Assimilation of Wind Power Data to Improve Numerical Weather Prediction and Wind Power Prediction

Erstellung innovativer **We**tter- und **Lei**stungsprognosemodelle für die **N**etzintegration wetterabhängiger **E**nergieträger

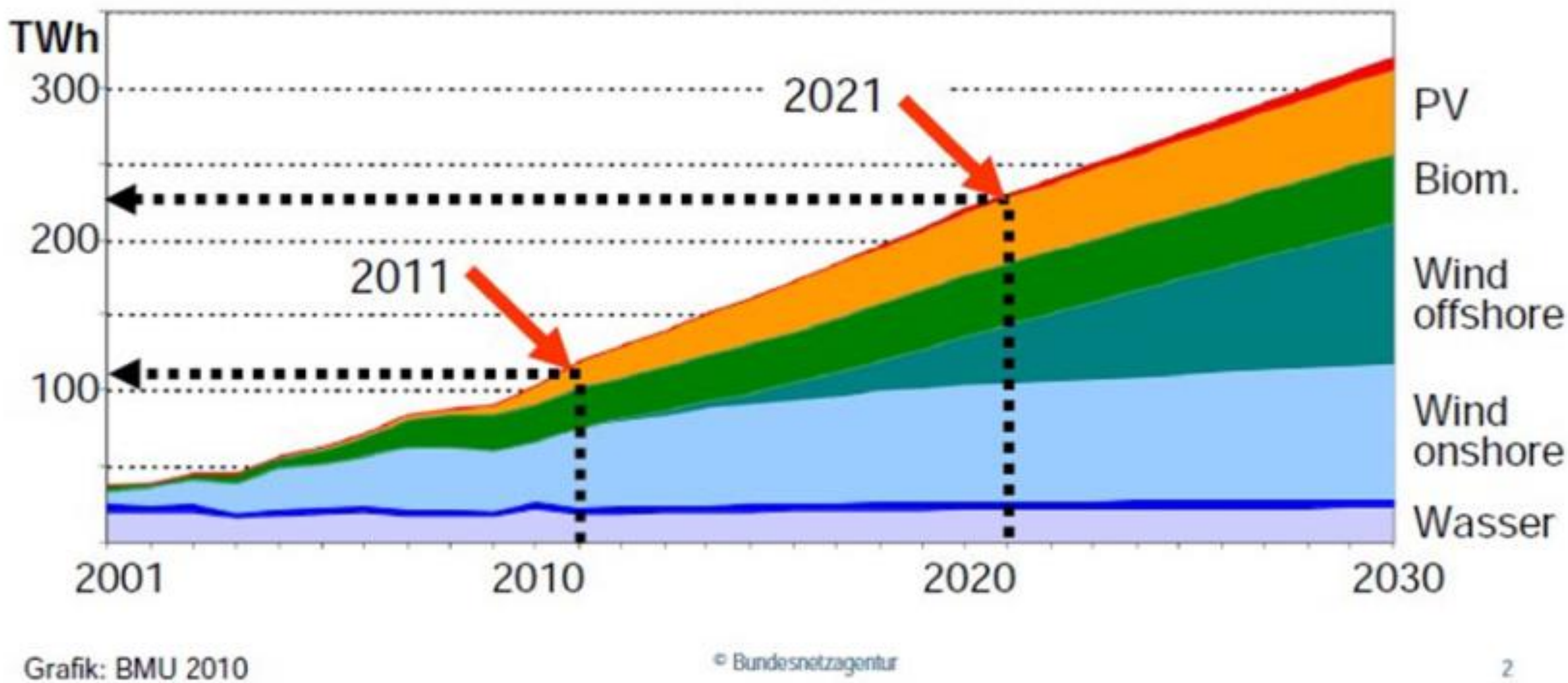
EWeLiNE

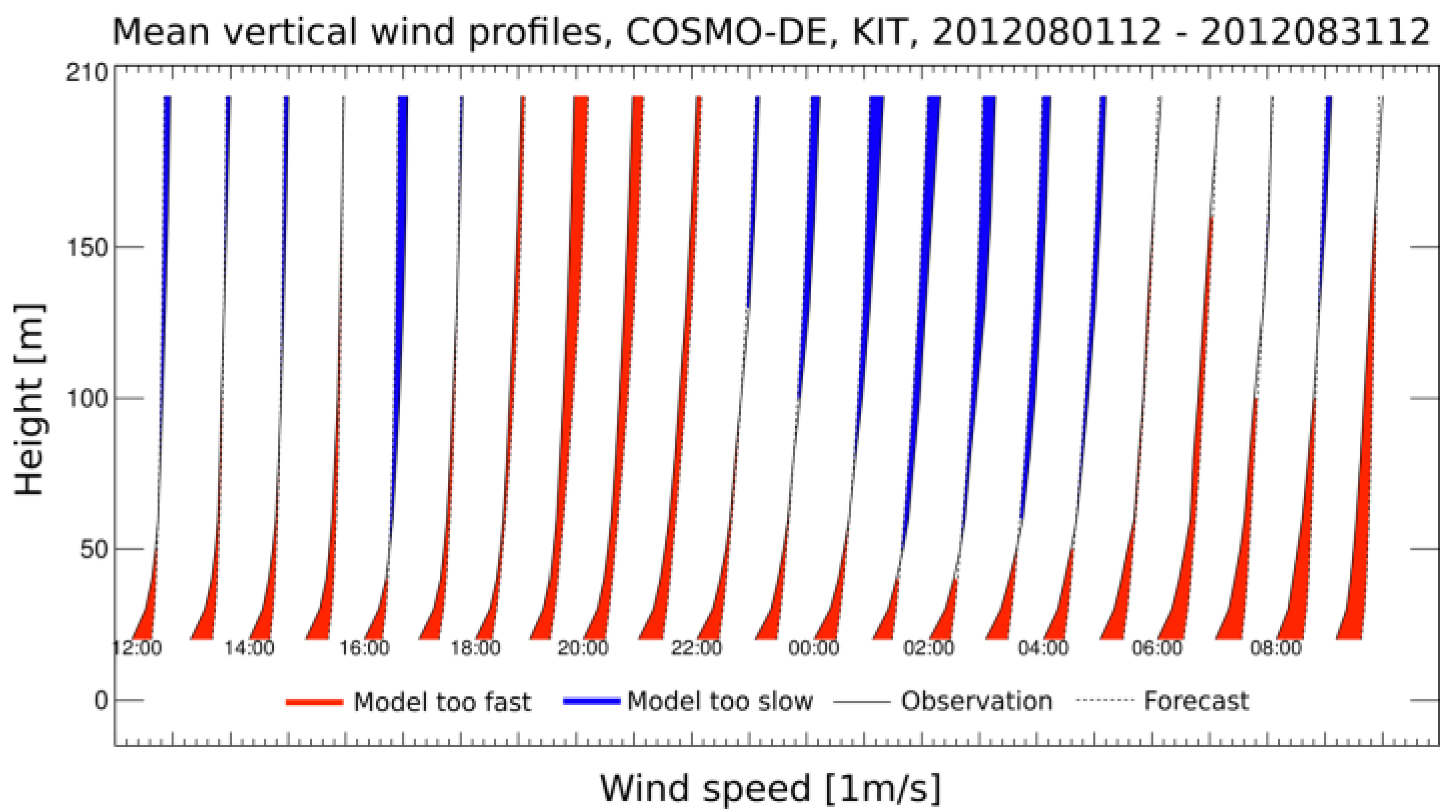
- Eine Kooperation von Meteorologie und Energiewirtschaft -

