Weather regime dependent impact of Initial Condition perturbations in COSMO-DE-EPS

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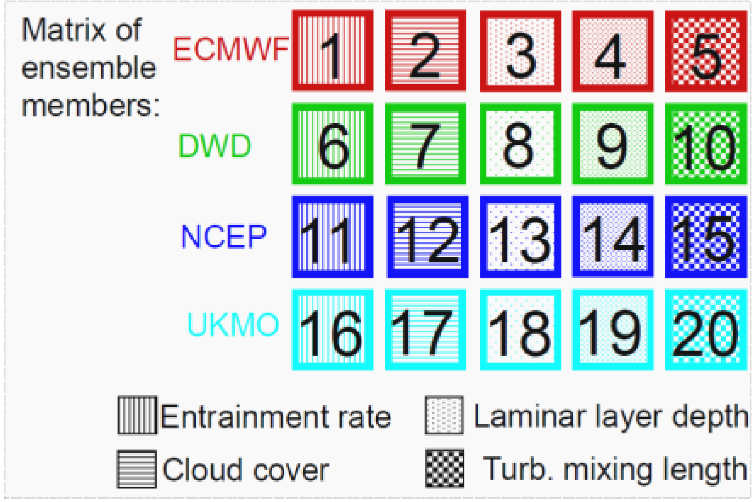
Weather regime dependent impact of **I**nitial **C**ondition **p**erturbations in **COSMO-DE-EPS**

- Keywords
- Experimental design
- Time series of area averaged precipitation
- Deterministic and probabilistic scores
- Precipitation variance
- Summary and outlook

A short history of COSMO-DE-EPS

- COSMO-DE-EPS is a 20 member convection-permitting ensemble system taking into account three sources of uncertainty
- 2007: first experimental version with boundary condition perturbations (BCPs) and physics perturbations (PYPs) *(Gebhardt et al. 2011, Keil and Craig 2011)*



- Dec 2010: pre-operational version including initial condition perturbations (ICPs), too *(Peralta et al. 2012)*
- May 2012: COSMO-DE-EPS becomes operational at DWD

Weather regime dependence

- Many properties of convective precipitation depend on the **large-scale environment**.

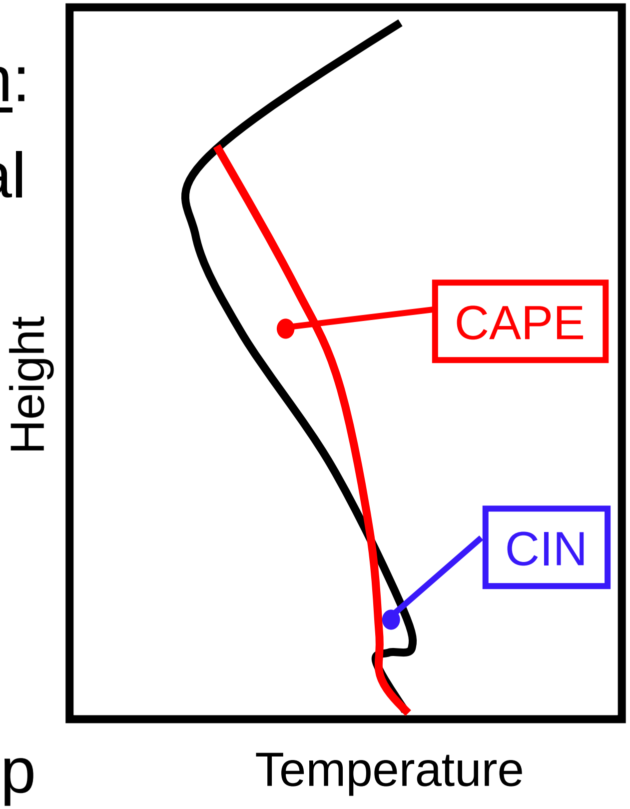
Two mechanisms for control of convection:

1. **Strong forcing** (equilibrium): dynamical production of CAPE

   i.e. convection removes CAPE rapidly in comparison to the rate it is being generated

2. **Weak forcing** (triggered): local perturbations to overcome CIN

   i.e. large amounts of CAPE can build up if triggers not present



(Done et al. 2006)

