Stochastic boundary layer perturbations: Systematic impact and perturbation growth

WAVES TO WEATHER
DFG Collaborative Research Center 165

Stephan Rasp, Kirstin Kober, George C. Craig

Meteorologisches Institut,
LMU Munich, Germany

Stochastic Boundary Layer Perturbations Based on Physical Information

Motivation

Missing subgrid-scale variability causes systematic errors in the representation of **convective initiation.**

Goal

To improve the representation of convective initiation by introducing perturbations to the model on the smallest resolved scales based on the following processes:

- **turbulence from surface heating** (*sh*, this poster)
- subgrid-scale orography (Fabian Brundke's poster)
- cold pools (future work)
- mesoscale circulations (future work)

Formulation of the surface-heating perturbations

$$\left(\frac{\partial \phi}{\partial t}\right)_{\mathrm{sh}}^{\mathrm{total}} = \left(\frac{\partial \phi}{\partial t}\right)^{\mathrm{param}} + \underbrace{\alpha_{\mathrm{sh}} \cdot \eta_{\mathrm{sh}} \cdot \sqrt{\langle \phi^2 \rangle_{\mathrm{sh}}}}_{\text{SH Perturbation}}$$

$\phi = \{T, q, w\}$ Variables to be perturbed by the surface heating scheme

$\langle \phi^2 \rangle_{\mathrm{sh}}$ Variances calculated in the **Mellor-Yamada turbulence parameterization**

α_{sh} Scaling factor

η_{sh}
- Random field with a horizontal correlation length of 14 km (effective resolution 5Δx)
- Constant in the vertical
- New random field drawn every 10 Minutes (approx. eddy turnover time)

Model

- COSMO-DE with 2.8 km horizontal resolution

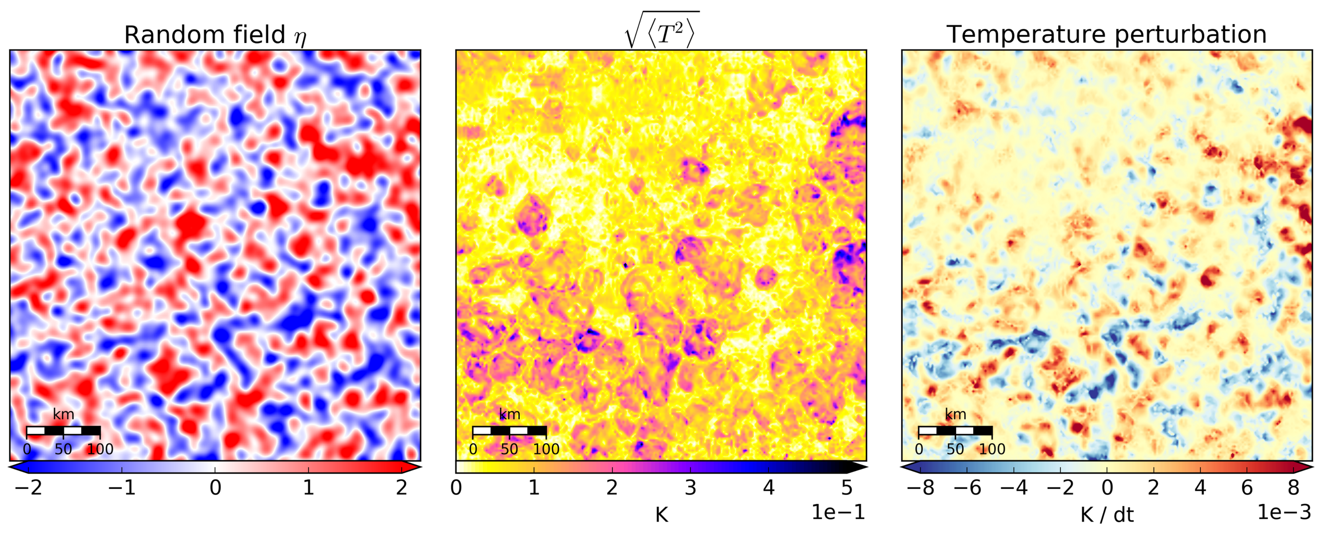

Fig. 1: *Example of how a temperature perturbation field is calculated. The variance field and the random field are multiplied to give the perturbation structure.*

➔ Physical information determines amplitude of random perturbations.

