Impact of ensemble perturbations provided by convective-scale ensemble data assimilation in the COSMO-DE model

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How to initialize convective-scale EPS?

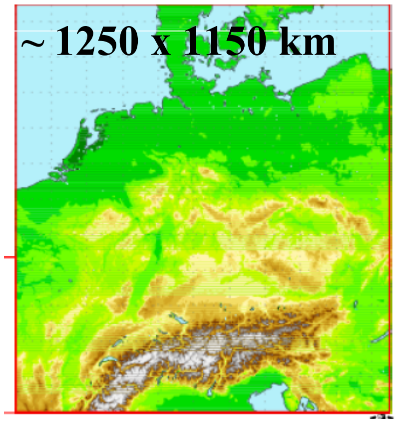
- Well-known methods for the synoptic global scales, but not clear how to use best for high-resolution limited area models

→ Downscaling of driving EPS

COSMO-DE-EPS

$\Delta x = 2.8$ km

- No parametrization of deep convection
- 20 ensemble member
- 21 hours forecast length
- Initialized every 3 hours
- Operational since May 2012



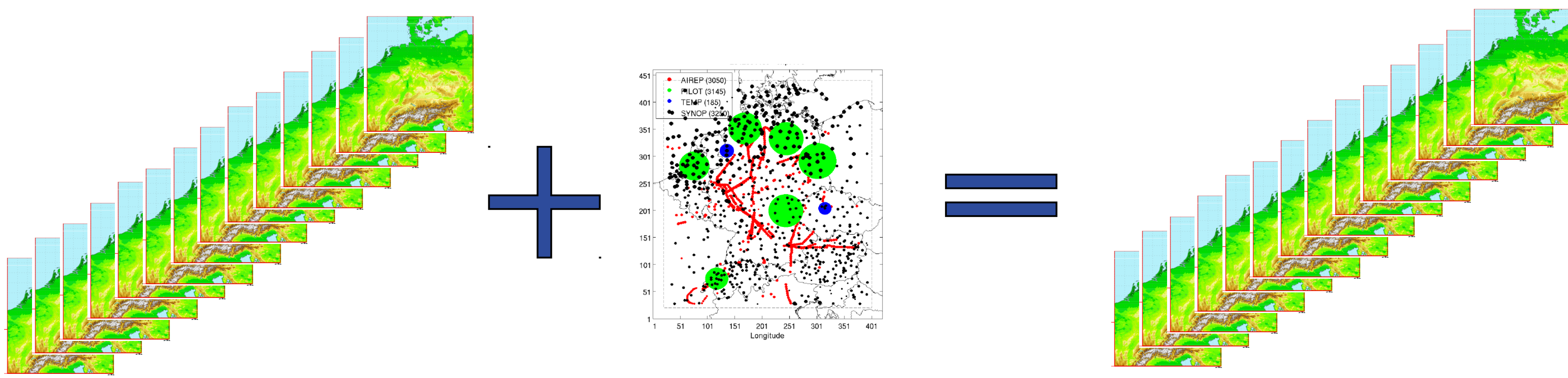
→ downscaled perturbations of 4 global models + 5 model physics parametrization perturbations → 20 members

→ Ensemble data assimilation at convective-scale

KENDA-COSMO

<u>K</u>ilometer-Scale <u>En</u>semble <u>D</u>ata <u>A</u>ssimilation (**KENDA**)
→ <u>L</u>okal <u>E</u>nsemble <u>T</u>ransform <u>K</u>alman <u>F</u>ilter (**LETKF**) *(Hunt el al. 2007)*

ensemble of COSMO-DE first-guess forecasts + set of observations → ensemble of analyses



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

KENDA-COSMO: Inflation

- LETKF: background error covariance matrix P^b is estimated from ensemble forecasts x^b

  Problem: not all sources of forecast error are sampled in P^b

  → sampling errors due to limited ensemble size & model error

  → estimate of P^b will systematically underestimate variances

  Solution: Inflation of estimate of P^b to enhance the variance

(1) multiplicative covariance inflation (adaptive / fixed)

(2) relaxation-to-prior-perturbations / relaxation-to-prior-spread

$$\mathbf{X}_k^a \leftarrow (1-\alpha)\mathbf{X}_k^a + \alpha\mathbf{X}_k^b$$

(Zhang et al. 2004)

$$\mathbf{X}_k^a \leftarrow \mathbf{X}_k^a \left(\alpha\frac{\sigma^b - \sigma^a}{\sigma^a} + 1\right)$$

(Whitaker and Hamill, 2012)

Setup of experiments

(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)

