Convergence behavior of convection-resolving simulations of summertime deep convection over land

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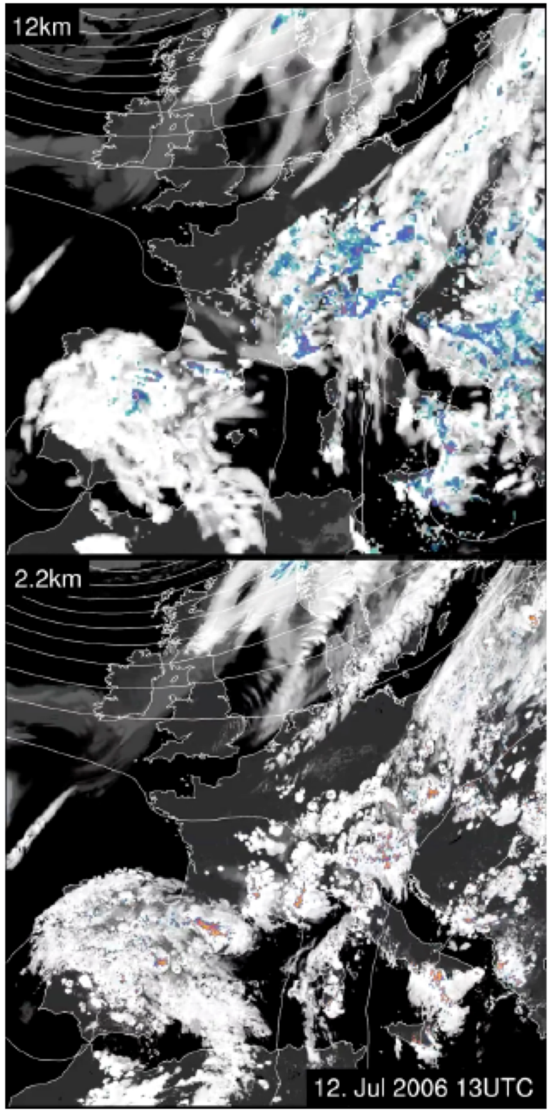
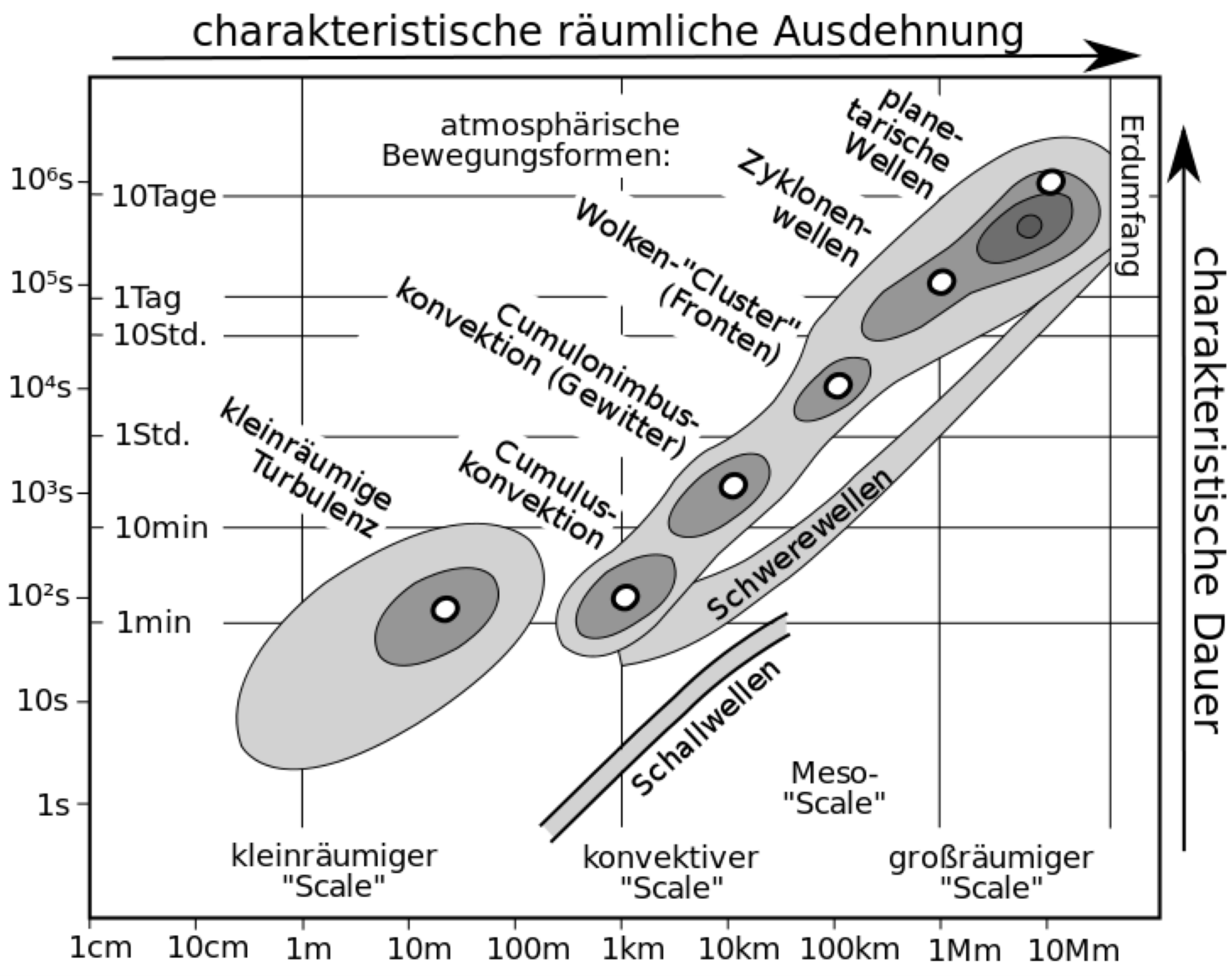
Convection-Resolving Models (CRMs)

- Clouds and convective transport partly resolved (e.g. Weisman et al. 1997, Hohenegger et al. 2008, Baldauf et al. 2011)
- Better representation of topography and surface fields
- Improved diurnal cycle of precipitation compared to convection-parameterizing models (e.g. Richard et al. 2007, Ban et al. 2014)
- Can be applied to decade-long, continental-scale climate simulations (e.g. Ban et al. 2014, Leutwyler et al. 2016)



Leutwyler et al. (2016)

The "grey zone" of convection



Fortak (1982)

- Fully resolving deep convection needs LES at Δx < 100 m
- Traditional assumptions behind convection parameterizations break down
- At Δx = O(1 km), the smallest features are sensitive to details of the numerical filter (e.g. grid-scale storms)

