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Impact of ensemble perturbations provided by convective-scale ensemble data assimilation

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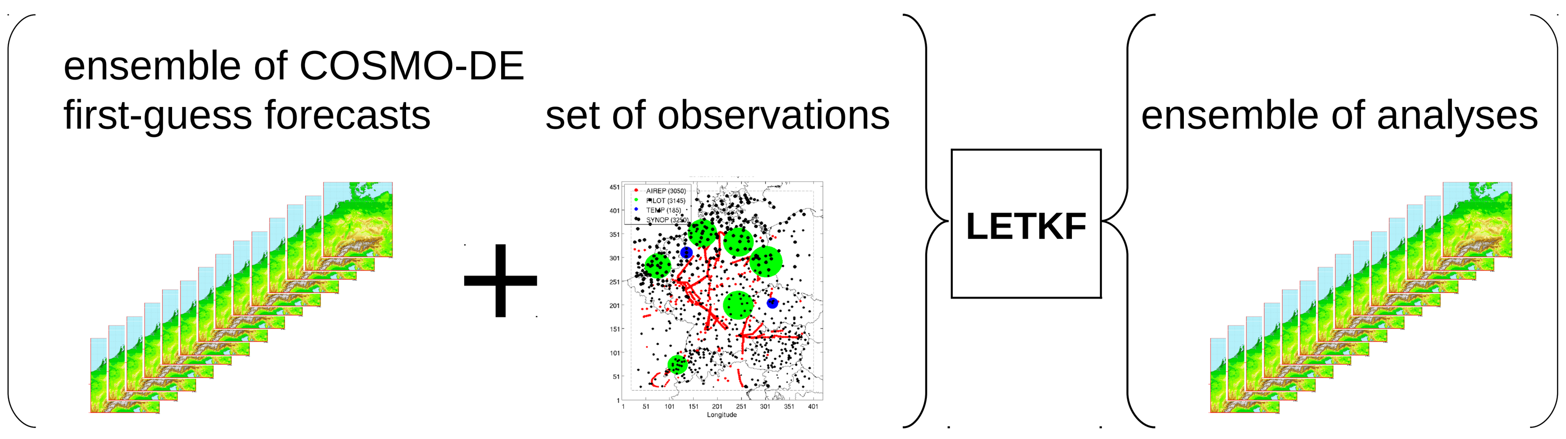
Convective-scale ensemble forecasting

- How to best initialize a convective-scale ensemble prediction system?
- COSMO-DE-EPS is currently initialized with downscaled perturbations of 4 global models
- Investigate the potential of kilometer-scale ensemble data assimilation (**KENDA**) to provide initial conditions for convective-scale ensemble forecasting
- Apply a Local Ensemble Transform Kalman Filter (LETKF) in the COSMO-DE model



→ ensemble of high-resolution initial conditions to directly initialise ensemble forecasts

KENDA-COSMO: Inflation

LETKF: background error covariance matrix $\mathbf{P}^b$ is estimated from ensemble forecasts $\mathbf{x}^b$

$$\mathbf{P}^b = (K-1)^{-1}\sum_{k=1}^{K}(\mathbf{x}_k^b - \bar{\mathbf{x}}^b)(\mathbf{x}_k^b - \bar{\mathbf{x}}^b)^{\mathrm{T}} = (K-1)^{-1}\mathbf{X}^b\left(\mathbf{X}^b\right)^{\mathrm{T}}$$

Problem: not all sources of forecast error are sampled in $\mathbf{P}^b$

→ sampling errors due to limited ensemble size & model error

→ estimate of $\mathbf{P}^b$ will systematically underestimate variances, which may result in not enough weight on new observations

Solution: Inflation of estimate of $\mathbf{P}^b$ to enhance the variance

(1) multiplicative covariance inflation (adaptive / fixed)

(2) relaxation-to-prior-perturbations: $\mathbf{X}^a \leftarrow (1-\alpha)\mathbf{X}^a + \alpha\mathbf{X}^b$ with $(\mathbf{x}_k^a - \bar{\mathbf{x}}^a)_k \rightarrow \mathbf{X}_k^a$

