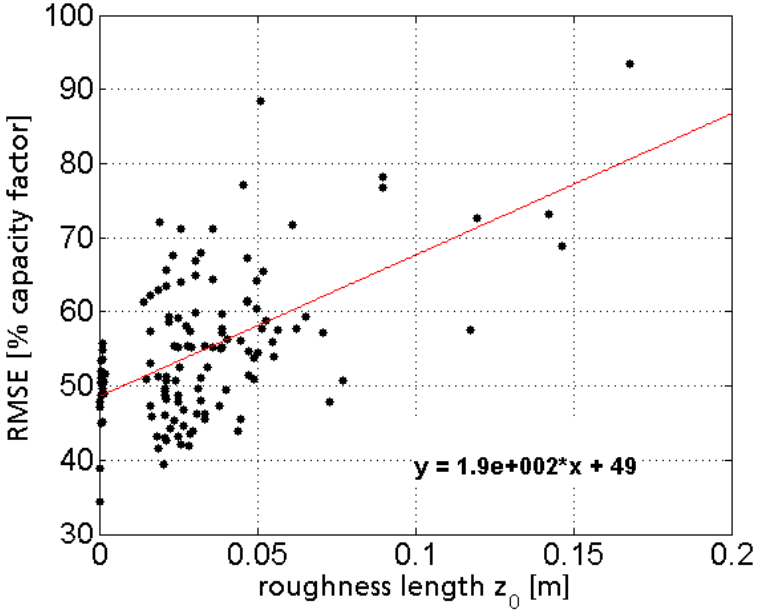
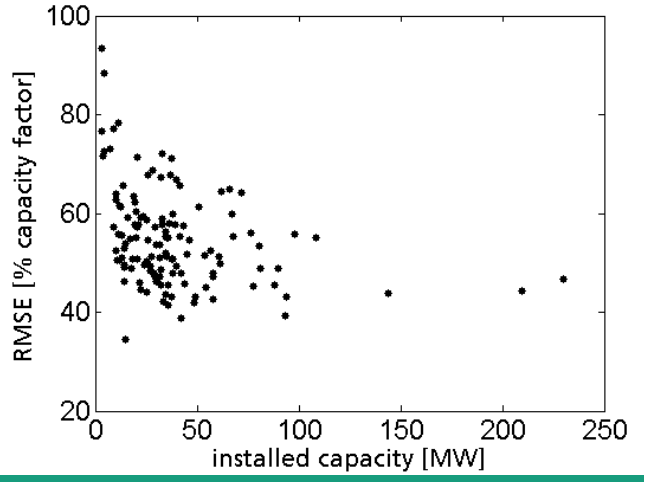
Results: RMSE in % of the capacity factor







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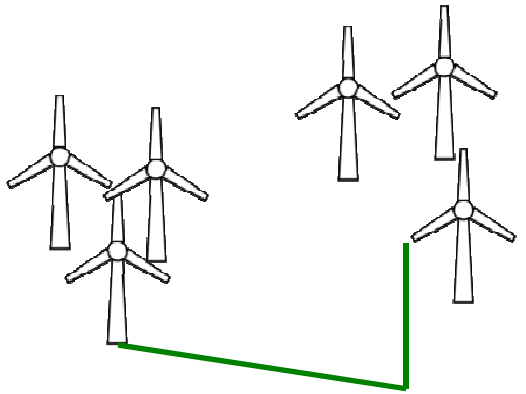
Question:

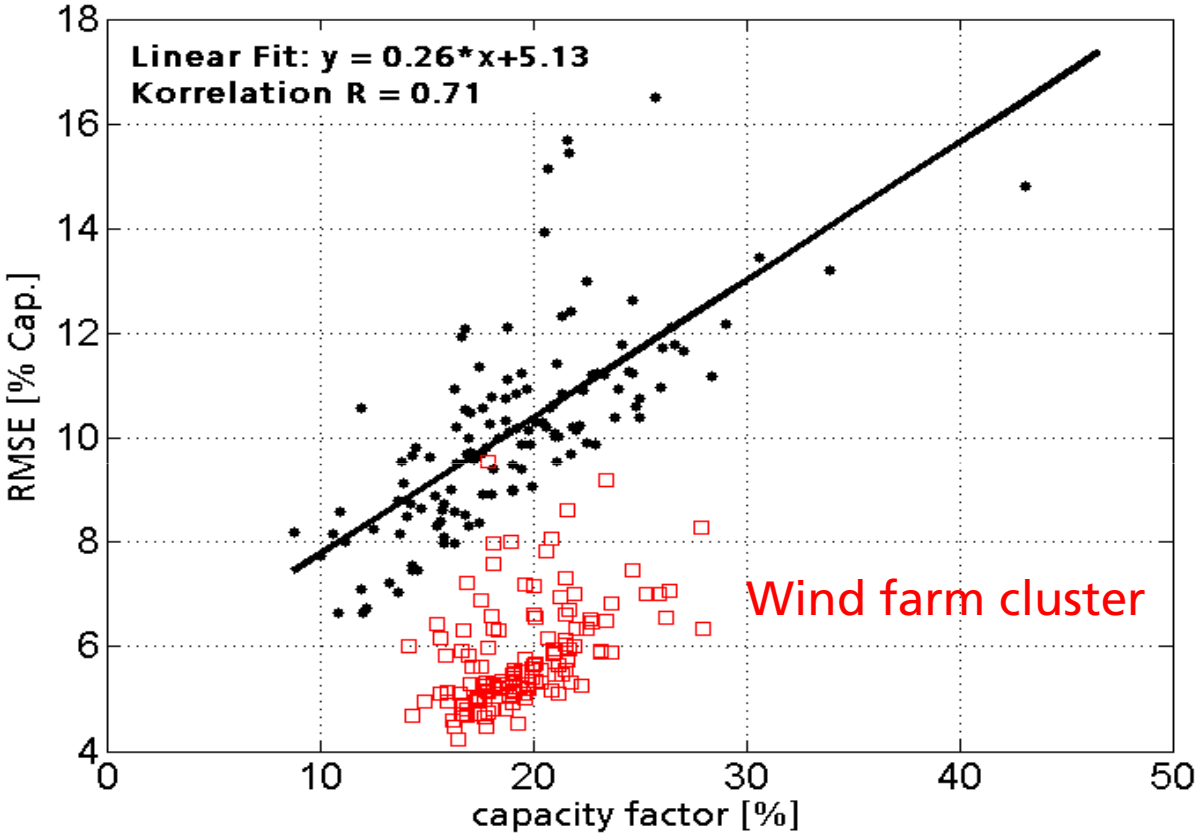


And what is with wind farm clusters ?

Is the dependency between forecast quality and capacity factor also observable ?

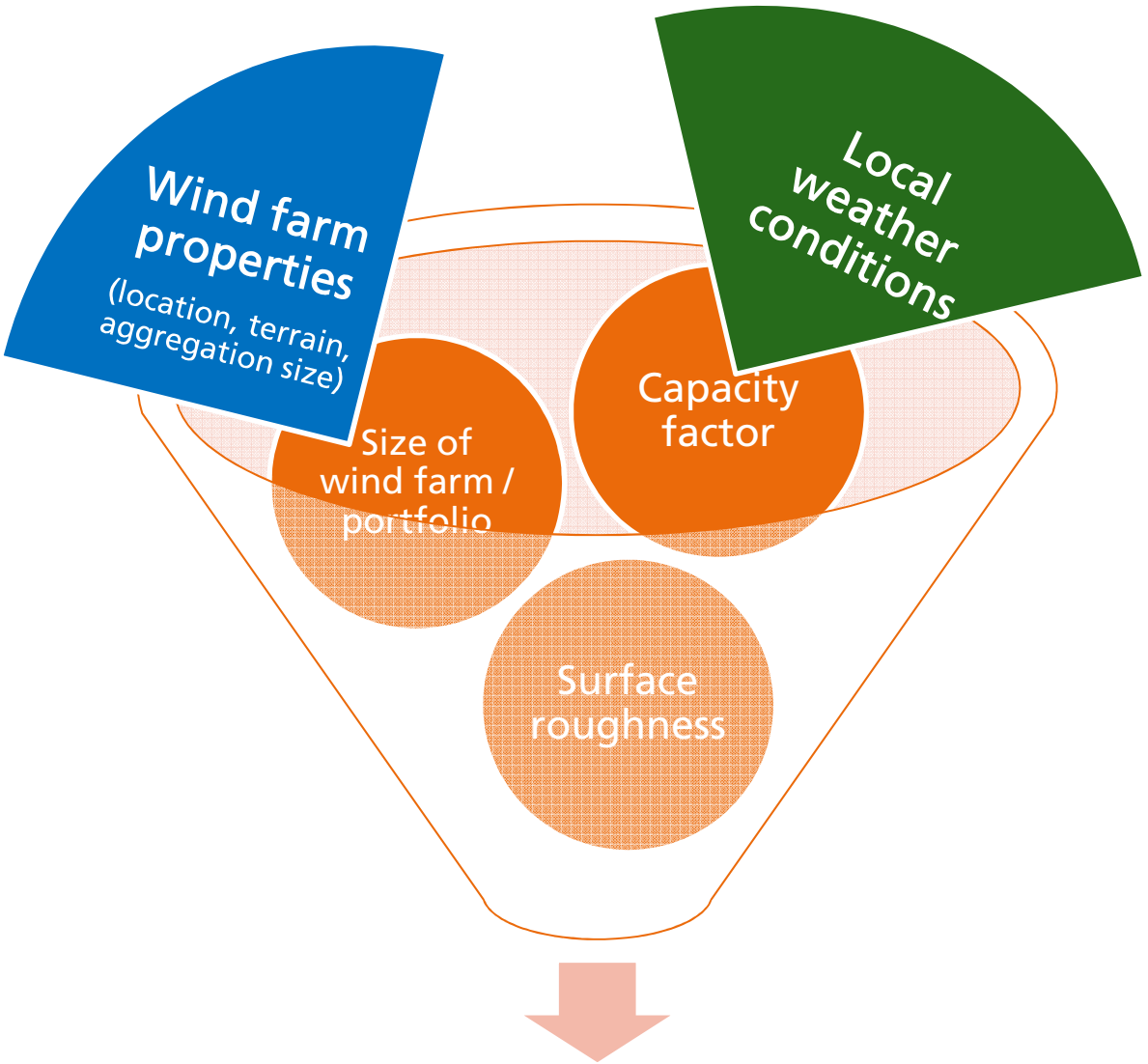
Approach: Random clustering of the 127 wind farms to clusters including 2- 12 wind farms.