The convective adjustment time scale τ_c

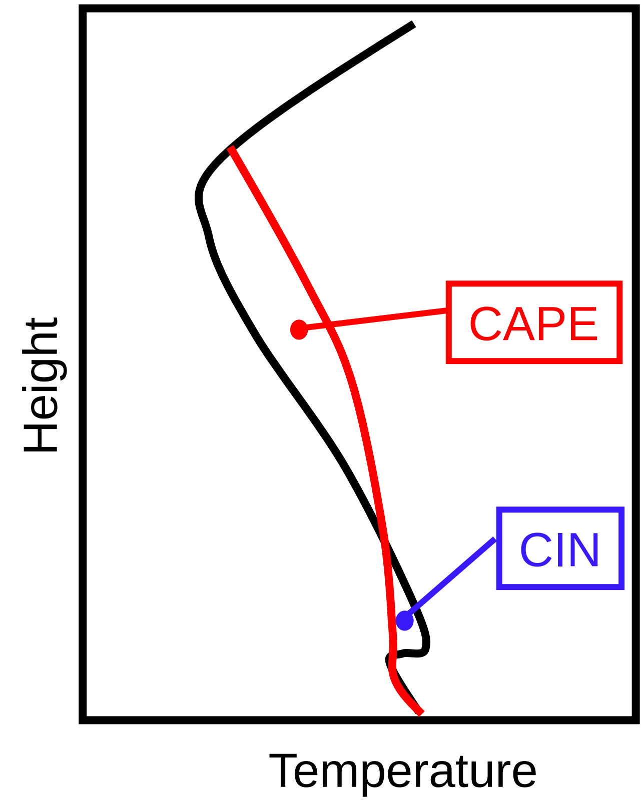
To identify regime, consider time scale over which convection removes CAPE:

$$\tau_c = \frac{CAPE}{\frac{dCAPE}{dt}}$$

$$\frac{dCAPE}{dt} = \frac{1}{3600} \cdot \frac{L_v}{c_p} \frac{g}{\rho_0 T_0} P$$

$$\tau_c \sim \frac{CAPE}{P}$$

(Done et al. 2006)



Classification:

$\langle \tau_c \rangle$ < 6 hours : strongly forced

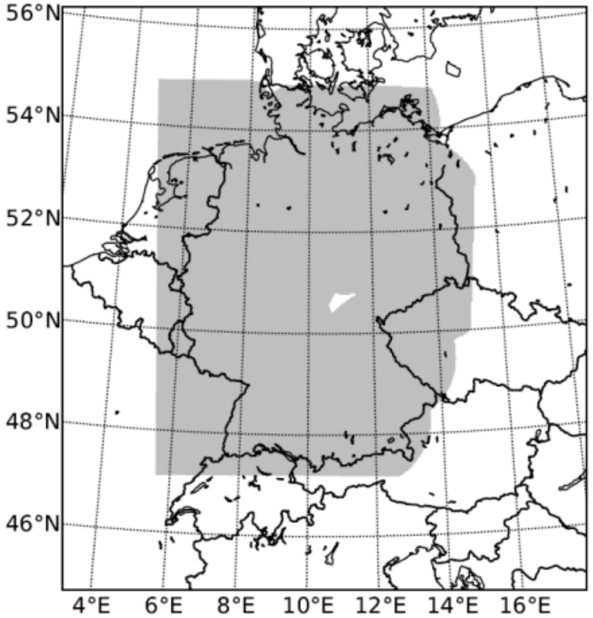
$\langle \tau_c \rangle$ > 6 hours : weakly forced situation

Goals

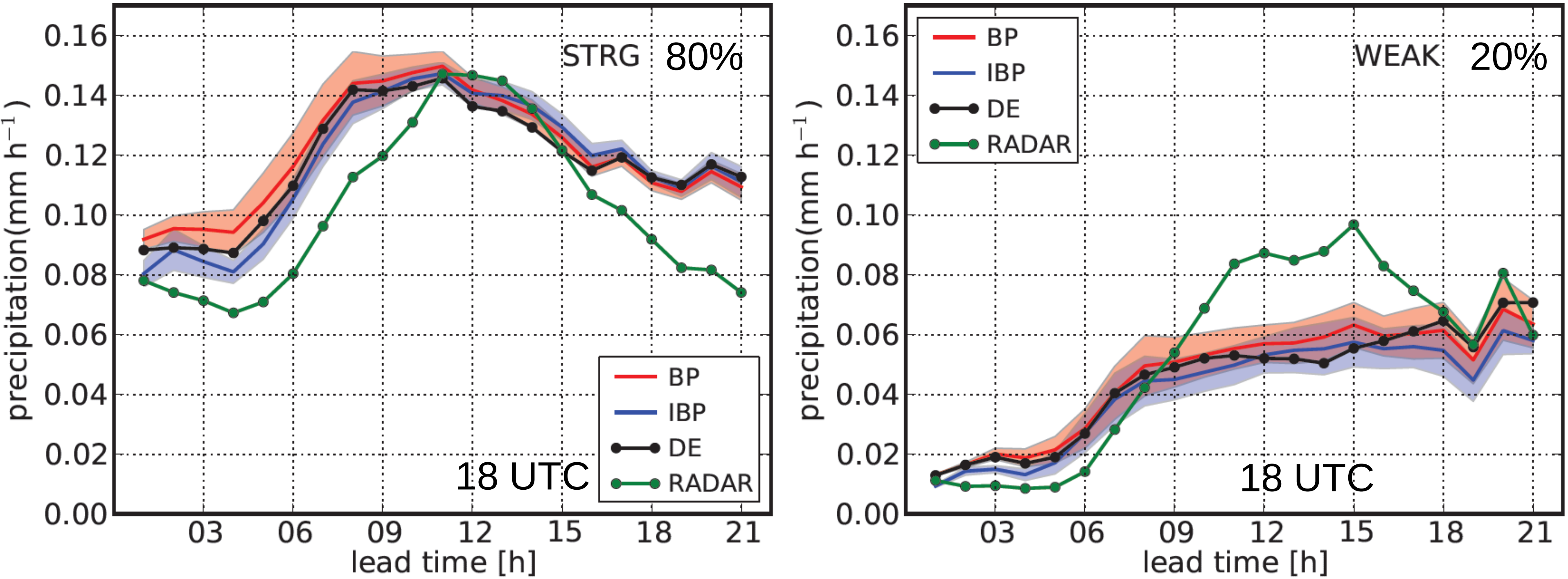
- Demonstrate weather regime dependent performance of summertime precipitation forecasts of COSMO-DE-EPS employing τ_c !
- How effective are ICPs based on downscaling approach at convection-permitting grid spacings? How long is their impact?
- Is there a benefit compared to the deterministic forecast?