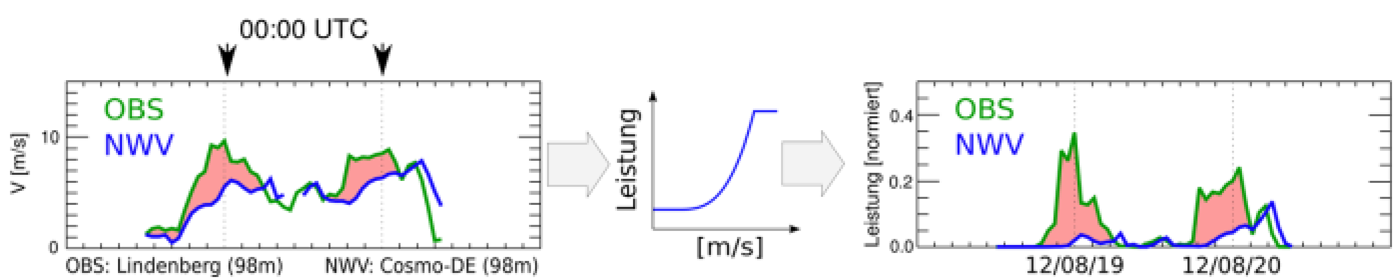
Stefan Declair

EWEA Technology Workshop – Wind Power Forecasting
Rotterdam, December 3rd 2013

Energiewende“ in Gemany: Haves and Wants

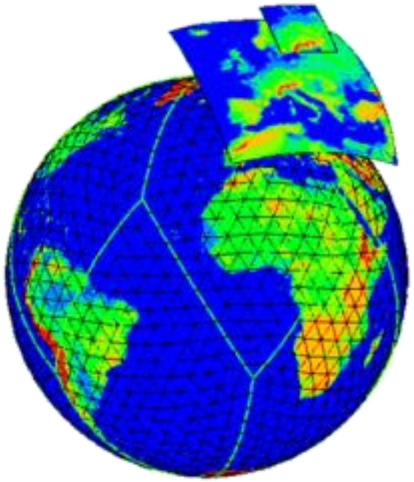



Mean vertical wind profiles, COSMO-DE, KIT, 2012080112 - 2012083112
Height [m]
210
150
100
50
0
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
08:00
Model too fast
Model too slow
Observation
Forecast
Wind speed [1m/s]


00:00 UTC
OBS
NWV
V [m/s]
10
0
OBS: Lindenberg (98m)
NWV: Cosmo-DE (98m)
Leistung
[m/s]
Leistung [normiert]
0.4
0.2
0.0
OBS
NWV
12/08/19
12/08/20

Who is EWeLiNE?

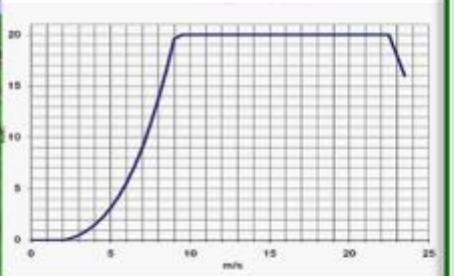
Weather forecasts
(wind, radiation fluxes,…)



Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Post-processing

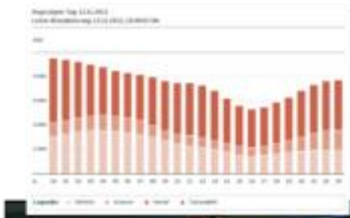
Transformation in power



Taking into account effects of e.g.:
- atmospheric stability
- orography
- wakes

Fraunhofer IWES

Power forecasts for decision making processes



50hertz
amprion
TenneT
Taking power further

Agenda

1. Data Assimilation

2. Data Situation

3. Impact-Study

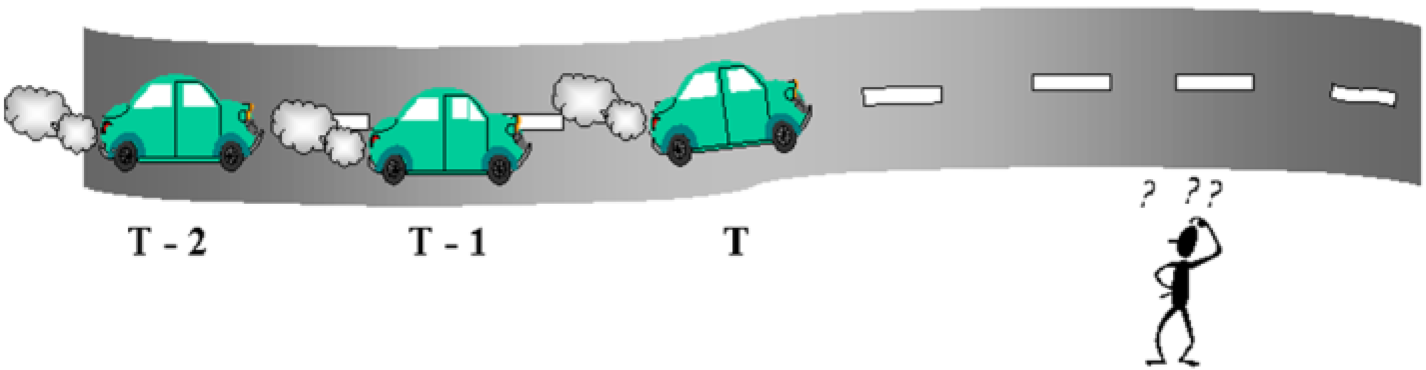
Agenda

1. **Data Assimilation**

2. Data Situation

3. Impact-Study

Forecast: Can i cross the street without getting hit?



