Producing probabilistic weather forecasts for renewable energy applications

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Motivation

➔ COSMO-DE-EPS was originally developed for the probabilistic forecasting of extreme weather

- ➔ We aim to extend its applicability so that it is also optimized towards helping to improve probabilistic forecasts of weather-dependent power production

➔ Two current projects at DWD are particularly important to this work:

- ➔ EWeLiNE
  - ➔ Focused (here) on forecasts on 0-48 hrs range
  - ➔ Involves TSOs and power forecast producers
- ➔ ORKA
  - ➔ Focused on “worse-case scenario“ calculations and risk management, and on the short forecast range (0-12 hrs)
  - ➔ Involves DSOs, aswell as TSOs and power forecast producers

Overview

- Overview of COSMO-DE-EPS
- Results from fine-tuning the initial condition perturbations for COSMO-DE-EPS
- Introduction of initial conditions from KENDA
- A new verification metric: ensemble added value
- Postprocessing of ensemble wind speed forecasts


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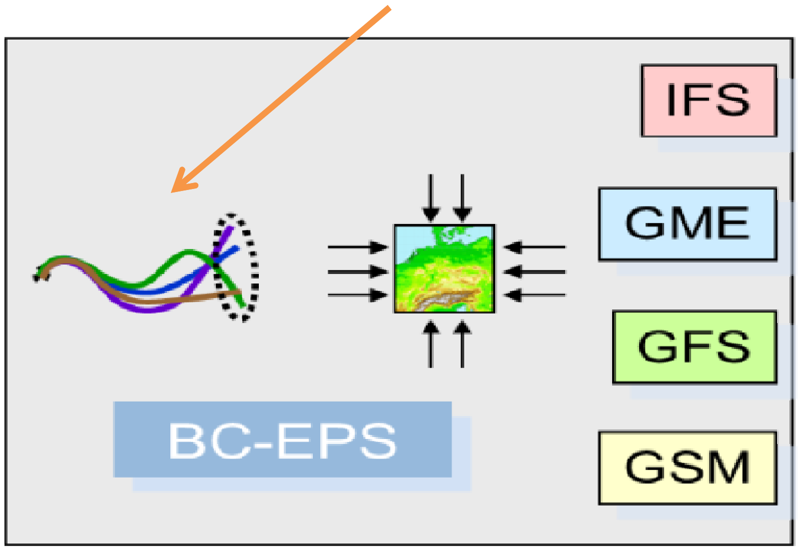
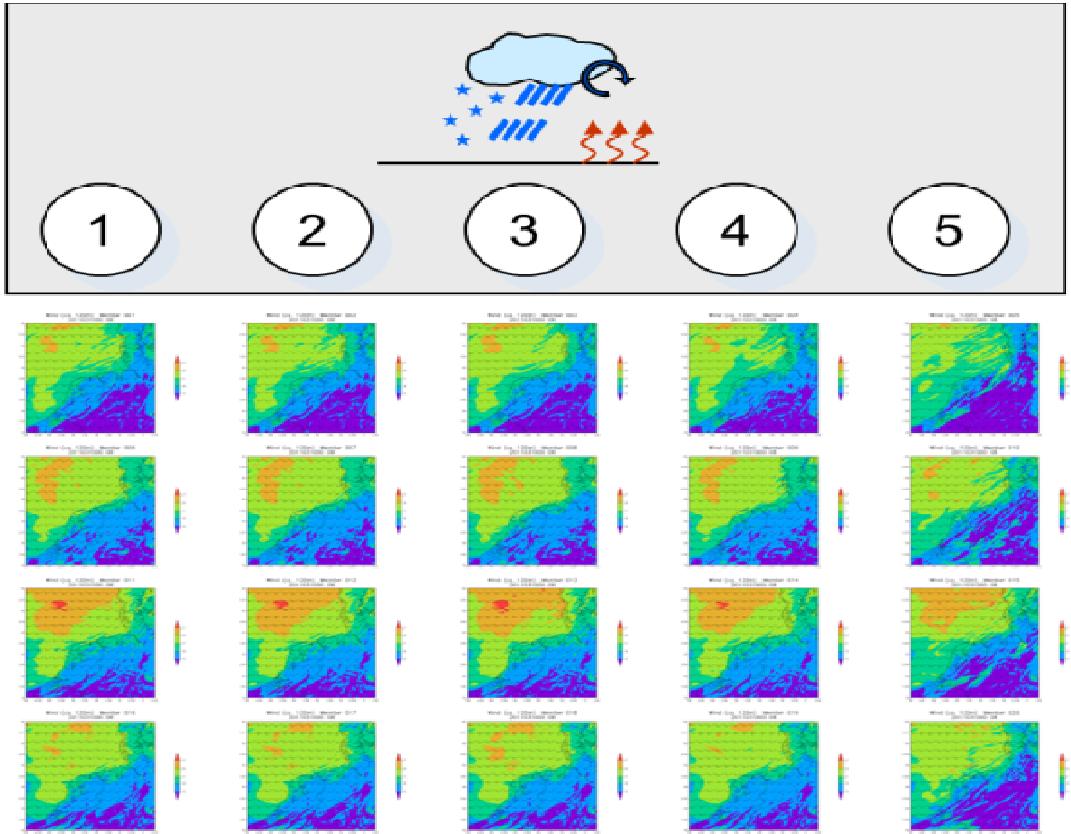
COSMO-DE-EPS: Current setup

- Horizontal resolution 2.8 km
- Operational from May 2012
- 8 starts per day (from 00, 03,..,18, 21 UTC)
- Lead time up to 27 h, soon: 45 h (3 UTC)

Initial conditions:

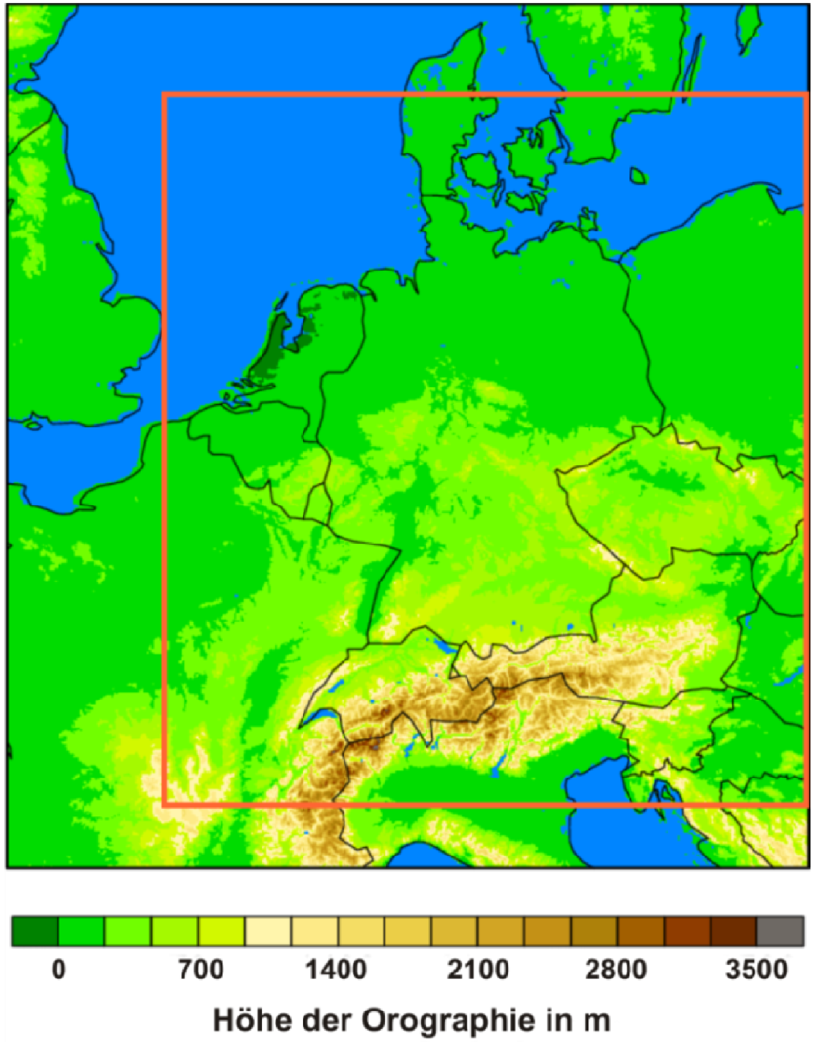
$$f = f_{DE} + W(k) * (f_{BCEPS} - f_{EU})$$





COSMO-DE-EPS: Ongoing work

- ➔ Extension to 40 members
- ➔ Extended model domain, increased horizontal (2.2 km) and vertical resolution
- ➔ Adjustment of vertical filtering of initial condition perturbations
- ➔ Initial conditions based on a Local Ensemble Transform Kalman Filter (developed within the KENDA project)
- ➔ More physics perturbations
- ➔ Inclusion of stochastic physics
- ➔ Further development of calibration and verification methods



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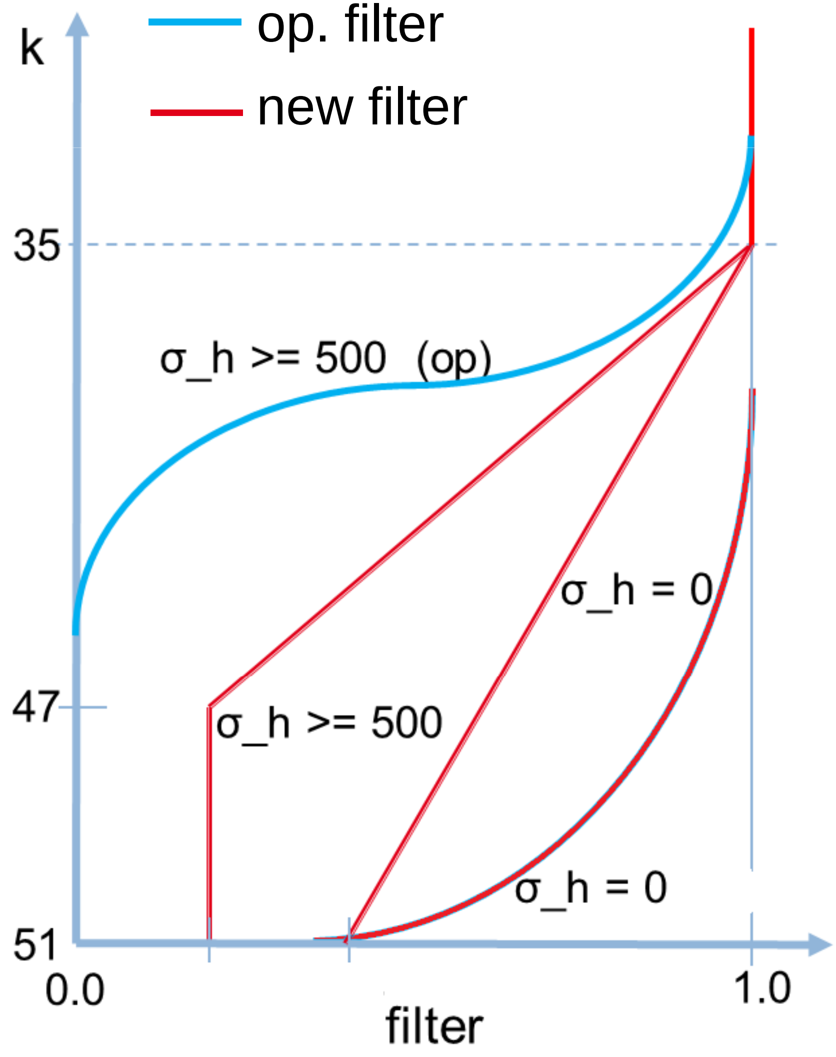
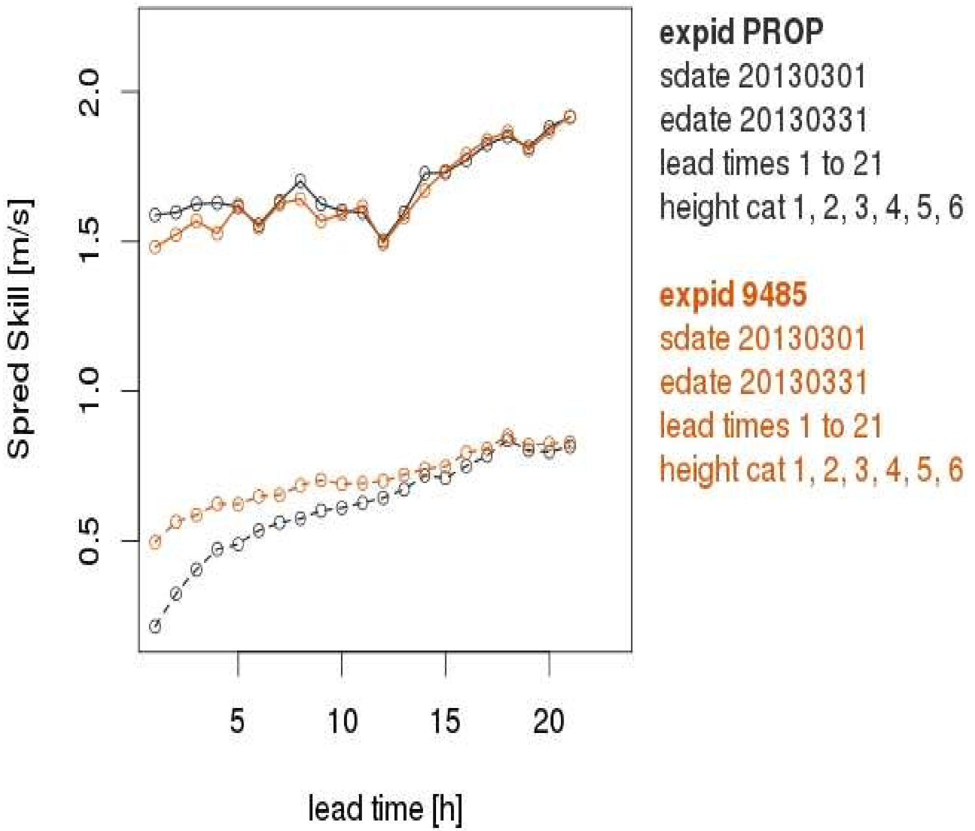
Ensemble perturbation

