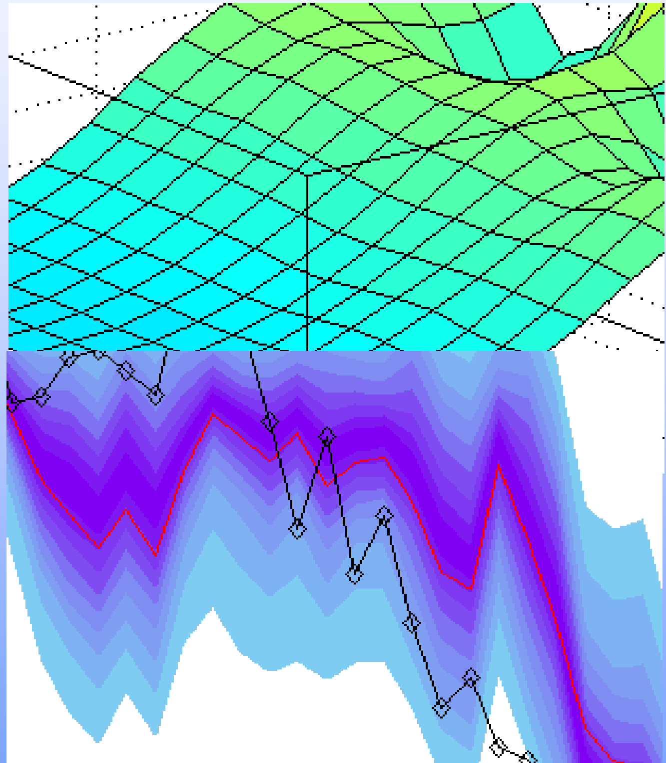
EUROPEAN COMMISSION
Community research

WIND POWER FORECASTING ANEMOS



Short-term Forecasting Using Advanced Statistical Models

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European Wind Energy Conference
Athens, 27 Feb. – 2 Mar. 2006.

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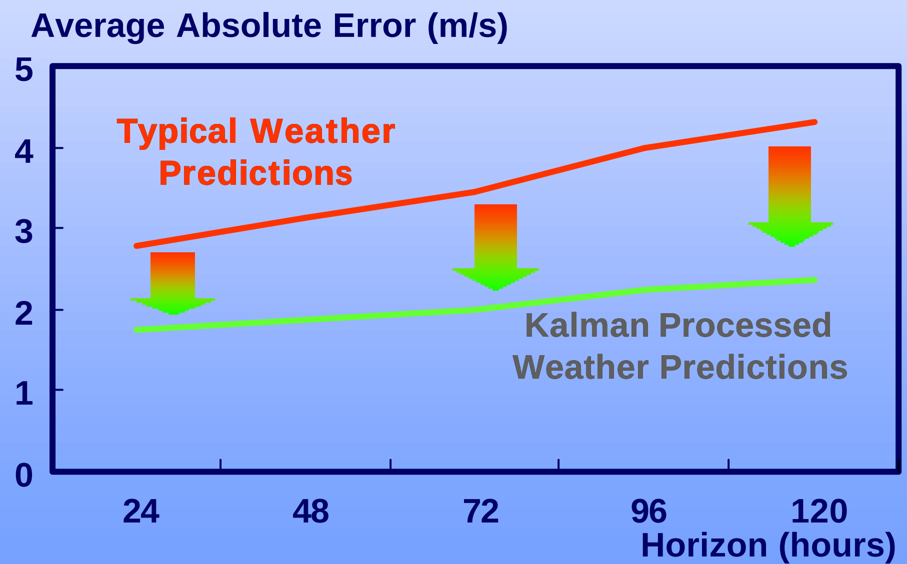
Research priorities

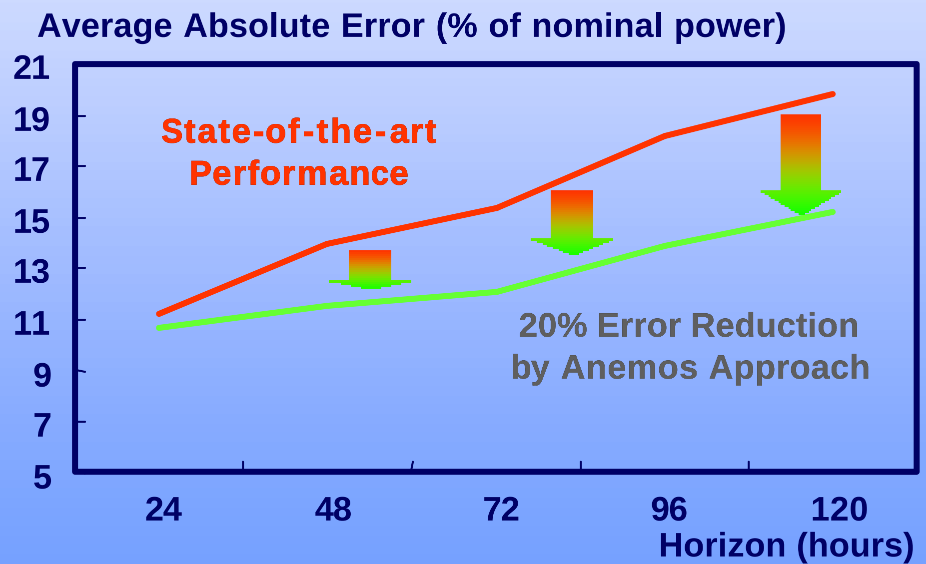
- Downscaling of NWP data to local conditions
- Power curve modeling
- Prediction of local power or wind speed
- Assessment of the prediction uncertainty: interval forecasts and prediction risk indices
- Regional upscaling of power predictions
- Automatic processes for online tuning

