Operational Wind Power Forecasting
Experiences from Europe, North America and Australia

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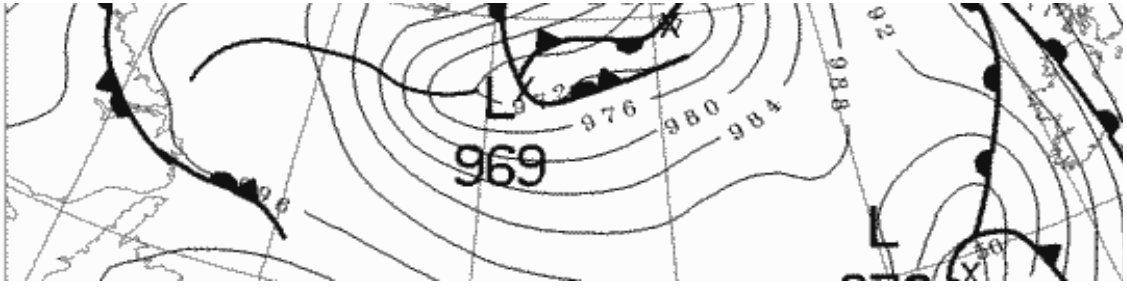
International Workshop on Wind Power Forecasting

Portland
July 24 -25, 2008



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Overview

- Introduction
- What we as the forecaster can do to provide good forecasts
- What the customer can do to support good forecasts
- Outlook

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Company profile

- Integration of renewables into grids and markets
- Service provider for energy meteorology since 2004
- Areas of business
  - Operational wind and solar power predictions worldwide
  - Platform for trading of wind power on wholesale markets
  - Decentralized energy management / demand side management
  - Development
    - Industry projects
    - European research project
- Member of ANEMOS consortium

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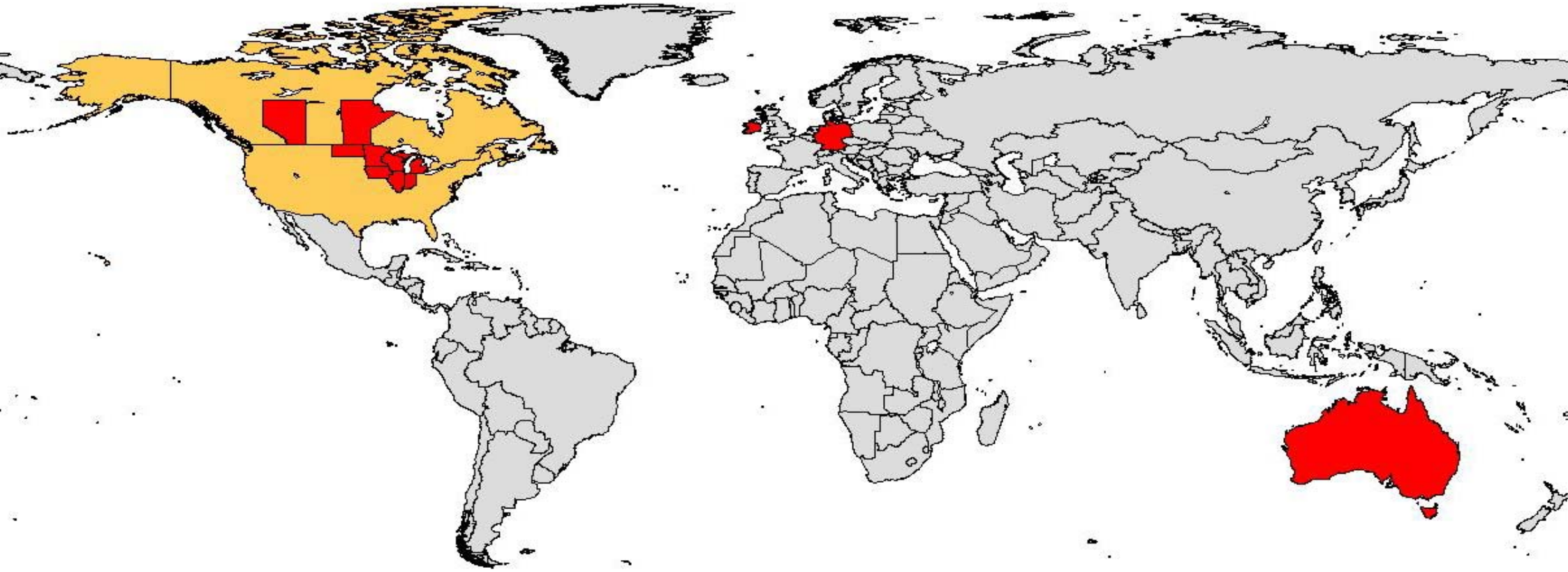
Areas with operational forecasting experience

- 28 GW of installed wind power currently predicted



Previento wind power forecasting for grid operators

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Choice of international customers

EnBW

EIRGRID

SONI
Systems Operator for Northern Ireland

RWE

aeso
ALBERTA ELECTRIC SYSTEM OPERATOR

VATTENFALL

MidwestISO

EWE

NEMMCO

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Focus today

How to produce optimal wind power forecasts

Lessons learned in Europe, Canada and Australia

- Best possible weather model input
- Advanced and robust forecasting system
- Meteorological know-how to tune the models
- Excellent measurement data: historical as well as online

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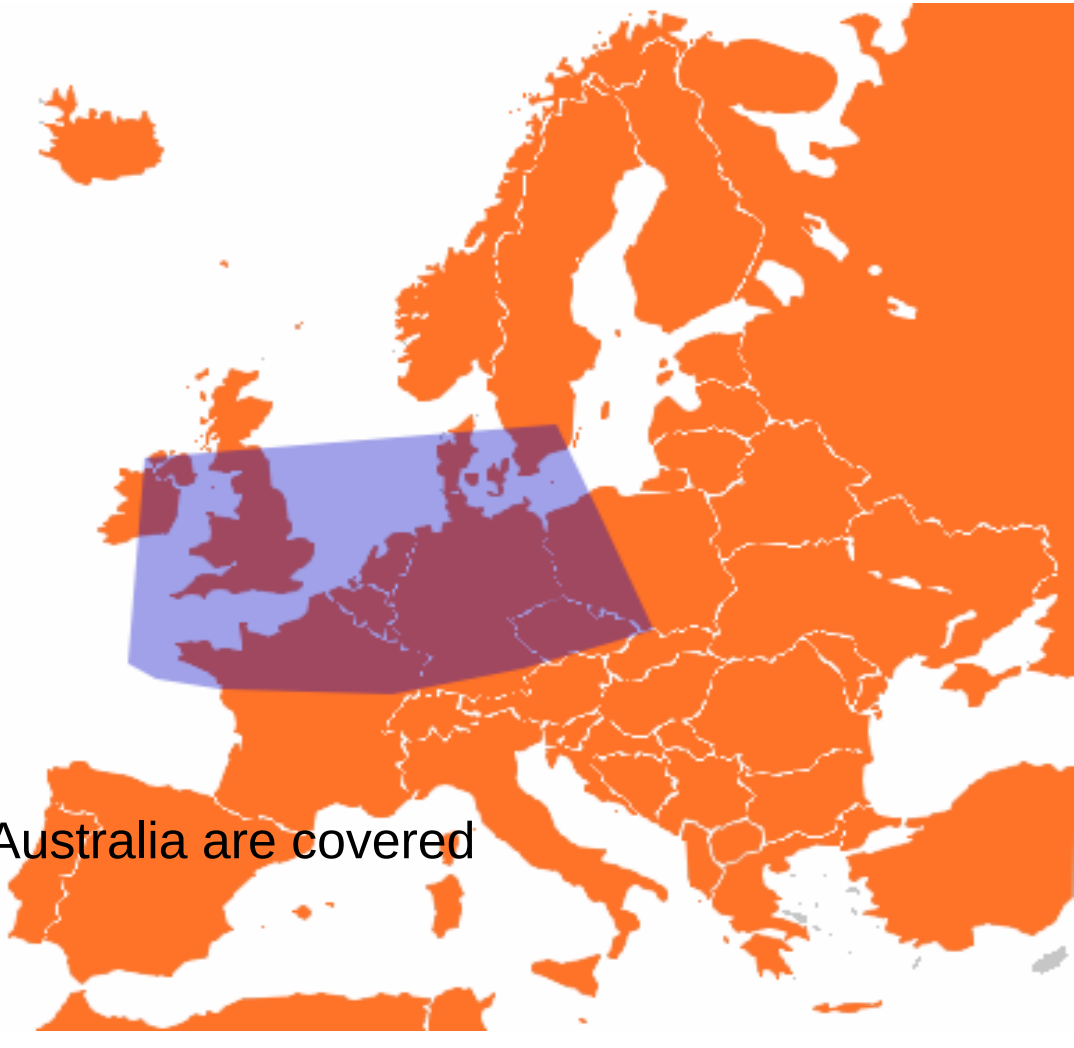
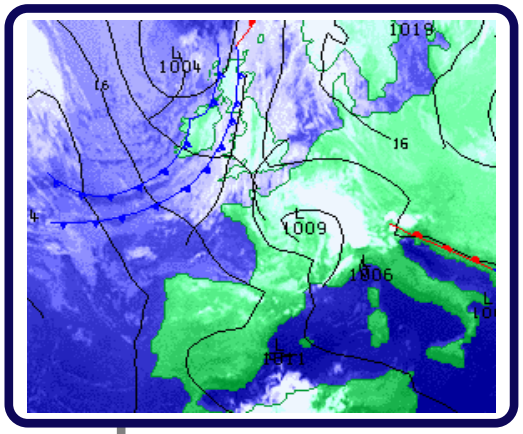
Best possible weather model input

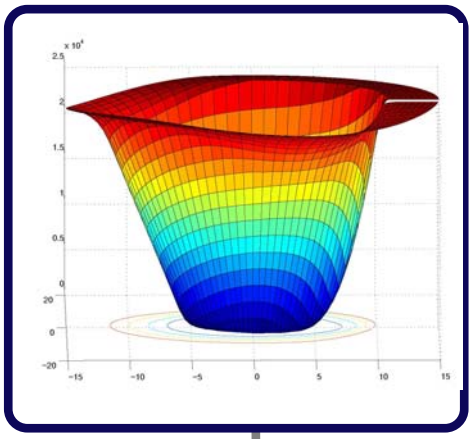
- Multi-model input: Select three to four established numerical weather models (NWP) covering the area of the wind farms



Many parts of Europe, North America and Australia are covered by at least two NWP models.