Experimental design

- **IBP** ensemble: pre-operational COSMO-DE-EPS forecasts from 1 May till 15 August 2011
- **BP** ensemble: COSMO-DE-EPS experiment without ICPs
- **DE**: operational deterministic COSMO-DE
- Focus: **Precipitation**
- Forecasts started at **6 UTC** to capture diurnal cycle
- **Observations**: quality-controlled, brightband-corrected radar data from DWD‘s network of 16 Doppler radars

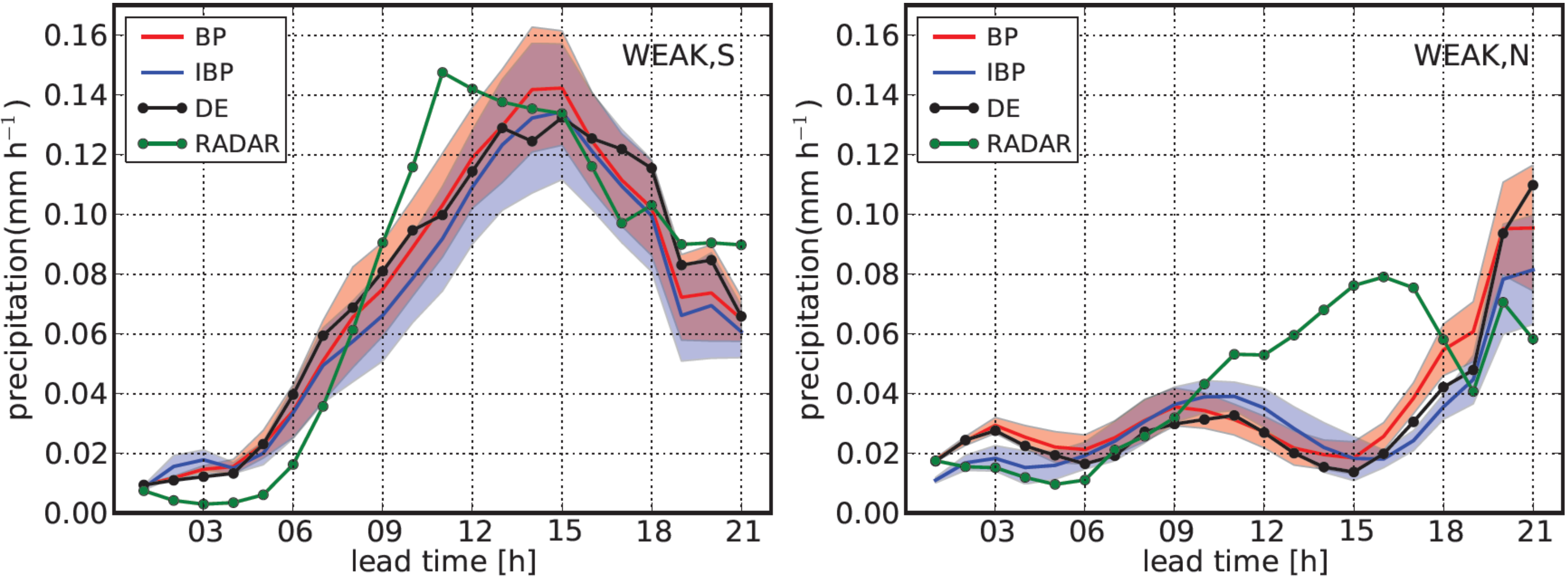