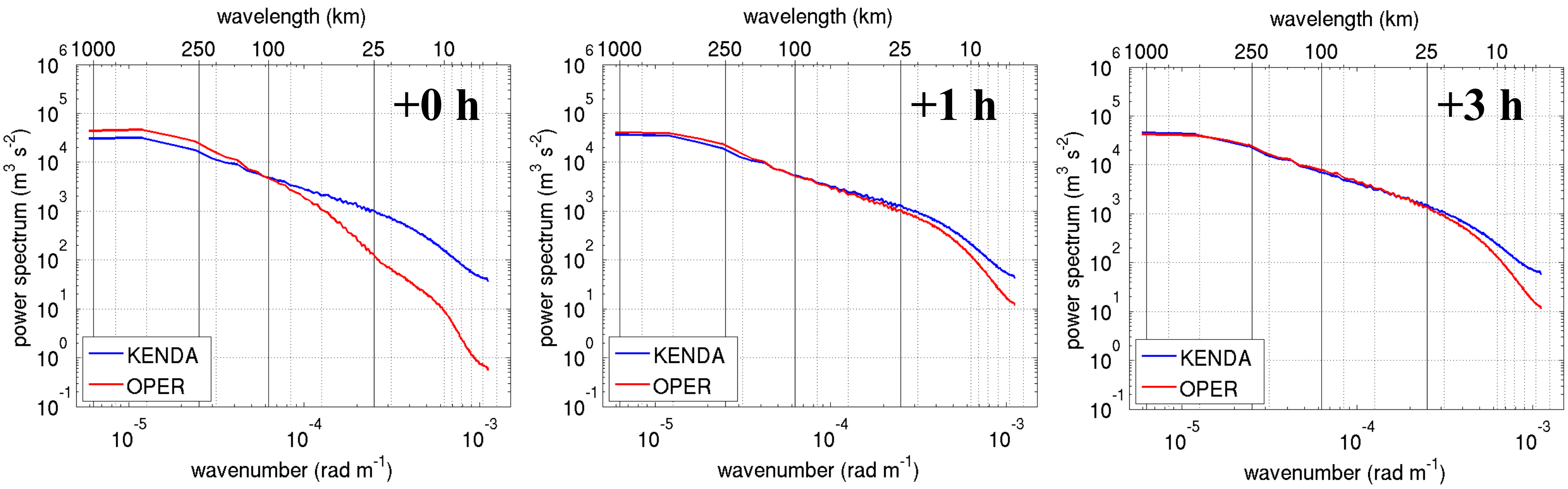
KENDArtpp: relaxation-to-prior-perturbation inflation ($\alpha = 0.75$)

KENDArtps: relaxation-to-prior-spread inflation ($\alpha = 0.95$)

KENDArtps40: 40 ensemble members / relaxation-to-prior-spread

Power spectrum of ensemble perturbations

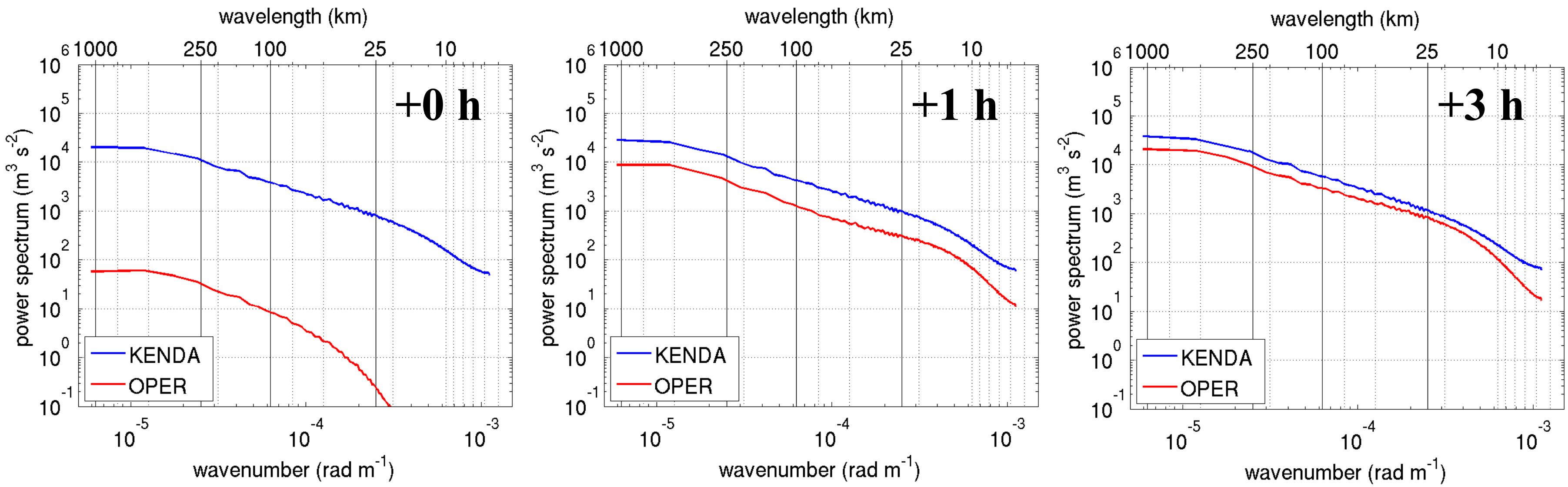
Horizontal wind, model level 30 (~3.1 km), average period (1)



- Variance at small scales (<100 km) is reduced *OPER*
- Most of the missing variance at small scales developes within 1-2 hours

Power spectrum of ensemble perturbations

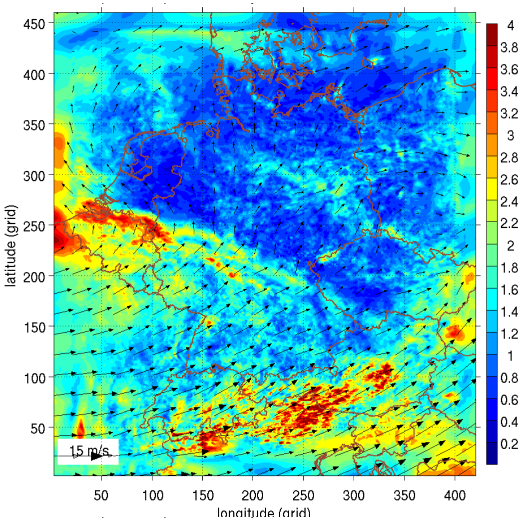
Horizontal wind, <u>model level 40 (~0.8 km),</u> average period (1)