Previento – the physical prediction system

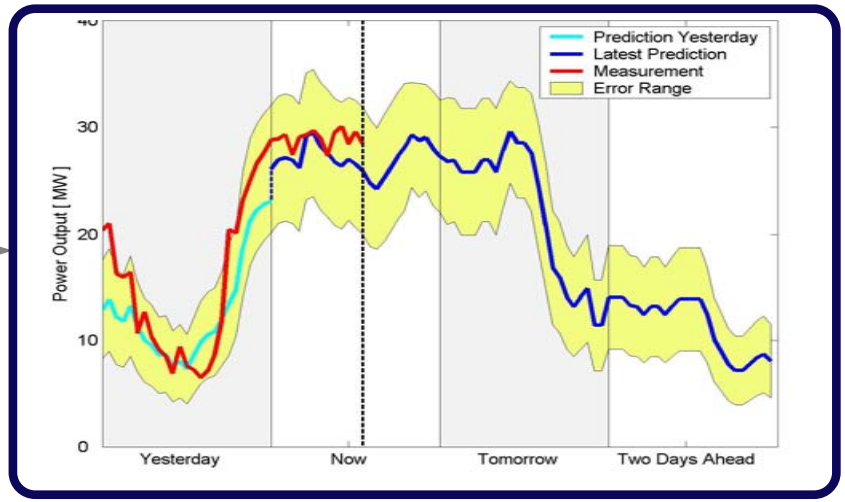




Previento

Physical Model:

- Spatial refinement
- Thermal stratification
- Site-specific power curve
- Forecast uncertainty



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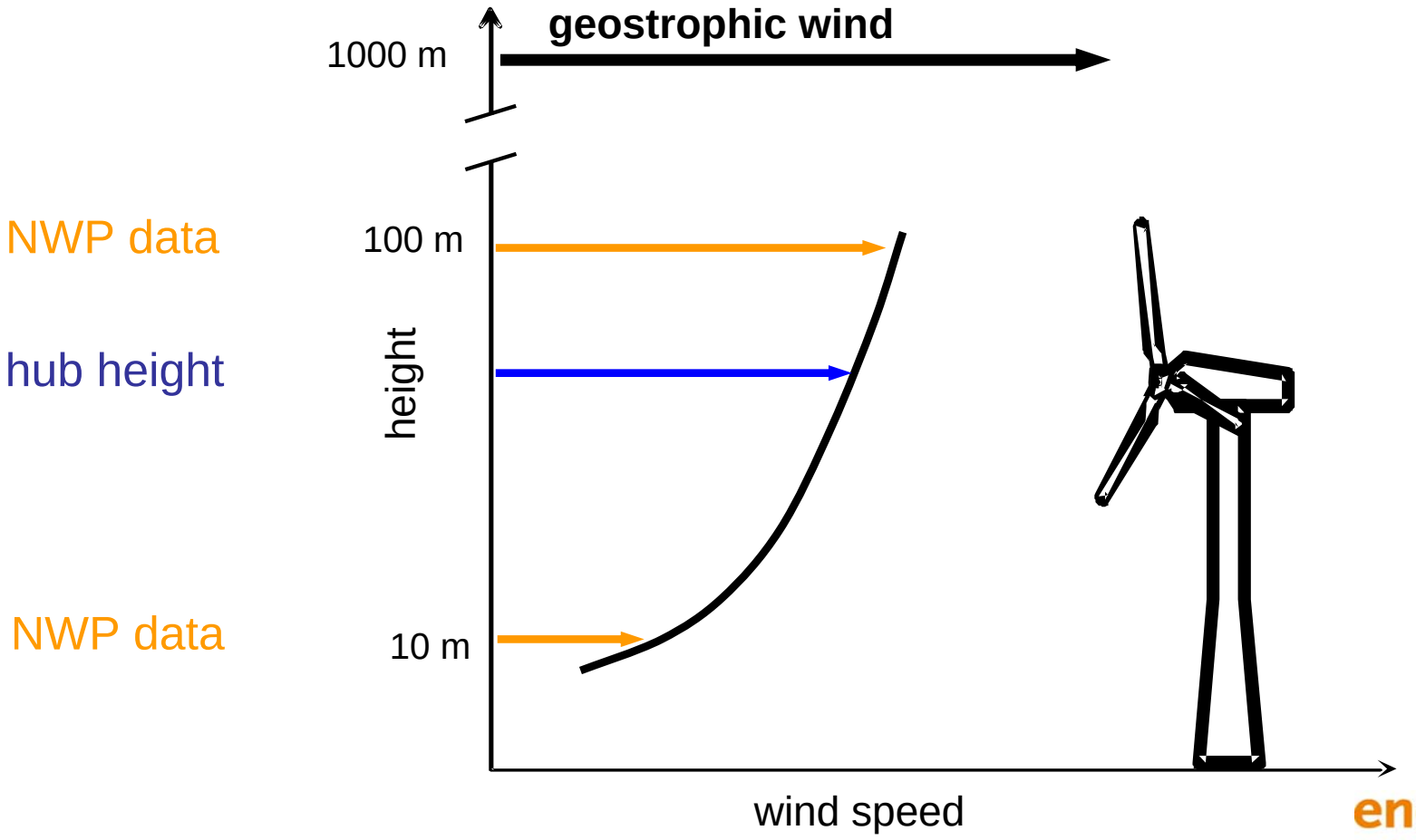
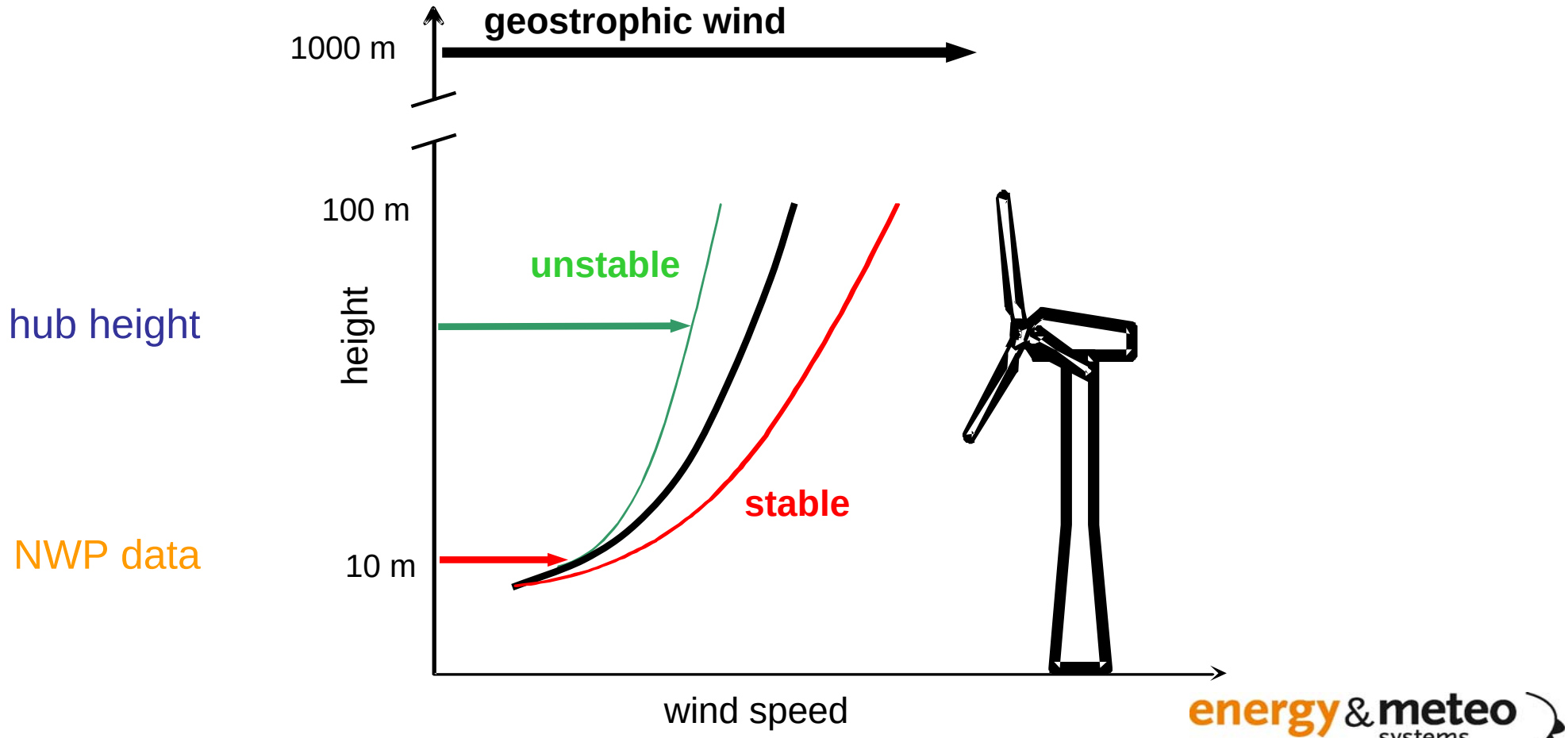
Physical system – Previento

- Modelling the lower atmospheric boundary layer



Physical system – Previento

- Vertical wind profile strongly depends on weather conditions



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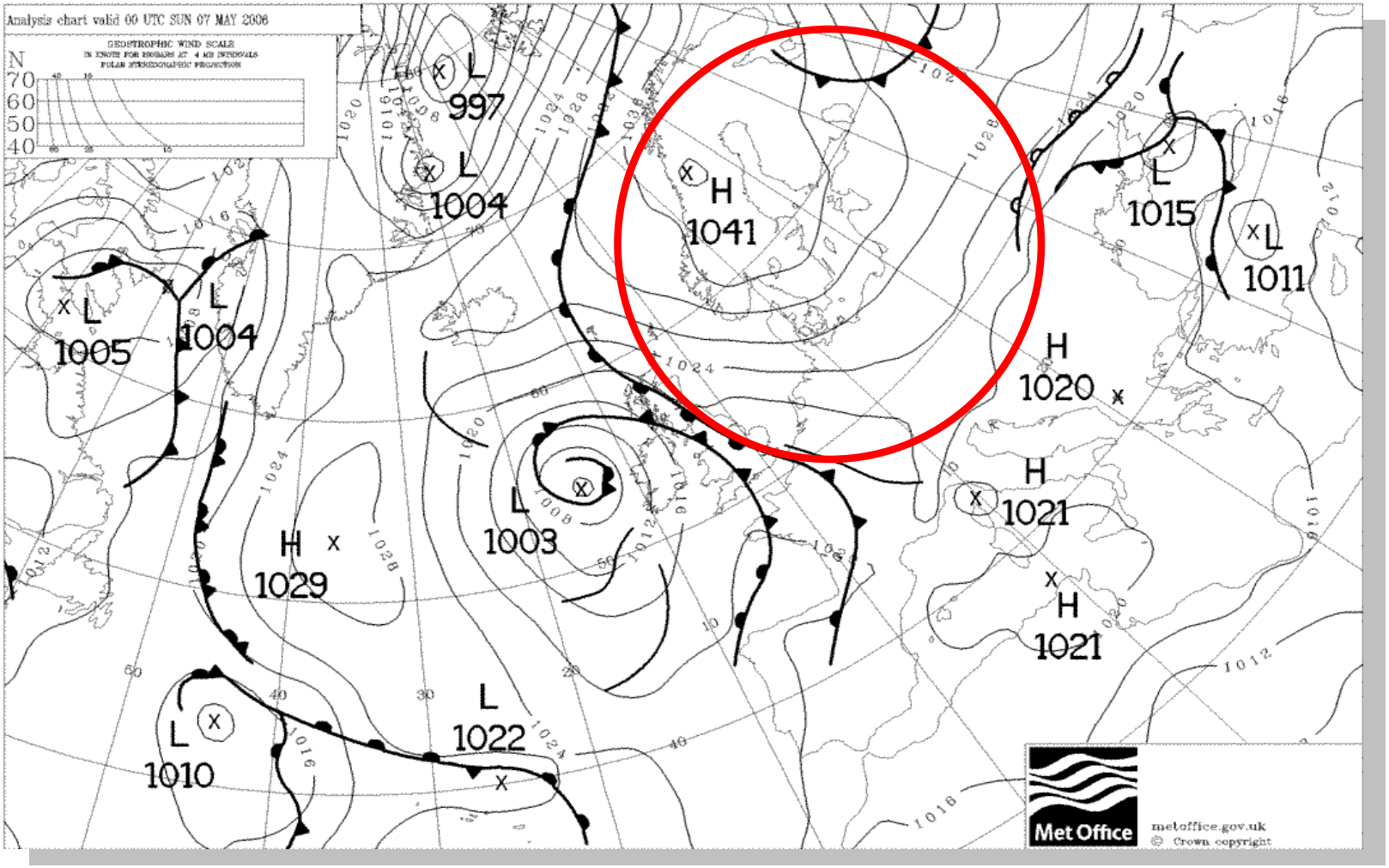
Stable high pressure situation



