



# SafeWind

Wind Power Forecasting with Focus on Extremes  
Public Workshop, 31.08.12, Paris

## Advances in Wind Power Forecasting using Weather Ensembles

**Lueder von Bremen**

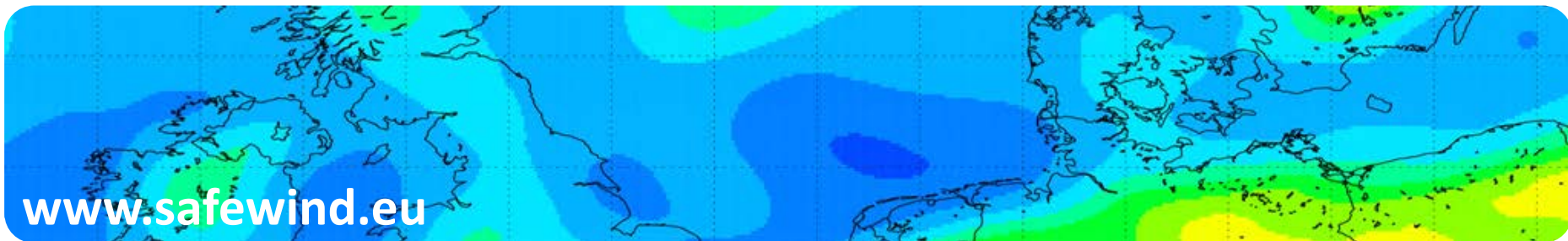
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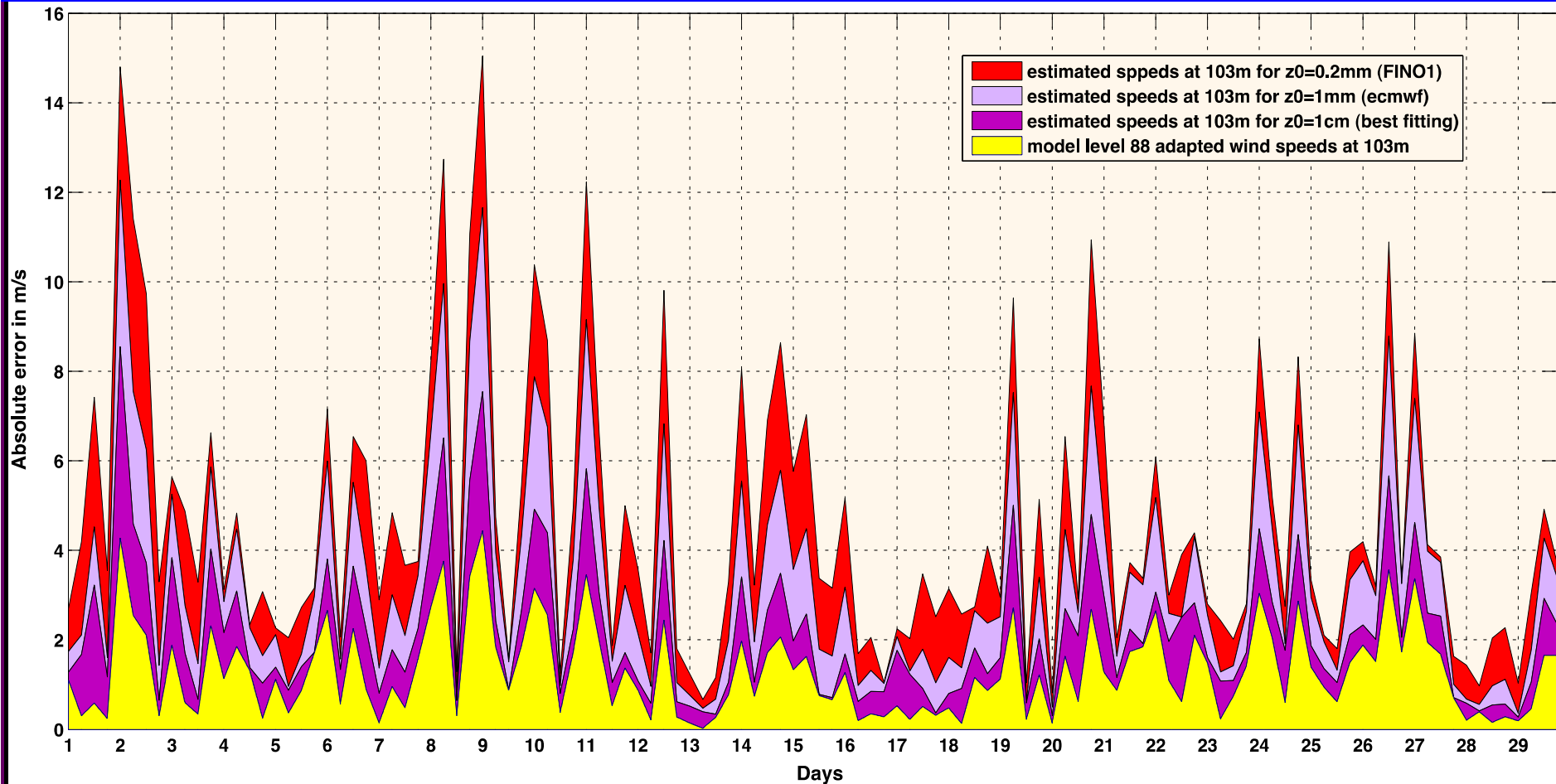
[www.safewind.eu](http://www.safewind.eu)