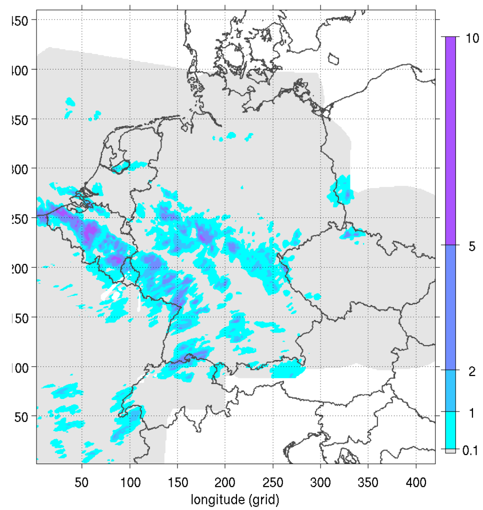


- Variance at small scales (<100 km) is reduced *OPER*
- Most of the missing variance at small scales developes within 1-2 hours
- Vertical filter: dampening at <u>lower levels</u> exists for more than 3 hours

KENDA covariance inflation, 12 UTC 11 June 2012

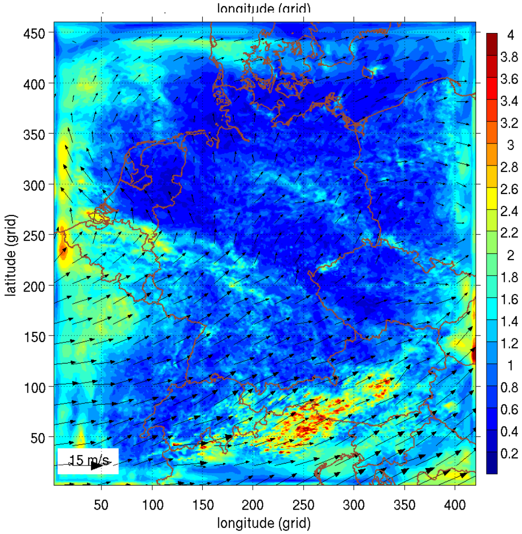
First-guess ensemble spread U-Wind (m s^{-1})

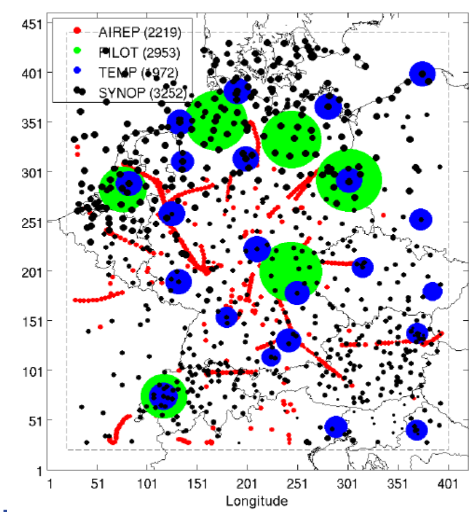




Radar derived precipitation (mm/h)

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

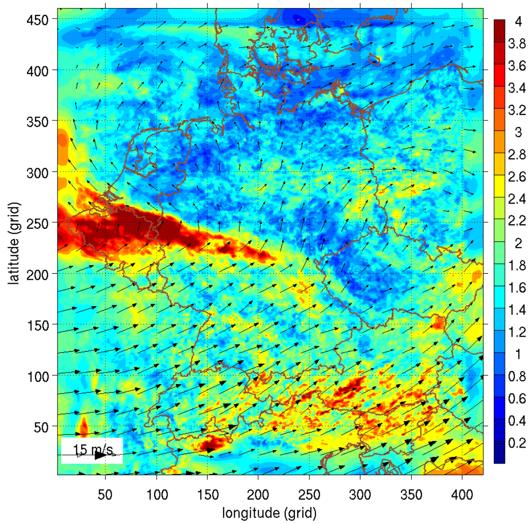


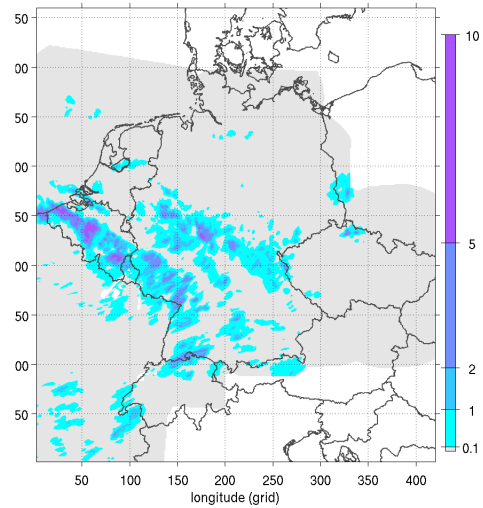


Observation used in the LETKF data assimilation

KENDA relaxation-to-prior-pert, 12 UTC 11 June 2012

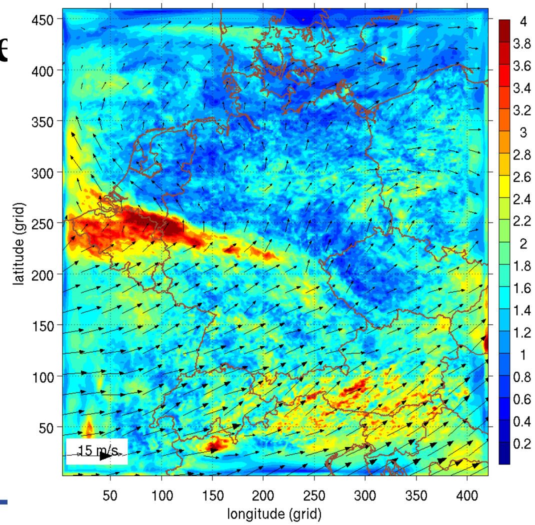
First-guess ensemble spread U-Wind (m s^{-1})