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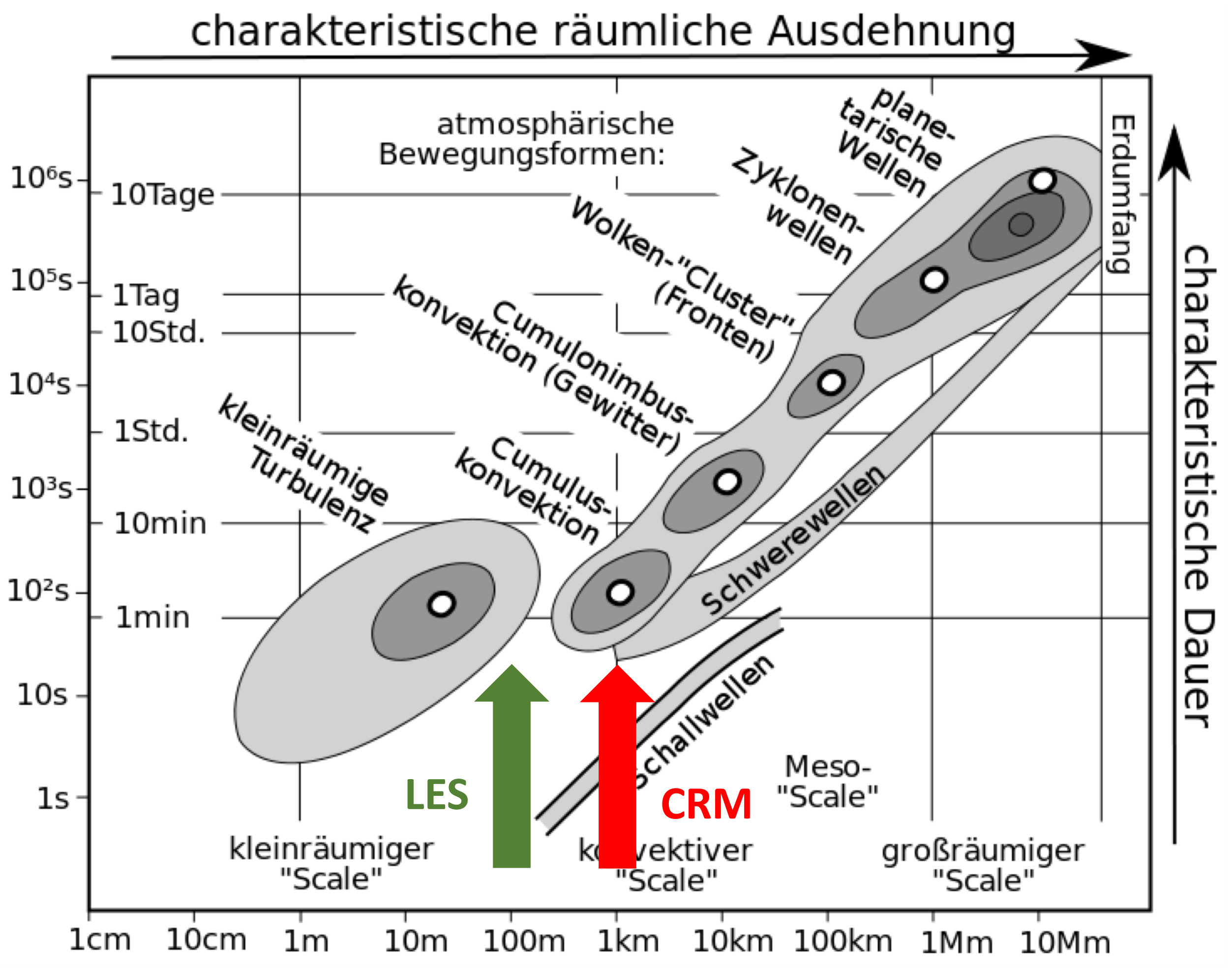

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Structural convergence

“Convergence of statistics and scales of individual clouds and updrafts.”

e.g. Bryan et al. (2003), Craig and Dörnbrack (2008), Hanley et al. (2015)

Idealized simulations

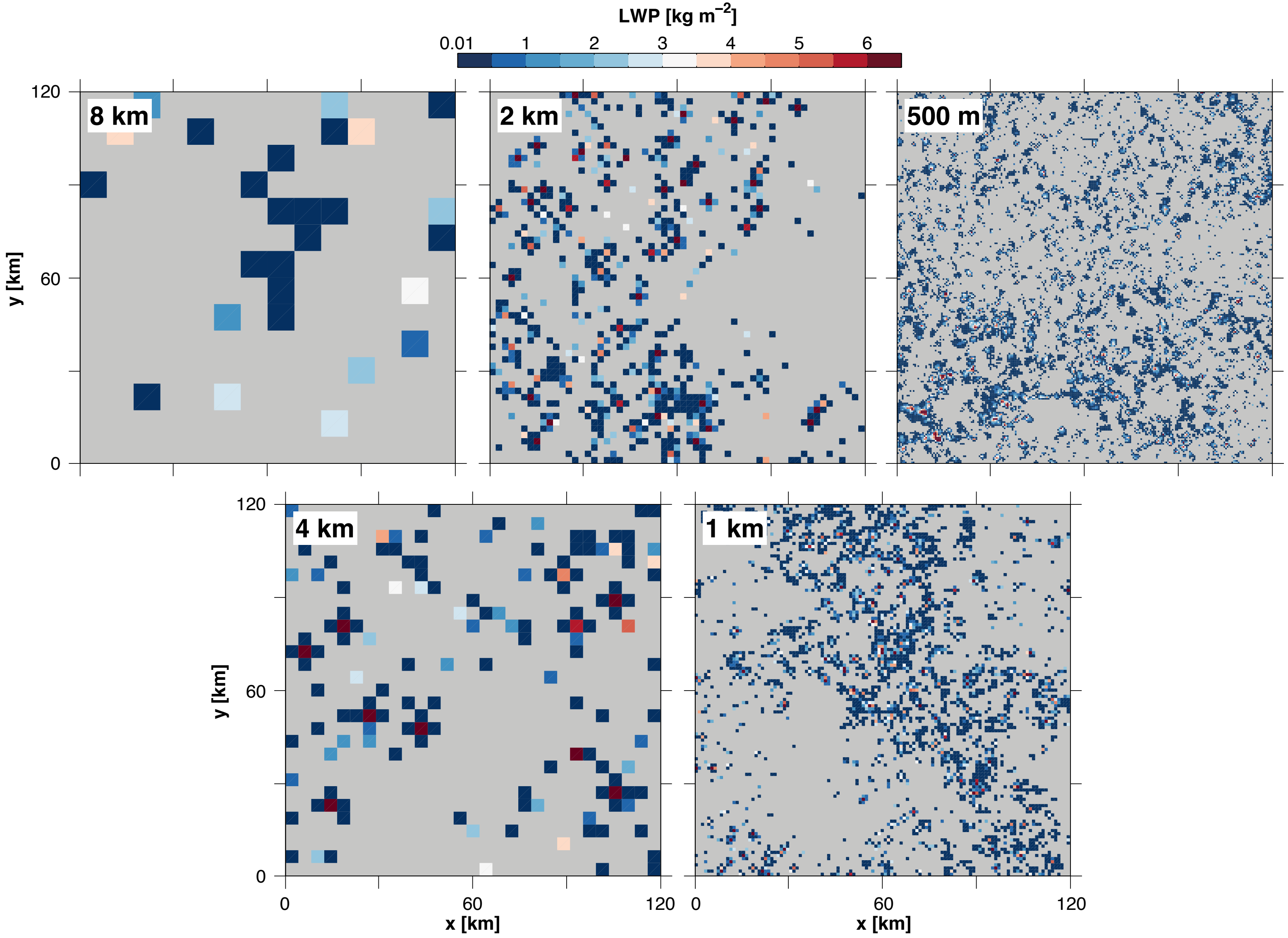
Basic setup

- Diurnal cycle of convection over land (Schlemmer et al. 2011)
- **COSMO v5.0** @ Δx = 8, 4, 2, and 1 km and 500 m
- Domain 200 x 200 km^2
- Simulation time 5 days, 5 ensemble members per experiment
- Interactive soil model and radiation scheme
- Explicit convection, 1D TKE-based/2D Smagorinsky turbulence scheme

