Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Fraunhofer IWES · 50hertz · TenneT Taking power further · amprion

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

The German Research Project *EWeLiNE*

Evaluating the calibration of a wind forecast ensemble for energy applications

RESEARCH PROJECT EWeLiNE

Partners:
- DWD (German Weather Service)
- Fraunhofer Institute IWES
- 3 German TSOs (transmission system operators)

General aim:
- Improvement of weather and power forecasts for renewable energy applications (Fig. 1).

Focus of this work:
- Wind speed at around 100 m hub height.
- Probabilistic forecasts:

Ensemble prediction system (EPS) for weather information → Probabilistic power forecast

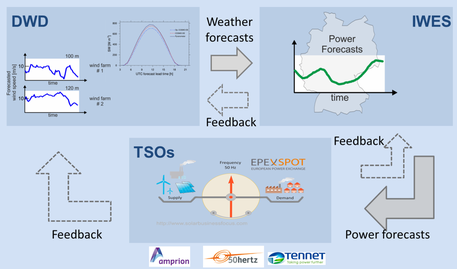

Fig. 1) Project structure of EWeLiNE. Users' requirements are directly integrated into the research and development activities.

METHOD

1) **Local non-homogeneous Gaussian regression (NGR/ EMOS)** [1]
   - Variable: horizontal wind vector.
   - Predictors: ensemble mean and standard deviation of horizontal wind components.
   - Local correlation of forecast wind components and observed wind direction at individual sites.
   - Locally adapted rolling 40-day training period.
2) **Regional quantile regression (QR)** [2]
   - Variable: wind speed.
   - Predictors: quantiles of the wind speed, regional predictors including geo-information as latitude/ longitude or on-/ offshore information.
   - Other possible predictors: ensemble mean and standard deviation of wind components, temperature, and pressure at certain model levels.
   - Predictor selection is performed by the **LASSO scheme** [3]. It computes coefficients related to different predictors. Coefficients of unrelated predictors are tend to be exactly 0.
   - Regionally adapted rolling 40-day training period.

Finally, we apply an **ensemble copula coupling (ECC)** [4] to redraw the rank order of the raw ensemble members to the calibrated ensemble output.

Test periods:
winter season 2012/13 and **spring season 2013**

MOTIVATION

- Raw ensemble wind forecasts suffer from bias and underdispersiveness.
- Calibration methods are developed for correction of the model bias and the ensemble spread bias.
- Additionally, ensemble members after calibration should remain physically consistent scenarios.

DATA

COSMO-DE-EPS FORECASTS
- Horizontal resolution 2.8 km
- 03 UTC, hourly forecasts
- Lead time 21h
- 20 members: variations in lateral boundaries and initial conditions based on 4 global models, and 5 physics perturbations.

  Gebhardt et al. 2011 [5], Peralta et al. 2012 [6]

OBSERVATIONS
- Mast and wind tower measurements at sites in Germany and Denmark.

EXAMPLES – wind speed

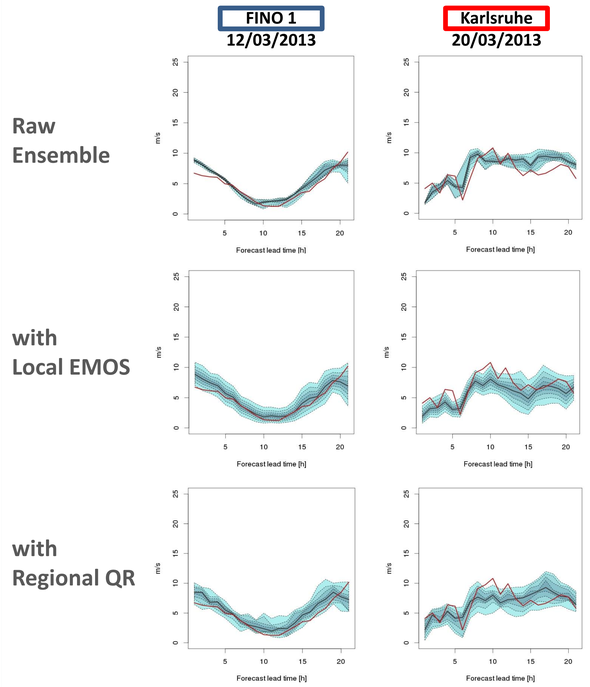

*Fig. 2) **Quantile forecast examples** of 100m wind speed at offshore station FINO1 and onshore station Karlsruhe. Two case studies are shown. Red: measurements, blue: forecasts, stepwise 10%-quantiles.*