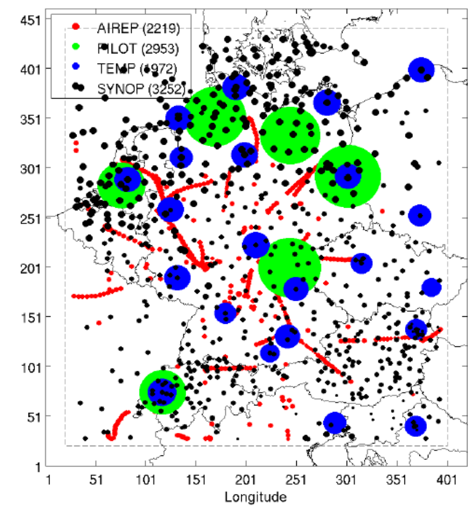




Radar derived precipitation (mm/h)

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



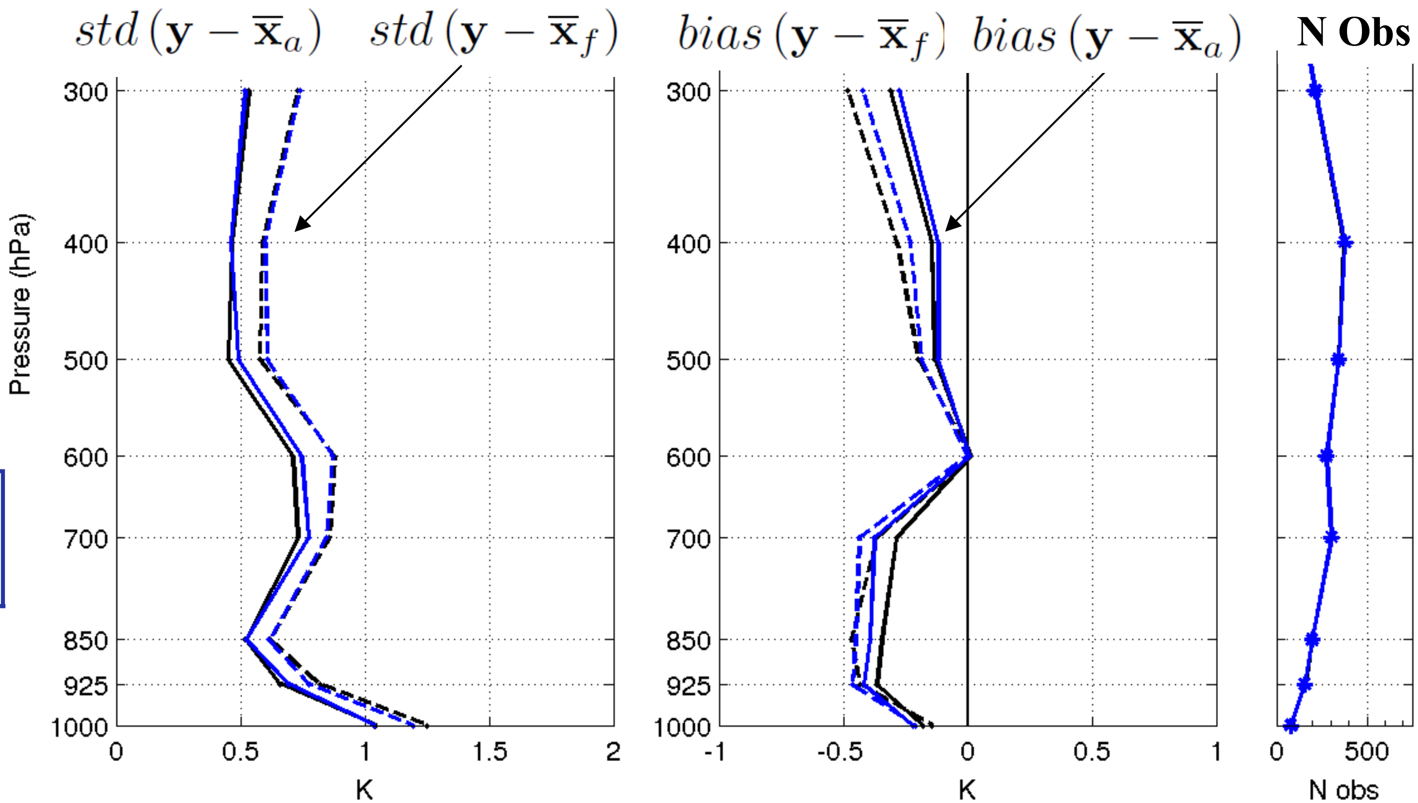


Observation used in the LETKF data assimilation

Departure statistics for KENDA experiment

Radiosonde temperature

KENDArtps
KENDA



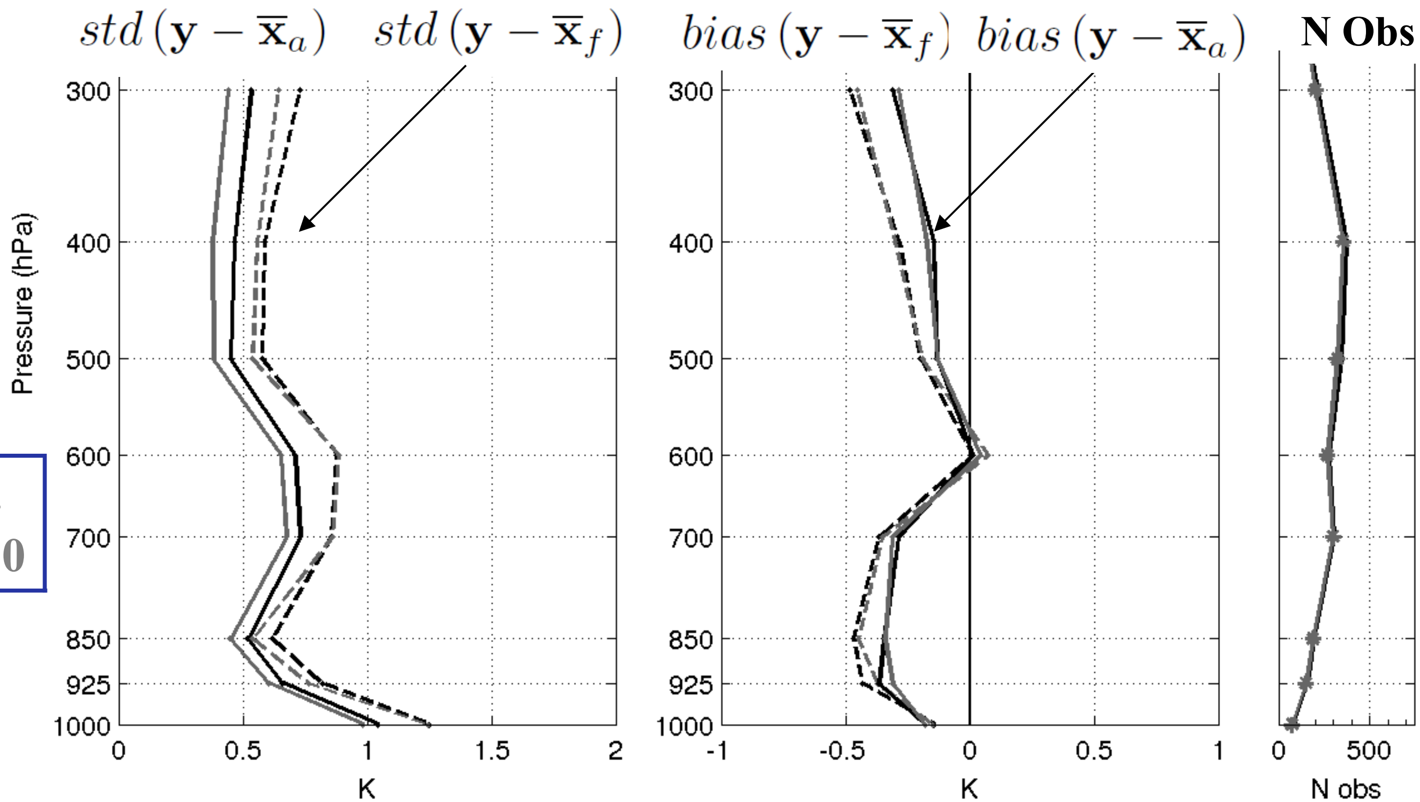
- Accuracy of the analysis ensemble mean (solid) compared to the first-guess (+3 h) ensemble mean (dashed)

