Effects of shallow convection schemes in perennial convection-permitting simulations with CCLM and WRF

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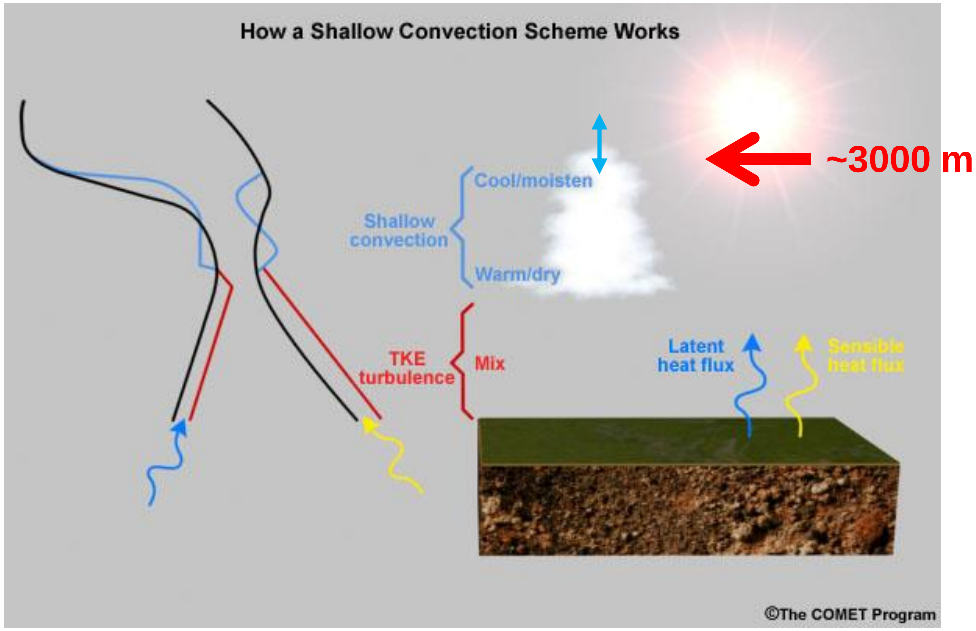
Initiative of WG CRCS

Introduction

- **Shallow cumulus convection**

(Flight from Vienna to Naples, 2019-09-16: Shallow convection in action)



(http://stream1.cmatc.cn/pub/comet/numerical/InfluenceofModelPhysicsonNWPForecastsversion2/comet/nwp/model_physics/navmenu.php_tab_1_page_2.6.5.htm)

