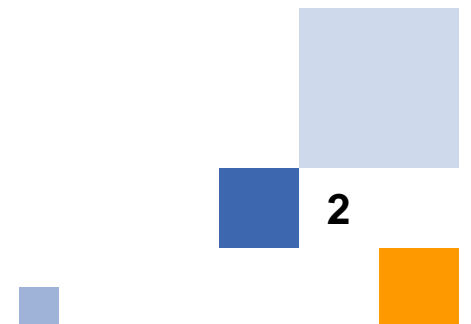


Optimal Combination of Different Numerical Weather Models for Improved Wind Power Predictions

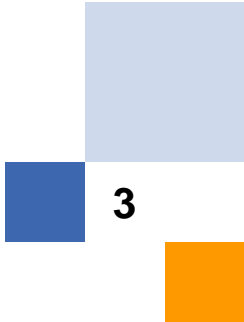
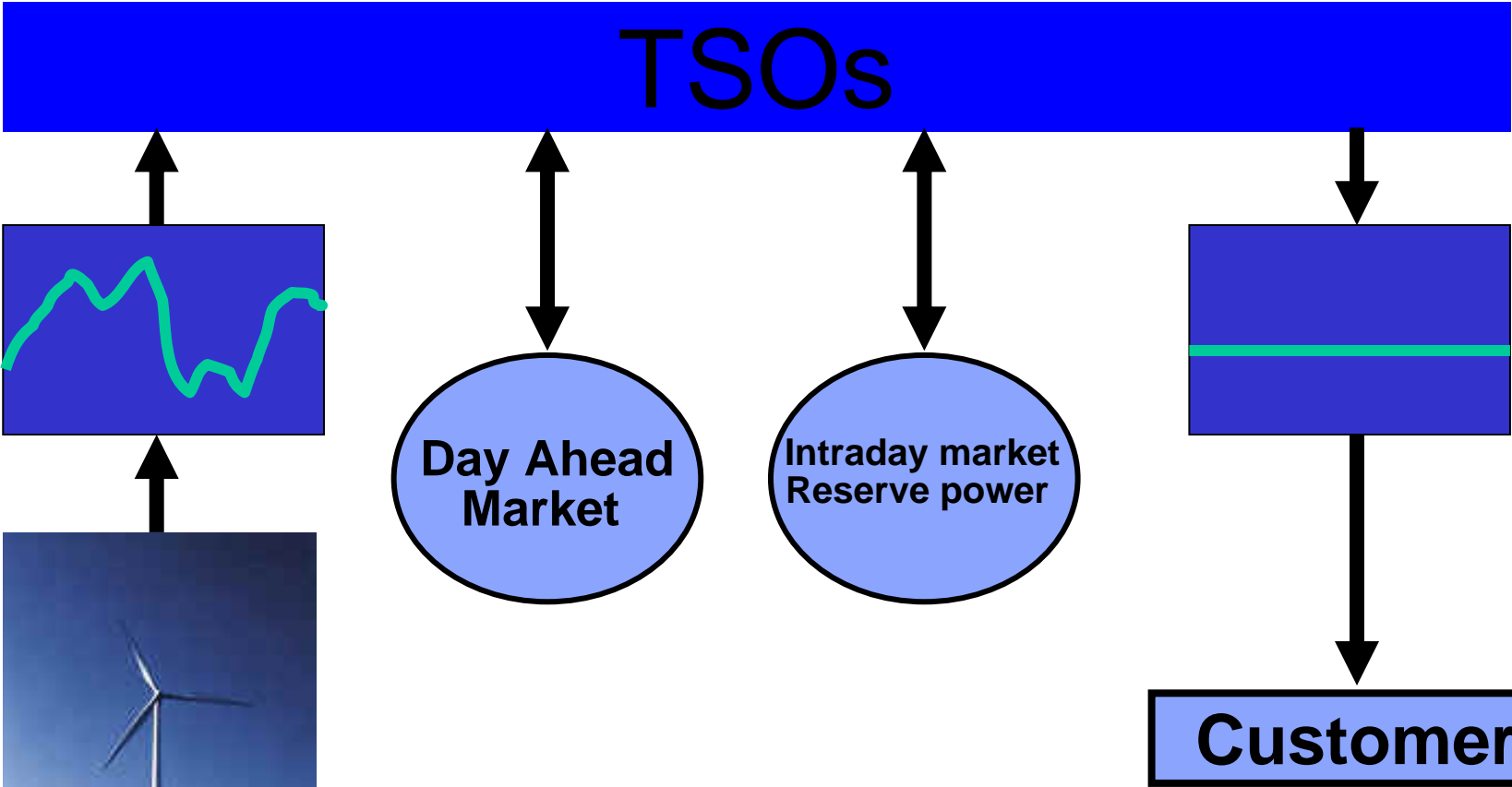
M. Lange, U. Focken, R. Meyer, M. Denhardt, B. Ernst, F. Berster

Overview

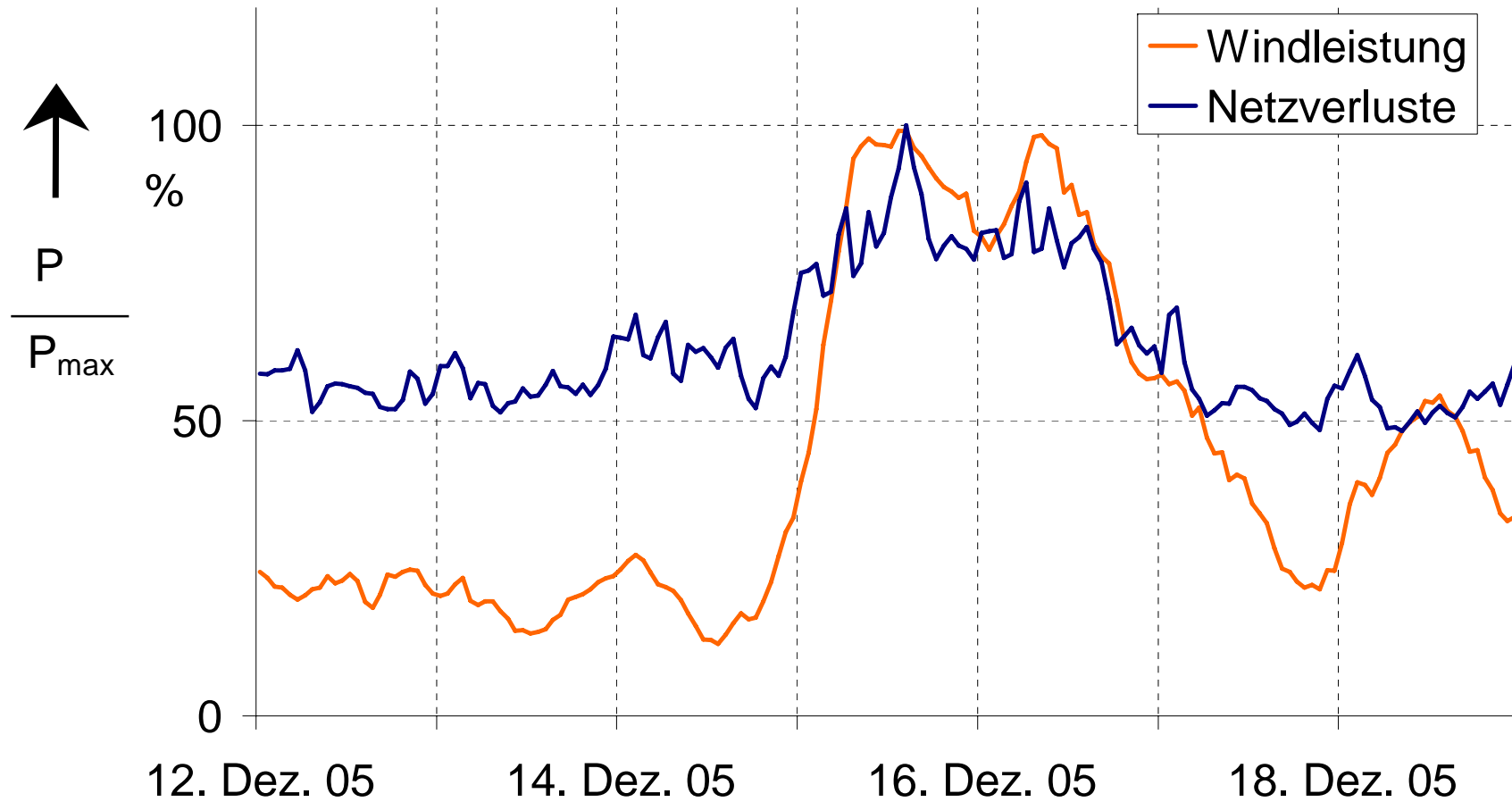
- ▶ **Motivation**
- ▶ Method
- ▶ Results
- ▶ Summary