→ relaxation method inflation ensemble = better accuracy

Departure statistics for KENDA experiment

Radiosonde temperature

KENDArtps
KENDArtps40

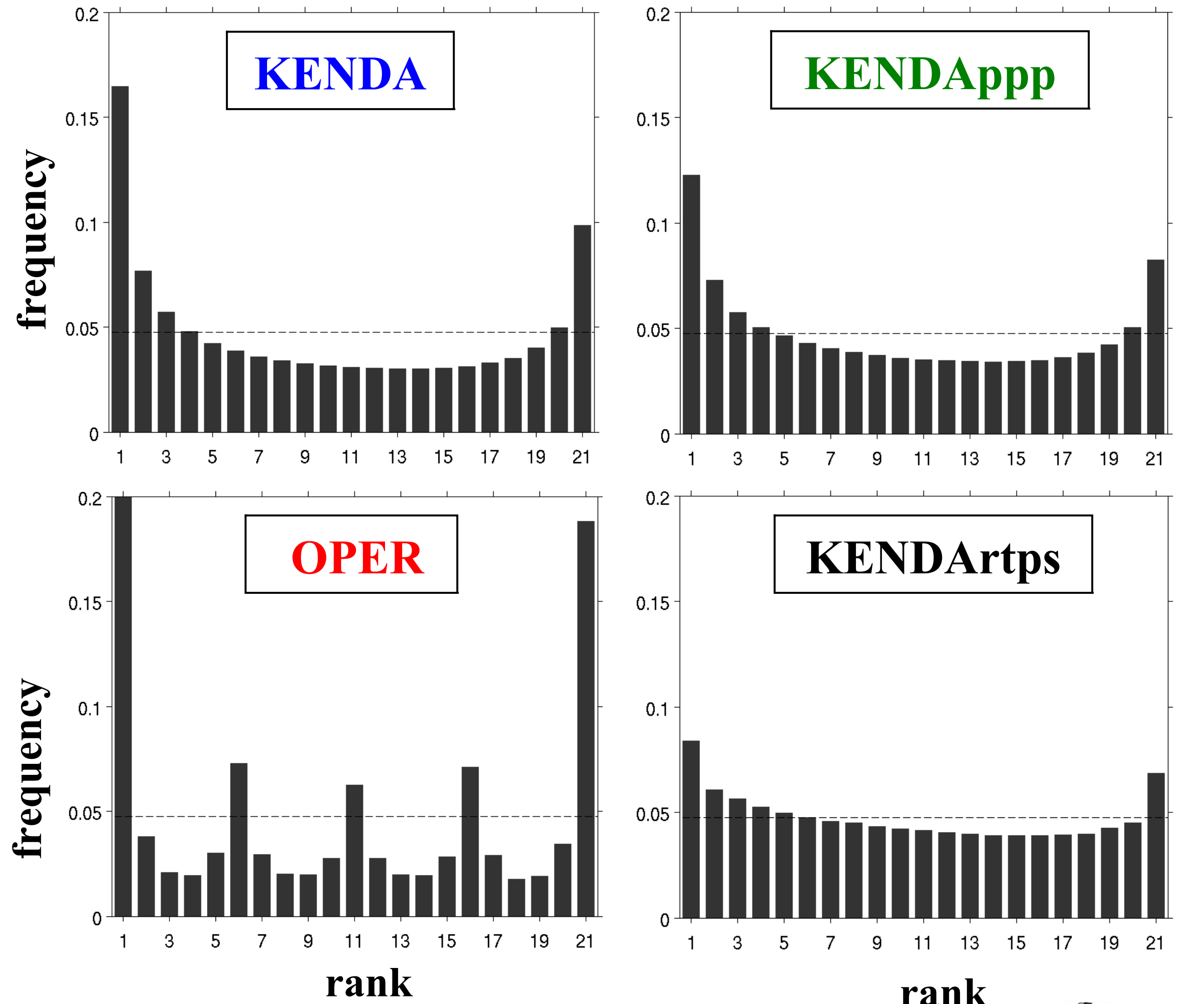


- Accuracy of the analysis ensemble mean (solid) compared to the first-guess (+3 h) ensemble mean (dashed)

  → larger ensemble = better accuracy