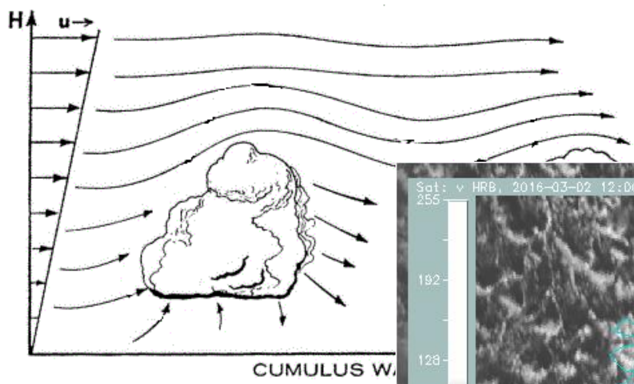
Shallow convection

➔ affects heat, moisture, and momentum exchange between PBL and free atmosphere

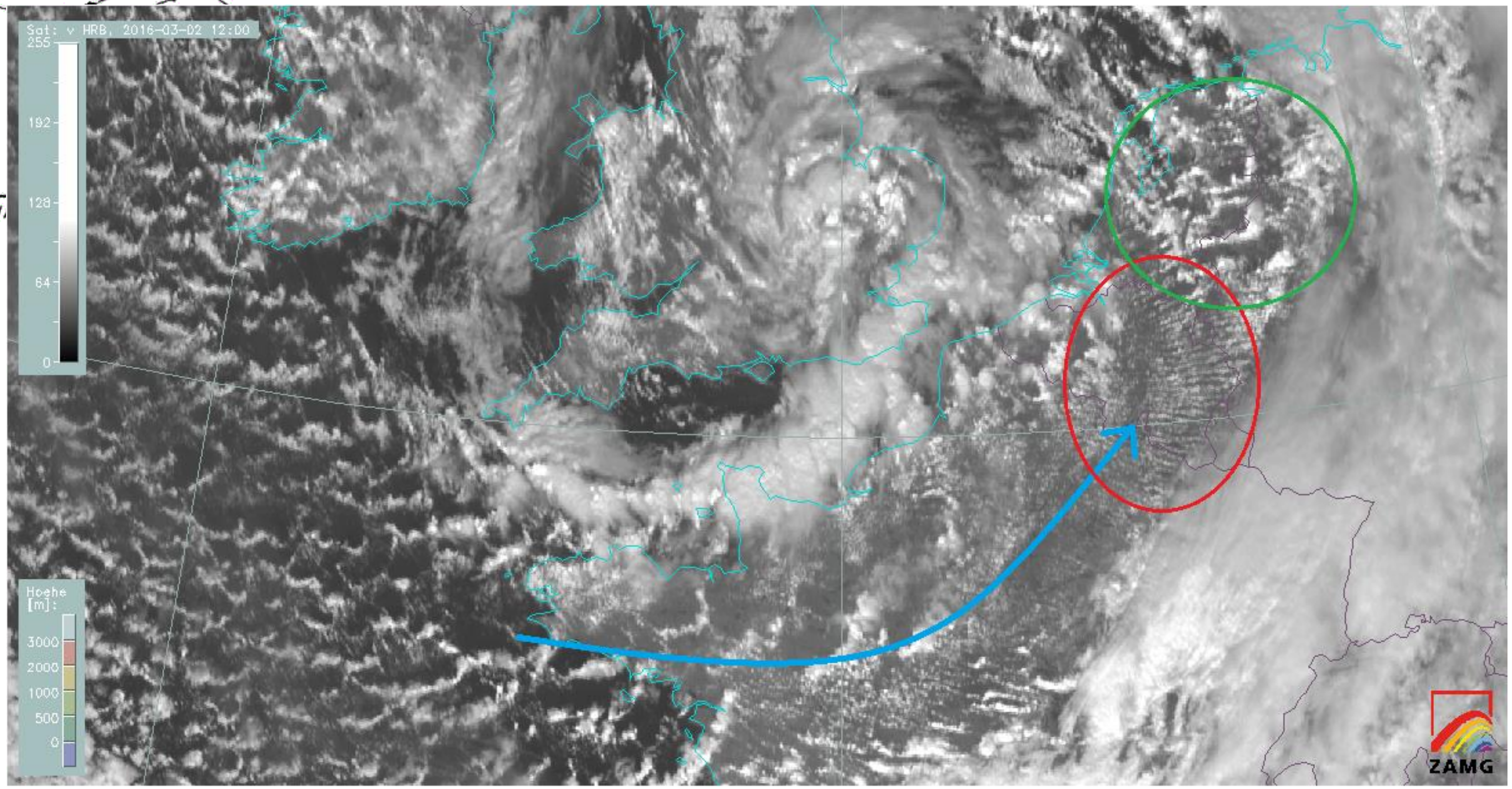
➔ changes radiation transfer via clouds

Introduction

- **Shallow cumulus convection**



(WMO, 1978)



(MSG HR-VIS image from 2nd March, 2016, 12:00 UTC from www.eumetrain.org)

Shallow convection induces deep convection hundreds of kilometers downstream via wave propagation

Introduction

- **Shallow cumulus convection has global consequences**

Geophysical Research Letters

Climate | Free Access

Interaction of deep and shallow convection is key to Madden-Julian Oscillation simulation

Guang J. Zhang, Xiaoliang Song

First published: 08 May 2009 | https://doi.org/10.1029/2009GL037340 |

Impacts of Vertical Structure of Convection in Global Warming: The Role of Shallow Convection

Chao-An Chen
Research Center for Environmental Changes, Academia Sinica, Taipei, Taiwan

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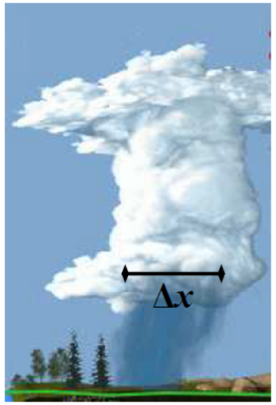
"Shallow convection…

→ … will strengthen the tropical circulation and enhance vertical motion…"

Introduction

- **Shallow cumulus convection**

Resolution Issues (cont'd)



Deep convection is "permitted",
do we need a parameterization scheme?

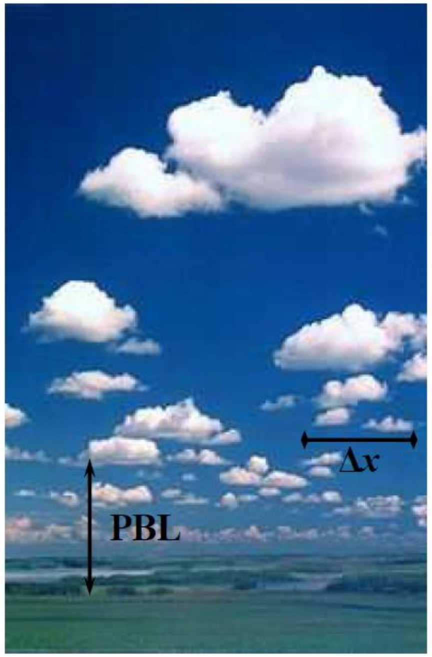
(i) Keep deep convection parameterization scheme but make it resolution dependent, i.e. the scheme should become less active as the mesh size decreases (e.g. Gerard and Geleyn 2005, Gerard et al. 2009, Gerard 2012, http://convection.zmaw.de for further references).

(ii) Switch off deep convection scheme but use shallow convection scheme (COSMO-DE solution).

(iii) Switch off deep convection scheme and use unified turbulence-shallow convection scheme formulated in the in the language of second-order closure (Machulskaya and Mironov 2013).

IMHO, (iii) is the way to go.

Resolution Issues (cont'd)



Shallow clouds and PBL turbulence are unresolved and should be parameterized.

Image http://en.wikipedia.org/wiki/Weather_lore

(With curtesy Mironov, 2015)