Information used:

- Observations
- Knowledge about cars, street, etc
- Experience → statistics

Forecast errors due to:

- Observation (estimation) errors
- Model errors (icy street)
- Case does not match statistics

LETKF

- Goal: compute a best-fit initial state for the next model integration step
- Method: **L**ocal **E**nsemble **T**ransform **K**alman **F**ilter
  - **L**ocal: localizes spatially around observations
  - **E**nsemble **T**ransform: works in ensemble space
  - **K**alman **F**ilter: tracks means and covariances

Cost function to minimize

$$J(x) = X^{b} P^{b^{-1}} X^{b^{T}} + [y^{o} - H(x)]^{T} \underline{\underline{R}}^{-1} [y^{o} - H(x)]$$

minimize in $\tilde{S}$

$$\overline{w}^{a} = \tilde{P}^{a} Y^{b^{T}} R^{-1} (y^{o} - \overline{y}^{b}) = K(y^{o} - \overline{y}^{b}) \qquad \tilde{P}^{a} = \left[(k-1)\mathrm{I} + Y^{b^{T}} R^{-1} Y^{b} \right]^{-1}$$

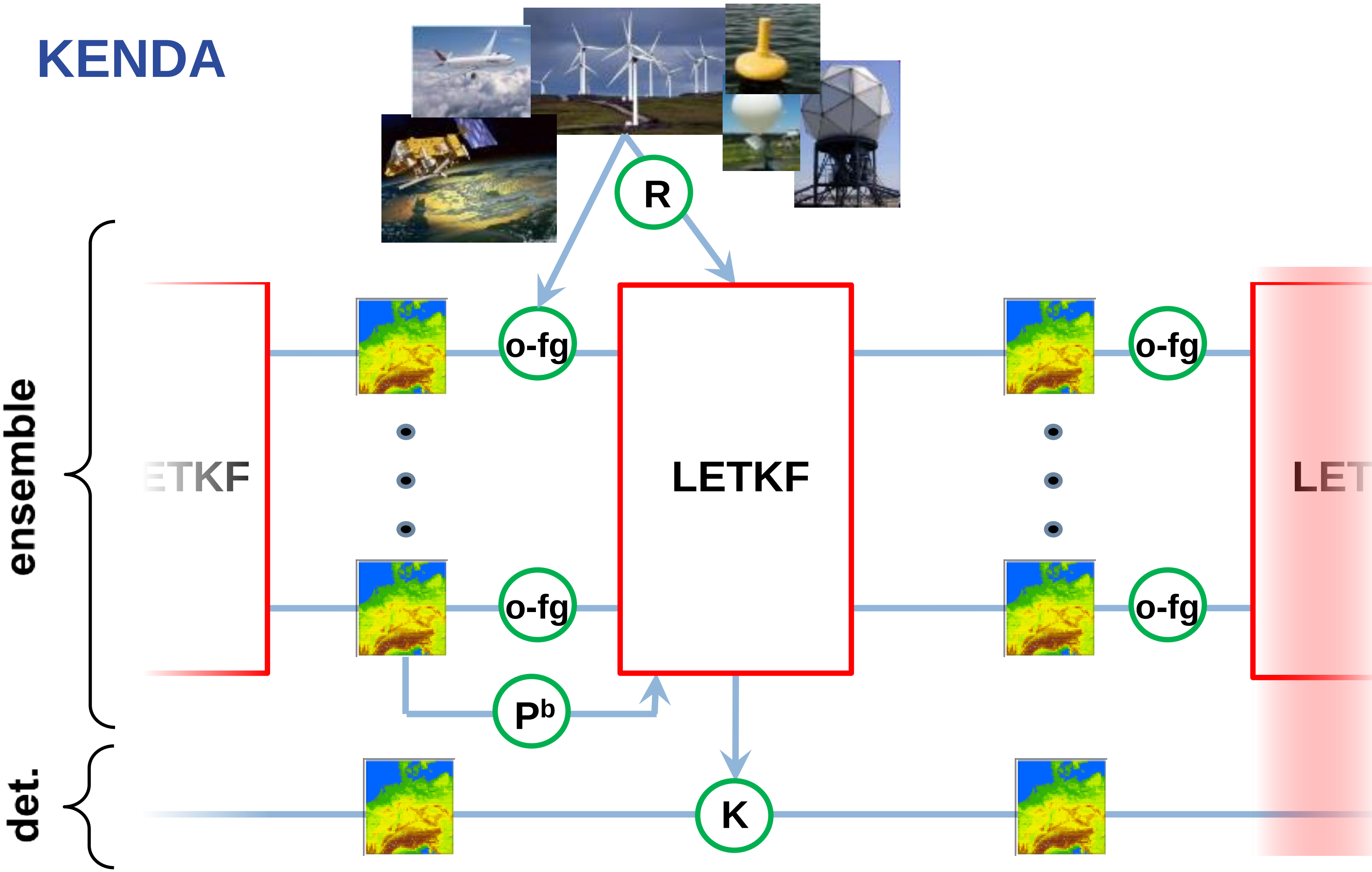
transform to observation space

$$x^{a(i)} = \overline{x}^{b} + X^{b} w^{a(i)} \qquad P^{a} = X^{b} \tilde{P}^{a} X^{b^{T}}$$

