The impact of initial condition perturbations in COSMO-DE-EPS under different synoptic-scale forcing

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Background and experimental design

- COSMO-DE-EPS operational convection-permitting (Δ=2.8km) ensemble prediction system at DWD since 2012
- Three sources of uncertainty span a 20-member ensemble:
  - **I**: Downscaled initial condition perturbations (ICPs) from four global models (**new!**)
  - **B**: Boundary condition perturbations (BCPs) from same four global models (GFS, GME, IFS, GSM)
  - **P**: Parameter perturbations in five physics parameterisation (PYP) to maximize warm season precipitation variability
- *How effective are ICPs based on downscaling approach at convection permitting grid spacings?*
- *Is there a benefit compared to the deterministic forecast?*

→ **Precipitation** forecasts of two EPS (**IBP** vs **BP** ensemble) and the deterministic COSMO-DE are systematically compared for 3.5 months in summer 2011

Weather regime dependence

Application of the convective adjustment time scale τ_c

$$\tau_c = \frac{CAPE}{d/dt\ CAPE} \sim \frac{CAPE}{P}$$

i.e. the rate of change of CAPE can be expressed by the precipitation rate P to distinguish two distinct meteorological regimes:

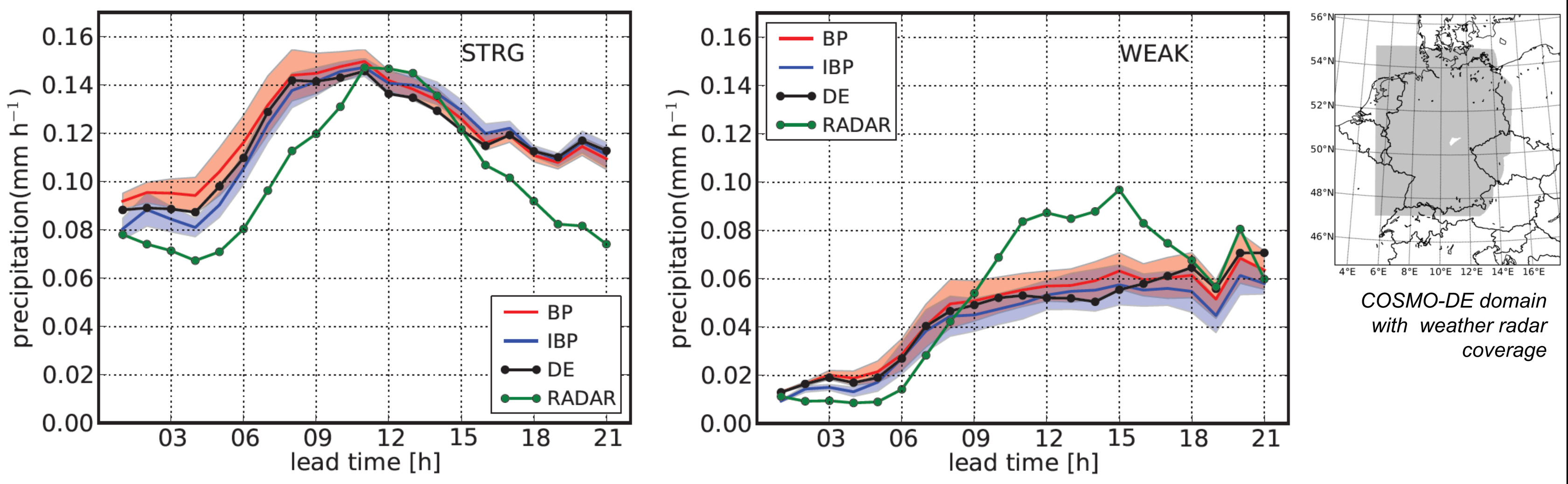
τ_c "small": convection is controlled by synoptic scale forcing

τ_c "large": convection is inhibited (lack of synoptic forcing) and can only released if local trigger mechanisms are available

Statistics of the classification into forecasts under strong and weak forcing conditions applying a threshold of 6 hours

	strong: $\langle\tau_c\rangle_{max} < 6$ h	weak: $\langle\tau_c\rangle_{max} > 6$ h	"dry"	missing	total
number of forecasts	83	16	6	2	107