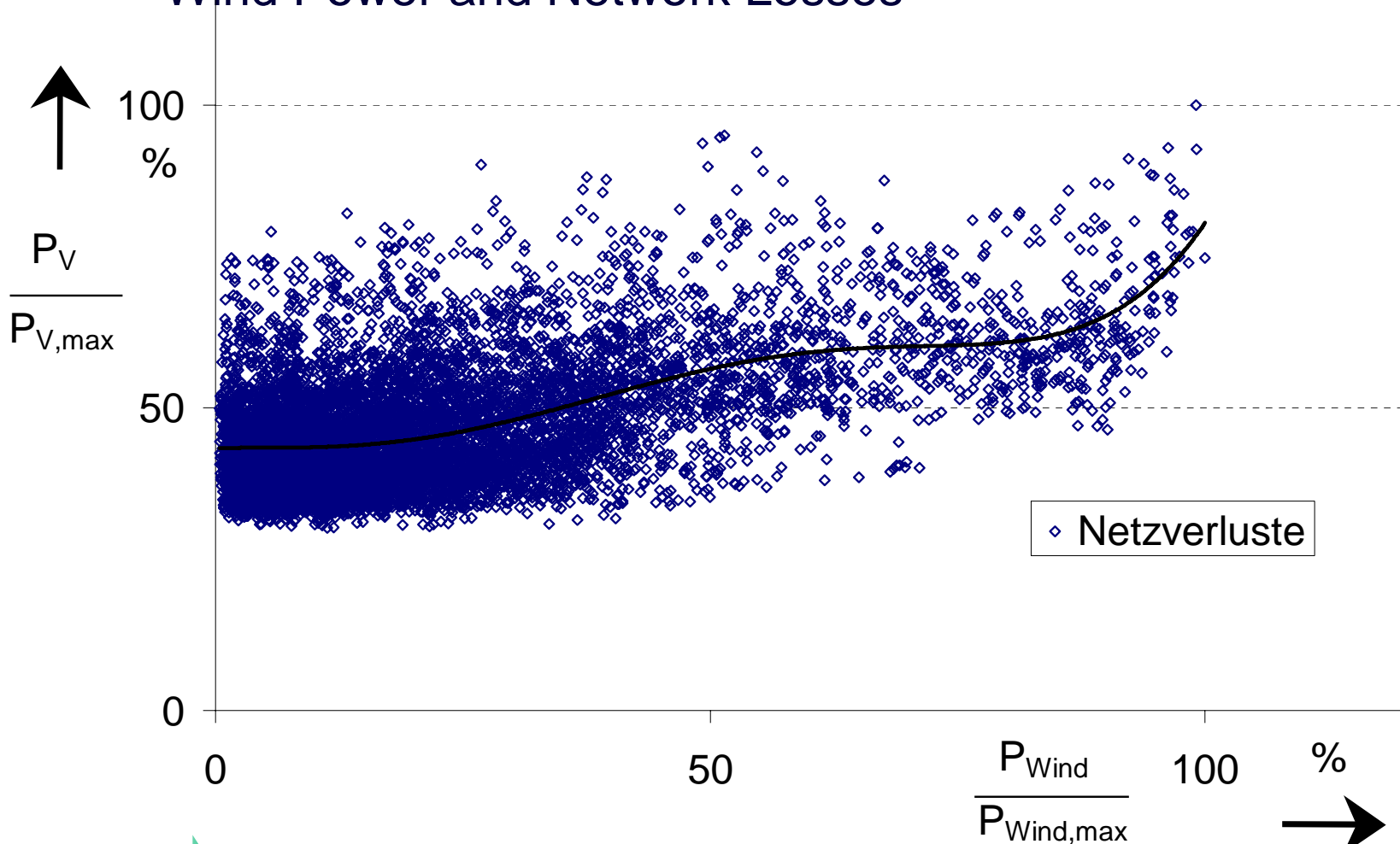
Motivation



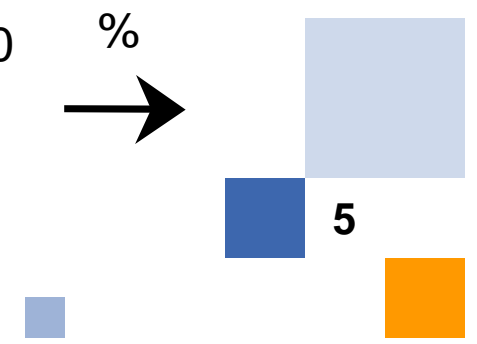
Wind Power and Grid Losses



Wind Power and Network Losses



Higher losses at situations with high wind power



Motivation

- ▶ **Wind power prediction systems commonly use only one single numerical weather prediction model (NWP).**
- ▶ **But: The NWP models have strengths and weaknesses in different situations.**
 - ▶ e.g.: convection is over-estimated by one model, which leads to increase in the predicted wind speed.
- ▶ **Our approach: Combine different deterministic NWP to minimise the error of wind power forecasts with a focus on finding an optimal combination of weather models with regard to different weather situations.**