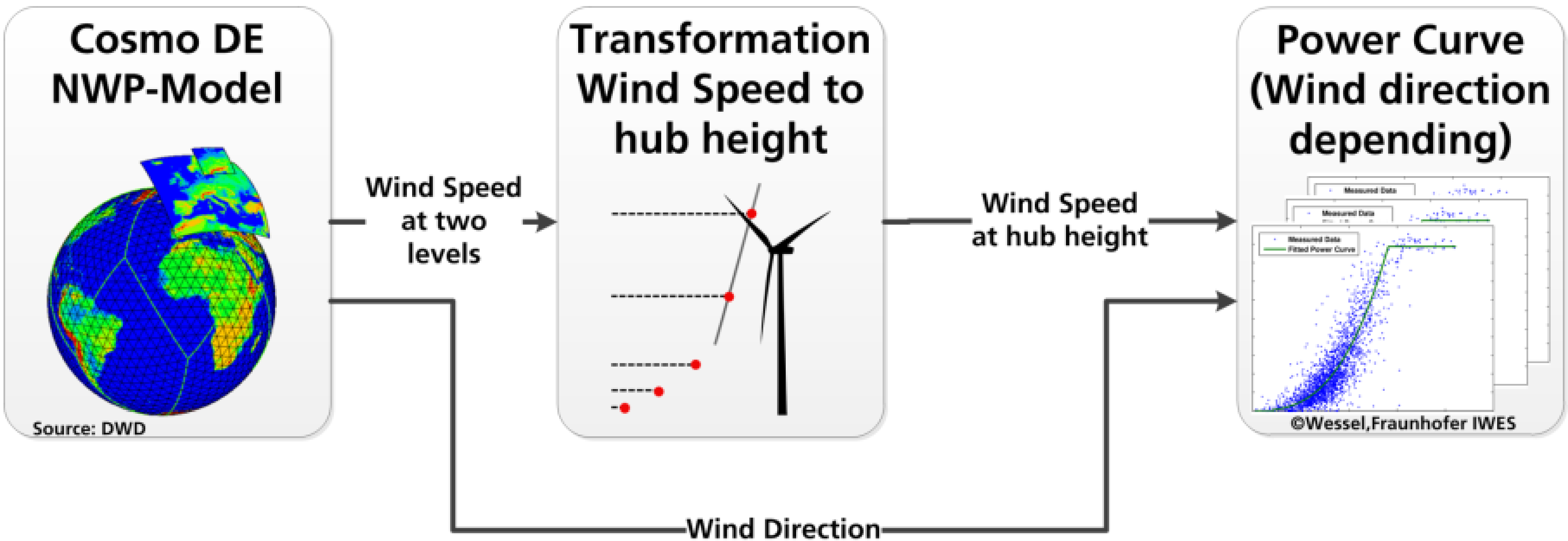
KENDA – Kilometer-scale Ensemble Data Assimilation

- Priority program within COSMO consortium
- LETKF for the nonhydrostatic COSMO-DE model of DWD
- Implementation following *Hunt et al., 2007*
- Basic Idea: perform the analysis in the space of the ensemble pertubations
  - computationally efficient, but also restricted to do corrections to space spanned by the ensemble
  - explicit localization
  - analysis ensemble members are local linear combinations of the first guess ensemble members