- Utilising model levels: the birth of **100-meter** winds



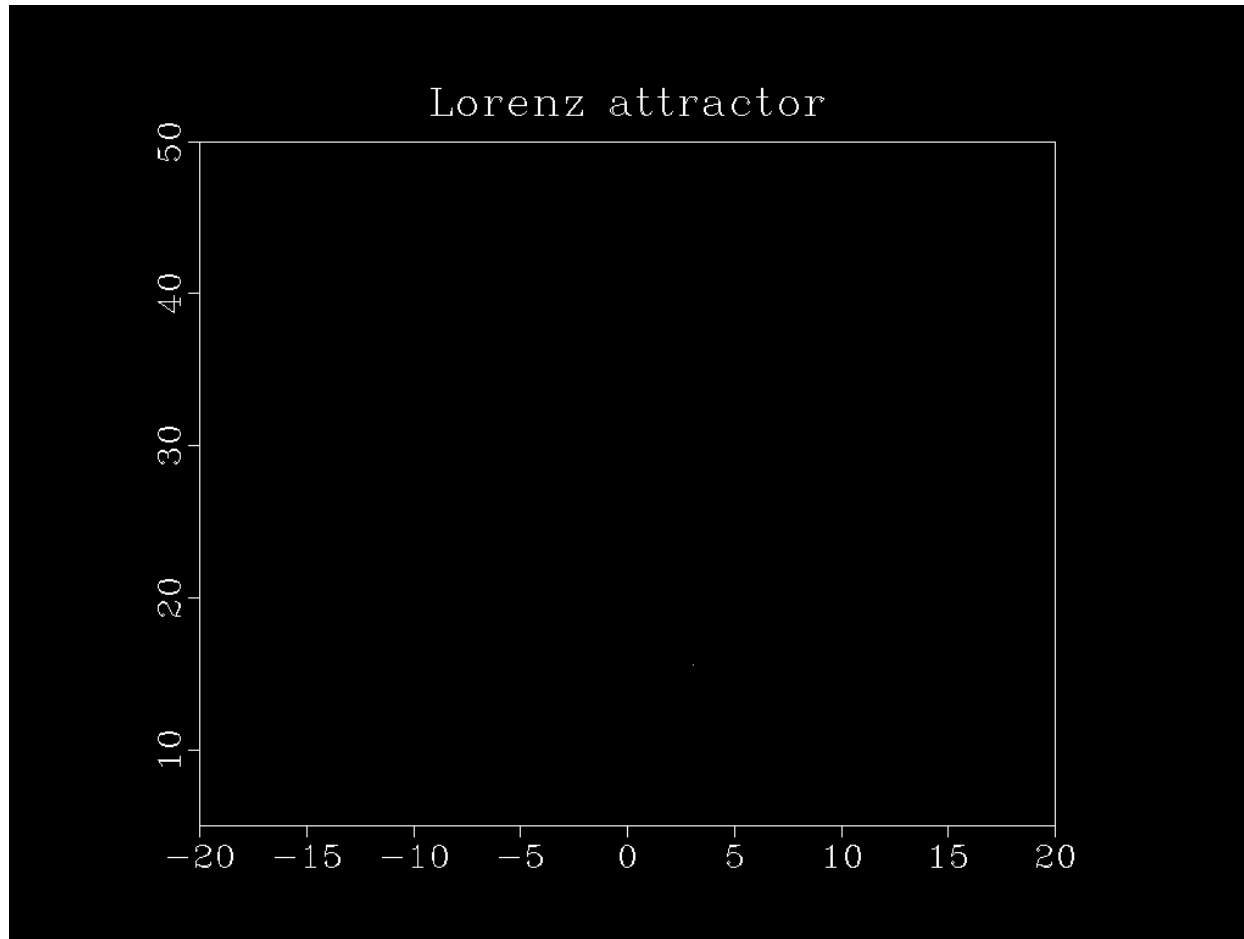
## *Smallest RMS Error by utilising model levels...*



# Outline

- Meteorological Ensembles for Wind Power Forecasting
- Spatial distribution of forecast uncertainty
- Ensemble Prediction System with 100m winds for improved Wind Power Forecasting
- Summary

# Why weather forecasts can not be precise?

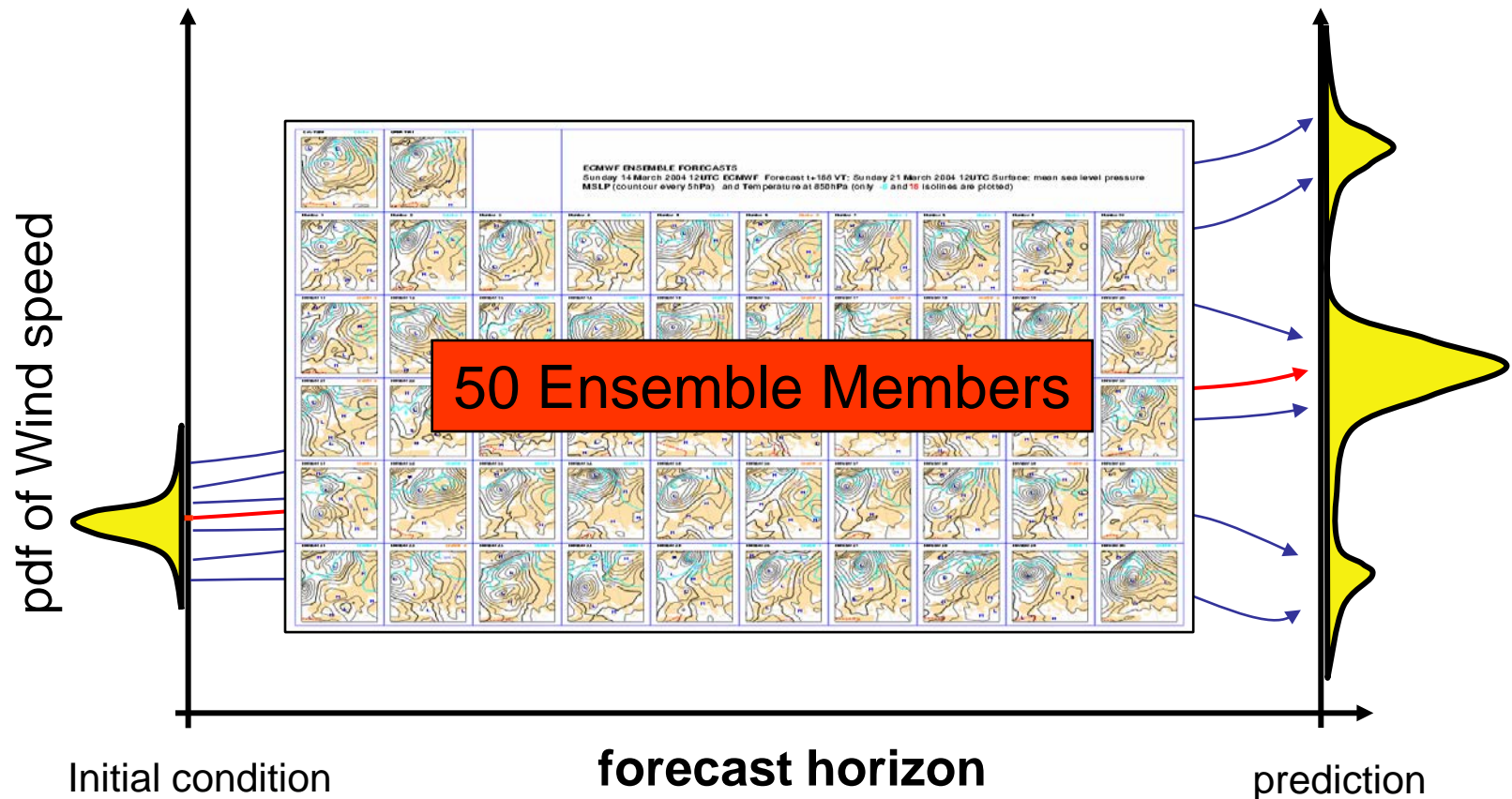


$$\begin{aligned} dx / dt &= a (y - x) \\ dy / dt &= x (b - z) - y \\ dz / dt &= xy - c z \end{aligned}$$