Stochastic approach, Rule-based forecasting

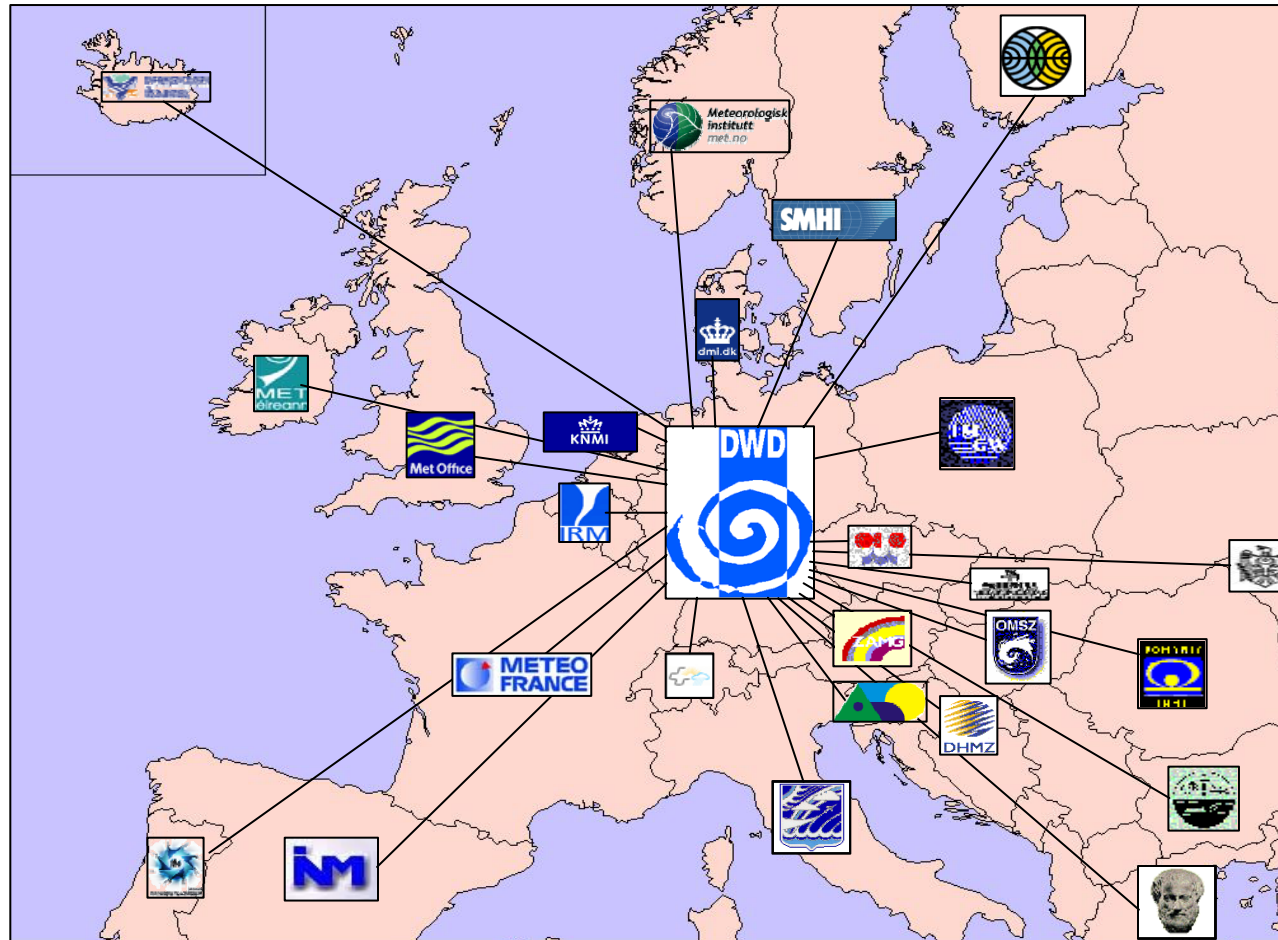
- ▶ *“Combine and average: [...] Simple average performs as well as more sophisticated statistical approaches.”*

Clemen, R.T., Combining forecasts: A review and annotated bibliography, Int. Journal of Forecasting 5 (1989) 559-582.

- ▶ *„**Rule-based forecasting:** [...] We believe that this procedure will lead to improvements.“*

Armstrong, J.S., Combining Forecasts: The End of the Beginning or the Beginning of the End?, Int. Journal of Forecasting 5 (1989) 585-588.

Combining Europe's best NWP for a better forecast



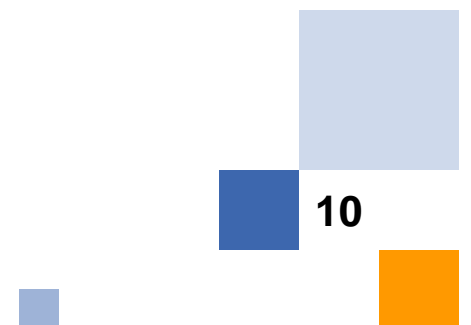
Project

- ▶ Coordinator/ Developer of „CombiTool“
 - ▶ energy & meteo systems GmbH
 - ▶ Operator of PREVIENTO, an operational wind power forecasting system
- ▶ Operational use:
 - ▶ RWE Transportnetz Strom GmbH
- ▶ Project partner:
 - ▶ Deutscher Wetterdienst (DWD)

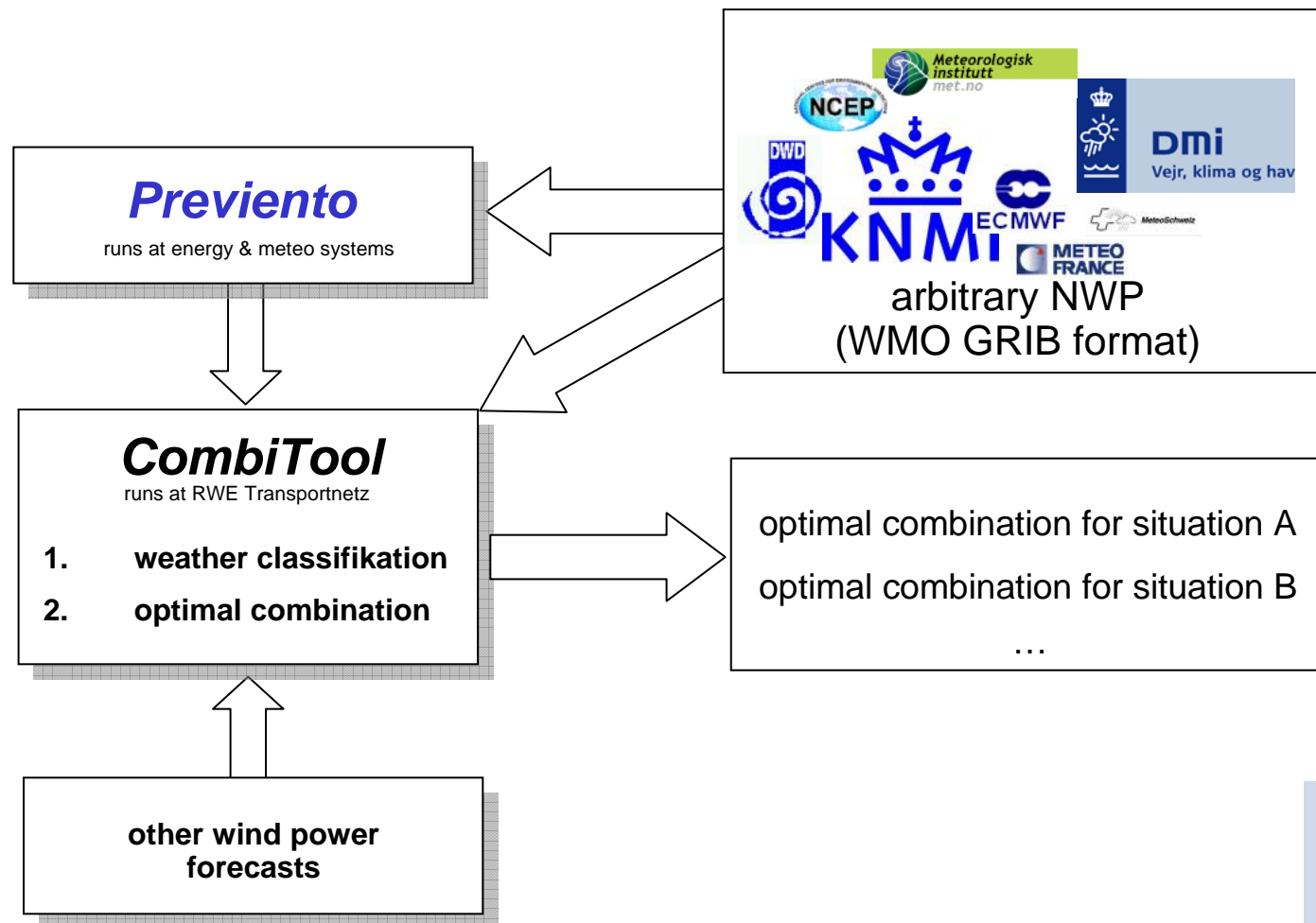
The project is partly funded by the German Federal Environment Ministry.