1. Diurnal cycle of precipitation



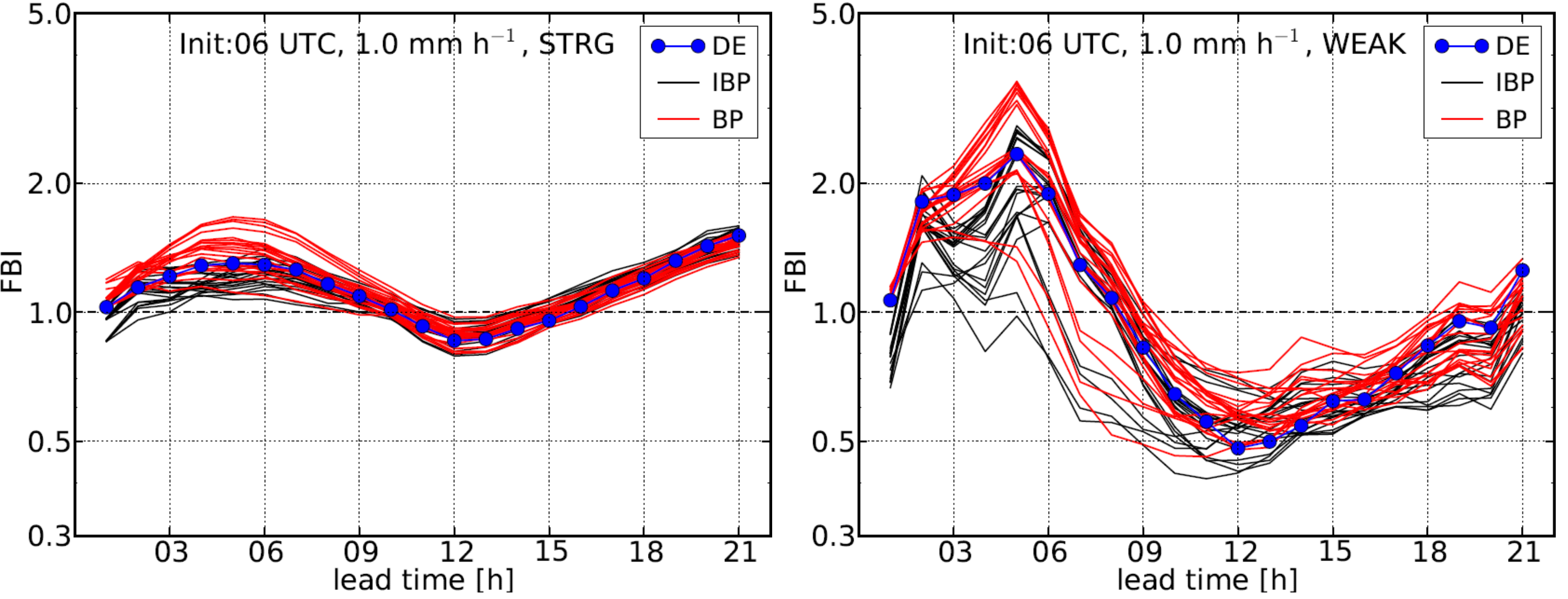
- ➢ Over- (Under)-estimation during strong (weak) forcing conditions
- ➢ WEAK: Poor representation of precipitation maximum

2. Orographic Control of precipitation



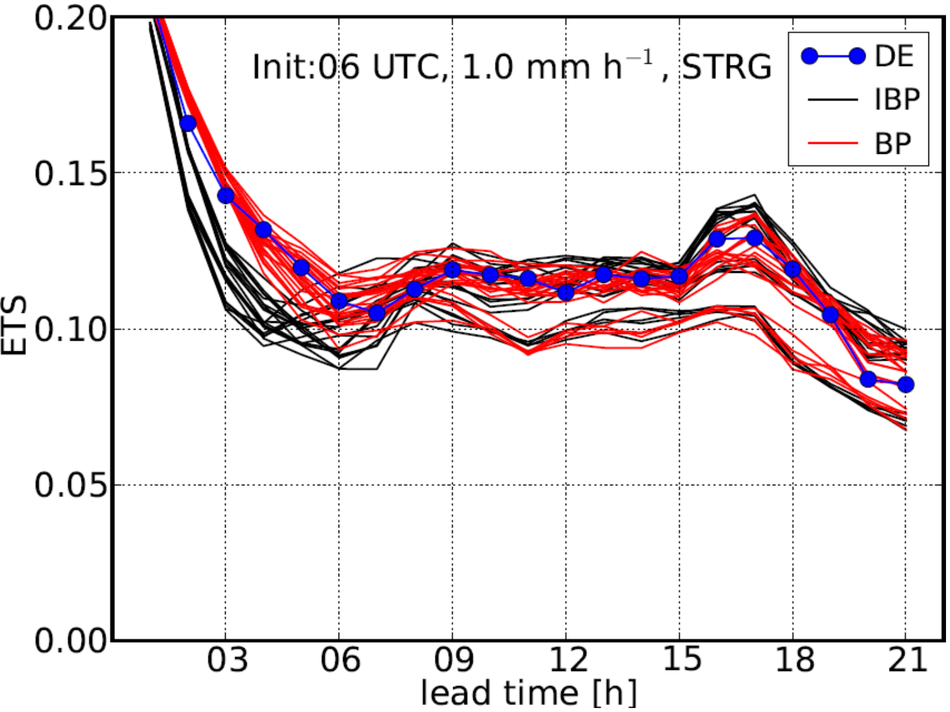
- Enhanced forecast quality associated with orographic forcing in mountainous southern part
- Systematic model error in flat northern part

