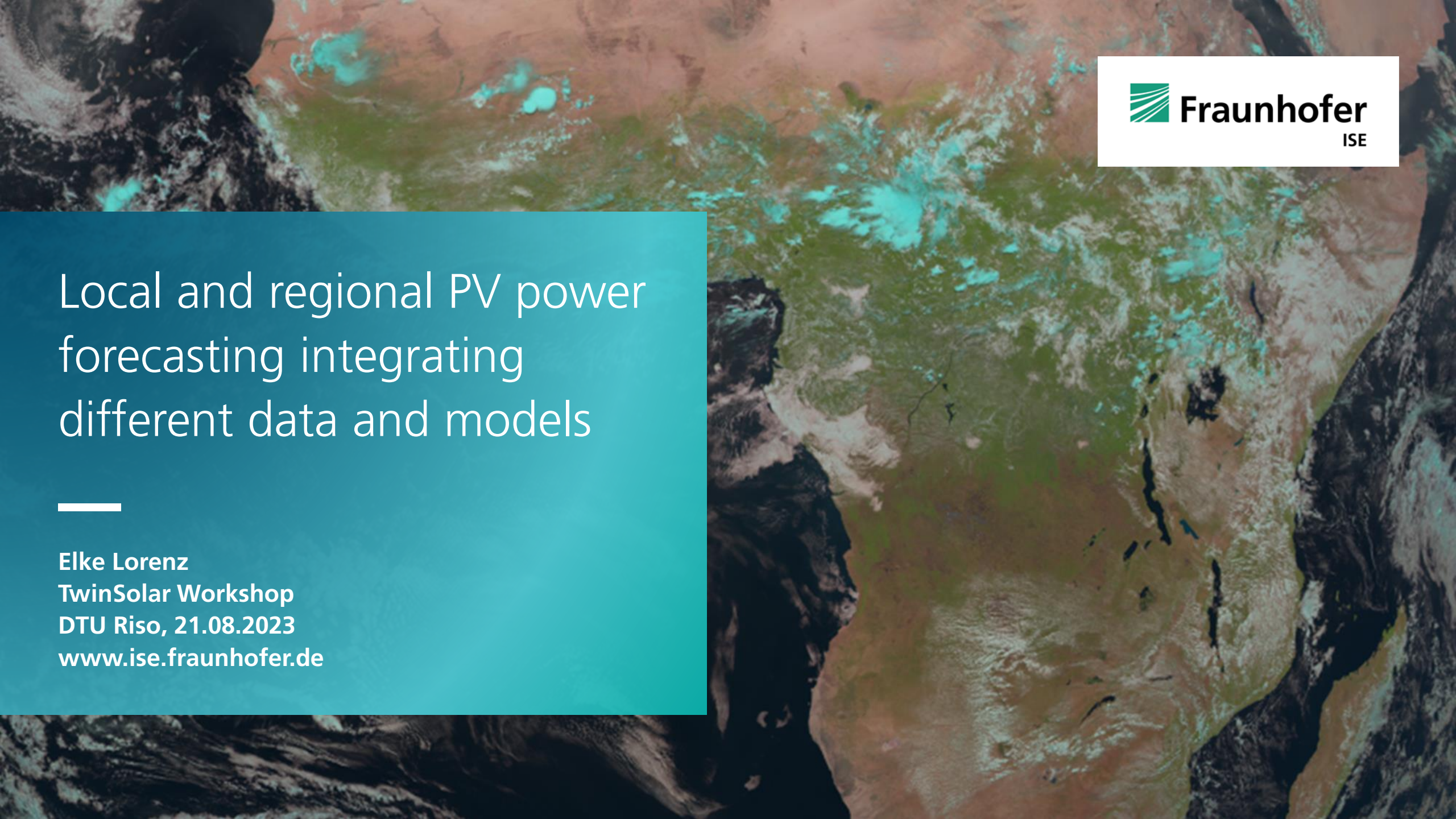


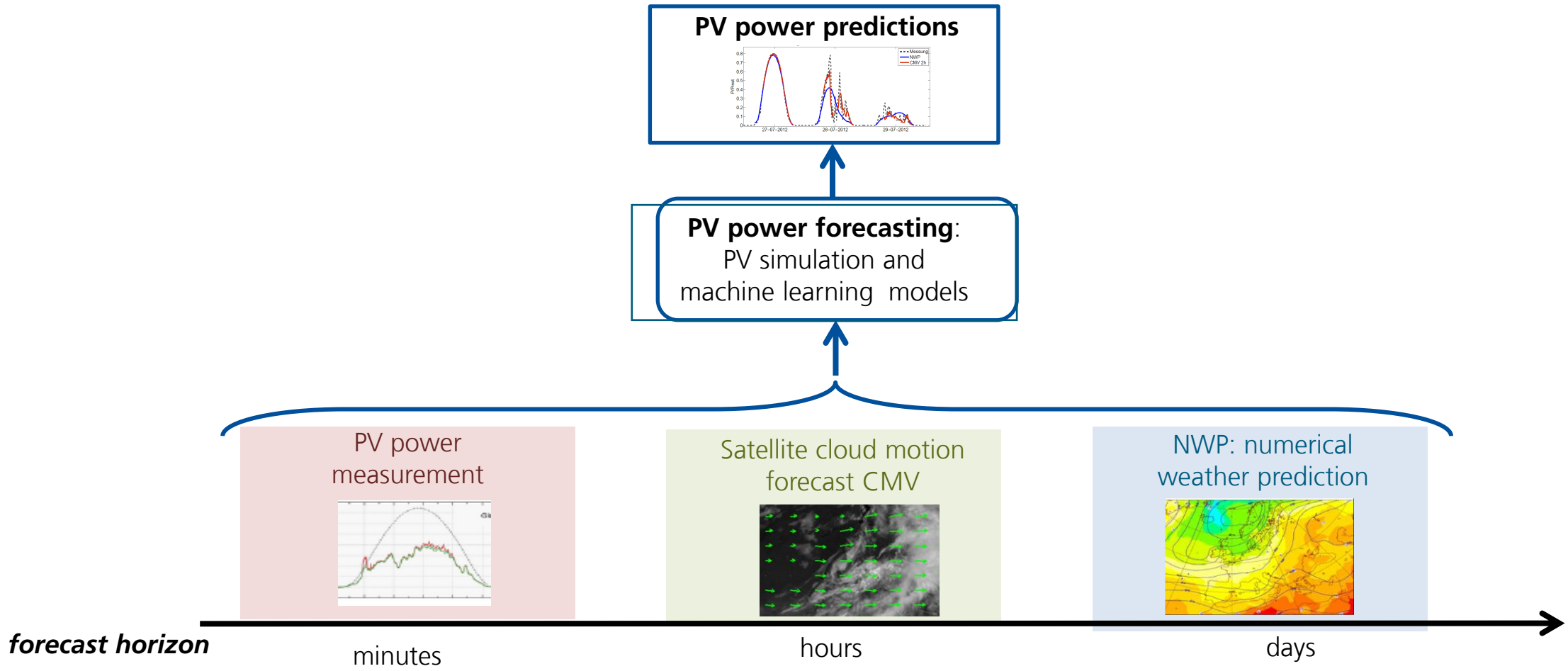
Local and regional PV power forecasting integrating different data and models

Elke Lorenz
TwinSolar Workshop
DTU Riso, 21.08.2023
www.ise.fraunhofer.de

Agenda

1. Model combination
2. Regional forecasting
3. Model comparison and evaluation

Overview of PV power prediction scheme



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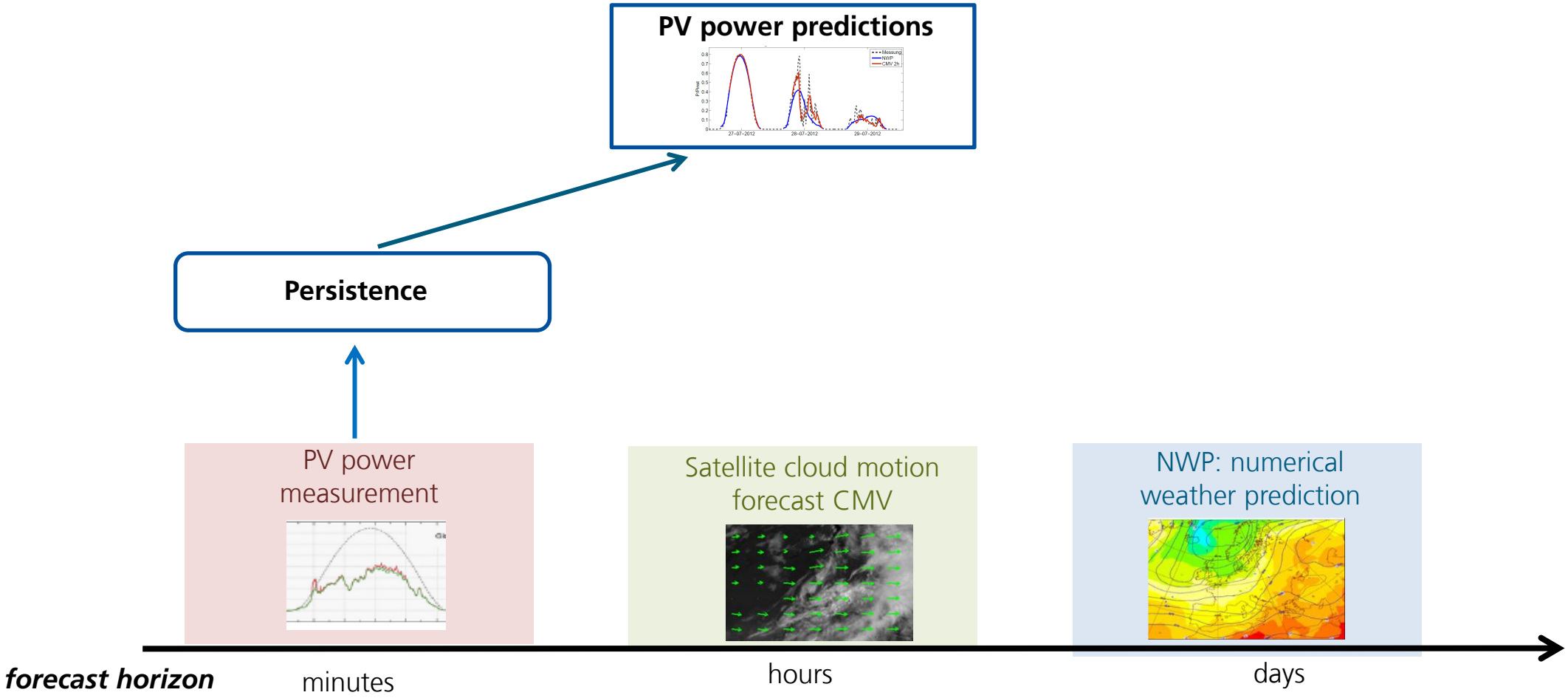
Overview of PV power prediction scheme



PV power prediction based on measurements

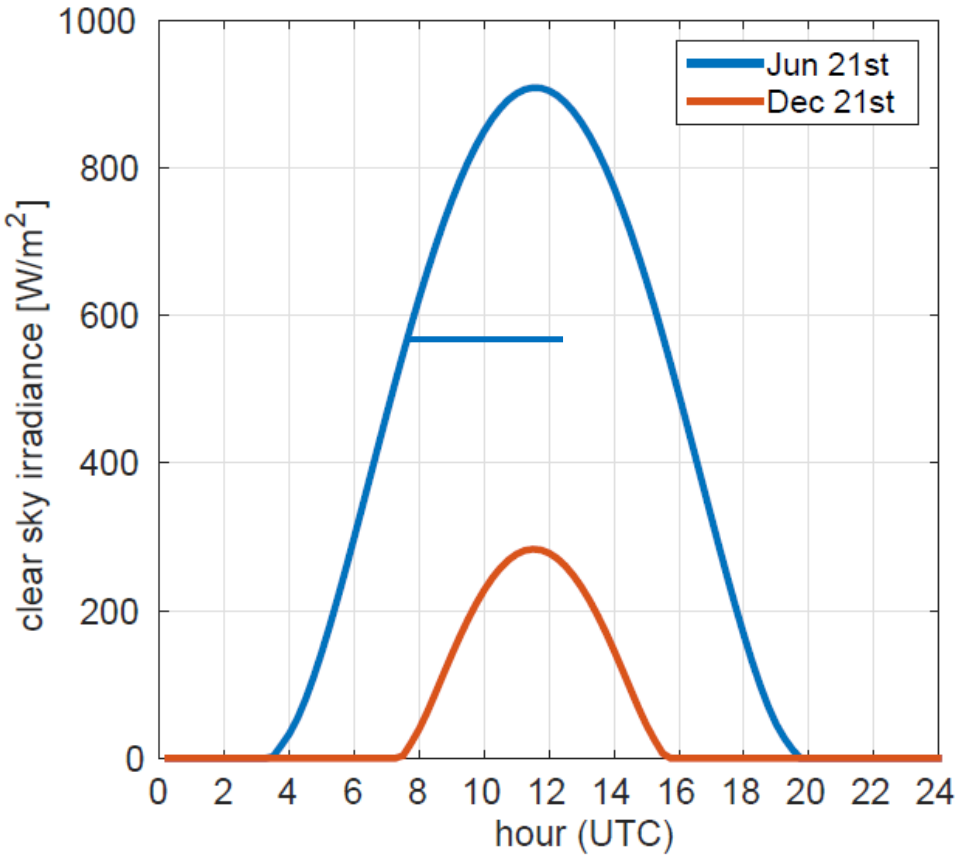
Baseline approach: persistence

Persistence:
"situation stays as it is"

$GHI(t+\Delta t)=GHI(t)$

$P_{PV}(t+\Delta t)= = P_{PV}(t)$

Do you think this is
a good idea?