List of experiments and different configurations

CTRL: control run, basic setup

Structural convergence



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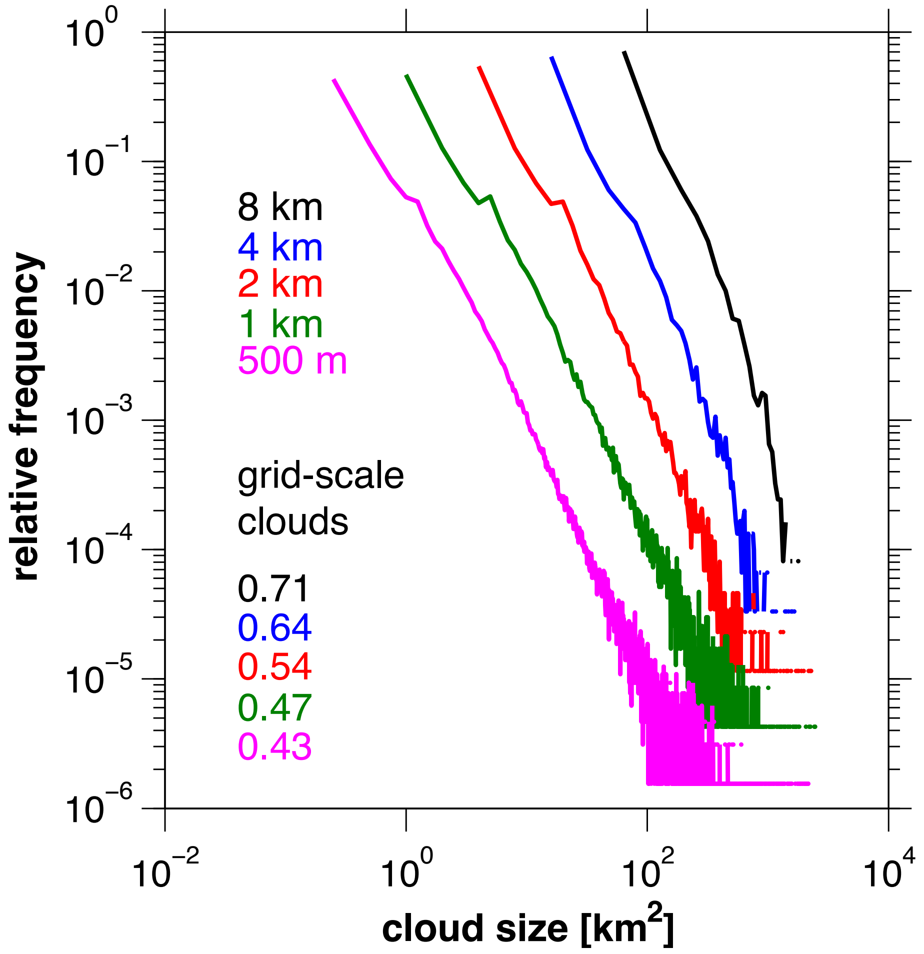
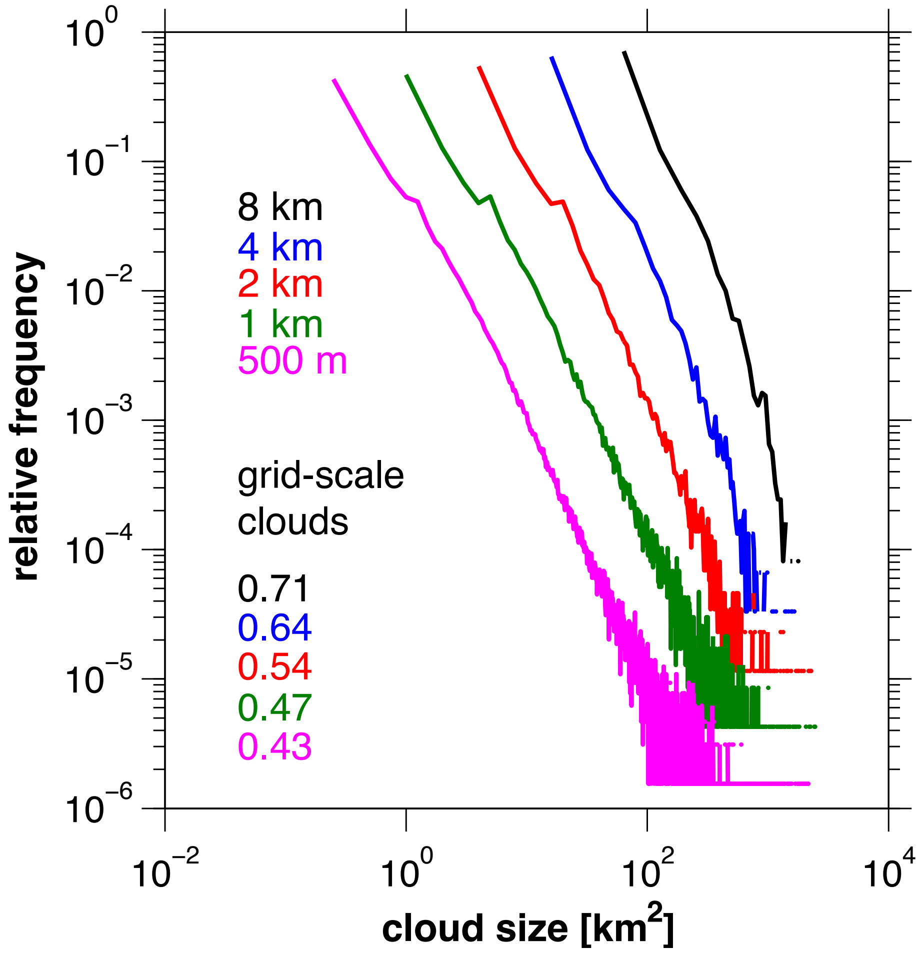
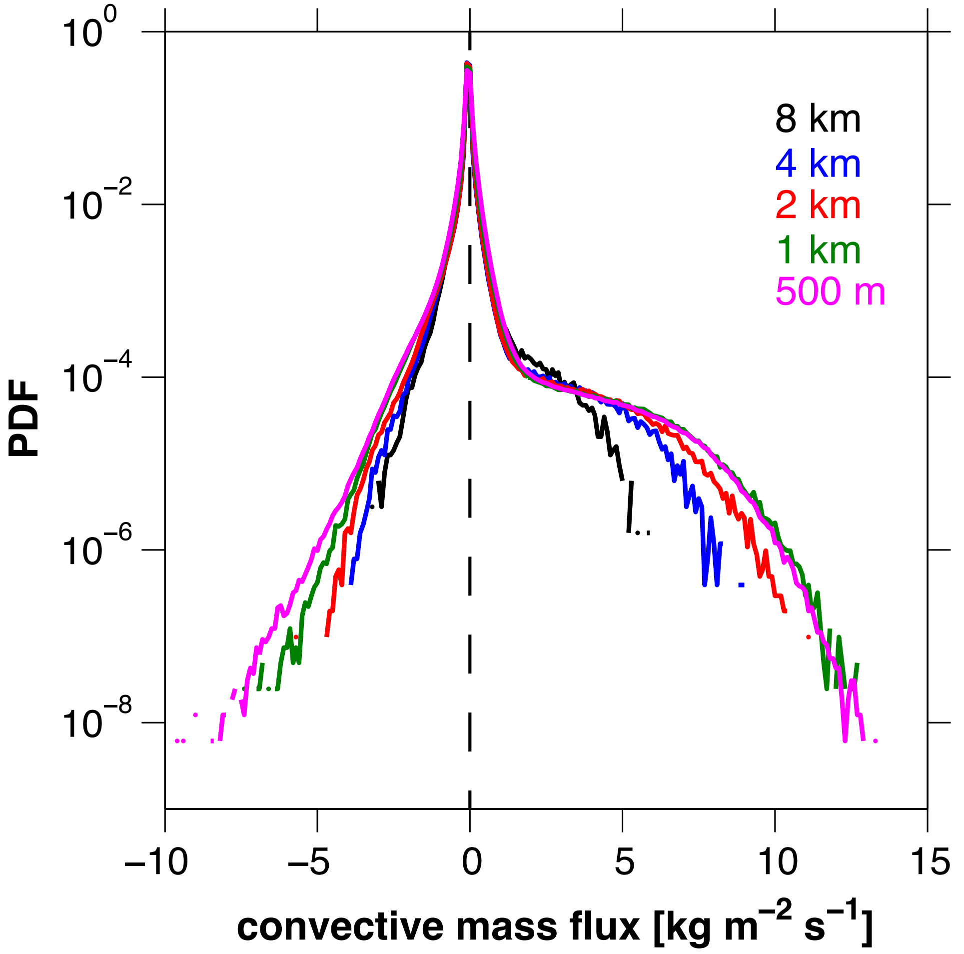


Structural convergence





Structural convergence

“Convergence of statistics and scales of individual clouds and updrafts.”

