Representation of model uncertainty in the ICON-D2 EPS ensemble using a physically based stochastic perturbation scheme

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INTRODUCTION

- Trial experiment with a physically based stochastic perturbation scheme for June, July and August 2021 in collaboration with DWD.
- Convective regime classification: strong and weak synoptic forcing.
- Analysis of regime dependence of forecast uncertainty for a whole summer.

RESEARCH QUESTIONS

1. How do small-scale perturbations impact precipitation amount and spread in strong/weak synoptic forcing conditions?
2. How well does the PSP2 scheme represent model error in an ensemble?

PHYSICALLY BASED STOCHASTIC PERTURBATION (PSP) SCHEME

- Representing **small-scale variability in the boundary layer** due to unresolved physical processes. A refined PSP version (PSP2) was developed by Hirt et al. (2019, [1]):

$$\partial_t \Phi|_{\text{PSP}} = \alpha_{\text{tuning}}\, \eta_t\, \frac{1}{\tau_{\text{eddy}}} \frac{l_{\text{eddy}}}{\Delta x_{\text{eff}}} \sqrt{\overline{\Phi'^2}} \qquad (1)$$

- For our experiment we used $\alpha_{\text{tuning}} = 5$ in combination with operational parameter perturbations.
- Helps triggering **weakly forced convection** and producing more widespread, but still realistic convective precipitation (Fig. 1).
- Increases the ensemble **spread** of precipitation and other variables (Fig. 4).

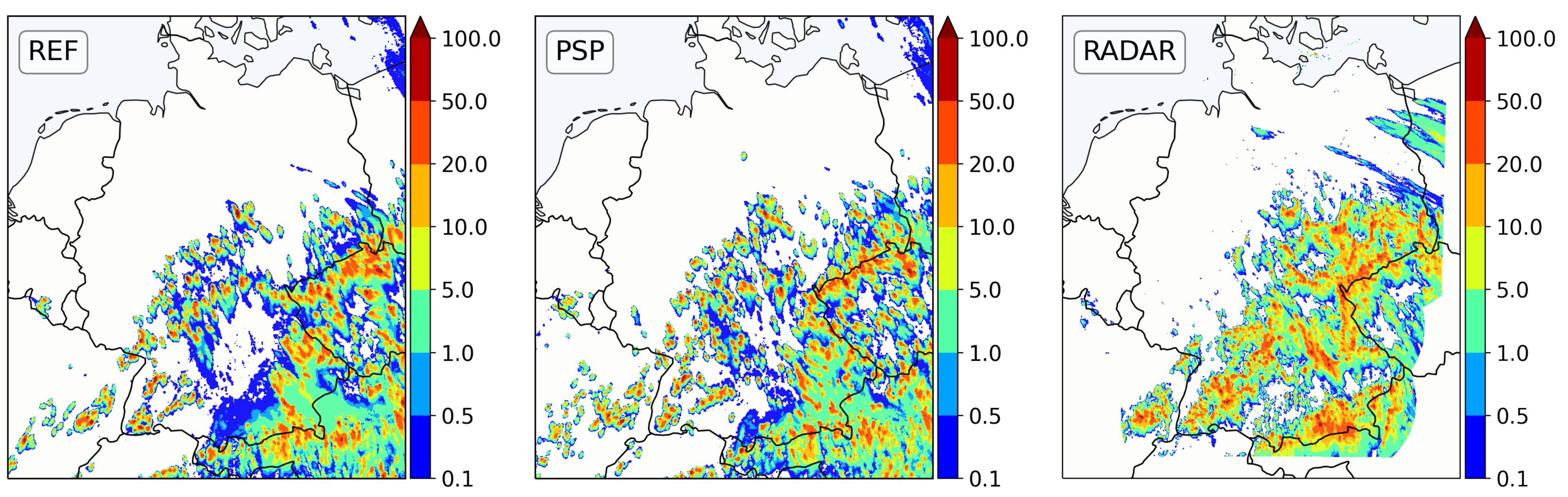

Fig. 1: Total daily precipitation for member 19 of the ensemble, for the 10 June 2021; reference experiment (left), PSP experiment (center); and estimate of accumulated precipitation from radar observations (right).