Results: Wind farm cluster



Theory not valid for clusters !!

Idea:



All outer impact parameters results in the final power fluctuations

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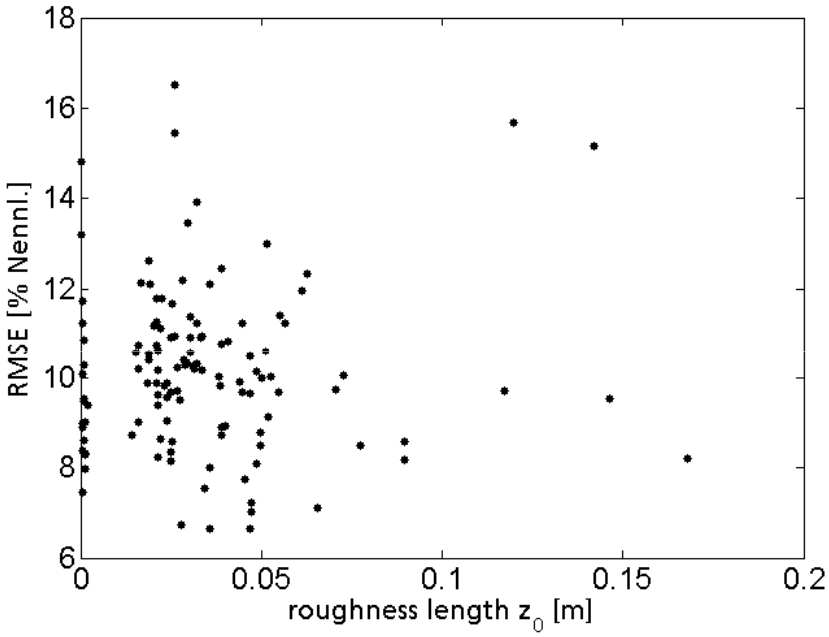
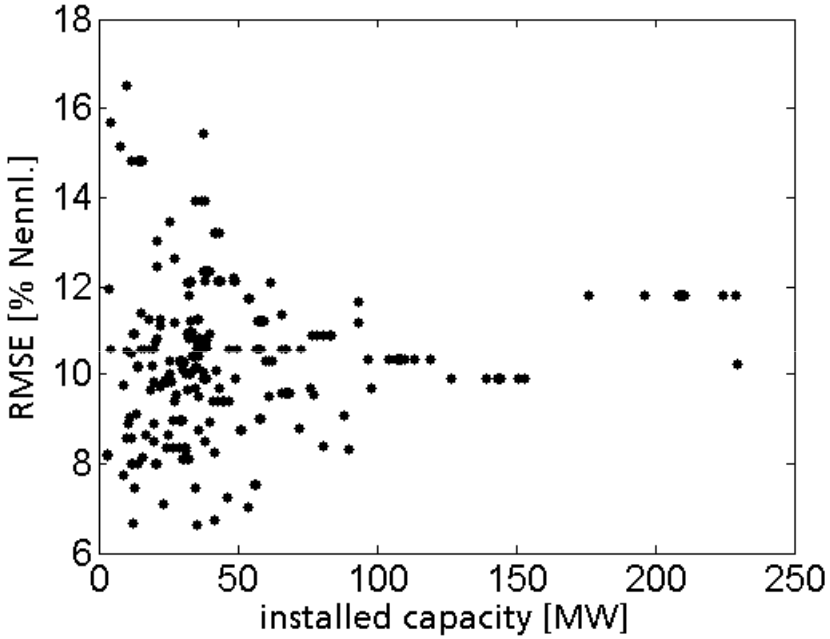
Results: Terrain complexity & wind farm size