Kalman filtering of NWP data

- **Example in complex terrain (Crete, GR):**

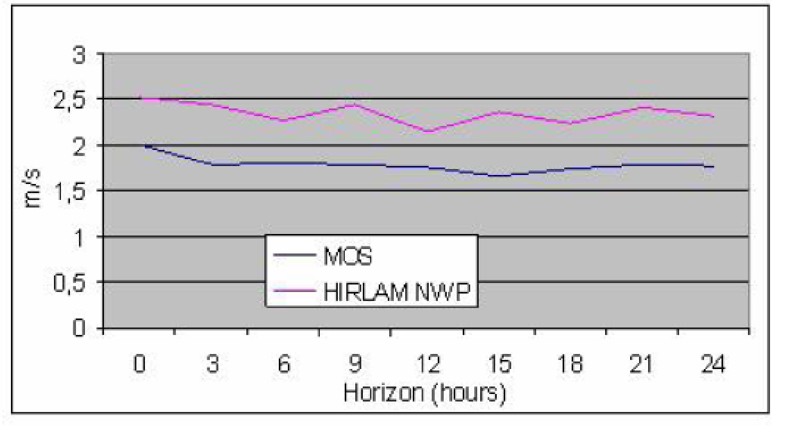
Error Reduction in Wind Speed Predictions ➔ **Error Reduction in Wind Power Predictions**



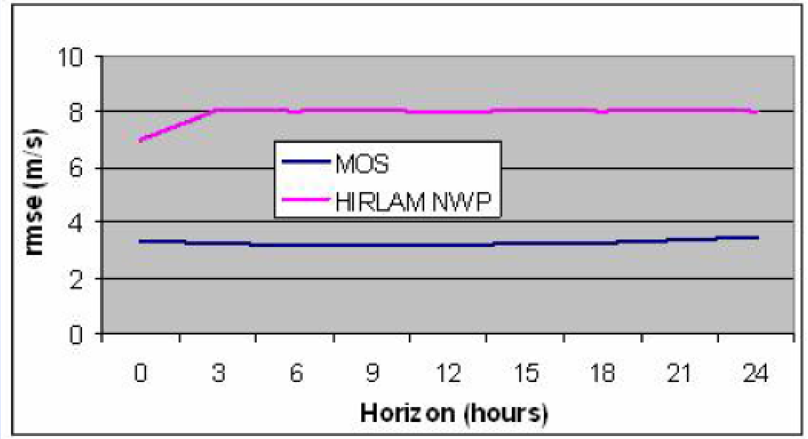


Statistical downscaling of NWP data

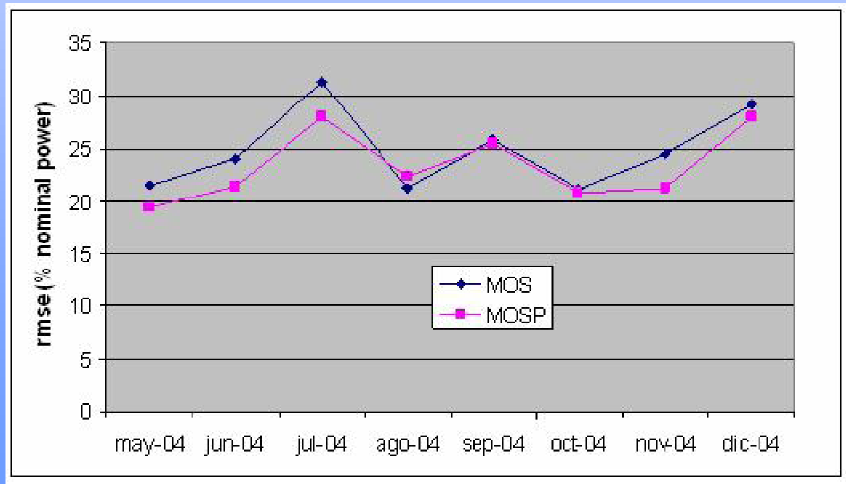
Sotavento test case



Alaiz test case

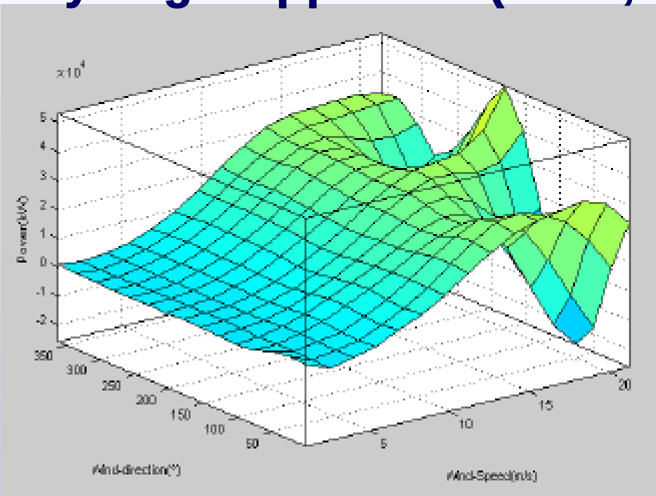


- **Downscaling (MOS) reduces forecast errors significantly, especially in complex terrain**
- **Methods with and without measured wind data have been developed**
- **Methods are based on principal components analysis on surrounding NWP grid points**