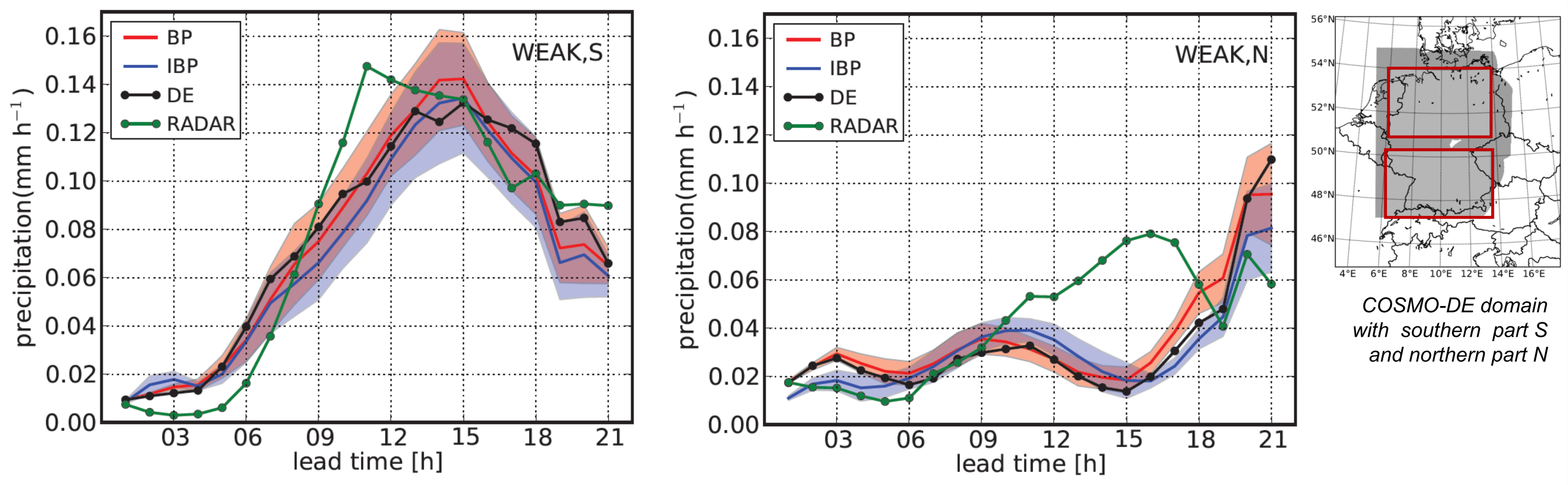
1. Diurnal cycle of precipitation



Spatially-averaged hourly precipitation rate as function of lead time from initialisation time 06 UTC. The spatial average is over the investigation region. Averages over forecasts under (left) strong and (right) weak forcing conditions of the investigation period are shown. The red and blue solid lines represent, respectively, the ensemble mean of the BP and IBP EPSs, with the shaded regions in lighter colours the corresponding ensemble standard deviation. The black-dot line is for COSMO-DE and the green-dot line for the verifying radar observations.

- Overestimation during strong and underestimation during weak forcing conditions
- Poor representation of precipitation maximum during weak forcing with all forecasting systems

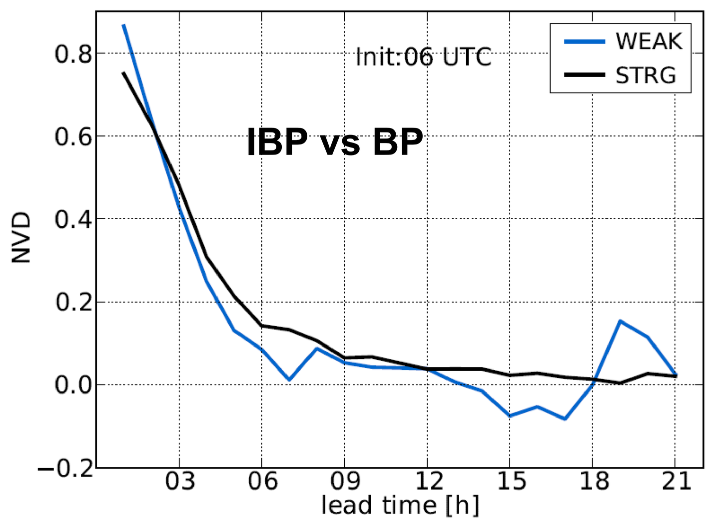
2. Orographic control of precipitation



Spatially-averaged hourly precipitation rate as function of lead time from initialisation time 06 UTC. The spatial average is over (a) southern and (b) northern Germany. The temporal average is over all forecasts under weak forcing conditions.

