HErZ Subproject 6: Ensemble methods - Representation of uncertainty in COSMO-DE-EPS

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⇒ Subproject goal: Improved representation of uncertainty in COSMO-DE-EPS

Main extensions planned:

- KENDA IC perturbations
- stochastic boundary layer parameterisation (under development at LMU)

- Focus of work so far: Analysis of the pre-operational COSMO-DE-EPS
  - EPS behaviour and impact(time) of different perturbations (in particular initial condition perturbations, ICPs)
  - dependence upon synoptic-scale forcing using the concept of the convective adjustment time scale

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Previous results

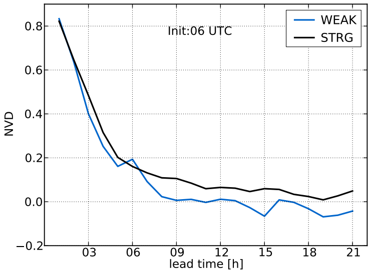
Selected results:

→ response of the EPS (bias und ensemble spread) very different under strong and weak forcing conditions

→ impact of ICPs on ensemble variance and probabilistic forecast measures generally positive

→ impact ICPs is generally largest in the first ∼6 forecast hours and decays afterwards

→ impact time of ICPs under strong forcing ∼9-21 h, whereas under weak forcing ∼6-9 h



Normalised variance difference (Clark et al., 2009; Gebhardt et al., 2011):

$$NVD = \frac{var(P_{IBP}) - var(P_{BP})}{var(P_{IBP}) + var(P_{BP})}$$

• open question: structure of the ICPs (Meeting at the HErZ workshop in April 2012)

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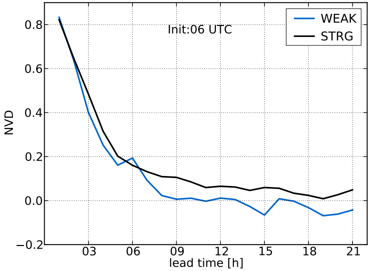

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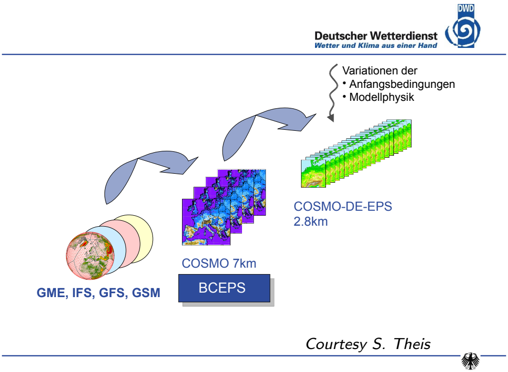


Courtesy S. Theis

IC Perturbations (Peralta et al., JGR 2012):

$$f - f_0 = W(k)(f_{BC} - f_{EU})$$

f: Perturbed COSMO-DE-EPS prognostic fields $(u, v, T, q_v, [p'];\ \Delta_h = 2.8$ km)

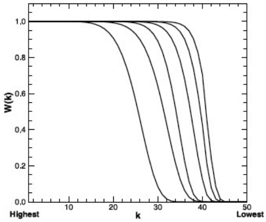
f_0: COSMO-DE analysis ($\Delta_h = 2.8$ km)

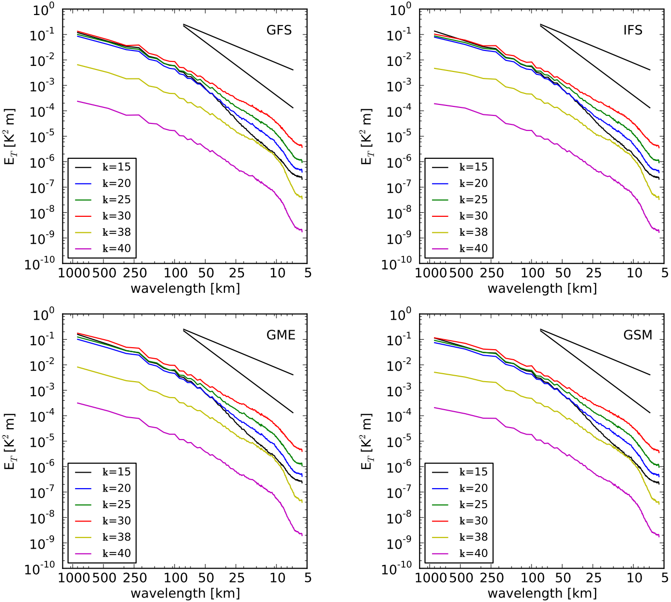
f_{BC}: BCEPS ($\Delta_h = 7$ km)

f_{EU}: COSMO-EU reference ($\Delta_h = 7$ km)