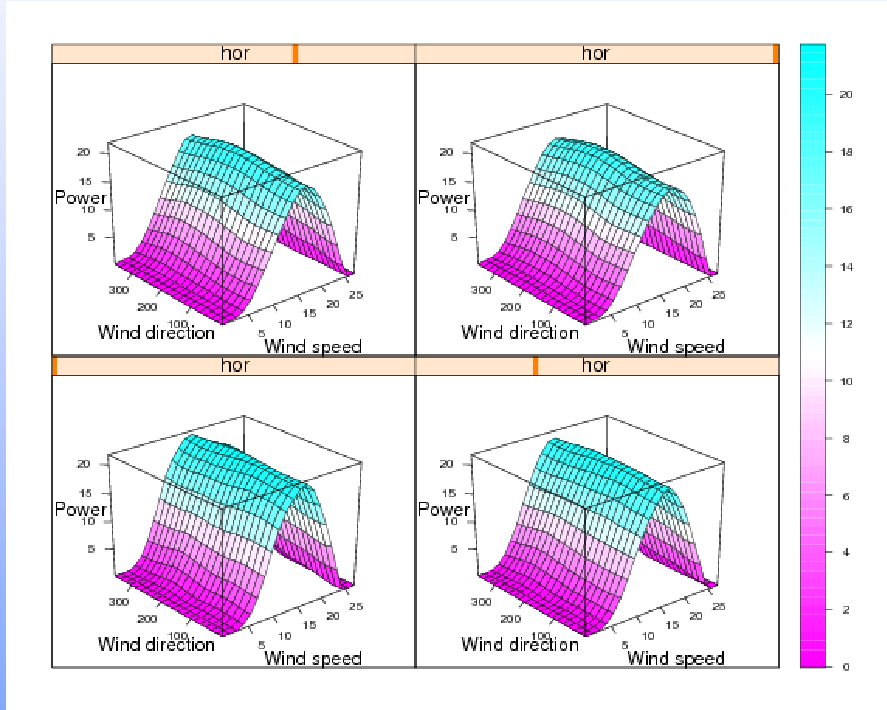


Power curve modeling

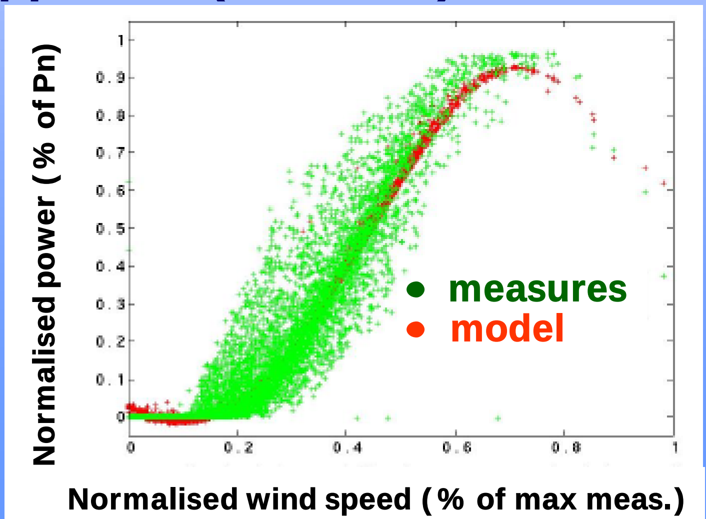
- **Fuzzy Logic approach (Alaiz, ES):**



- **Local Regression approach (Klim, DK):**

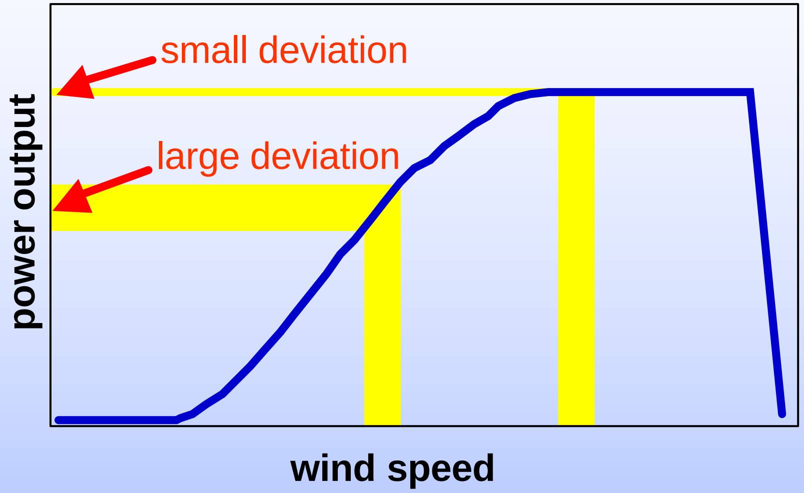


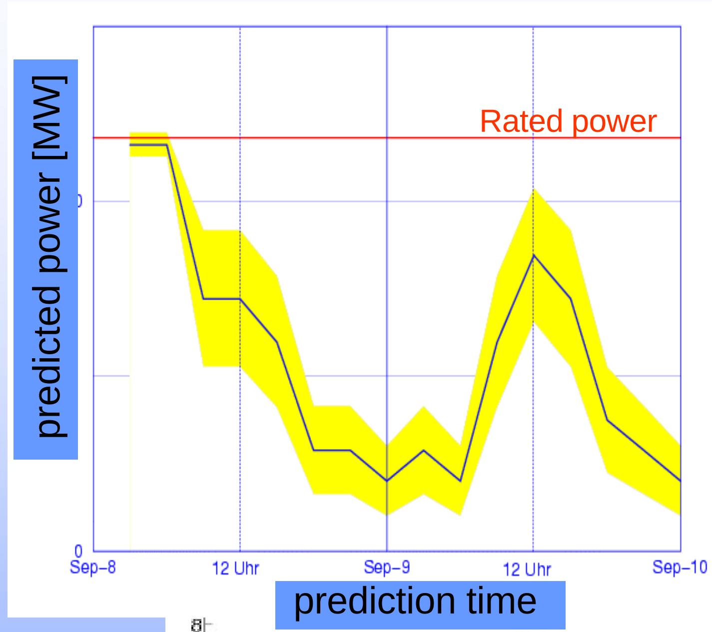
- **Support Vector Regression approach (Klim, DK):**

