Stochastic perturbations to account for convection initiation by subgrid-scale orography and turbulence

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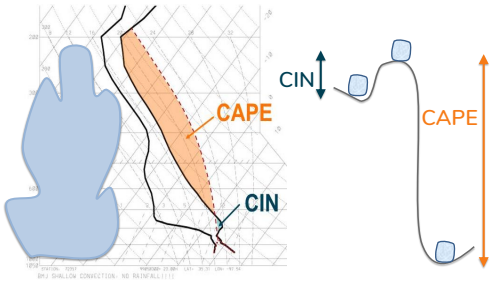
Motivation



Adapted from http://slideplayer.fr/slide/3284387/ (L. Beauvais)

Subgrid-scale processes are relevant for triggering convection in km-scale models:

1. **Subgrid-scale orography (SSO)**
2. **Turbulence variability** (modifications to Kober and Craig, 2016)

→ Deficits in precipitation forecasts

Goal:

- Reduce total precipitation bias
- Improve locations of precipitation
- Increase model ensemble spread of precipitation

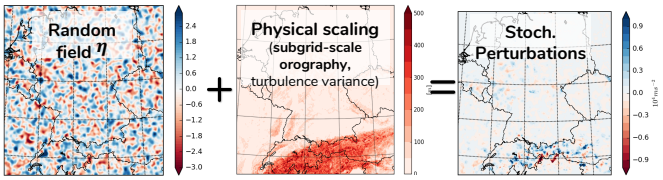
Idea:

Account for subgrid-scale physical processes responsible for convection initiation in a stochastic manner: Physically based stochastic perturbations (PSP)

Physically based stochastic perturbations (PSP)

$$\left(\frac{\partial \phi}{\partial t}\right)_{all} = \frac{\partial \phi}{\partial t} + \underbrace{\alpha \cdot \eta \cdot \phi'}_{\text{Stochastic perturbations}}$$

$\eta(\tau, \sigma)$: Random field with Autoregressive process (τ) and spatial correlation σ
α: perturbation ampl., scaling factors
ϕ': physical scaling of variable ϕ

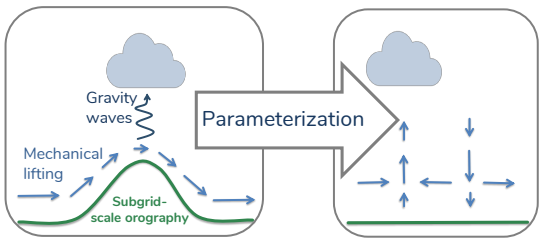


1) Turbulence (PSP-TUR)

Perturbing ϕ ={T, q, w} tendencies scaled to turbulence variance from turbulence parameterization as in Kober and Craig (2016), with some modifications for physical consistency (AR-process, constraint to PBL)

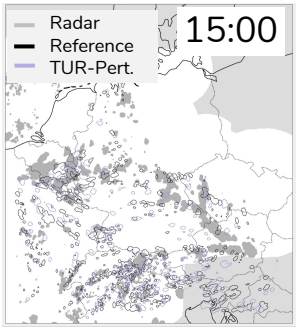
2) Subgrid-scale orography (PSP-SSO)

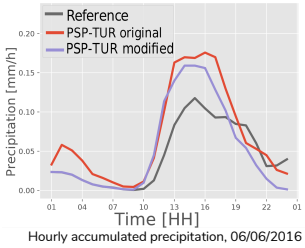
mechanical lifting & gravity waves enhance vertical velocities and trigger convection: perturbing ϕ =**w** and **u, v** in 3D non-divergent manner, with $\boldsymbol{w'} = \boldsymbol{w'(SSO, N_z^2, \vec{v}_h)}$



Impact of the PSP schemes

1) Turbulence (PSP-TUR)

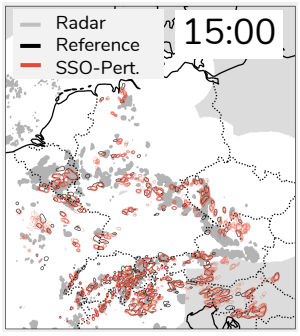


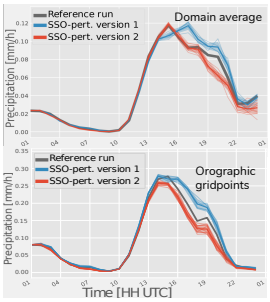


Hourly accumulated precipitation, 06/06/2016

Increase of precipitation with PSP-TUR scheme by enhanced triggering

2) Subgrid-scale orography (PSP-SSO)





Hourly accumulated precipitation, 06/06/2016

- Rearrangement of precipitation cells
- Different random seeds generate moderate ensemble spread in period of convective activity
- No systematic increase in convection triggering also in orographic regions

Conclusions

- PSP-TUR increases triggering of convection resulting in more precipitation
- SSO perturbations do not increase convection triggering and induce moderate ensemble spread
- Subgrid-scale orography is mainly strong in regions of strong resolved orography: In such regions, small scale orography is not essential for precipitation triggering (cf. Kirshbaum et al., 2007, Schneider et al. 2018)
- Side effect of PSP-SSO Scheme: Enhanced mixing decreases CAPE

References

Kober, K., & Craig, G. C. (2016). Physically Based Stochastic Perturbations (PSP) in the Boundary Layer to Represent Uncertainty in Convective Initiation. *Journal of the Atmospheric Sciences*, 73(7), 2893–2911. http://doi.org/10.1175/JAS-D-15-0144.1

Kirshbaum, D. J., Rotunno, R., & Bryan, G. H. (2007). The spacing of orographic rainbands triggered by small-scale topography. *Journal of the Atmospheric Sciences*, 64(12), 4222-4245.

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