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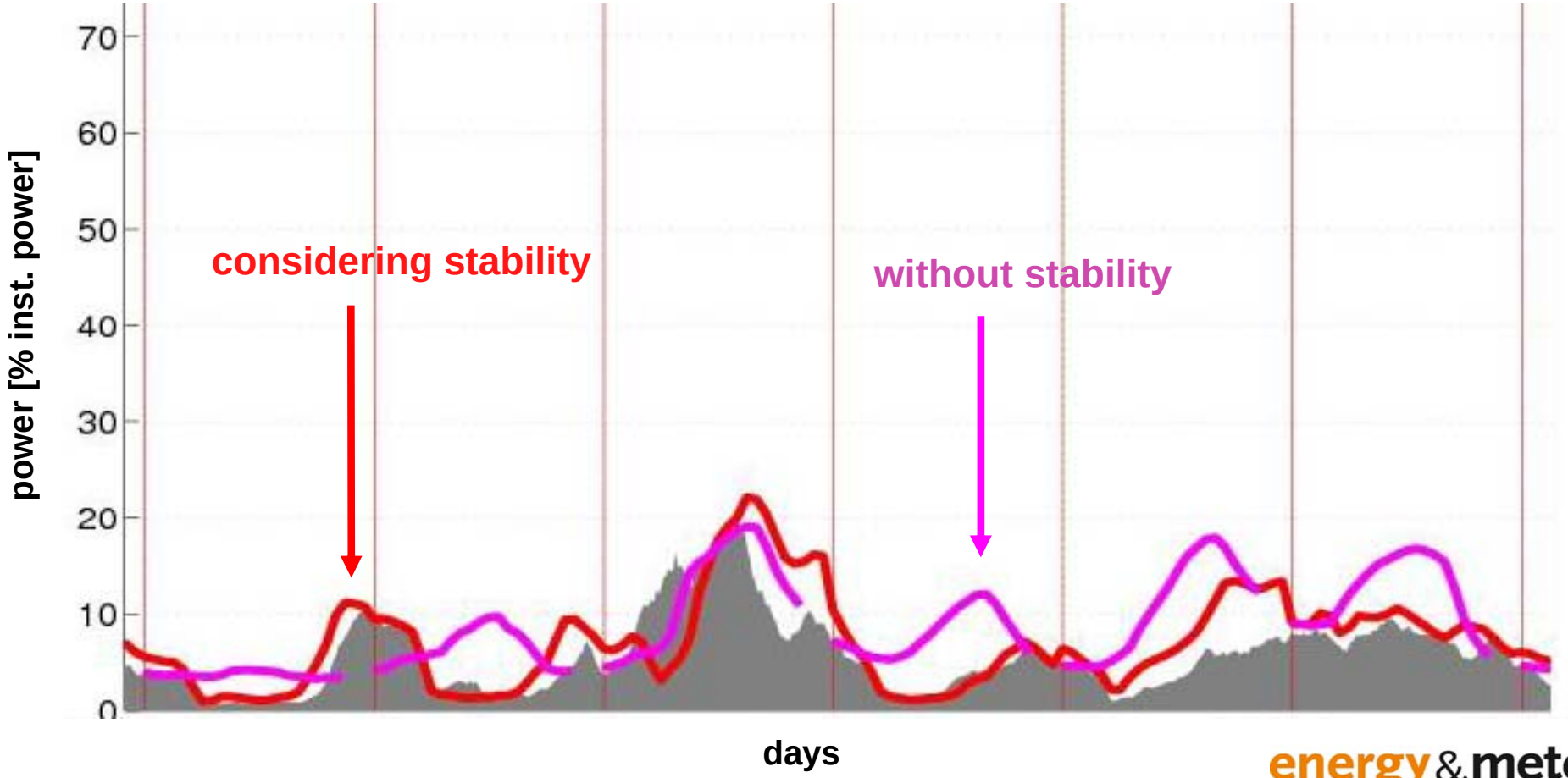
Physical system – Previento

- Effect of thermal stratification on forecast



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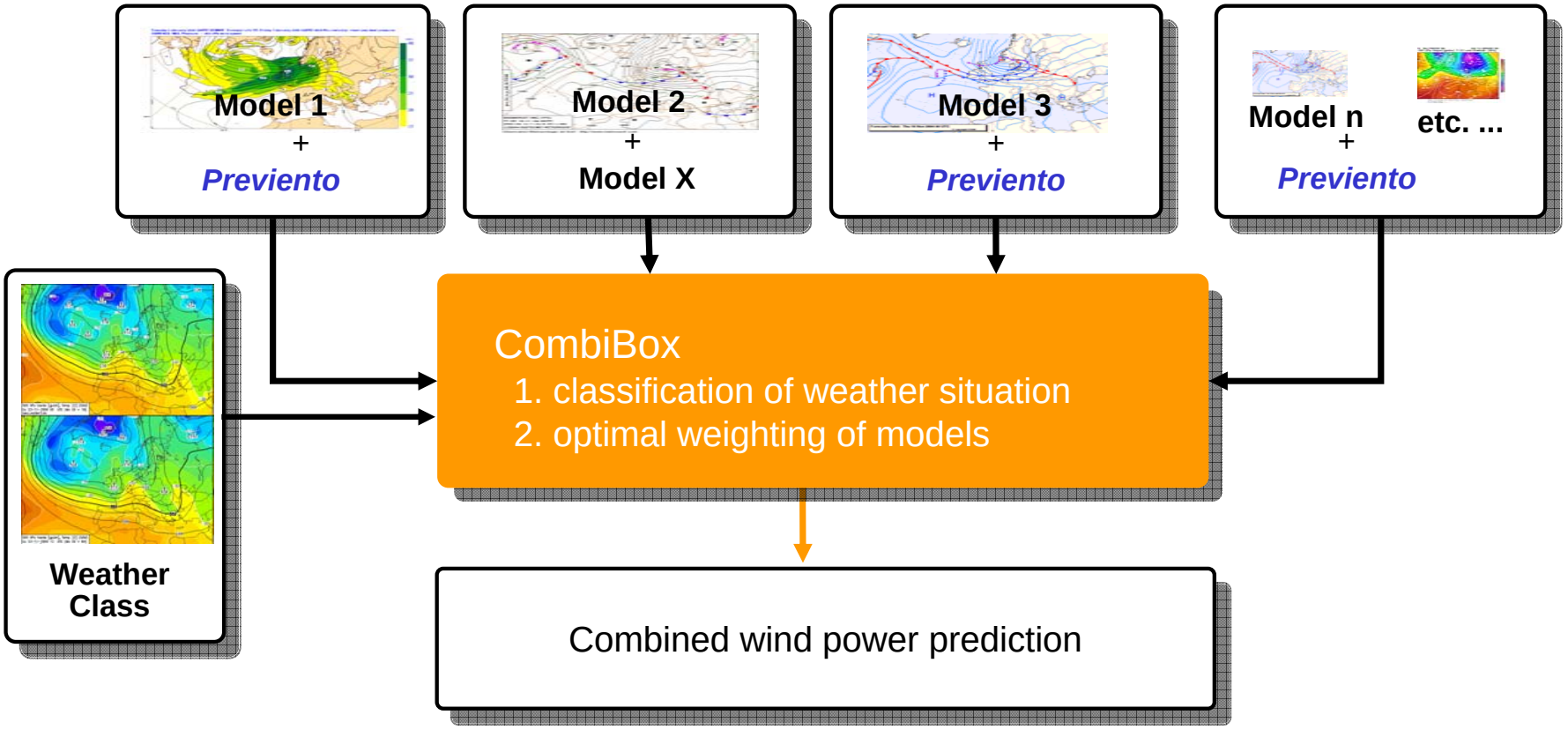
Combination of forecasts



- Weighting of different forecasts according to capabilities of NWP in different weather situations
- CombiBox in operational use

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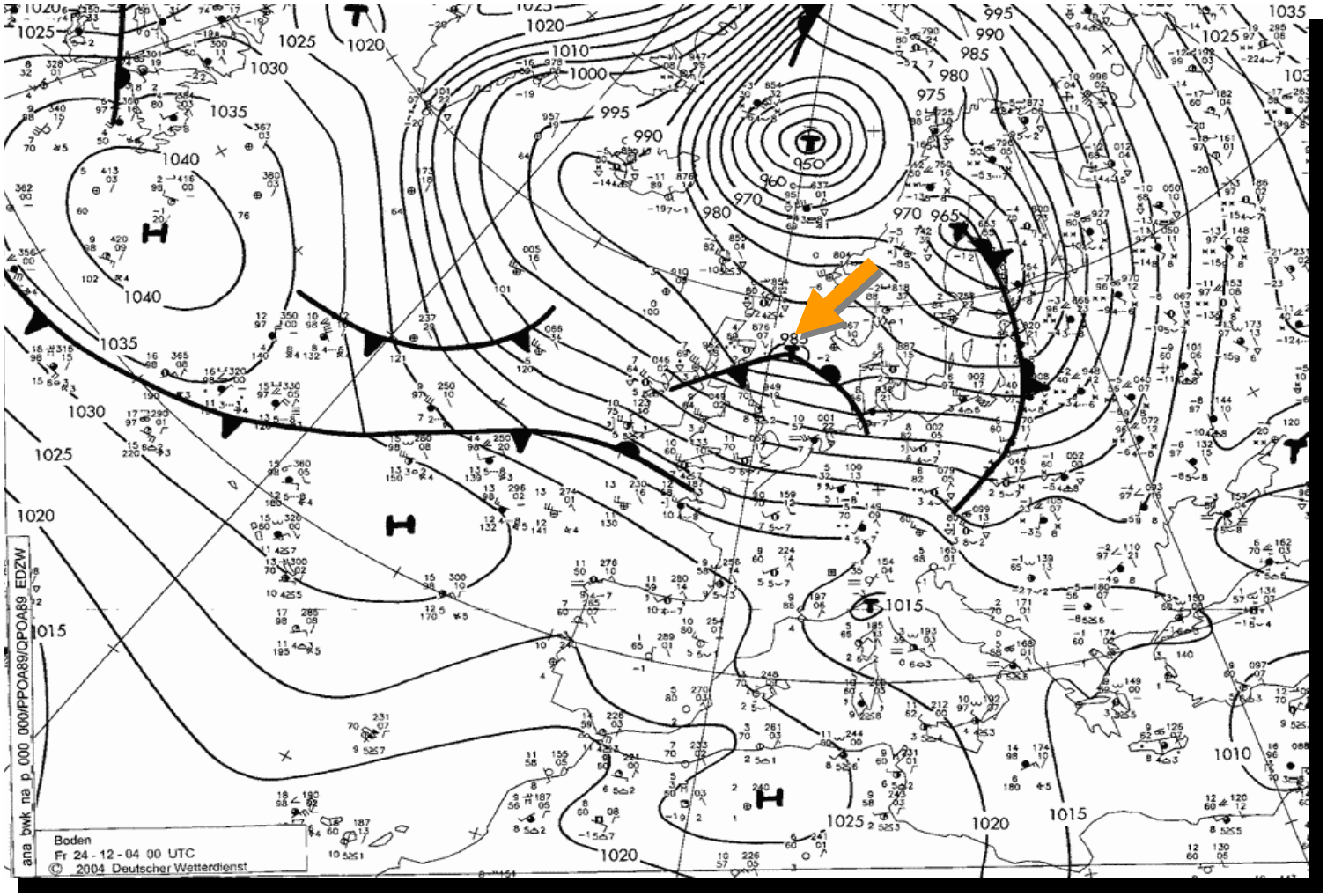
Example: low pressure system is passing