(Zhang et al. 2004)

relaxation-to-prior-spread: $\sigma^a \leftarrow (1-\alpha)\sigma^a + \alpha\sigma^b \;\Rightarrow\; \mathbf{X}_k^a \leftarrow \mathbf{X}_k^a\left(\alpha\frac{\sigma^b - \sigma^a}{\sigma^a} + 1\right)$

(Whitaker and Hamill, 2012)

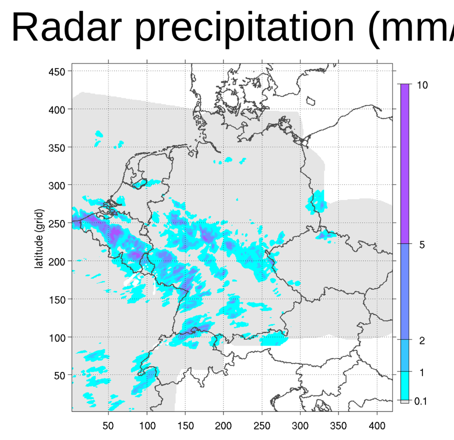
Experimental setup

(1) 15 UTC 10 June - 00 UTC 12 June 2012: → 21-h fc at 00 UTC 11 / 12 June
(2) 06 UTC 18 June – 12 UTC 19 June 2012: → 21-h fc at 12 UTC 18 June

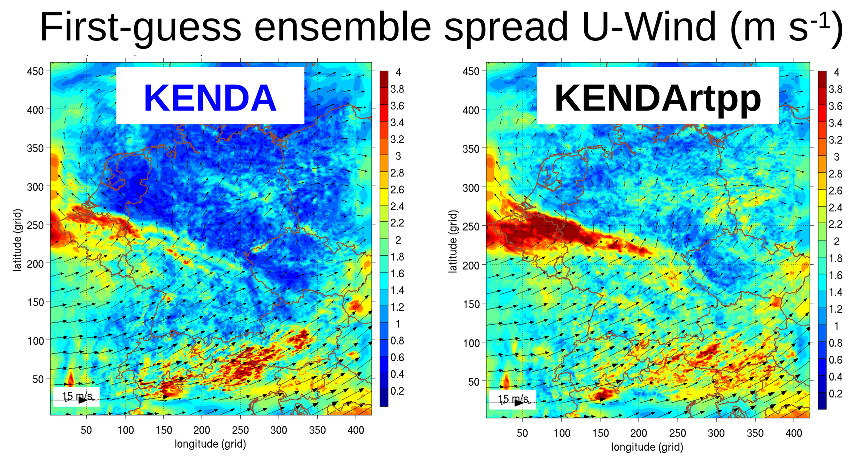
KENDA	- 3-hourly LETKF data assimilation of conventional data
	- 3-hourly analysis ensemble with **20** ensemble members
	- 20 member ECMWF EPS lateral boundary conditions (16 km)
	- No physics parametrization perturbations (PPP)
	- Multiplicative adaptive covariance inflation
KENDAppp	- including 10 physics parametrization perturbations (PPP)
KENDArtpp	- relaxation-to-prior-perturbation inflation (α = 0.75)
KENDArtps	- relaxation-to-prior-spread inflation (α= 0.95)
KENDArtps40	- 40 ensemble members / relaxation-to-prior-spread

Impact of inflation procedure at 12 UTC 11 June 2012

Radar precipitation (mm/h)

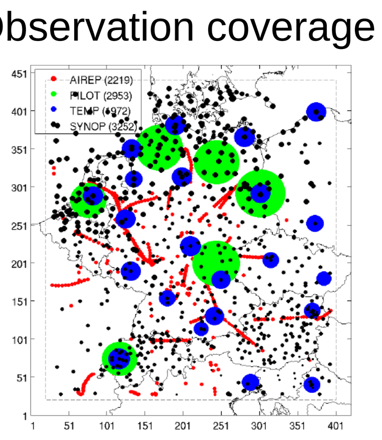


First-guess ensemble spread U-Wind (m s^{-1})