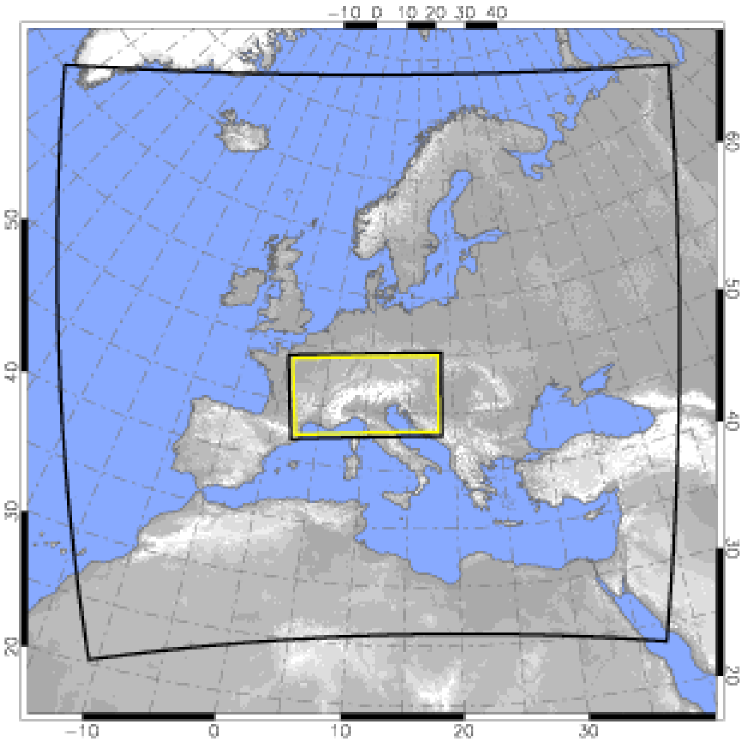
For convection permitting simulations

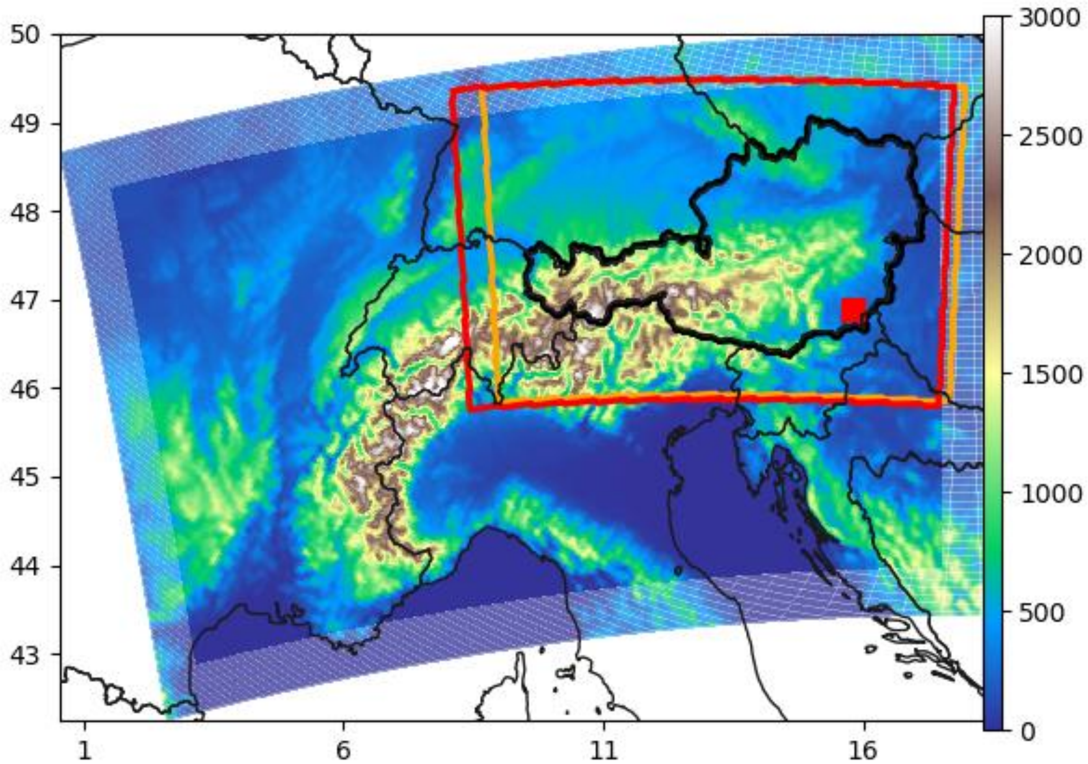
➔ It is generally advisable to make use of a shallow convection parameterisation scheme

Experimental setup

- **NHCM-2**

(Piazza et al., Met. Z., 2019)



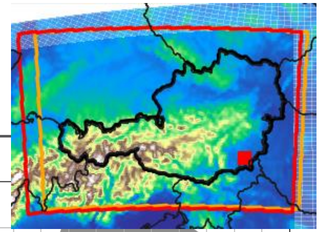


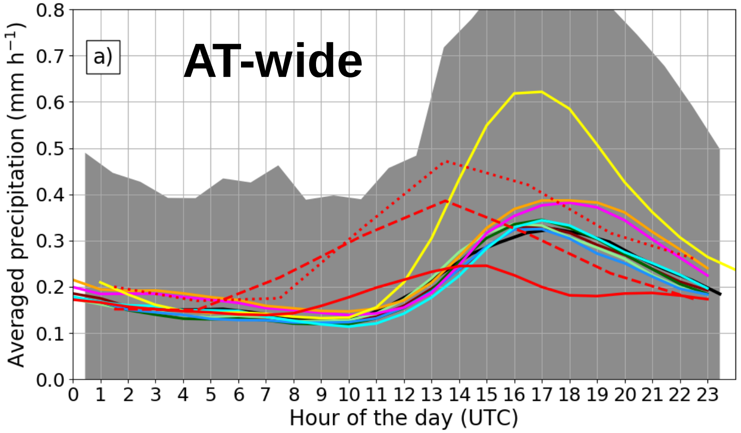
- 12.5 km (EUR-11) → 3 km (GAR) and **direct nesting**
- 3 km: deep conv. OFF; sh. conv. ON/OFF
- 7 sensitivity runs with **CCLM5.0**
- period: JJA 2006 to 2009
- spin-up: 26 years (CCLM4.8)
- ERA-Interim, **IFS**

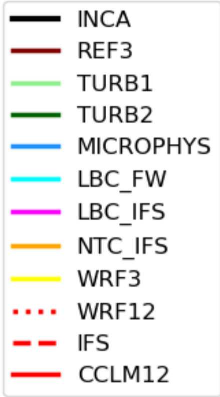
REF	no deep conv.; sh.conv. = Tietdke	REF
turbulence	tur_len = 150; q_crit = 1.6; iadv_order = 5	TURB1
	no correction of vertical turbulent diffusion	TURB2
mirco physics	v0snow = 15; qc0 = 0.0005	MICROPHYS
LBCs	1 h update freq., incl. W	LBC_FW
	IFS as driving data	LBC_IFS
	no shallow conv.	**NTC_IFS**
WRF 3.7.1	no deep conv.; sh.conv. via PBL (Quasi-Normal Scale Elimination; QNSE)	WRF3

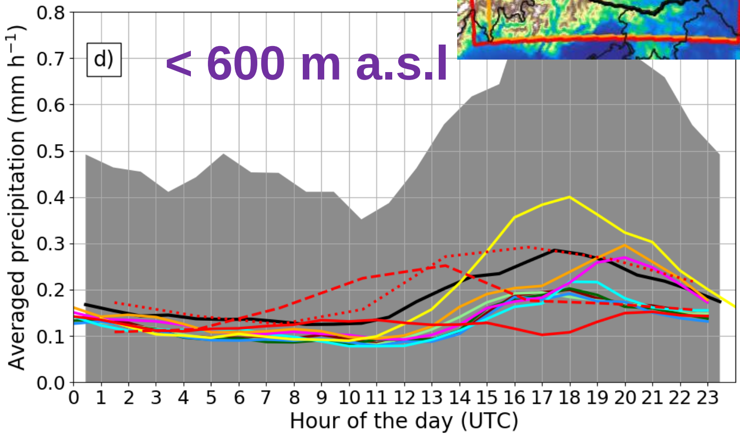
- INCA (Haiden et al., 2011) → diurnal cycles in averaged precipitation AT-wide, below 600 m a.s.l.