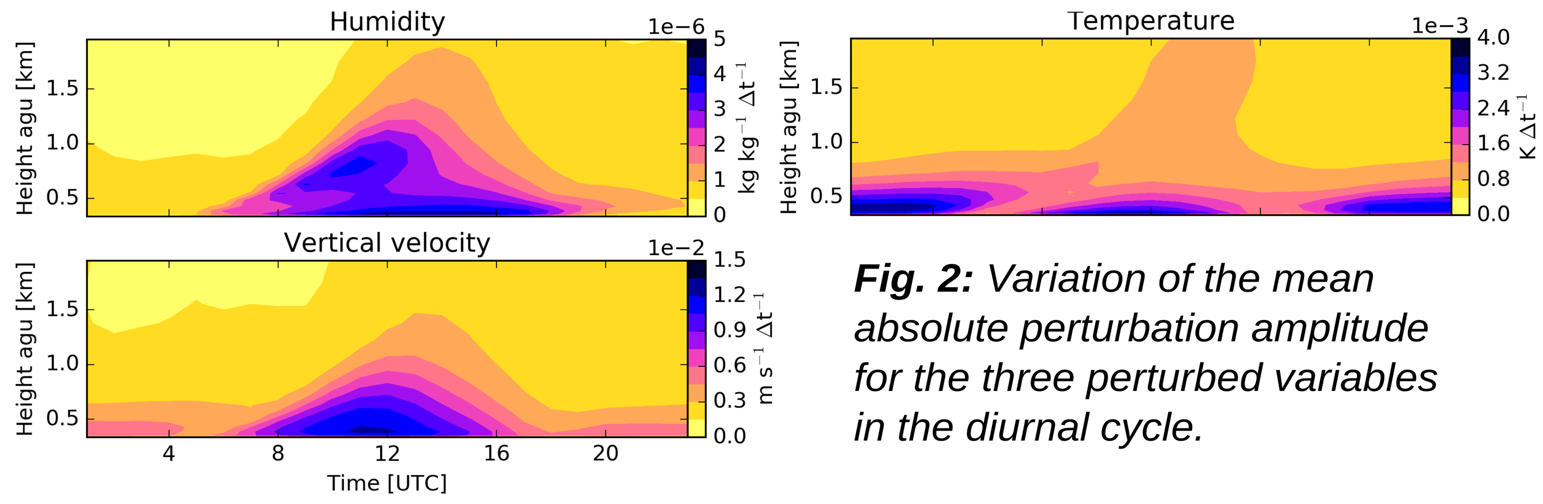

Fig. 2: *Variation of the mean absolute perturbation amplitude for the three perturbed variables in the diurnal cycle.*

➔ Perturbation amplitude depends strongly on the diurnal cycle.

Impact on Precipitation Spread

- Ensembles of 10 members started at 9UTC from same initial conditions
- Only the random seed differs between the ensemble members

Comparison with equivalent single perturbations

- Members perturbed once at 9UTC
- Perturbation structure mimicks the stochastic perturbations
- Perturbation amplitude approximately equivalent to 10 minutes of stochastic perturbations: σ(T, q, w) = 0.1 K, 1e^{-4} kg kg^{-1}, 0.375 m s^{-1}