Ensemble rank histogram

+3 h forecasts of
10 m wind speed

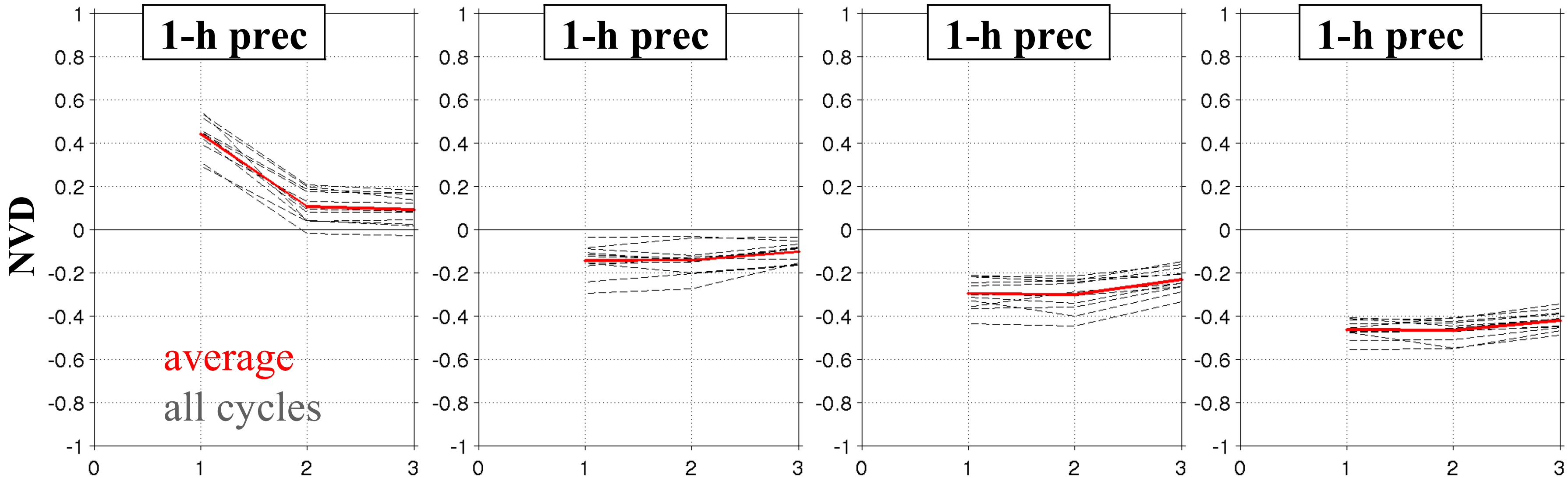


Verified against
COSMO-DE analysis
(similar results
against observations)

Ensemble dispersion

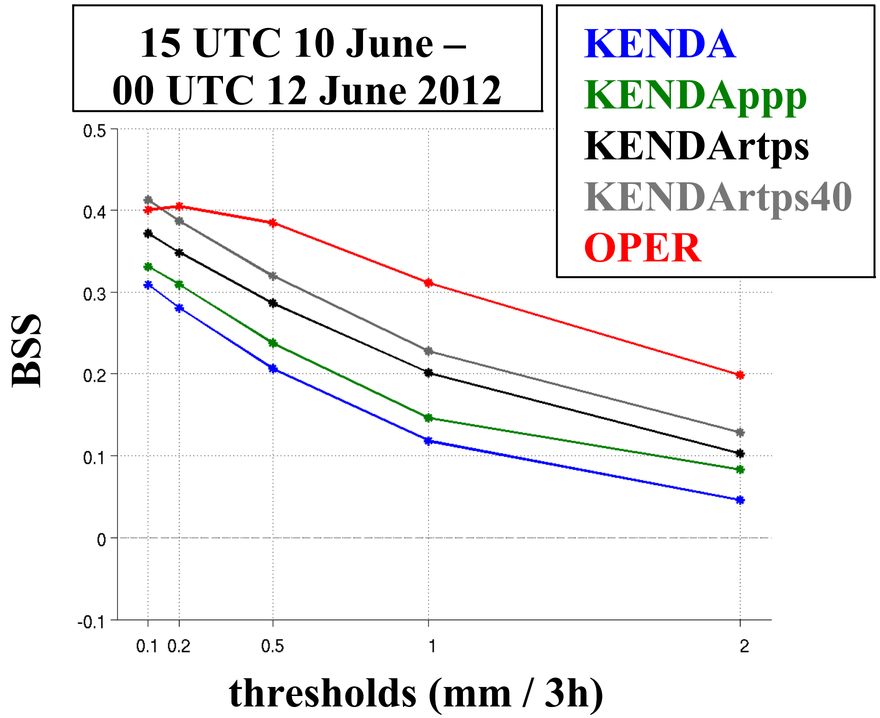
- Normalized variance difference (NVD): $$\frac{var(eps\ 1) - var(eps\ 2)}{var(eps1) + var(eps\ 2)}$$