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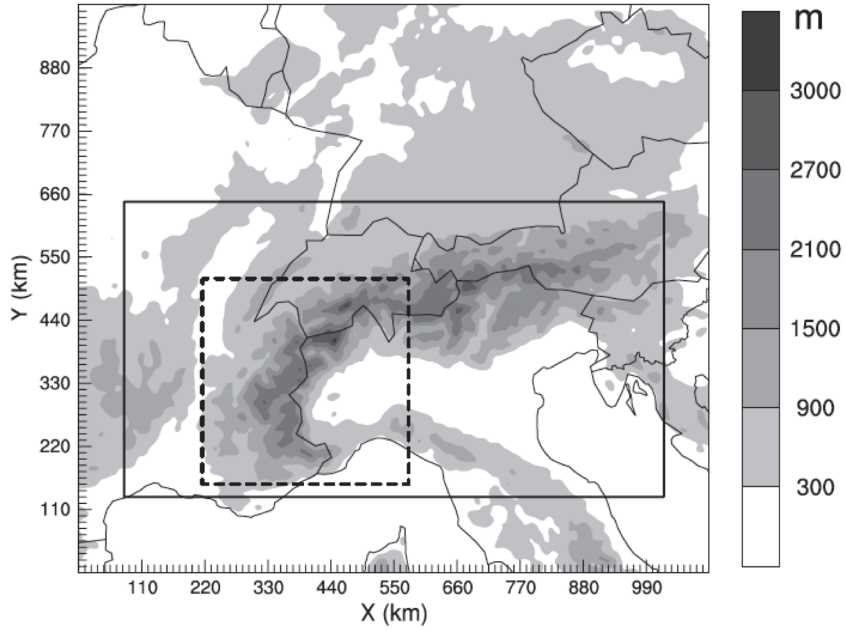
Bulk convergence

“Convergence of domain-averaged and integrated quantities over large domain.”

e.g. Langhans et al. (2012)



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List of experiments and different configurations

CTRL: control run, basic setup

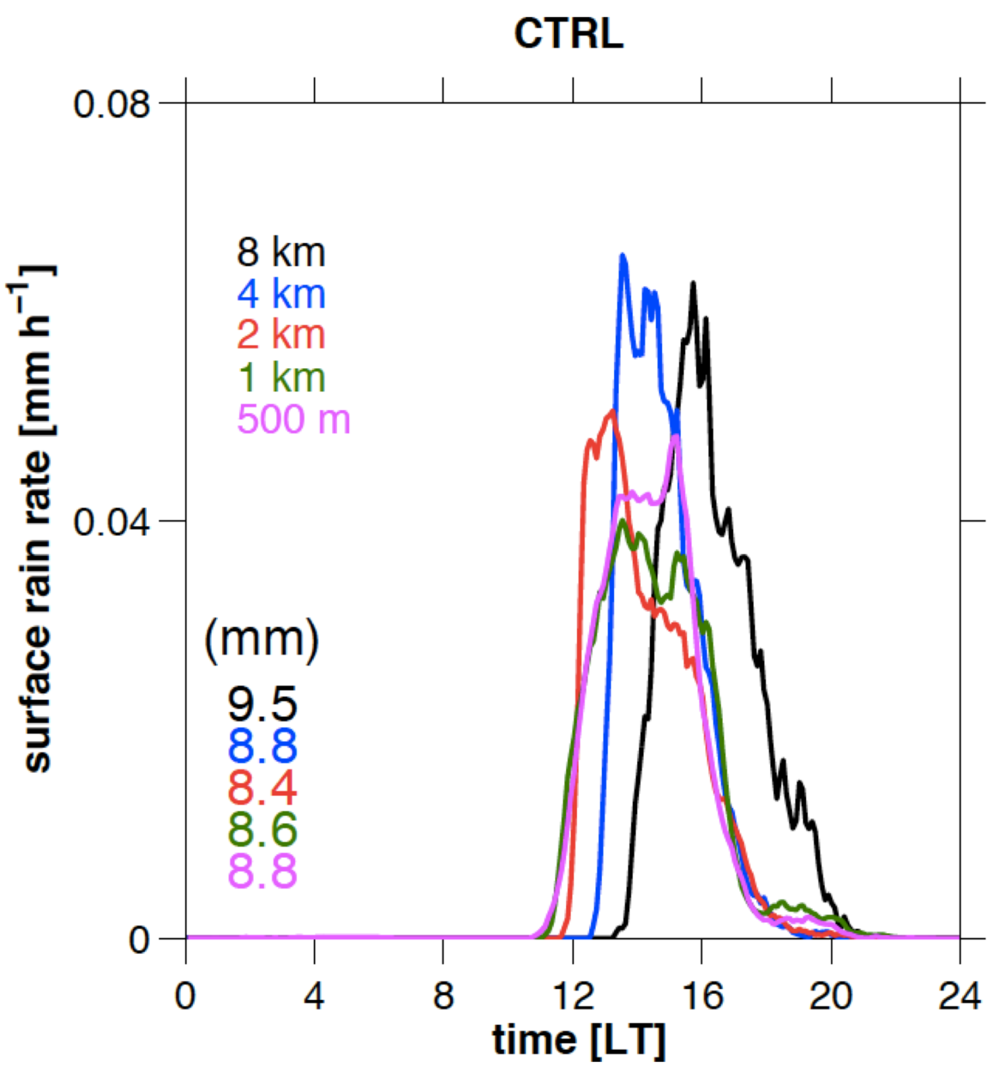
WIND: CTRL + environmental wind shear (Schlemmer et al. 2011)

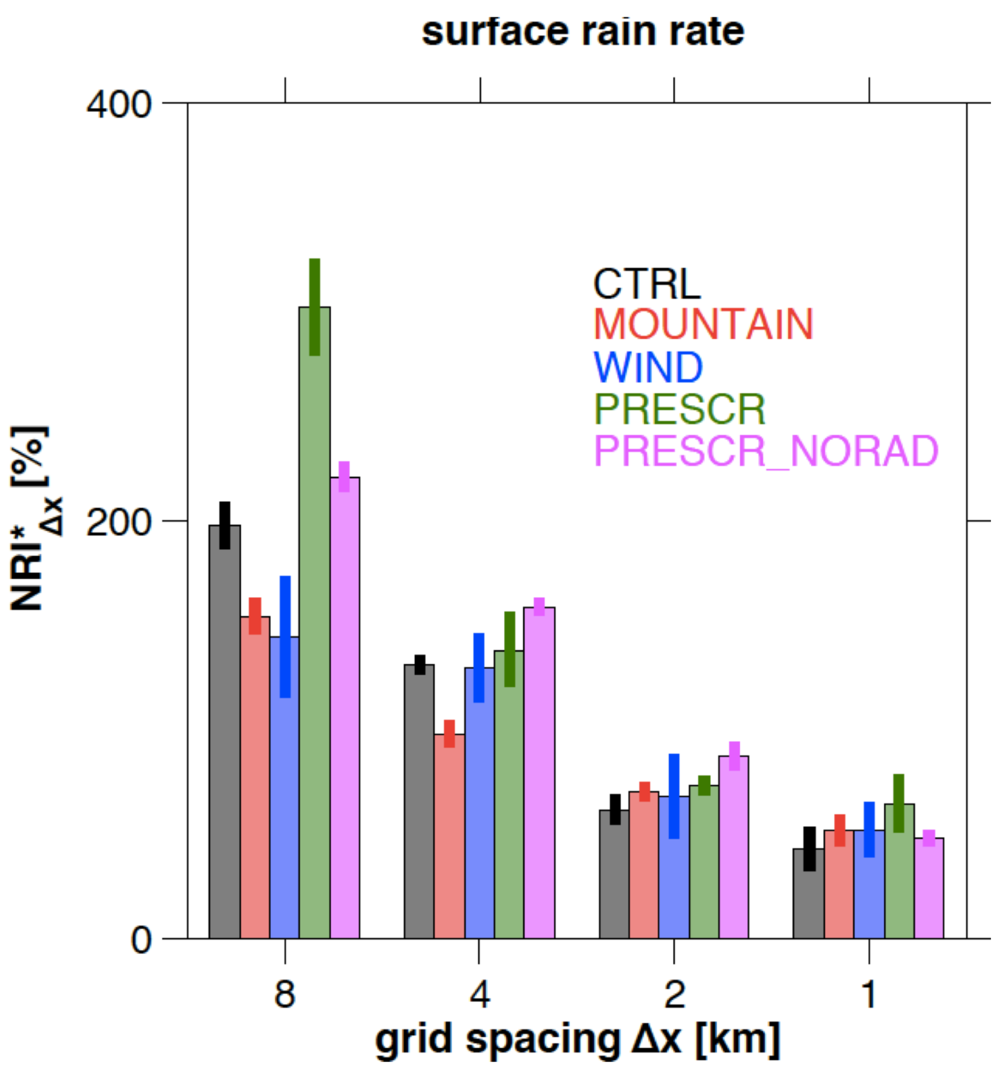
MOUNTAIN: CTRL + 500-m 3D gaussian hill

PRESCR: CTRL with prescribed surface fluxes

PRESCR_NORAD: PRESCR without radiation scheme (prescribed radiative cooling)

Surface precipitation





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Summary

- Although structural convergence is not yet attained at the kilometer-scale, bulk convergence is generally achieved

References

Langhans W., J. Schmidli and C. Schär: **Bulk convergence of cloud-resolving simulations of moist convection over complex terrain.** *J. Atmos. Sci.,* **69**, 2207–2228.