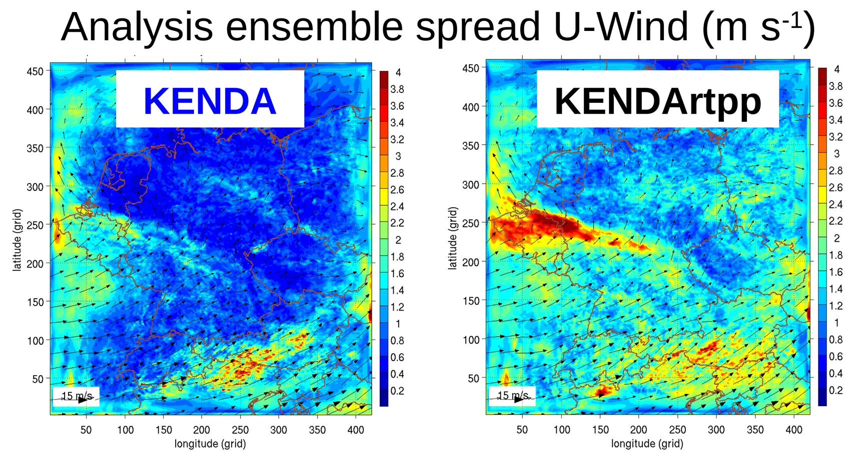


Observation coverage

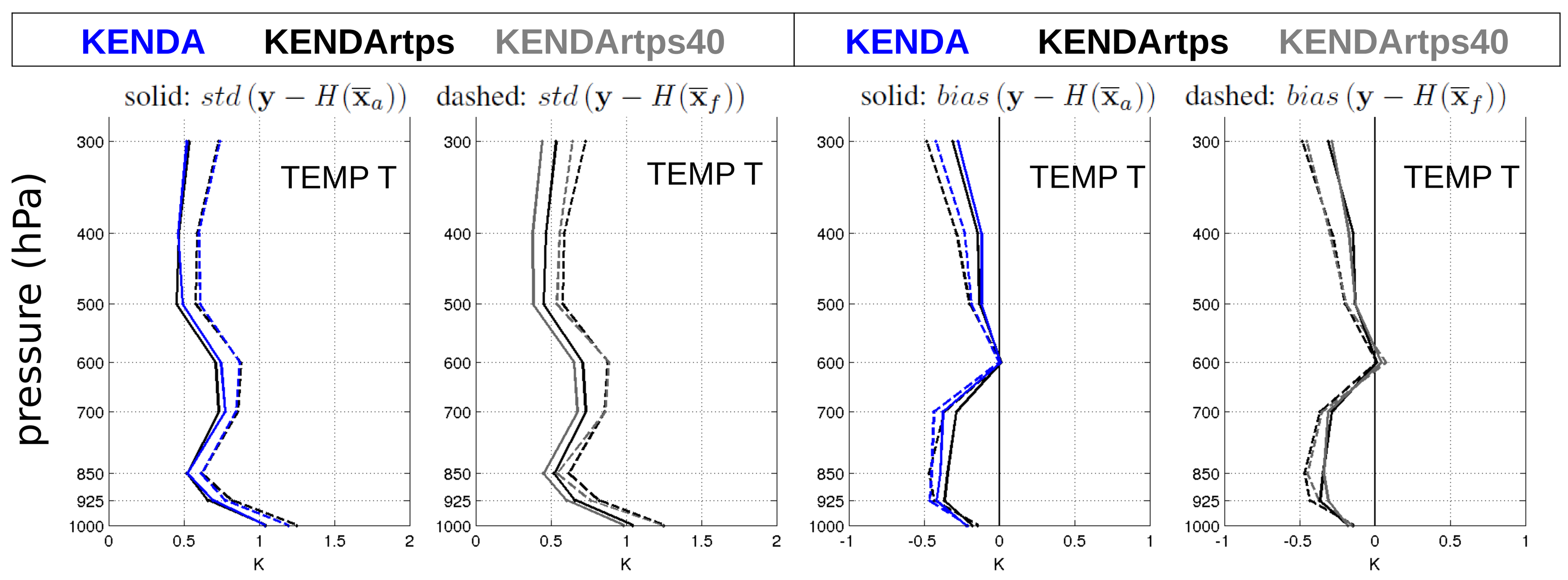
TEMP
AIREP
SYNOP
PILOT



Analysis ensemble spread U-Wind (m s^{-1})



