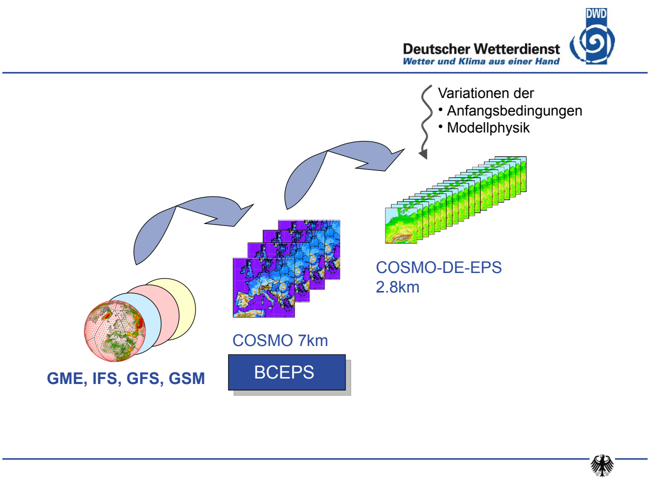
# COSMO-DE-EPS

- Convection-permitting COSMO-DE limited-area forecast model ($\Delta_h \approx 2.8$ km) operational since April 2007
  $\rightarrow$ convection-scale dynamics are partially resolved, sub-grid scale (shallow) convection effects on resolved scales parameterised
  $\Rightarrow$ Improve forecast of convective precipitation and extreme events in general

- COSMO-DE-EPS with 20 ensemble members pre-operational since December 2010. Perturbations of initial conditions (ICs) and lateral boundary conditions (BCs), plus physical parameterisations (PHs).

  $\Rightarrow (\mathrm{IC} + \mathrm{BC}) \times \mathrm{PH} = 4 \times 5 = 20$

# COSMO-DE-EPS




| | entr_sc | q_crit | rlam_heat | rlam_heat | tur_len + lhn_coef |
|---|---|---|---|---|---|
| GFS (NCEP) | m1 | m2 | m3 | m4 | m5 |
| GME (DWD) | m6 | m7 | m8 | m9 | m10 |
| IFS (ECMWF) | m11 | m12 | m13 | m14 | m15 |
| GSM (JMA) | m16 | m17 | m18 | m19 | m20 |

# Previous results

Previous investigation based on experimental COSMO-DE-EPS forecasts:

- Gebhardt et al., Atmos. Res. 2011 investigated 12-members ensemble by BC, PH, and combined BC+PH perturbations over period of 15 days in August 2007.

  $\longrightarrow$ Probabilistic precipitation forecasts superior to deterministic forecasts
  $\longrightarrow$ Impact of perturbations on ensemble dispersion is dominated by PH in the first hours, and by BC afterwards
  $\longrightarrow$ Combined BC+PH perturbations give best forecast quality in general

  $\Rightarrow$ What is the influence of the additional IC perturbations in the current pre-operational COSMO-DE-EPS forecasts ?

# Investigation of COSMO-DE-EPS

- Investigate BC+PH (BP) versus IC+BC+PH (IBP) perturbations in 20-member COSMO-DE ensemble

  → IBP: pre-operational COSMO-DE-EPS

  → BP: "Experiment 8247" is currently run at DWD under supervision of C. Gebhardt

- 3-month period from May to July 2011
- Forecasts for 21 h lead time started 8 times per day (00,03,06,09,12,15,18,21 UTC)
- Verification of total precipitation based on DWD's high-resolution radar network

- Python codes for ensemble verification

  → Deterministic quality measures: frequency bias index, equitable threat score, false alarm ratio, ....

  → Probabilistic quality measure: Brier score

  → Measures for ensemble dispersion: correspondence ratio, normalised variance difference

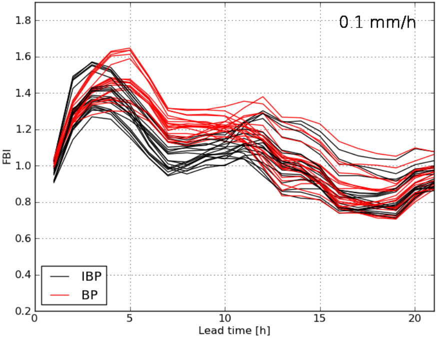
- Check quality of all individual ensemble members
- Consider discrete variable (yes/no) for exceeding a threshold (e.g. precipitation, wind speed)
- Frequency Bias Index (FBI)

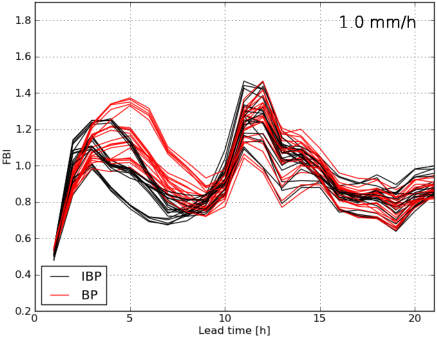
$$\text{FBI} = \frac{\textit{hits} + \textit{false alarms}}{\textit{hits} + \textit{misses}}$$

$\rightarrow$ How does the forecast frequency of "yes" events compare to the observed frequency of "yes" events?