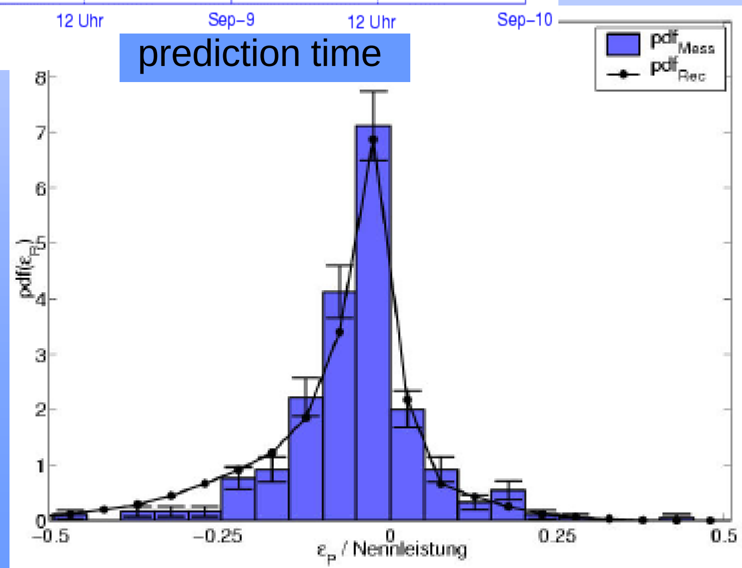


Estimated power curves for prediction horizons of 13, 23, 33 and 43 hours

Power curve transformation of wind speed forecast errors



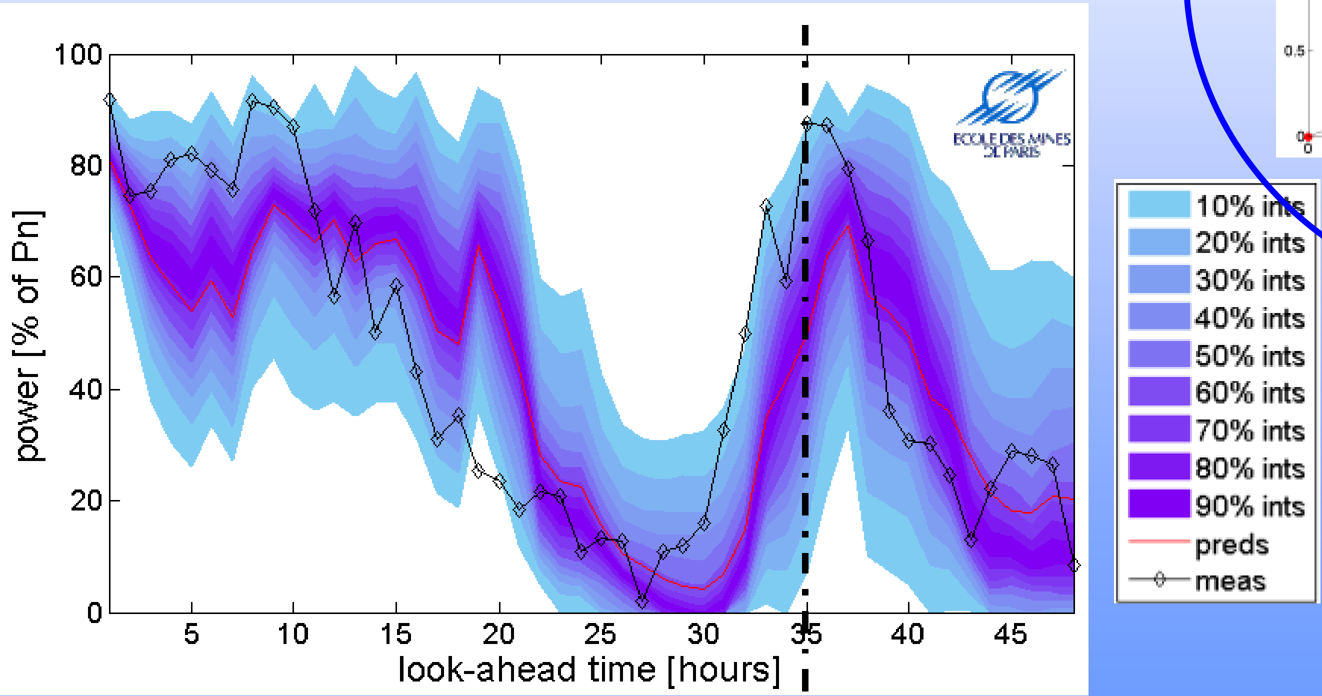


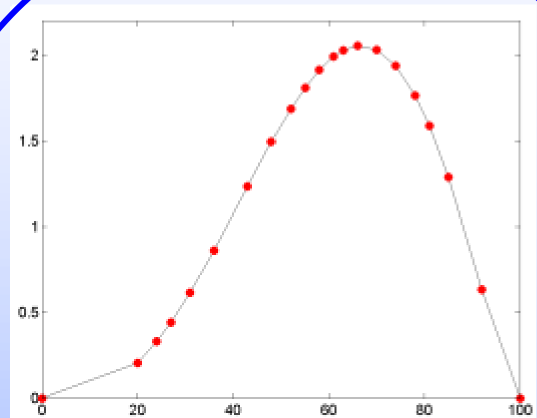


- **Errors are amplified according to local slope**
- **The statistical distribution of power forecast errors can be modeled**

Estimation of prediction intervals

- **Original methods based on:**
  - **Adapted resampling (with fuzzy modeling)**