Experiment with adding an orography dependence to the vertical filter:

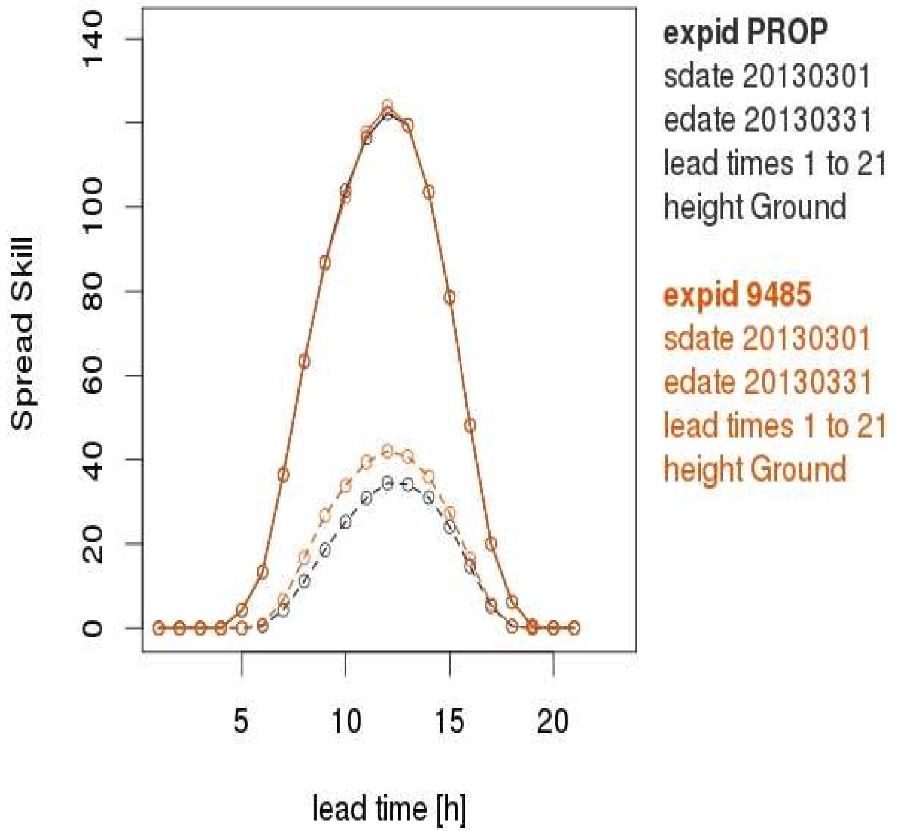


Orography-dependent filter

Compared against orography-independent filter (as run operationally in March 2013)



Wind speed (against obs. at 9 stations, up to 250m height)



Solar radiation (32 stations)

Linear filter

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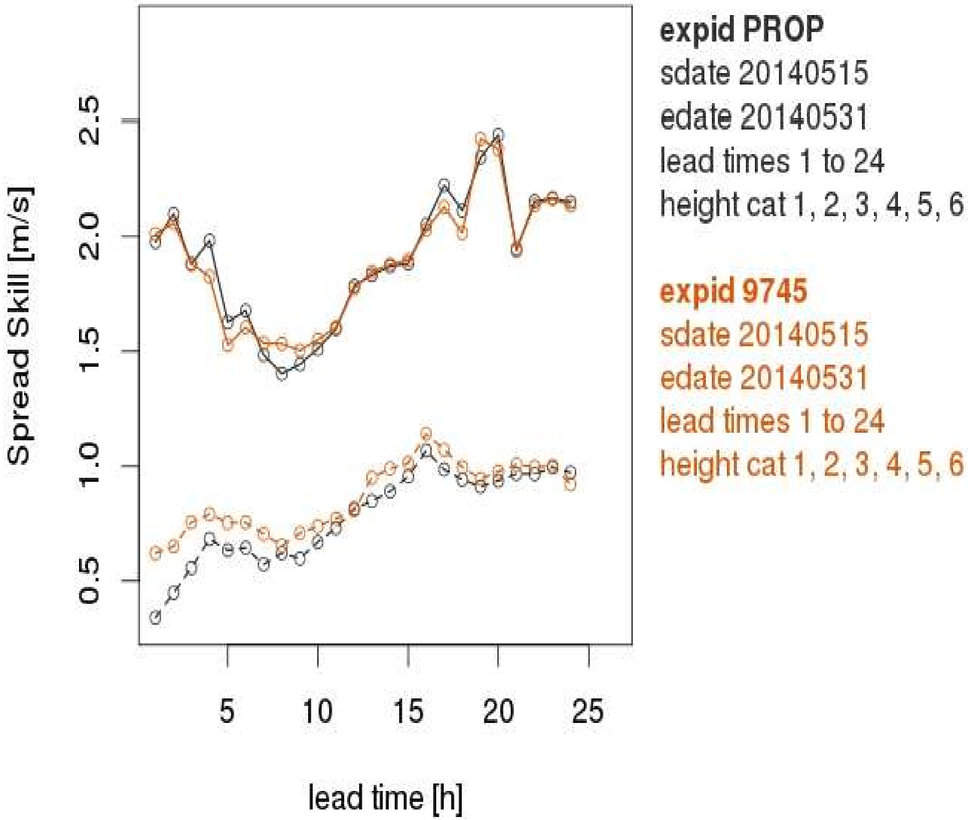
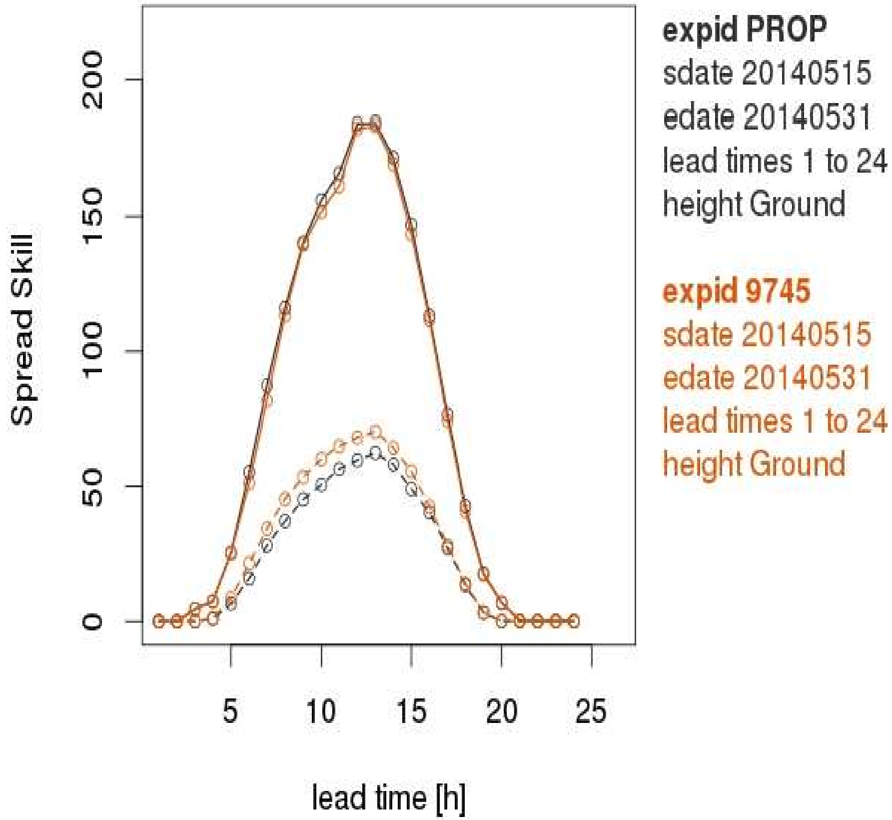
Now operational!