Overview

- ▶ Motivation
- ▶ **Method**
- ▶ Results
- ▶ Summary



What the CombiTool does



How the CombiTool works

1. Classification – *Find significant weather situation*

- ▶ Principal Component Analysis

Simplifying the dataset of meteorological parameters by reducing multi-dimensional data set to lower dimensions

- ▶ Clustering

Clustering groups similar objects into different subsets (clusters), so that the data in each subset share some common trait.

here: similar weather situation

2. Optimal Combination – *Find the best combined forecast*

Find in each situation (cluster) the optimal weighting factors

Overview

- ▶ Motivation
- ▶ Method
- ▶ **Results**
- ▶ Summary

1.5 TByte weather data of ten weather services in WMO-GRIB-format

weather data as input for *Previento*:

- ▶ HIRLAM, KNMI, Netherlands
- ▶ ALADIN, Meteo France, France
- ▶ LME, DWD, Germany
- ▶ ECMWF, United Kingdom
- ▶ GFS, NCEP, USA
- ▶ HIRLAM, DMI, Denmark
- ▶ aLMo, Meteo Schweiz, Switzerland
- ▶ HIRLAM, DNMI, Norway
- ▶ ALADIN-LACE, DHMZ, Croatia
- ▶ UM-EU, UK Met Office, United Kingdom
- ▶ Probabilistic product (PEPS), DWD

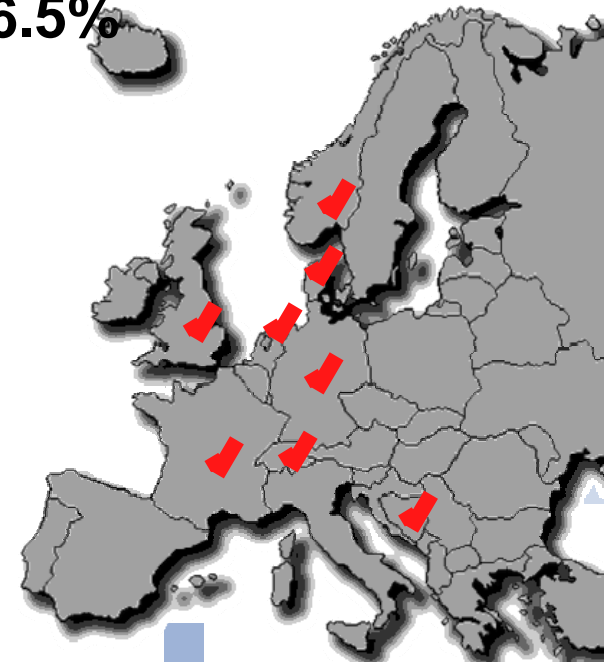
- ▶ Two time series of wind power forecasts not derived by energy & meteo systems



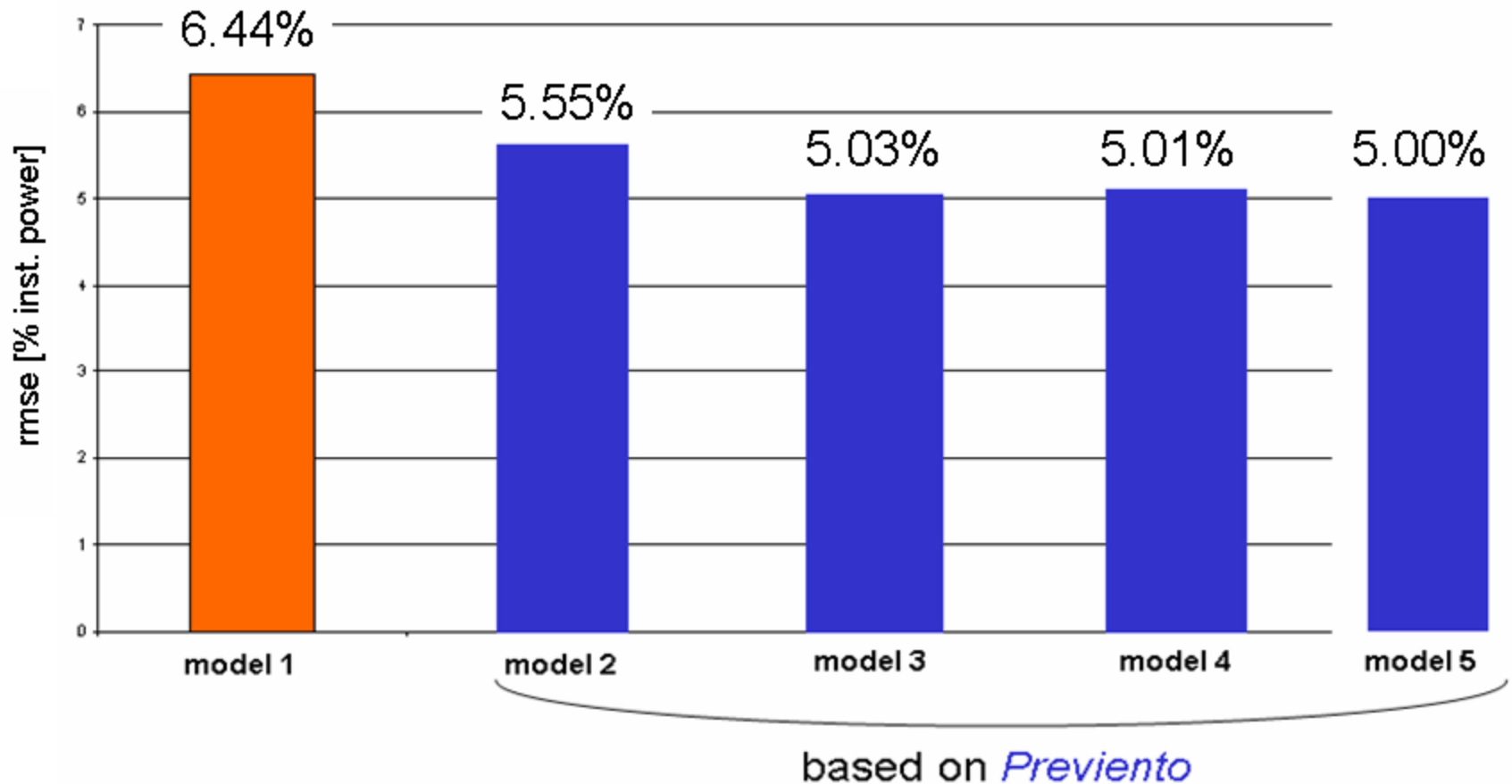
Size of the Forecast Area

Root mean square error (rmse) of the dayahead-forecast (in % of installed capacity)