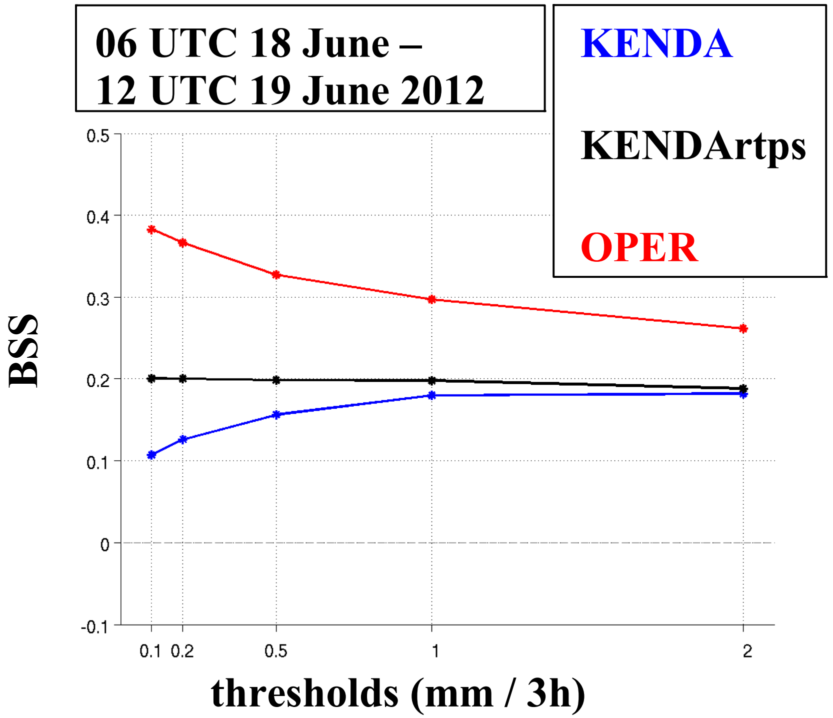
KENDA / OPER | KENDA / KENDAppp | KENDA / KENDArtps | KENDA / KENDArtps40



forecast steps (h)