Panosetti D., L. Schlemmer and C. Schär: **Convergence behavior of idealized convection-resolving simulations of summertime deep convection over land.** *Clim. Dyn.*, revised version submitted.

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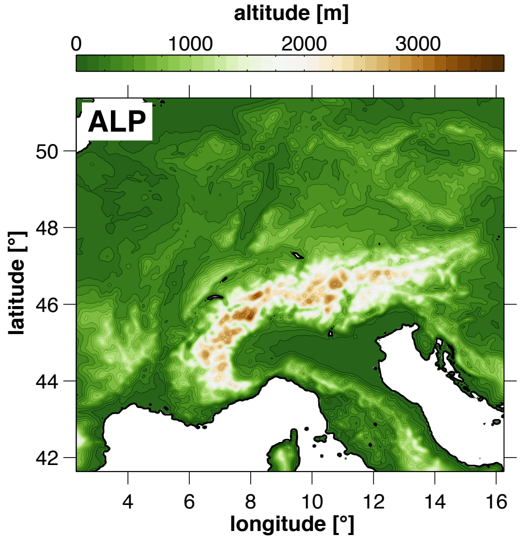
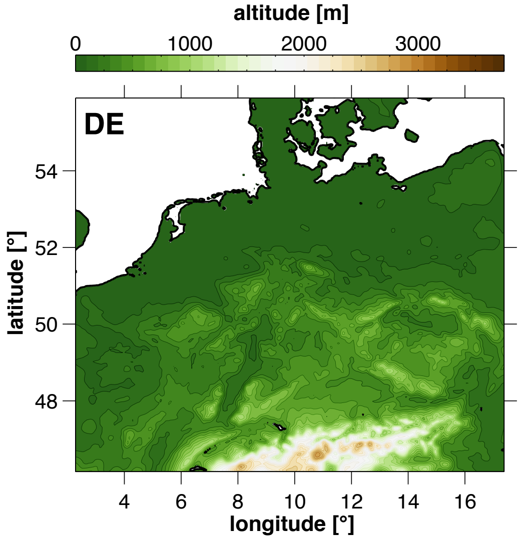
Real-case simulations





Basic setup

- Domain 1100 x 900 km^2
- **COSMO v5.0** @ Δx = 4.4, 2.2, and 1.1 km and 550 m
- Soil initialized from 10-yr climate run at 12-km horizontal grid spacing (Ban et al. 2014)
- Initialized with and driven by 12-km run
- Interactive soil model and radiation scheme
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Experiments

ALP: 11-20 July 2006 (Langhans et al. 2012)

DE: 4-13 June 2007 (Keller et al. 2015)

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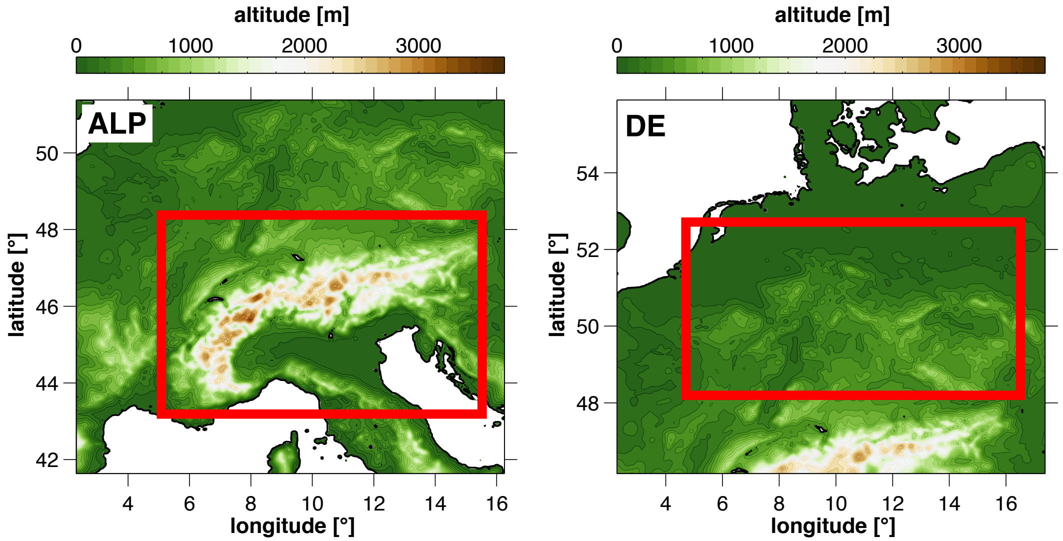

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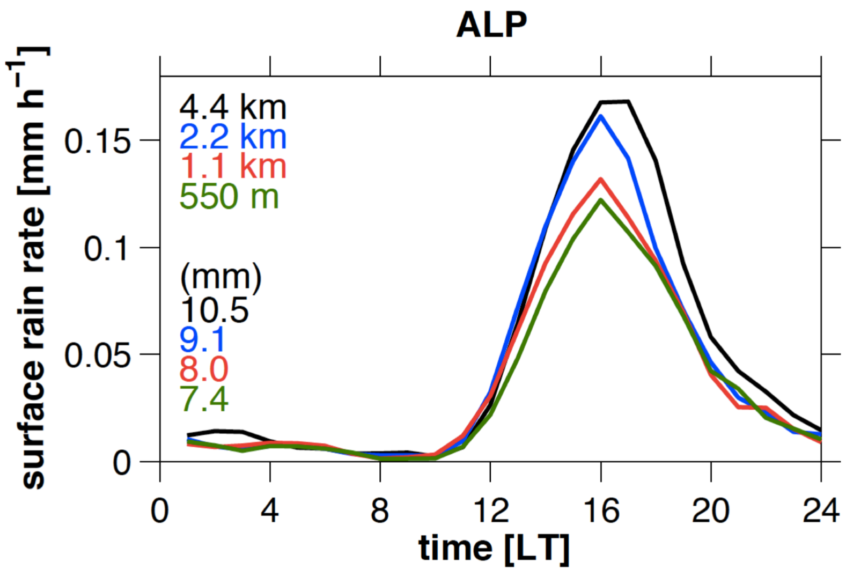