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PV power prediction based on measurements

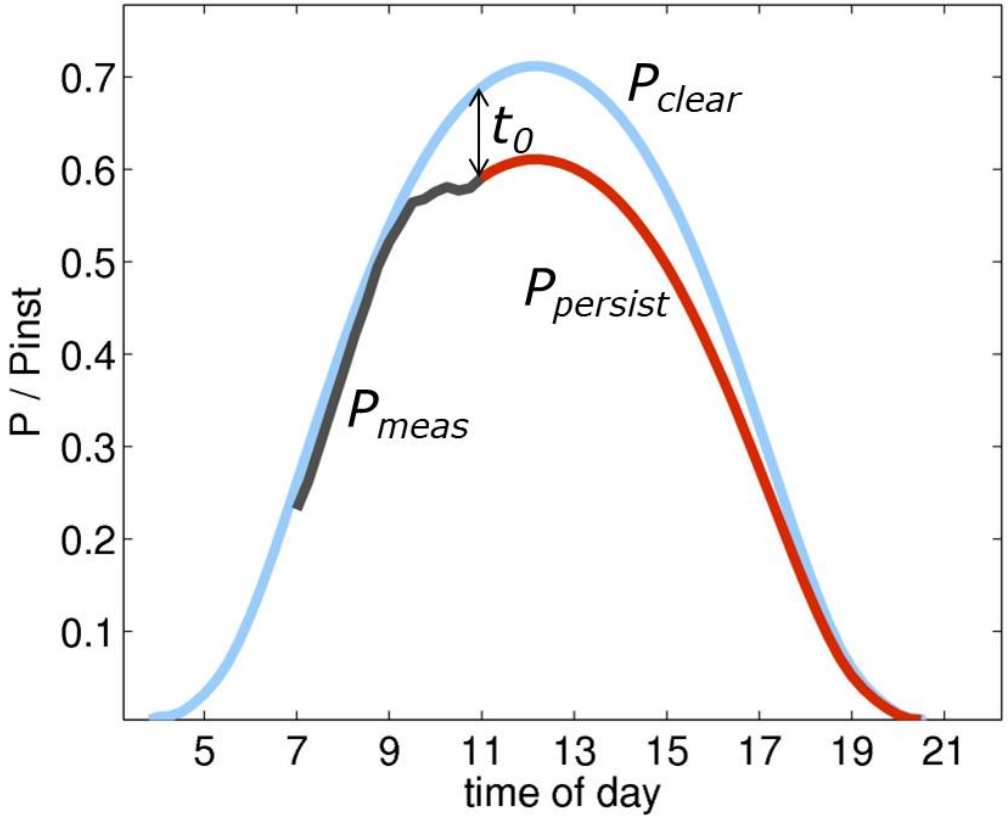
Baseline approach: persistence

Persistence:
"situation stays as it is"

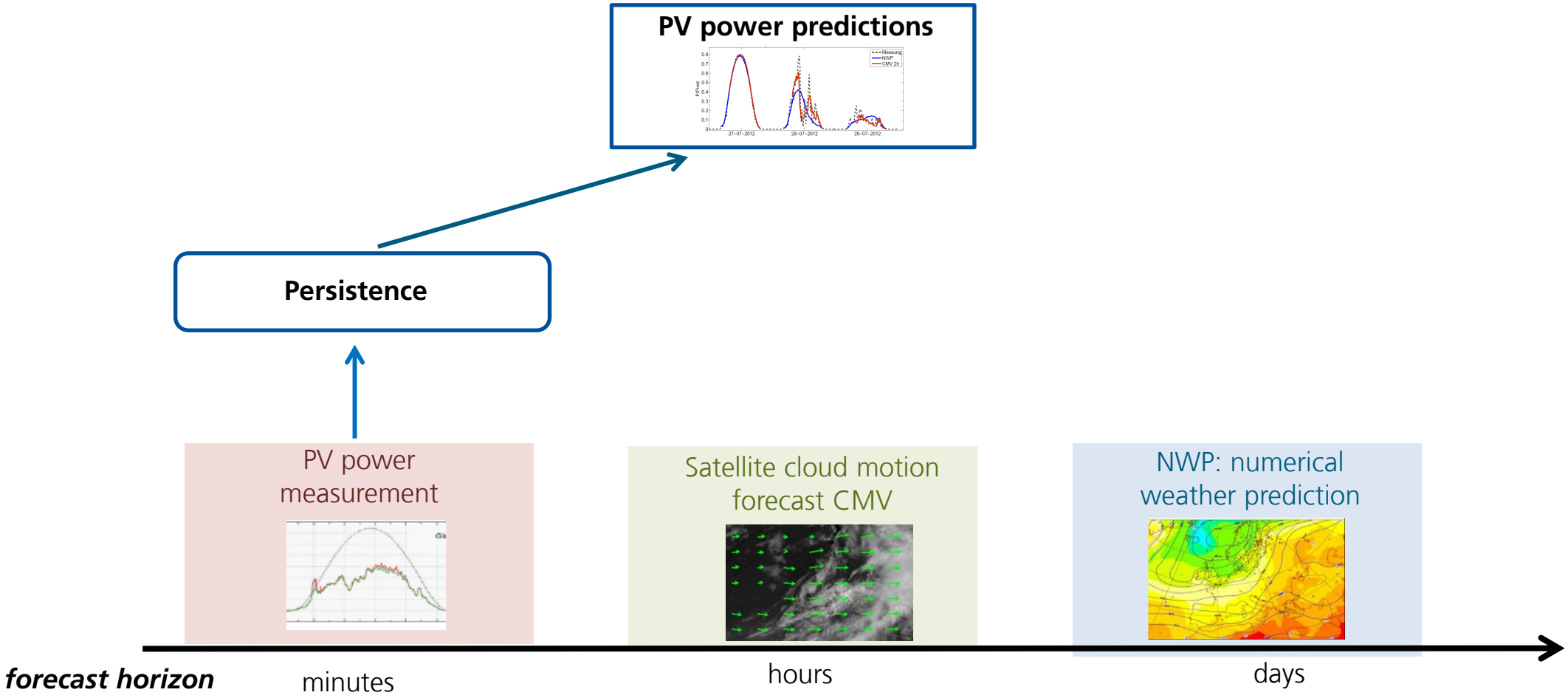
For irradiance and PV power forecasting:
persistence of cloud situation,decribed by „clear sky index" to capture diurnal course of irradiance

$k^*(t+\Delta t)=k^*(t)$
$GHI(t+\Delta t)=k^*(t) \times GHI_{clear}(t+\Delta t)$

For PV power
$k^*_P=P_{meas}/P_{clear}$
$P(t+\Delta t)=k_P^*(t) \times P_{clear}(t+\Delta t)$



Overview of PV power prediction scheme



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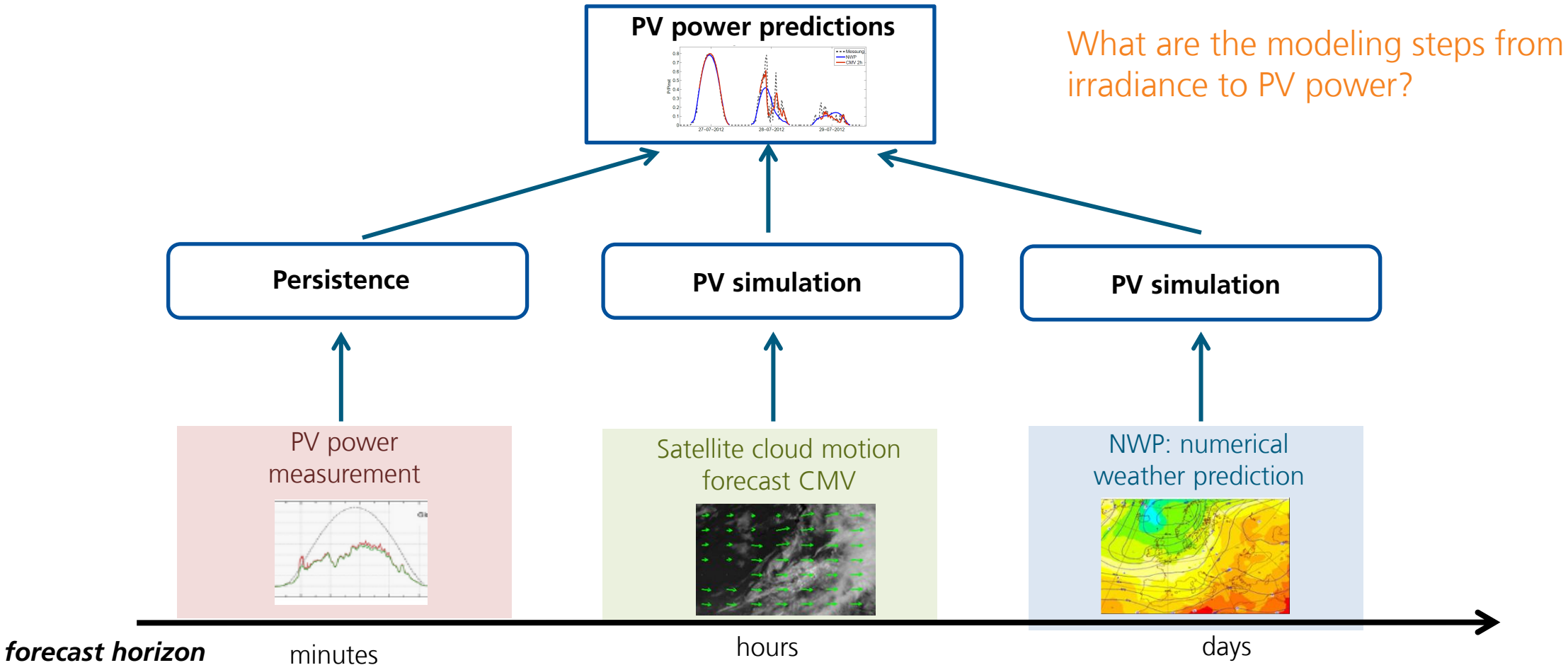

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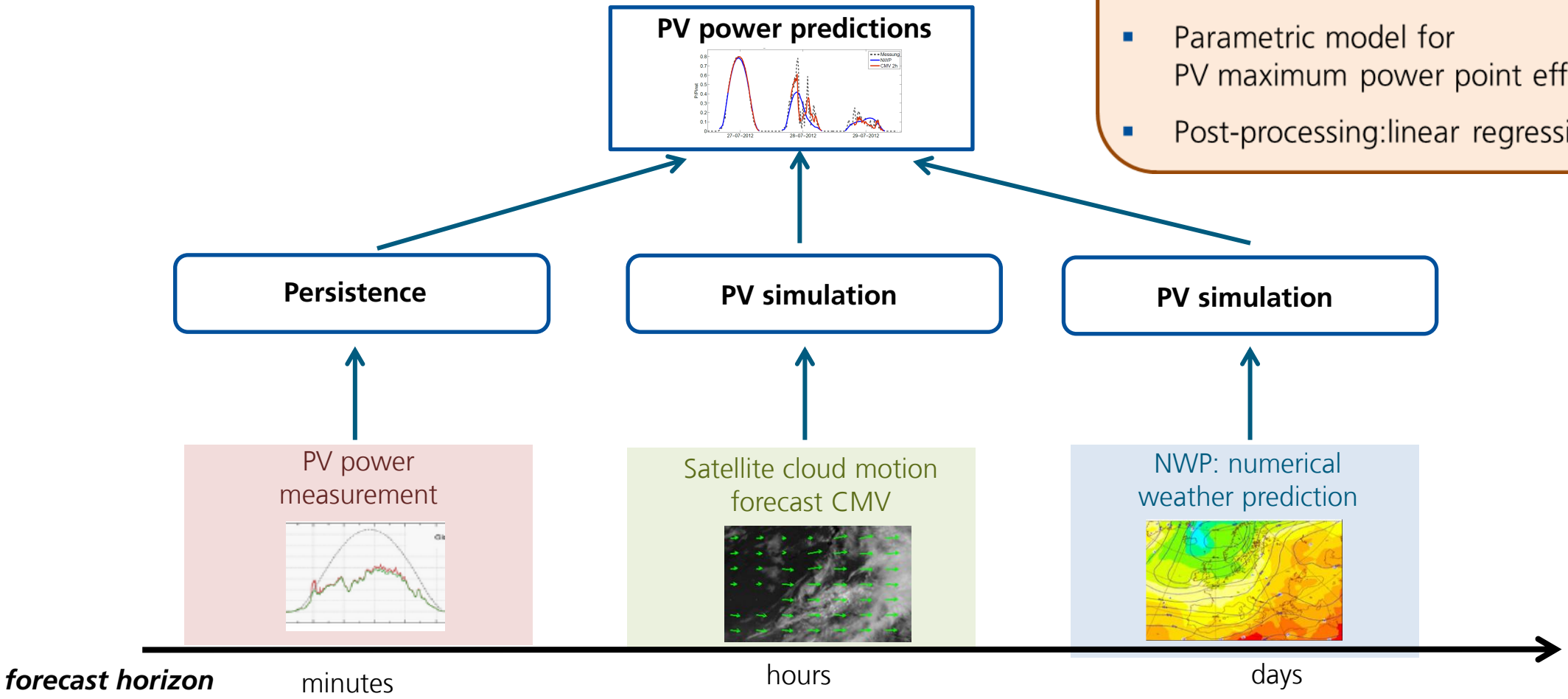
Overview of PV power prediction scheme

PV simulation:

- Diffuse fraction model
- Tilt model
- Parametric model for PV maximum power point efficiency
- Post-processing:linear regression



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Evaluation of PV power forecasting

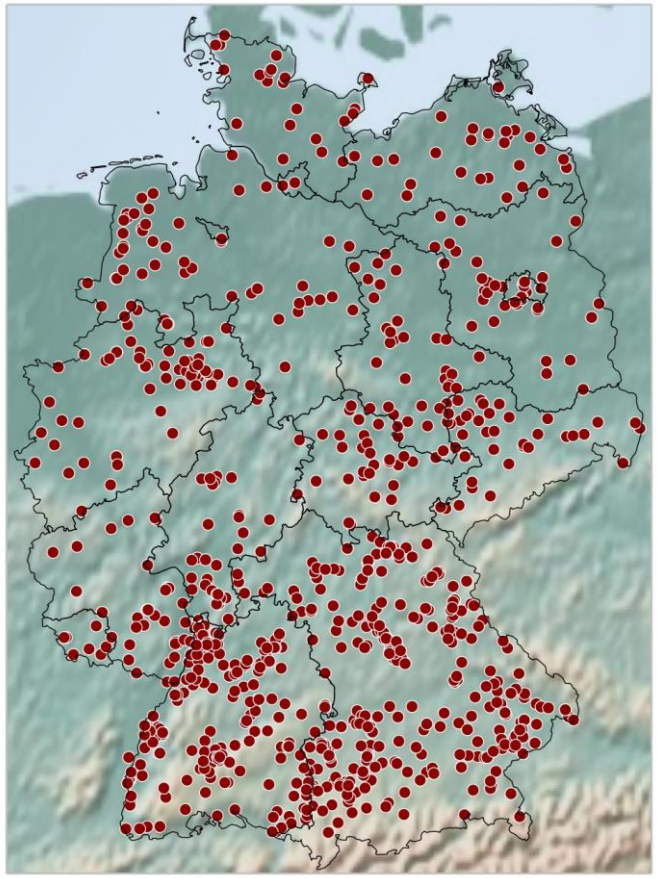
Measurement data

March- November 2013

15 minute values

921 PV systems1) in Germany

information on PV system tilt and orientation



1)Monitoring data base of Meteocontrol GmbH

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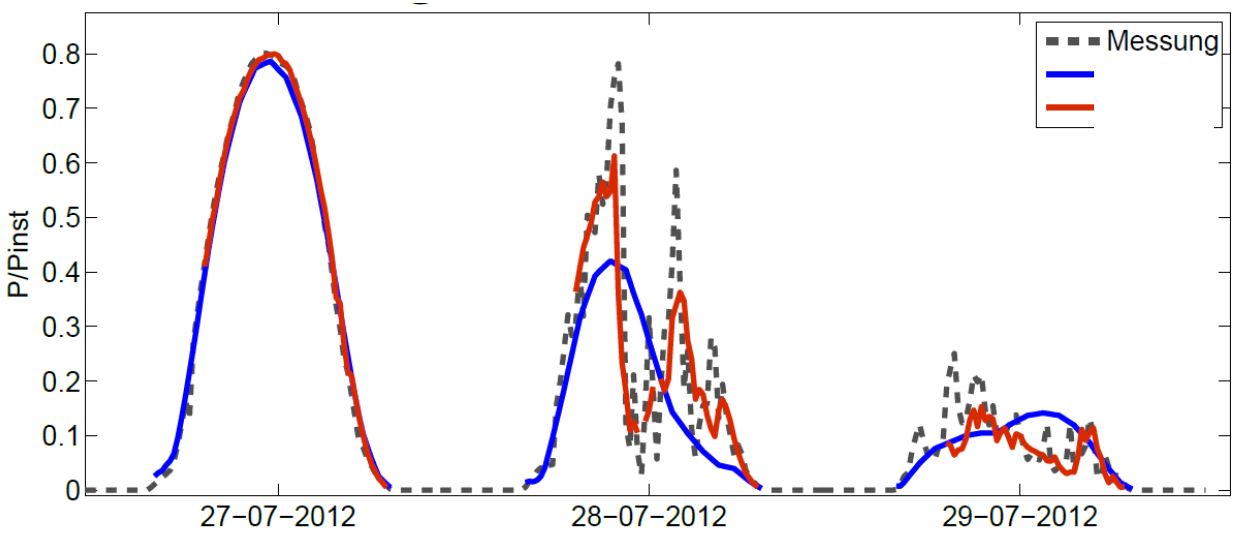
Evaluation of local forecasts
Comparison of NWP and CMV based forecasts



Forecast1 ?