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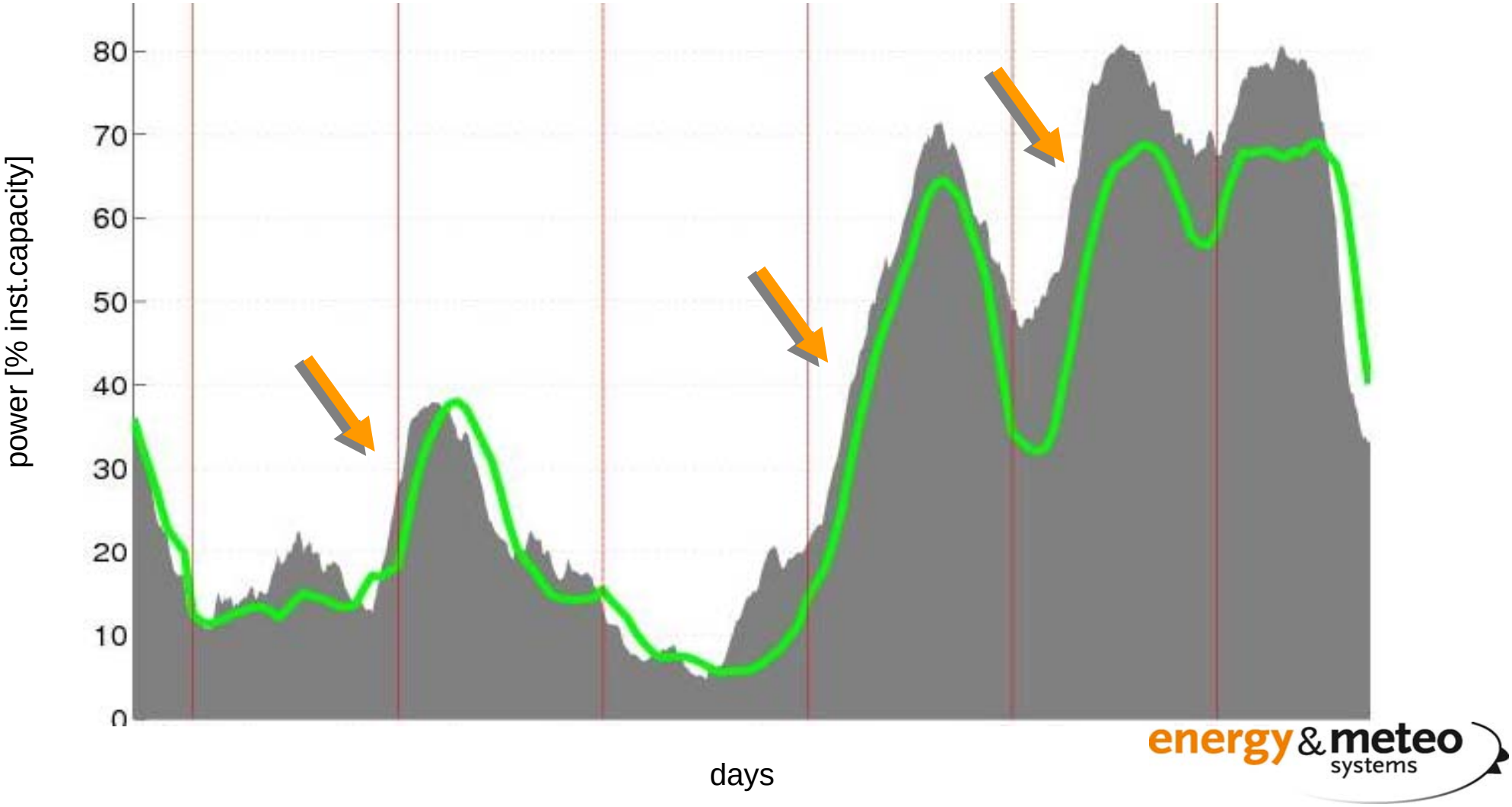
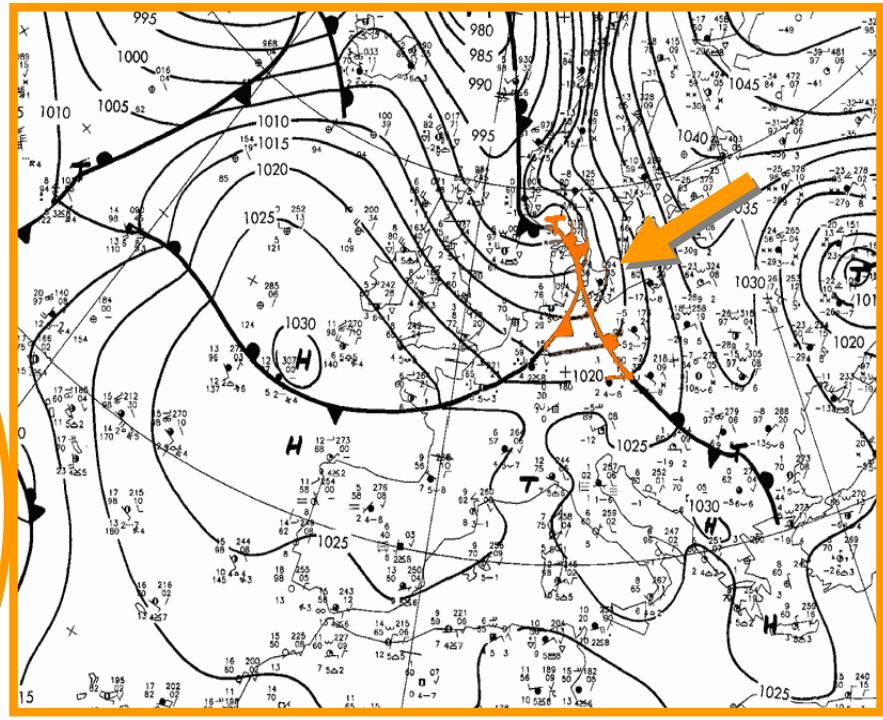
Example: low pressure system is passing

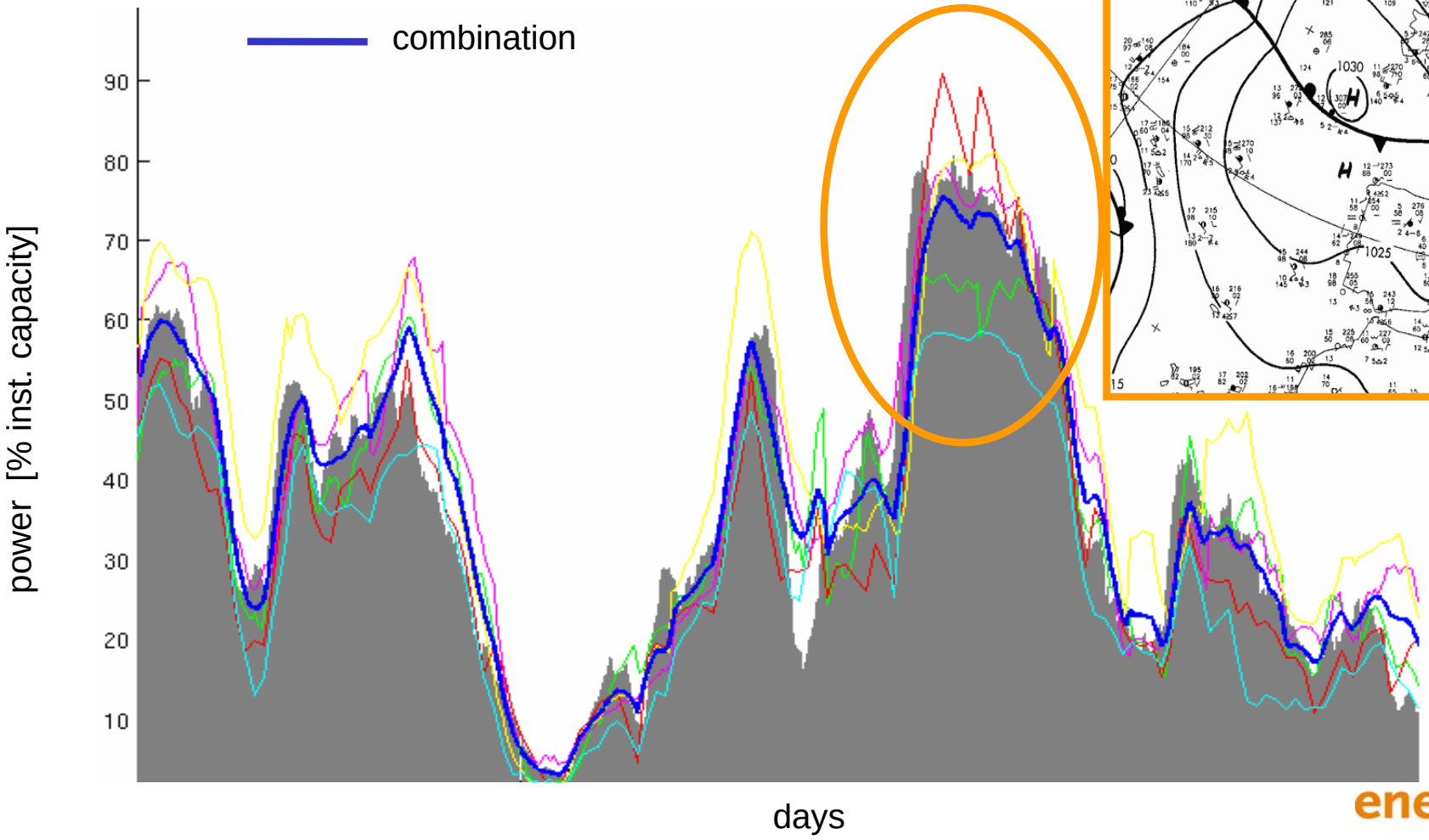
- One model predicts fronts with delay



Combination of forecasts

- Avoid extreme forecast errors





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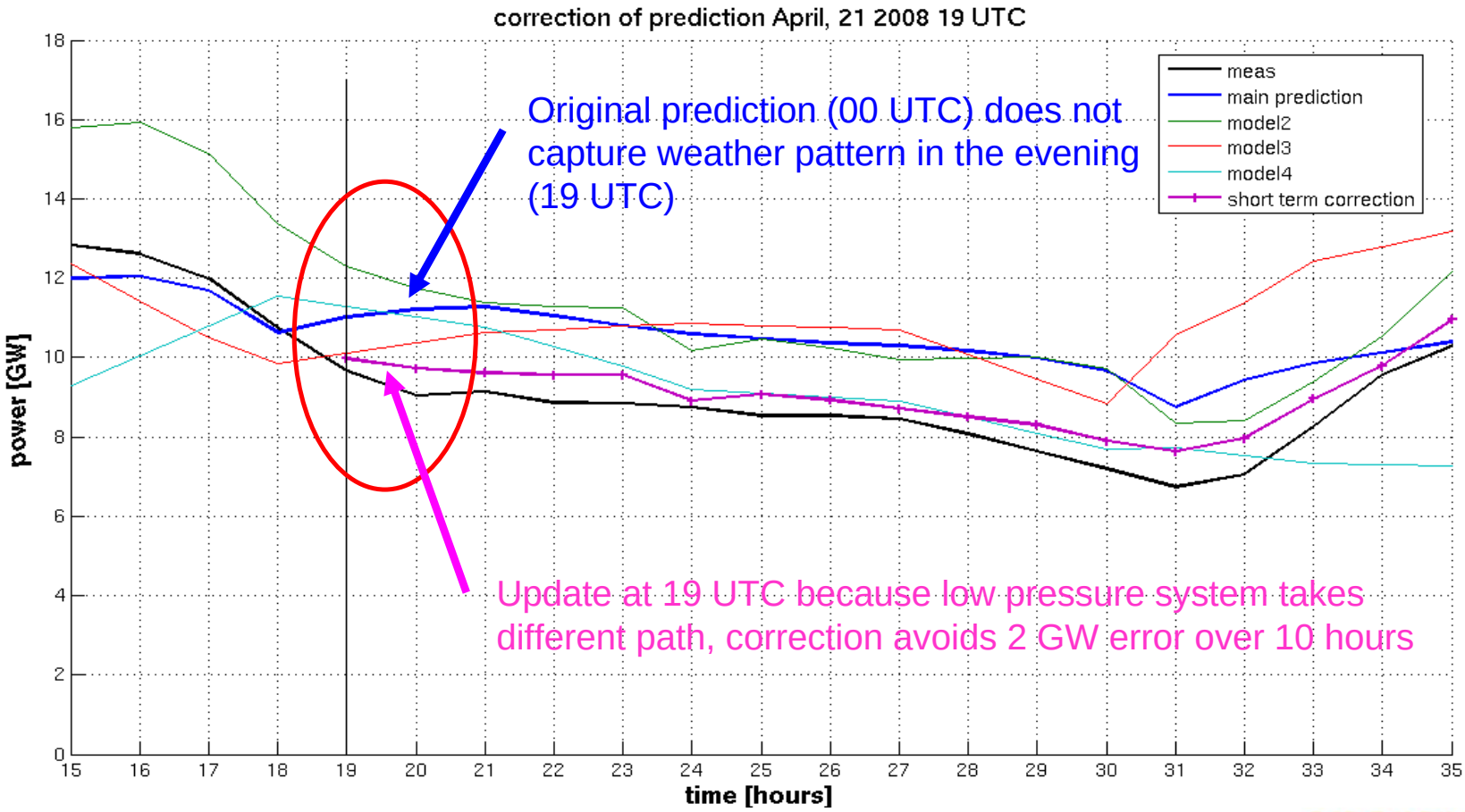
Shortest-term prediction (0 – 12 h)