VERIFICATION – wind speed and wind ramps

Wind speed

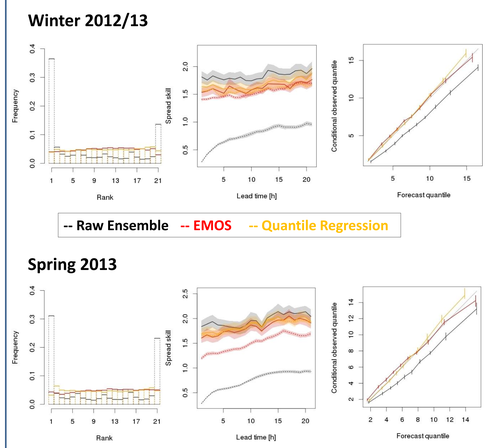

*Fig. 3) Verification results of the raw ensemble forecasts and the postprocessed ensemble forecasts. The improvement by postprocessing is displayed. Left: **Rank histogram** for the 20 ensemble members. Middle: **Spread-skill-relation** (solid = RMSE, dashed = ensemble spread). Right: **Quantile reliability diagram** for the **10%-quantile** (Units at axes: m/s). Bars show 5-95% confidence intervals estimated by bootstrapping.*

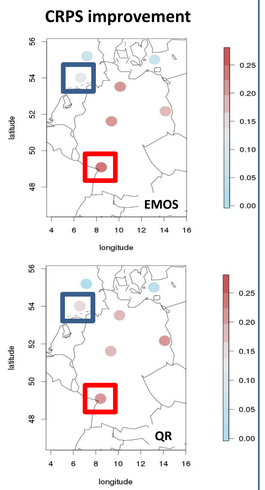

Fig. 4) Continuous ranked probability skill score (CRPSS) of 100m wind speed at 7 stations in Germany (spring 2013). Reference forecast: raw ensemble. The CRPSS is always positive. Increase of forecast quality is up to 25%. Note the differences between on- and offshore stations.

Wind ramps

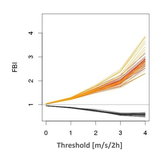

Fig. 5) Frequency bias index (FBI) of the 2h-gradients of wind speed for spring 2013. The postprocessed members result from the ECC. Note the overforecasting of the extreme gradients. This needs further investigation.

CONCLUSIONS

- The **local** calibration method EMOS improves the COSMO-DE-EPS wind forecast performance.
- **Regional** quantile regression (LASSO approach with different predictors) obtains similar quality.
- Quantile regression appears more robust than the local variant with regard to the ensemble spread for different time periods.

PERSPECTIVES

- Further exploration of suitable predictors (stability parameters, mixing terms).
- Investigation of the time-consistency of calibrated ensemble members.
- Extension to the entire grid rather than studies for single stations.

References:

[1] Schuhen et al. "Ensemble model output statistics for wind vectors", *Mon. Wea. Rev.*, *vol.* 140, *pp.* 3204-3219, 2012.

[2] Koenker and Bassett, "Regression quantiles", *Econometrica*, *vol.* 46, *pp.* 33-50, 1978.

[3] Tibshirani, "Regression shrinkage and selection via the Lasso", *J.R. Stat. Soc.* B, *vol.* 58, *no.* 1, *pp.* 267-288, 1996.

[4] Schefzik et al. "Uncertainty quantification in complex simulation models using ensemble copula coupling", *Statist. Sci.*, *vol.* 28, *no.* 4, *pp.* 616-640, 2013.

[5] Gebhardt et al. "Uncertainties in COSMO-DE precipitation forecasts introduced by model perturbations and variation of lateral boundaries", *Atm. Res.*, *vol.* 100, *pp.* 168-177, 2011.

[6] Peralta et al. "Accounting for initial condition uncertainties in COSMO-DE-EPS", *J. Geophys. Res.*, *vol.* 117, D07108, 2012.

Observations operated by: Deutscher Wetterdienst, Fraunhofer IWES, Uni Hamburg (Brümmer et al., 2012), Met. Observatorium Lindenberg, DTU Wind Energy, KIT

CC BY

Tobias Heppelmann, Zied Ben Bouallègue, and Susanne Theis
Deutscher Wetterdienst DWD, Offenbach, Germany
tobias.heppelmann@dwd.de

Visit us at www.projekt-eweline.de