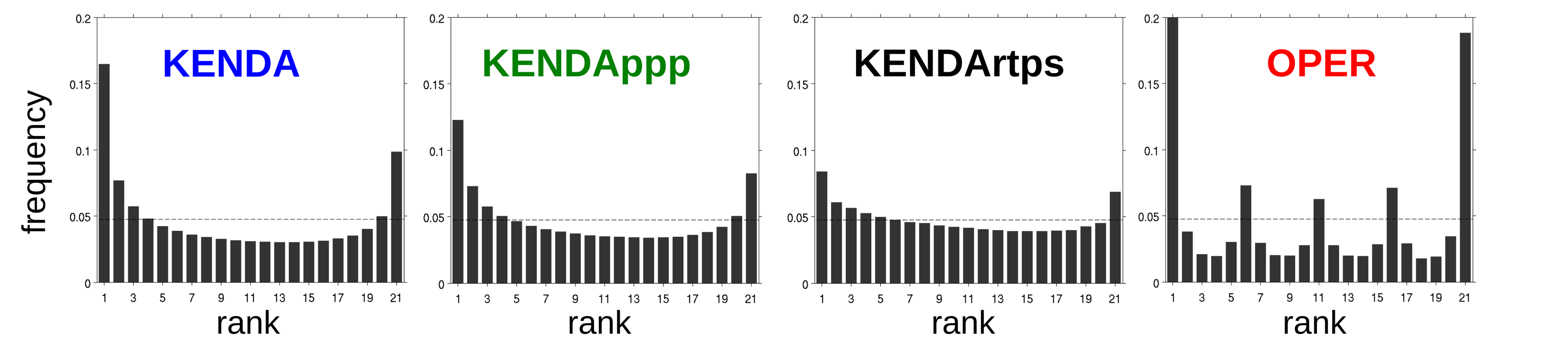
Observation statistics for KENDA experiments



→ relaxation inflation and larger ensemble size leads to a better fit to the observations

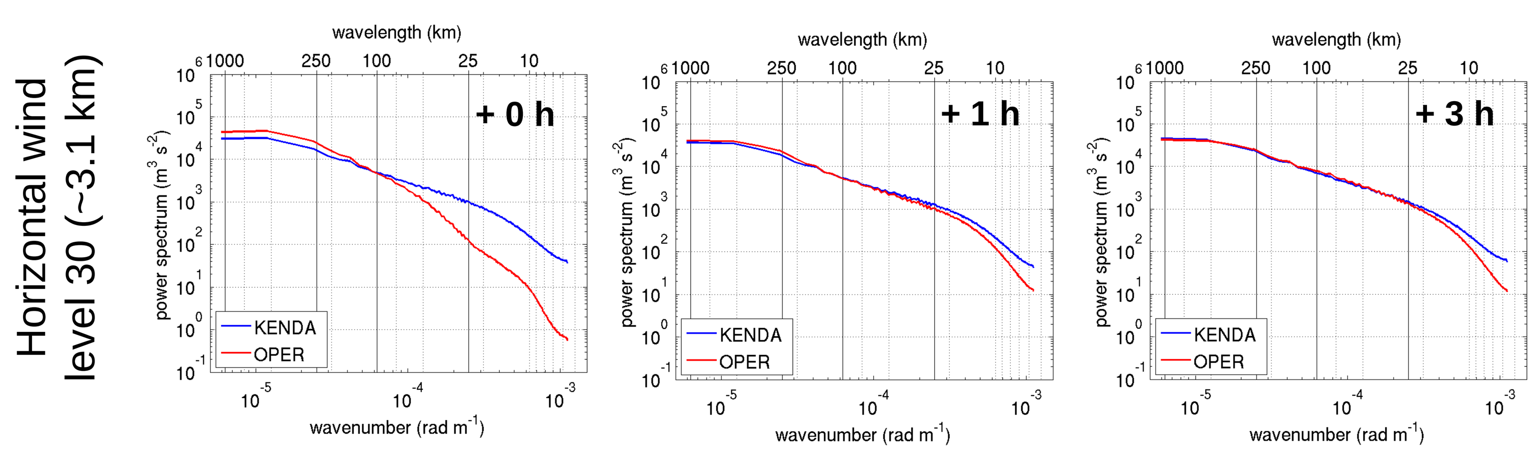
Ensemble rank histogram

+3 h forecasts of 10 m wind speed, period (1)