Wind speed (4 stations, up to 250m height)



Solar radiation (25 stations)

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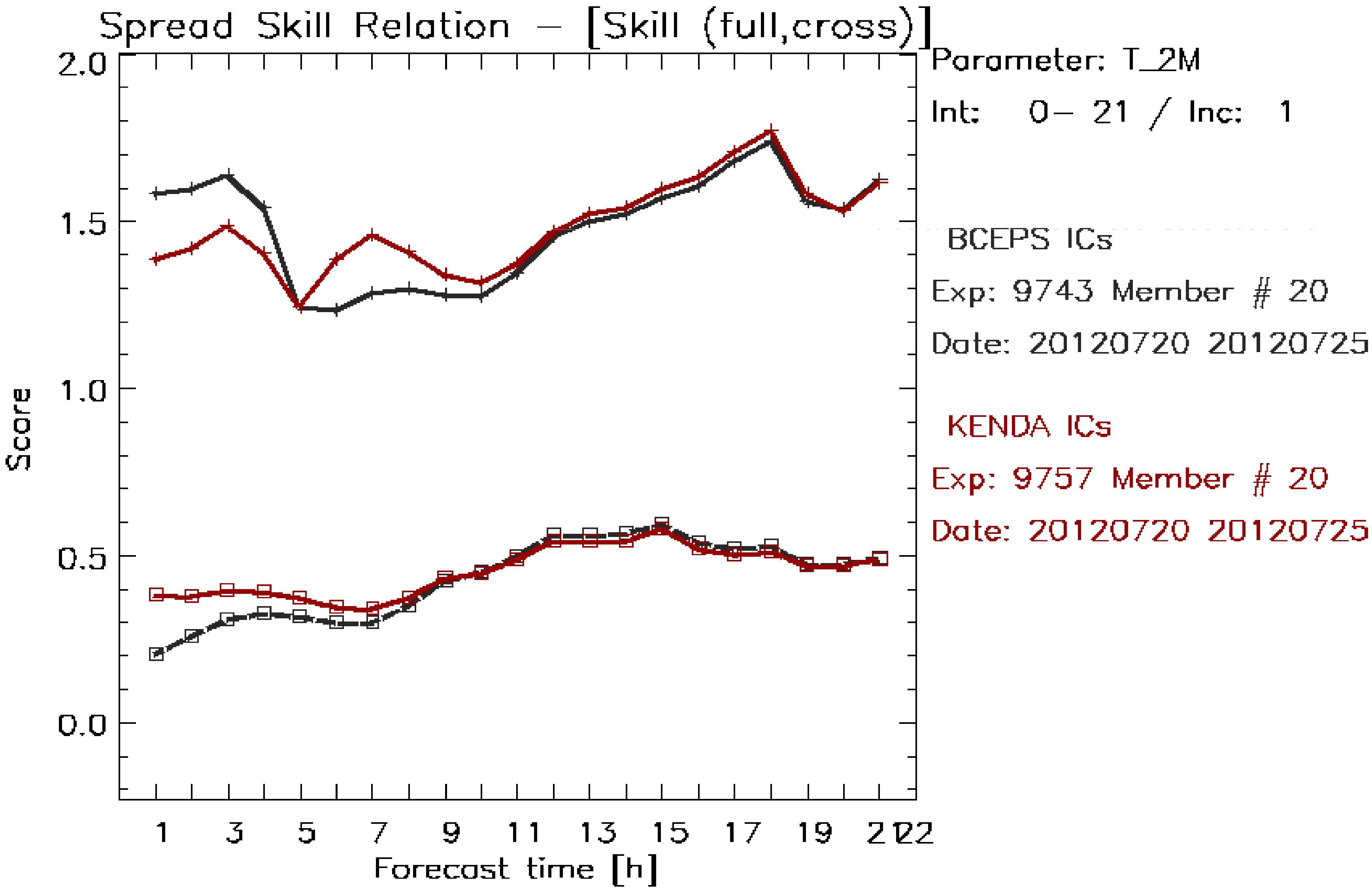
Initial conditions from KENDA

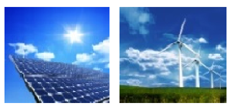
➔ Compared with operational COSMO-DE-EPS setup (i.e. with BCEPS initial conditions), for 20th – 25th July 2012, for 00UTC forecasts

- ➔ ICON with LETKF used as boundary for the KENDA assimilation cycle.
- ➔ **Same** boundary conditions (BCEPS) and physics perturbations (5 parameters) for both forecasts
- ➔ No latent heat nudging in KENDA run
- ➔ Only the first 20 KENDA members are used