$W(k)$: filter at kth level

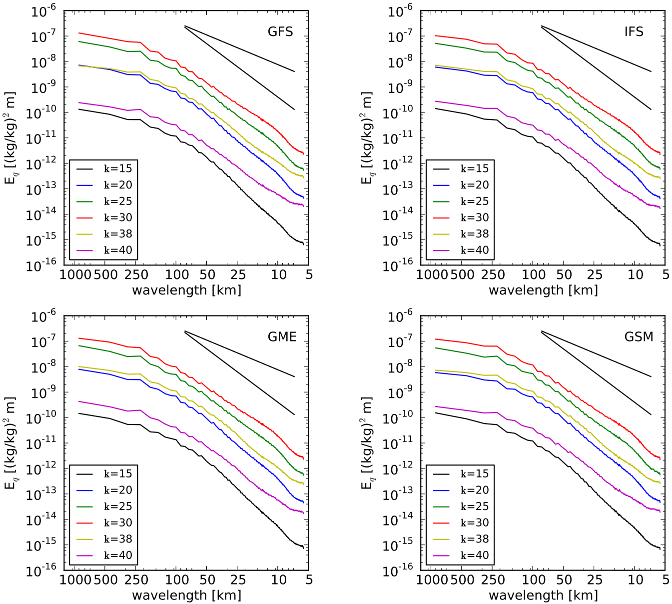
$$W(k) = \exp\left(-\epsilon \left|\frac{k}{N_{ke}}\right|^{\gamma}\right)$$





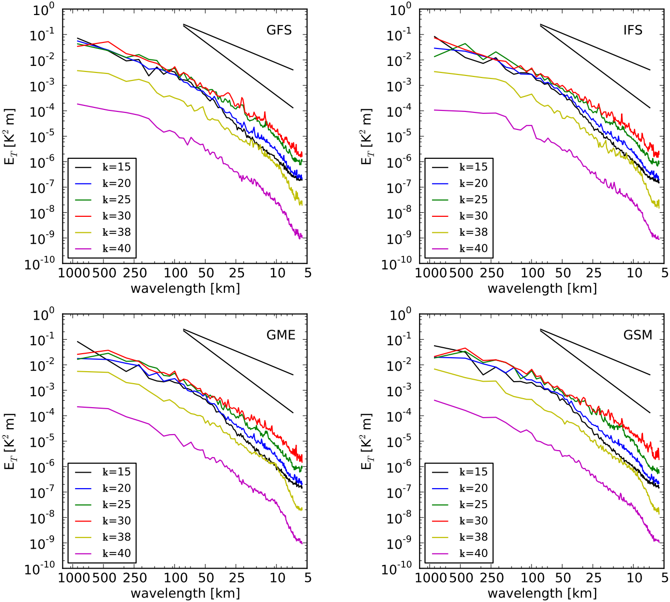
(**k** = 15, 20, 25, 30, 38, 40 correspond to ∼ 10150, 7280, 4960, 3140, 1160, 830 m altitude)

Spectra of specific humidity IC perturbations (May-Aug 2011, init: 06 UTC)



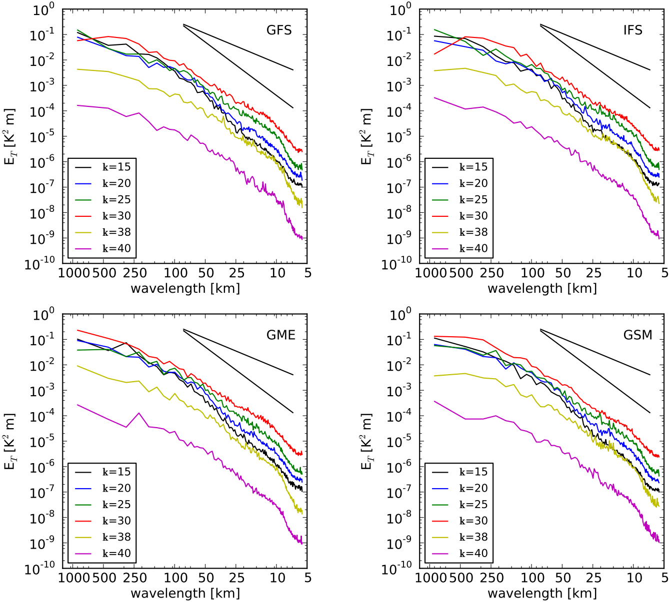
(**k** = 15, 20, 25, 30, 38, 40 correspond to ∼ 10150, 7280, 4960, 3140, 1160, 830 m altitude)