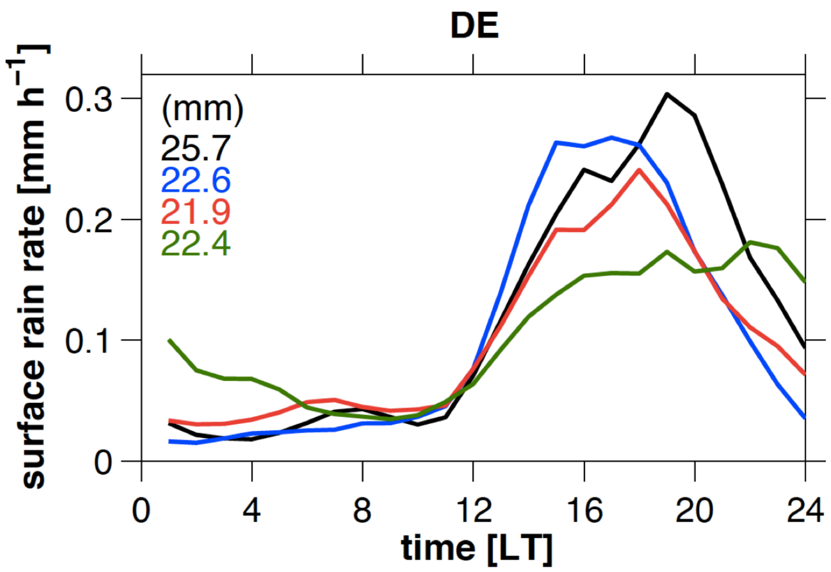

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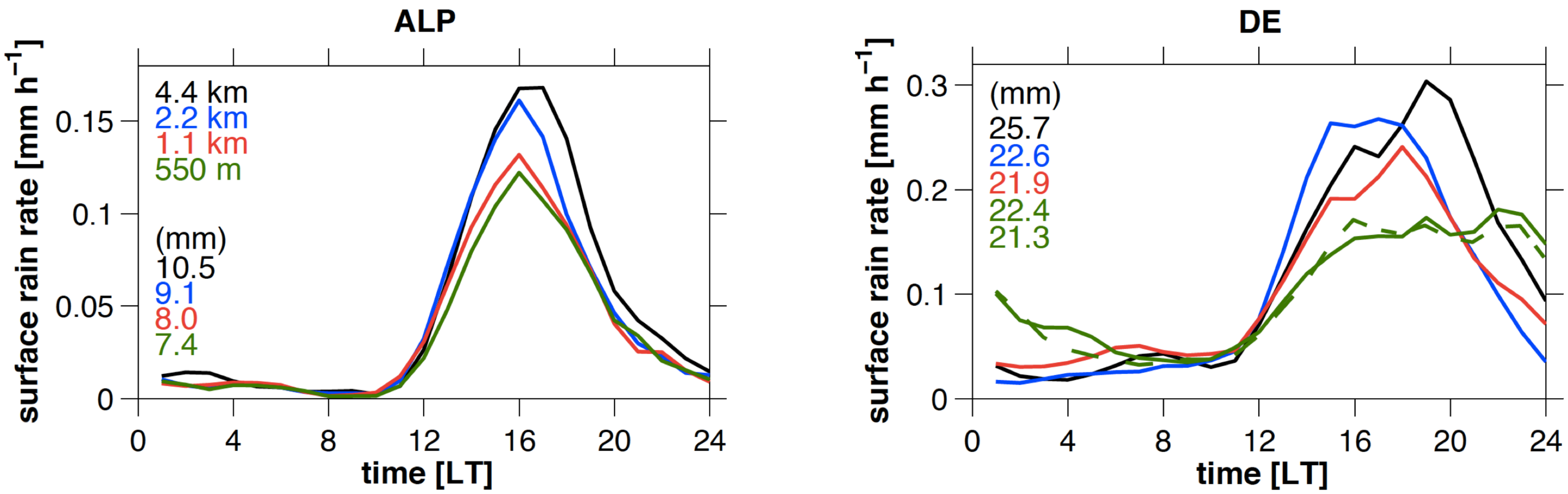

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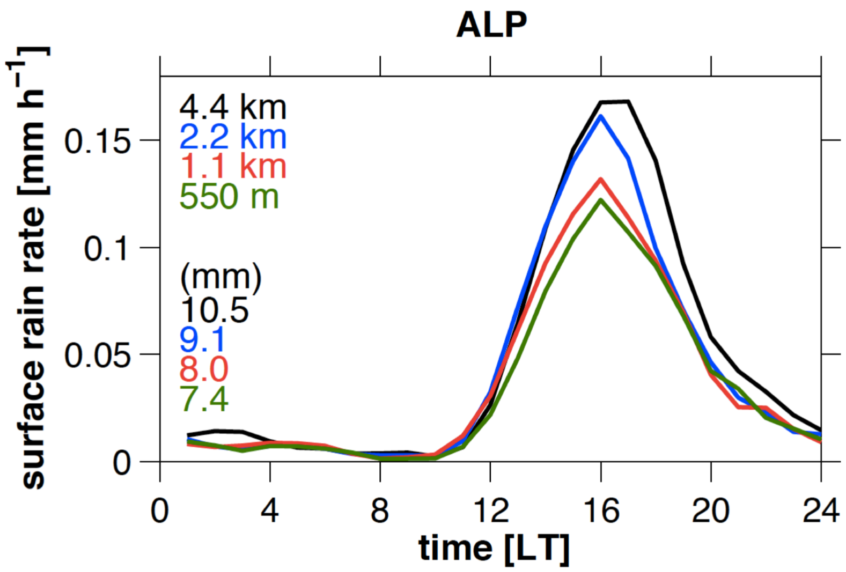
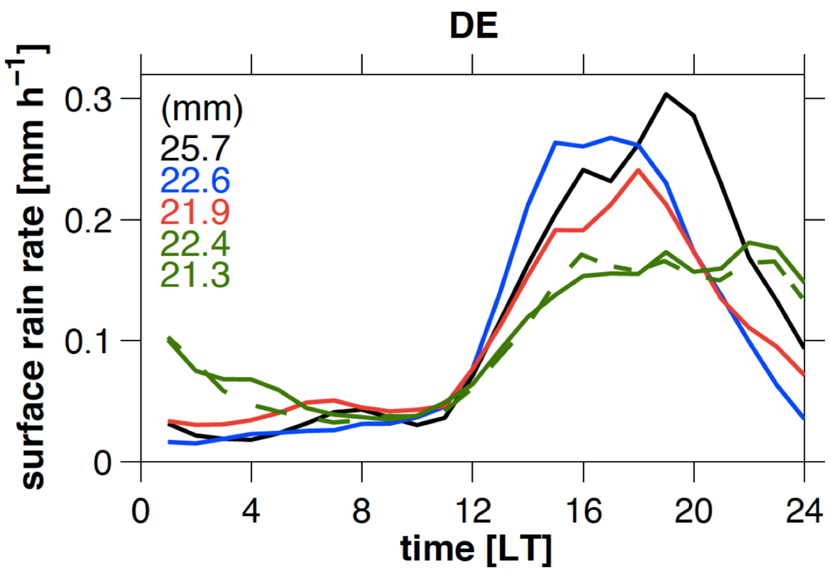
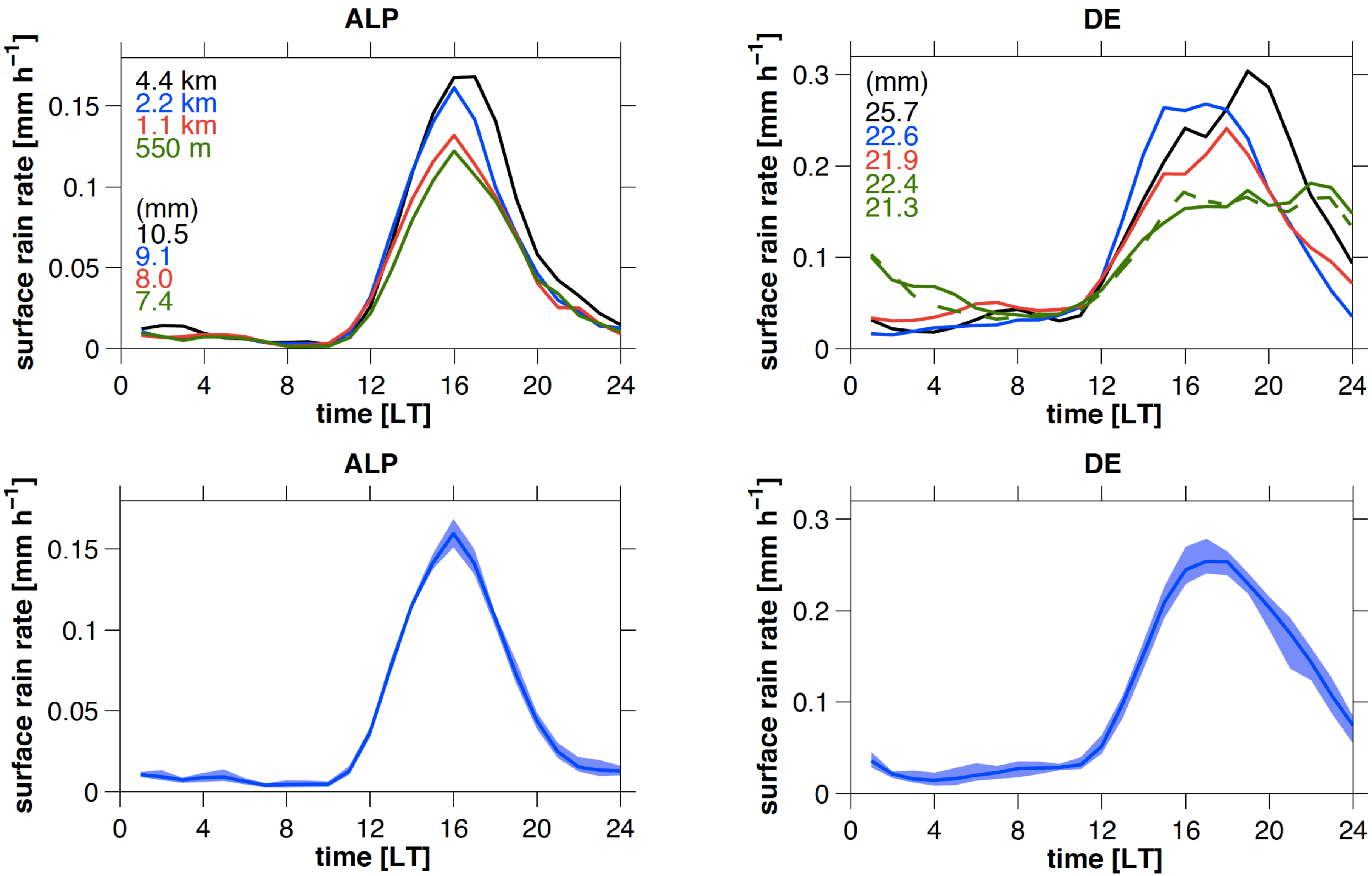