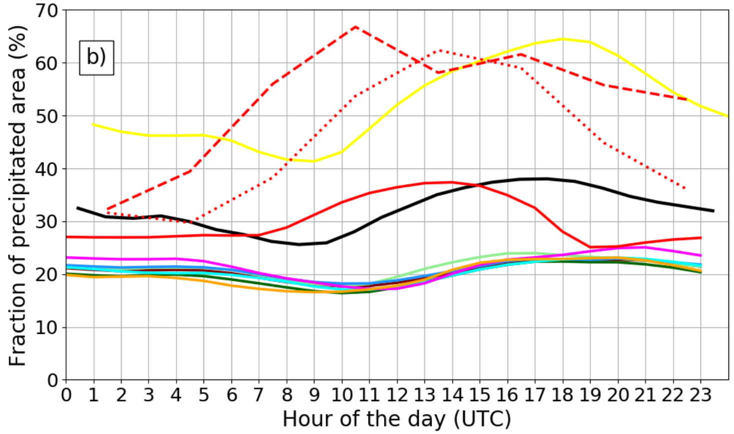
Results NHCM-2





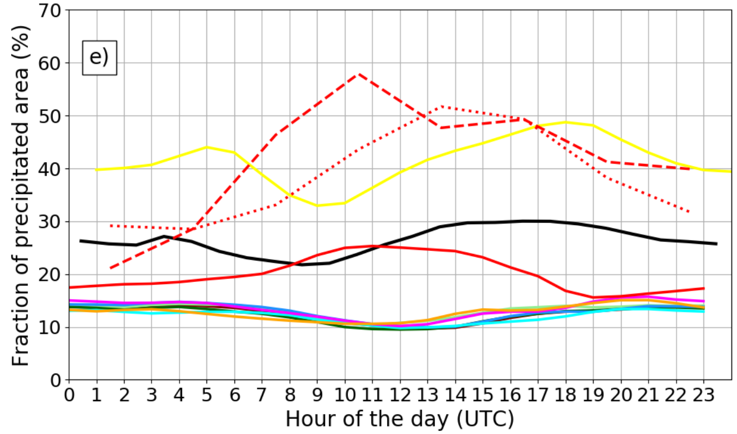


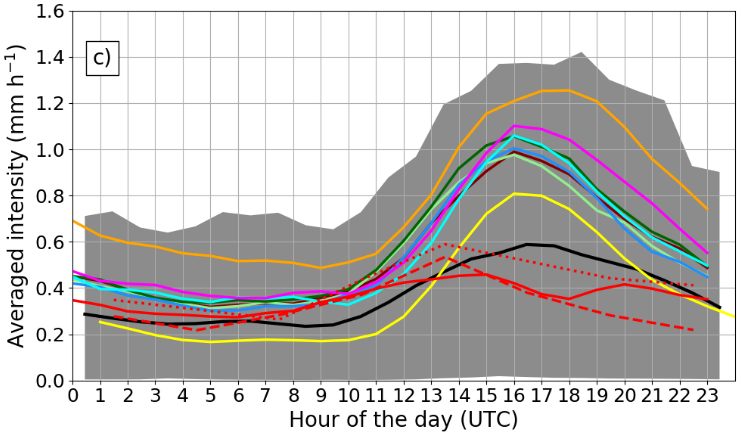




AT-wide:

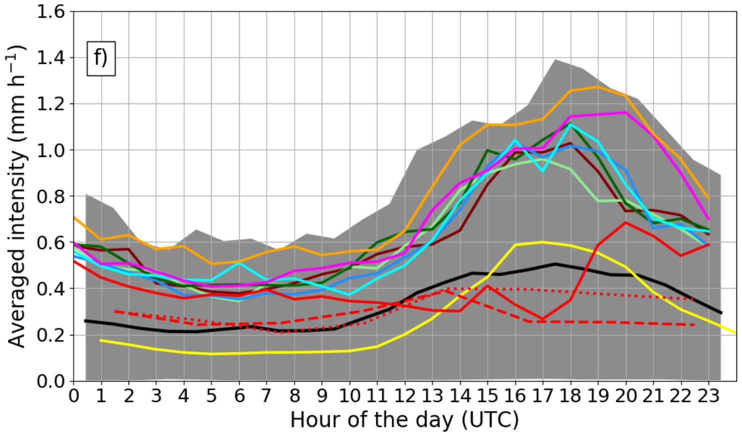
- ➔ added value compared to coarser resolution
- ➔ diurnal cycle is well represented, but precipitation events are too small and too intensive
- ➔ shallow conv. gives more intensive events