BSS: 3-h ensemble forecasts of precipitation

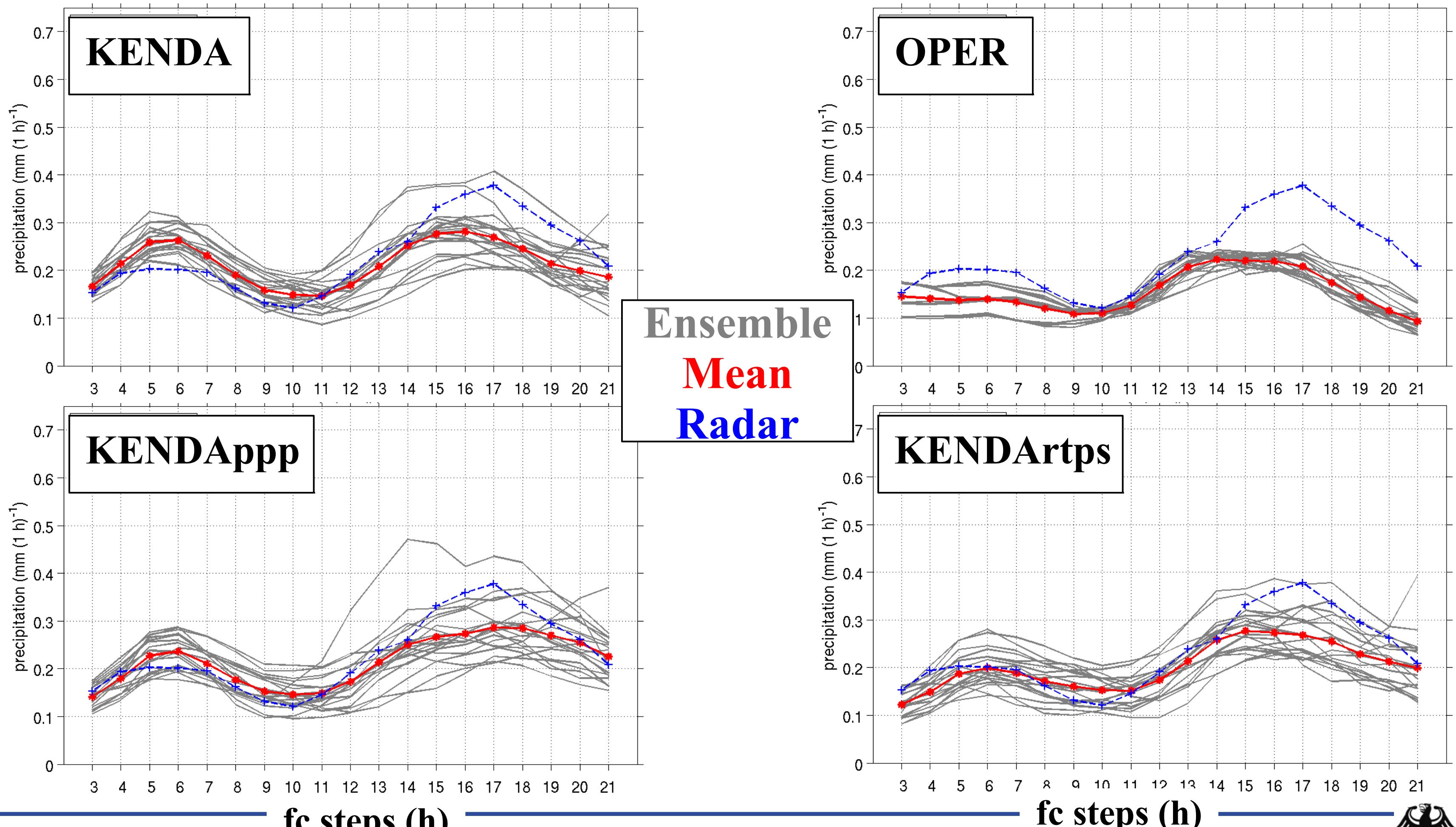




- Brier Skill Score = [resolution – reliability] / uncertainty
- Hard to beat COSMO-DE-EPS on up to 3-h hours: LHN in analysis
- Impact of model physics perturbations, inflation method and ensemble size

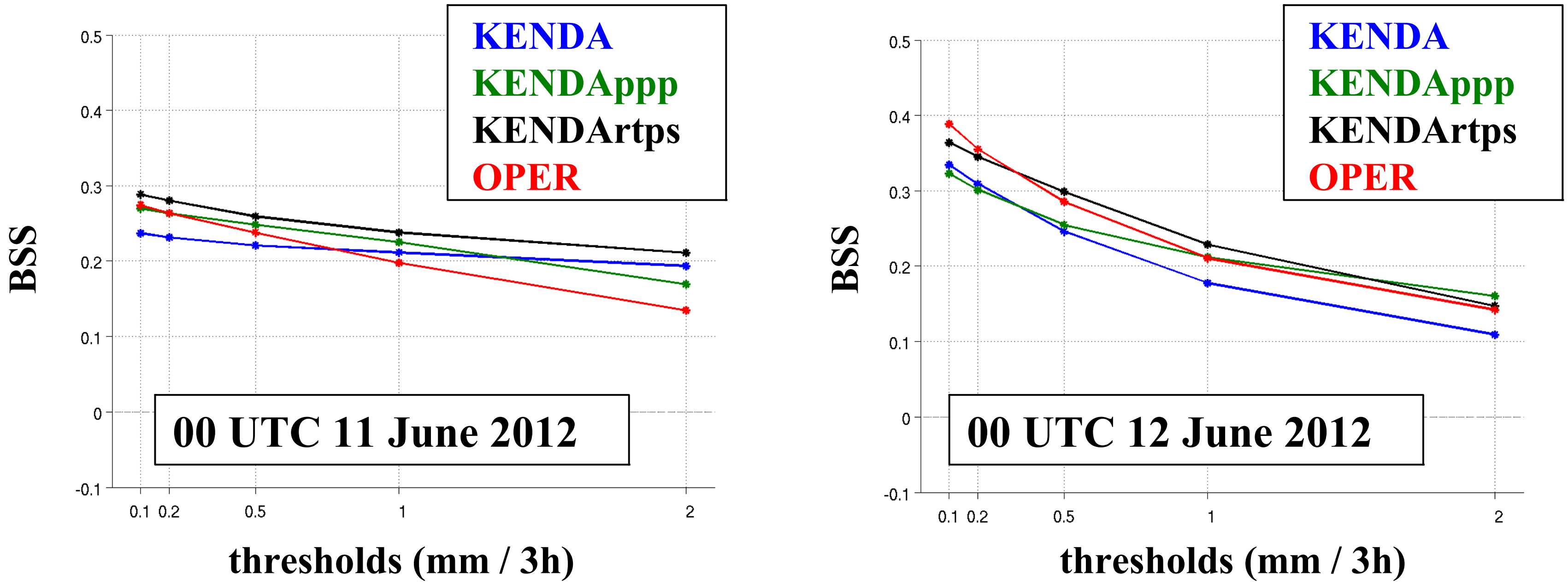
21-h ensemble forecasts of precipitation

Forecast of 1-h precipitation averaged over Germany, 00 UTC 11 June 2012



BSS: 21-h ensemble forecasts of precipitation

3-21 h forecasts averaged over Germany



- Brier Skill Score = [resolution – reliability] / uncertainty
- Accounting for model errors with ***PPP*** shows positive impact
- Large impact of ***inflation*** procedure

Summary

- Current Initial conditions (ICs) in COSMO-DE-EPS based on downscaling
- KENDA: km-scale ensemble data assimilation by means of an LETKF for the COSMO model

  → Consistent ICs for ensemble forecasts

  → ICPs are present at all scales / all levels from the beginning

  → Represent the approximated probability density function (PDF) around the high-resolution deterministic / ensemble mean analysis
- Necessary to use ***inflation methods*** to account for unrepresented error sources: relaxation-to-prior-pert / -spread lead to good results
- ***Physic parameter perturbation****s* can only partially account for model error (→ *stochastic boundary layer scheme*)