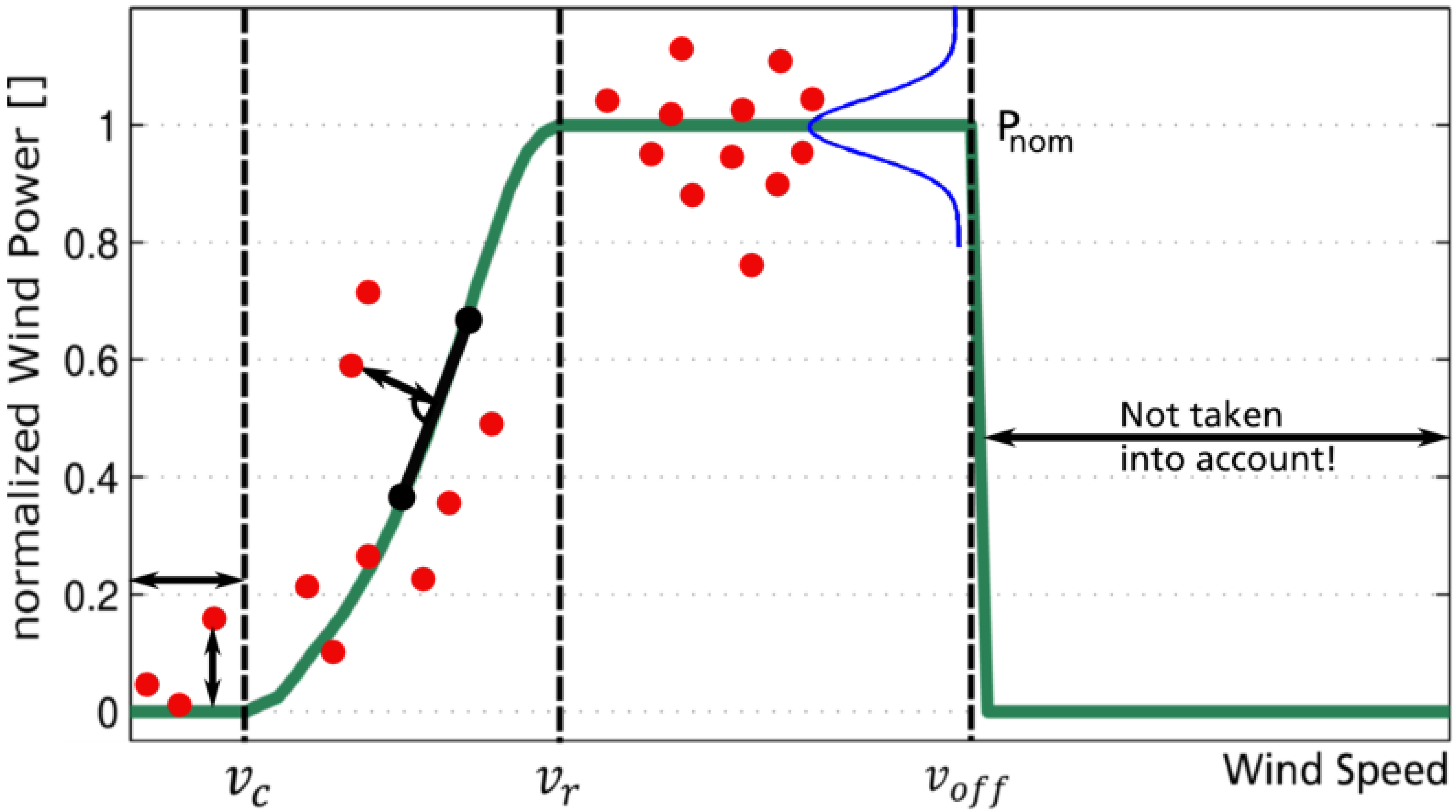
KENDA



Forward Operator – Process chain



Forward Operator – Powercurve Fit



Forward Operator - Example

Input

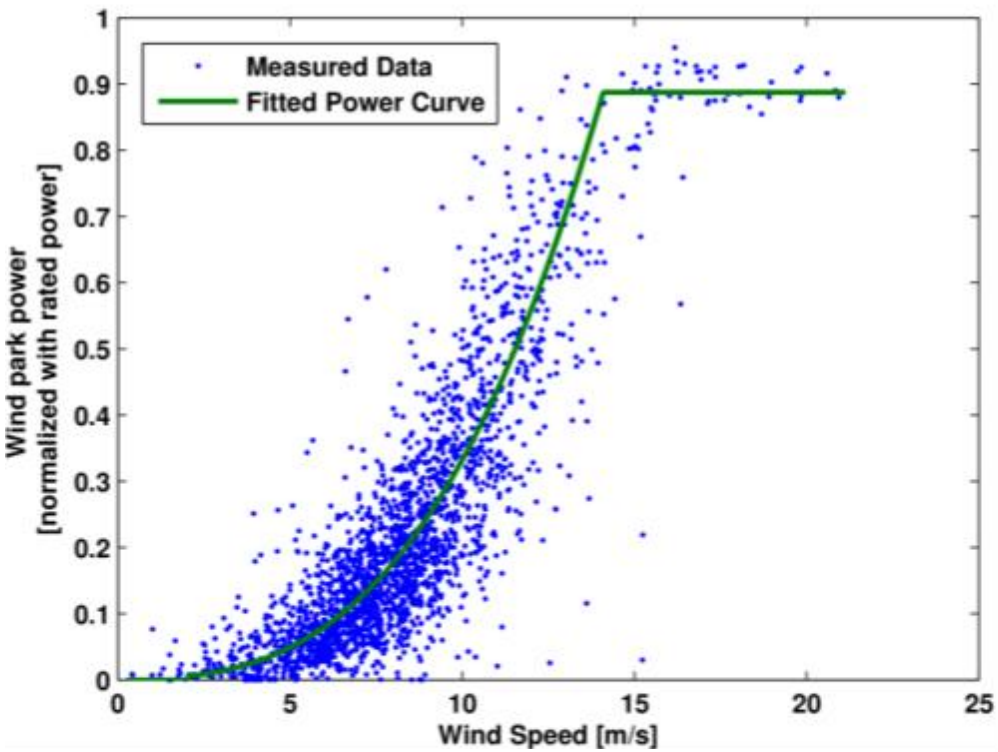
- Wind speed/direction from COSMO-DE Analysis
- Power observations