Simplified model  
of atm. convection  
(E. Lorenz, 1963)

- Lorenz Paradigm: Numerical Weather Forecasting is an initial state problem
- Quantify the uncertainty in the forecast to be aware of forecast errors

# Ensemble Prediction System (EPS) at ECMWF

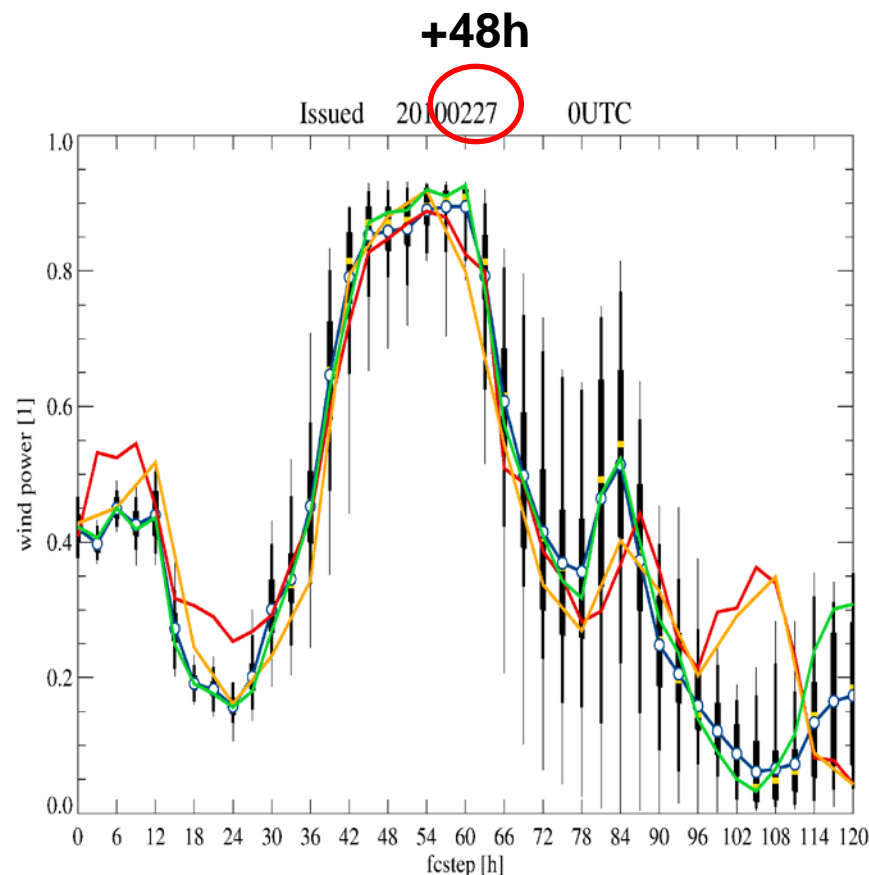
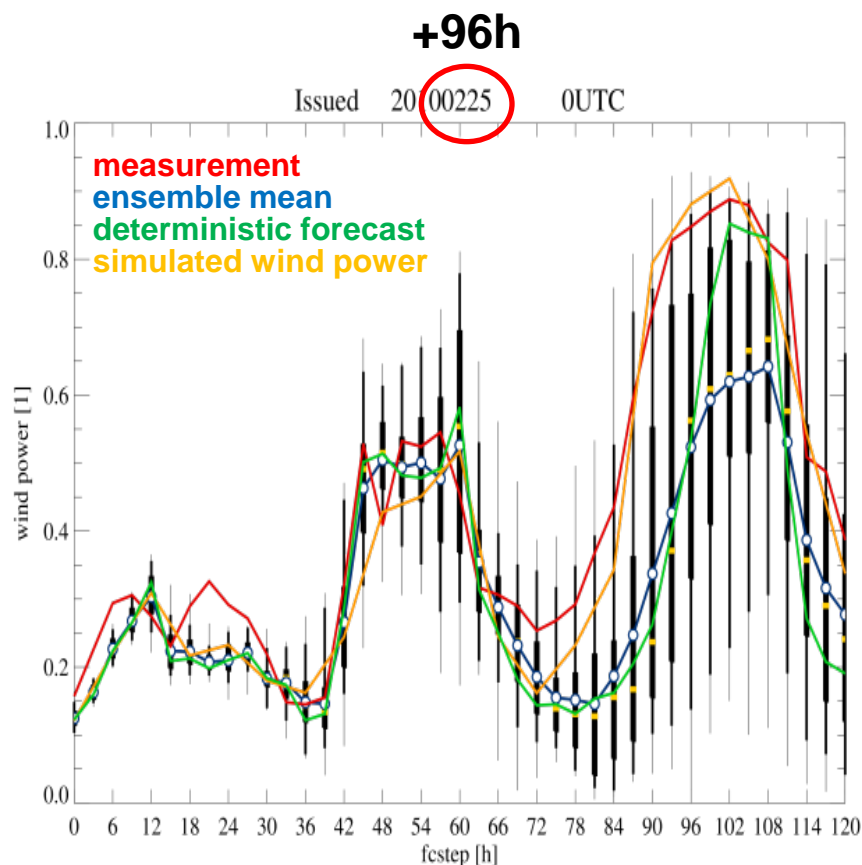


Source: European Centre for Medium-Range Weather Forecasts (ECMWF), R. Hagedorn

- Sample the initial state and project the possible uncertainty in the future
- Quantify the uncertainty in the forecast with probabilities

# Powergrams: Communicating Ensemble Forecasts

- Example: 1 March 2010 extreme event Storm Xynthia in Eastern Germany (50Hertz, ~10.7 GW)