# Frequency bias index

Forecast initialisation 00 UTC for May 2011:



- Quality of probabilistic forecast using the Brier Score

$$\mathrm{BS} = \frac{1}{N}\sum_{i=1}^{N}(p_i - o_i)^2 \quad \in [0,1]$$

$\longrightarrow$ What is the magnitude of the probability forecast errors?

$\longrightarrow$ Perfect score 0

$\Rightarrow$ Compare different EPS configurations by means of the Brier Skill Score

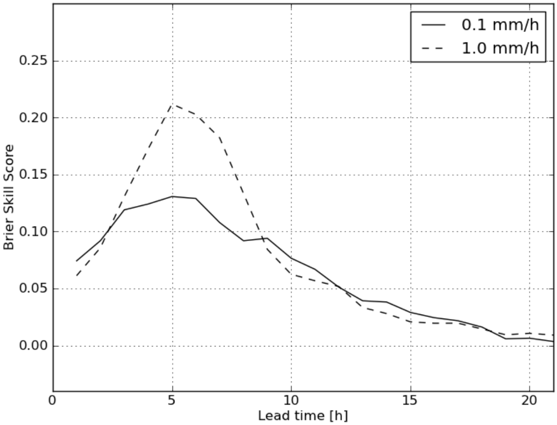
$$\mathrm{BSS} = 1 - \frac{\mathrm{BS}}{\mathrm{BS}_{ref}} \quad \in [-\infty, 1]$$

$\longrightarrow$ What is the relative skill of one EPS configuration (IBP) over another (reference) EPS configuration (BP), in terms of predicting whether or not a threshold is exceeded ?

$\longrightarrow$ Perfect score 1

# Brier Skill Score

Forecast initialisation 00 UTC for May 2011:




$$BSS = 1 - \frac{BS_{IBP}}{BS_{BP}}$$

- Correspondence Ratio (Stensrud and Wandishin 2000; Gebhardt et al. 2011)

$$\mathrm{CR} = \frac{N(GP_{all})}{N(GP_{\geq 1})}$$

$\longrightarrow$ Measure of the ensemble spread

$\longrightarrow$ Lower CR values indicate a larger spread

$\Rightarrow$ Compare different EPS configurations by means of Correspondence Ratio Gain

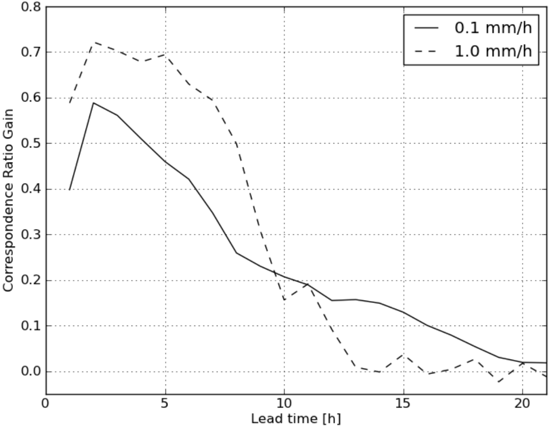
$$\mathrm{CRG} = 1 - \frac{\mathrm{CR}}{\mathrm{CR}_{ref}} \quad \in [-\infty, 1]$$

$\longrightarrow$ Measure of the spatial gain in spread of one EPS configuration (IBP) over another (reference) EPS configuration (BP)

$\longrightarrow$ Perfect score 1

# Correspondence Ratio Gain

Forecast initialisation 00 UTC for May 2011:




$$\mathrm{CRG} = 1 - \frac{\mathrm{CR_{IBP}}}{\mathrm{CR_{BP}}}$$

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

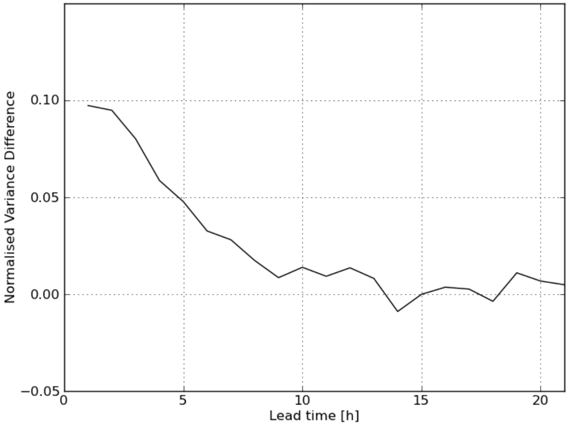
$$\text{NVD} = \frac{\text{var(IBP)} - \text{var(BP)}}{\text{var(IBP)} + \text{var(BP)}}$$

$\longrightarrow$ Measure of the ensemble spread, which is not threshold-dependent

$\longrightarrow$ A value of NVD $= 0$ indicates IBP and BP have same impact on spread, a value of NVD $> 0$ means that IBP has larger impact and vice versa.