- Ad-hoc update due to changing weather conditions



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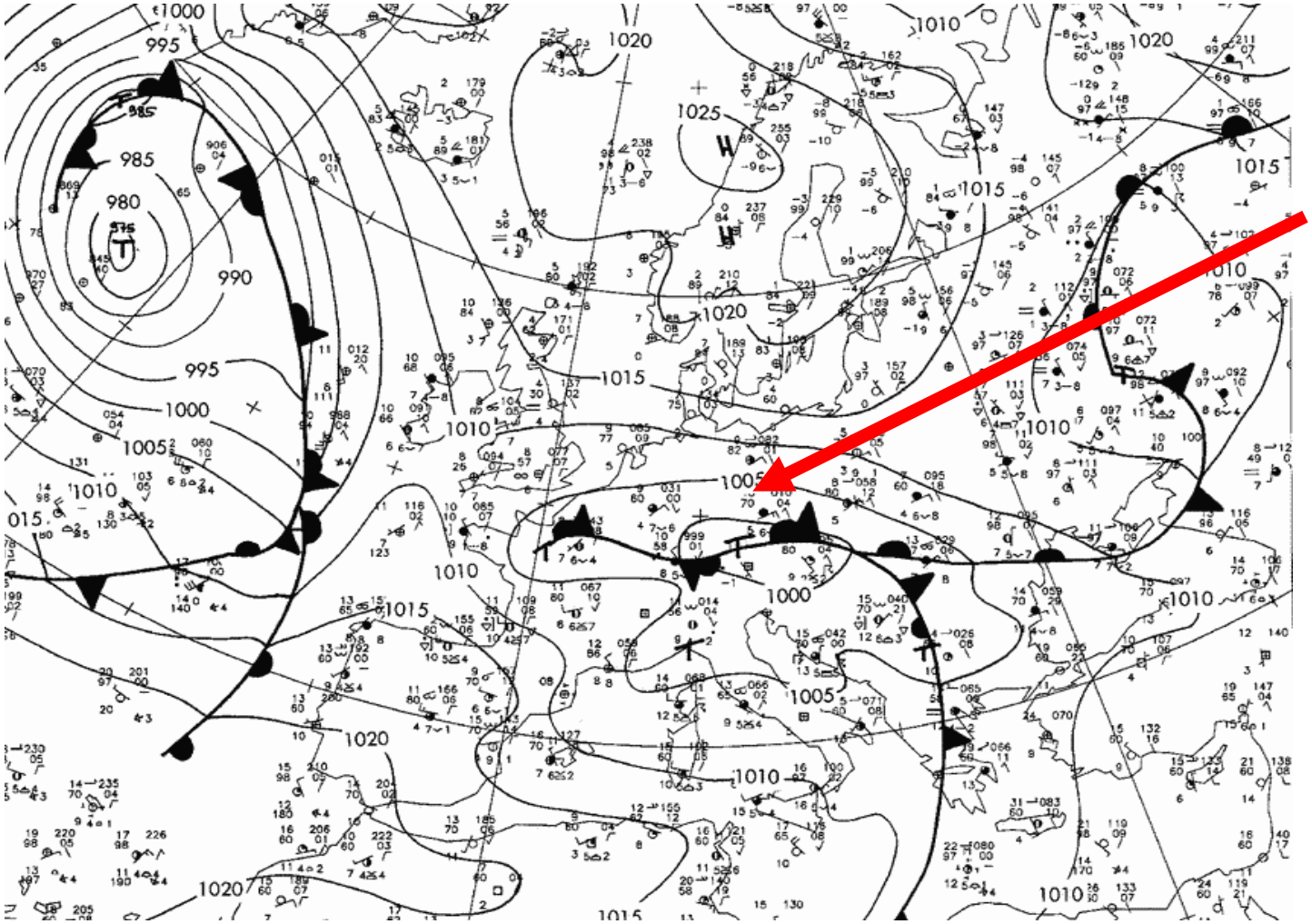
Shortest-term prediction

- Small low pressure system took path further in South



Weather situation in Germany 2008/04/21

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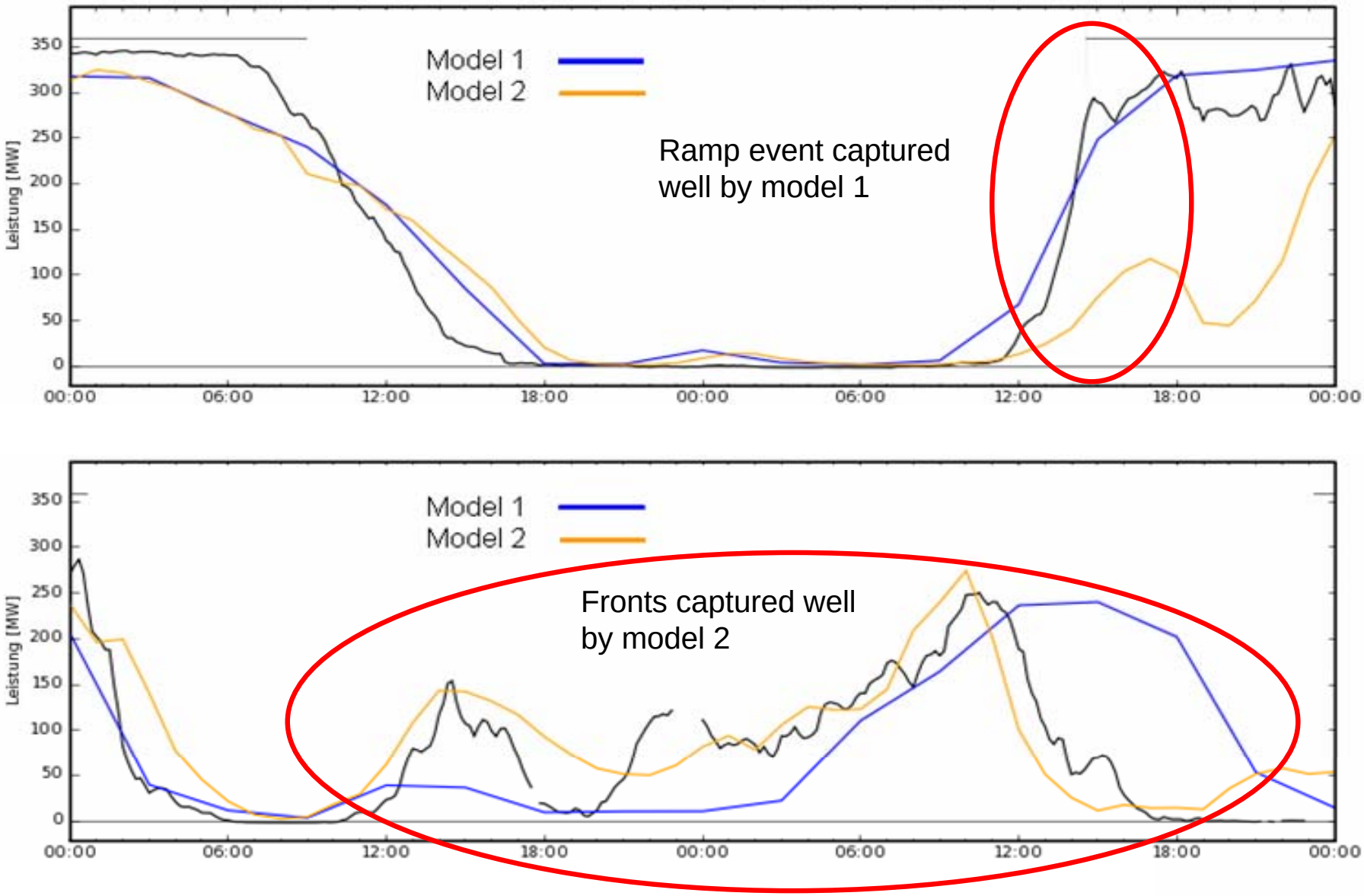
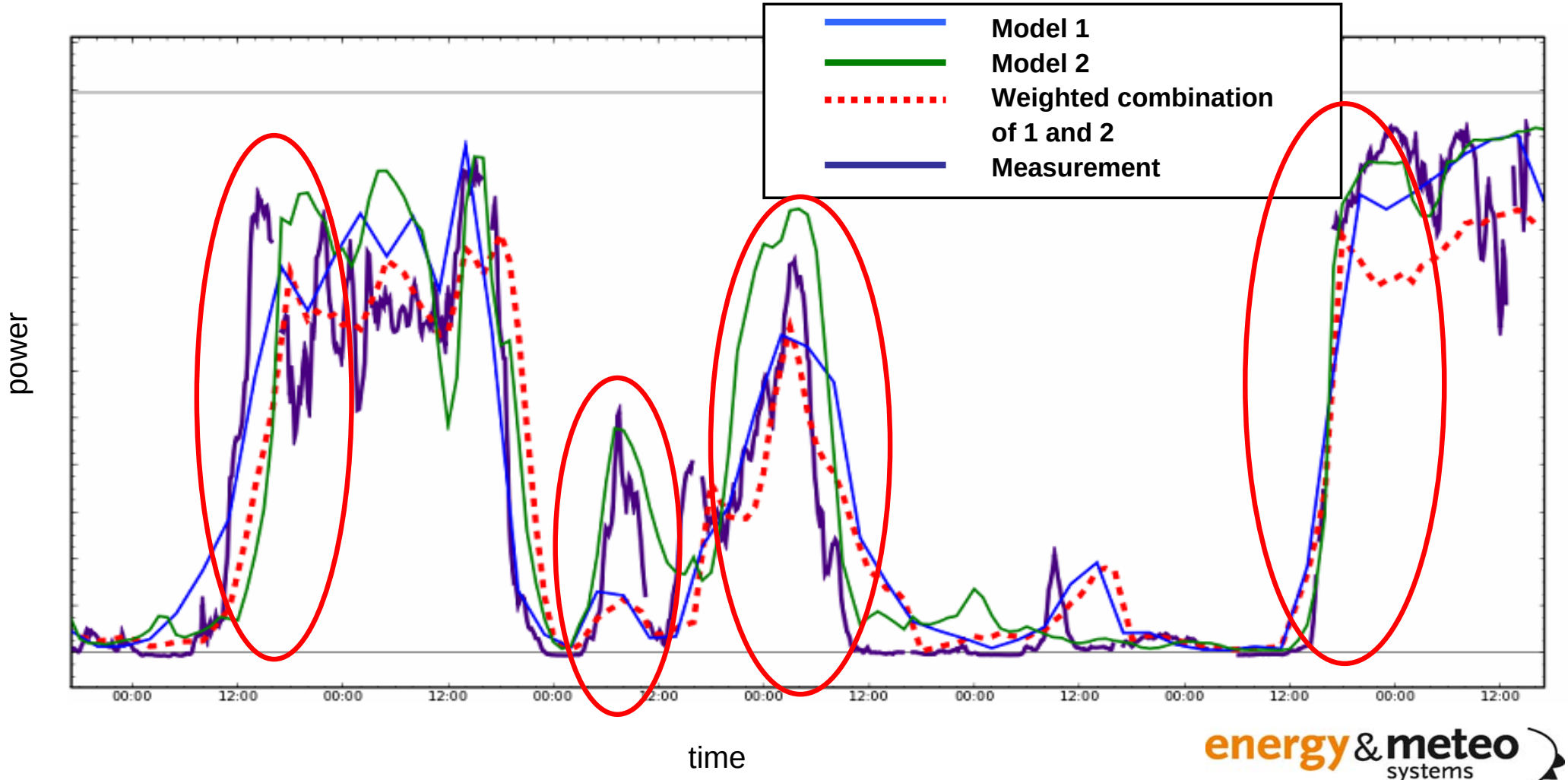
Alberta forecasting challenge