- New: What is the **distribution** of uncertainty in the control zone

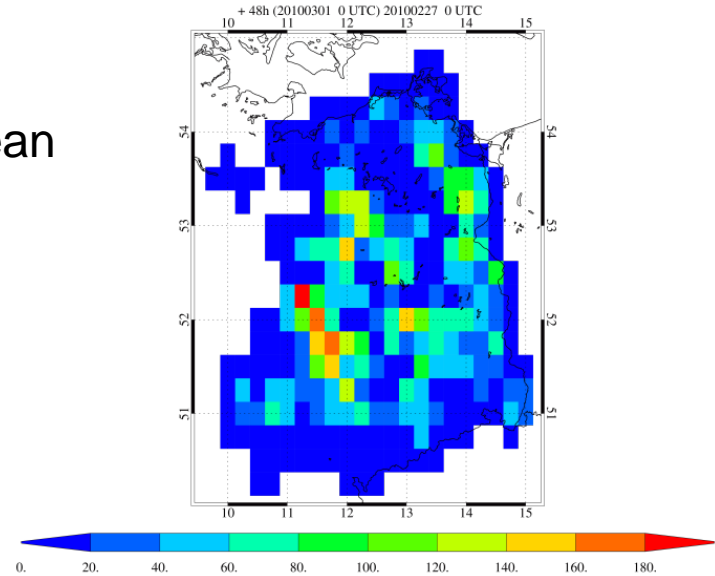
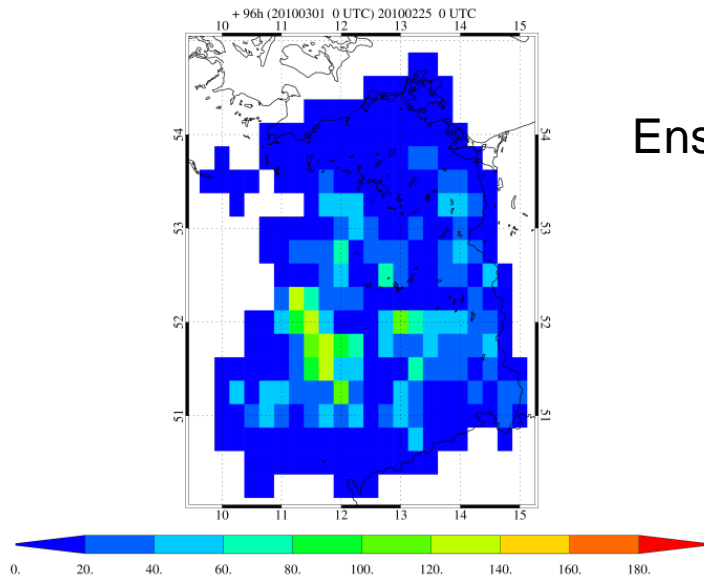
# Example: Storm Xynthia (50 Hertz)

1 March 2010, 0UTC

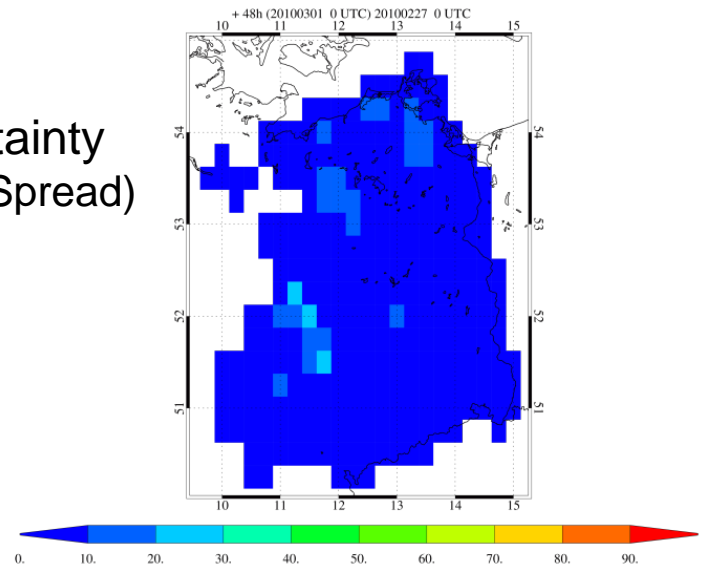
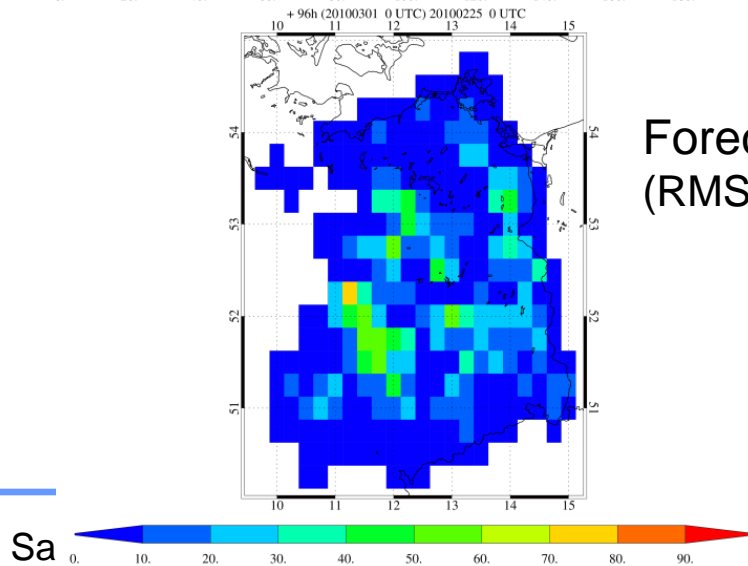
+96h

+48h

Ensemble Mean



Forecast Uncertainty  
(RMS Ensemble Spread)