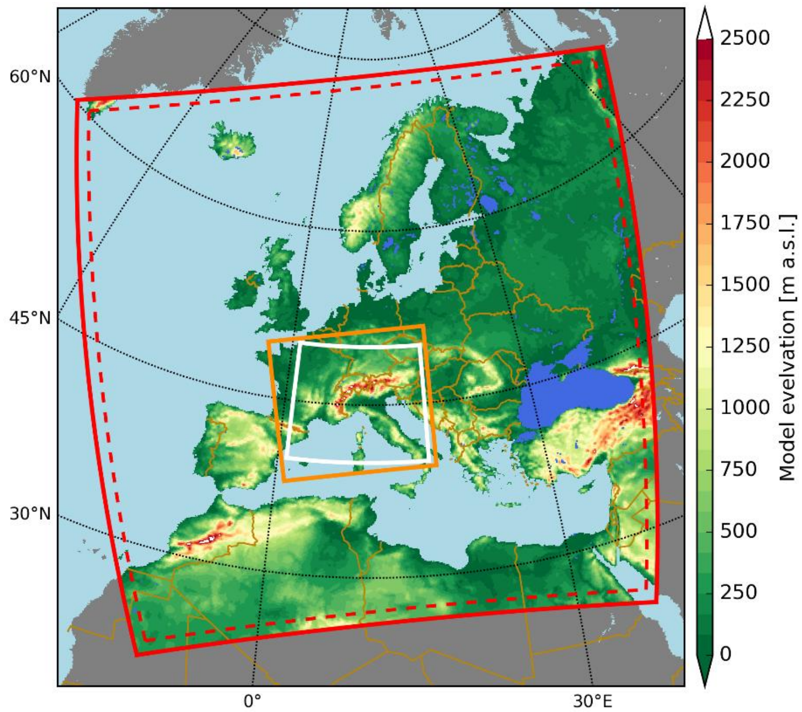
< 600 m

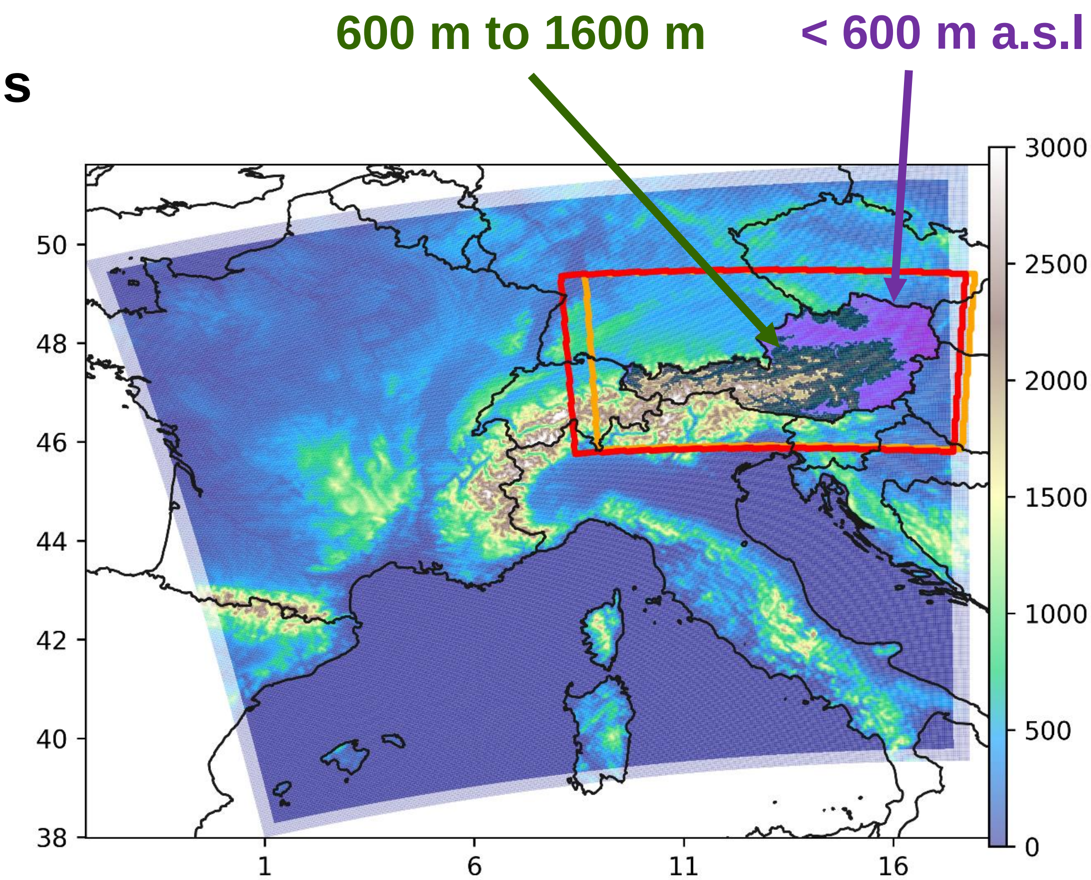
- ➔ afternoon peak is underrepresented
- ➔ events are even smaller; intensity is unchanged
- ➔ diurnal cycle of sizes is missing
- ➔ shallow conv. gives more intensive events



Experimental setup CORDEX-FPS WRF

- **CORDEX-FPS WRF twin simulations**





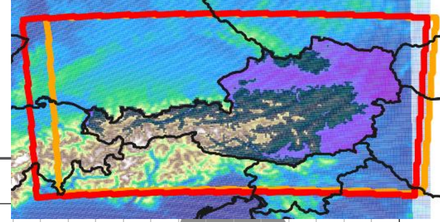
- 15 km (EUR-15) → 3 km (GAR) online nesting
- period: JJA 2006 to 2009
- spin-up: 7 years
- ERA-Interim
- INCA
- → diurnal cycles below **600 m** a.s.l. and from **600 m to 1600 m** a.s.l

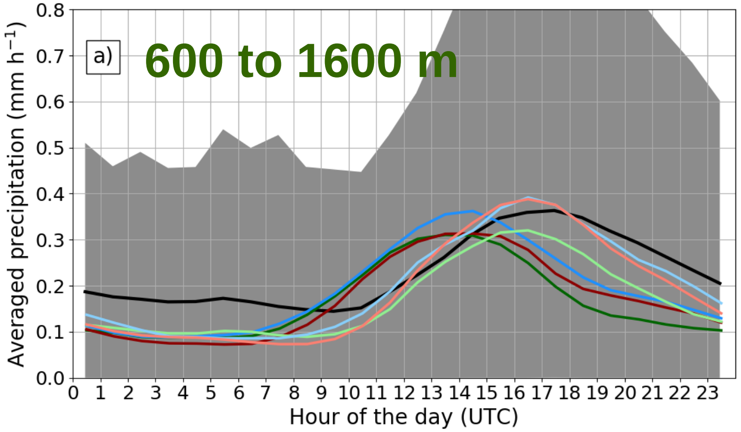
WRF 3.8.1 on same machine

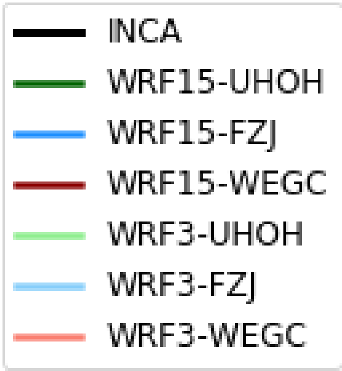
Josipa Milovac (University of Hohenheim)