Spectra of temperature IC perturbations (Jun 5th 2011, init: 06 UTC)



(**k** = 15, 20, 25, 30, 38, 40 correspond to ∼ 10150, 7280, 4960, 3140, 1160, 830 m altitude)

Spectra of temperature IC perturbations (Jun 22nd 2011, init: 06 UTC)



($\mathbf{k} = 15, 20, 25, 30, 38, 40$ correspond to $\sim 10150, 7280, 4960, 3140, 1160, 830$ m altitude)

Outlook

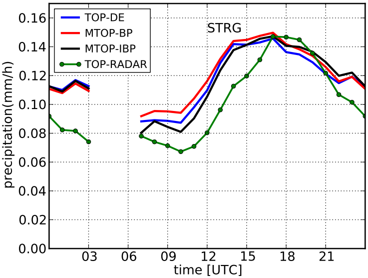
Next working steps:

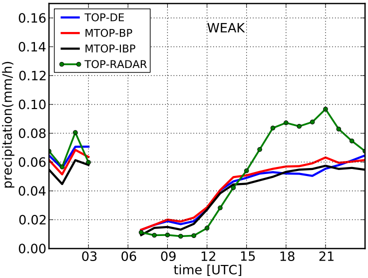
- ◇ publication of results about regime-dependent impact of IC perturbations in COSMO-DE-EPS
- ◇ comparison study of structure and impact of analysed IC perturbations in current COSMO-DE-EPS with IC perturbations from COSMO-KENDA

  - test period for the comparison study ? June 2011 ?

  - setup for the comparison study ? KENDA-IC + BCEPS + PHY ?

Spatio-temporal mean of forecasted and observed precipitation





Mean and variance of IC perturbations (May-Aug 2011, init: 06 UTC)

T	mean(GFS)	variance(GFS)	mean(GME)	variance(GME)	mean(GSM)	variance(GSM)
$\mathbf{k}=15$	$-3.9\cdot10^{-2}$	$3.8\cdot10^{-1}$	$1.9\cdot10^{-2}$	$4.2\cdot10^{-1}$	$-6.0\cdot10^{-4}$	$3.6\cdot10^{-1}$
$\mathbf{k}=20$	$-1.8\cdot10^{-1}$	$2.7\cdot10^{-1}$	$9.5\cdot10^{-3}$	$3.1\cdot10^{-1}$	$-1.8\cdot10^{-1}$	$2.5\cdot10^{-1}$
$\mathbf{k}=25$	$-1.1\cdot10^{-1}$	$3.1\cdot10^{-1}$	$-2.5\cdot10^{-2}$	$3.6\cdot10^{-1}$	$-2.6\cdot10^{-1}$	$2.9\cdot10^{-1}$
$\mathbf{k}=30$	$-7.6\cdot10^{-2}$	$4.0\cdot10^{-1}$	$-3.2\cdot10^{-2}$	$5.0\cdot10^{-1}$	$-2.2\cdot10^{-1}$	$3.8\cdot10^{-1}$
$\mathbf{k}=38$	$-6.4\cdot10^{-2}$	$2.0\cdot10^{-2}$	$-1.8\cdot10^{-2}$	$2.4\cdot10^{-2}$	$-6.4\cdot10^{-2}$	$1.9\cdot10^{-2}$
$\mathbf{k}=40$	$-1.5\cdot10^{-2}$	$7.6\cdot10^{-4}$	$-3.5\cdot10^{-3}$	$9.2\cdot10^{-4}$	$-1.4\cdot10^{-2}$	$7.4\cdot10^{-4}$
$\mathbf{k}=44$	$-2.3\cdot10^{-6}$	$5.5\cdot10^{-10}$	$-1.1\cdot10^{-9}$	$4.6\cdot10^{-6}$	$-2.3\cdot10^{-6}$	0.0