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2012 - Lued

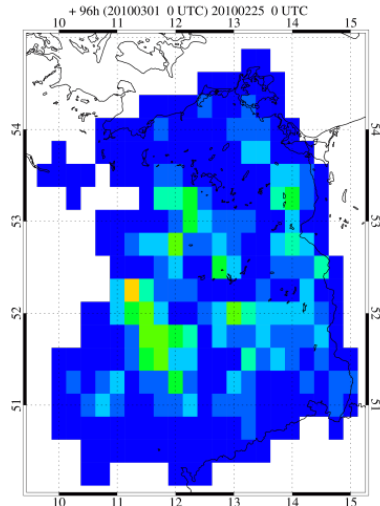




# Example: Storm Xynthia (50 Hertz)

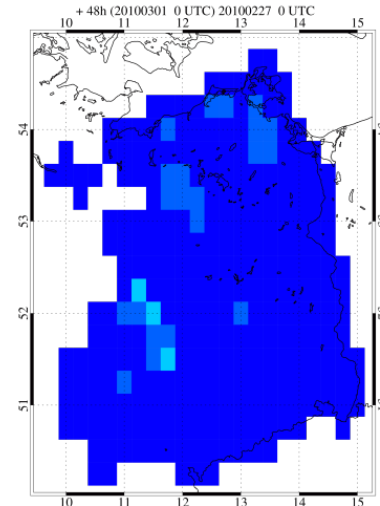
1 March 2010, 0UTC

**+96h**

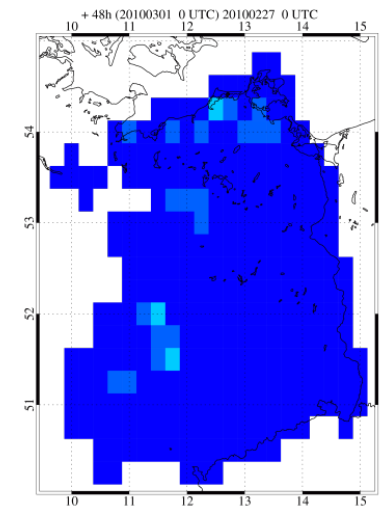
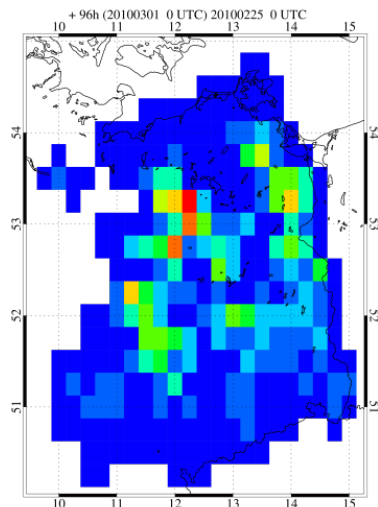


Forecast uncertainty  
(RMS Ensemble Spread)

**+48h**



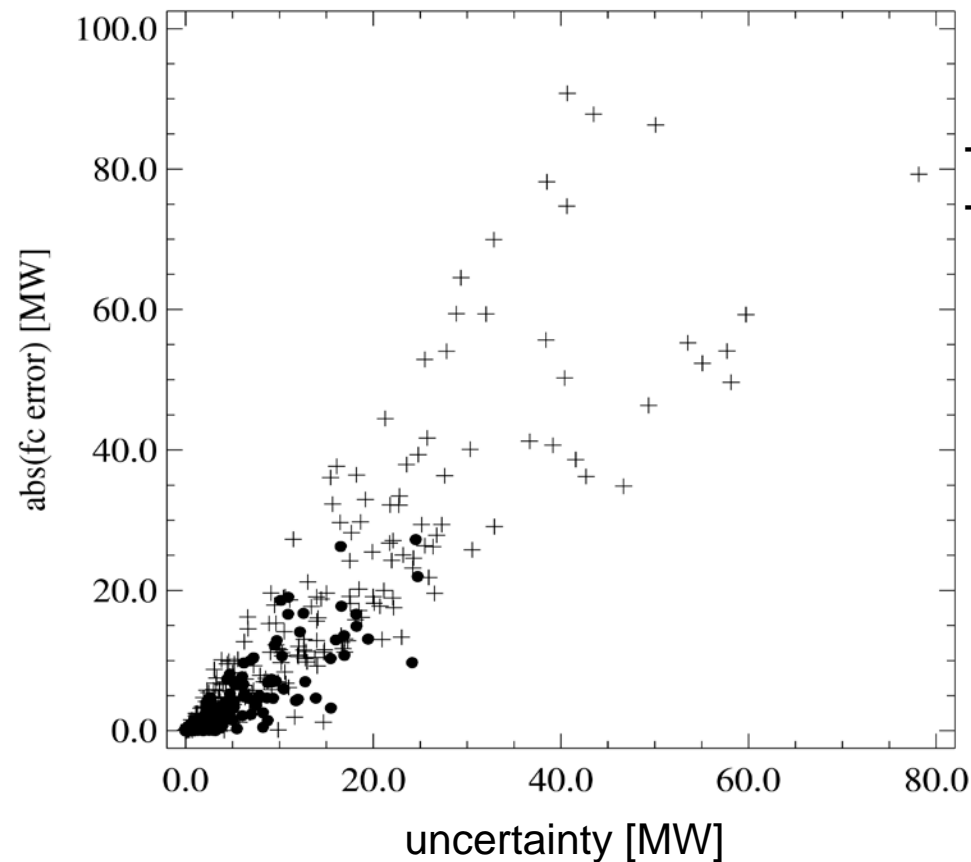
absolute forecast error





# Evaluation of storm Xynthia (50 Hertz)

1 March 2010, 0UTC



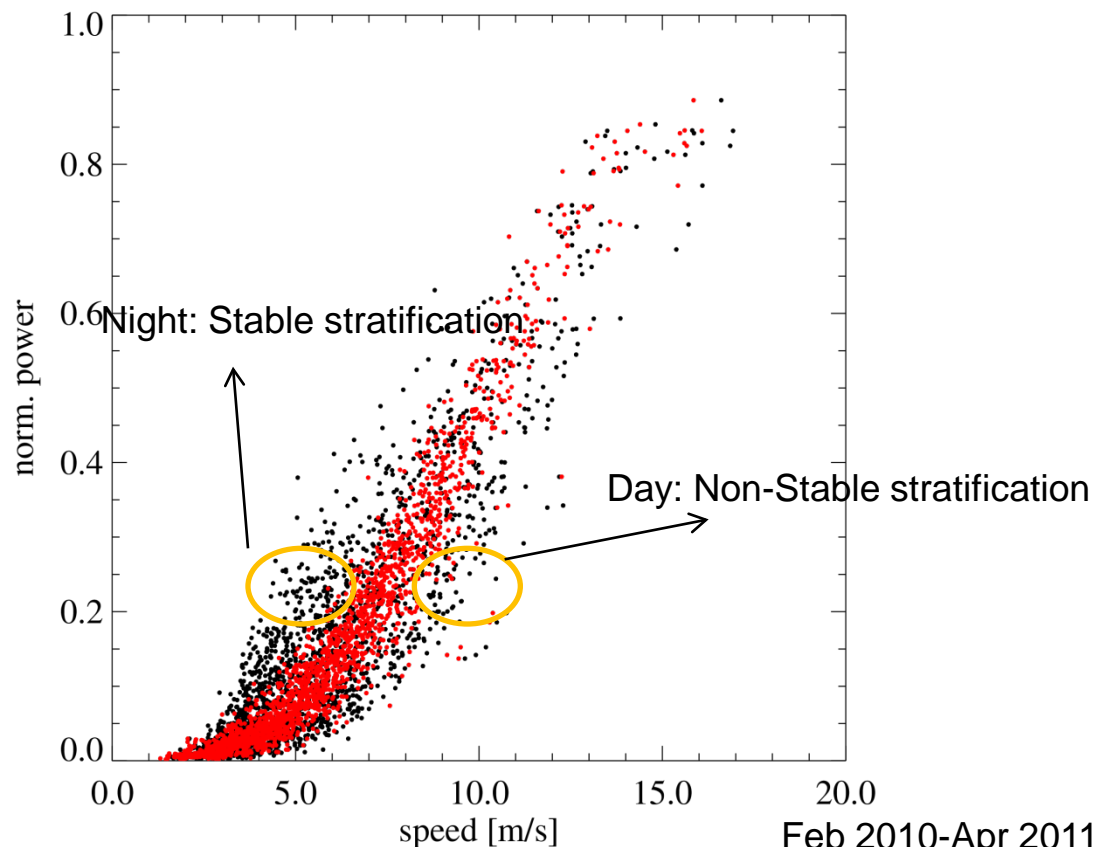
+96h forecast: crosses  
+48h forecast: bullets