  - **Quantile regression.**
- **Towards probabilistic forecasting**

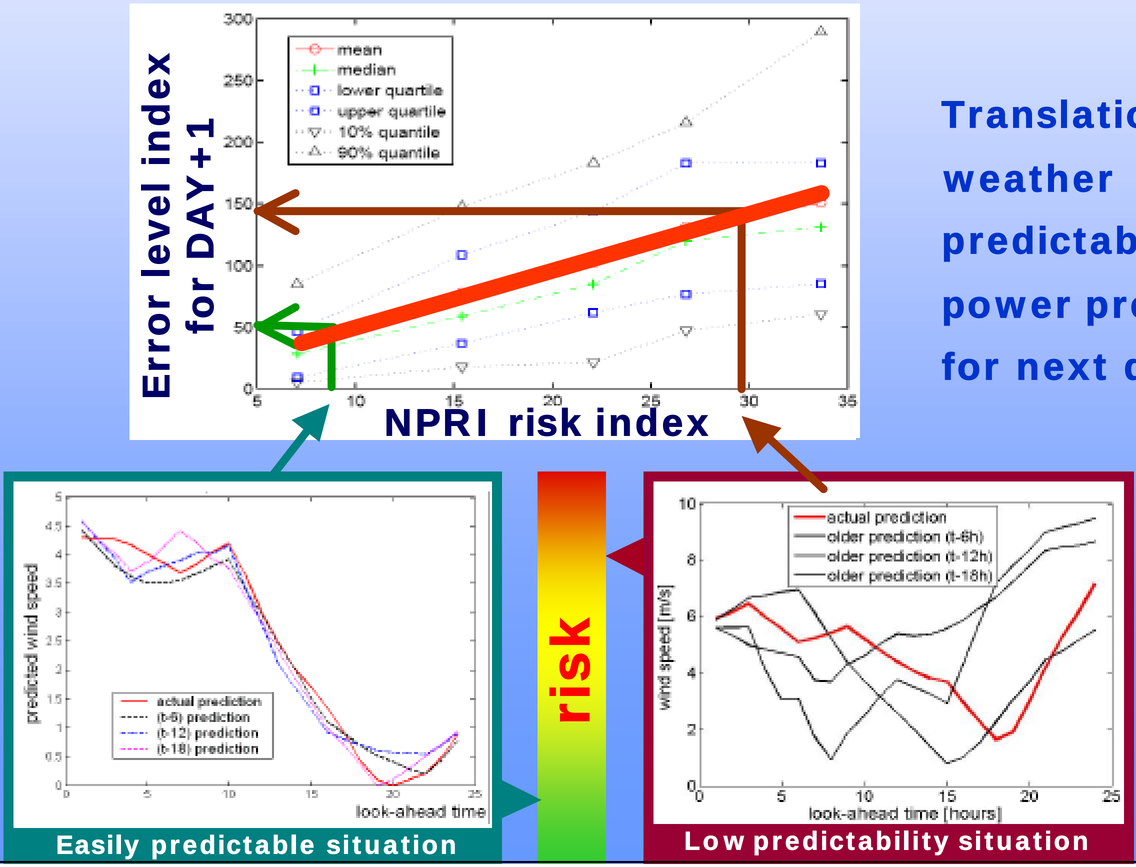




predictive distribution for horizon t_0+35h

Ensemble forecasts and risk indices for assessing prediction uncertainty

- **Risk indices based on ensembles provide information on the wind power predictability for the next 24 hours.**
  - **Value for developing advanced strategies in decision making processes (i.e. trading, reserves definition)**