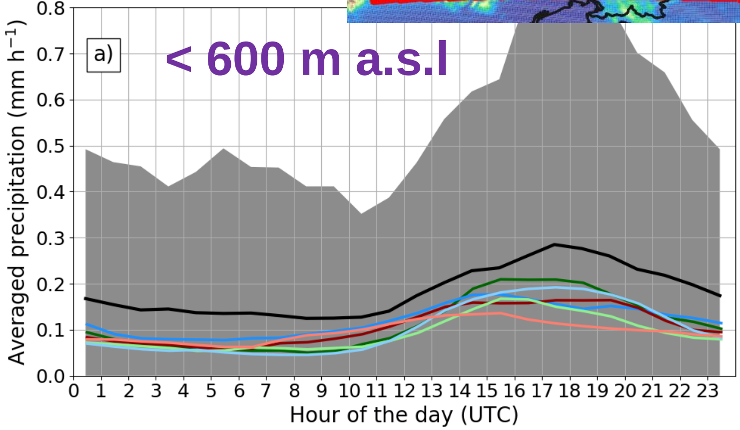
	FZJ	WEGC	UHOH
mirco physics	Thompson 28	Thompson 28	Thompson 28
pbl	YSU	YSU	MYNN2
land surface model	NOAH	NOAH	NOAH-MP
deep convection	d01: Grell-Freitas d02: none	d01: Grell-Freitas d02: none	d01: Grell-Freitas d02: none
shallow convection	GRIMS	d01: GRIMS **d02: none**	GRIMS
radiation	RRTMG	RRTMG	RRTMG
surface layer	MM5	MM5	MYNN
aerosol treatment	ra & mp impact	ra & mp impact	ra & mp impact

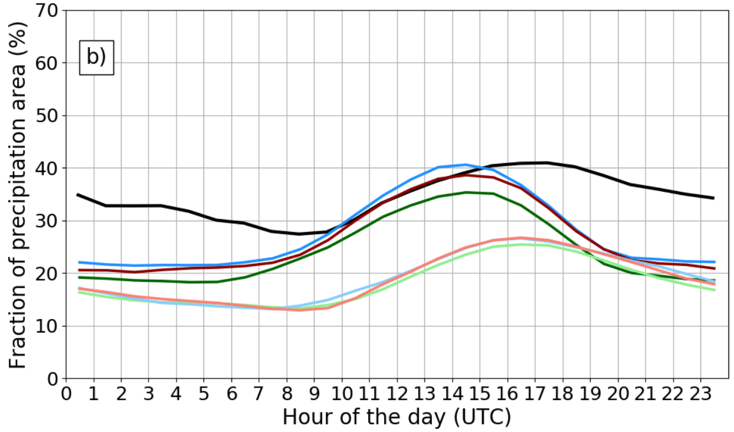
Results WRF





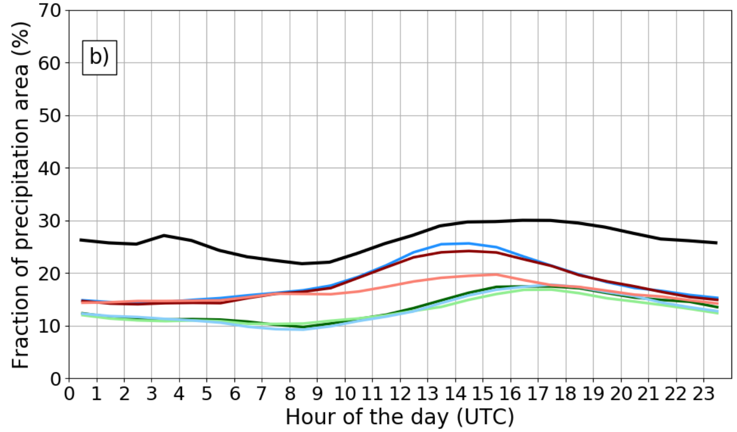


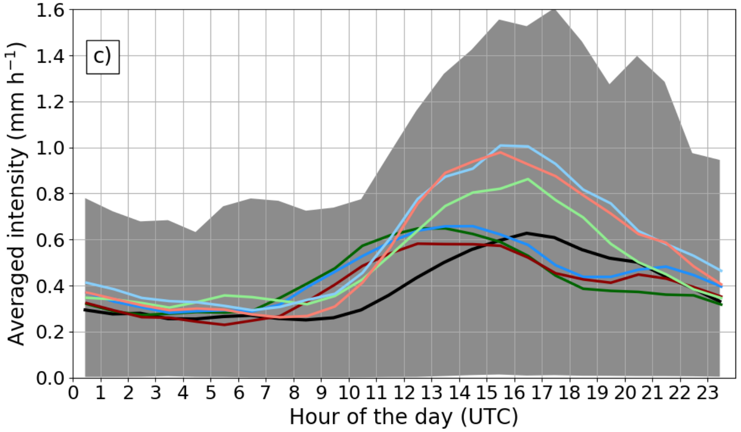




600 m to 1600 m

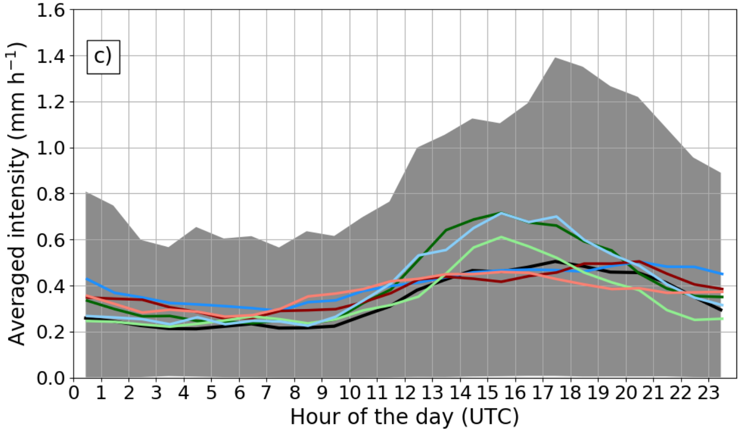
- ➔ added value compared to coarser resolution
- ➔ diurnal cycle is well represented, but precipitation events are too small and too intensive
- ➔ shallow conv. has no effect