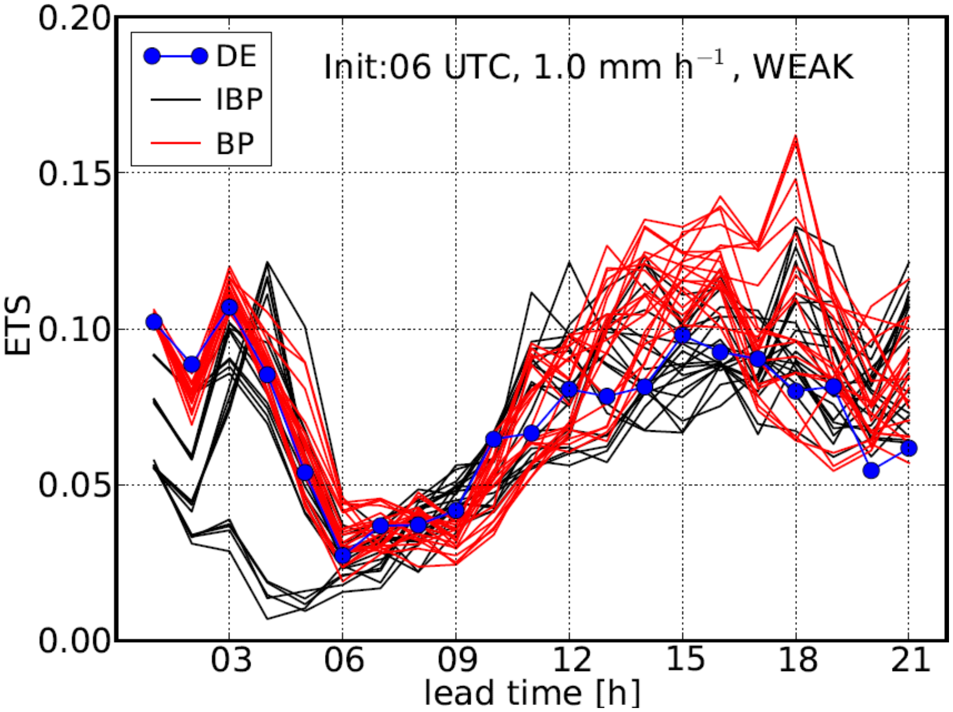
3.1 Deterministic Score FBI



- WEAK: larger error amplitudes and spread
- IBP – BP differences largest within the first 9 hours

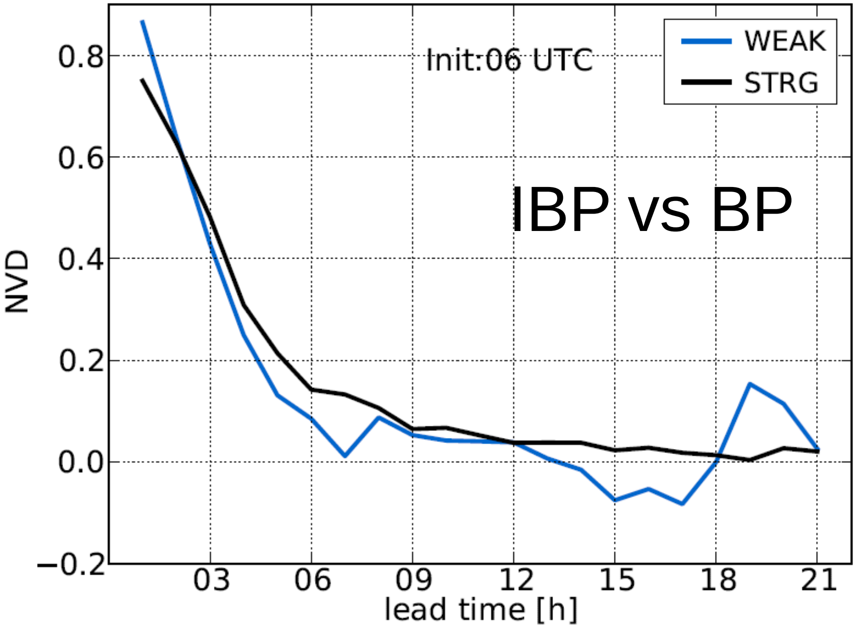
3.2 Deterministic Score ETS





- WEAK: low skill, that is convection is at wrong locations
- WEAK: quick and strong response to ICP

