

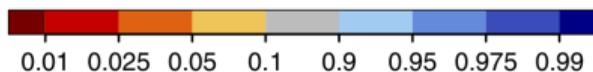
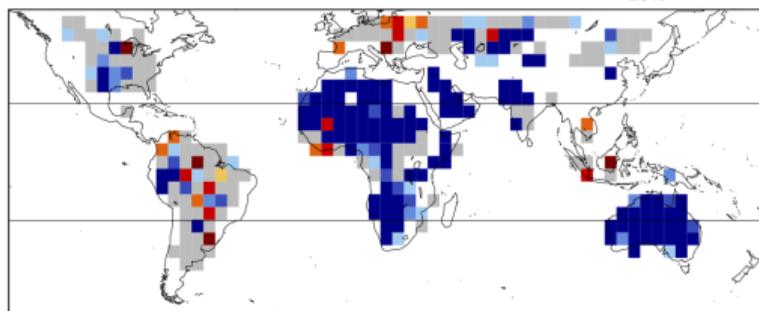
Interactions between soil moisture anomalies on different scales and the dynamics of the lower atmosphere

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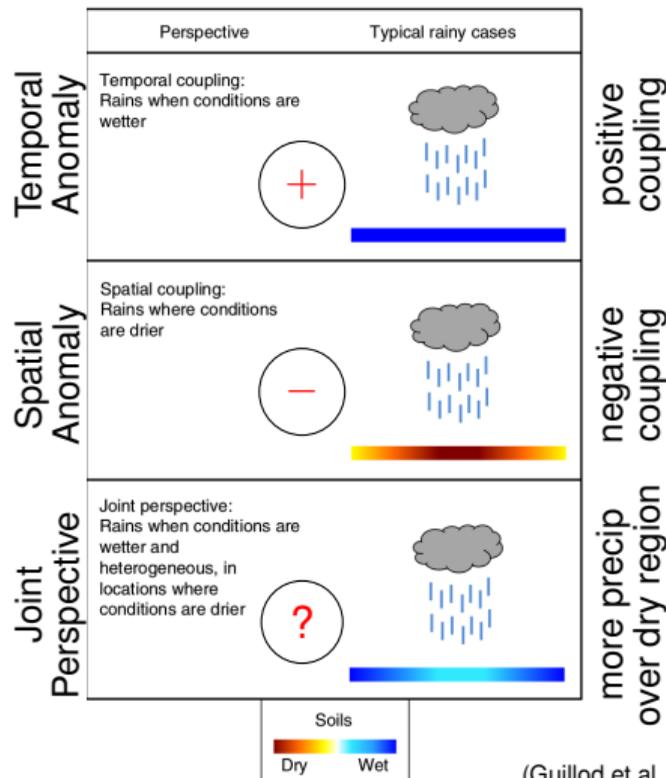
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Spatial and temporal soil moisture effects in satellite data

Temporal heterogeneity preference ($Y^h = \sigma^{sp}(S'_{Levl})$)