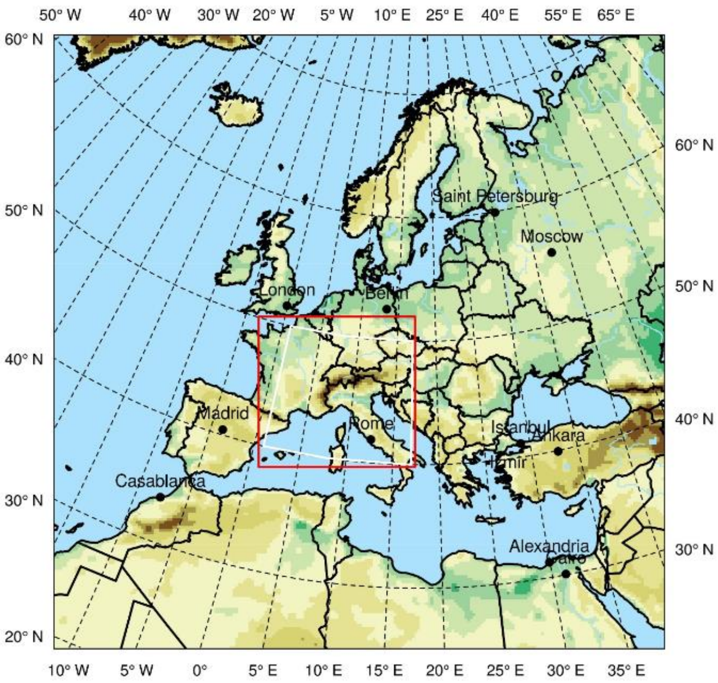
< 600 m

- ➔ afternoon peak is underrepresented
- ➔ events are even smaller; intensity is unchanged
- ➔ shallow conv. Is important for realistic diurnal cycle



Experimental setup CEGPC5.0

- **CEGPC5.0**



- 3 km (GAR) direct nesting
- period: 2008
- spin-up: 1 year
- COSMO-DE
- INCA
- → diurnal cycles below **600 m** a.s.l. and from **600 m to 1600** m a.s.l

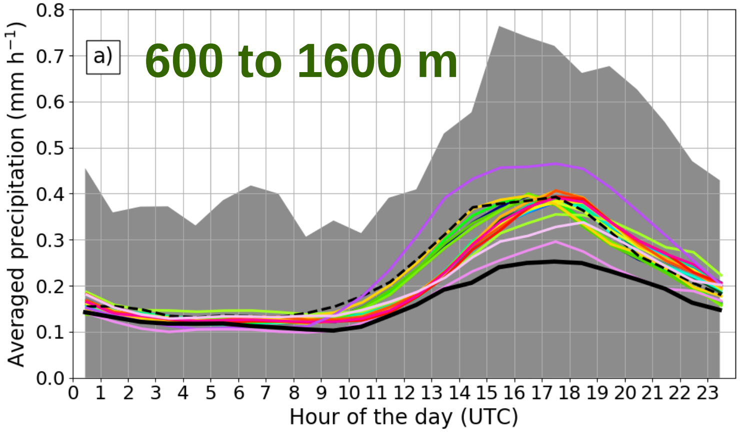
Simulation ID	Namelist-Parameter	value in reference config CEG100	tested values
CEG100		reference config cosmo-SW2_20150421_5.0	
CEG101	dt	25s	10s
CEG102	dt	25s	15s
CEG105	itype_heatcond	1	2
CEG108	llake	TRUE	FALSE
CEG109	itype_root	1	2
CEG110	itype_albedo	1	2 forcing CEG_albedo
CEG111	itype_albedo	1	3 (try without new spin up)
CEG112	itype_albedo	1	4 (try without new spin up)
CEG113	lradtopo	FALSE	TRUE
CEG114	lsso	FALSE	TRUE
CEG115	hincrad	0.25	0.1667
CEG116	hincrad	0.25	0.5
CEG118	itype_aerosol	1	2(Tegen)
CEG119	itype_evsl	2	3
CEG		2	4
CEG		3	1
CEG122	itype_turb	3	2
CEG123	lconv	TRUE	FALSE
CEG127	radqc_fact radqi_fact	0.5	0.8
CEG130		5	4
			TRUE
		not existing	TRUE
	ladv_symmetric	not existing	TRUE
	l_diff_cold_pools hd_corr_u_bd	0.75	0
	hd_corr_t_bd hd_corr_p_bd	0.75	0
		0.75	0
CEG131	as CEG130 but lsso		
	tkhmin	.FALSE.	.TRUE.
	tkmmin	0.4	0.01
	rlamheat	0.4	0.01
	gkwake	1	0.5249
	l_diff_Smag	0.5	0.8
	ltkesso	.TRUE.	.FALSE.
		.FALSE.	.TRUE.

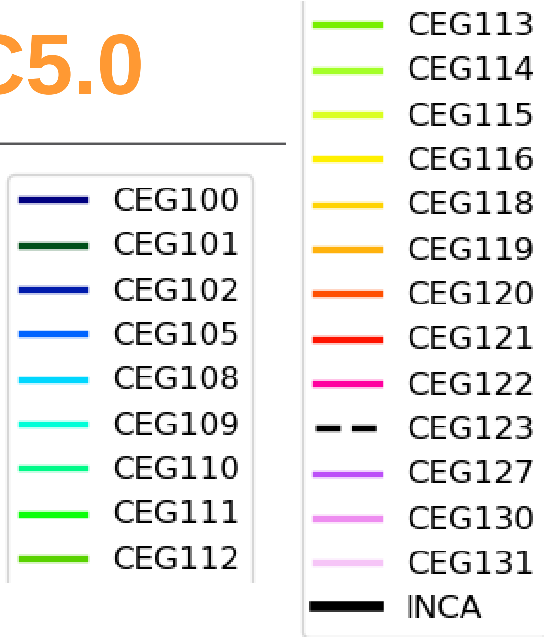
→ CEG123: no shallow conv.