TRIAL EXPERIMENT AT DWD

- A 20-member ICON-D2 ensemble with the PSP2 scheme on HPC at DWD.
- Synoptic forcing classification using the **convective adjustment timescale** τ_c, an indicator of predictability of convective precipitation (Keil et al., 2014, [2]):
  - Upper 20% (13 days) of daily averaged τ_c: **weak forcing**.
  - Lower 20% (13 days) of daily averaged τ_c: **strong forcing**.

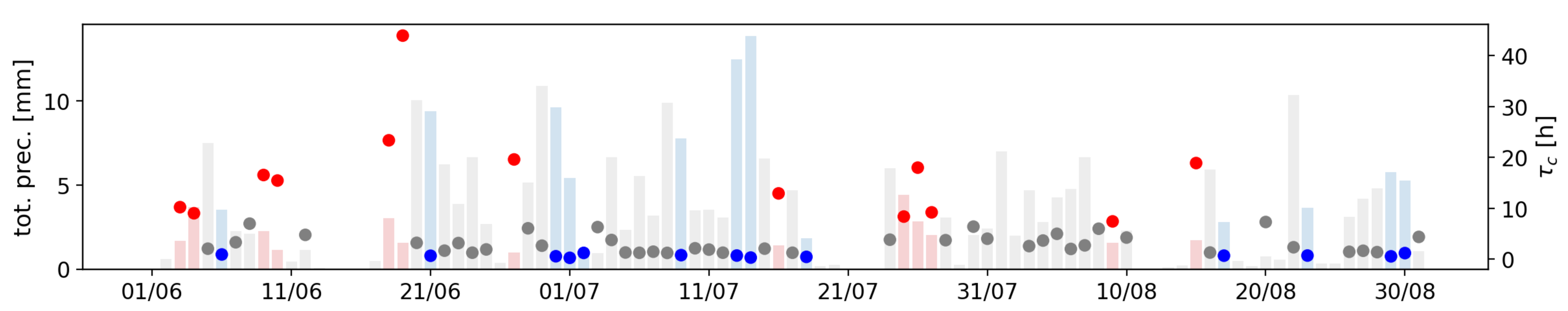

Fig. 2: Overview of reference total daily precipitation (bars) and daily averaged convective adjustment timescale (dots). Red indicates weak forcing, blue strong forcing and grey unclassified days.

PUBLICATIONS AND FUTURE WORK

- *M. Puh, C. Keil, C. Gebhardt, C. Marsigli, M. Hirt, F. Jakub and G. C. Craig. Representation of model uncertainty in the ICON-D2-EPS ensemble using a physically based stochastic perturbation scheme. In preparation.*

- Run a big ensemble (120 members) for other cases of this period (e.g. MOSES field campaign) using operational initial and boundary conditions, with PSP2 and parameter perturbations as sources of model error, to study forecast uncertainty.
- Carry out sensitivity studies and accelerate the process of operational implementation of PSP2 in ICON-D2 at DWD.

REGIME DEPENDENT FORECAST UNCERTAINTY

- Larger and positive impact of the PSP2 scheme on precipitation amount and spread on **weak forcing** days.
- Smaller effect on **strong forcing** days and no clear daily cycle of precipitation.