Forecast 2?

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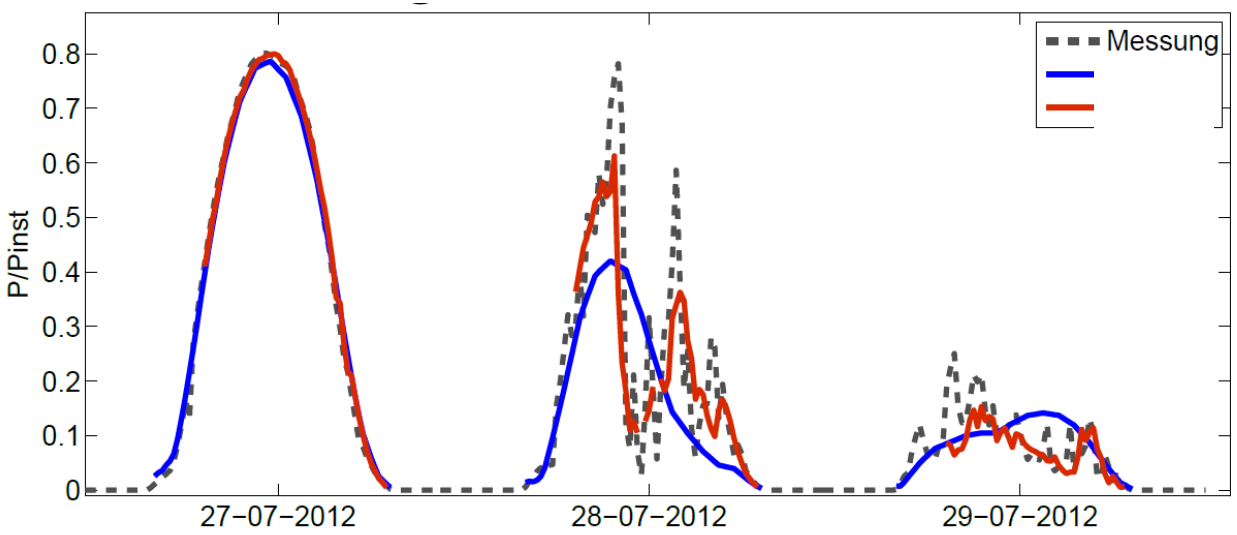
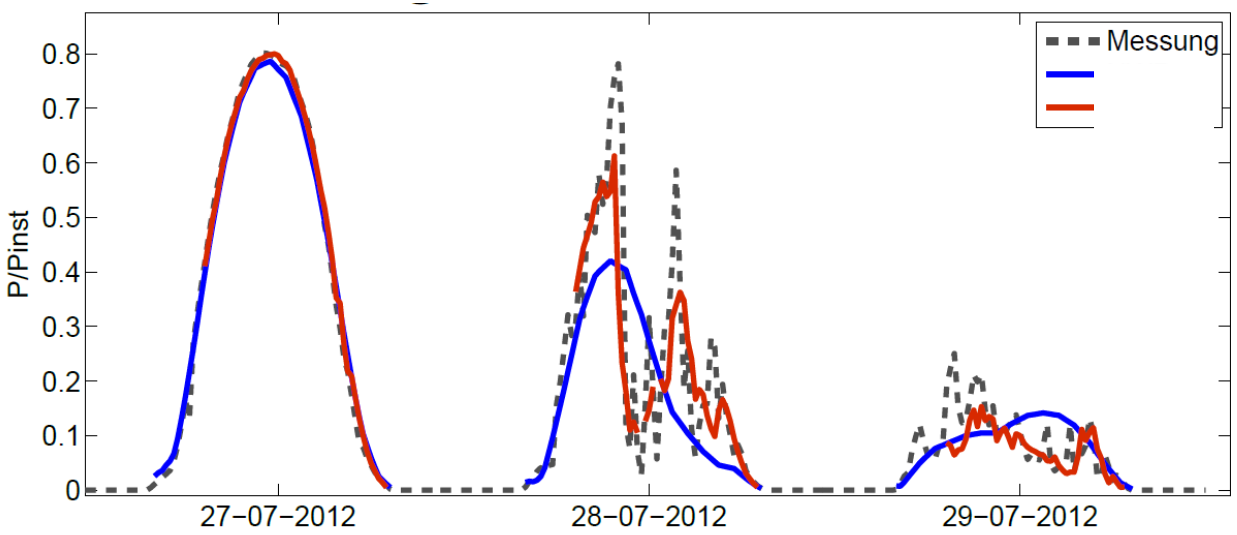
Evaluation of local forecasts: comparison of NWP and CMV based forecasts



CMV 2h:
2 hour ahead cloud motion vector forecast

NWP:
12:00 UTC ECMWF run of previous day

Evaluation of local forecasts
Comparison of NWP and CMV based forecasts



CMV 2h:
2 hour ahead cloud motion vector forecast

NWP:
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Clear sky: good agreement of NWP and CMV forecasts with measurements

variable clouds: CMV 2h ahead forecasts capture changes in PV power

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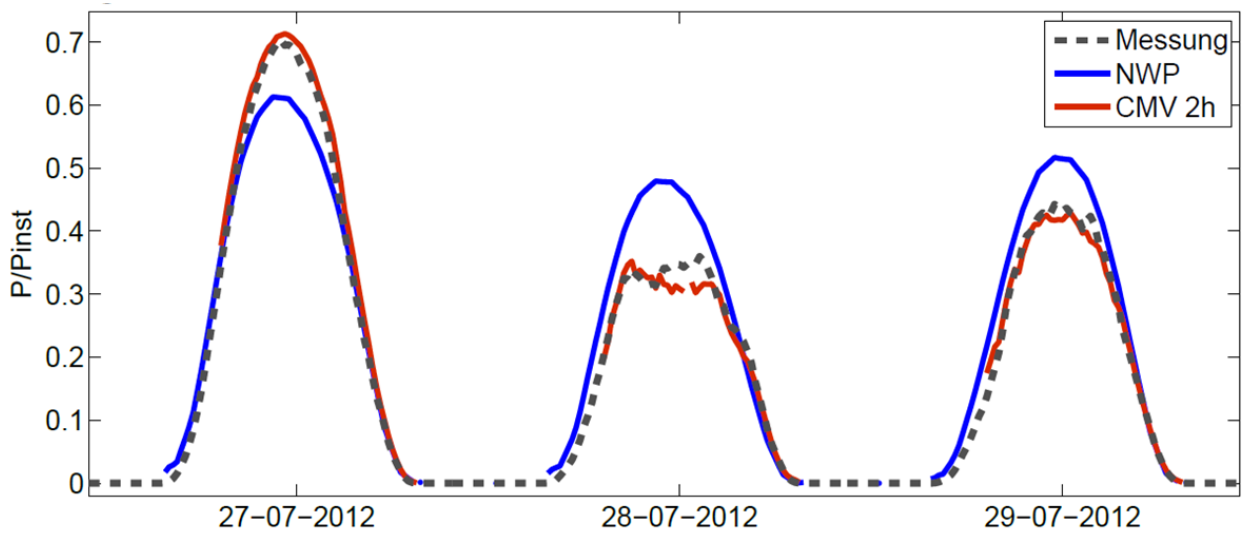
Evaluation of regional forecasts
Comparison of NWP and CMV based forecasts



CMV 2h:
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NWP:
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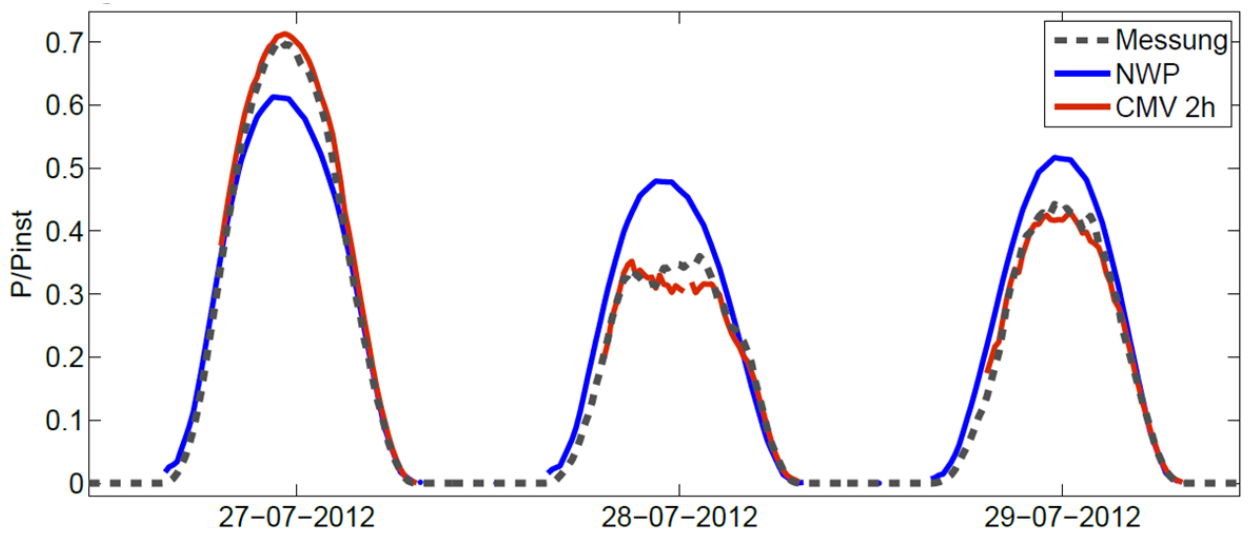
Regional forecast/Virtual power plant: Sum of PV power output of all systems

Smoother curves and better agreement between forecasts and measurements: spatial averaging effects

2h ahead CMV forecasts perform better than NWP forecasts

Evaluation of regional forecasts persistence, CMV and NWP forecasts



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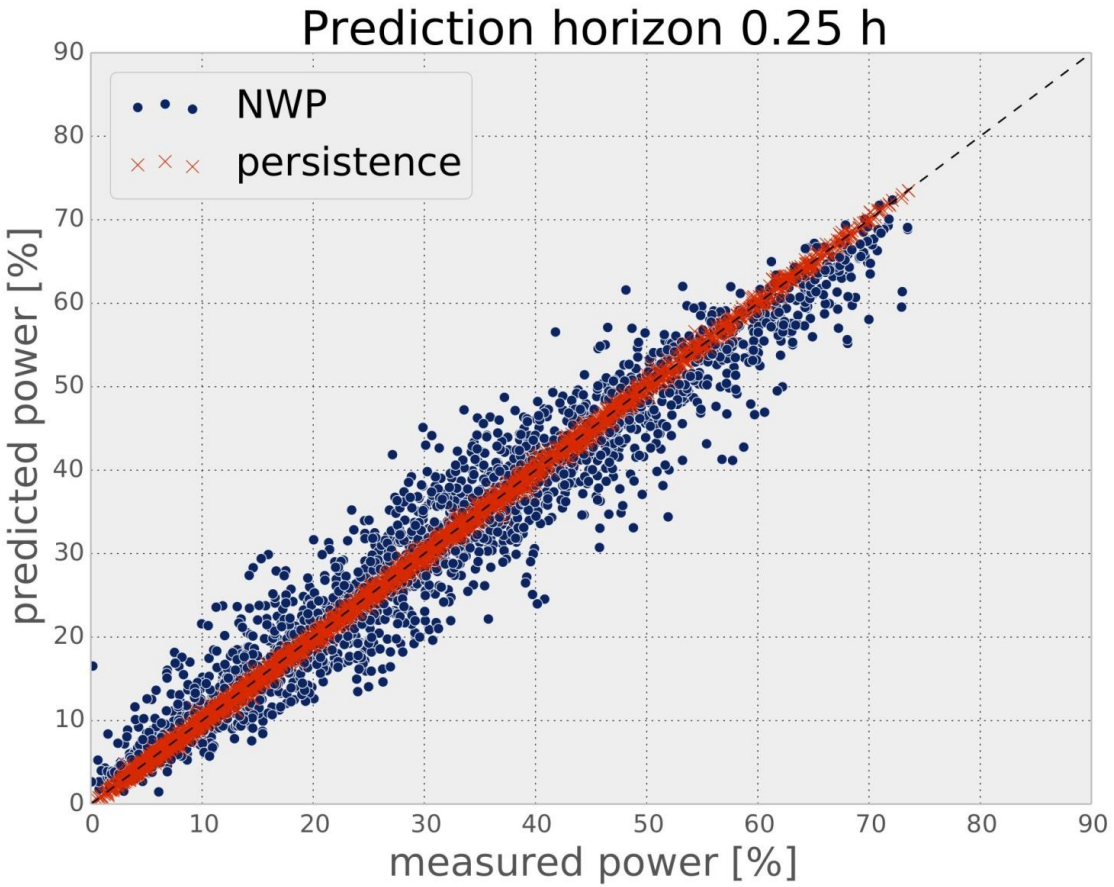
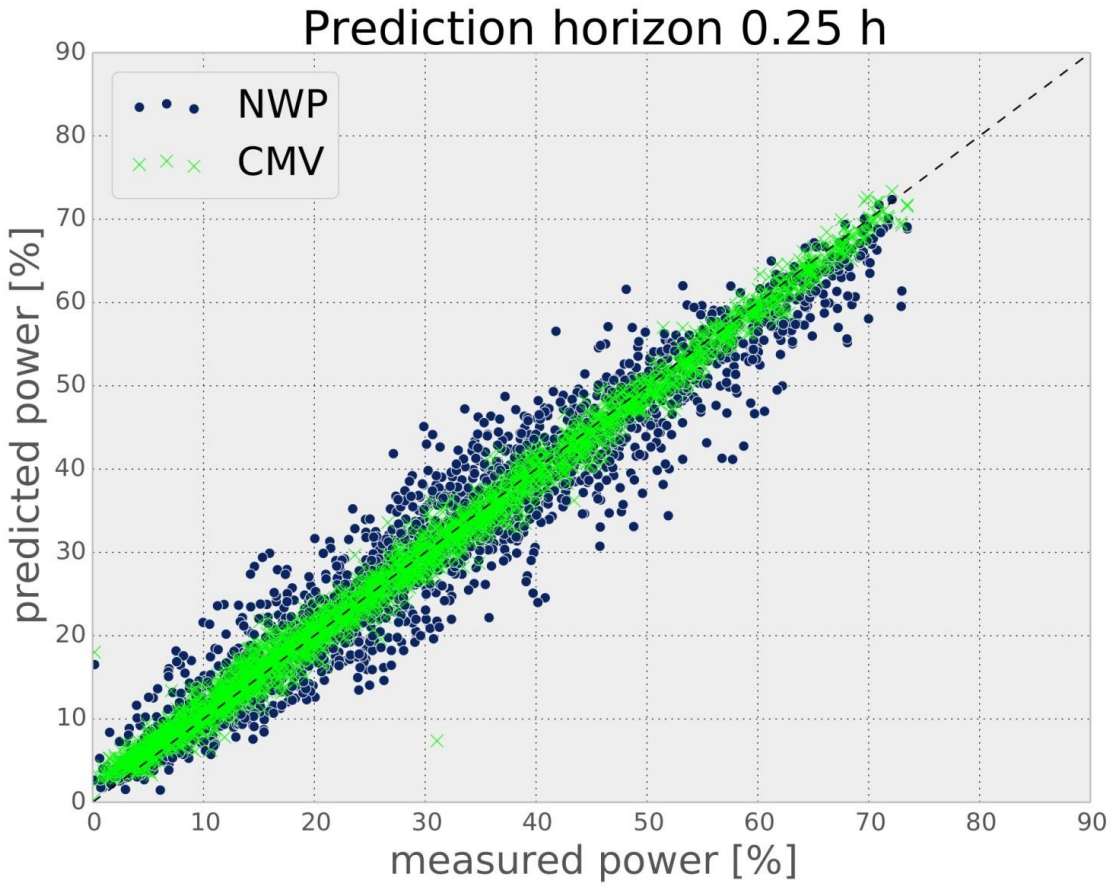
Regional forecasts:

Persistence, CMV and NWP based forecasts





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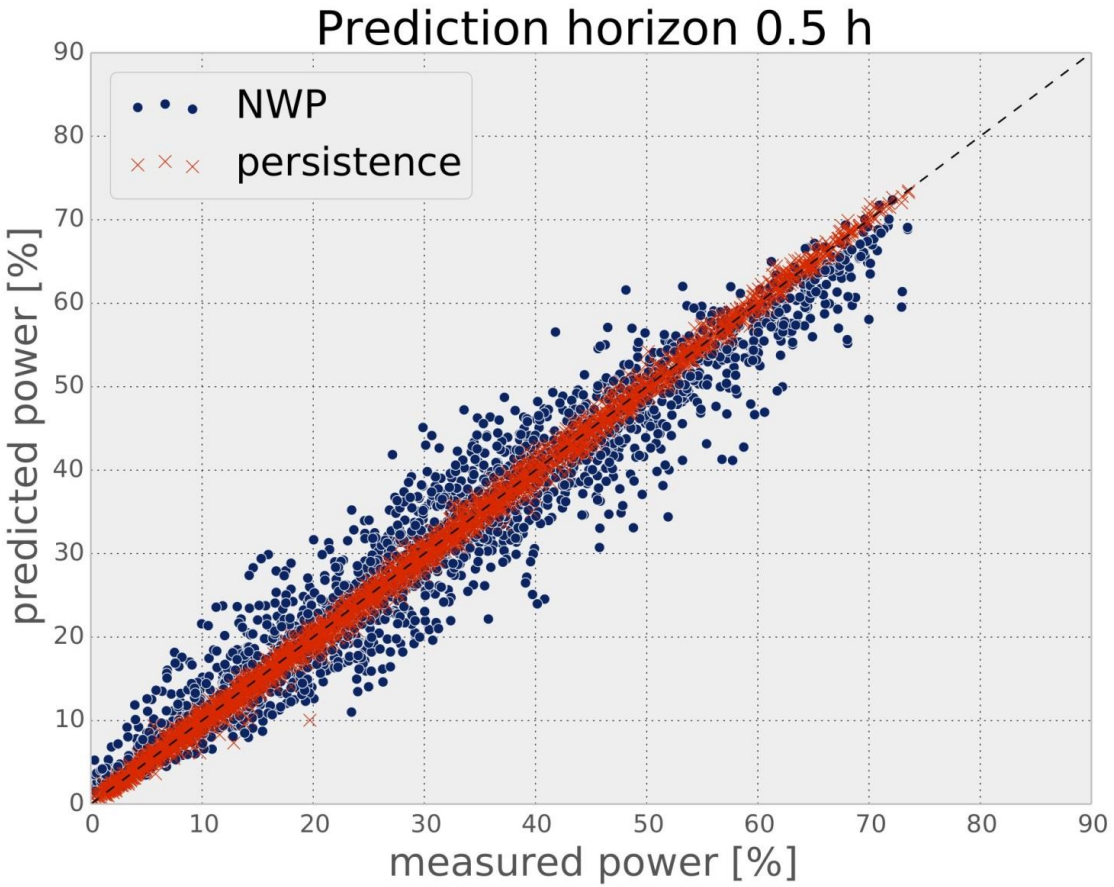
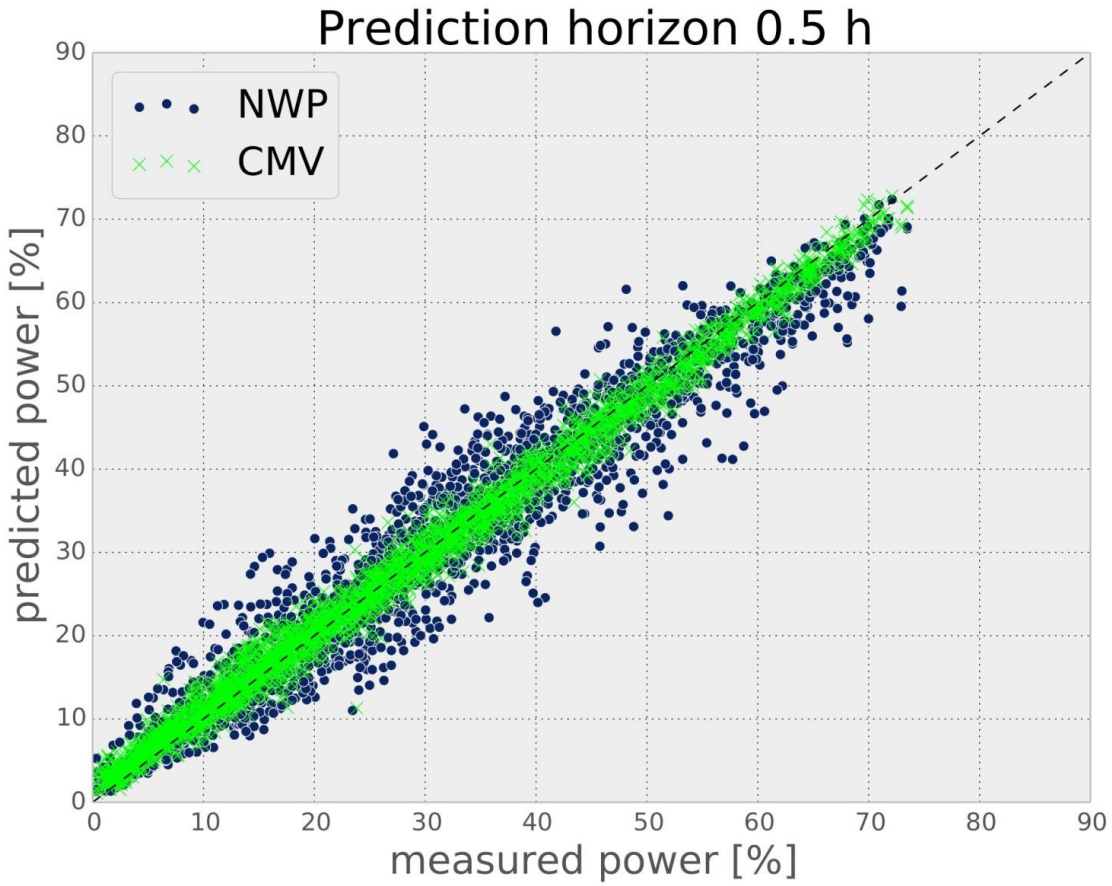
Regional forecasts:

Persistence, CMV and NWP based forecasts





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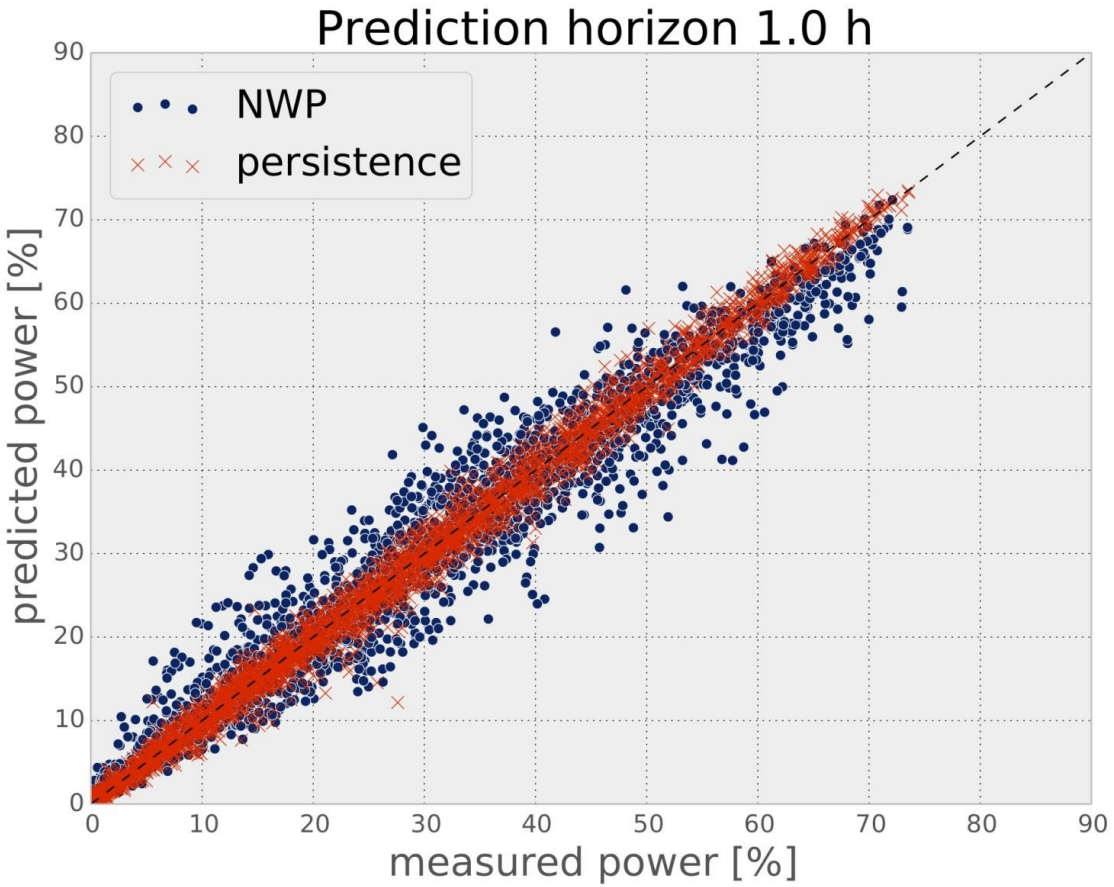
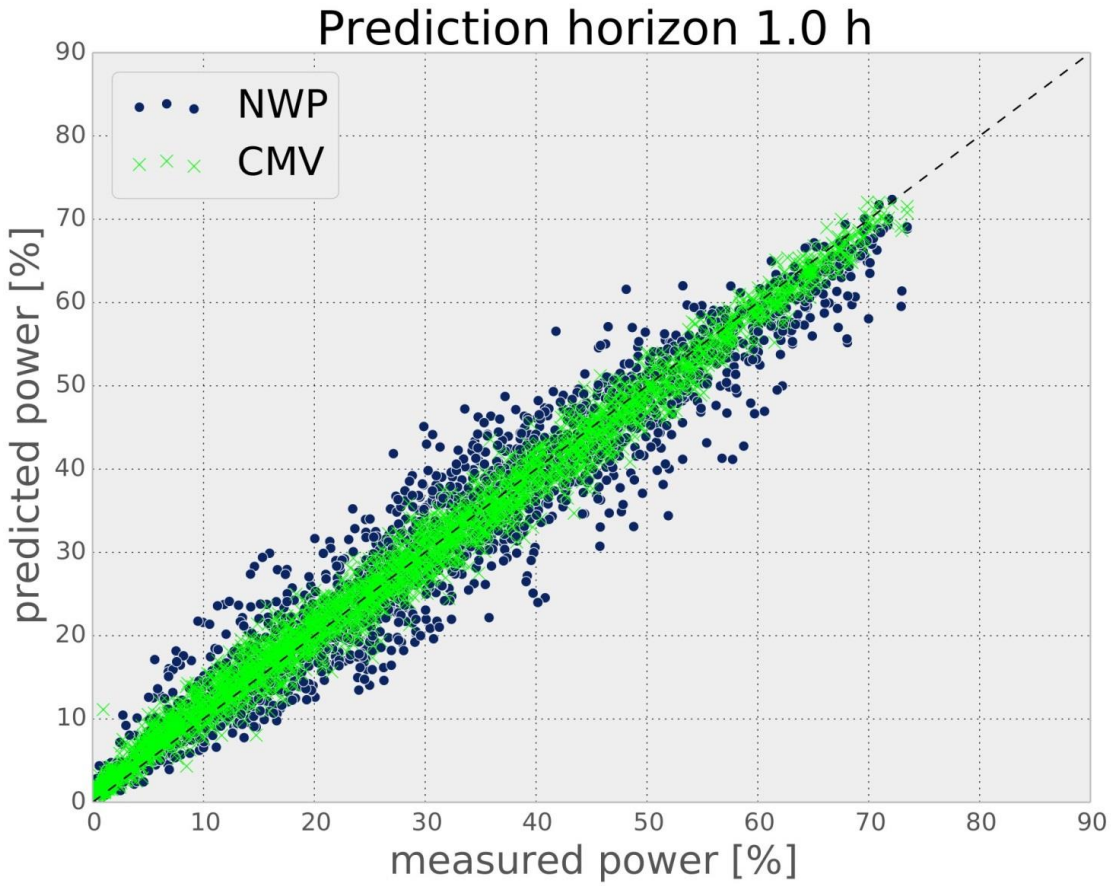
Regional forecasts:

Persistence, CMV and NWP based forecasts





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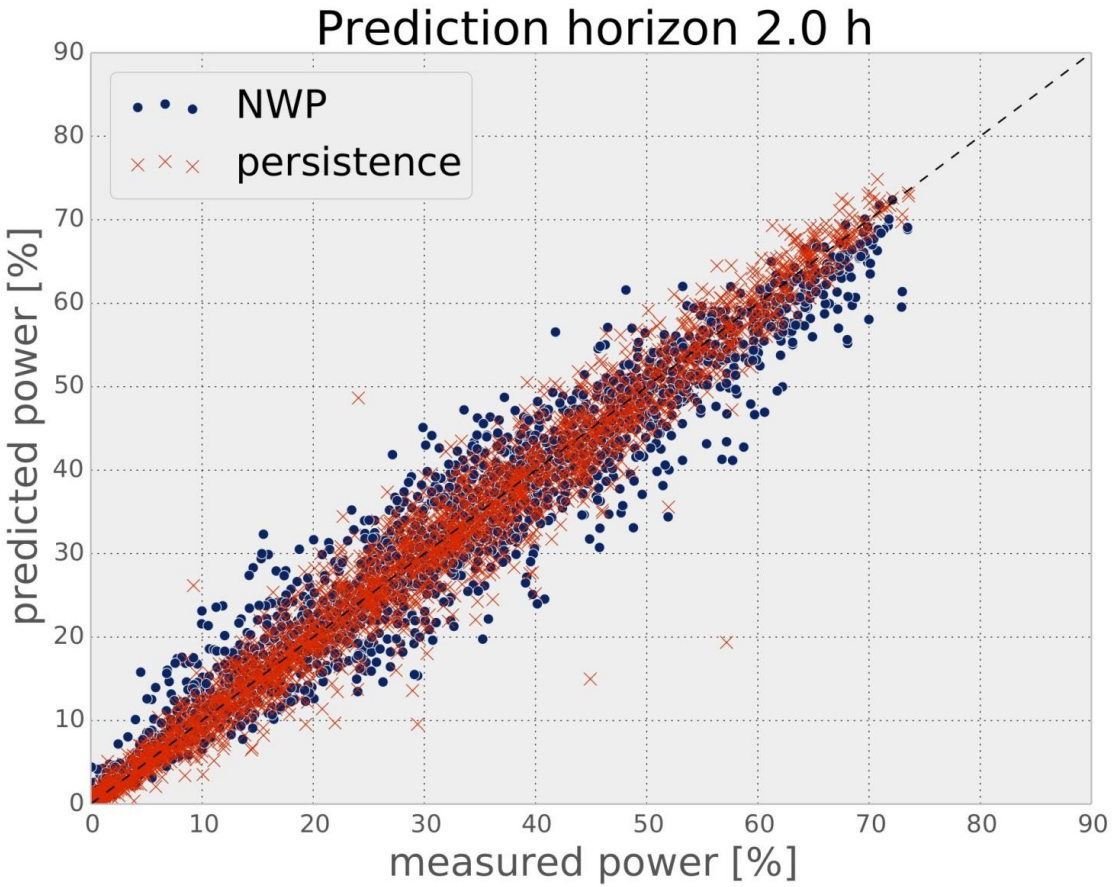
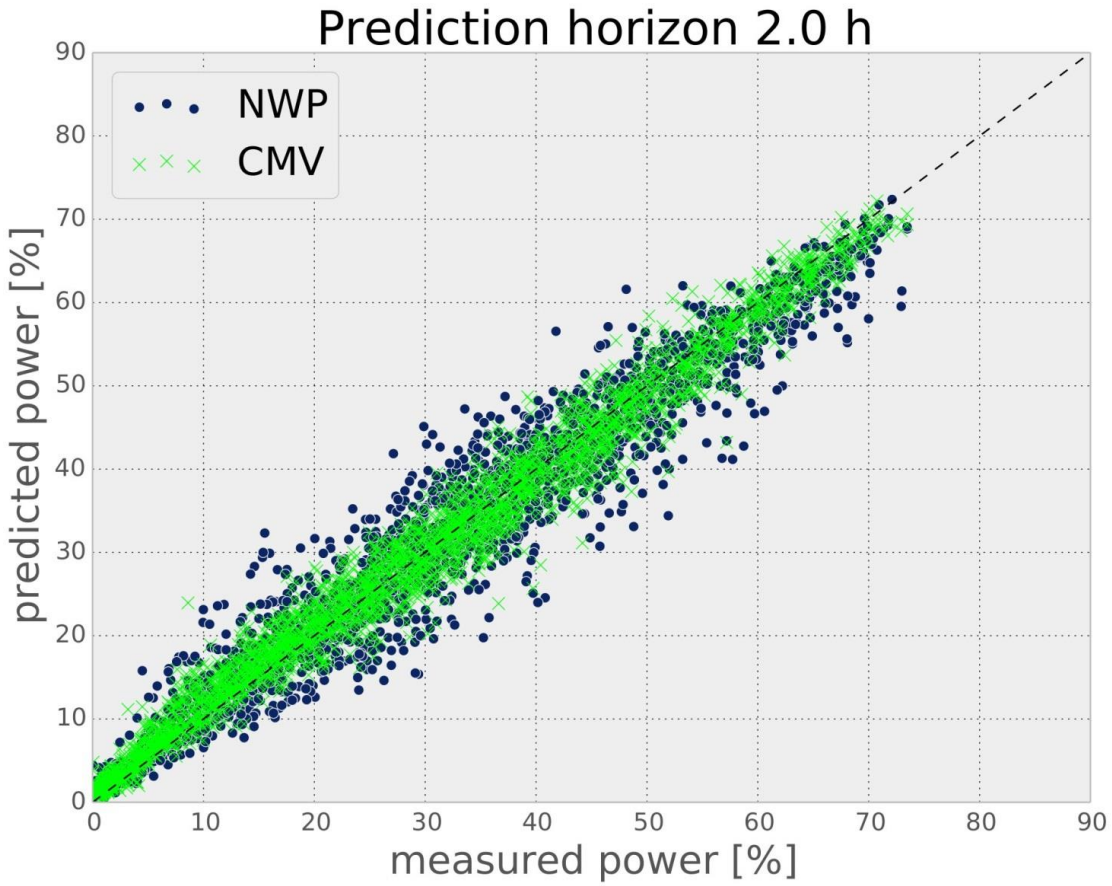
Persistence, CMV and NWP based forecasts





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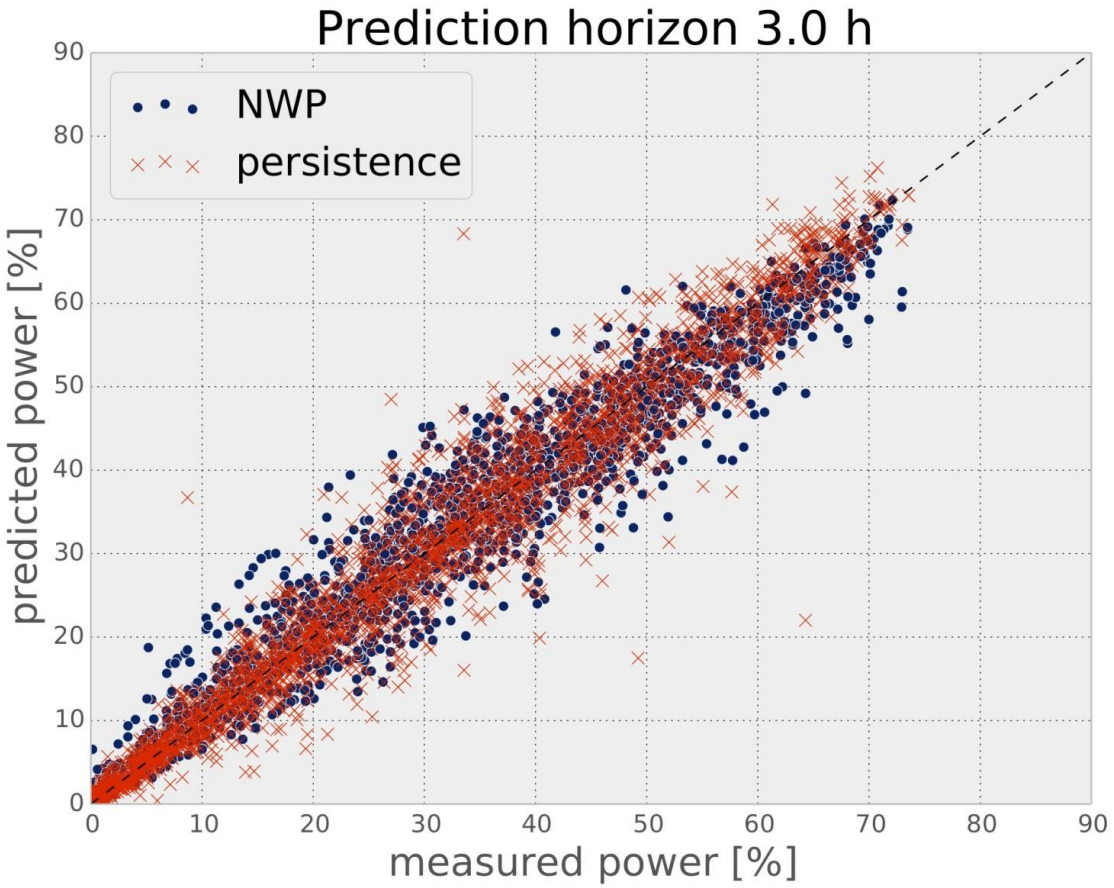
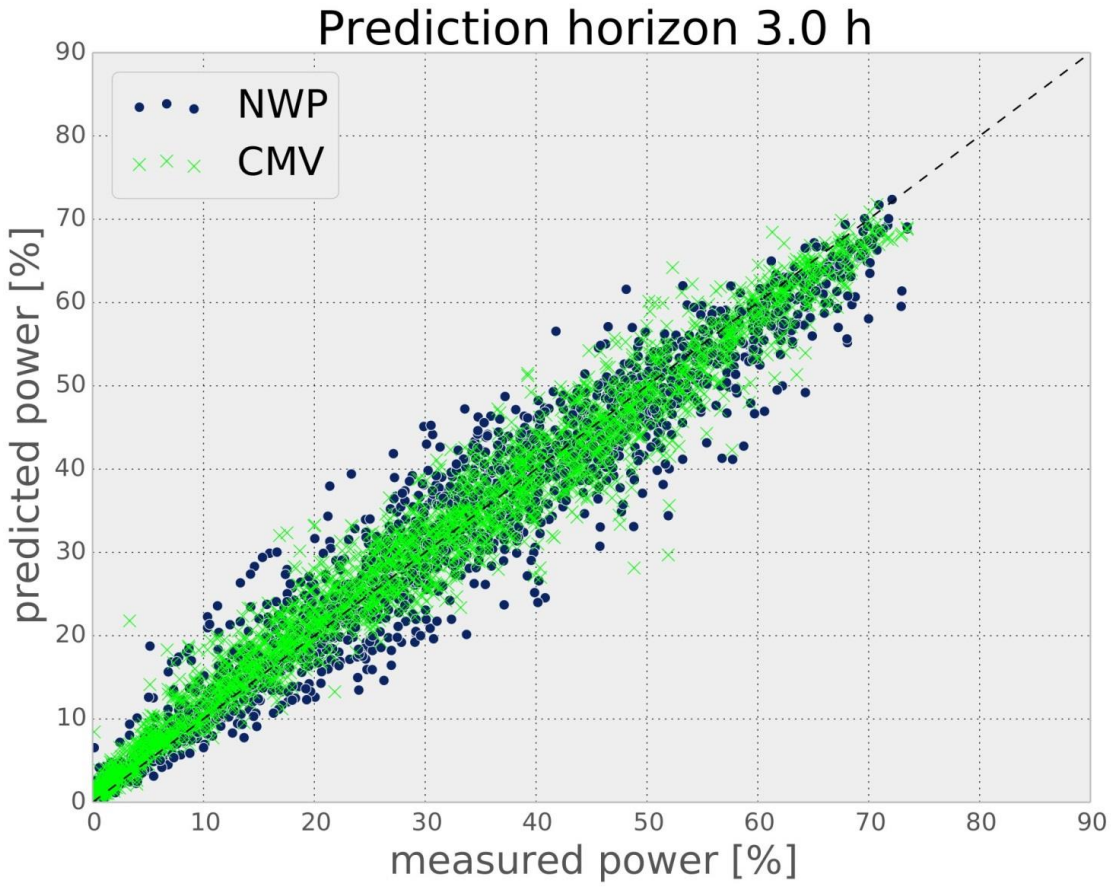
Regional forecasts:

Persistence, CMV and NWP based forecasts





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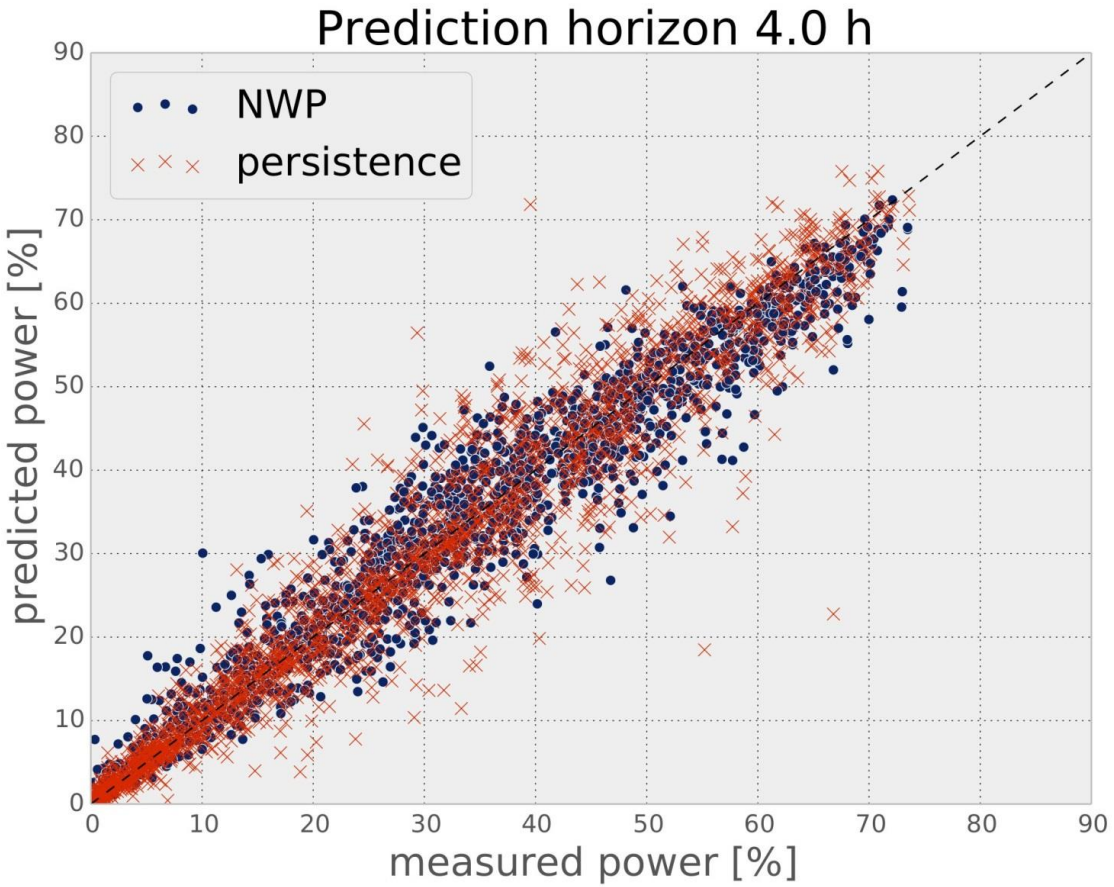
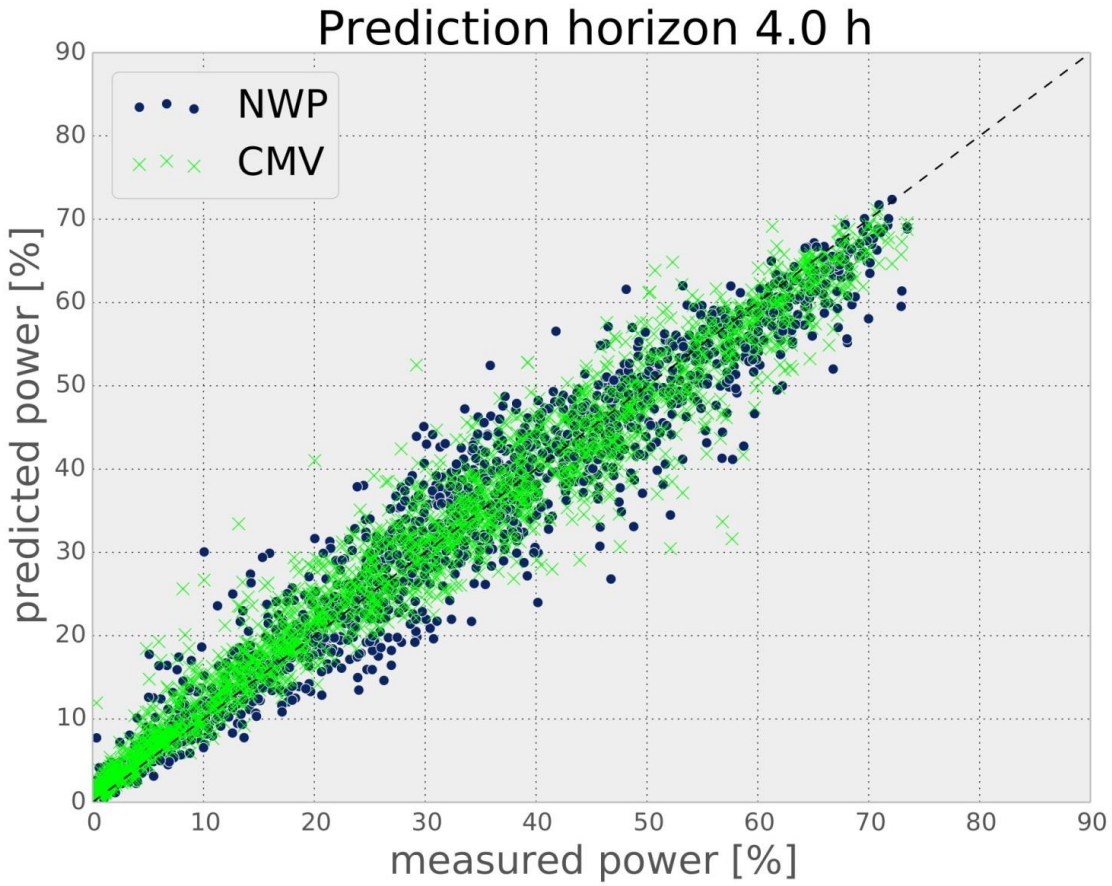
Regional forecasts:

Persistence, CMV and NWP based forecasts





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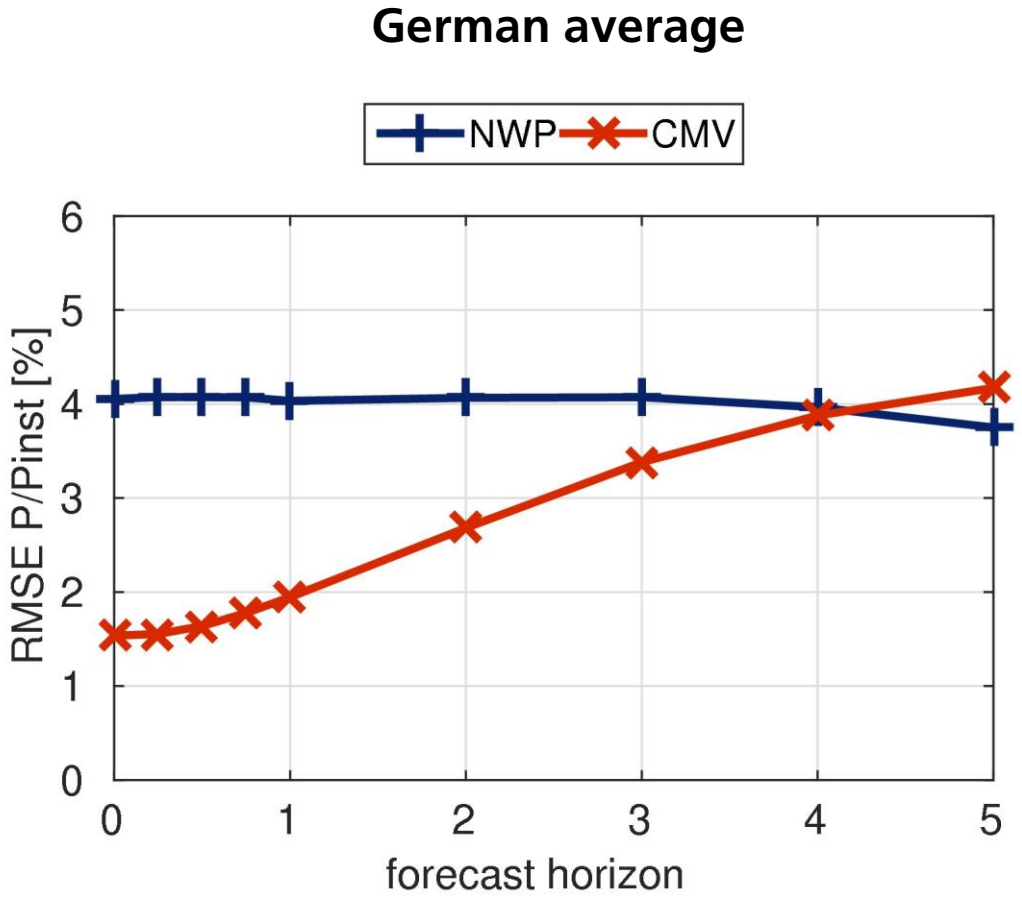
RMSE in dependence of forecast horizon

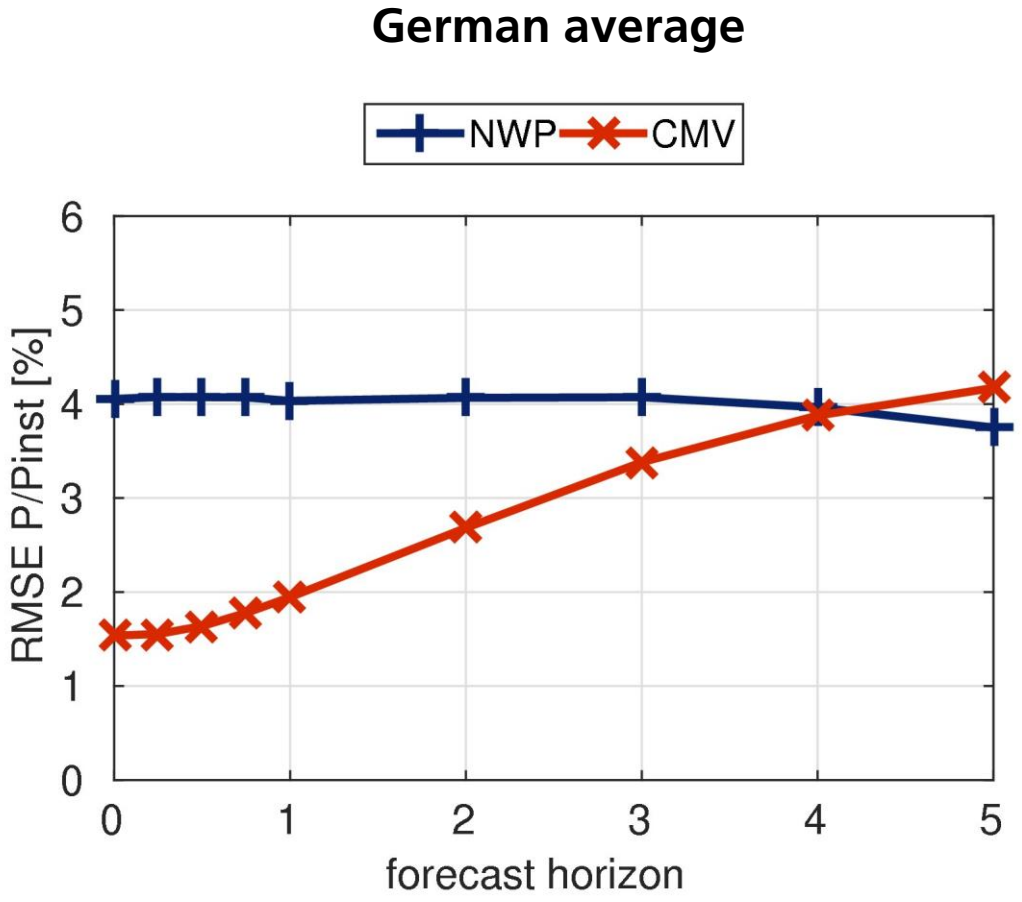


Data set for validation:

- 15 minute values
- normalization to installed power Pinst
- only daylight values, calculation time of CMV: sunel > 10°
- only hours with all models available included in dependence of forecast horizon

$$rmse = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\frac{P_{meas}}{P_{inst}} - \frac{P_{pred}}{P_{inst}}\right)^2}$$

RMSE in dependence of forecast horizon

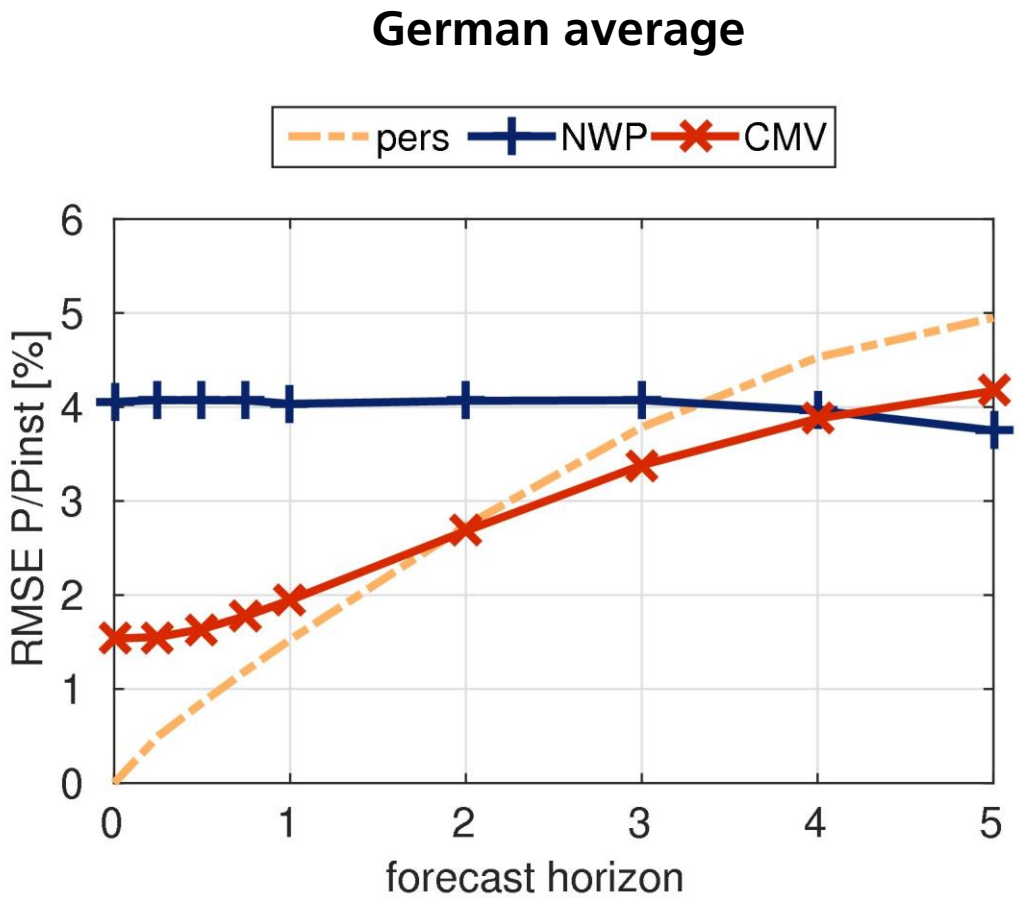


Forecasts for German average

CMV forecasts better than NWP based forecast up to 4 hours ahead

Fraunhofer ISE

RMSE in dependence of forecast horizon



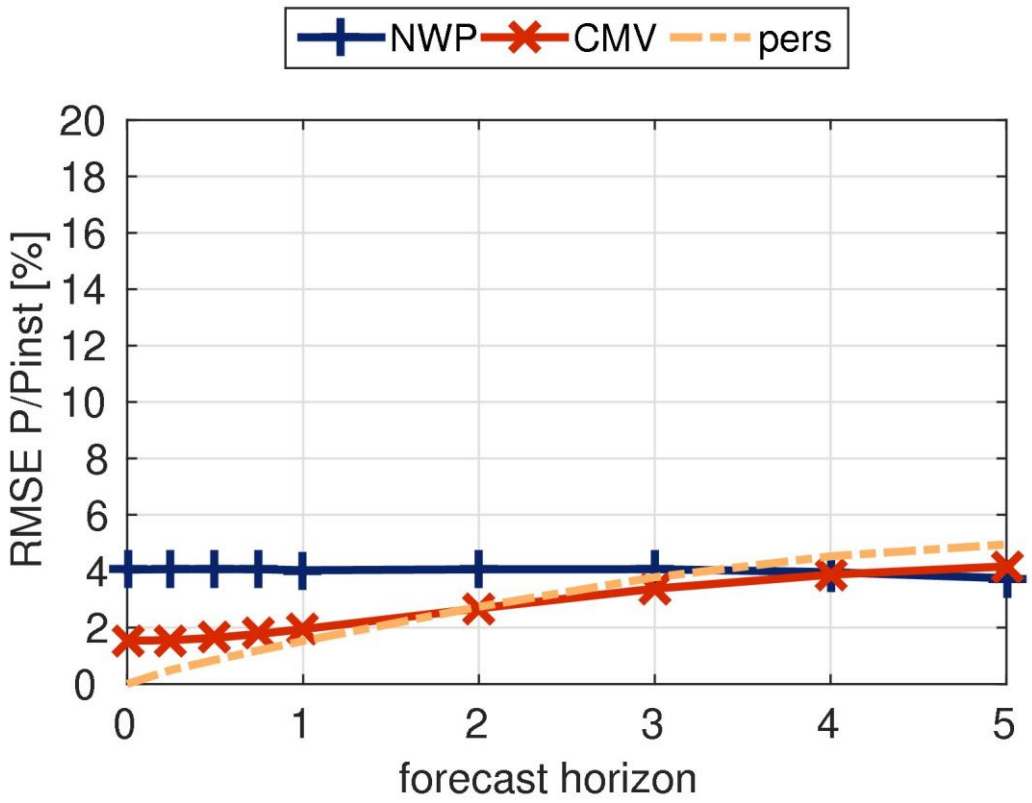
Forecasts for German average

CMV forecasts better than NWP based forecast up to 4 hours ahead

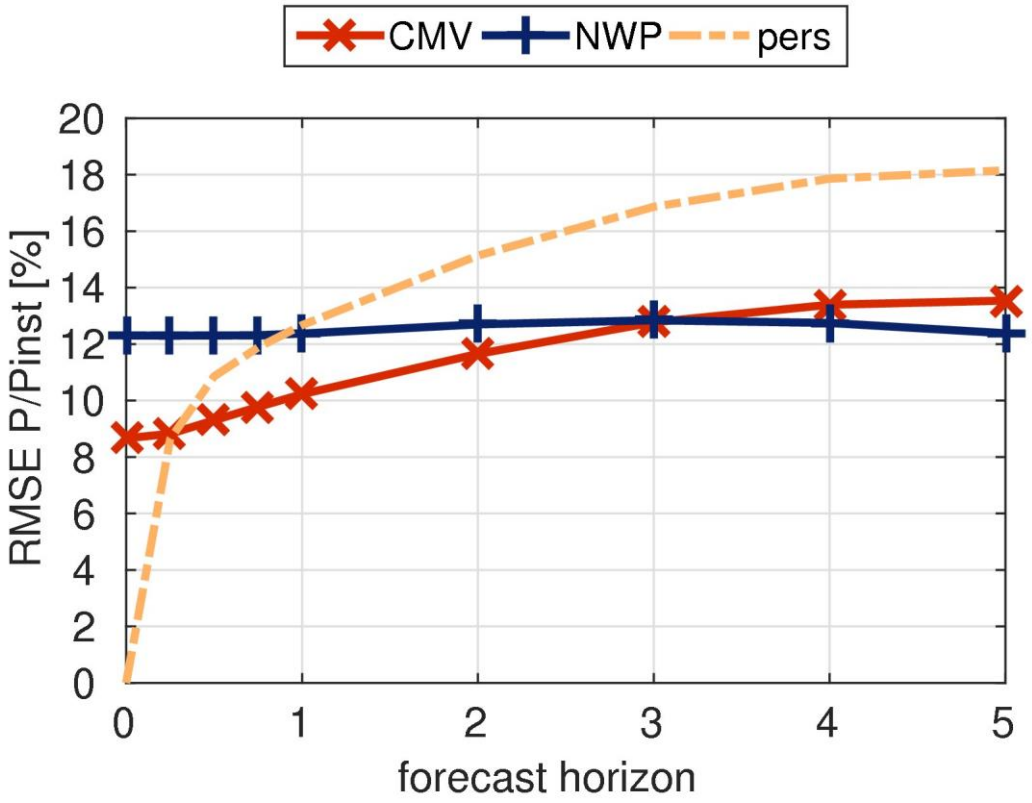
persistence better than CMV forecasts up to 1.5 hour ahead