Stochastic perturbations | **Equivalent single perturbations**

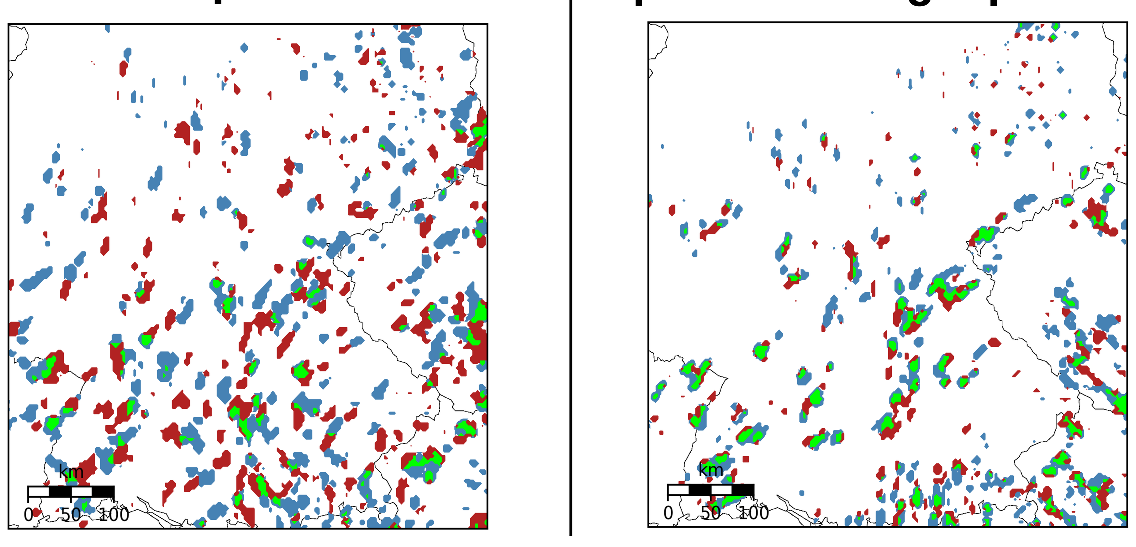

Fig. 3: *Comparison of precipitation features between two ensemble members at 14UTC. Red (blue) shadings indicate precipitation in member one (two). Green shading indicates overlapping cells.*

➔ Continuous stochastic perturbations cause faster displacement of convective cells compared to equivalent single perturbations.