- The level of uncertainty can be used as indicator of a (likely) forecast error

# Overcome the usage of 10m winds

- Isn't that old?
- New Ensemble System: **100 m winds instead of 10m winds** from 26 Jan 2010 at ECMWF
- ECMWF analysis speeds are weighted according to spatial wind power distribution
- „Regional Power Curve“ for 50Hertz (VET)

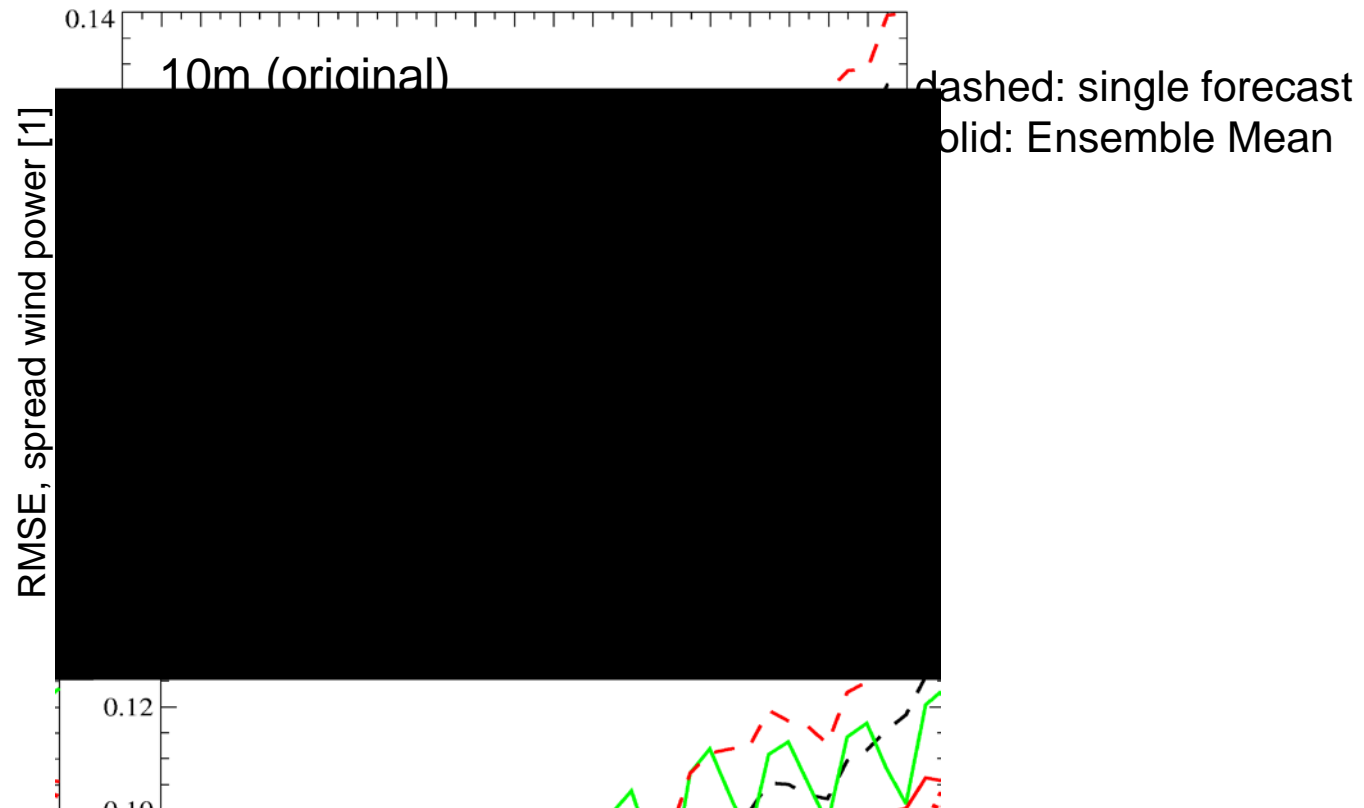
10m winds → hubheight  
100m winds → hubheight



# Improvement/Spread Skill Relation

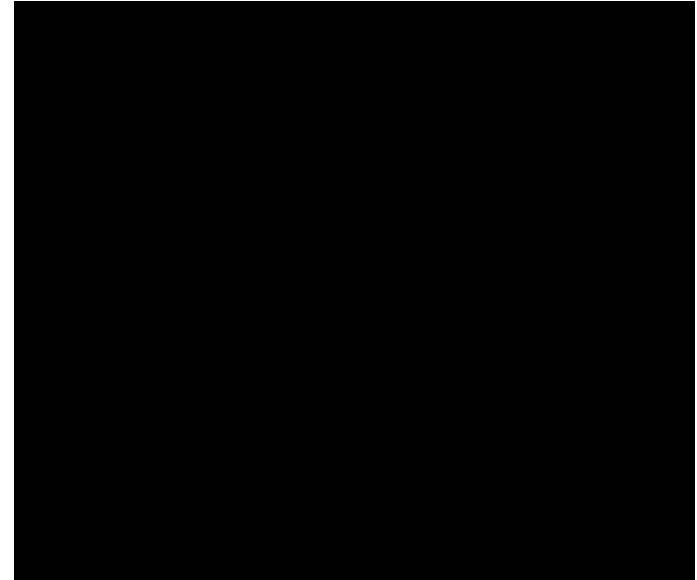
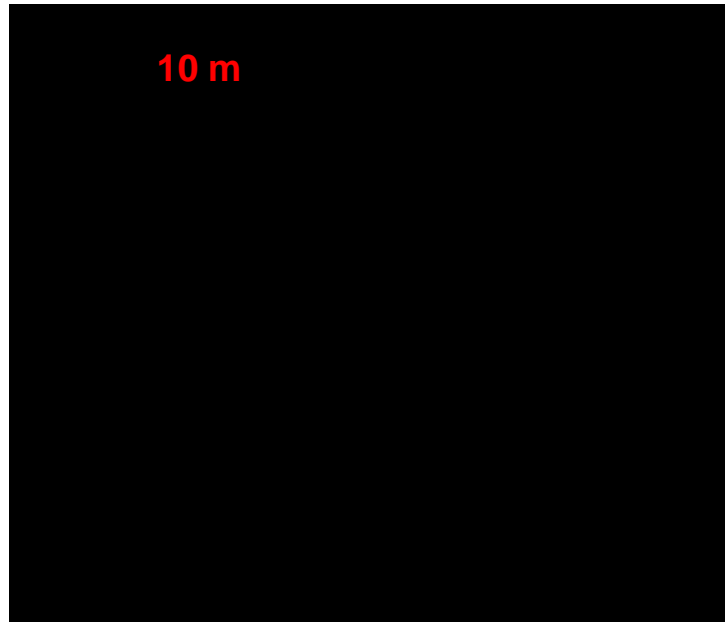
- Verification with **real** wind power (Germany)
- spread: RMS spread (std. dev) of ensemble members around ensemble mean
- **Spread < skill** → **underdispersive ensemble**