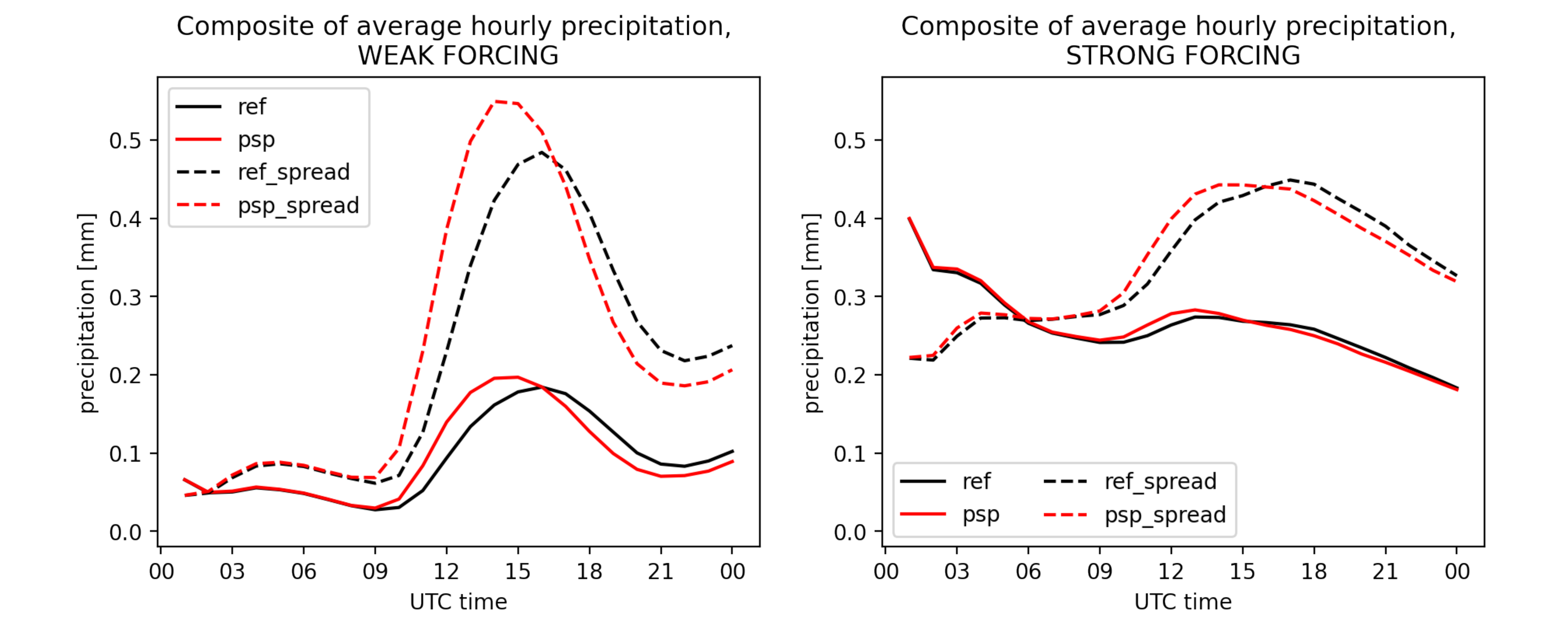

Fig. 3: Composites of 13 days of domain, ensemble and daily averaged hourly precipitation (continuous) and its spread (dashed) for weak forcing (left) and strong forcing days (right), for the reference experiment (black) and the one including the PSP2 scheme (red).