Cost function

- Depending on orthogonal distance between data points and objective function

Results

- Wind direction sector 190°-250°
  - RMSE=10.1%



Agenda

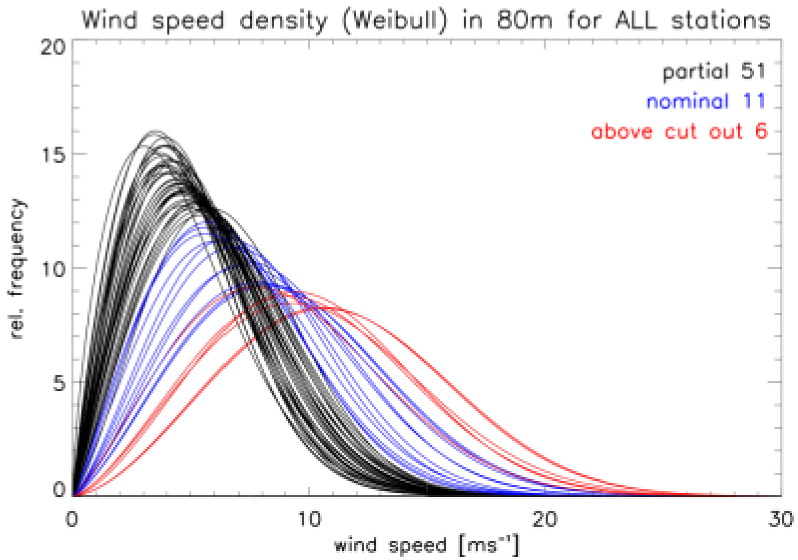
1. Data Assimilation

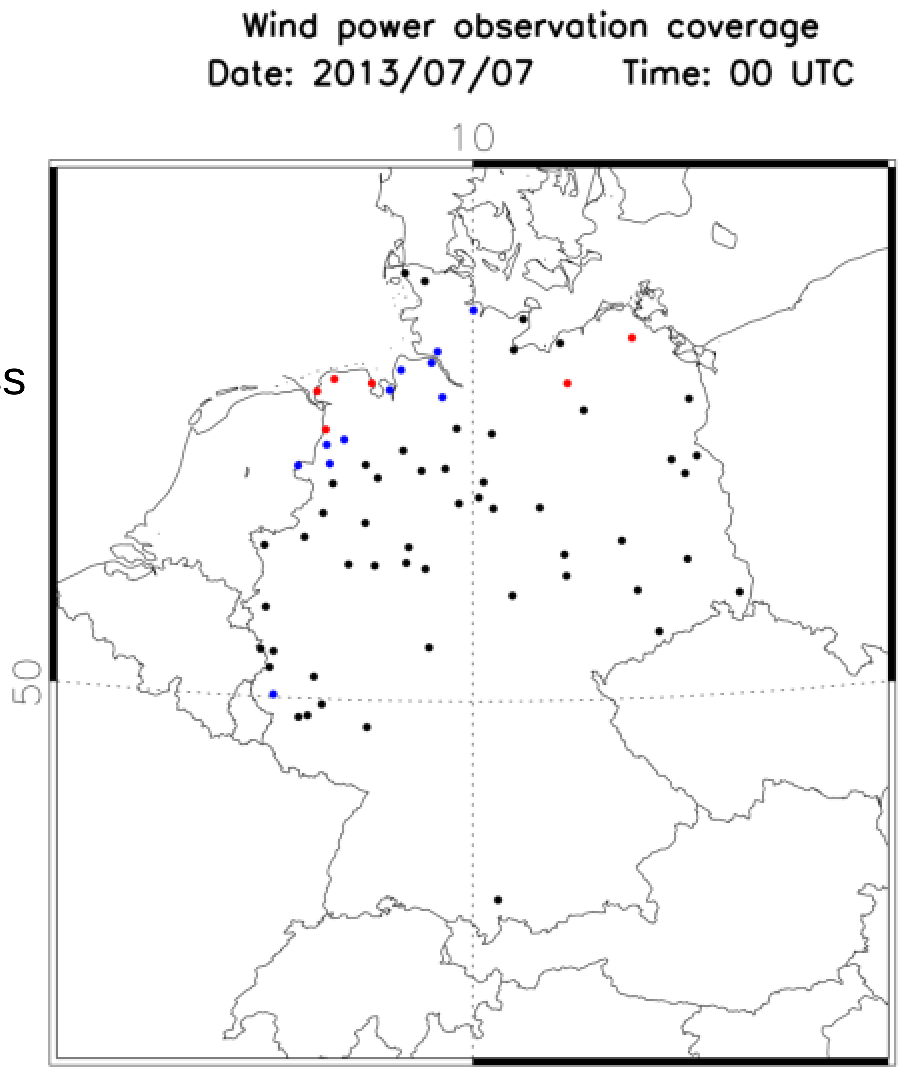
2. **Data Situation**

3. Impact-Study

Data - Haves

- 68 wind farms, node-sharp
- 15min resolution/10min delay
- Average hub heights, farm point of mass
- Installed farm nominal power