- KENDA forecasts are underdispersive, ***ppp*** and ***rtps*** /***rtpp*** inflation increases spread
- COSMO-DE-EPS shows clustering around the initial perturbations from 4 global models

Power spectrum of ensemble perturbations

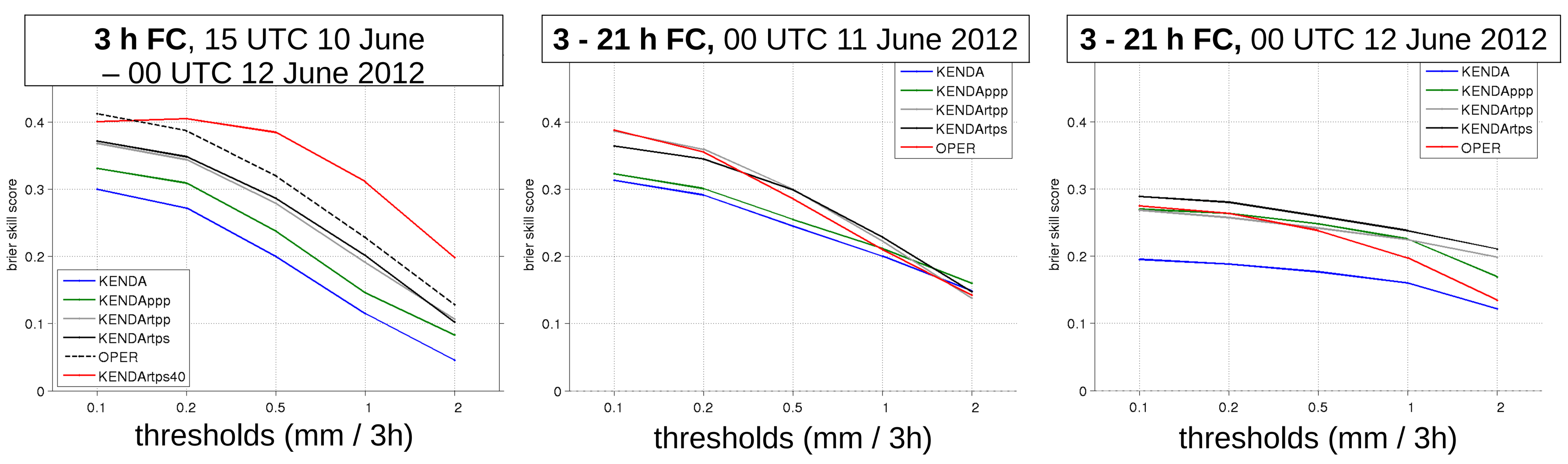


- Variance at small scales (<100 km) is reduced in COSMO-DE-OPER
- Most of the missing variance at small scales developes within 1-2 hours
- Vertical filter: dampening at lower levels exists for more than 3 hours (not shown)

Precipitation forecasts

Brier Skill Score = [resolution – reliability] / uncertainty

- COSMO-DE-EPS shows best performance up to +3 h forecasts: Latent heat nudging of radar derived precipitation data used in analysis ensemble
- Impact of parameter perturbations (***ppp***), inflation method (***rtpp***/***rtps***), and ensemble size (40)



SUMMARY & OUTLOOK

- **KENDA-COSMO** ensemble of analyses: consistent ICs for ensemble forecasts, ensemble perturbations present at all scales and all levels in the initial conditions
- Necessary to use ***inflation methods*** to account for unrepresented error sources:
  → large impact of inflation method, relaxation improves the fit to observations and FC skill
- ***Physic parameter perturbations*** can only partially account for model error
  → add stochastic boundary layer scheme to improve representation of uncertainty in the PBL
- ***Ensemble size*** affects the accuracy of the analysis emsemble
  → test 40 member LETKF analysis ensemble and 20 member COSMO-DE-EPS FC