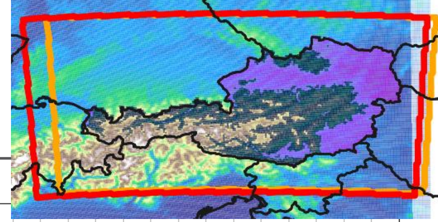
→ CEG127: revised optical thickness of sub-grid clouds

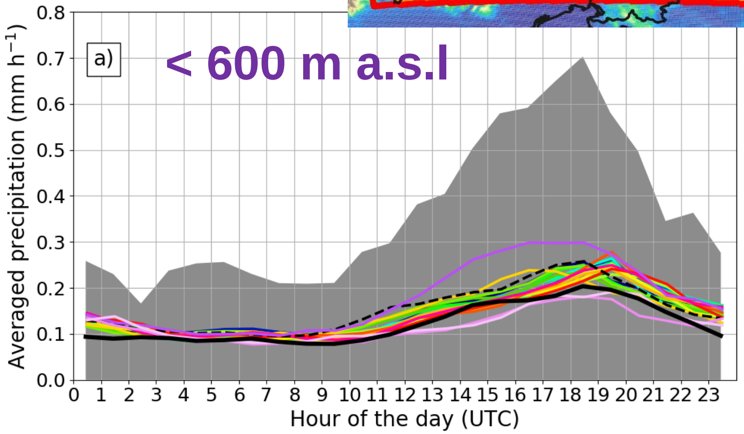
Results CEGPC5.0

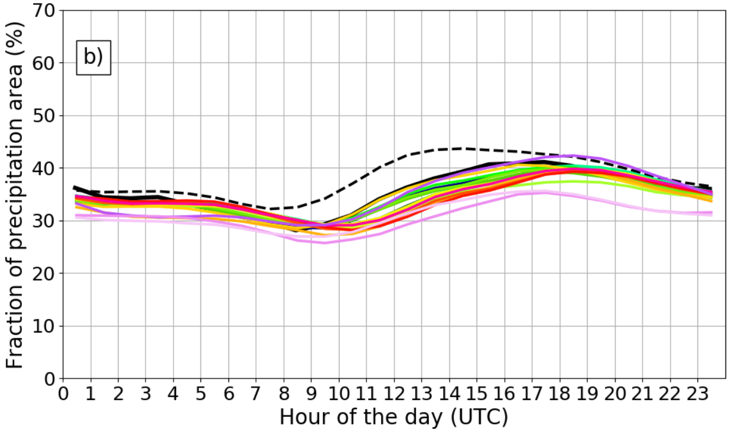
AMJJAS 2008





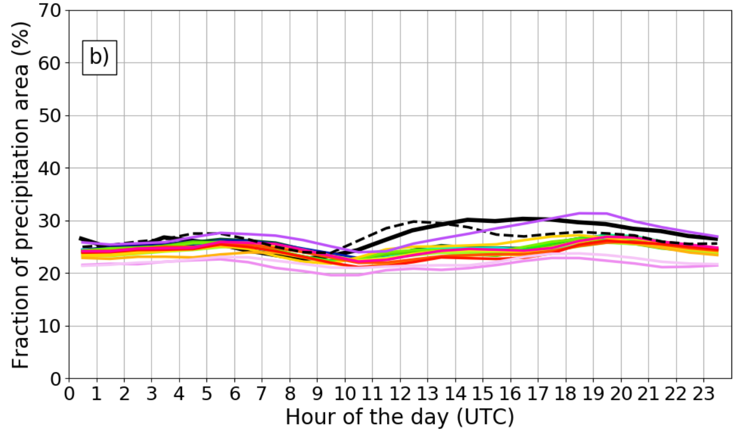


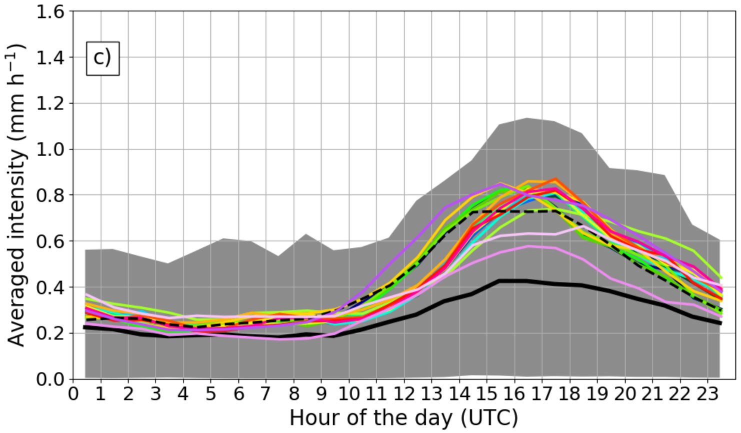




600 m to 1600 m

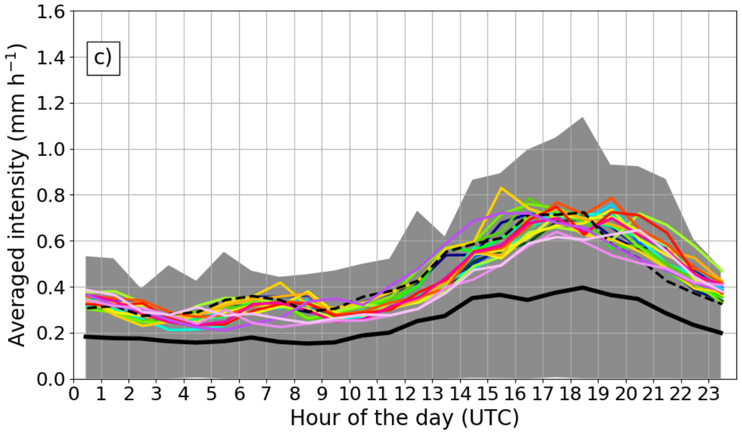
- ➔ afternoon peak is systematically overestimated
- ➔ events are too small and too intensive
- ➔ no shallow conv. overestimates size of events and onset is too early





< 600 m

- ➔ afternoon peak is better captured
- ➔ events are still too small; intensity is unchanged
- ➔ diurnal cycle of event size is largely missing
- ➔ no shallow conv.: onset is too early



Conclusions

- A shallow convection parameterisation is required in low lands; it has a minor impact in mountains
- "Good looking" afternoon peak in summertime precipitation is based on a cancellation of different biases (overestimated intensities and underestimated areas)
- Phenomenon of "too small and too intensive" events is unclear
- Missing afternoon peak in event "sizes" is unclear
  → CEG127 gives most promising results