q_v	mean(GFS)	variance(GFS)	mean(GME)	variance(GME)	mean(GSM)	variance(GSM)
$\mathbf{k}=15$	$1.1\cdot10^{-6}$	$4.7\cdot10^{-10}$	$-3.4\cdot10^{-6}$	$5.2\cdot10^{-10}$	$1.1\cdot10^{-6}$	$5.4\cdot10^{-10}$
$\mathbf{k}=20$	$-1.8\cdot10^{-5}$	$2.5\cdot10^{-8}$	$-1.8\cdot10^{-5}$	$2.7\cdot10^{-8}$	$-5.5\cdot10^{-1}$	$2.4\cdot10^{-8}$
$\mathbf{k}=25$	$-8.2\cdot10^{-5}$	$2.0\cdot10^{-7}$	$-5.3\cdot10^{-5}$	$2.2\cdot10^{-7}$	$-1.3\cdot10^{-4}$	$1.94\cdot10^{-7}$
$\mathbf{k}=30$	$-1.7\cdot10^{-4}$	$4.5\cdot10^{-7}$	$-9.2\cdot10^{-5}$	$4.7\cdot10^{-7}$	$-2.2\cdot10^{-4}$	$4.8\cdot10^{-7}$
$\mathbf{k}=38$	$5.7\cdot10^{-6}$	$2.9\cdot10^{-8}$	$1.2\cdot10^{-6}$	$3.9\cdot10^{-8}$	$-2.6\cdot10^{-5}$	$3.3\cdot10^{-8}$
$\mathbf{k}=40$	$2.7\cdot10^{-6}$	$9.8\cdot10^{-10}$	$7.1\cdot10^{-6}$	$1.5\cdot10^{-9}$	$-1.7\cdot10^{-2}$	$1.1\cdot10^{-9}$
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k = 20	$-1.8\cdot10^{-1}$	$2.7\cdot10^{-1}$	$9.5\cdot10^{-3}$	$3.1\cdot10^{-1}$	$-1.8\cdot10^{-1}$	$2.5\cdot10^{-1}$
k = 25	$-1.1\cdot10^{-1}$	$3.1\cdot10^{-1}$	$-2.5\cdot10^{-2}$	$3.6\cdot10^{-1}$	$-2.6\cdot10^{-1}$	$2.9\cdot10^{-1}$
k = 30	$-7.6\cdot10^{-2}$	$4.0\cdot10^{-1}$	$-3.2\cdot10^{-2}$	$5.0\cdot10^{-1}$	$-2.2\cdot10^{-1}$	$3.8\cdot10^{-1}$
k = 38	$-6.4\cdot10^{-2}$	$2.0\cdot10^{-2}$	$-1.8\cdot10^{-2}$	$2.4\cdot10^{-2}$	$-6.4\cdot10^{-2}$	$1.9\cdot10^{-2}$
k = 40	$-1.5\cdot10^{-2}$	$7.6\cdot10^{-4}$	$-3.5\cdot10^{-3}$	$9.2\cdot10^{-4}$	$-1.4\cdot10^{-2}$	$7.4\cdot10^{-4}$
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k = 20	$-1.8\cdot10^{-5}$	$2.5\cdot10^{-8}$	$-1.8\cdot10^{-5}$	$2.7\cdot10^{-8}$	$-5.5\cdot10^{-1}$	$2.4\cdot10^{-8}$
k = 25	$-8.2\cdot10^{-5}$	$2.0\cdot10^{-7}$	$-5.3\cdot10^{-5}$	$2.2\cdot10^{-7}$	$-1.3\cdot10^{-4}$	$1.94\cdot10^{-7}$
k = 30	$-1.7\cdot10^{-4}$	$4.5\cdot10^{-7}$	$-9.2\cdot10^{-5}$	$4.7\cdot10^{-7}$	$-2.2\cdot10^{-4}$	$4.8\cdot10^{-7}$
k = 38	$5.7\cdot10^{-6}$	$2.9\cdot10^{-8}$	$1.2\cdot10^{-6}$	$3.9\cdot10^{-8}$	$-2.6\cdot10^{-5}$	$3.3\cdot10^{-8}$
k = 40	$2.7\cdot10^{-6}$	$9.8\cdot10^{-10}$	$7.1\cdot10^{-6}$	$1.5\cdot10^{-9}$	$-1.7\cdot10^{-2}$	$1.1\cdot10^{-9}$
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Study the influence of IC perturbations in COSMO-DE-EPS

Comparison of two EPS:

(i) "IBP": pre-operational COSMO-DE-EPS with (IC+BC+PH) perturbations

(ii) "BP": special "Experiment 8247" in COSMO-DE-EPS with only (BC+PH) perturbations

- ◇ Both IBP and BP use 20 ensemble members
- ◇ 3.5 month period from May 1st to August 15th 2011
- ◇ 21 h-forecasts with initialisation times 00,<u>06</u>,12,18 UTC
- ◇ Verification of total precipitation using DWD's high-resolution radar composite over Germany

Convective adjustment time scale

◇ EPS performance in terms of convective precipitation forecasts under different meteorological conditions – strong vs. weak synoptic-scale forcing

◇ Convective adjustment time scale τ_c (Done et al. 2006; Zimmer et al. 2011; Keil and Craig 2011):

$$\tau_c = \frac{CAPE}{d(CAPE)/dt} = 0.5 \left(\frac{\rho_0 c_p T_0}{L_v g} \right) \frac{CAPE}{P}$$

→ τ_c represents the rate at which convection releases conditional instability.