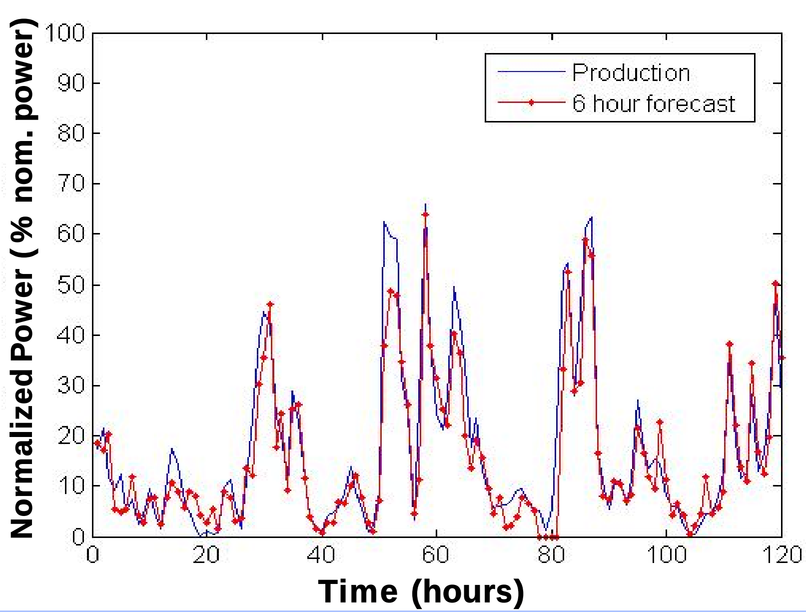
Translation of weather predictability to power predictability for next day

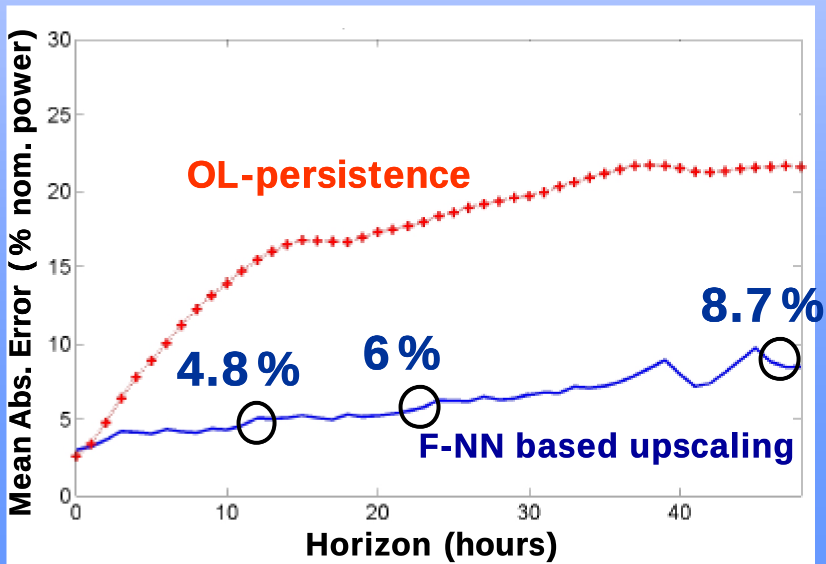
Regional forecasting in Denmark

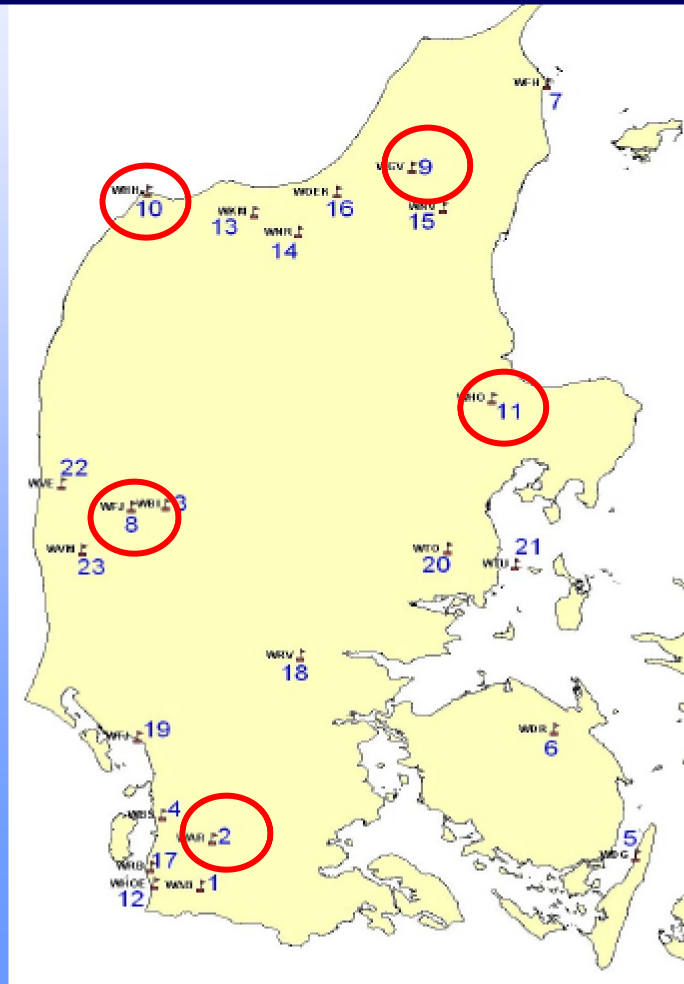
Jutland area: 2200 MW

Data: 23 WF's (10 %) + total.