Alberta: NWP models have different capabilities



Alberta: Meteorological analysis of extreme events

- Ramps occur in different weather conditions



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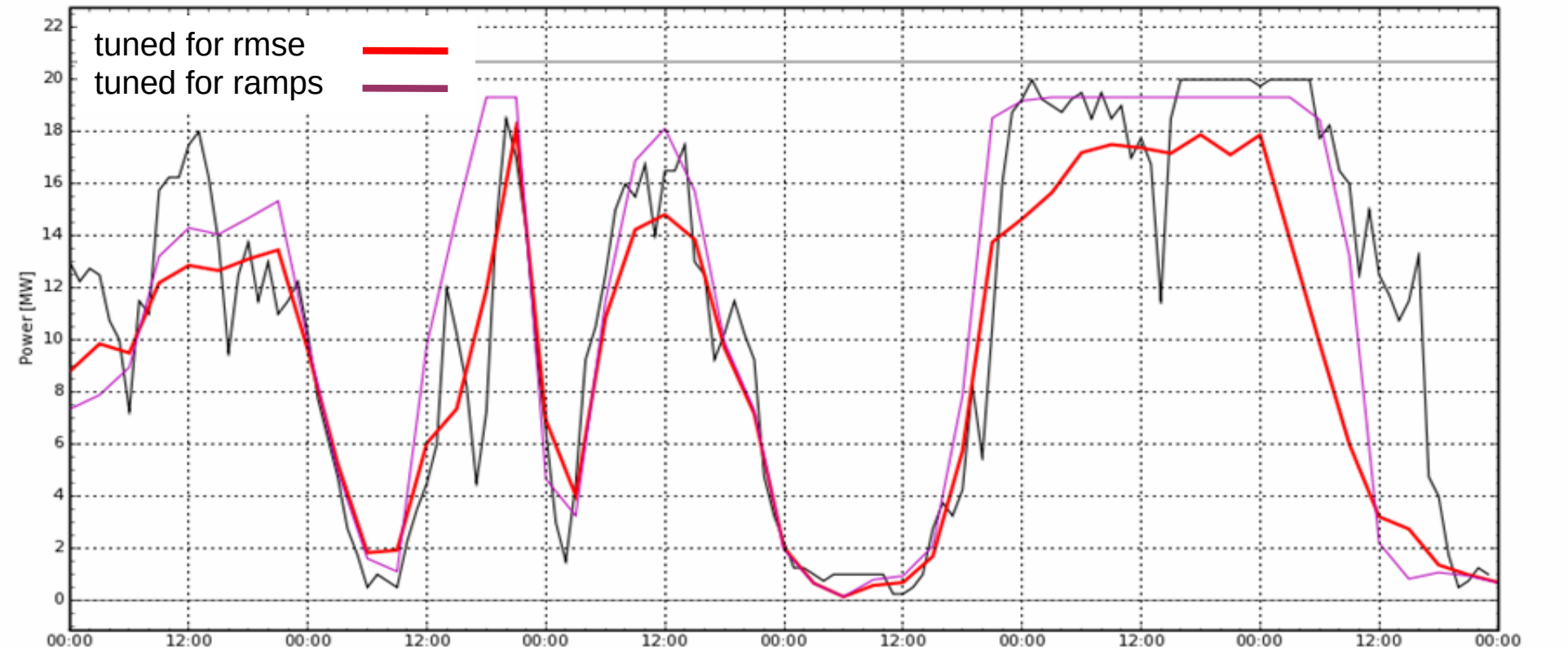
Ramp event forecast

- Special tuning for Ramp Events required



- Two different strategies: Tuning of forecasts for low average error (e.g. rmse) or for capturing ramp events

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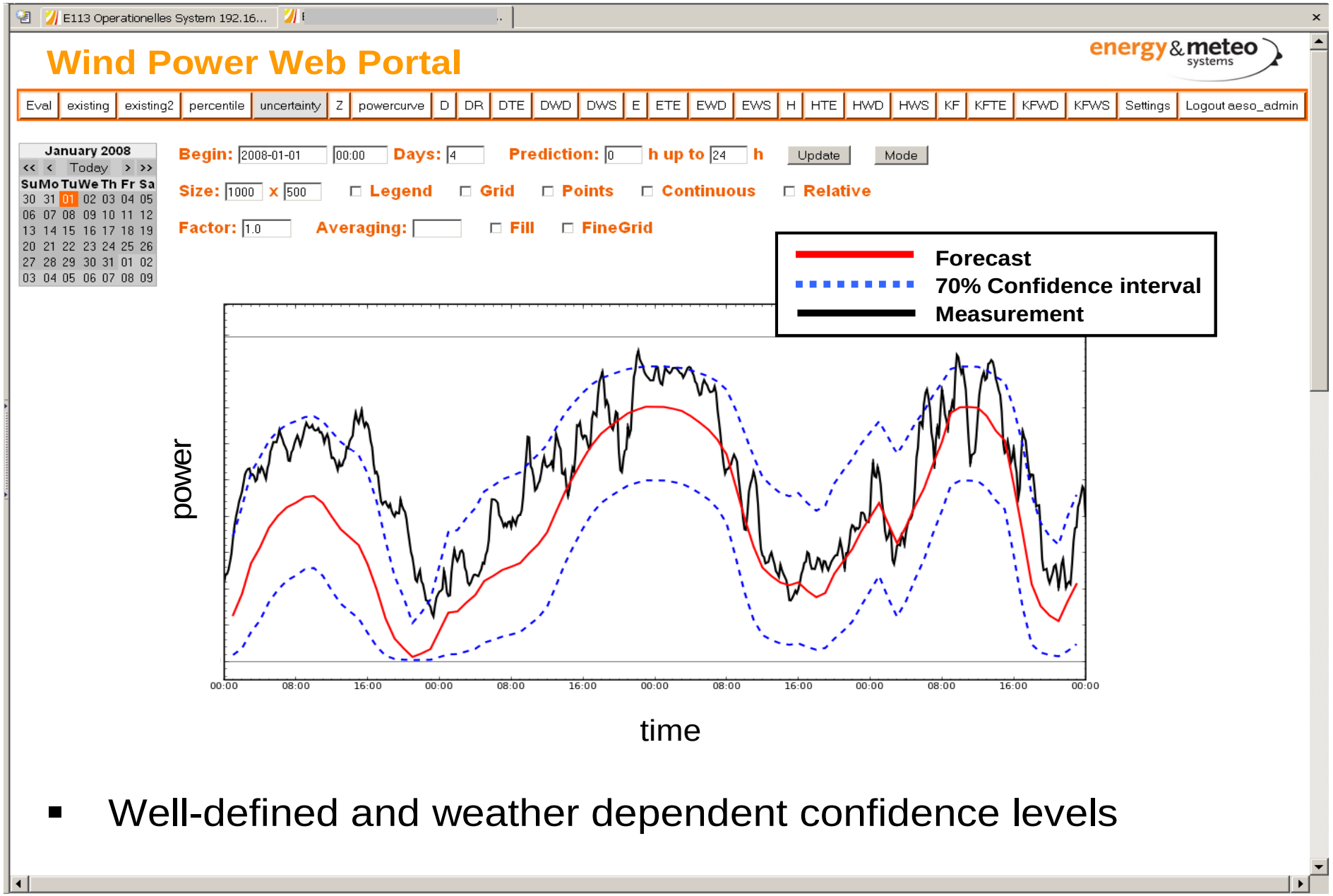
Prediction of the uncertainty of forecasts



- Well-defined and weather dependent confidence levels

Keep in mind – the atmosphere is highly non-linear

How accurate are wind power predictions ?

- Different metrics
  - Mean absolute error (MAE)
  - Root mean square error (RMSE)
  - Correlation between
  - Skill scores
- Different normalizations
  - Installed power
  - Average output
  - Actual forecast value
- Visusal / subjective
  - Scatter plots
  - Time series plots (ramps)

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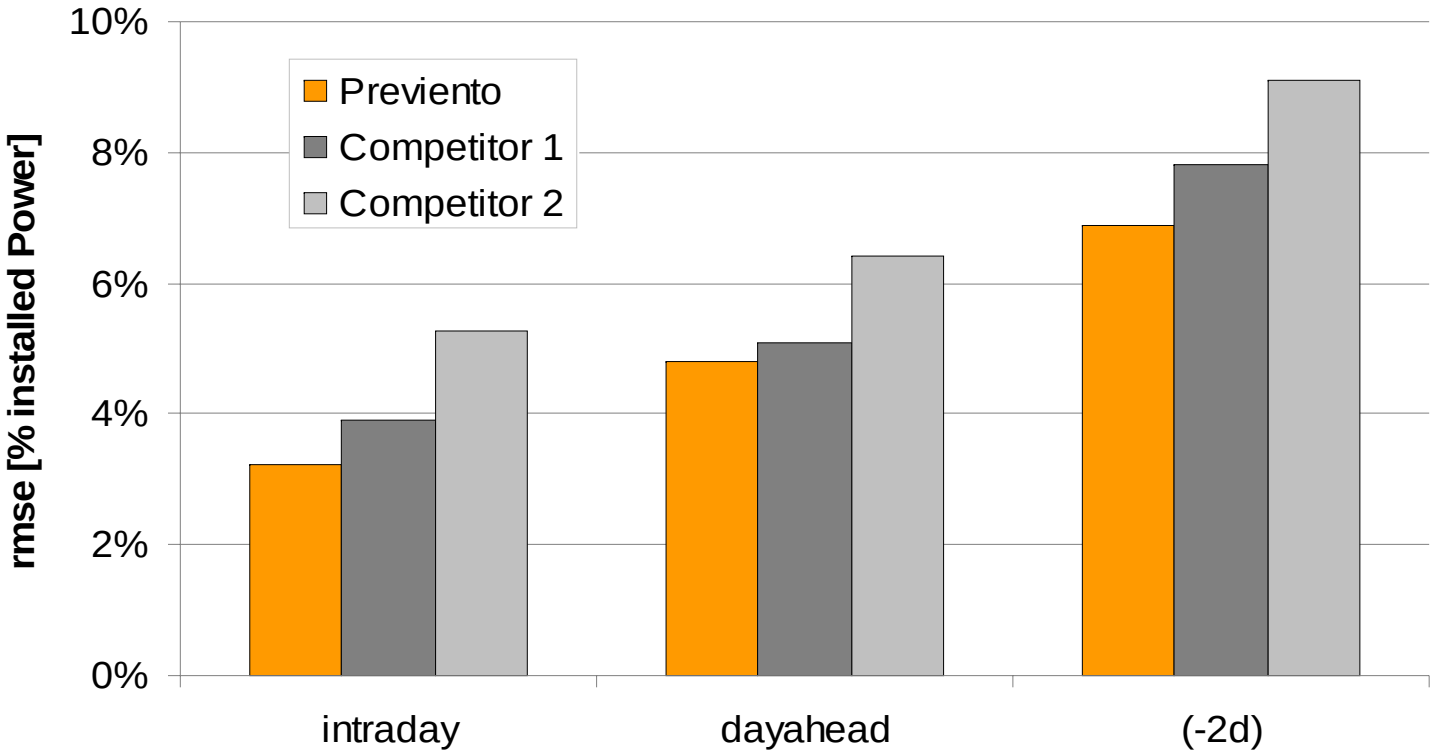
How accurate are wind power predictions ?