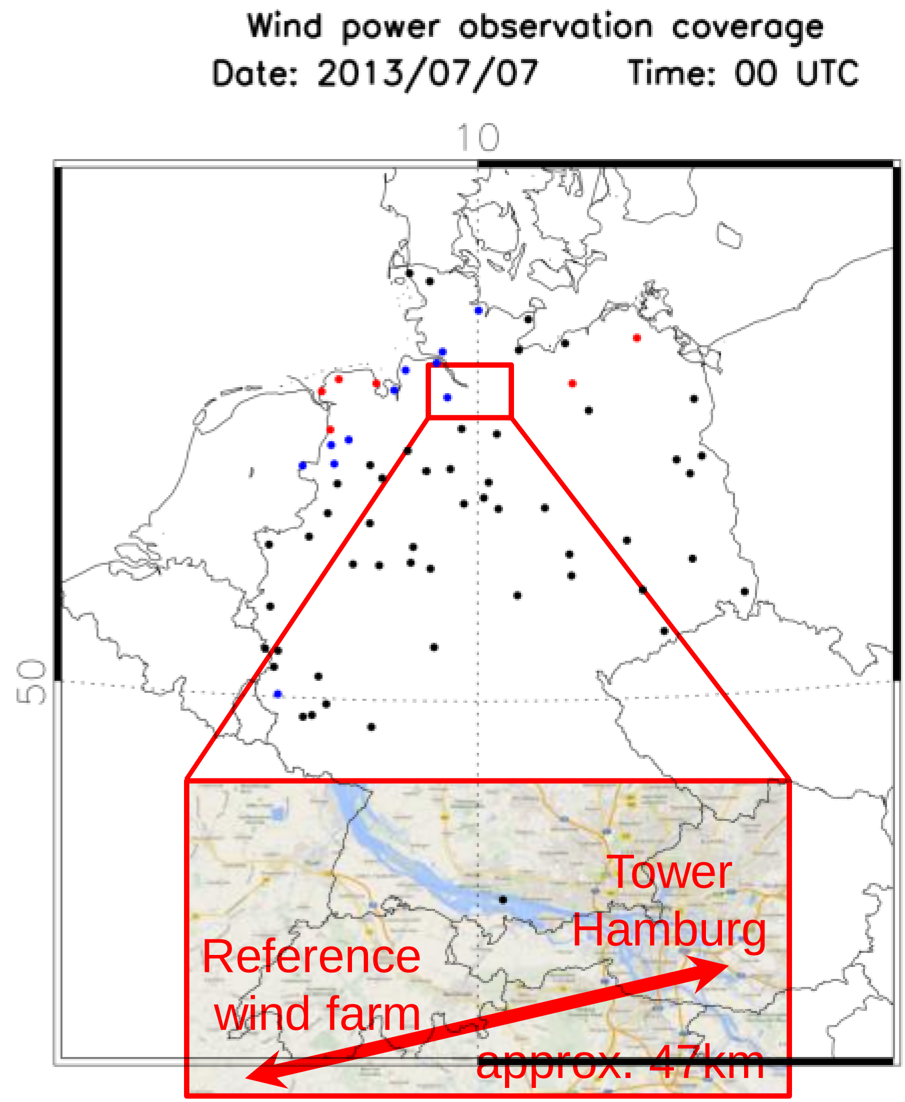




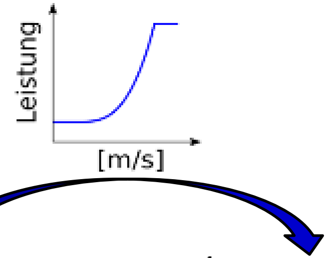
Data - Comparison

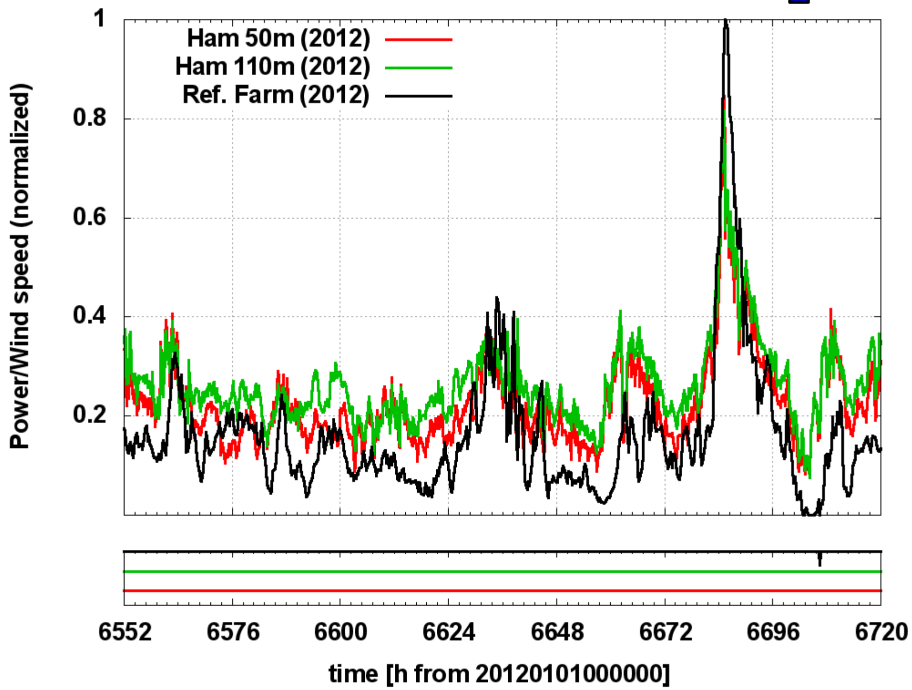
- Wind observations
  - University of Hamburg
    - Height 50+110m
    - Available from 2005/01/01
    - 10min temporal resolution

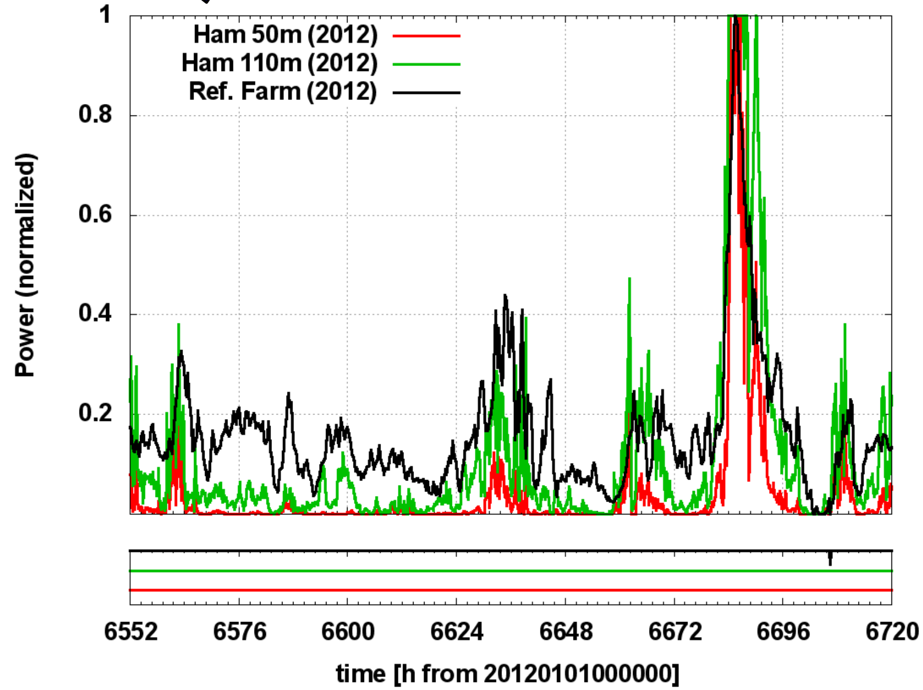
- Power observations
  - Reference wind farm
    - Average hub height 67m
    - Available from 2012/01/01
    - 15min temporal resolution