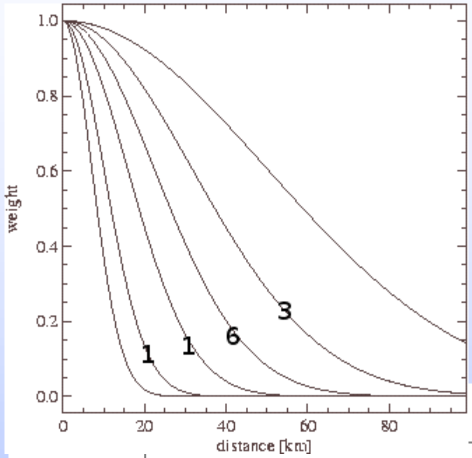
Prediction based on 5 reference WFs.



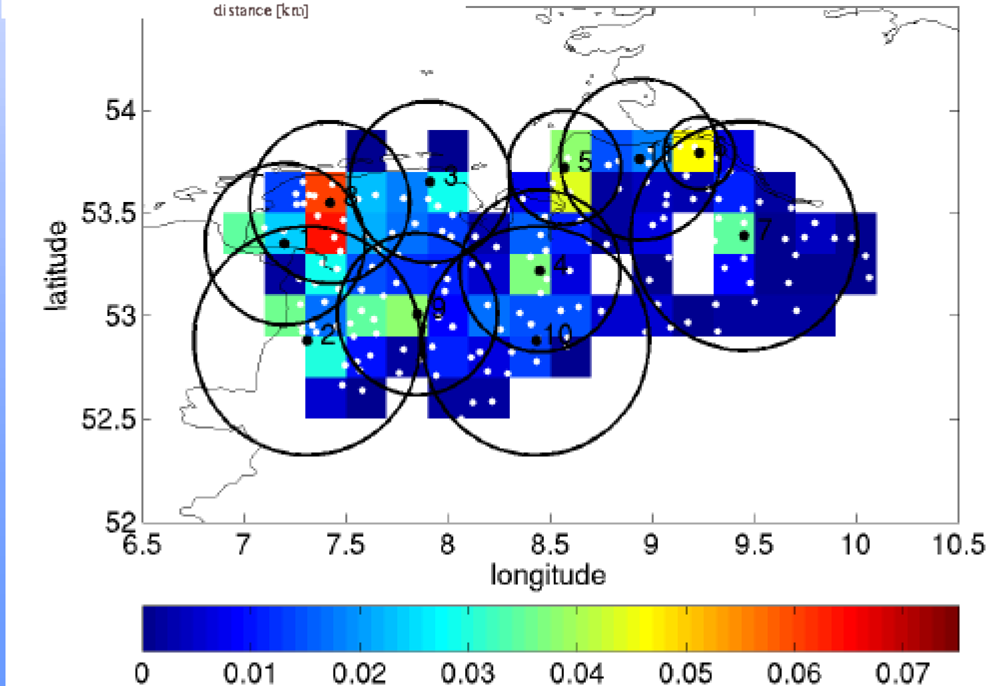


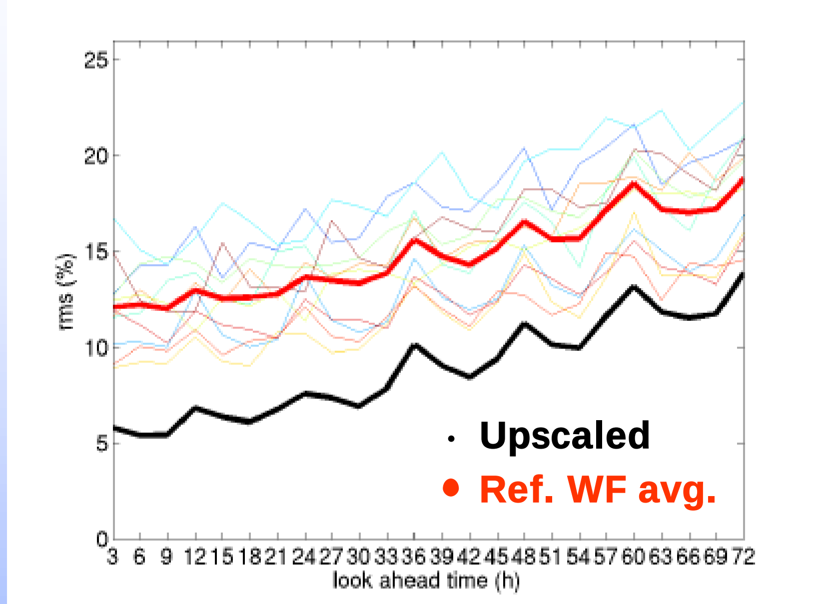


Regional forecasting in Germany



Area: 2000 WT
Data: 11 WF's+total.
Upscaling based on gaussian weight functions in distance

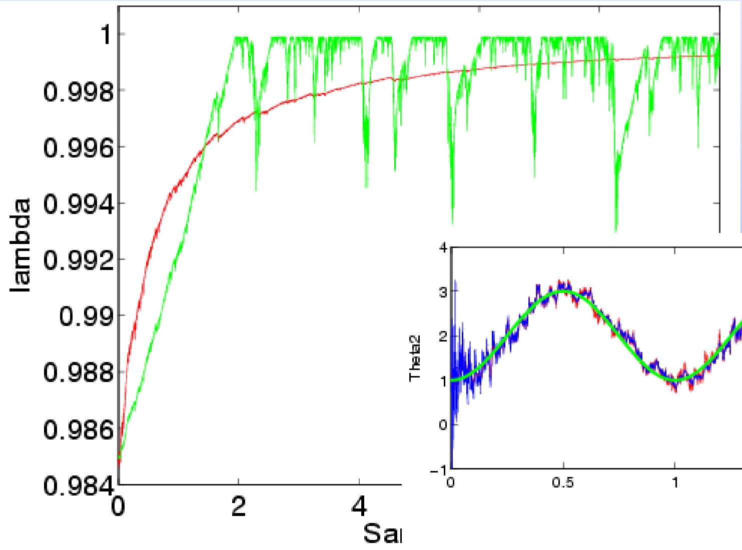




- **Spatial smoothing effect gives a 22-50 % error reduction for a fairly small area**
- **The color squares indicate how large a fraction of the total the local WT's represent**