No correlations !

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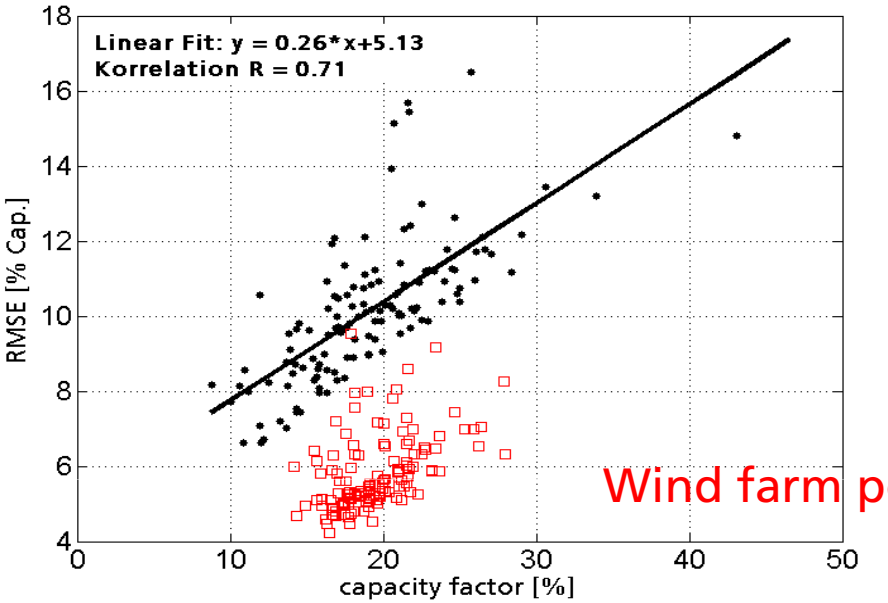
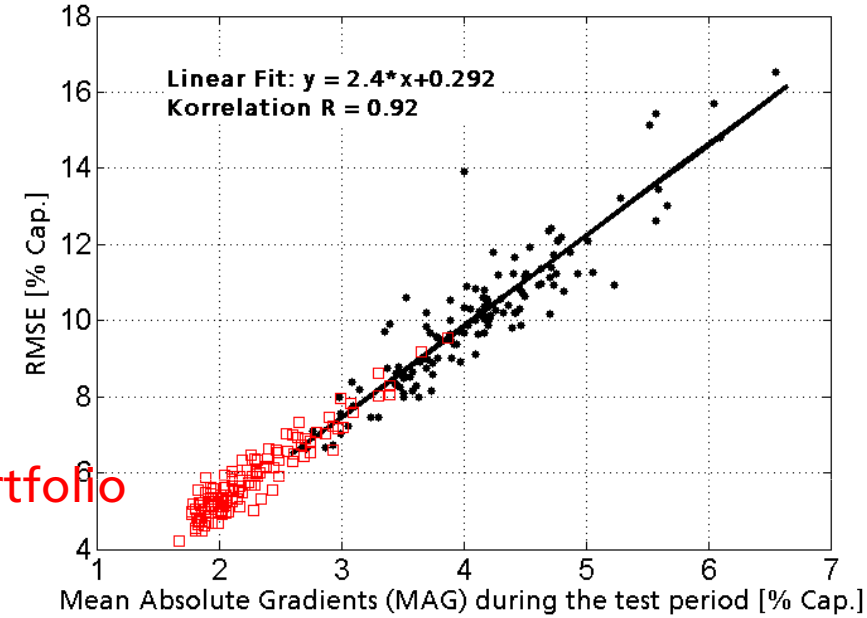
Results: Forecast Quality vs Power Fluctuations



Wind farm portfolio



Much better correlation 0.92 > 0.71 !!
Also valid for wind farm portfolios!!