# Normalised variance difference

Forecast initialisation 00 UTC for May 2011:




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

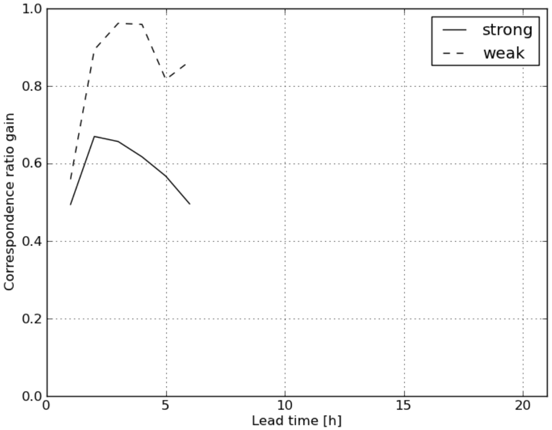
# Upcoming work

- Include more forecast initialisation times (possibly 00,03,06,09,12,15,18,21 UTC)
- Consider entire period (May-July) when data is complete
- Additional verification measures
- Investigate possible regime dependence using the concept of the convective time scale $\tau_c$

  $\longrightarrow$ Different impact of the IC perturbations under weak and strong large-scale forcing ?

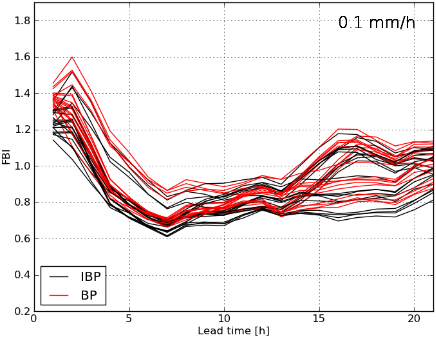
# Regime-dependent correspondence ratio gain

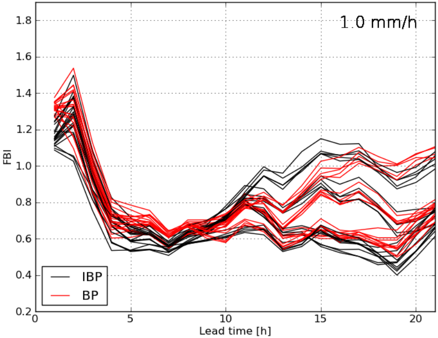
Forecast initialisations 00, 06, 12,18 UTC for May 2011; precipitation threshold 1 mm/h:




$$\mathrm{CRG}^X = 1 - \frac{\mathrm{CR}^X_{\mathrm{IBP}}}{\mathrm{CR}^X_{\mathrm{BP}}} \qquad X \in (\text{strong}, \text{weak})$$

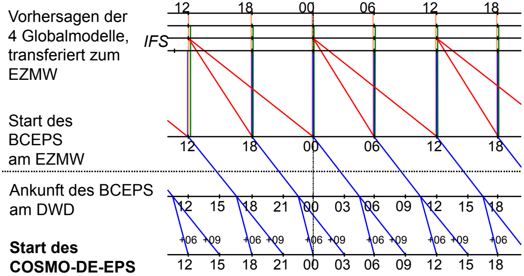
Forecast initialisation 12 UTC:



# COSMO-DE-EPS

Deutscher Wetterdienst
*Wetter und Klima aus einer Hand*



| parameter | perturbed value | default value |
|---|---|---|
| entr_sc | 0.002 $m^{-1}$ | 0.0003 $m^{-1}$ |
| q_crit | 1.6 | 4.0 |
| rlam_heat | 0.1 | 1.0 |
| rlam_heat | 10.0 | 1.0 |
| tur_len | 150 m | 500 m |

entr_sc: Mean entrainment rate for shallow convection
q_crit: Critical value for normalized oversaturation
rlam_heat: Scaling factor for the thickness of the laminar boundary layer for heat
rlam_heat: Scaling factor for the thickness of the laminar boundary layer for heat
tur_len: Maximal (asymptotic) turbulent mixing length scale