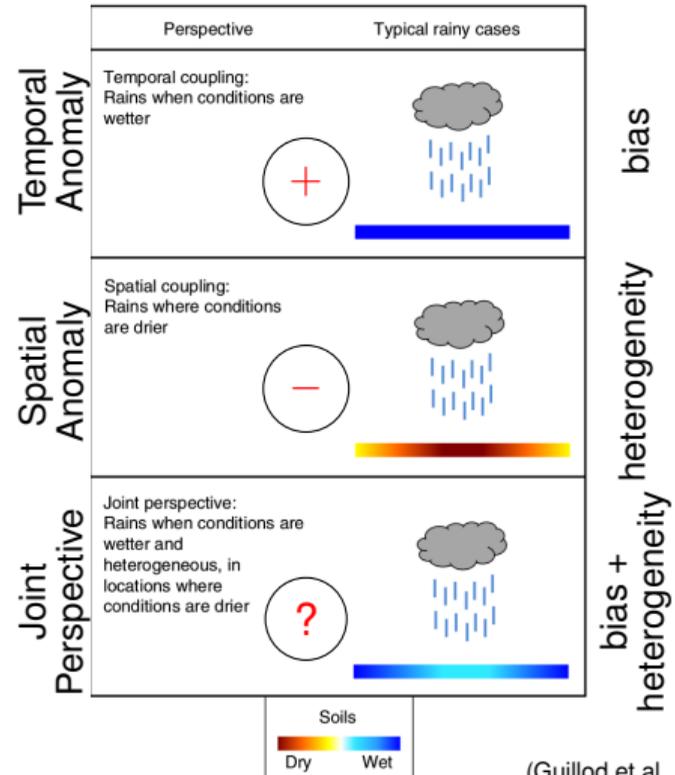


- 10 year data set of global satellite precipitation measurements
 - Spatial Resolution: 0.25°
 - Temporal Resolution: 3 h
- Comparison of temporal and spatial structures in soil conditions prior to afternoon precipitation



(Guilod et al. 2015, Nature Communications)

Spatial and temporal soil moisture effects in COSMO?

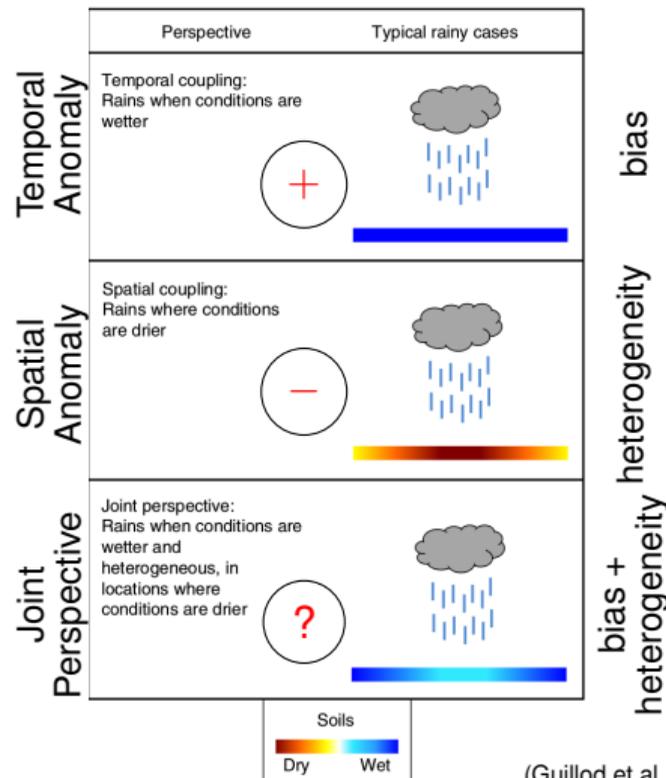


(Guilod et al. 2015, Nature Communications)

Spatial and temporal soil moisture effects in COSMO?

Research Questions:

- ① What is the influence of soil moisture bias and heterogeneity on convective precipitation?
- ② Is the impact of soil moisture heterogeneity scale dependent?
- ③ What are dominant processes?
- ④ Are our findings dependent on the synoptic regime?



(Guilod et al. 2015, Nature Communications)

COSMO – Experimental Setup

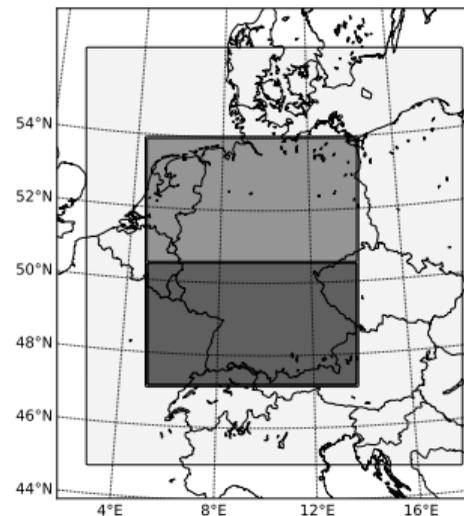
Model:

- Deterministic COSMO-DE
- 2.8 km resolution
- 1 hourly COSMO-EU analysis data
- Initial time 0 UTC + 24 h forecast lead time
- 2 Moment microphysics scheme

Type of heterogeneity: Idealized perturbations of initial soil moisture conditions

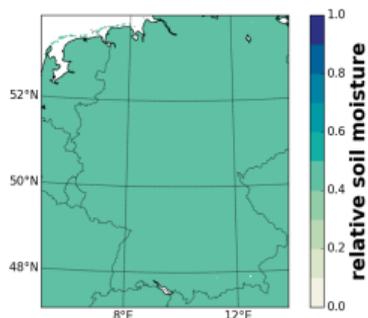
8 Case Studies

30 June 2009	01 July 2009
20 May 2011	23 July 2013
29 May 2016	04 June 2016
05 June 2016	06 June 2016

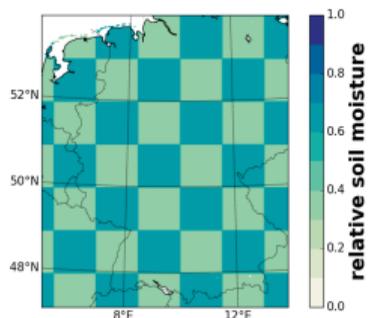


Sets of experiments

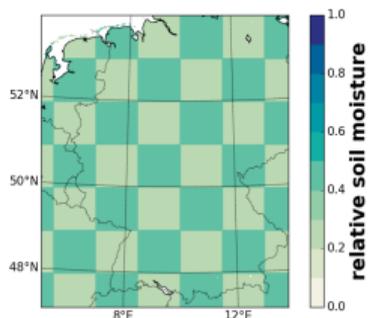
set of experiments	bias (B)	patch sizes	w_{so}	w_{so}
			dry patch	moist patch
UNI	–	uniform	$w_{so} = \overline{w_{so}}$	
CDB	0.75	28 km, 42 km,		
CNB	1.00	56 km, 84 km,	$(B \overline{w_{so}})$ 0.75	$(B \overline{w_{so}})$ 1.25
CMB	1.25	112 km		