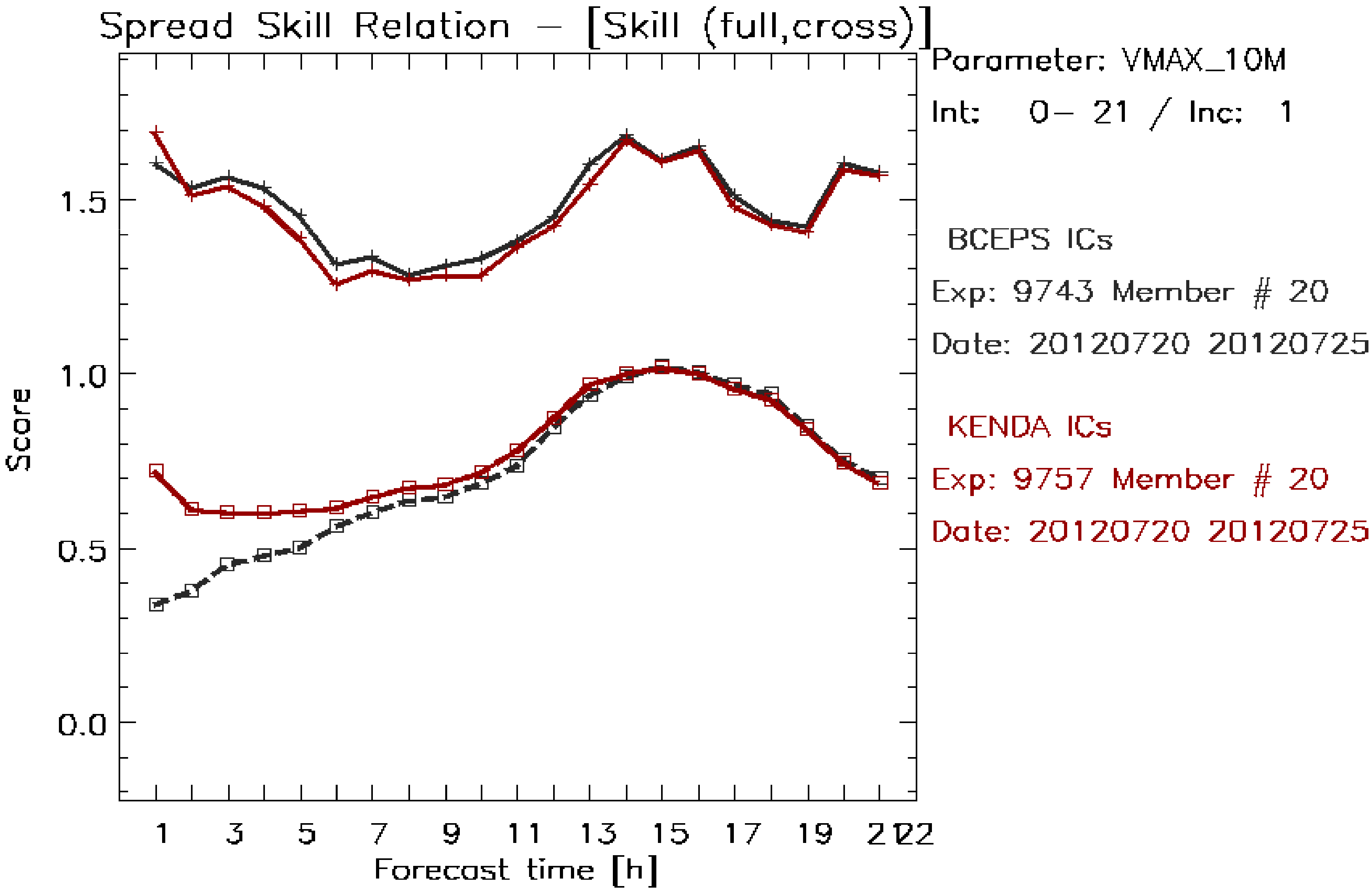
➔ These are intermediate results, as KENDA remains under development

KENDA: 2 metre temperature





KENDA: 10 metre wind gusts



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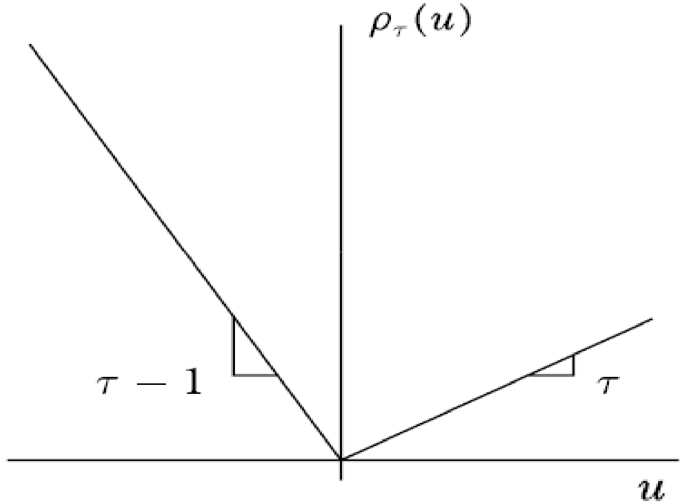
Verification of ensemble added value

Based on quantile score:

$$QS\{\tau\} = \rho\left(x_{\text{obs}} - x\{\tau\}\right)$$

$$\rho(u) = \begin{cases} \tau u & \text{if} \quad u > 0 \\ (\tau - 1)u & \text{if} \quad u < 0 \end{cases}$$



This can be decomposed into a reliability component and a potential component

➔ The potential component is the potential score after calibration

$$QS = QS_{\text{rel}} + QS_{\text{pot}}$$

The ensemble added value is then given as a skill score as

$$EAV = 1 - \frac{\sum_\tau QS_{\text{pot}}\{\tau\}}{\sum_\tau QS_{\text{pot,ref}}\{\tau\}}$$

Where here the reference is a randomly selected ensemble member

Verification of ensemble added value

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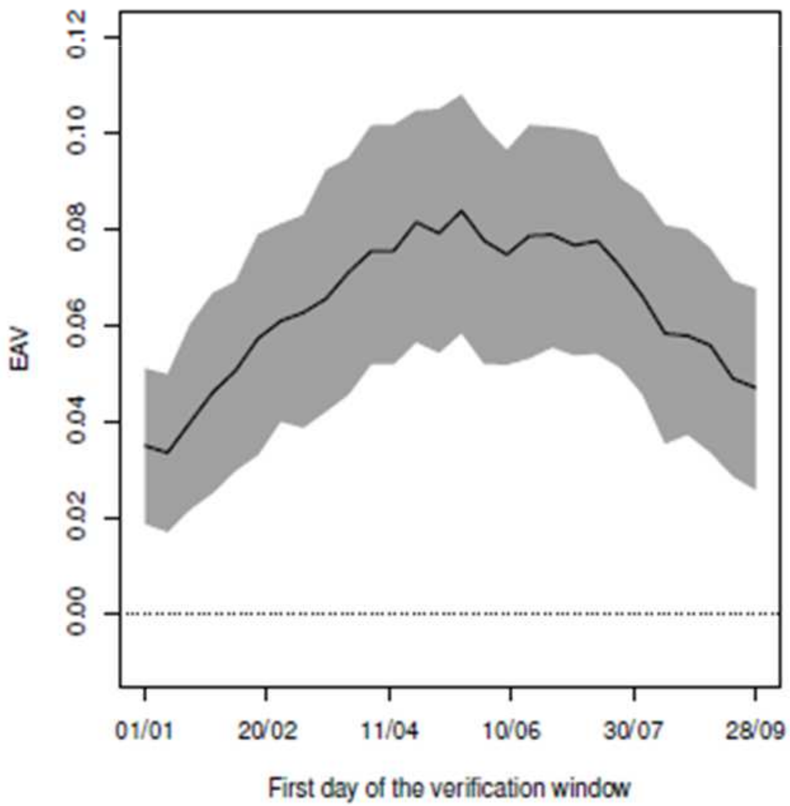
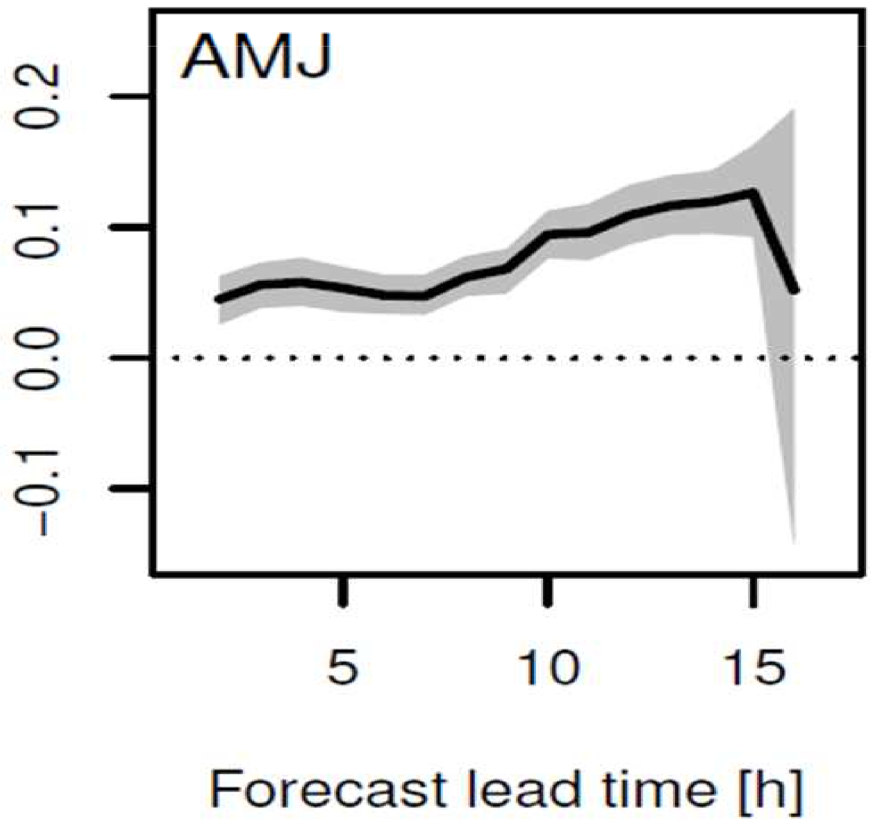
Rolling 90 day verification window
Grey shading indicates 5-90% confidence intervals
Applied to 03UTC forecasts of clearness index, in 2013