- 7 ensemble members per experiment at Δx = 2.2 km
- Initialized -12h $\pm$ 3h from first day (e.g. for **ALP** 10 July 2006 12h $\pm$ 3h)

Real-case simulations



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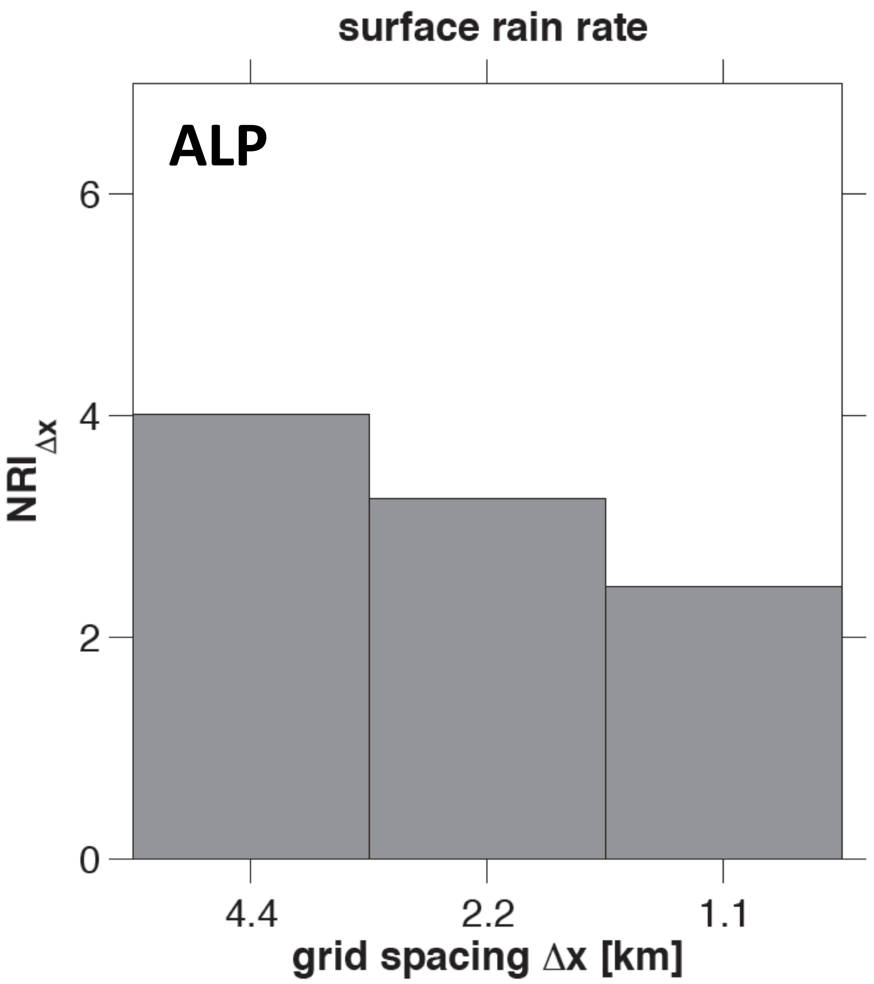