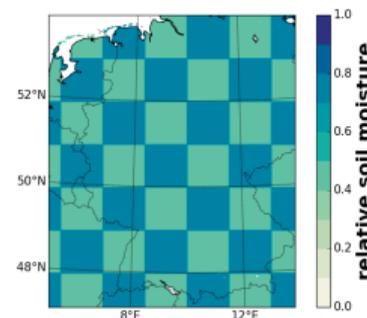
UNI
 $\overline{w_{so}} \approx 0.50$



CNB_112k
 $\overline{w_{so}} \approx 0.50$

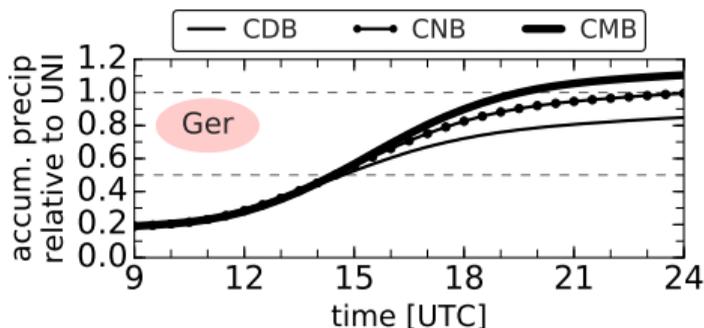


CDB_112k
 $\overline{w_{so}} \approx 0.62$



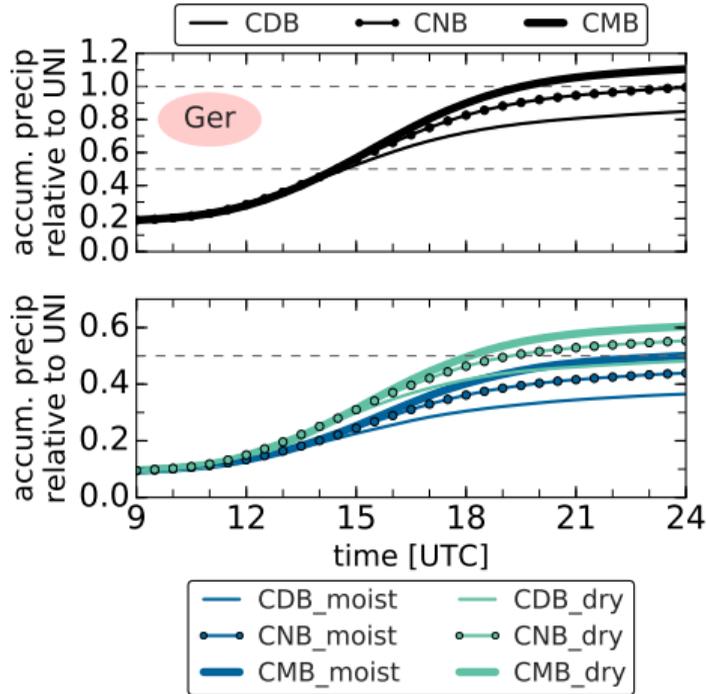
CMB_112k
 $\overline{w_{so}} \approx 0.37$

1. Mean impact of soil moisture bias $\pm 25\%$

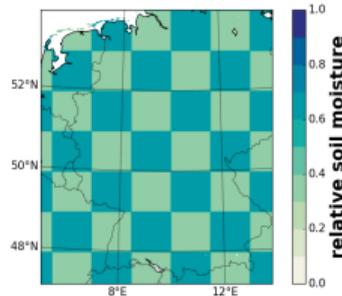


- Before 15 UTC: Differences less than 5 %
- After 24 h: stratified according to bias
 - CMB $\rightarrow \approx 10\%$ more precipitation
 - CDB $\rightarrow \approx 15\%$ less precipitation
 - CNB $\rightarrow \approx$ similar precipitation

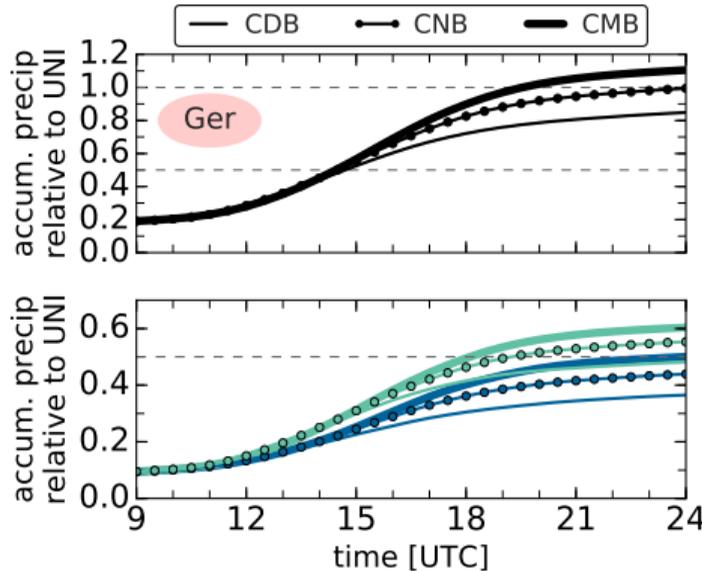
1. Mean impact averaged over dry and moist tiles