- ▶ Single Wind Farm: **10 % to 20 %**
- ▶ Single Control Area (250 mi x 250 mi): **7.5 % to 10 %**
- ▶ All Control Areas (400 mi x 500 mi): **5% to 6.5%**

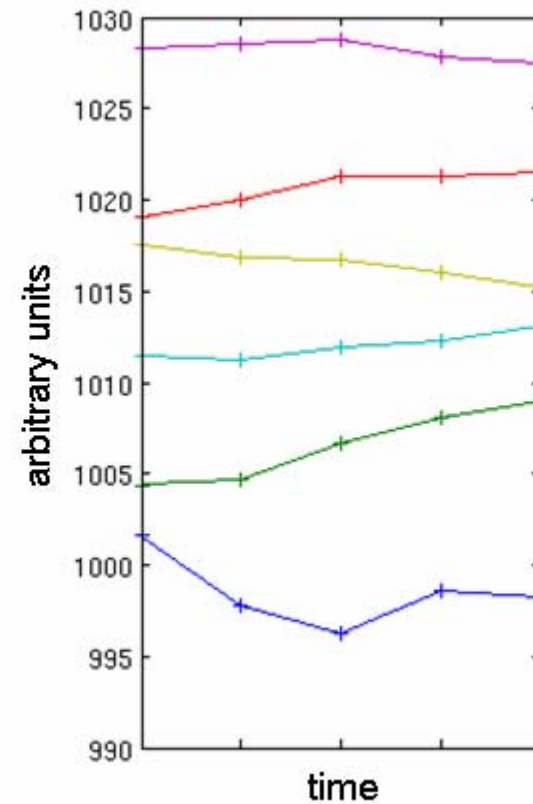
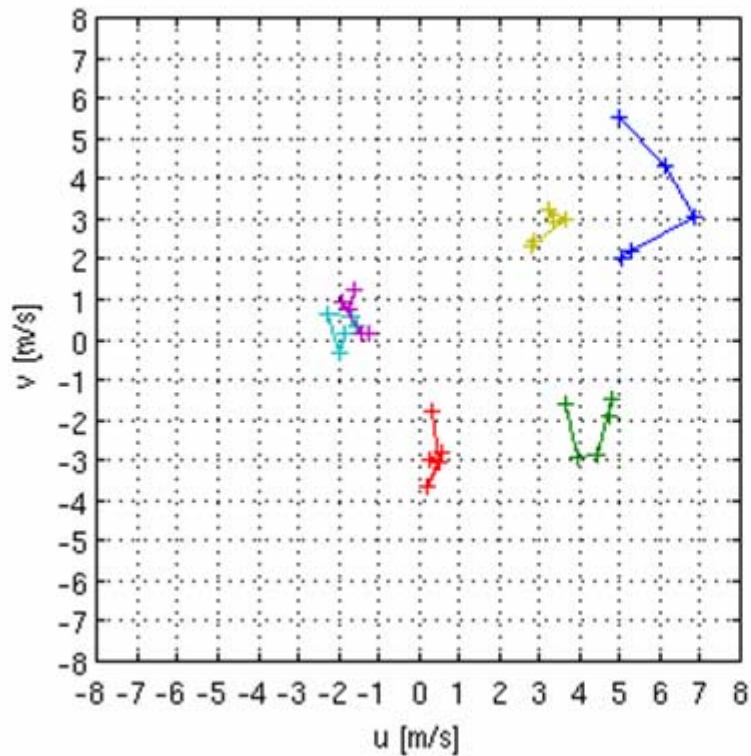


Root mean square error (rmse) dayahead-forecast January-October (all control Areas)

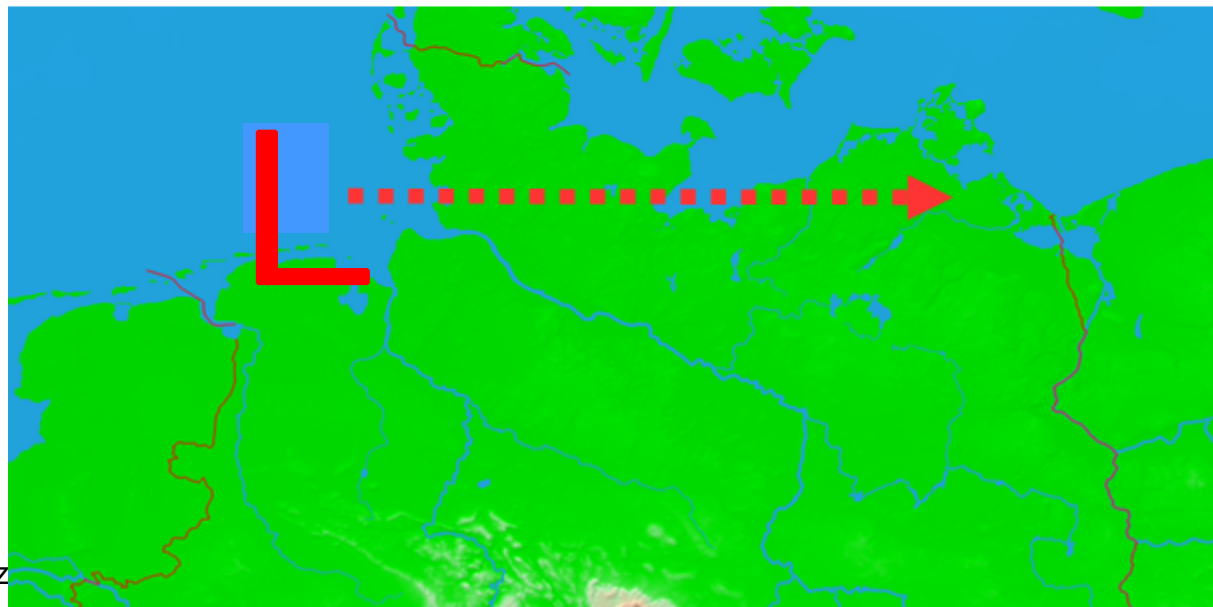
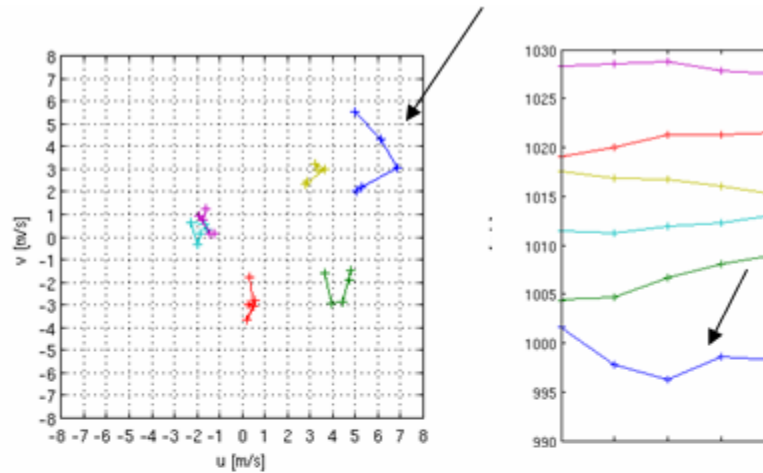


Results Clustering:

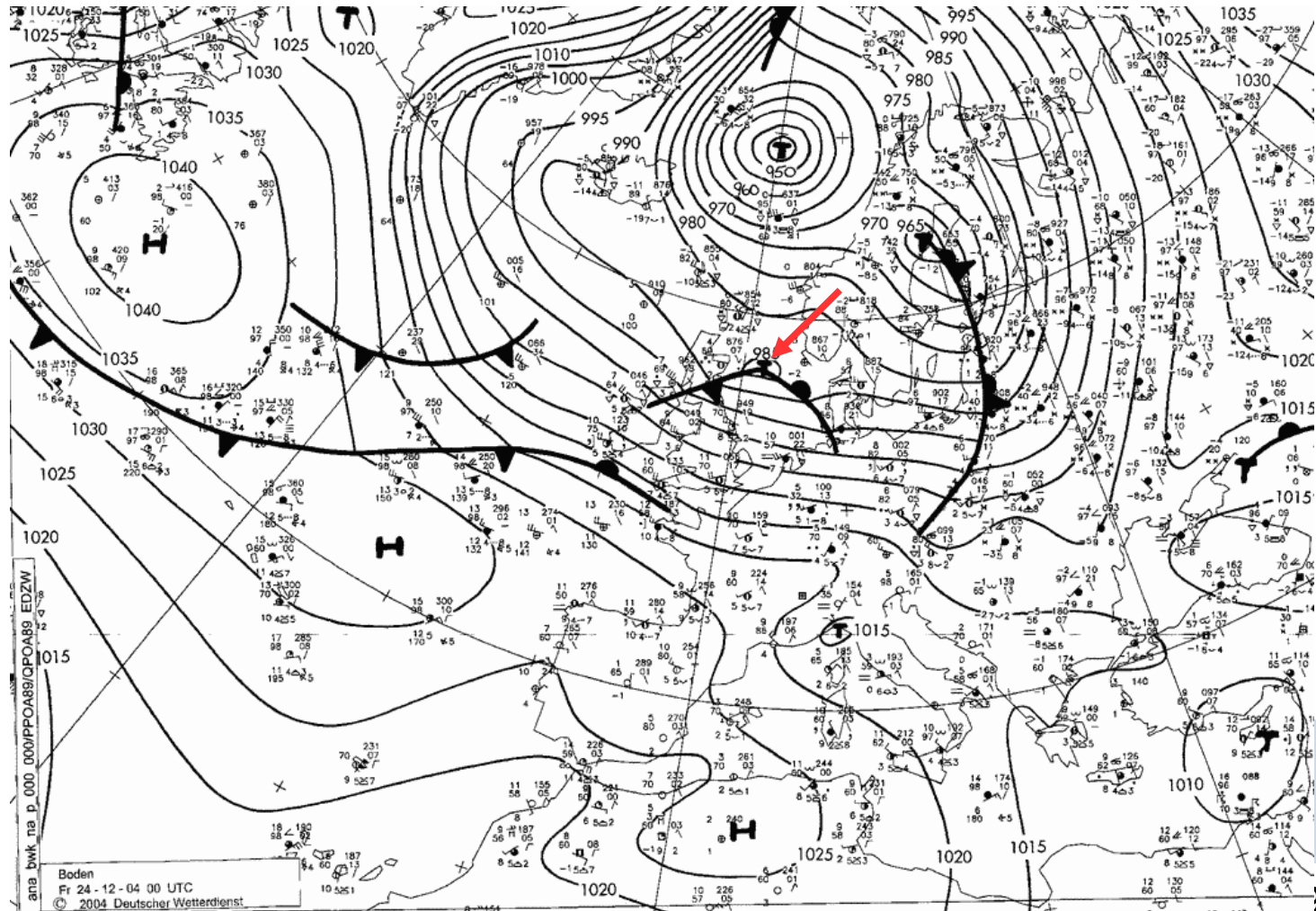
Mean of u- und v-component and pressure in clusters



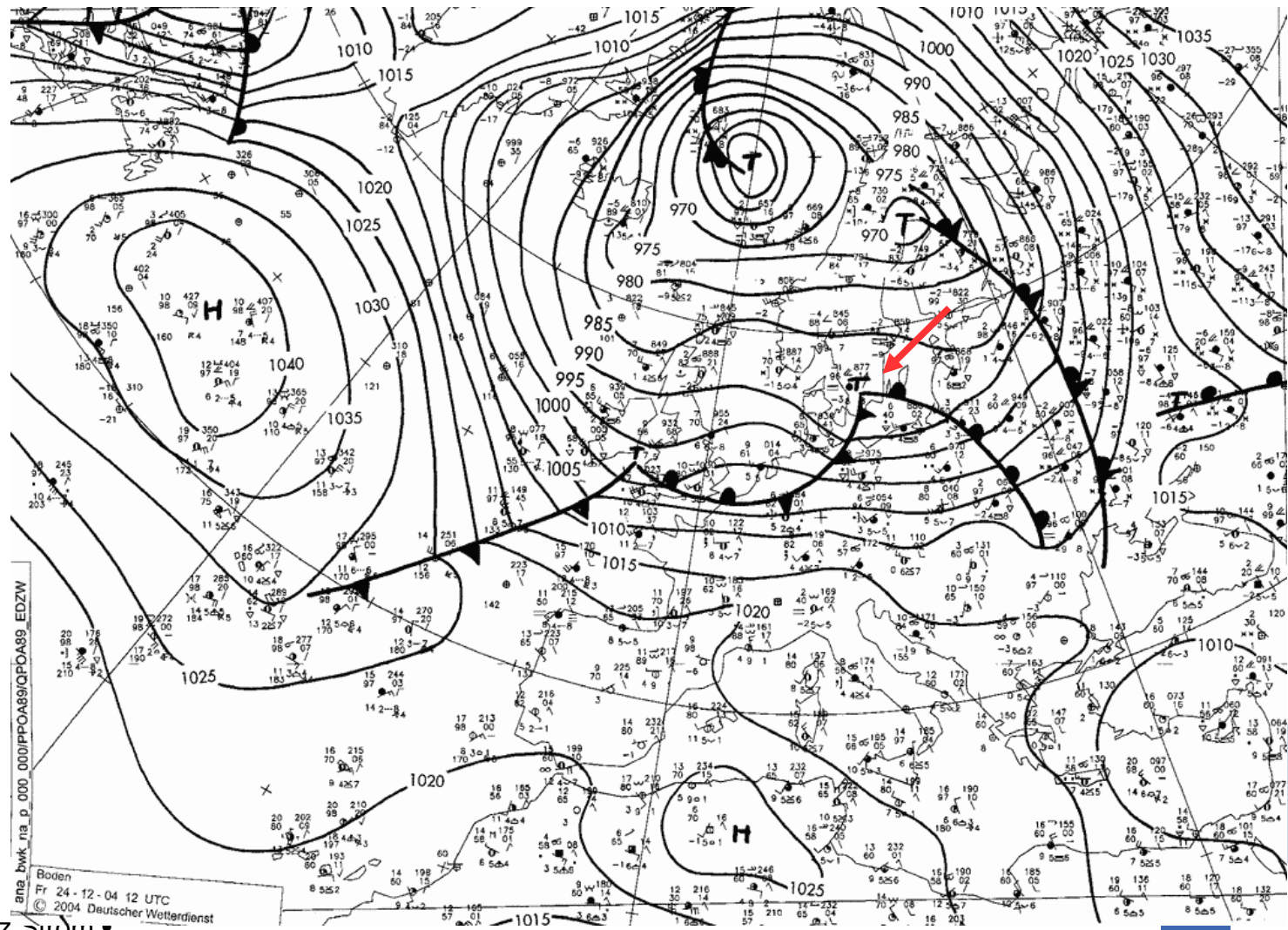
Example: Weather cluster „Cyclone passing – type A“