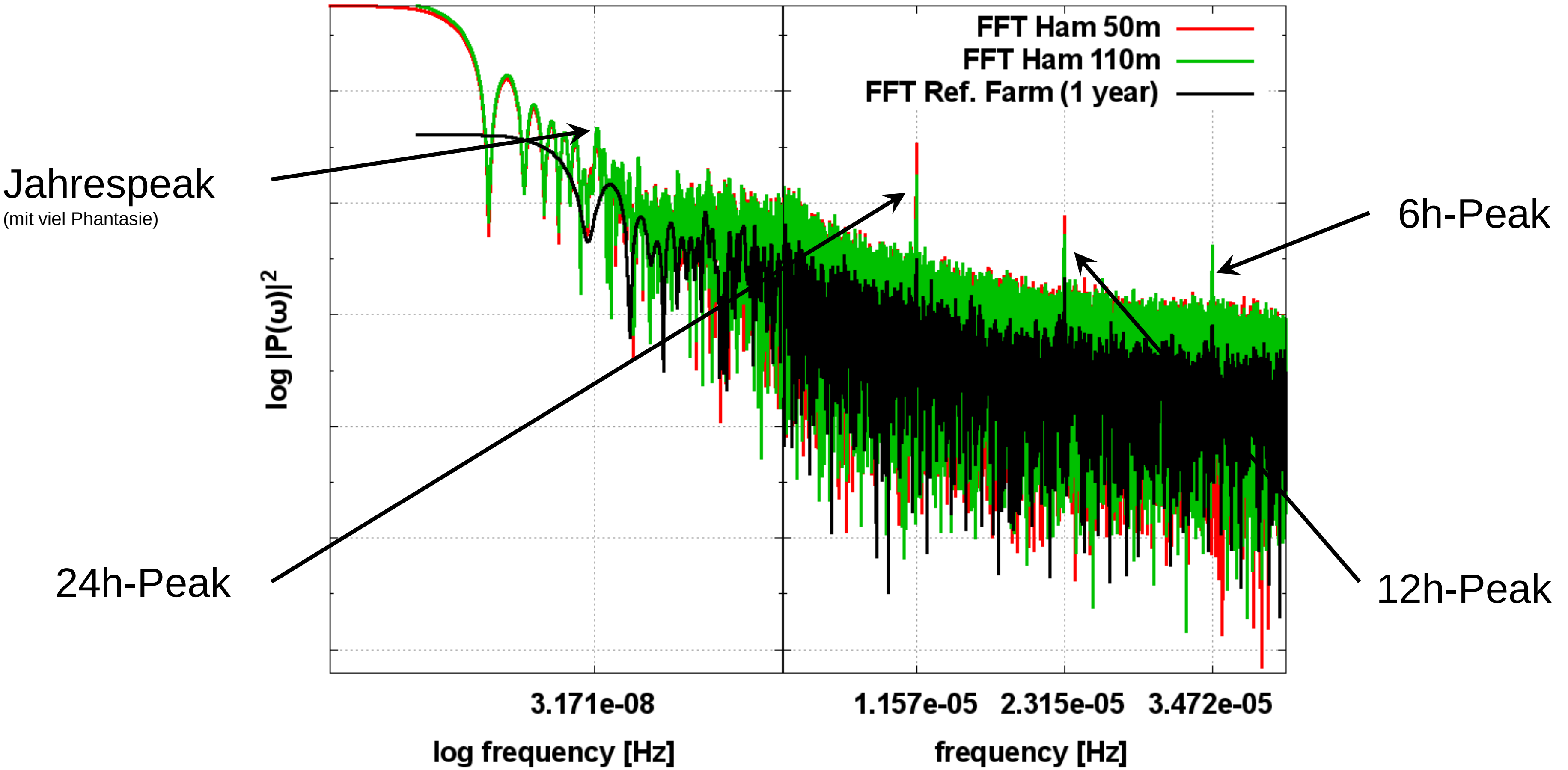
Data - Comparison







Data - Comparison



Data - Wants

Additional information needed…

- Average hub distance
- Average blade radius
- Hub alignment

} account wake effects

- Information content outside of partial power
- Hub activity
- Losses between farm (hubs) and nodes

} increase information density

…because all the uncertainties enter the LETKF via the observation error covariance matrix

→ reduce uncertainties

Agenda

1. Data Assimilation

2. Data Situation

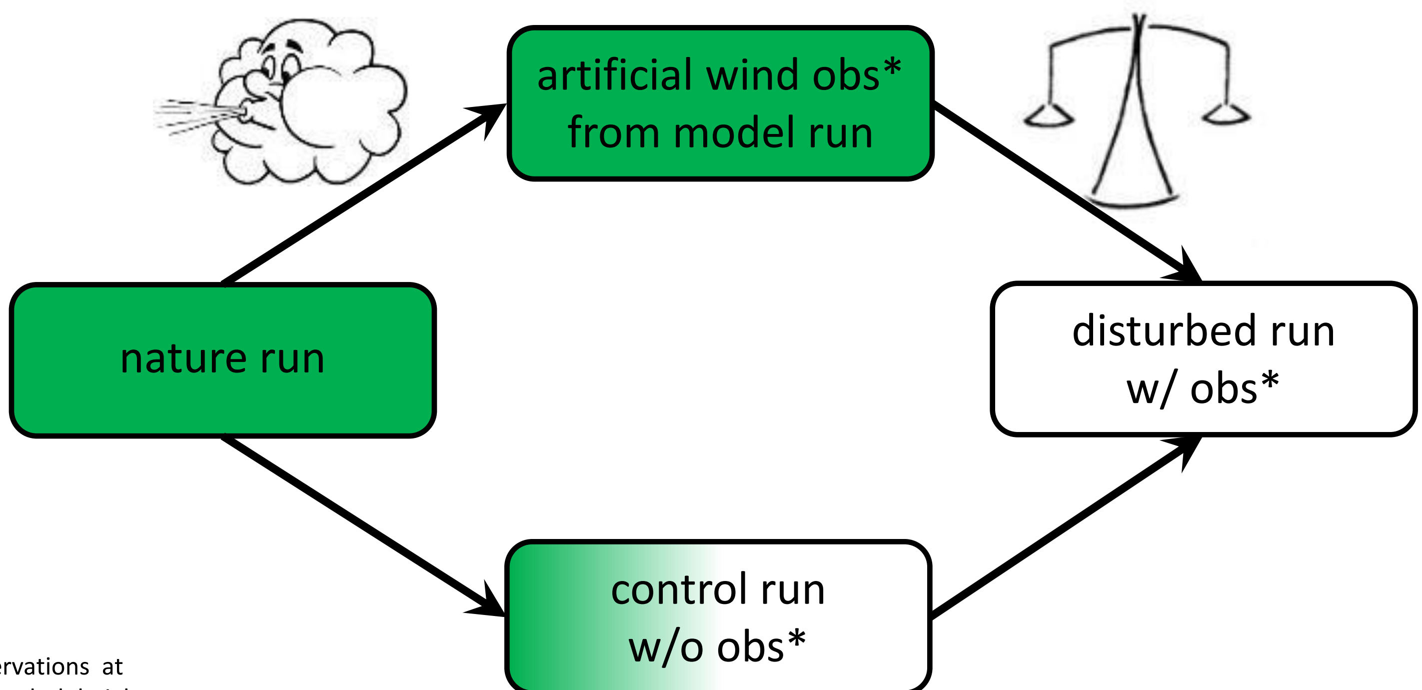
3. **Impact-Study**

OSSE – Observation System Simulation Experiment

- Goal: Test the impact of newly available observations in the data assimilation
- Method: assimilate artificial observations in slightly perturbed truth
- Advantages:
  - Truth is known exactly
  - All generated fields can be used as observations
  - Observation system can be altered easily
    - Observation errors
    - Observation densities
    - Temporal resolution/delay


OSSE – Observation System Simulation Experiment

- Current state



* obs: wind observations at average wind farm hub height

Conclusion

- Data assimilation
  - KENDA: LETKF data assimilation scheme in COSMO-DE
  - Forward operator: lookup table approach in progress
- Data situation
  - Available data are of good quality
  - More detailed information necessary to reduce uncertainty for LETKF
- OSSE
  - Determine the impact of a new observation system
  - Work in progress

Thank you for your attention!