- Good diurnal cycle representation of precipitation for southern Germany
- Failure to simulate the diurnal cycle of convective precipitation over flat terrain in northern part
- Enhanced predictability associated with orographic forcing in mountainous southern part

3. Impact on precipitation variance

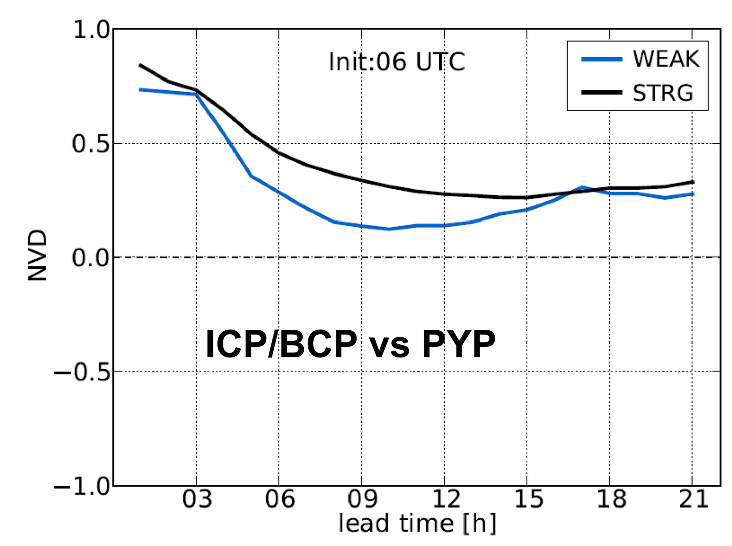


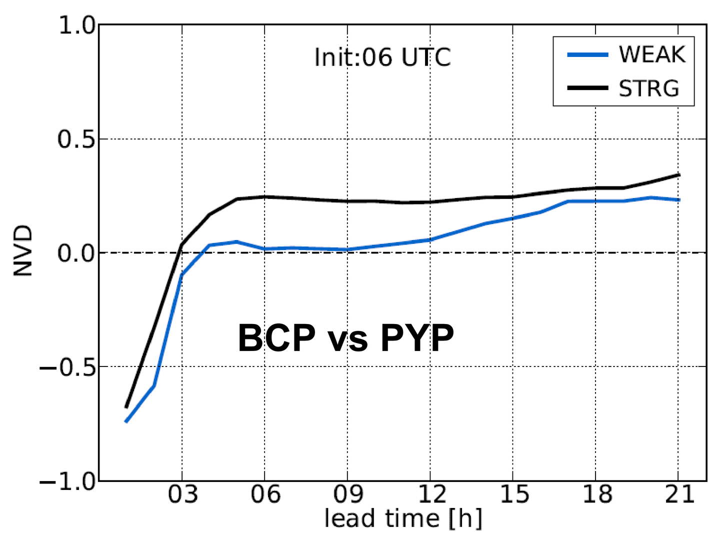
Normalized Variance Difference of hourly precipitation

$$\mathrm{NVD}(\tau) = \frac{\sigma^2_{\mathrm{IBP}}(P) - \sigma^2_{\mathrm{BP}}(P)}{\sigma^2_{\mathrm{IBP}}(P) + \sigma^2_{\mathrm{BP}}(P)}$$

A positive NVD indicates a positive impact on ensemble variance, and vice versa.