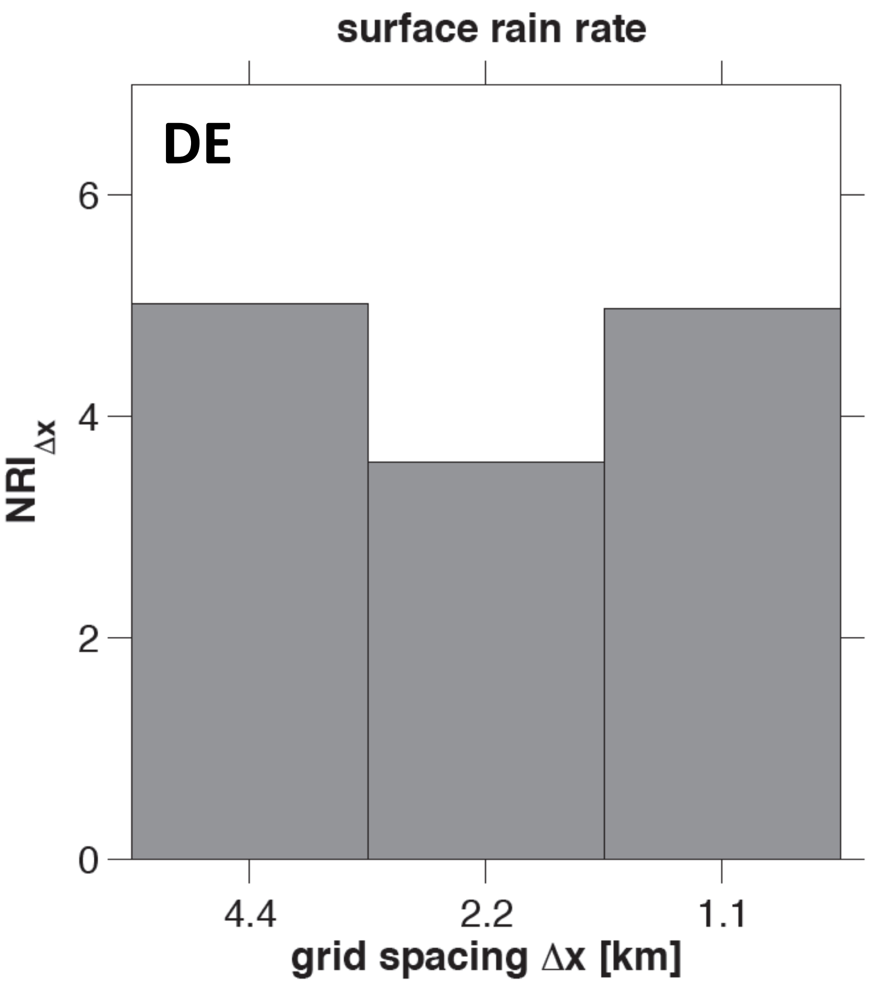

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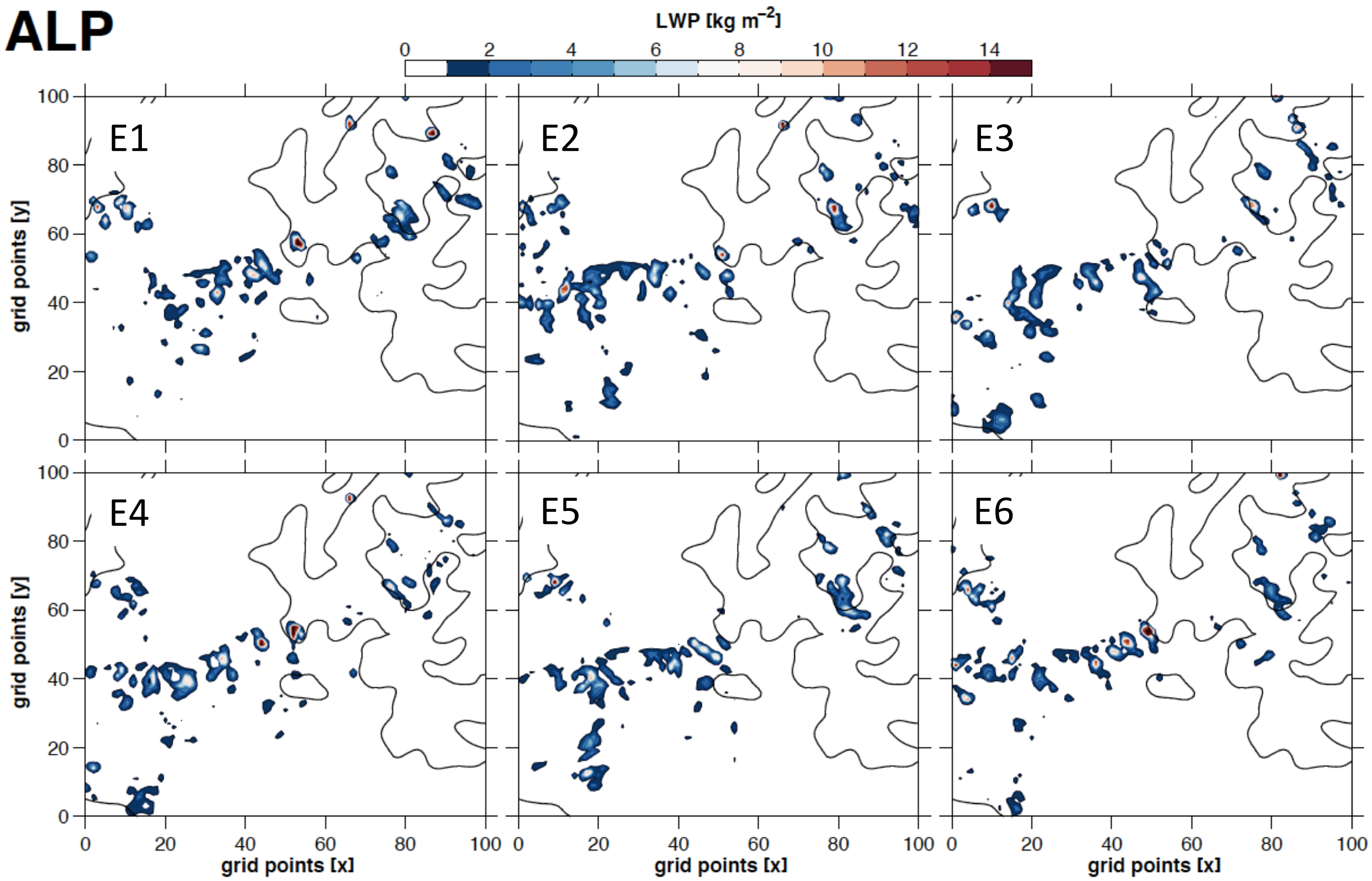

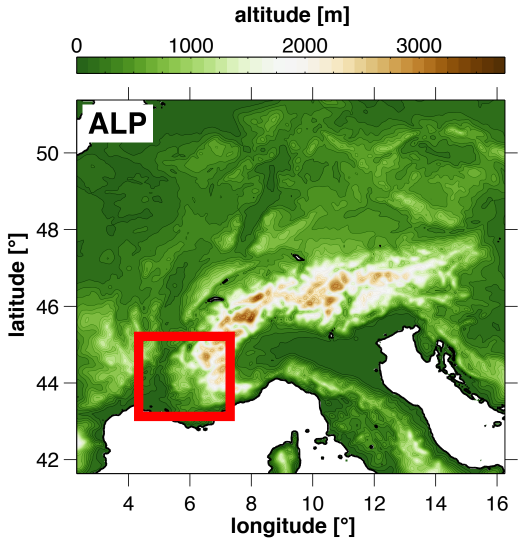

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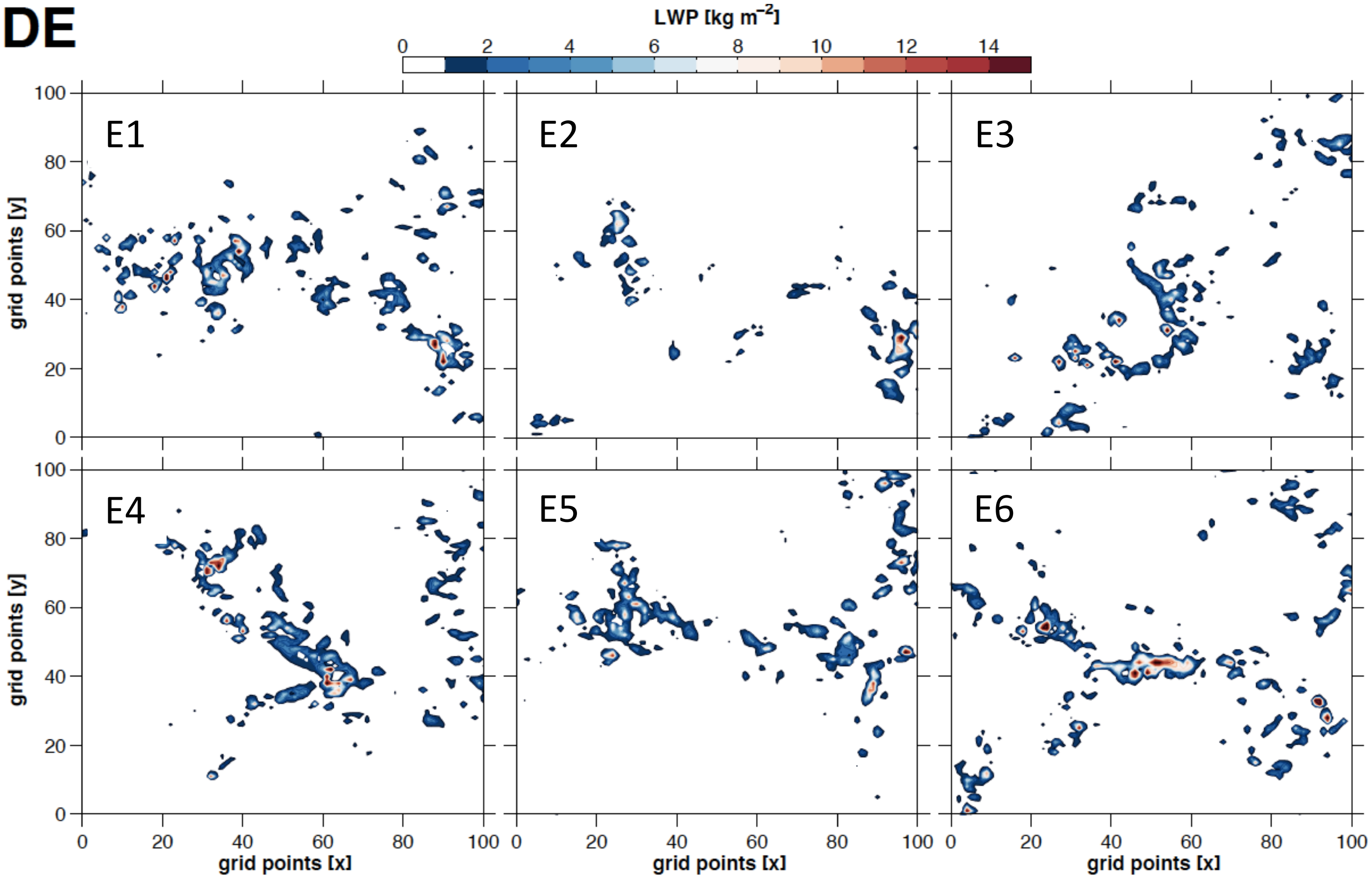

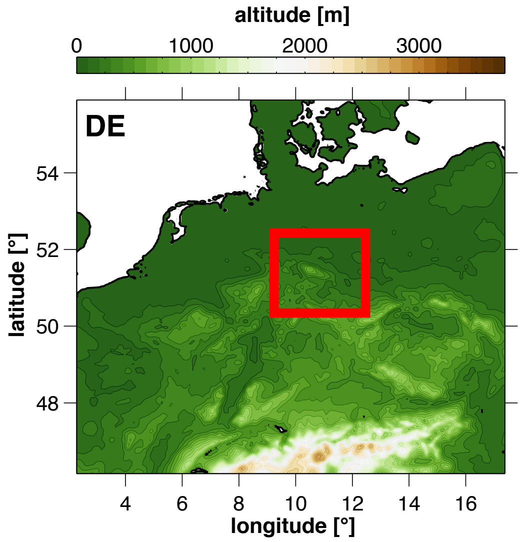

Summary

- Although structural convergence is not yet attained at the kilometer-scale, bulk convergence is generally achieved (in idealized simulations)
- Orographic forcing reduces resolution sensitivity and generally helps achieving bulk convergence (in real-case simulations)

References

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