RMSE in dependence of forecast horizon

German average



Singel site



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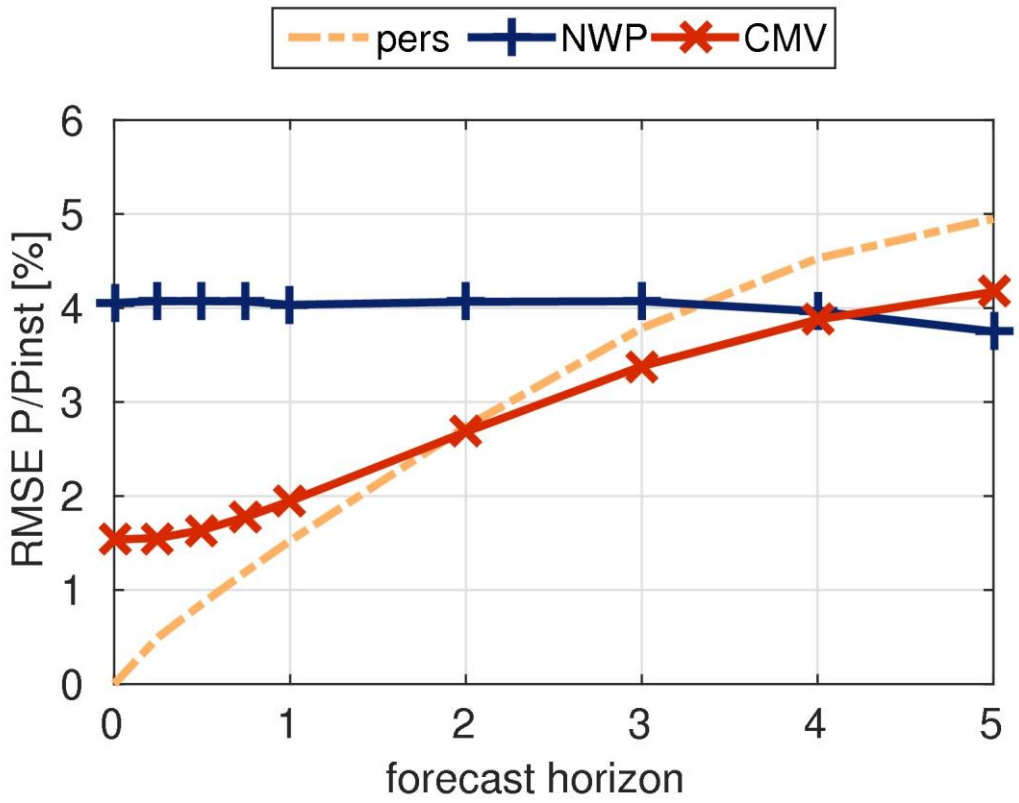
RMSE in dependence of forecast horizon

German average



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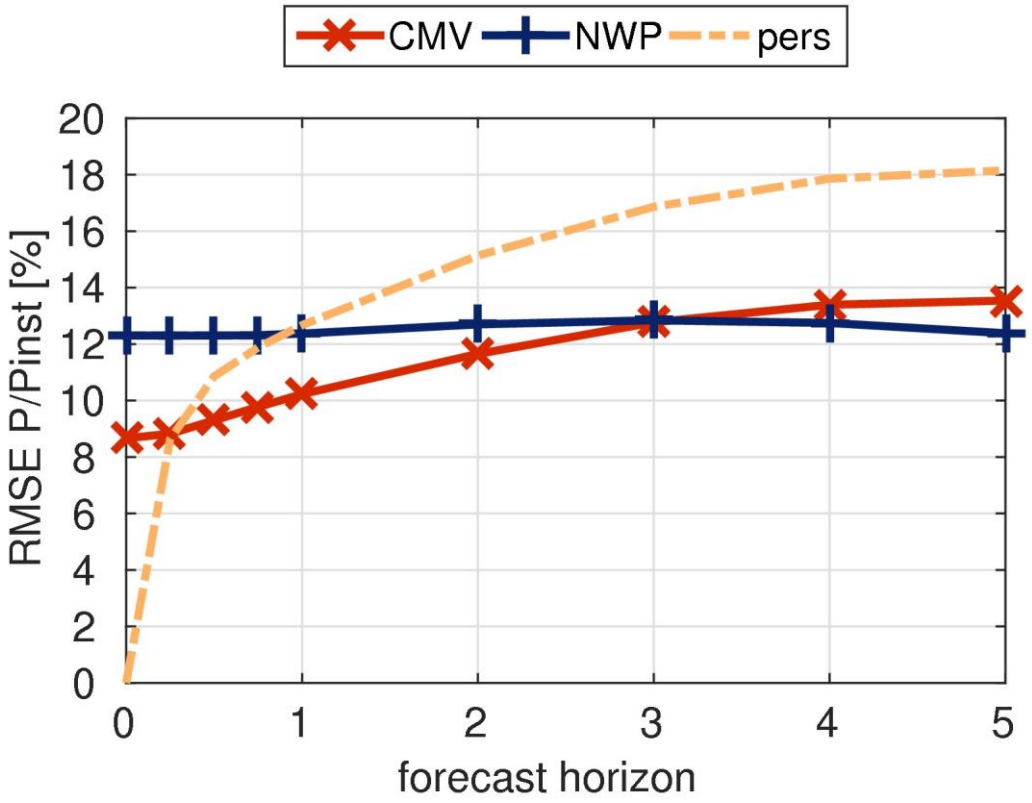

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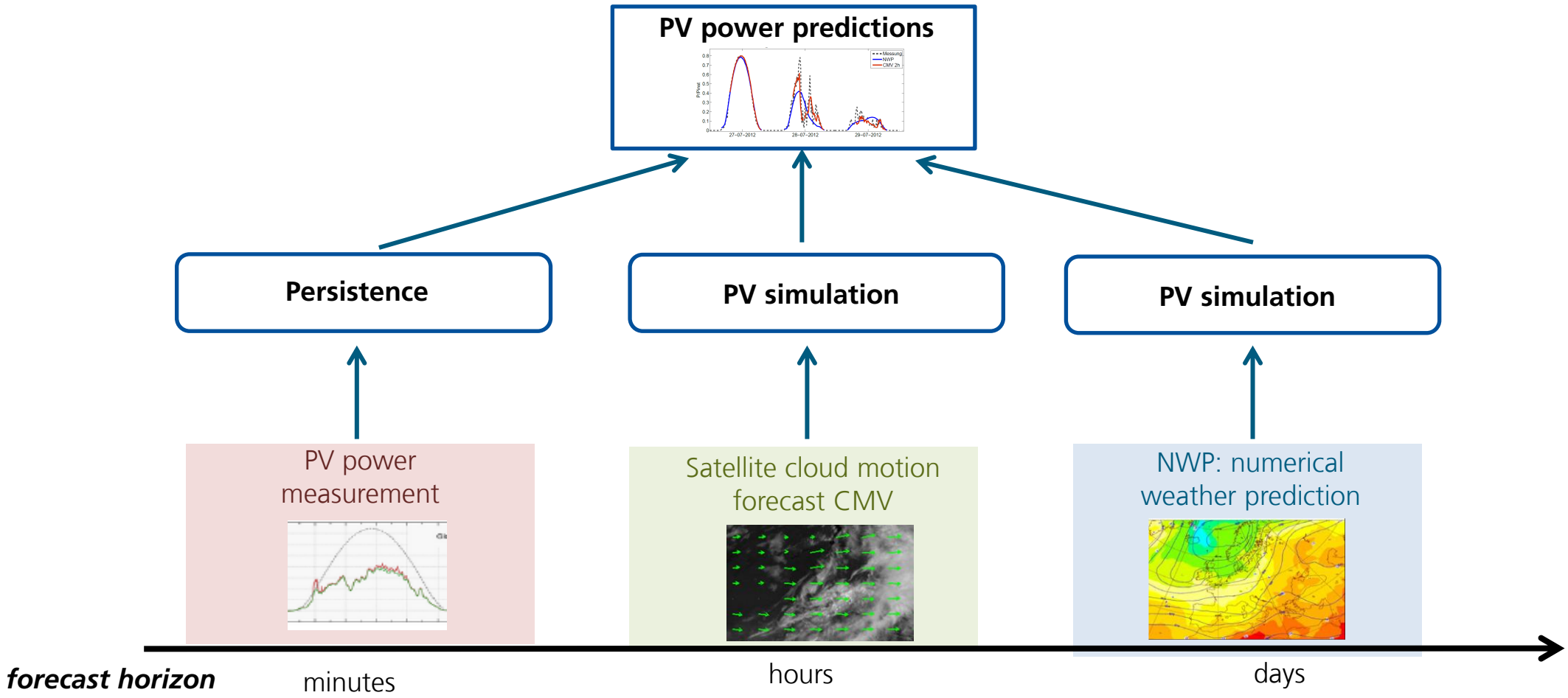
Overview of PV power prediction scheme



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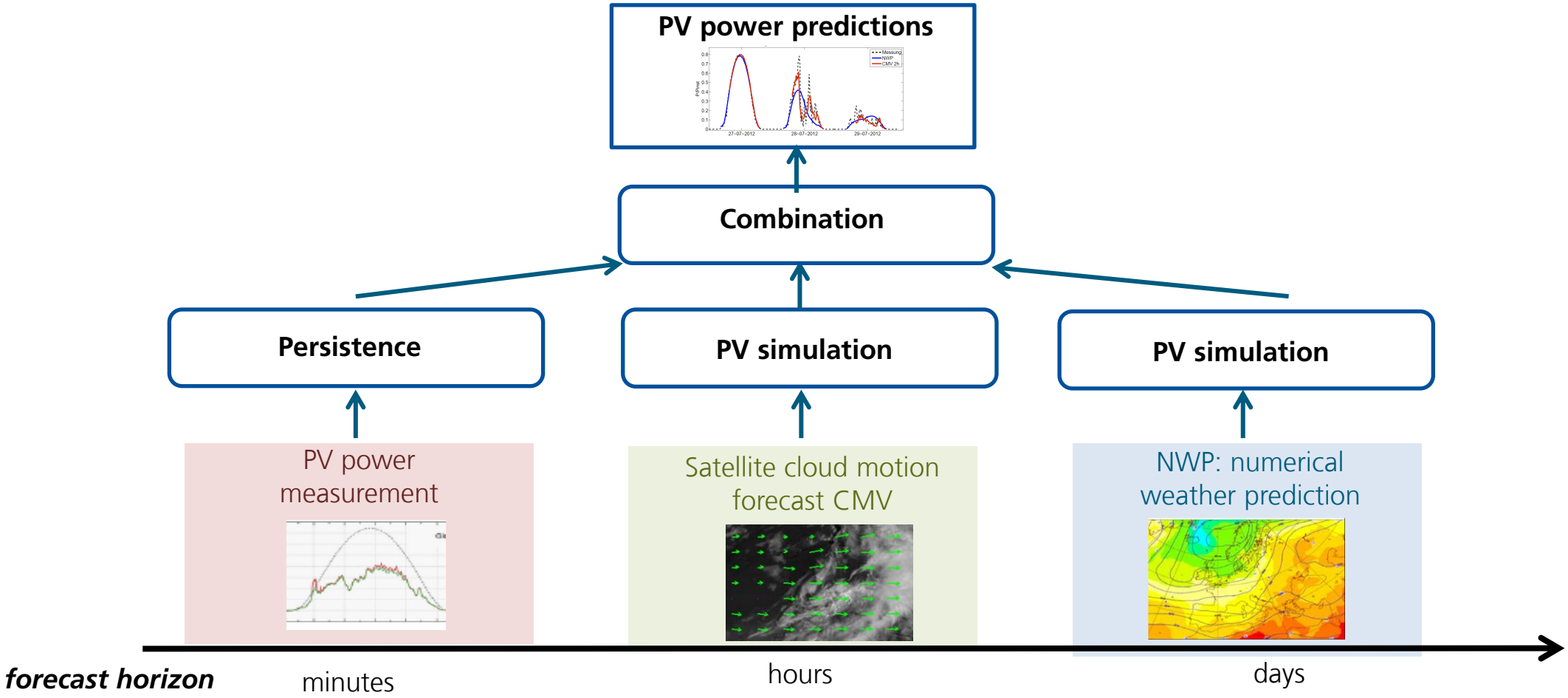

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Combination of forecasting methods

Combination of forecast models with linear regression:

$$P_{combi} = a_{NWP} P_{NWP} + a_{CMV} P_{CMV} + a_{persist} P_{persist} + a_0$$

Coefficients a_{NWP}, a_{CMV}, $a_{persist}$, a_0 are fitted to measured data

What are the influencing factors that determine the weight?