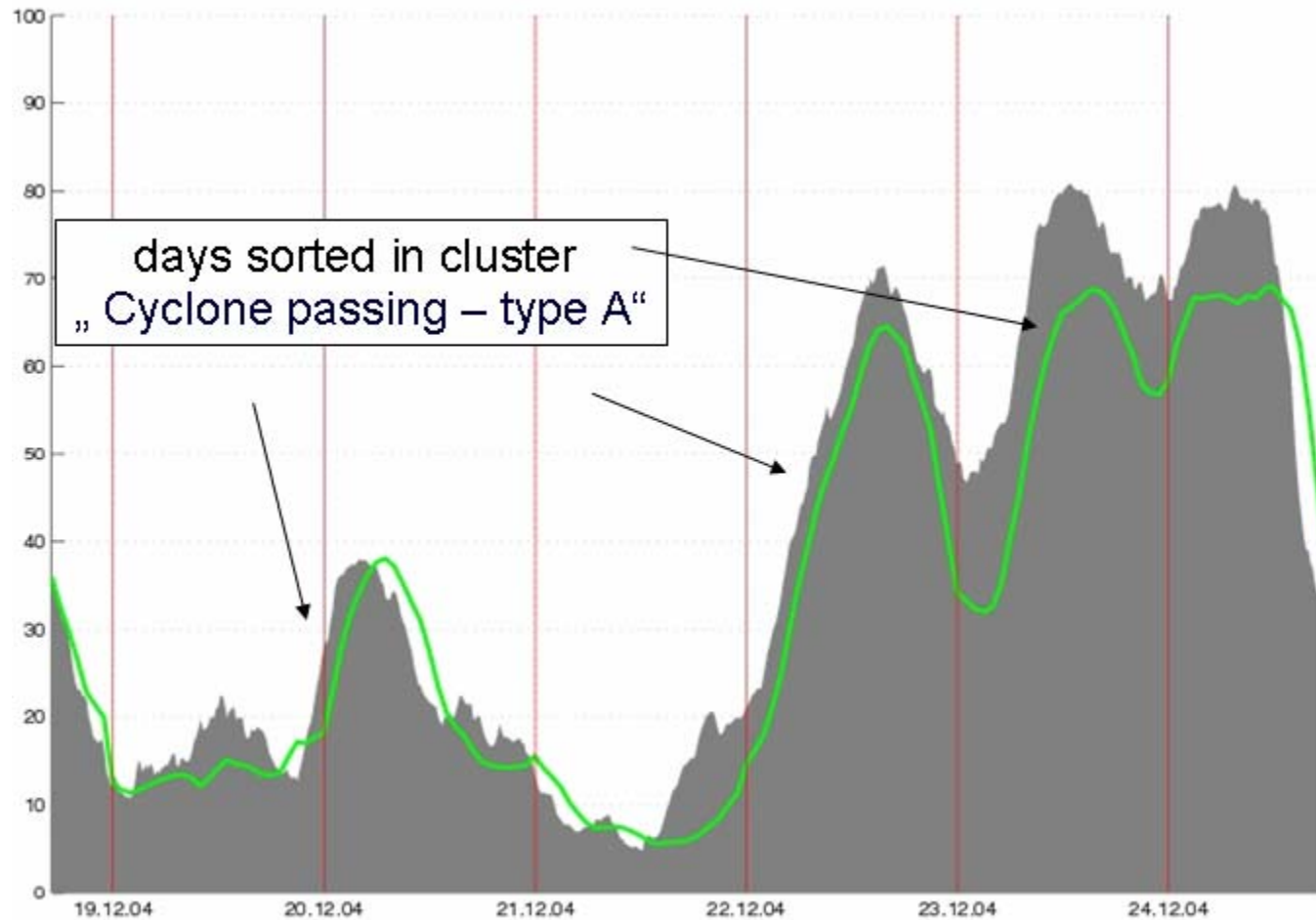
Weather cluster „Cyclone passing – type A“



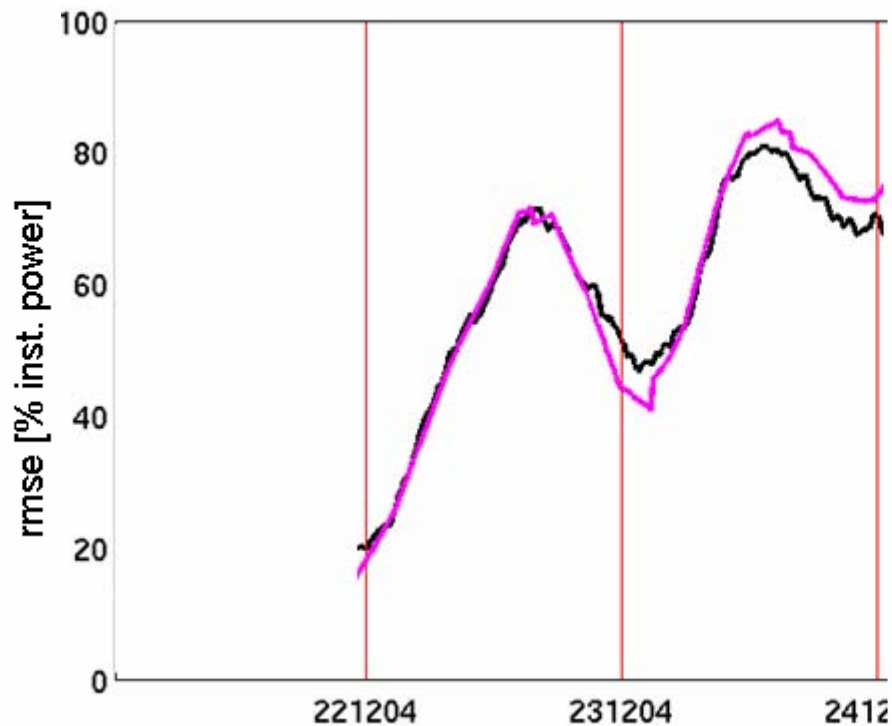
Weather cluster „Cyclone passing – type A“



Example: Typically behaviour of one forecast in cluster „Cyclone passing – type A“