Customer evaluation of aggregated forecast of German wind farms



Source:
EnBW Trading
2006

Different metrics to assess accuracy: here root mean square error normalized to installed power

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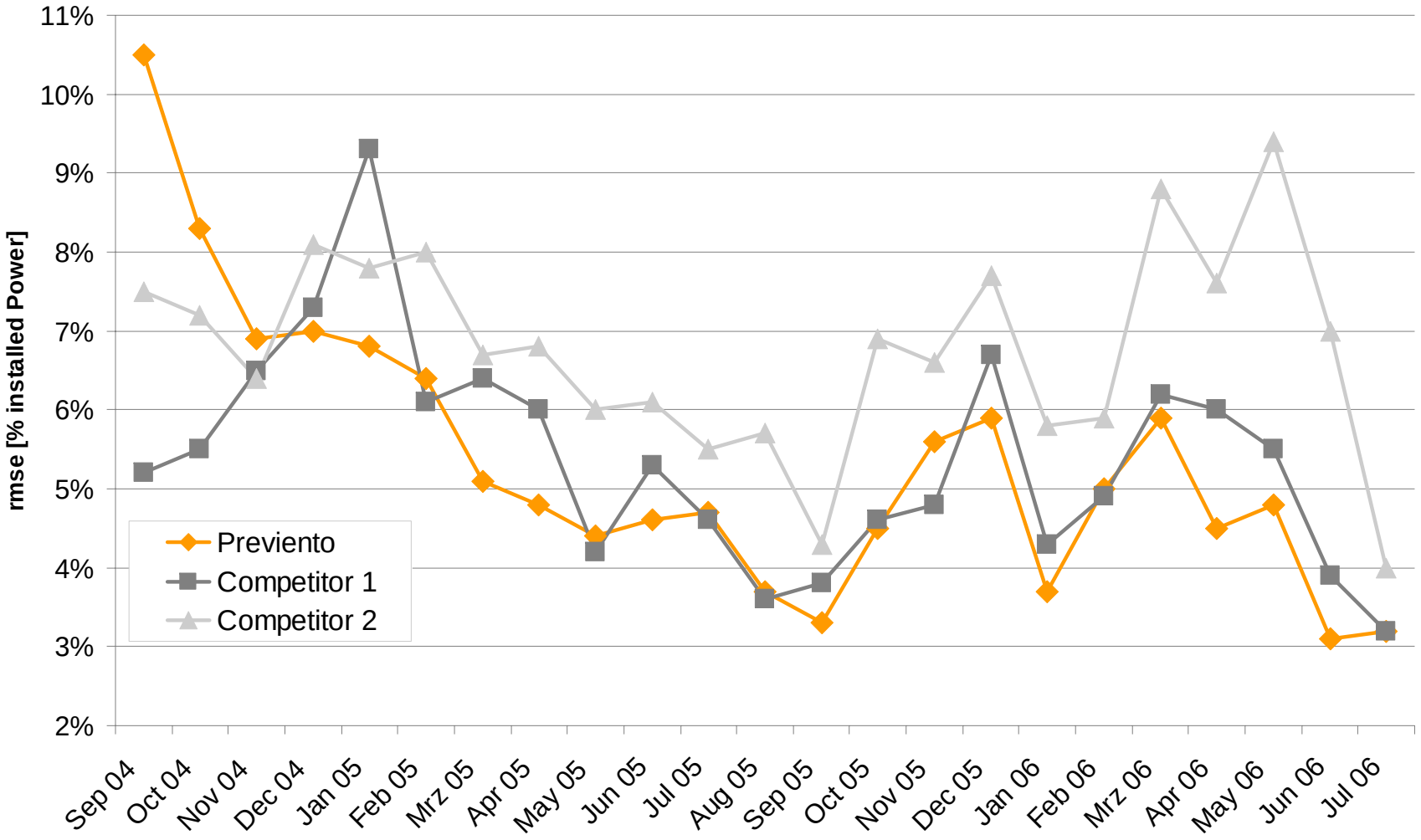
Seasonal variations in forecast accuracy



Source: EnBW Trading

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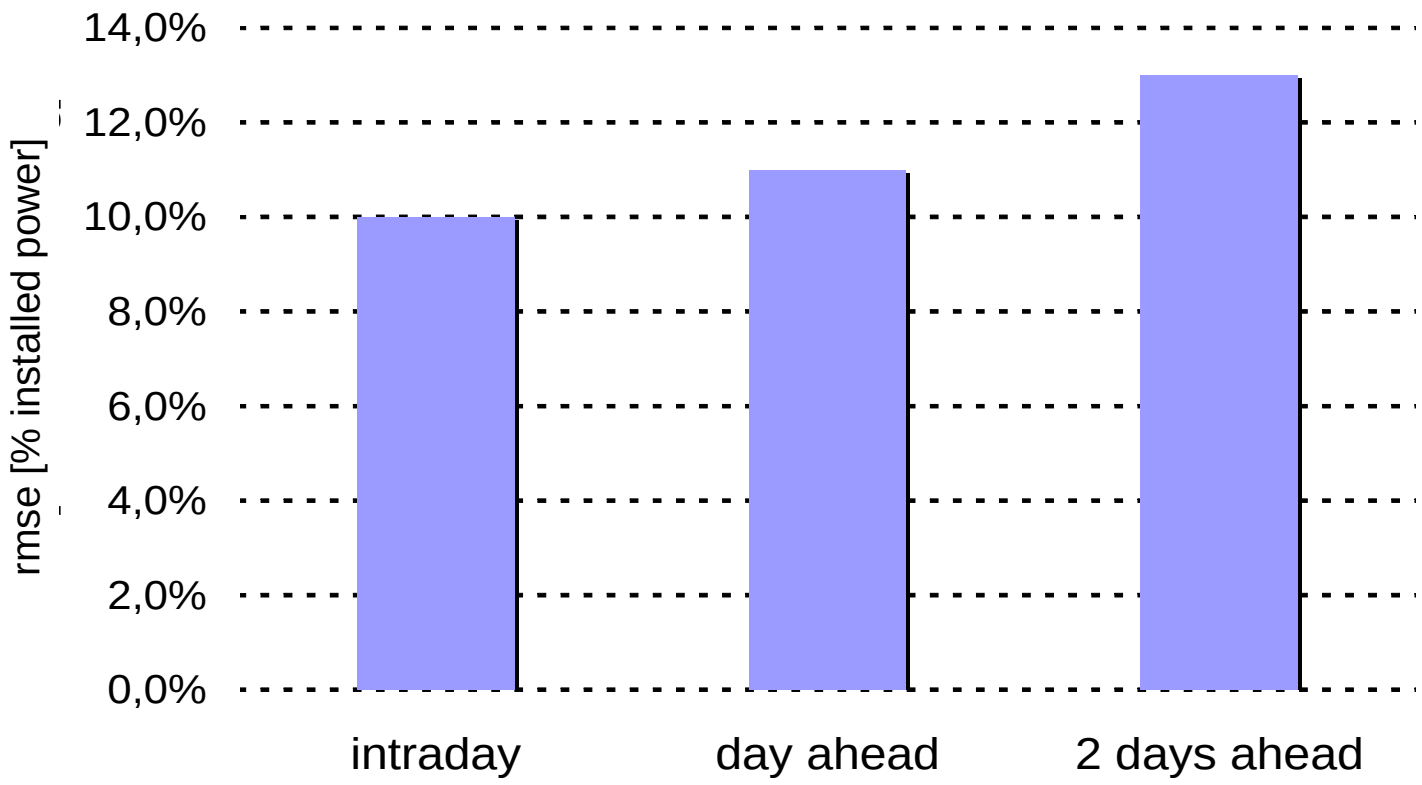
Single wind farm

Typical values for wind farm in Northern Germany (17 MW)



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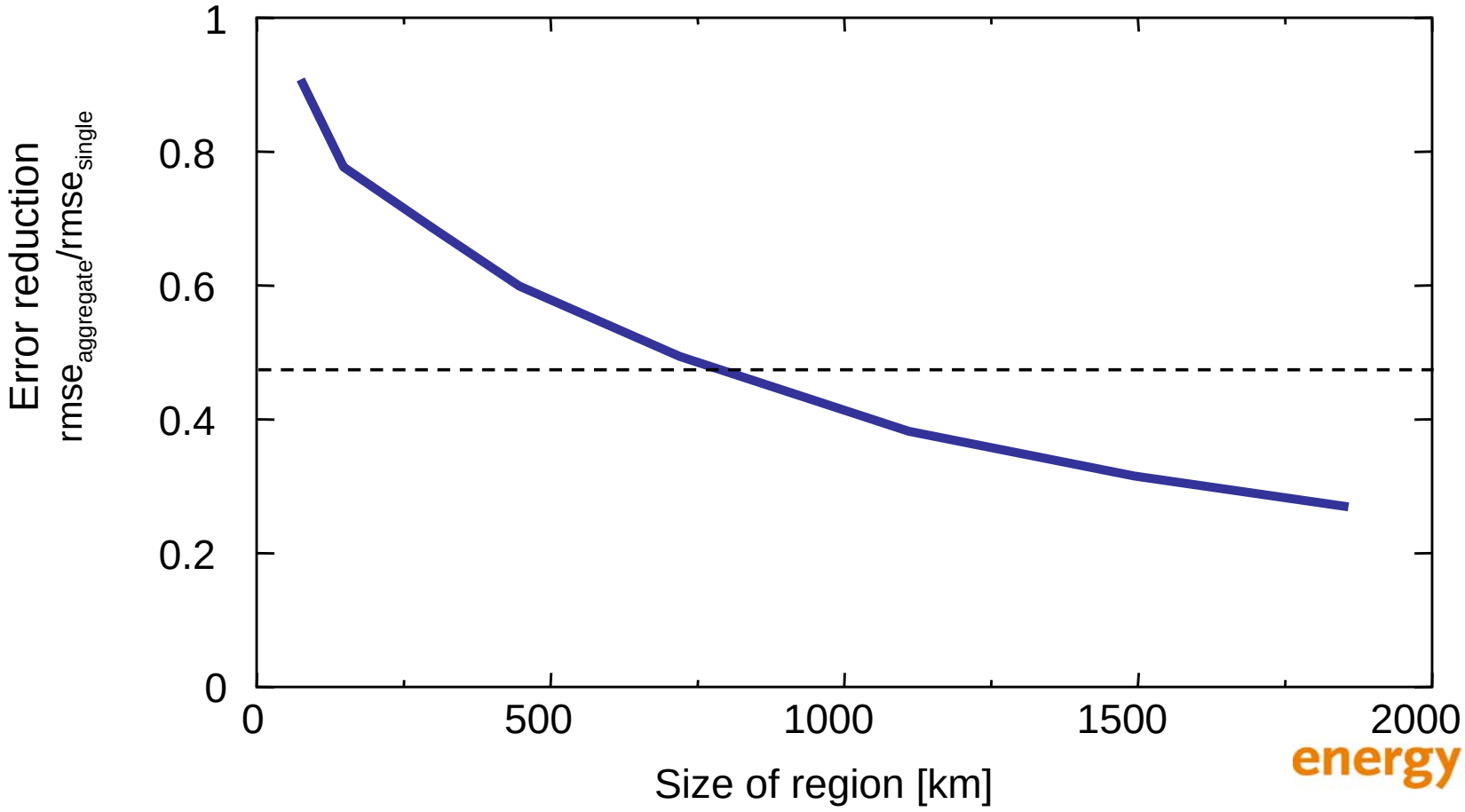
Aggregation of spatially dispersed wind farms

- Significant error reduction due to spatial smoothing effects
- The larger the spatial dispersion of the wind farms the better the forecast accuracy