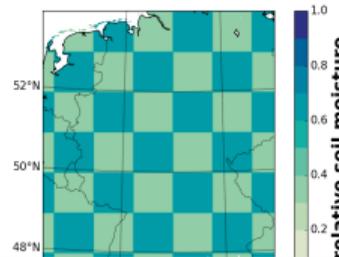
- Earlier increase of afternoon convective precipitation over dry patches
- Increased precipitation over dry patches
- Influence of soil moisture bias still prevalent



1. Mean impact averaged over dry and moist tiles



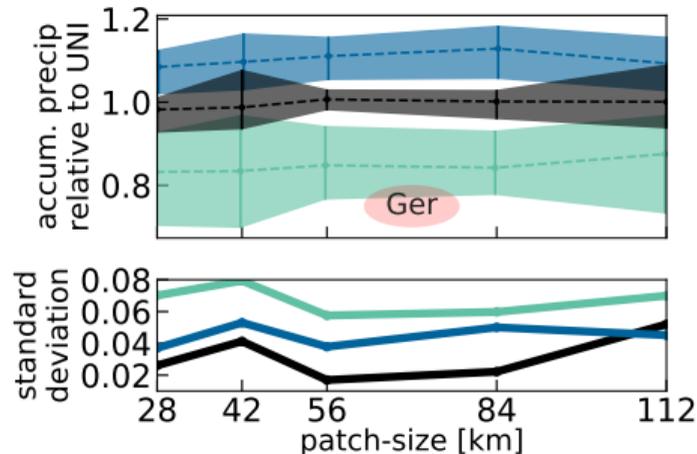
- Earlier increase of afternoon convective precipitation over dry patches
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→ Confirmation of observational results

Is the influence of soil moisture heterogeneity negligible after averaging over a large domain and several weakly forced case studies?

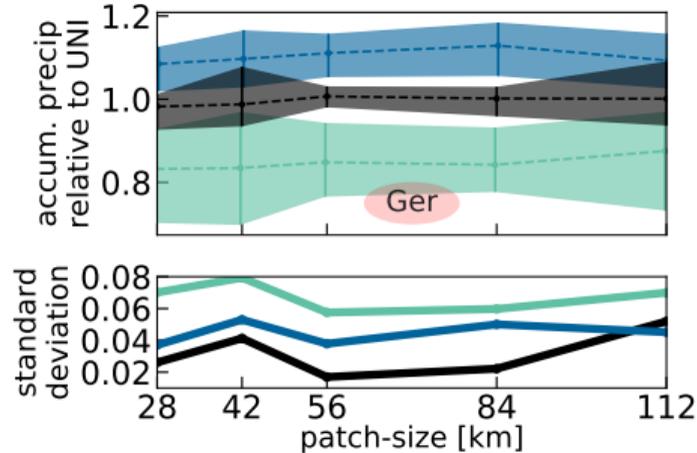
2. Scale dependence of soil moisture heterogeneity



Domain averaged, daily precipitation
dependent on patch size

- Domain averaged precipitation shows no scale dependence
- But: dependence on bias clearly visible
- Envelope shows scale dependent variability
- Standard deviation of CNB shows minimum in variability in scale range 50 – 80 km