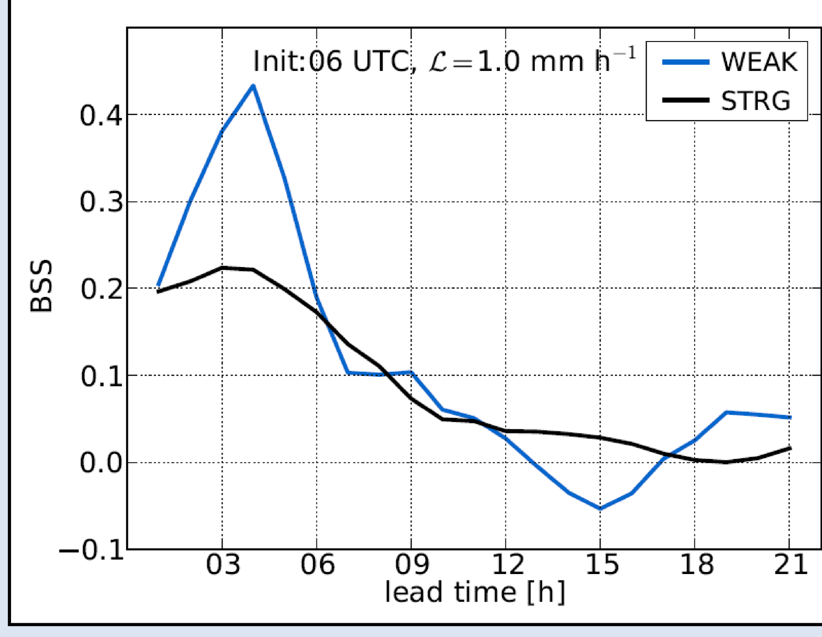
- Positive impact of ICPs, largest in the first hours
- Similar impact during both regimes, with slightly faster decay in weakly forced conditions





- ICPs dominate over the physics perturbations (PYP) for lead times < 3 h
- PYP dominate over boundary condition perturbations (BCP) for lead times < 3 h
- Both EPS show larger impact of PYP in weak forcing during convectively active part of the day

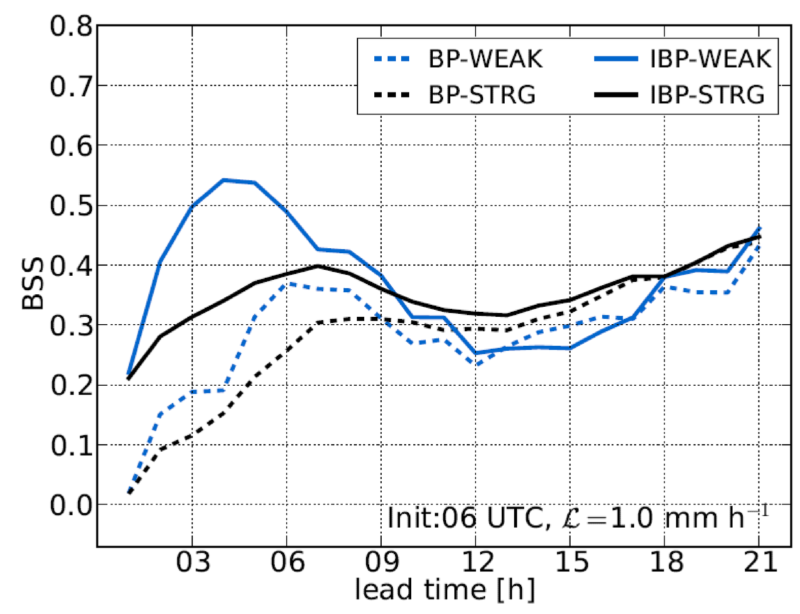
4. Probabilistic Scores



$$\mathrm{BSS} = 1 - \frac{\mathrm{BS}_I}{\mathrm{BS}_J} \qquad \mathrm{BS}(\tau) = \frac{1}{M}\sum_{i=1}^{M}\left[p(\mathcal{L}) - \hat{p}(\mathcal{L})\right]^2$$

- Brier Skill Score of IBP vs BP EPS shows positive ICP impact on the Brier Score, that is largest in the first 9 forecast hours
- Positive impact on the BSS is twice as large initially during weak forcing conditions in the 06 UTC forecasts
- Smaller regime dependence for other initialisation times