As a function of time of year, with 90-day rolling verification window

As a function of forecast lead time, for April-May-June

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Ensemble post-processing

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➔ Applied here to wind speeds at ~100m

➔ Non-homogeneous (bivariate) Gaussian regression using the following steps:

- ➔ Linear regression of the mean wind vector
- ➔ Maximum likelihood estimation of the variances
- ➔ Trigonometric function applied to correlation coefficient between wind components, as a function of forecast wind direction

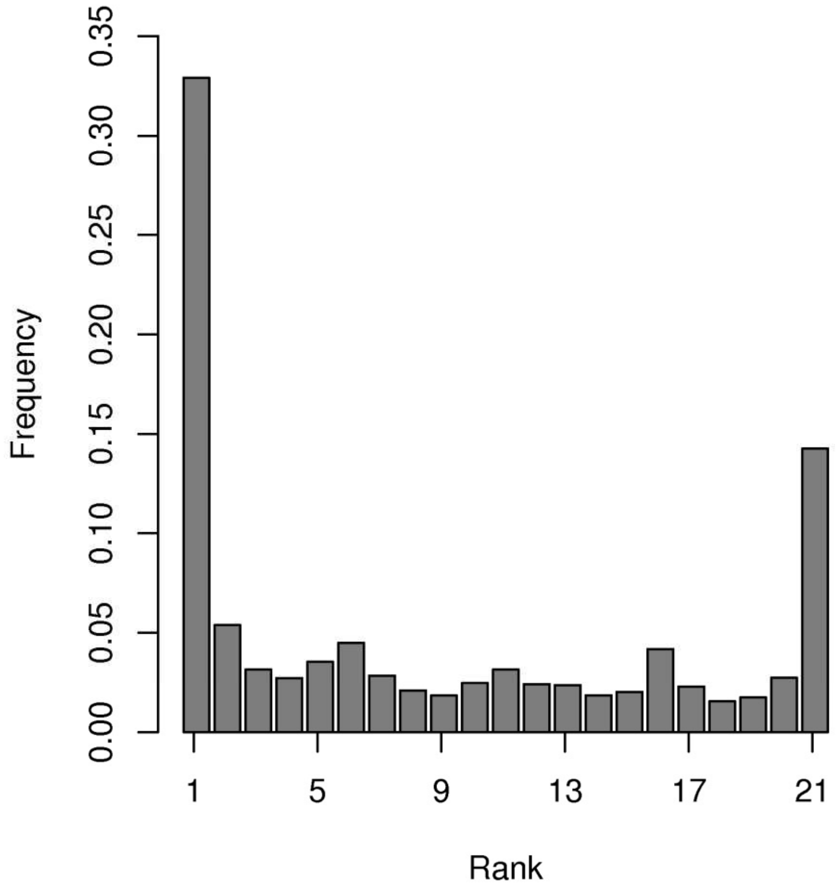
➔ 40 day training period

➔ Ensemble copular coupling is then applied to ensure that the ordering of the members is physically consistent

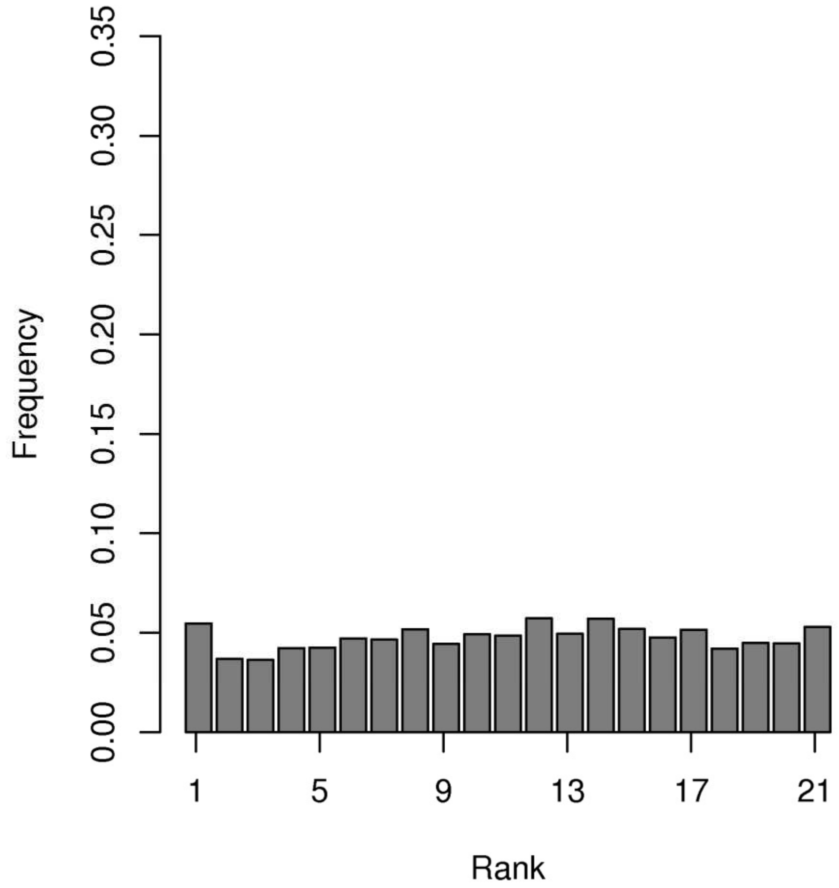
➔ Calibration locally applied at 5 locations in Northern Germany and Denmark, for 03 UTC forecasts