Combination of forecasting methods

Combination of forecast models with linear regression:

$$P_{combi} = a_{NWP} P_{NWP} + a_{CMV} P_{CMV} + a_{persist} P_{persist} + a_0$$

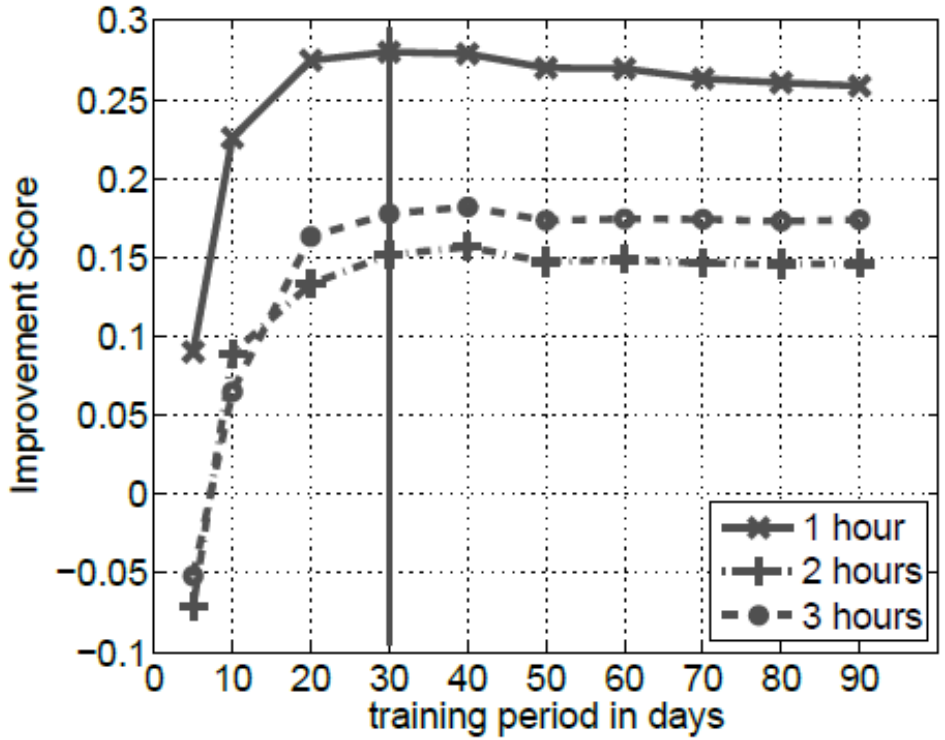
Coefficients a_{NWP}, a_{CMV}, $a_{persist}$, a_0 are fitted to measured data

In dependence:

- Forecast Horizon
- Hour of the day, andforecast horizon

Combination of forecasting methods

How many days to train forecast combination?



Why is it bad, if only few days are used for training?
Why are too many days less favorable?

Improvement score:

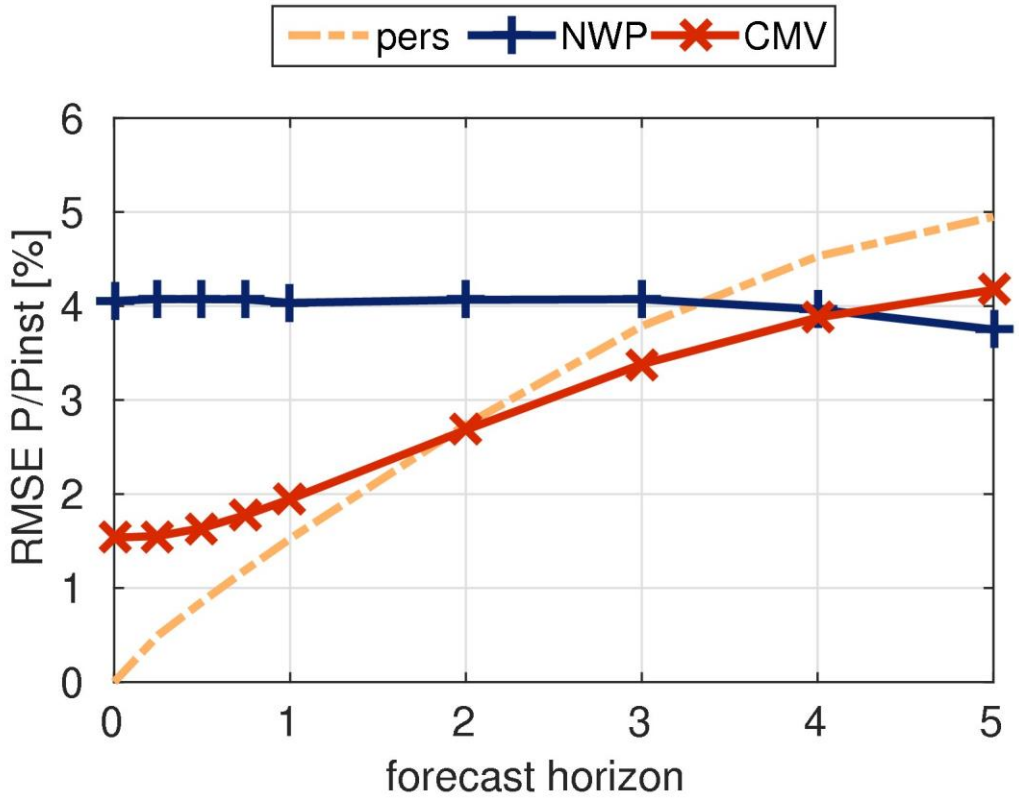
$$\frac{rmse_{ref} - rmse_{combi}}{rmse_{ref}}$$

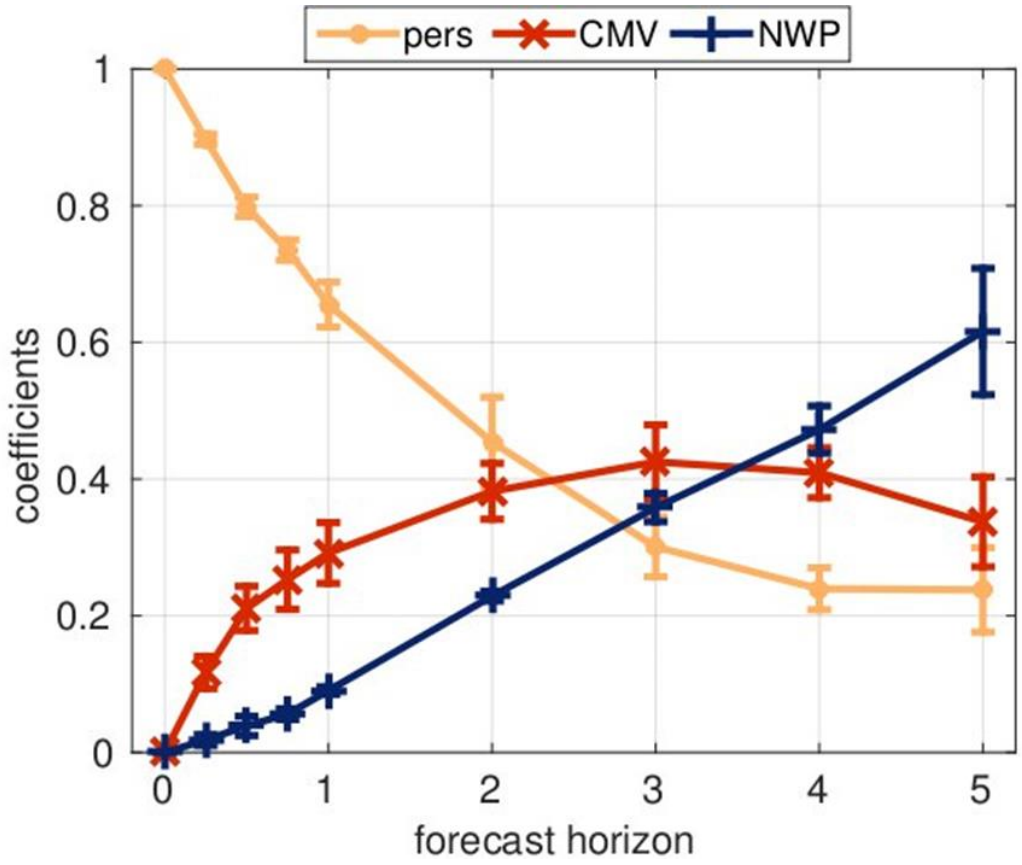
with respect to best single model

Data set:
All sites average, May to November, 2012
independent test year for model configuration

Combination of forecasting methods

Regression coefficients in dependence of forecast horizon





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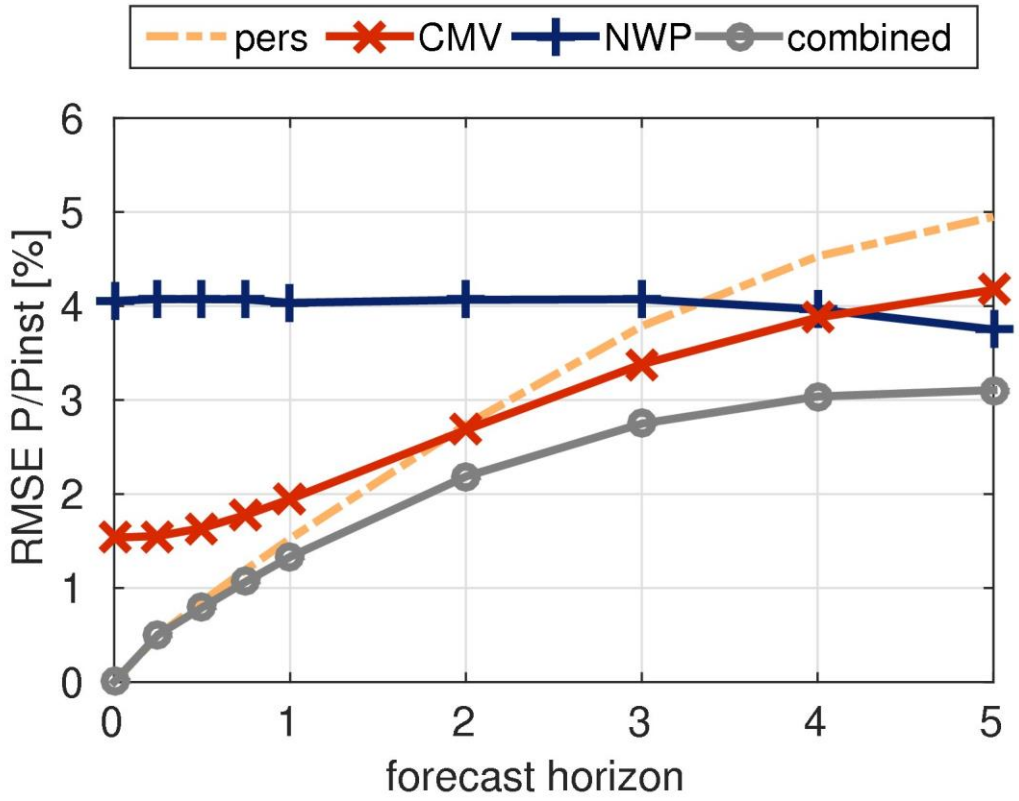
Combination of forecasting methods



Considerable improvement with combined model over single model forecasts

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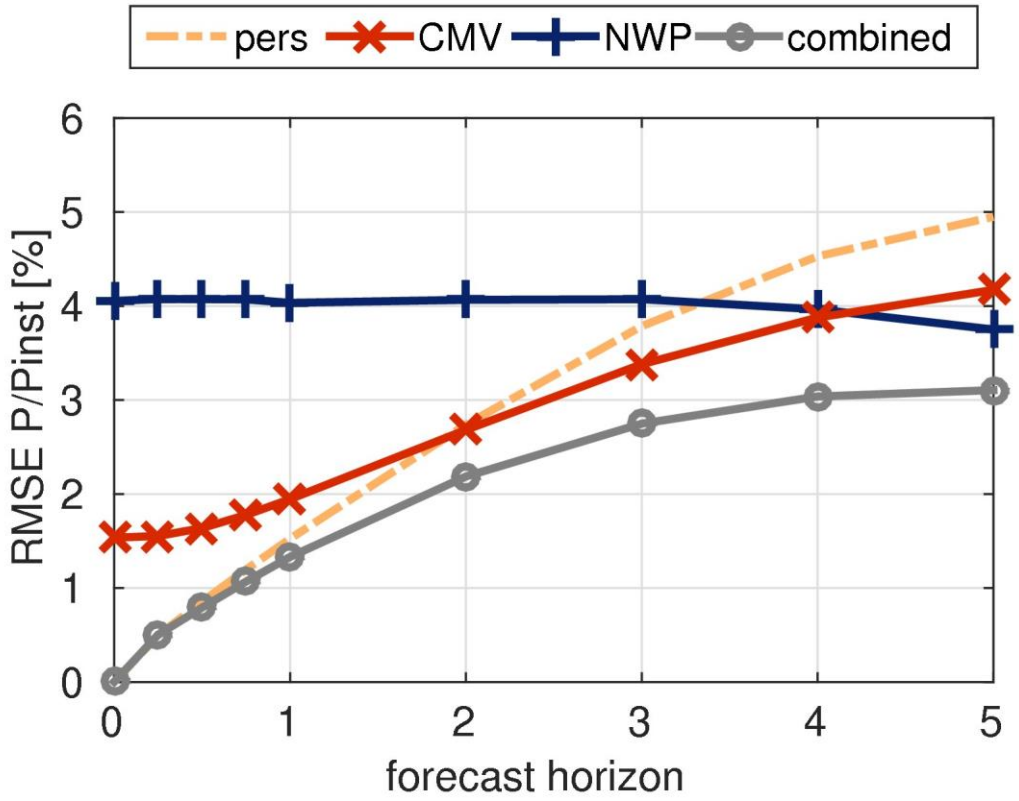
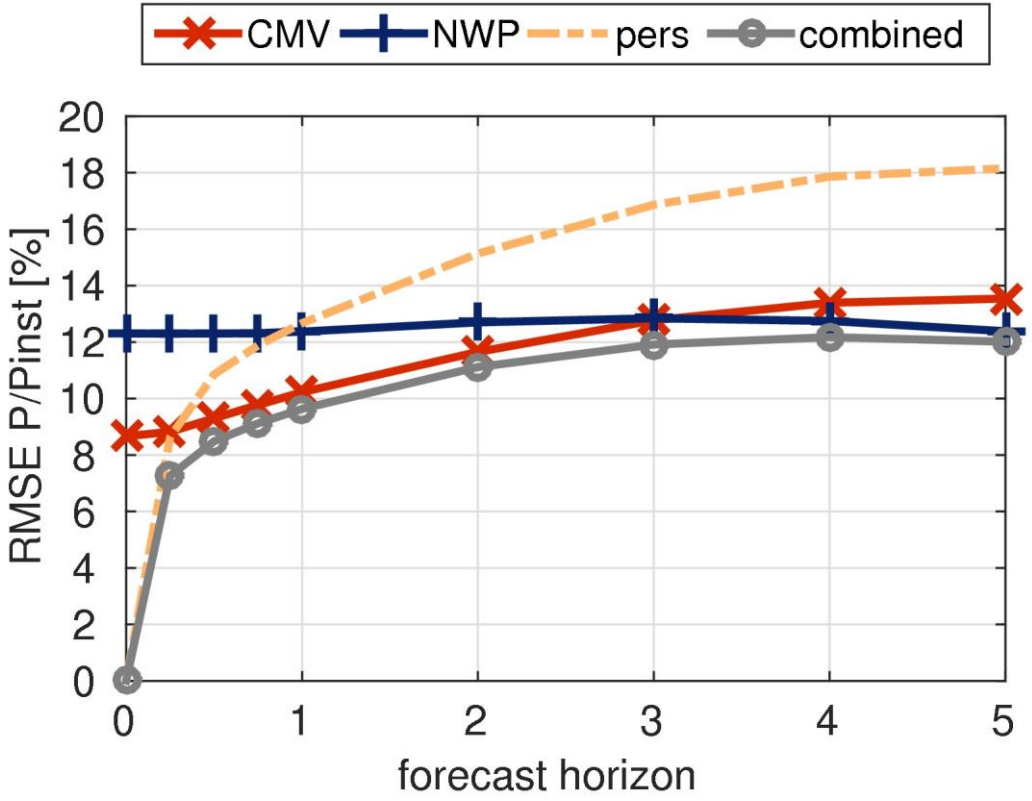
Combination of forecasting methods





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Thank you for your attention!

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