4.1 Impact on precipitation variance



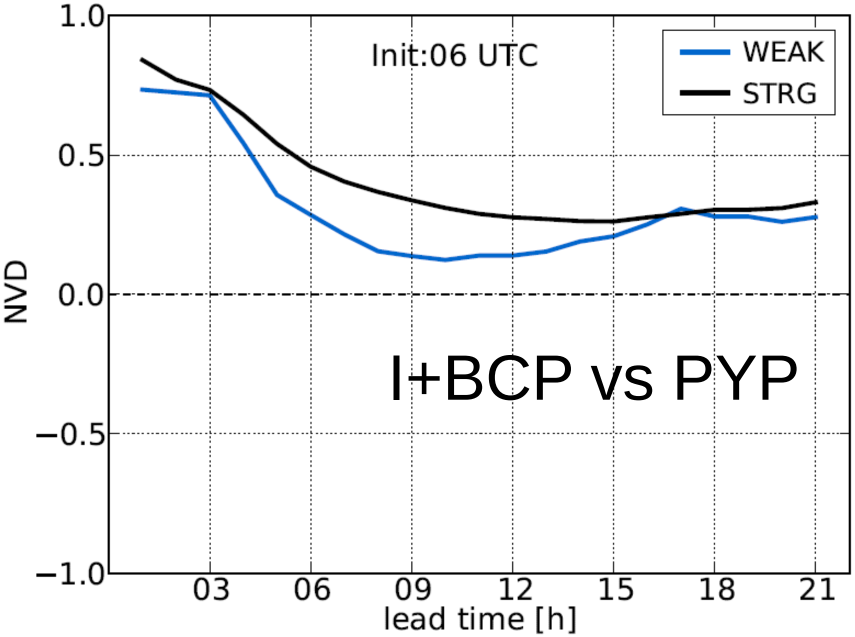
Normalized Variance Difference of hourly precipitation:

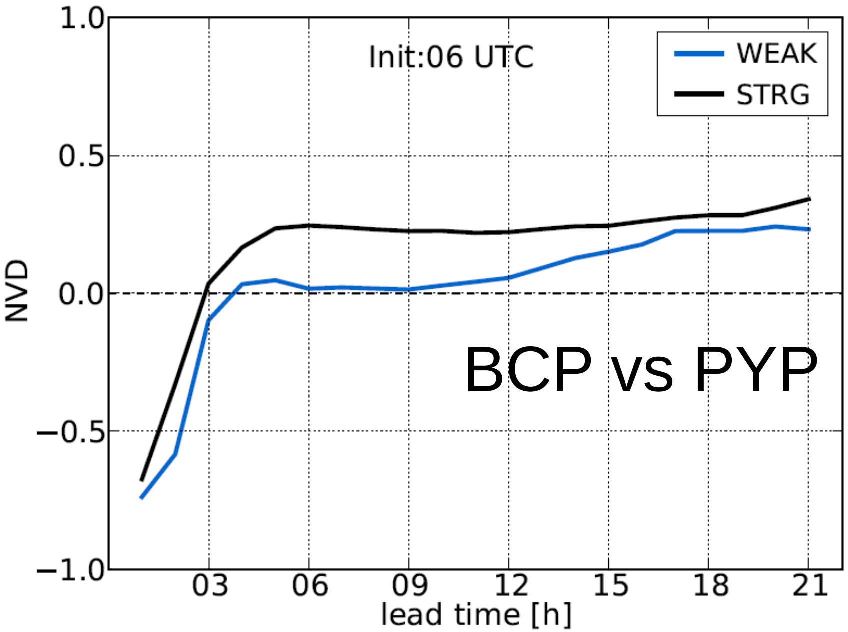
$$\mathrm{NVD}(\tau) = \frac{\sigma^2_{\mathrm{IBP}}(P) - \sigma^2_{\mathrm{BP}}(P)}{\sigma^2_{\mathrm{IBP}}(P) + \sigma^2_{\mathrm{BP}}(P)}$$

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, but somewhat faster decay in weakly forced conditions