new system  
with 100m winds  
old system (10 m)



- at D+2 ensemble mean is better than control forecast
- spread lower than skill → ensemble is underdispersive
- situation for 10m winds very bad (also after bias correction)
- S ➤ No WPP bias correction for 100m winds

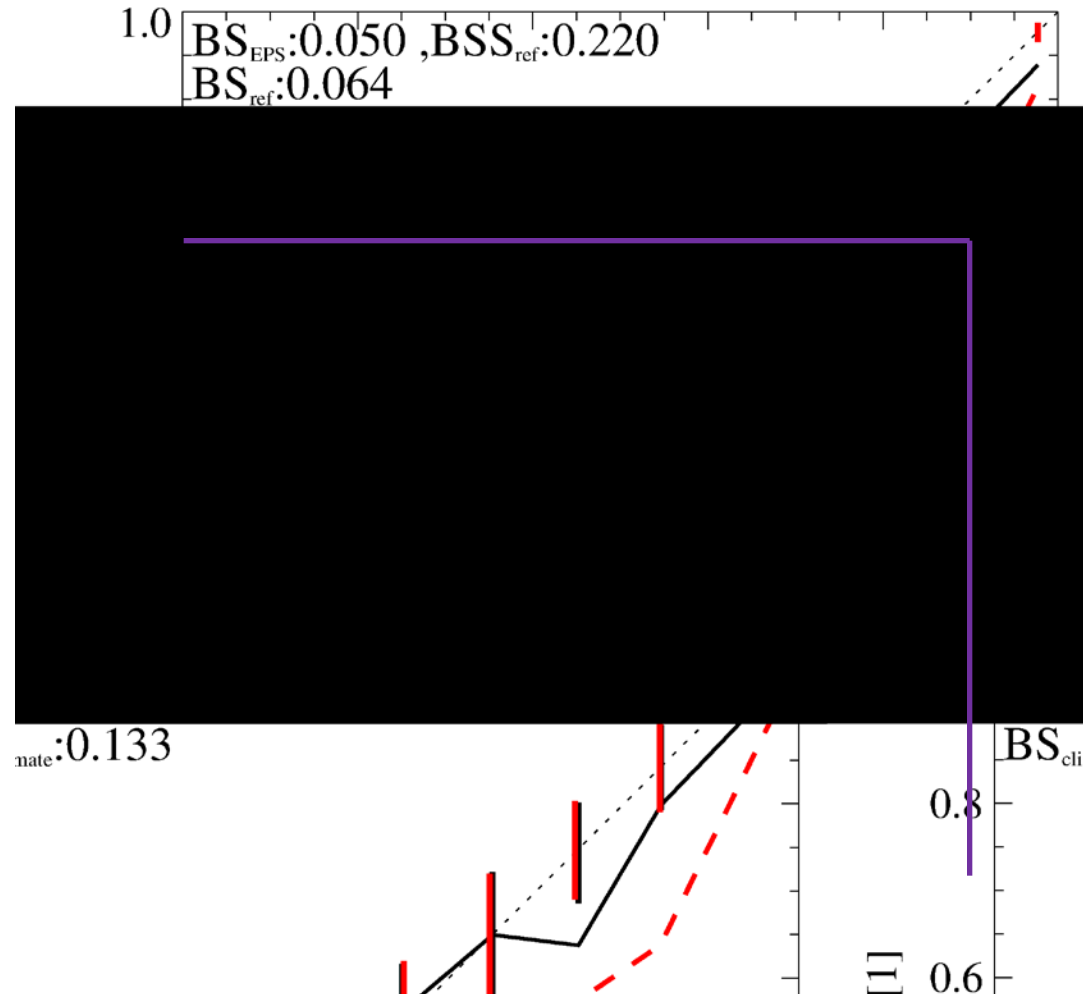
# Talagrand Diagram for Day+3 (Germany)



- 10 m Ensemble is highly underdispersive
- Increased range of the ensemble members for 100 m winds (higher ensemble spread)

# Can we trust the probabilistic forecast?

- Evaluation of reliability of the Ensemble Prediction System
- here: Event wind power > 9GW in Germany
- +72h forecast horizon