2. Scale dependence of soil moisture heterogeneity

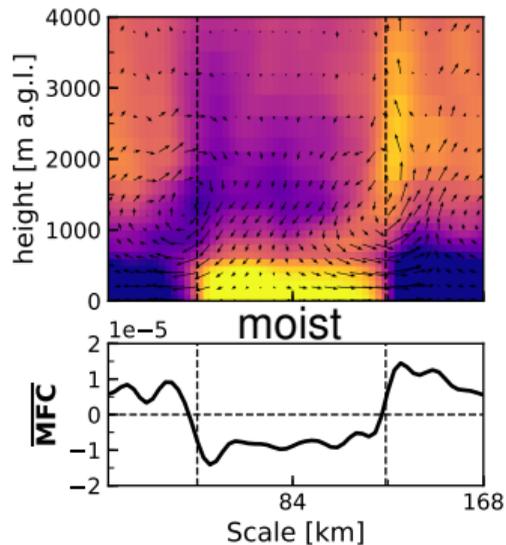


- Domain averaged precipitation shows no scale dependence
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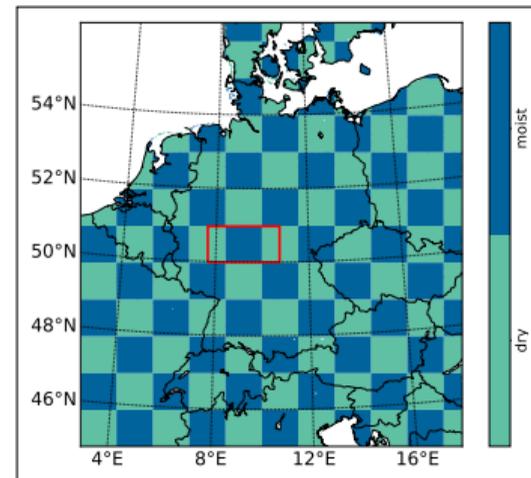
Is the minimum in variability linked to a physical mechanism?

3. Mechanisms: Mean vertical cross-section

6 June 12UTC: CNB_084k - UNI



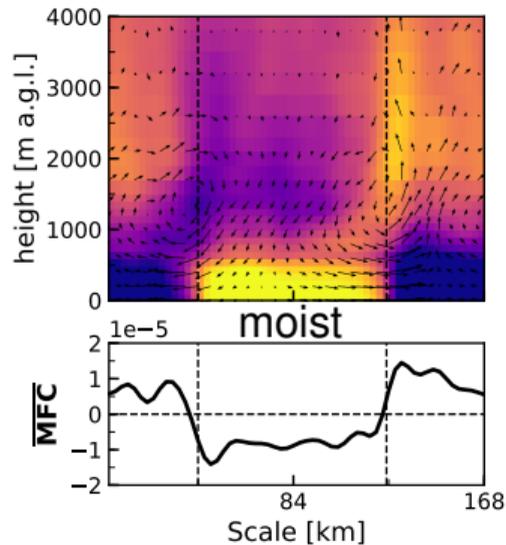
- Moist Static Energy (*MSE*, shaded)
- u- & w-wind (arrows)
- Moisture Flux Convergence (\overline{MFC}) vertically averaged over lowest 1000 m



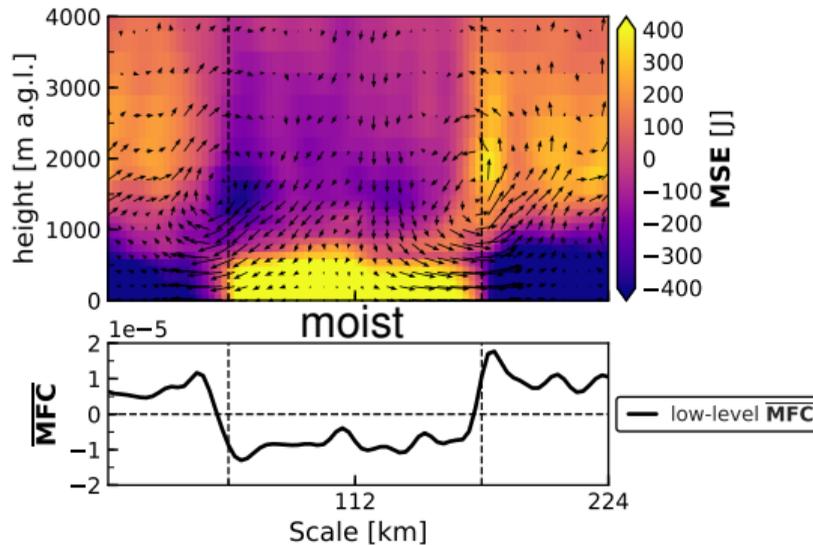
Averaging pattern shifted zonally through the domain and averaged meridionally