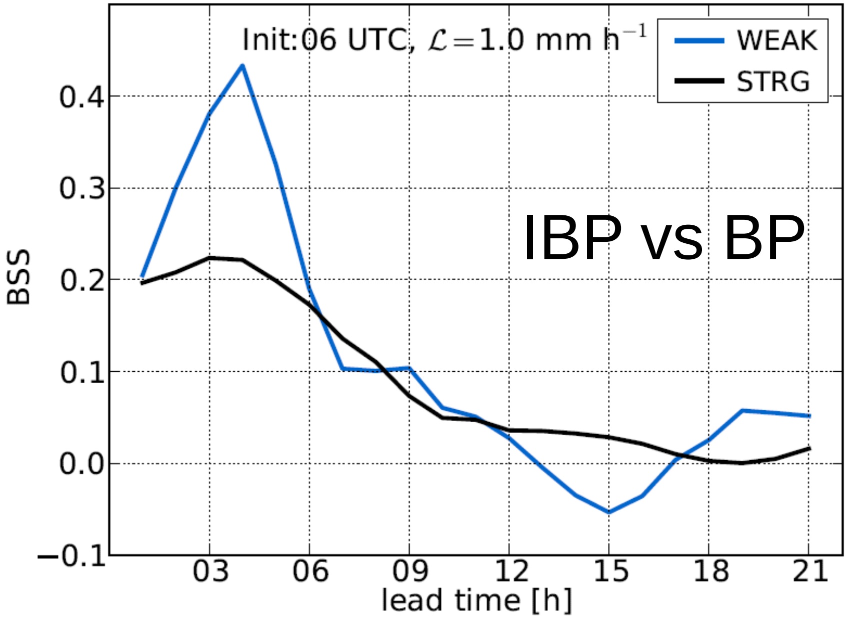
4.2 Impact on precipitation variance





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

5. Probabilistic Score: Brier Skill Score

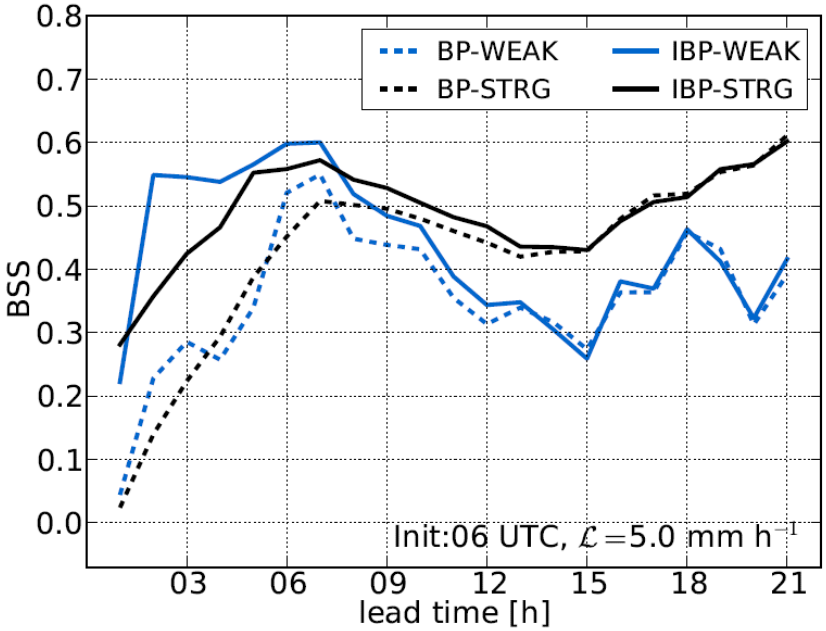


$$\mathrm{BSS} = 1 - \frac{\mathrm{BS}_I}{\mathrm{BS}_J}$$

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

- Positive ICP impact 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 6 UTC forecast

6. Ensemble vs deterministic forecast



- BSS of BP vs det COSMO is close to zero initially since they share by design the same ICs
- BSS of IBP vs det COSMO is significantly positive
- IBP and BP EPSs converge at forecast times larger than 9 h

- Overall better performance of EPS precipitation forecasts compared to the deterministic forecast at same resolution during all weather conditions.

Summary

- Demonstrate weather regime dependent performance of summertime precipitation forecasts of COSMO-DE-EPS.
  - distinct responses are found in all measures
  - enhanced forecast skill in mountainous region

- How effective are ICPs based on downscaling approach? How long is their impact?
  - Pragmatic though effective way to increase variance
  - ICPs impact fades out after 9 h, and is similar in both regimes