Ensemble post-processing

Rank histograms for Dec 2012 – Feb 2013



Before calibration



After calibration

Ensemble post-processing

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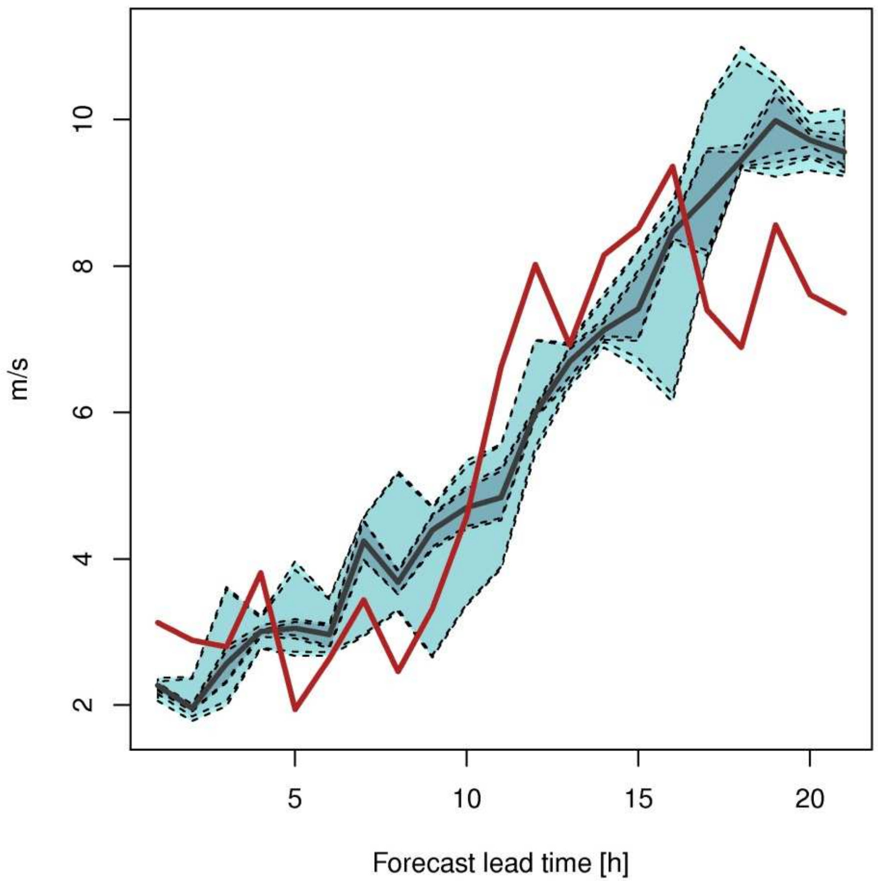
Quantile forecast example: Hamburg, 25 Jan 2013, with observed wind speed at station



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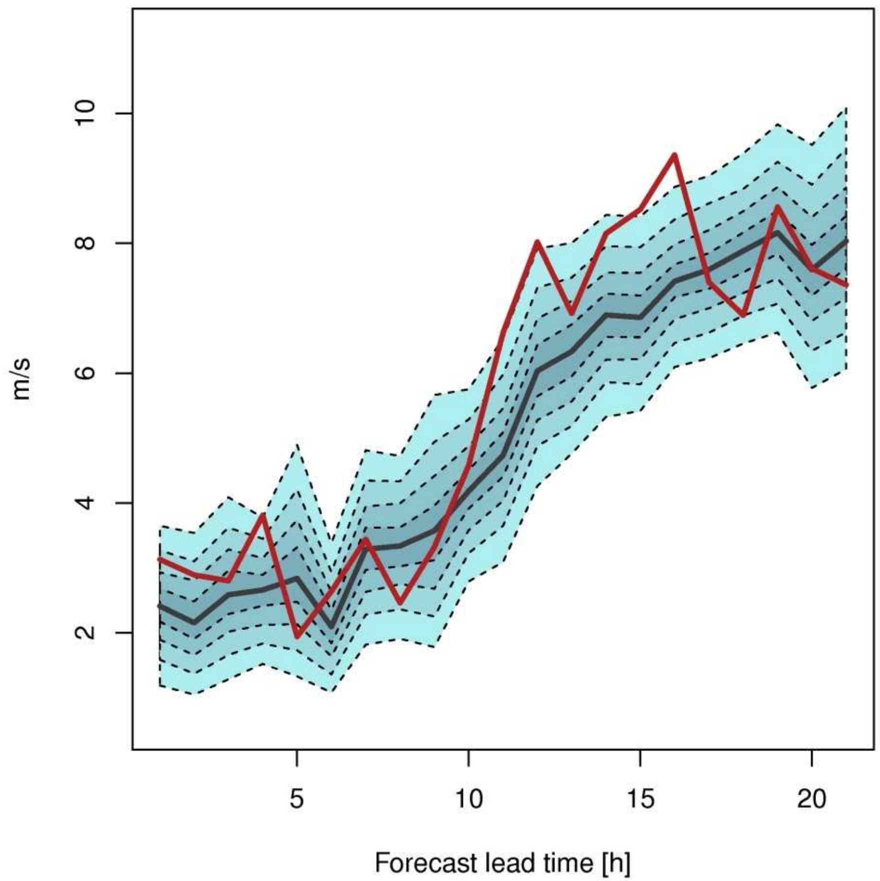


After calibration

Conclusions

➔ Fine-tuning to the initial condition perturbations has lead to improvements in probabilistic forecasts relevant for renewable energy

- ➔ This has now been incorporated into the operational system at DWD

➔ KENDA is a promising method for producing initial conditions

- ➔ This could be combined with the current setup at DWD

➔ The ensemble is useful for solar radiation forecasts all year round, with greatest added value in summer months, and increasing with lead time