3. Mechanisms: Scale dependence

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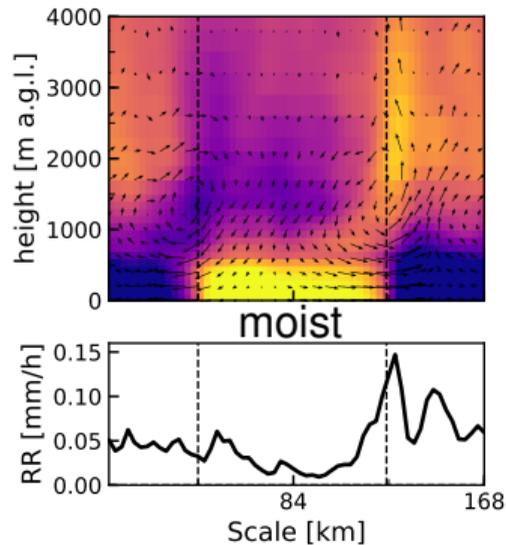
6 June 12UTC: CNB_112k - UNI



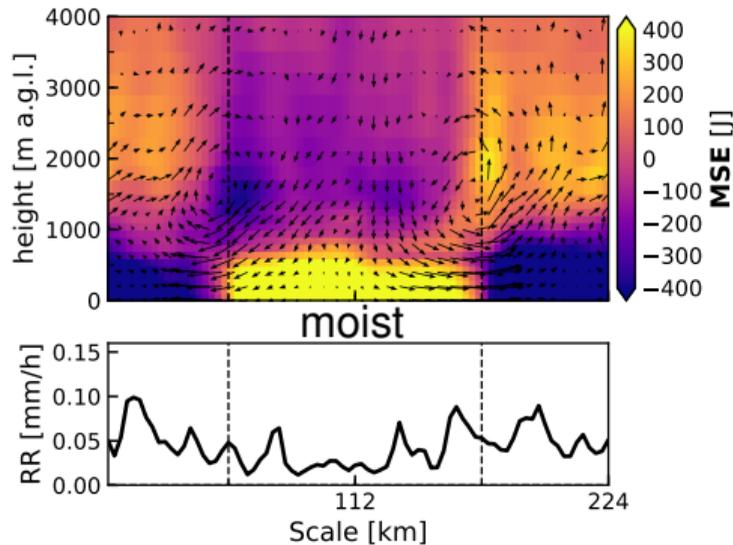
- Divergence over moist patch; Convergence over dry patch
- Highest MSE in moist Boundary Layer over moist patch
- Downwind flank of dry patch shows increased convergence → export of MSE

3. Mechanisms: Scale dependence of hourly precipitation

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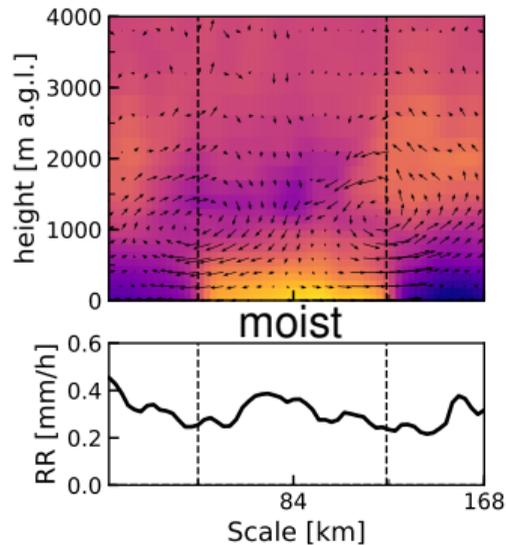
6 June 12UTC: CNB_112k - UNI