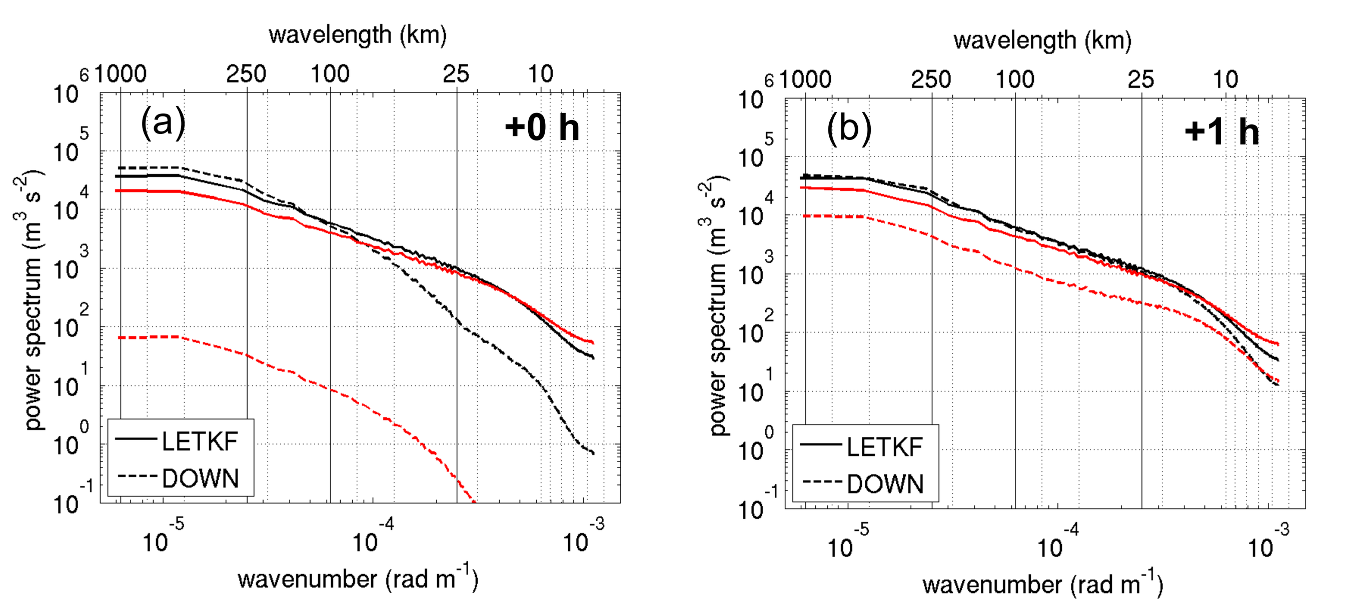
5. Ensemble vs deterministic forecast



- Brier Skill Score of IBP vs deterministic COSMO-DE is significantly positive
- BSS of BP vs COSMO-DE is close to zero initially since they share by design the same ICs
- IBP and BP EPSs converge at forecast times larger than 9 hours
- **Overall better performance of EPS precipitation forecasts compared to the deterministic forecast at same resolution during all weather conditions**

6. Summary and Outlook

- COSMO-DE-EPS forecasts (**IBP** / **BP**) outperforms deterministic COSMO-DE forecasts of precipitation in probabilistic terms
- COSMO-DE-EPS shows a regime dependent behaviour of forecast skill
- ICPs show a significant impact on the ensemble variance and forecast scores especially up to 9 hours
  → For more information see also **Kuehnlein et al. 2013** (*accepted in QJRMS*)
- Current downscaled ICPs are not representative of the initial condition probability distribution around the convective-scale LAM analysis of COSMO-DE (e.g. they have a much larger variance at large scales (~100km) than small scales (~10km) and are strongly damped in the boundary layer)
- Next steps: evaluate ICPs provided by the Local Ensemble Transform Kalman Filter (LETKF) used for the convective-scale data assimilation within COSMO-DE



(a) Power spectra of ICPs from the LETKF and IBP using horizontal wind. Spectra are averaged over 8 times from 12 UTC 10 June - 12 UTC 11 June 2012 (b) shows the same as (a), but for 1-h ensemble forecast perturbations. Red lines denote results on COSMO model level 30 (~3.1 km) and black lines on model level 40 (~0.82 km).