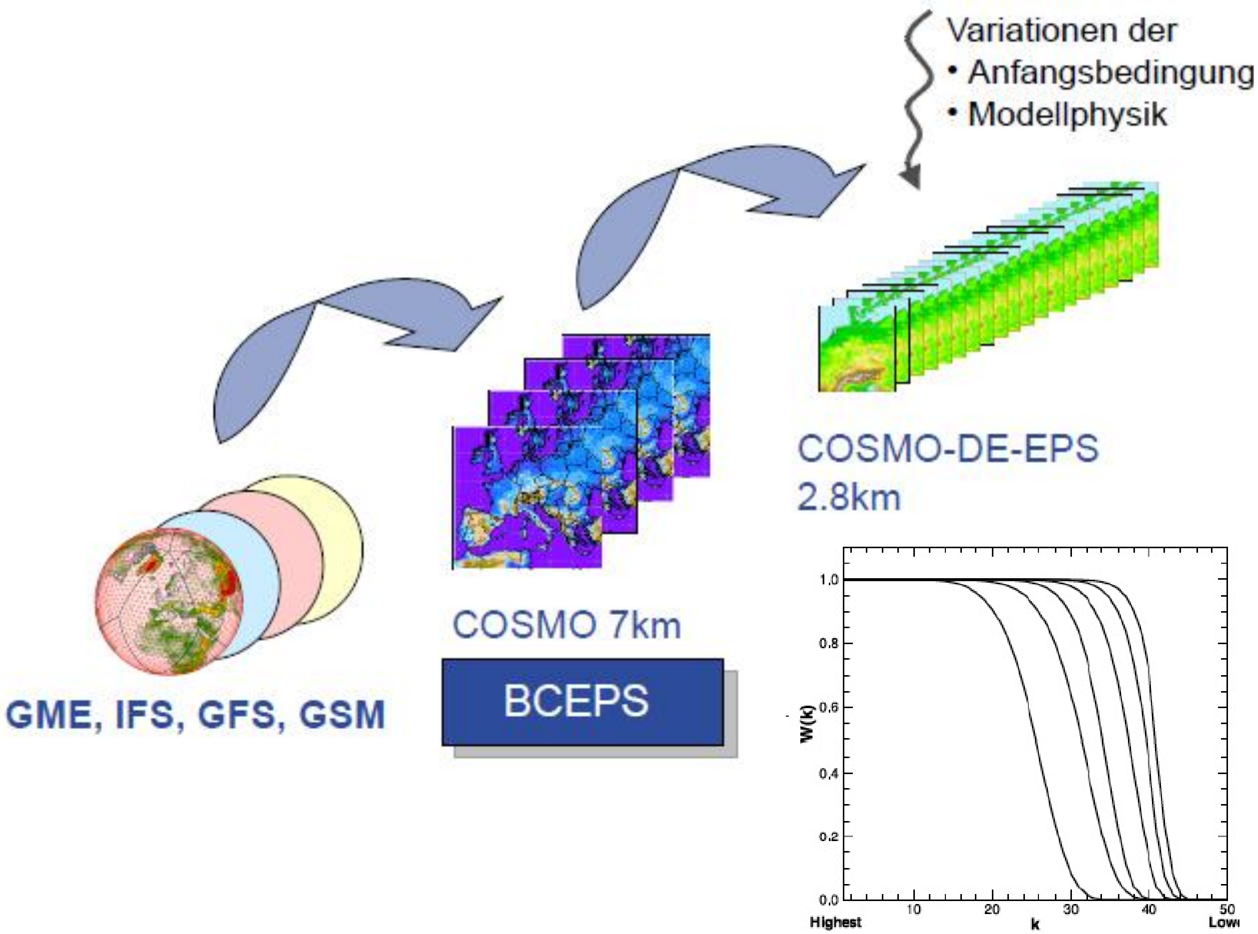
- Is there a benefit compared to the deterministic forecast?
  - yes, better performance of EPS precipitation forecasts

Outlook

- Is COSMO-KENDA a good system to provide initial conditions?
- Introduce model error in COSMO-KENDA-EPS through a stochastic boundary layer parametrization

Kühnlein et al. 2013: The impact of downscaled initial condition perturbations on convective-scale ensemble forecasts of precipitation. Revised version submitted to Q.J.R.

COSMO-DE-EPS: set-up



ICPs (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

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

Outlook towards the stochastic BL scheme

- Perturbations based on subgrid variability (from buoyancy flux, orography etc.)
- Basic concept (following Teixeira and Reynolds 2008):
  perturbation of tendencies of resolved variables (T, q, w) based on information from physical scheme

$$tens_{\Phi,p} = tens_{\Phi} + fac \cdot \eta \cdot bl_{\Phi}$$

$tens$: tendency of Φ of all physical parameterizations
Φ : resolved variable (T, q, w)
p : perturbed
fac : factor to scale amplitude of additive noise
η : Gaussian random perturbation
bl_{Φ} : variance of Φ: $\langle \Phi^2 \rangle$ (turbulence scheme)

(courtesy of Kirstin Kober)

Absence of Orographic Control of precipitation