Scale-dependent analysis of precipitation dispersion

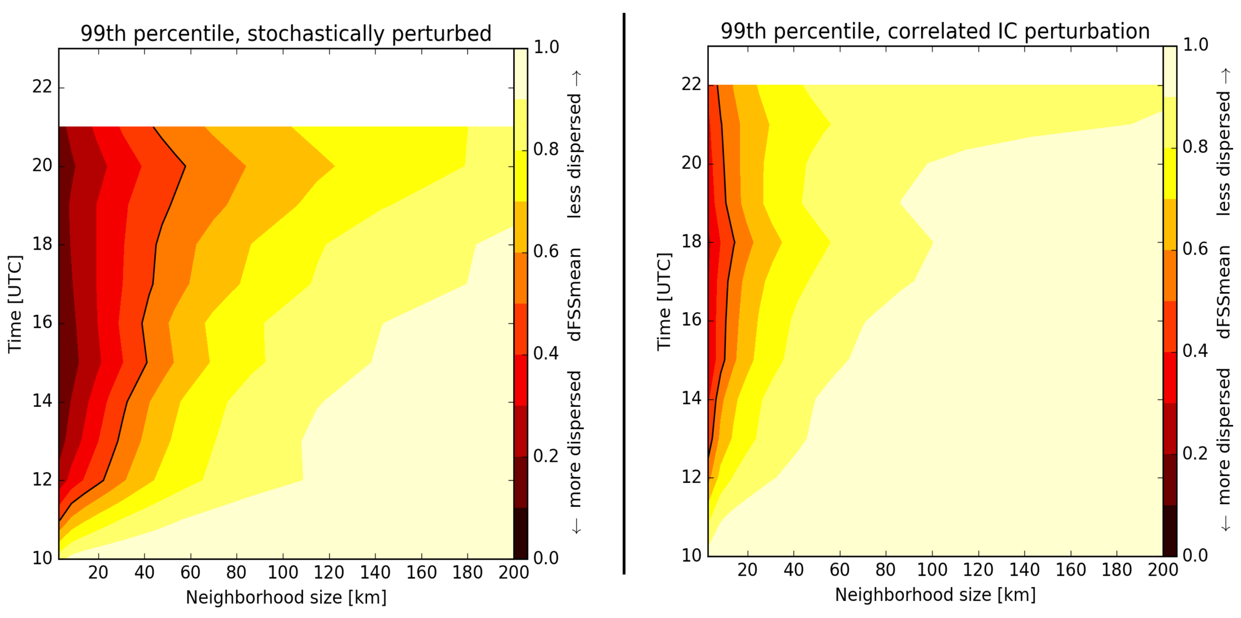

Fig. 4: *dFSSmean of an ensemble with stochastic perturbations introduced at 9UTC. The FSS is a scale dependent measure of the spatial agreement between precipitation forecasts (Dey et al. 2014).*

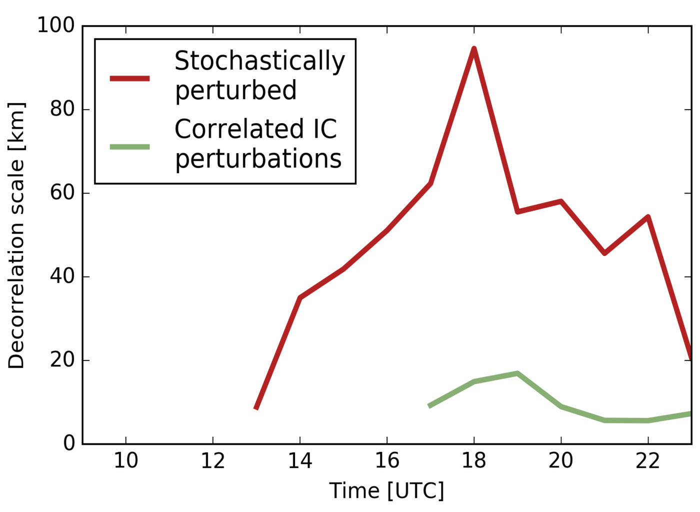

Fig. 5: *Evolution of the precipitation decorrelation scale after Surcel et al. (2015) for perturbations introduced at 9UTC. This metric indicates up to which scale an ensemble of precipitation forecasts is totally decorrelated.*

➔ Results indicate an accelerated stage one of the error growth model by Zhang *et al*. (2007) (see also Selz and Craig 2015).