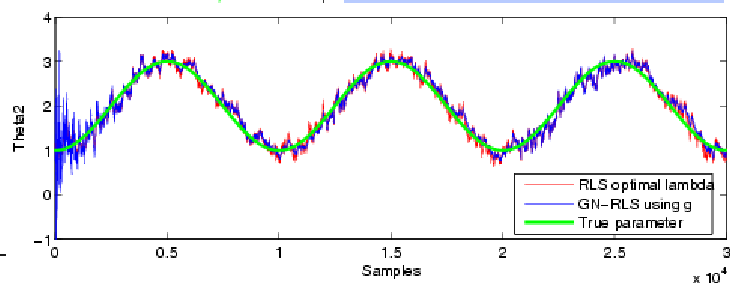
Automatic tuning processes

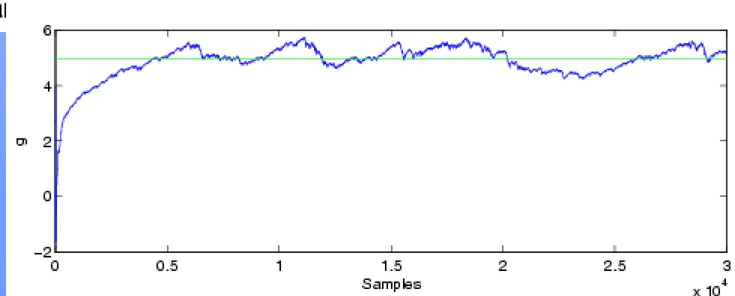
- **Towards plug&play models: Automatic adaptation to local conditions:**
  - Easier installation
  - Reduced model maintenance

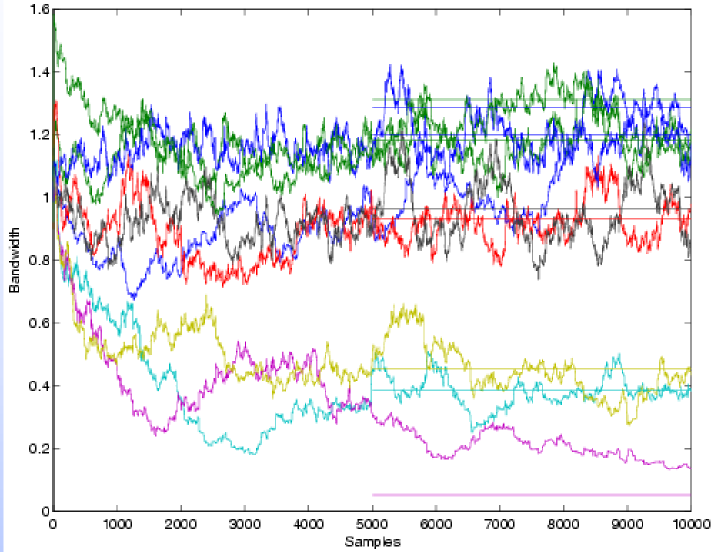


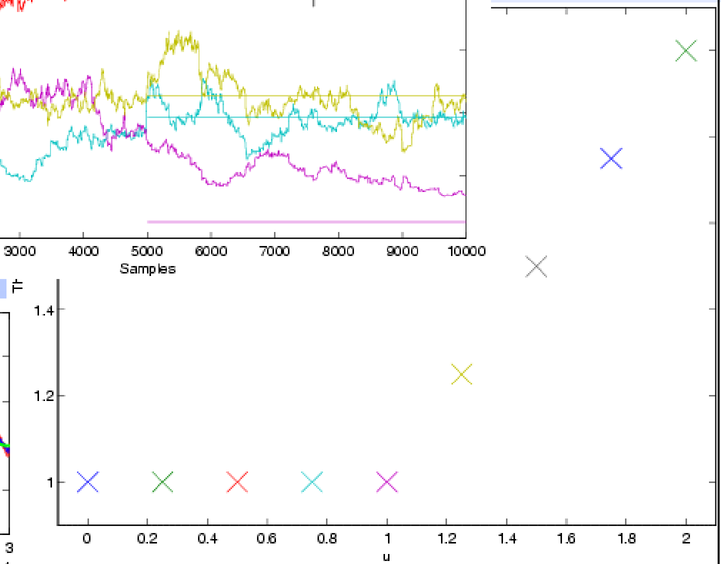
Ex1: $P_t = a_t P_{t-1} + e_t$

a_t estimated using RLS with forgetting factor









Ex2: $P_t = f(w_t) + e_t$

f() estimated using local regression with linear approximation

Conclusions

- Statistical modeling solutions for all links in the model chain from area average NWP over local predictions to regional power predictions have been developed.
- Each link in the statistical modeling chain performs equally well or better than other modeling approaches.
- Appropriate models are provided for uncertainty estimation.
- The model solutions are being made available for operational use within the ANEMOS shell.