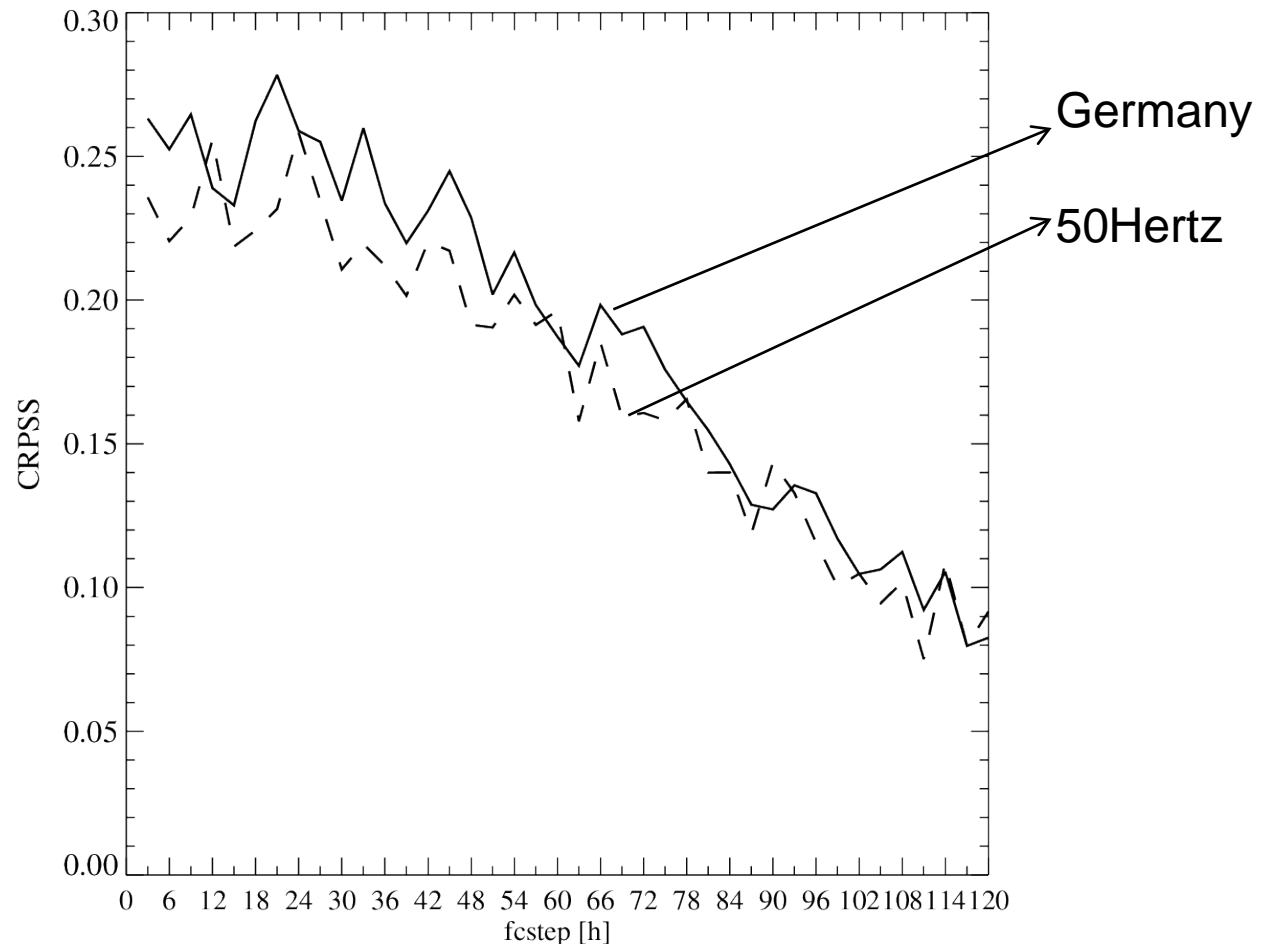


new System  
with 100m winds  
old System:  
overconfident

- New system has much better reliability

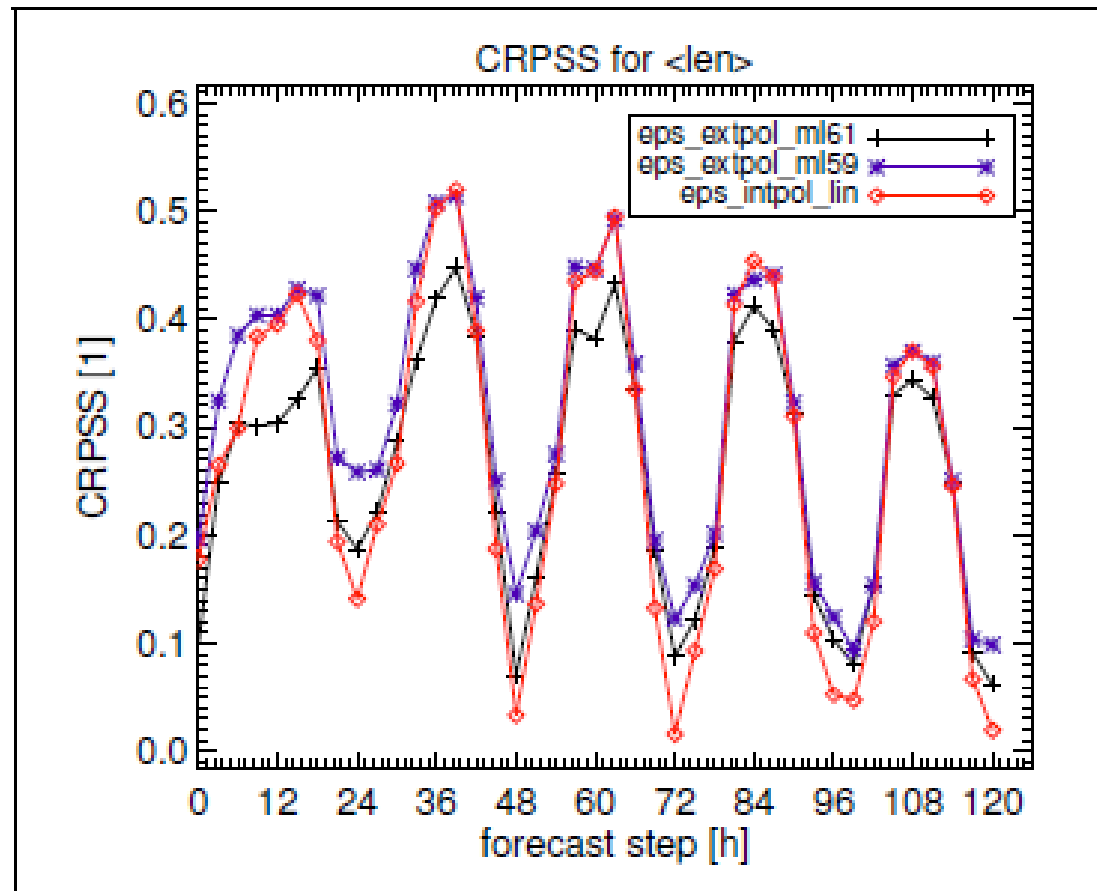
# Improvement of probabilistic forecast

- Continuous Rank Probability Skill Score:  $CRPSS = 1 - CRPS_{\text{new}} / CRPS_{\text{old}}$



- **Very strong (25%) improvement of probabilistic forecast skill**

# Improvement of probabilistic forecast for single wind farm over 10m wind speed





# Summary

- Forecast uncertainty can be derived from meteorological Ensembles and is related to the occurrence of fc errors
- Geographical display of forecast uncertainty
- at Day+2 ensemble mean starts to be better than single fc
- Improved ensemble spread for 100 m winds → better capturing of low and high wind power events
- Probabilistic forecast score is improved by 10-25% using the new Ensemble Prediction System



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Community research

## Wind Power Forecasting with Focus on Extremes

# SafeWind Project Public Workshop

**Thank you for your attention**

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