The Systematic Impact: More Convection

Comparison of precipitation forecasts with COSMO reference run

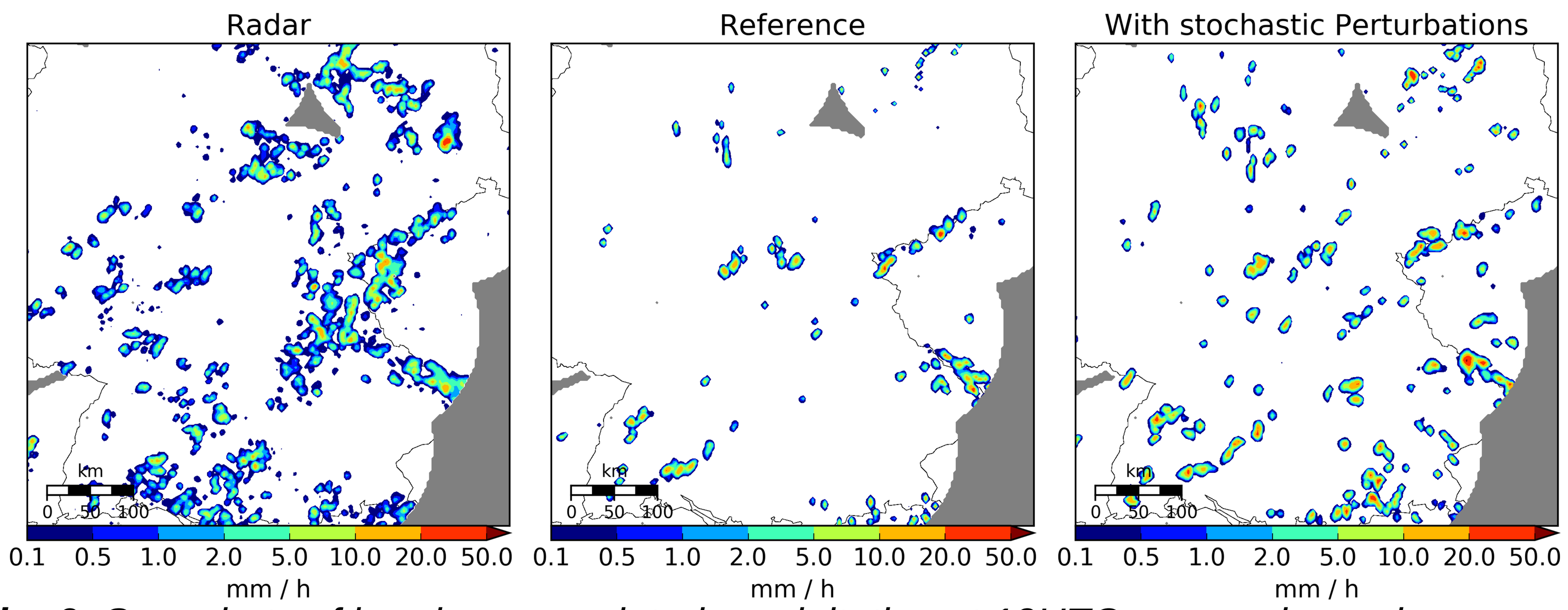

Fig. 6: *Snapshots of hourly accumulated precipitation at 12UTC, comparing radar, reference run and one stochastically perturbed run. Adapted from Kober and Craig (2016).*

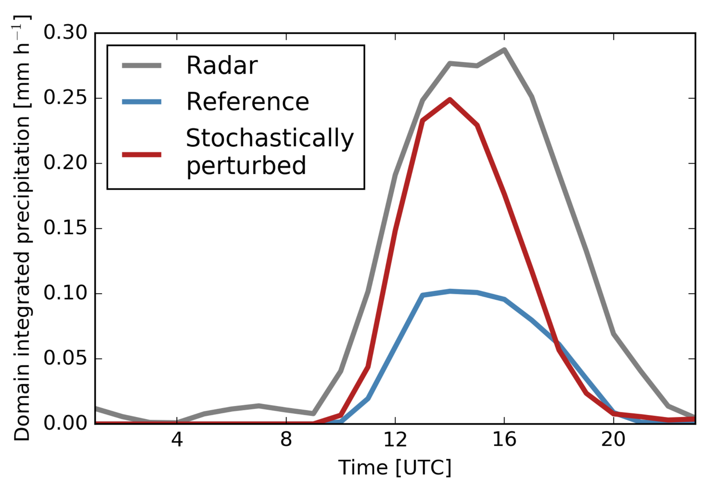

Fig. 7: *Domain integrated hourly precipitation of a reference run, the mean of a perturbed ensemble and the matching radar observations. Adapted from Kober and Craig (2016).*

➔ In a case with weak synoptic forcing, the stochastic perturbation scheme produces more realistic precipitation amounts.

Future Work

- Evaluation and verification of ensemble simulations in comparison/ combination with other ensemble techniques (SPPT, downscaling)
- Comparison with statistical postprocessing techniques in collaboration with HITS group (Prof. Tillmann Gneiting)
- Evaluation of the interaction of stochastic representations of different physical processes (see Goal and Fabian Brundke's Poster)

References

Dey, S. and Coauthors, 2014: A spatial view of ensemble spread in convection permitting ensembles. *MWR*, **142**, 4091-4107.

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Surcel, M. and Coauthors, 2015: A study on the scale dependence of the predictability of precipitation patterns. *JAS*, **72**, 216-235.

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s.rasp@lmu.de