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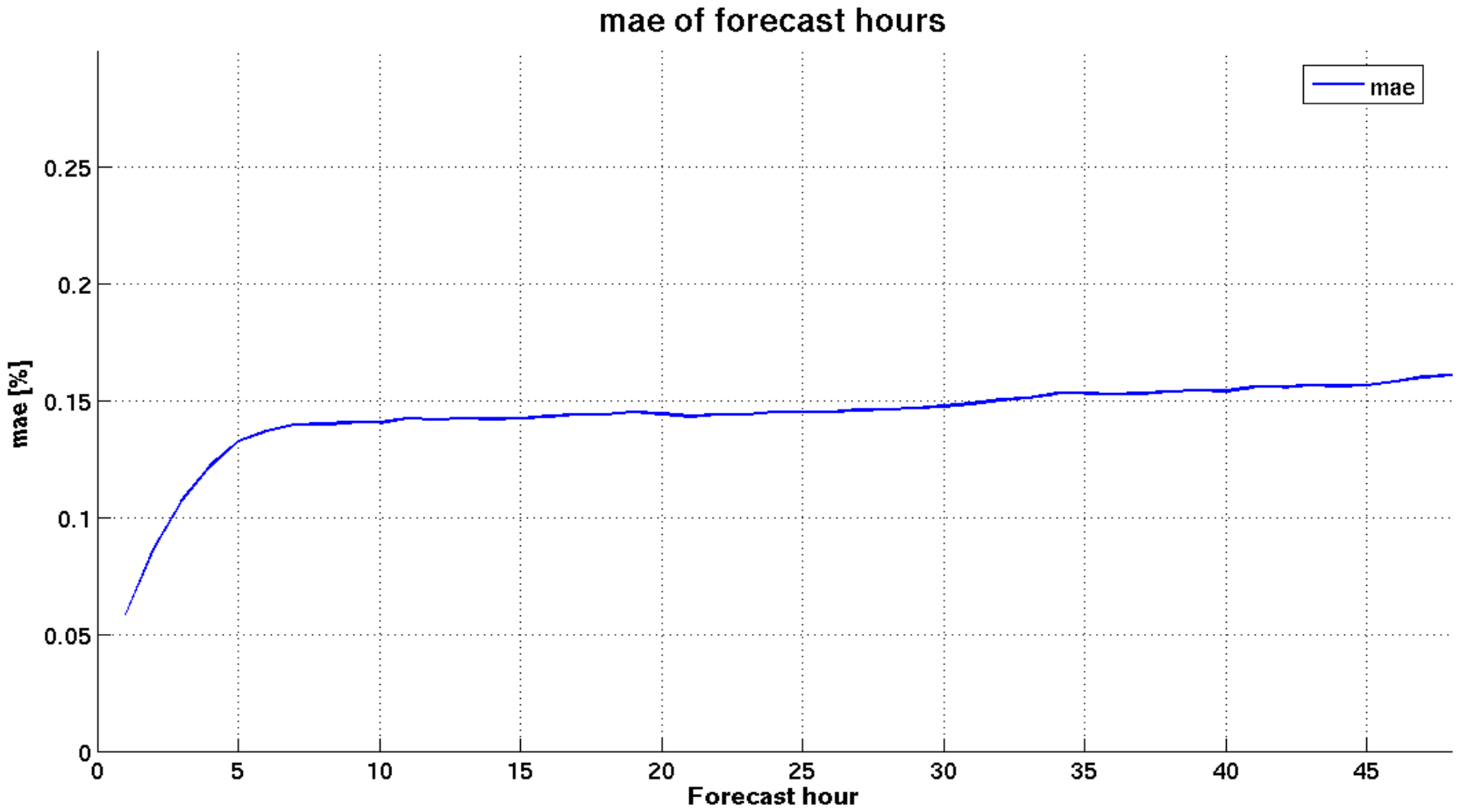
Alberta: evaluation

- Normalized MAE of regional prediction (existing facilities)



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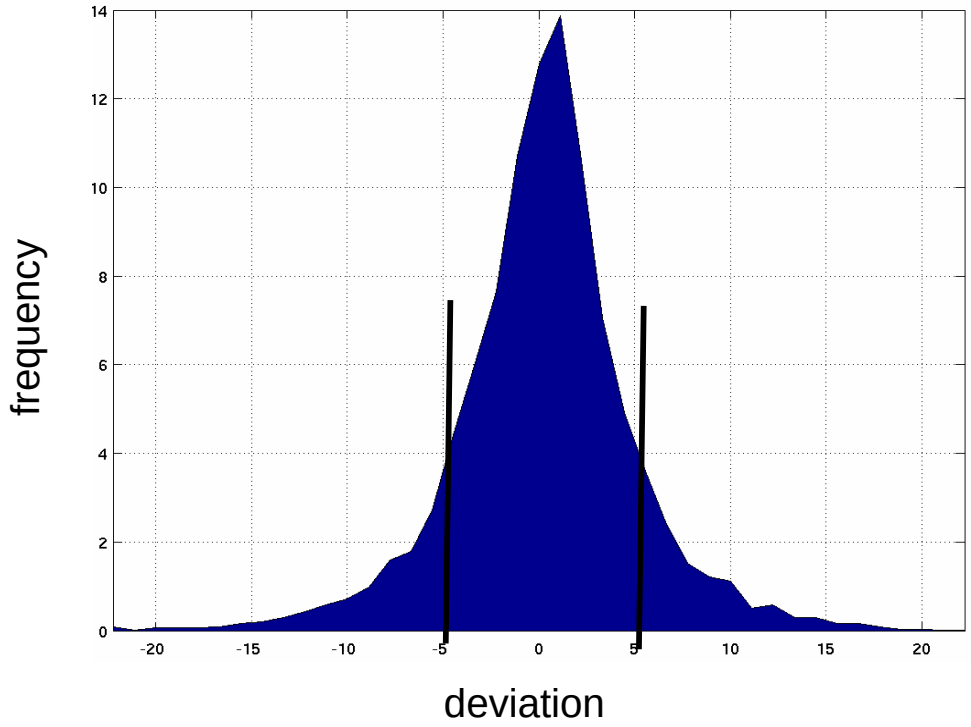
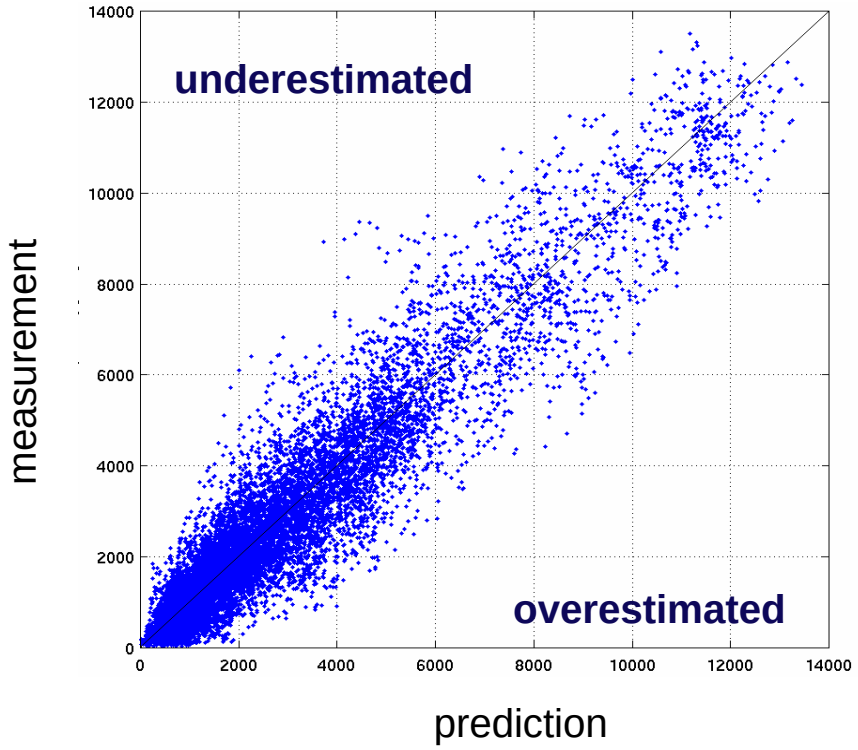
Distribution of forecast errors

Frequency distribution of errors



Scatter plot



Non-Gaussian distribution
approx. 72% of deviations in σ-interval

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Excellent measurement data required

- Contribution by the customer
- Historical data with high quality covering at least one year
- Online data feeds with high availability
- Important variables:
  - Power output
  - Turbine availability
  - Information on curtailment
  - Wind speed and direction from nacelle anemometer
  - Information on future maintenance
- Nice to have but not strictly necessary
  - Measurement data from surrounding met towers
  - Erection of additional towers

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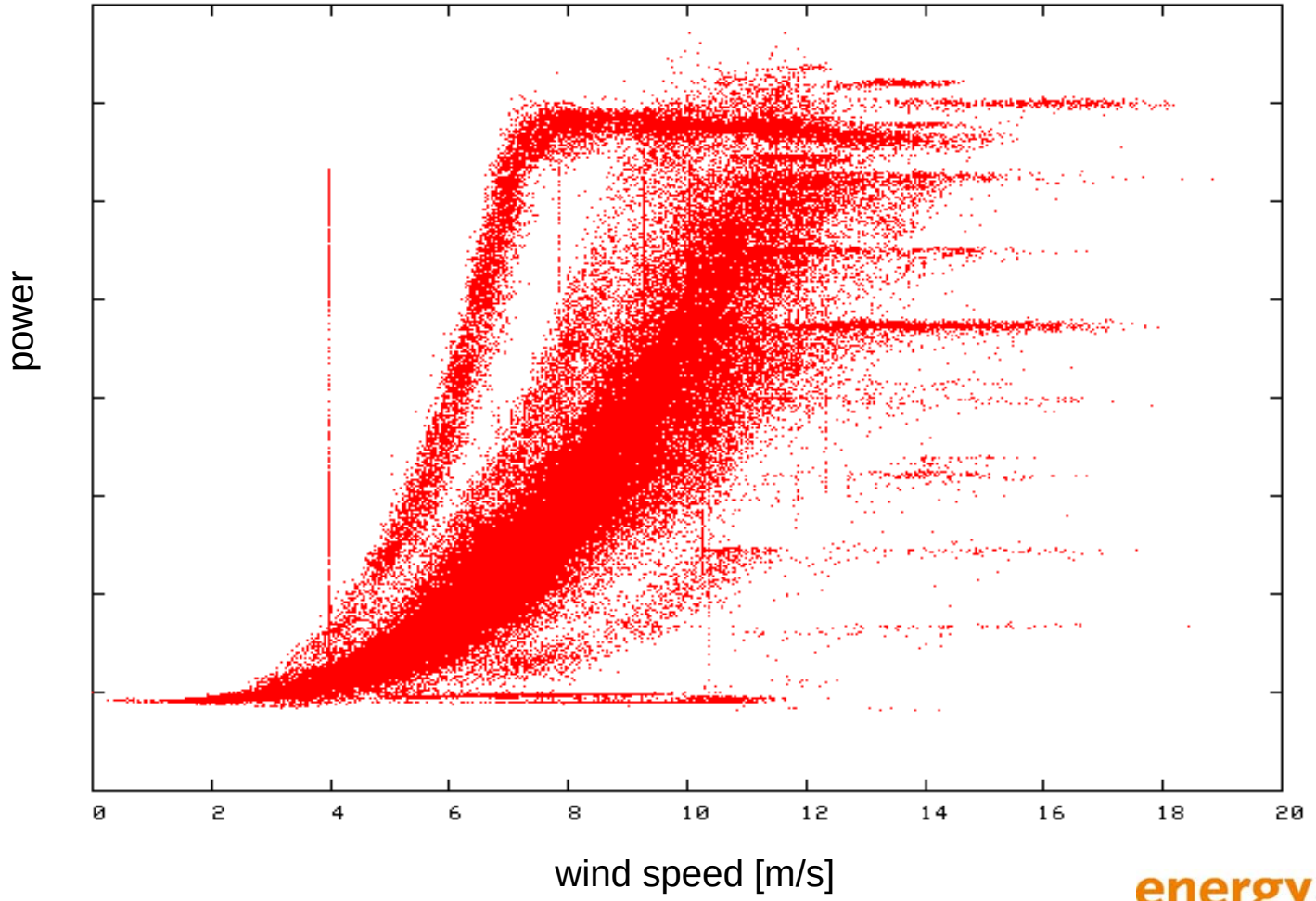
Bad data example

- Curtailment info helpful to avoid this



Outlook

- Forecast improvements through
  - Advanced multi-model approaches
  - Ensemble predictions
  - Optimization of NWP towards wind energy
- Integrate wind power forecasts into downstream processes (ANEMOS.plus)
  - Use for load flow calculations / congestion forecasts
  - User-friendly way to use uncertainty
- Online monitoring of the current weather situation (SafeWind)
  - detect wrong predictions with large errors
  - issue warnings to users in extreme events
  - produce „quick and dirty“ forecast updates
- Wind power in virtual power plants (eTelligence)
  - Renewables together with conventional generation, storage and demand side management
  - Management of distributed generation
  - Standardization of communication

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Previento forecasts

- Multi-model input weather data
  - Use of at least two established NWP for desired location
- Wind power forecasts
  - Up to ten days (0 – 228 h)
  - Resolution: hourly down to 5 min
  - Optimal combination due to weather situation
  - Shortest-term forecast (0 – 6 h) based on online measurement data
  - Uncertainty with well-defined confidence level
- Delivery
  - Email, ftp, modem
  - Via web interface

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Thanks for your attention !

www.energymeteo.com

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