Additional conclusion: Minimizing the power fluctuations of the wind farm portfolio leads to a better forecast quality

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Model evaluation:
Forecasting the RMSE of 50 wind farms using different NWP models

Approaches:

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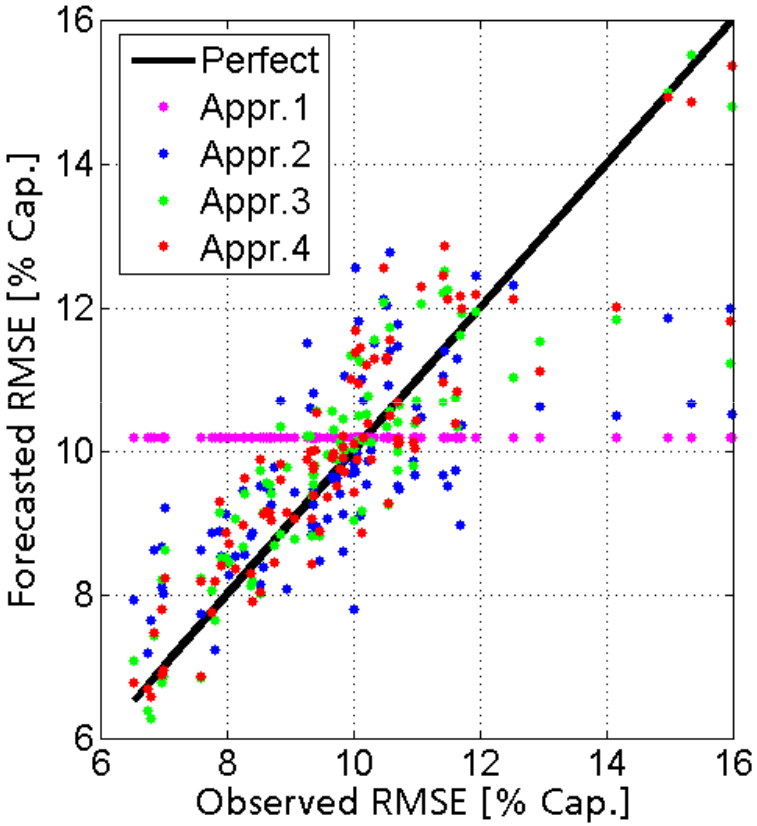
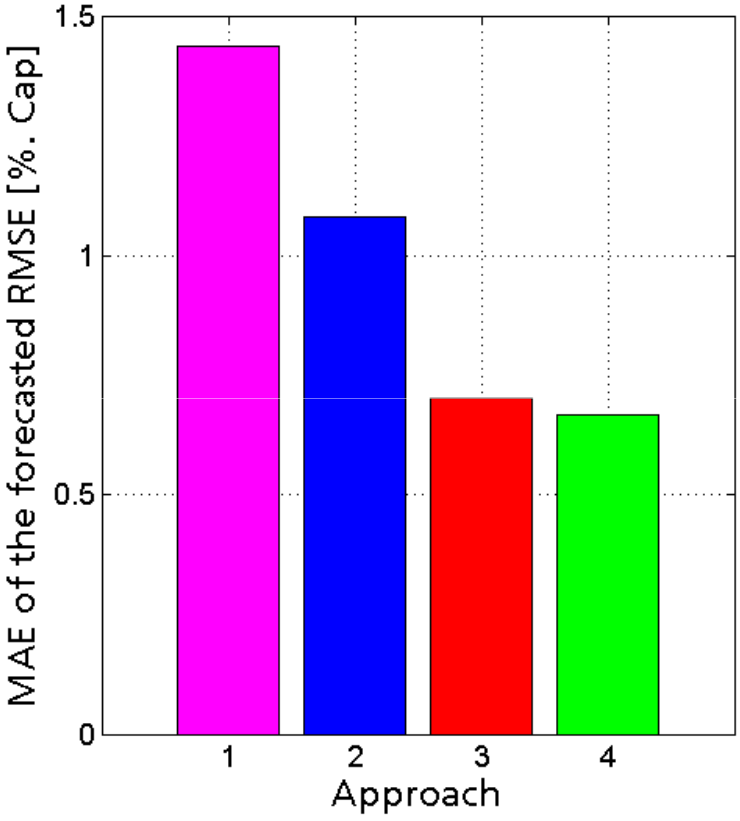
4. $RMSE_{WPi} = (2.4 * \mathbf{MAG}_{WPi} + 0.384) * (100 - Imp)/100$
   with $IMP = -56 * \mathbf{MAGws}(i) + 18.5$

Model evaluation:

Forecasting the RMSE of 50 wind farms using different NWP models





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