➔ Post processing can correct many of the remaining deficiencies in the model

- ➔ The bivariate EMOS method produces a well-calibrated ensemble for wind speed

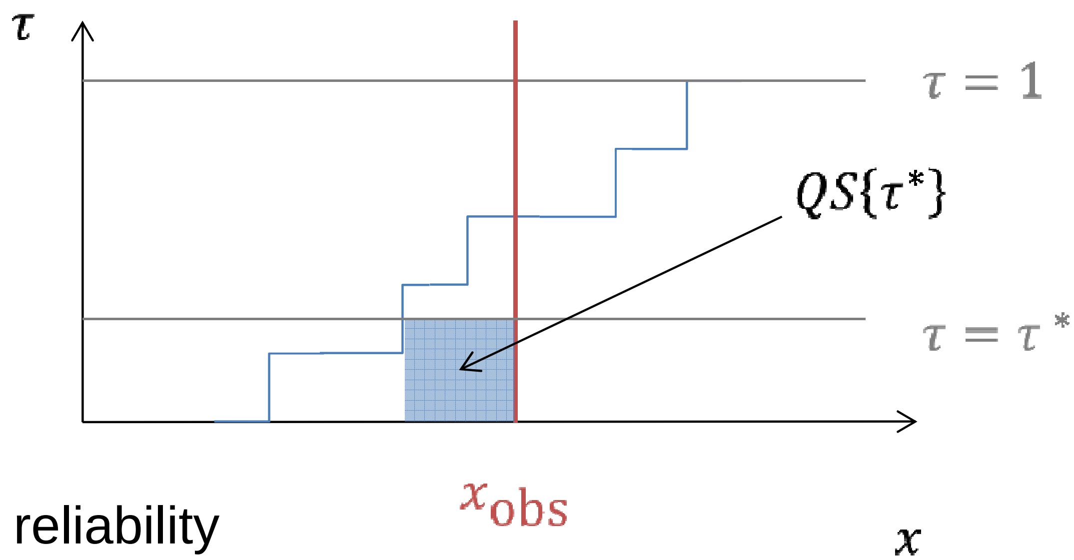

Ongoing and future work

- ➔ Improvement to the handling of model error
  - ➔ Perturbation of new parameters in the standard setup
  - ➔ Introduction of stochastic physics perturbations
- ➔ Further development of the KENDA system
  - ➔ Further tuning of the setup for deterministic forecasts (see also talk by Christoph Schraff)
  - ➔ Use of ICON LETKF to provide boundary conditions for the forecast
- ➔ Postprocessing of radiation forecasts
- ➔ Further development of the postprocessing of wind speed forecasts
  - ➔ Possibly to include postprocessing on the model grid


Verification of ensemble added value

Based on quantile score:

$$QS\{\tau\} = \left(x_{\text{obs}} - x\{\tau\}\right) \times \left(\tau - H\{x\{\tau\} - x_{\text{obs}}\}\right)$$



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The research project EWeLiNE 12/2012 – 11/2016

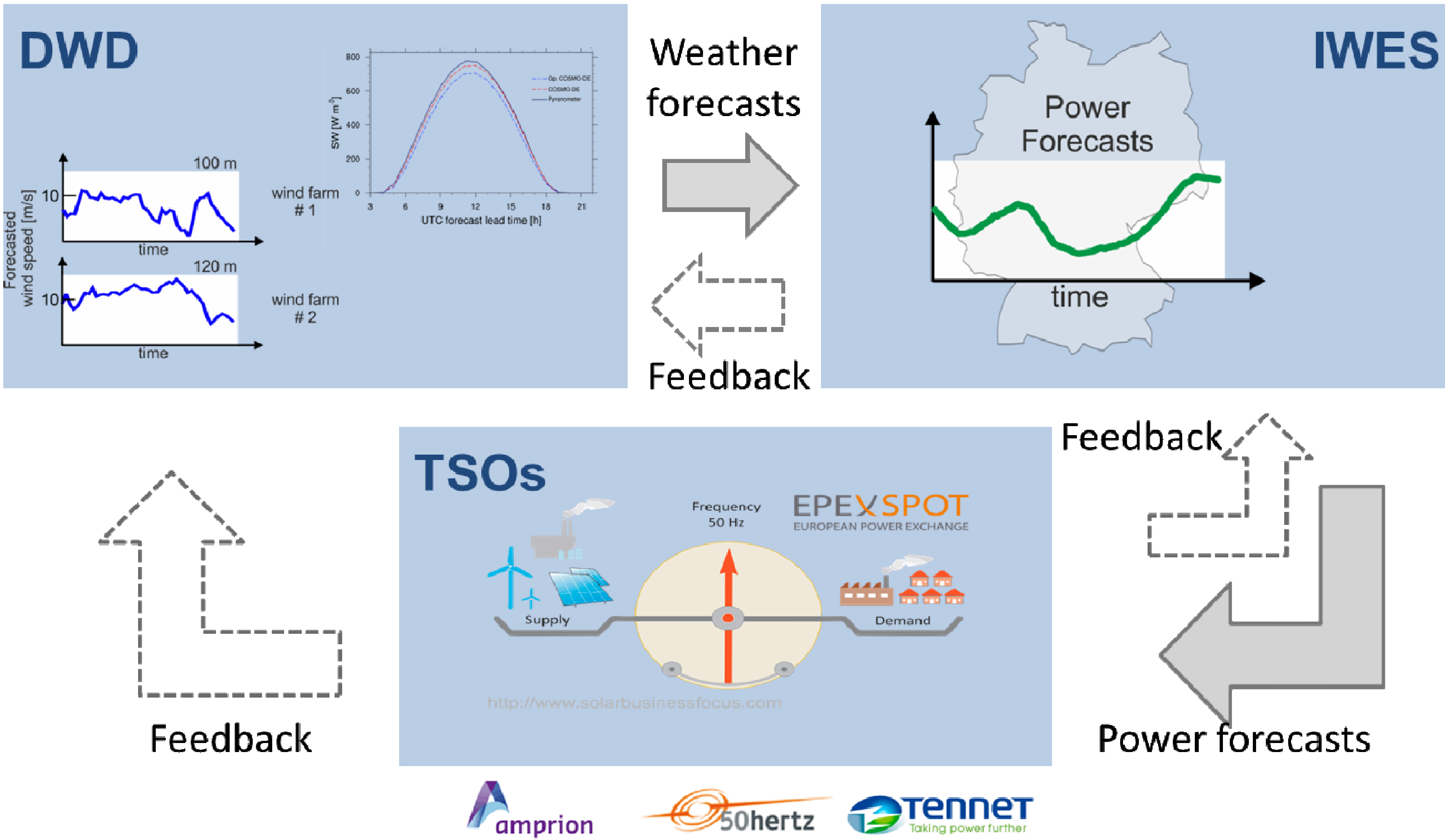
Erstellung innovativer **We**tter- und **L**e**i**stungsprognosemodelle für die **N**etzintegration wetterabhängiger **E**nergieträger

→ Key research areas:

- → Optimization of the model system towards energy applications (wind and solar)
- → Integration of new types of data (power production) into meteorological prediction system
- → Development of forecast products in close communication with the users

→ Feedback from a wide range of user communities


The research project EWeLiNE 12/2012 – 11/2016



The ORKA project 08/2012 – 07/2015

- ➔ Funded by: Bundesministerium für Wirtschaft und Energie — The German Federal Ministry for Economic Affairs and Energy

- ➔ Aim: to iteratively improve the whole forecast chain from the meteorological to the power ensemble forecasts, especially in order to
  - ➔ secure grid stability by using meteorological ensemble forecasts for „worst case“ scenario calculations and risk management,
  - ➔ with a special focus on the short forecast range (0-12 hrs)
- ➔ Project partners and associates:

energy & meteo systems | DWD | 50hertz | Thüringer Energienetze | avacon