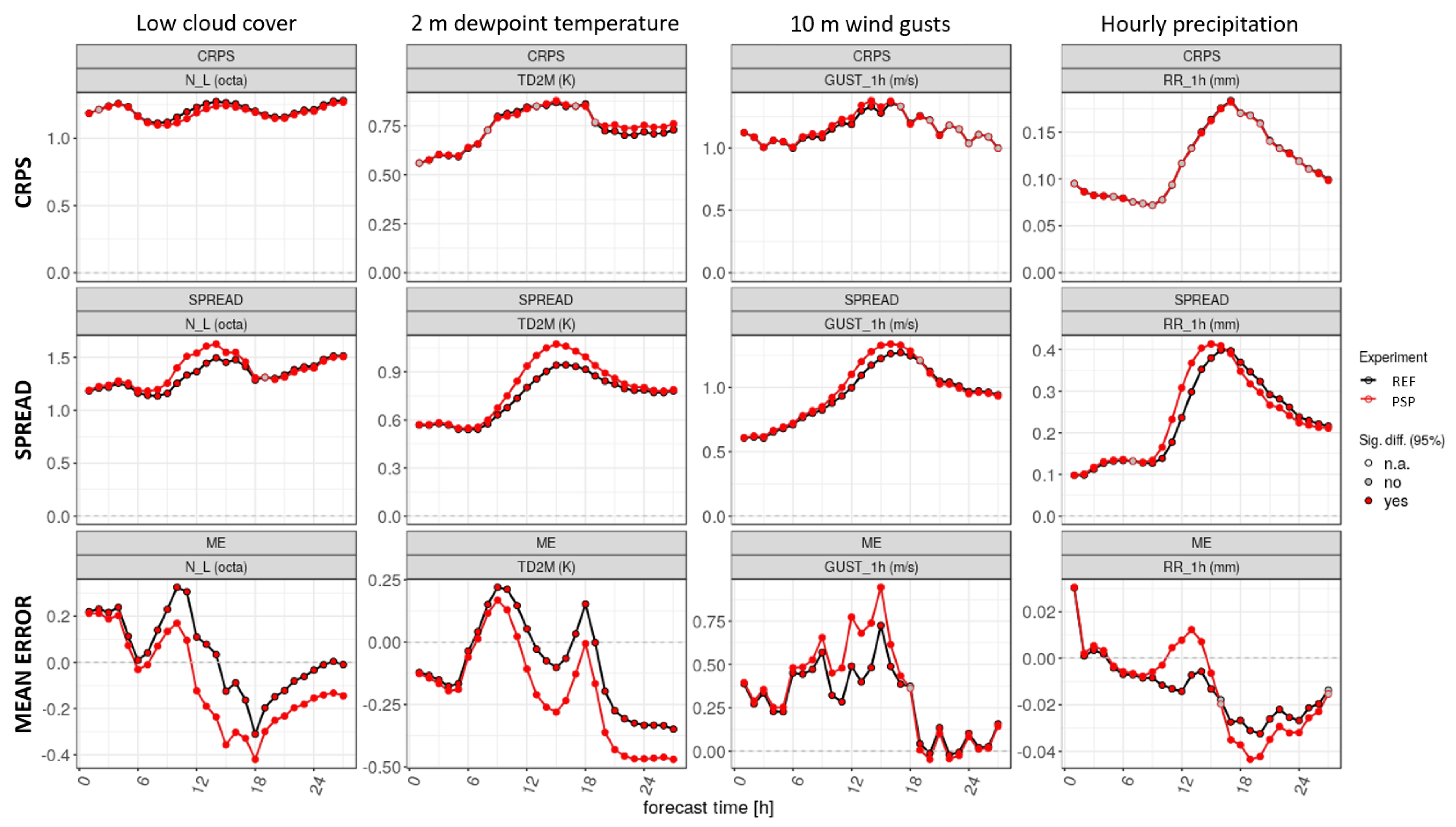

Fig. 4: Domain and daily averaged time series of CRPS, ensemble spread and mean error for selected variables, verified against SYNOP observations, for the period between 26 May and 31 August 2021.