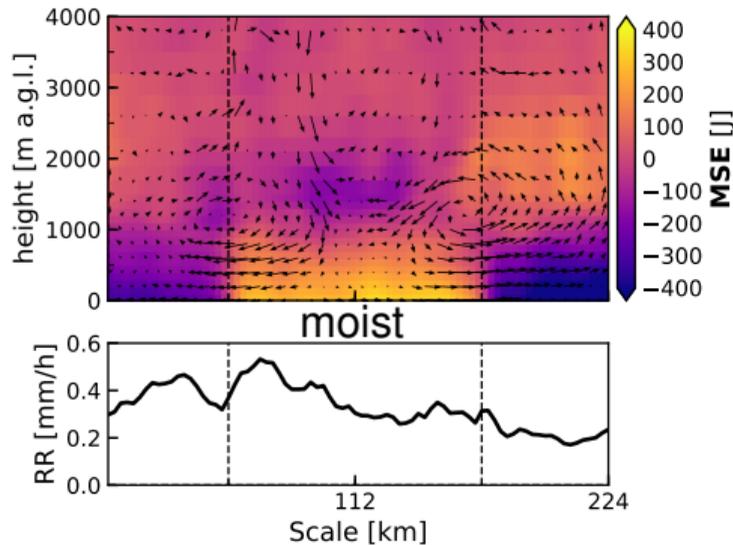
- Updraft region on downwind flank of dry patch more prominent for 84 km scale
- Strongest precipitation locked at this updraft region
- Weaker signature of patch size at 112 km scale

4. Regime dependence

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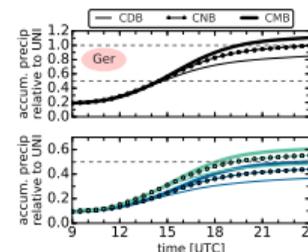
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- Weaker dipole in MSE
- Circulation cells shallower
- No distinct updraft region to lock convection

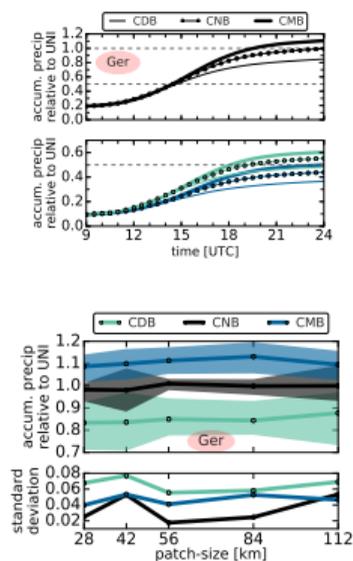
Summary

- COSMO experiments confirm satellite observations
- ① • Soil moisture **bias** influences **domain averaged precipitation**
- Soil moisture **heterogeneity** influences **local precipitation**



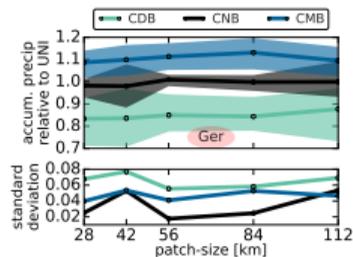
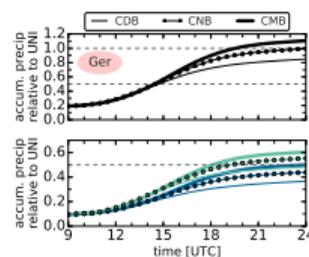
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- Daily precipitation independent of heterogeneity length scale
- ② • **Smallest day-to-day variability** of daily precipitation at scales of **50 – 80 km**



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- Daily precipitation independent of heterogeneity length scale
- ② • **Smallest day-to-day variability** of daily precipitation at scales of **50 – 80 km**
- **Locking** of maximal precipitation **at upwind flank of moist anomaly** with 50 – 80 km patch size
- ③ • Less constraint of precipitation on soil moisture anomalies at larger sizes
- ④ • **Clearer signature** of soil moisture anomalies during **weak forcing**



6 June 12UTC: CNB_084k - UNI