→ τ_c small (e.g. <6 h) indicates equilibrium convection (strong forcing)

→ τ_c large (e.g. >6 h) indicates non-equilibrium convection (weak forcing)

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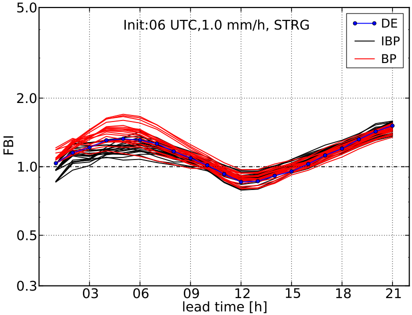
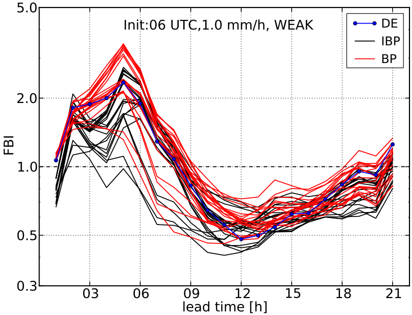
Forecast time series of frequency bias index (FBI); init 6 UTC

	strong: $\langle\tau_c\rangle_{max} < 6\ h$	weak: $\langle\tau_c\rangle_{max} > 6\ h$	"dry"	missing	total
number of days	80	16	6	5	107

All days (80) with $\langle\tau_c\rangle_{max} < 6\ h$

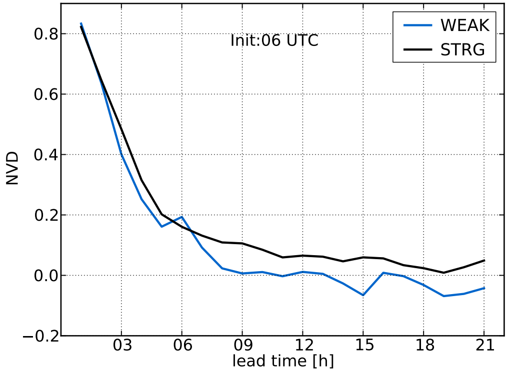


All days (16) with $\langle\tau_c\rangle_{max} > 6\ h$



$$\text{FBI} = \frac{hits + false\ alarms}{hits + misses}$$

Influence of initial condition perturbations on ensemble variance



Normalised variance difference (Clark et al., 2009; Gebhardt et al., 2011):

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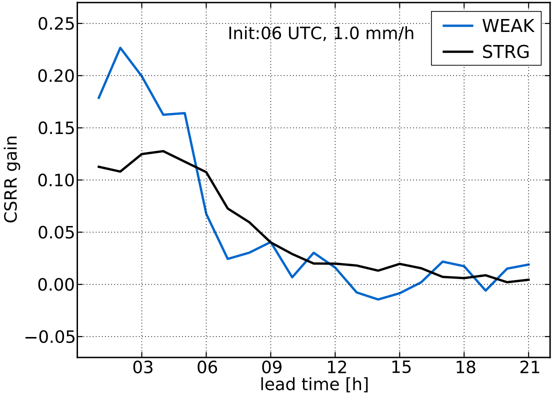
Influence of initial condition perturbations on probabilistic measures



Single-threshold (1mm/h) conditional square-root of ranked probability score (Germann and Zawadzki, 2003; Kober et al., 2011):

$$\mathrm{CSRR}(t) = \left(\frac{1}{\widetilde{\widetilde{\Omega}}} \int_{\Omega} \left[p(t_0 + t, \mathbf{x}) - \hat{p}(t_0 + t, \mathbf{x}) \right]^2 d\mathbf{x} \right)^{0.5}$$

Consider CSRR gain:

$$\mathrm{CSRRG} = 1 - \frac{\mathrm{CSRR_{IBP}}}{\mathrm{CSRR_{BP}}}$$