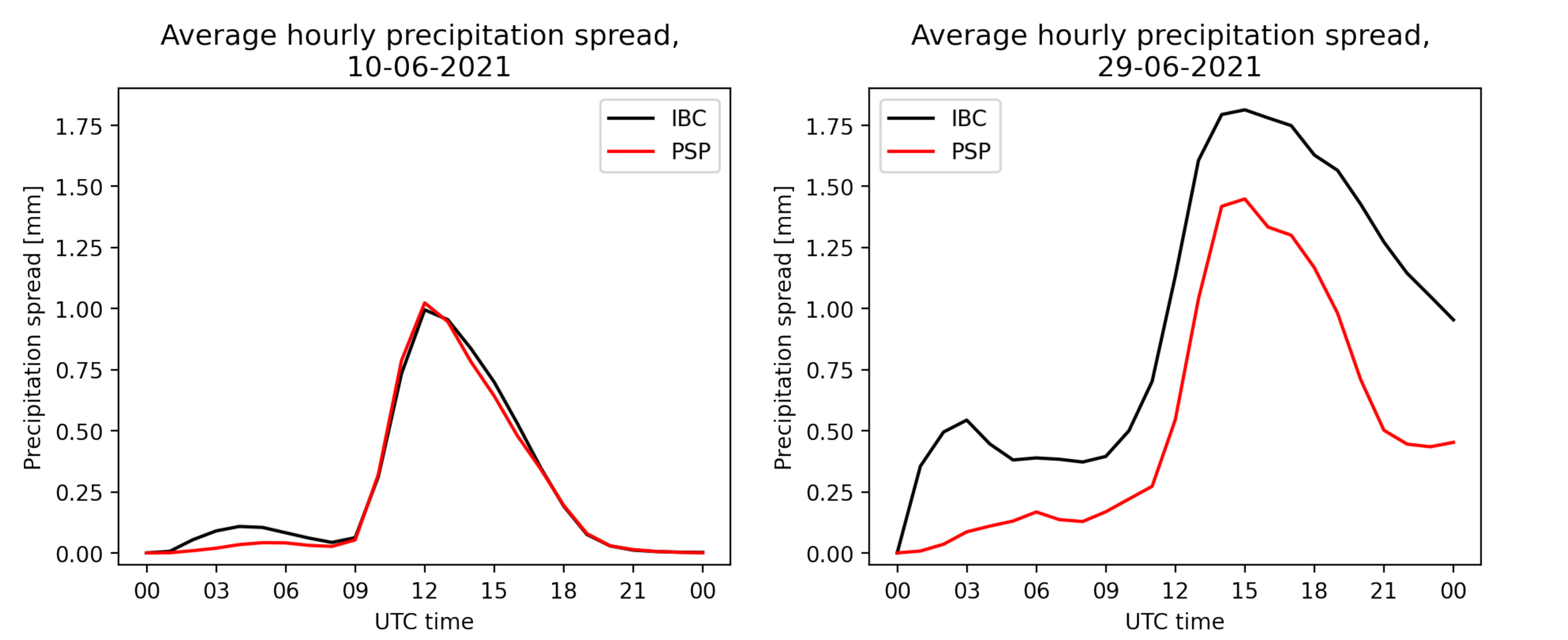

Fig. 5: Hourly precipitation spread, averaged over Germany, for a weakly forced case (left, 10 June 2021) and a strongly forced case (right, 29 June 2021), calculated for two experiments with 40 ensemble members: one with 40 different initial and lateral boundary conditions, but one PSP random seed (IBC, black), and one with 40 different PSP random seeds, but only using initial and lateral boundary conditions for member 1 (PSP, red).

MAIN CONCLUSIONS

1. On **weak** synoptic forcing days, **small-scale perturbations** in the boundary layer are an important source of error.
2. On **strong** forcing days the uncertainty coming from **initial** and **boundary conditions** prevails.

REFERENCES

[1] M. Hirt, S. Rasp, U. Blahak, and G. C. Craig. Stochastic parameterization of processes leading to convective initiation in kilometer-scale models. *Monthly Weather Review*, 147(11):3917 – 3934, 2019. doi: 10.1175/MWR-D-19-0060.1.

[2] C. Keil, F. Heinlein, and G. C. Craig. The convective adjustment time-scale as indicator of predictability of convective precipitation. *Quarterly Journal of the Royal Meteorological Society*, 140(679):480–490, 2014. doi: 10.1002/qj.2143.

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