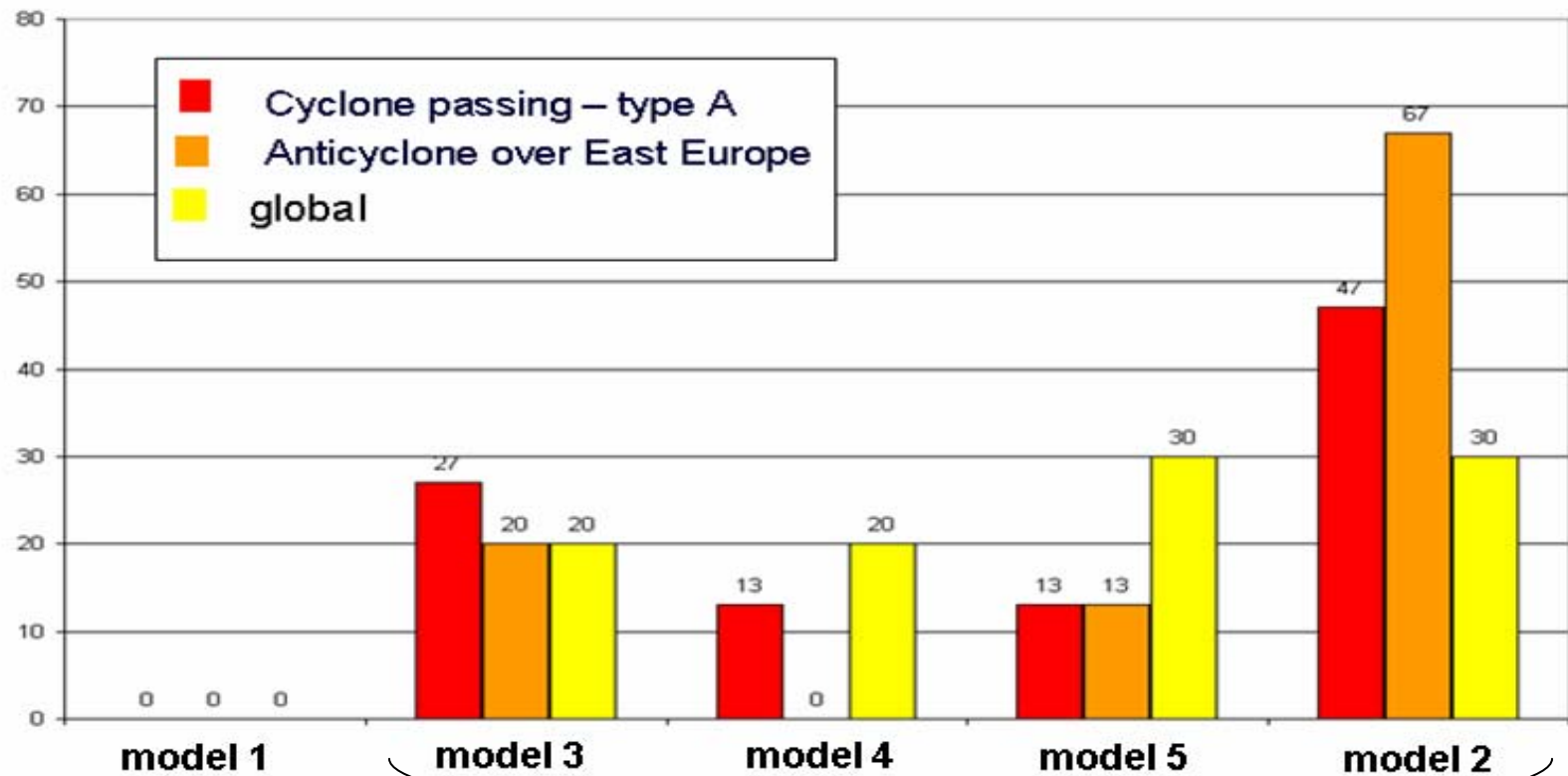
Example: Optimal combination in cluster „Cyclone passing – type A“



optimal linearfactors

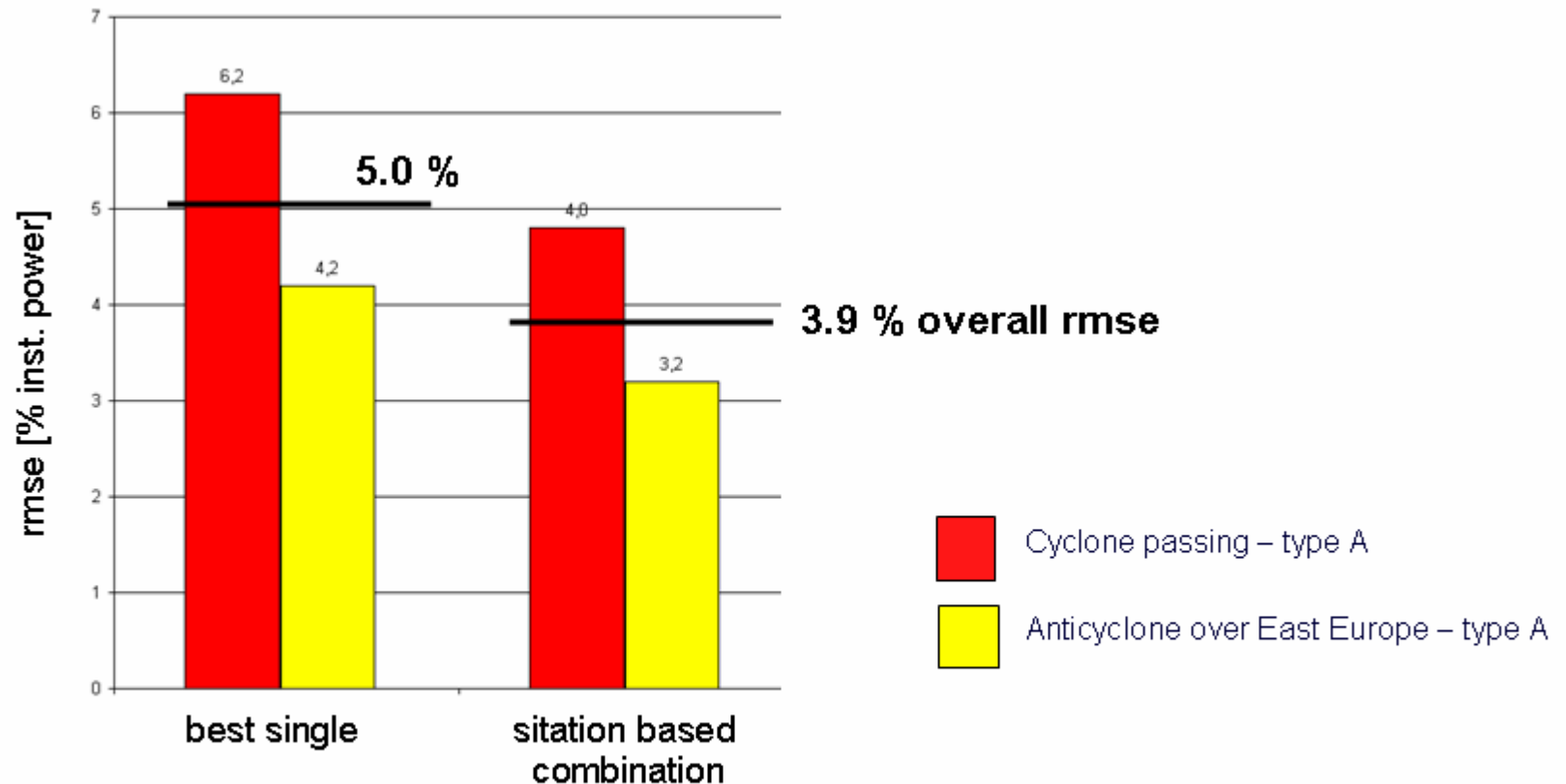
- ▶ 0% model 1
- ▶ 47% model 2
- ▶ 27% model 3
- ▶ 13% model 4
- ▶ 13% model 5

Optimal factors differ from situation to situation



based on *Previento*

Accuracy in individual weather situations



- ▶ using optimal weights for each weather situation leads to considerable improvement

Summary

- ▶ NWP have strengths and weaknesses in different weather situations.
- ▶ An automatic classification scheme, based on methods from synoptic climatology generates useful weather classes. A situation of a passing cyclone was presented in detail.
- ▶ Just putting together forecasts is not sufficient, careful selection needed.
- ▶ The optimal combination, i.e. based on weighting factors that have been obtained specifically for this weather class outperforms the individual forecasts.
- ▶ The systems will be used operational at RWE Transportnetz.

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Thank you for your attention!