Sensitivity of orographic precipitation in a set of convection-permitting simulations in the Alpine region

Marie Piazza[1], Heimo Truhetz[1], Andras Csaki[1], Andreas Prein[2]
(1) University of Graz, Wegener Center for Climate and global Change, Graz, Austria
(2) National Center for Atmospheric Research, Boulder, Colorado

Regional and Local Climate Modelling Research Group

R e L o C l i m

Motivations

The added-value of Convection-Permitting Climate Modeling (CPCM; review paper Prein et al. 2015) - State of the art:

- better representation of deep convection and diurnal cycle of precipitation in summer
- improved representation of extreme events on hourly time scales
- better representation of the spatial structure of precipitation objects
- improved frequency of wet-days (overcome the 'drizzling effect' of coarser resolution RCMs with parametrized convection)

Goals of this study

- Estimate the role of physical parameters on the representation of precipitation in climate simulations in the Alpine region
- Investigate the role of the driving data

High resolution gridded datatsets for precipitation

Name and reference	Type of measurments	Domain and resolution	Period and frequency
INCA* *Haiden et al. 2011*	Radar + stations	Austria+ 1 km	Since 2006, hourly
GPARD-1* *Hofstätter et al. 2015*	Rain gauges	Austria+ 1 km	Since 1961, daily

*Provided by the Austrian Department for Meteorology and Geodynamics (ZAMG)

RCMs setup and sensitivity experiments

Domain: Greater Alpine Region
Resolution: 0.0275° (~3km)
Period: 2006 – 2010
Spin-up run (soil): 17 years
Reference simulation with COSMO-CLM v5.0

- **REF3**
- Driving data **CLM12**: EURO-CORDEX 0.11° hindcast (K. Keuler, BTU Cottbus); update freq.:3-hourly

WRF simulation WRF3
similar setup as for REF3

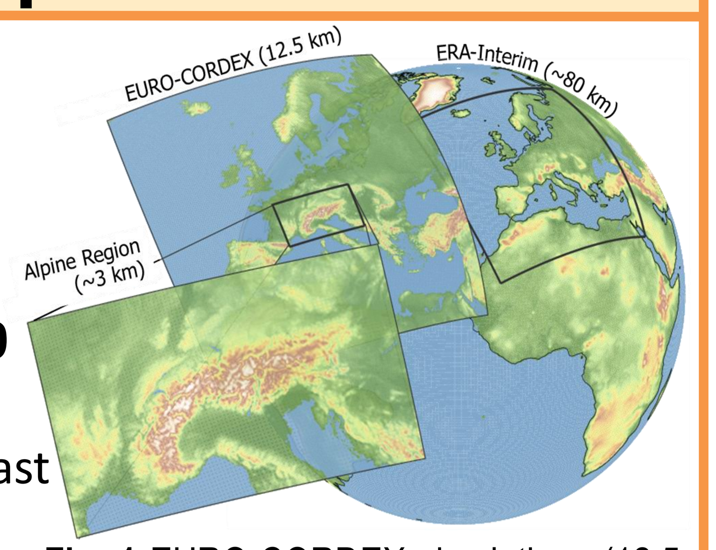

Fig. 1 EURO-CORDEX simulations (12.5 km resolution) are downscaled at 3 km over the Greater Alpine Region. From Prein et al. 2015.

Parameters	Description	Name
Lateral boundary conditions	Increase frequency (3h → 1h) and include W New driving run: ERAint_011_r2i1p1	LBC_FW
	IFS as driving data (*stops in 2009*)	LBC_IFS
Turbulence	Unstable summer condition Decrease turbulent length scale: tur_len=150 q_crit=1.6;iadv_order=5	TURB1
	Turn off correction of vertical turbulent diffusion (turbulent heat and moisture fluxes due to subgrid-scale condensation) lexpcor=FALSE	TURB2
Orography	Smoothed orography at 0.11°	OROG11
Microphysics	Tuning microphysics - increase falling speed of snow: v0snow=15 - decrease conversion rate to graupel: qc0=0.0005	MICROPHYS

Model-dependency of the afternoon peak of precipitation im summer

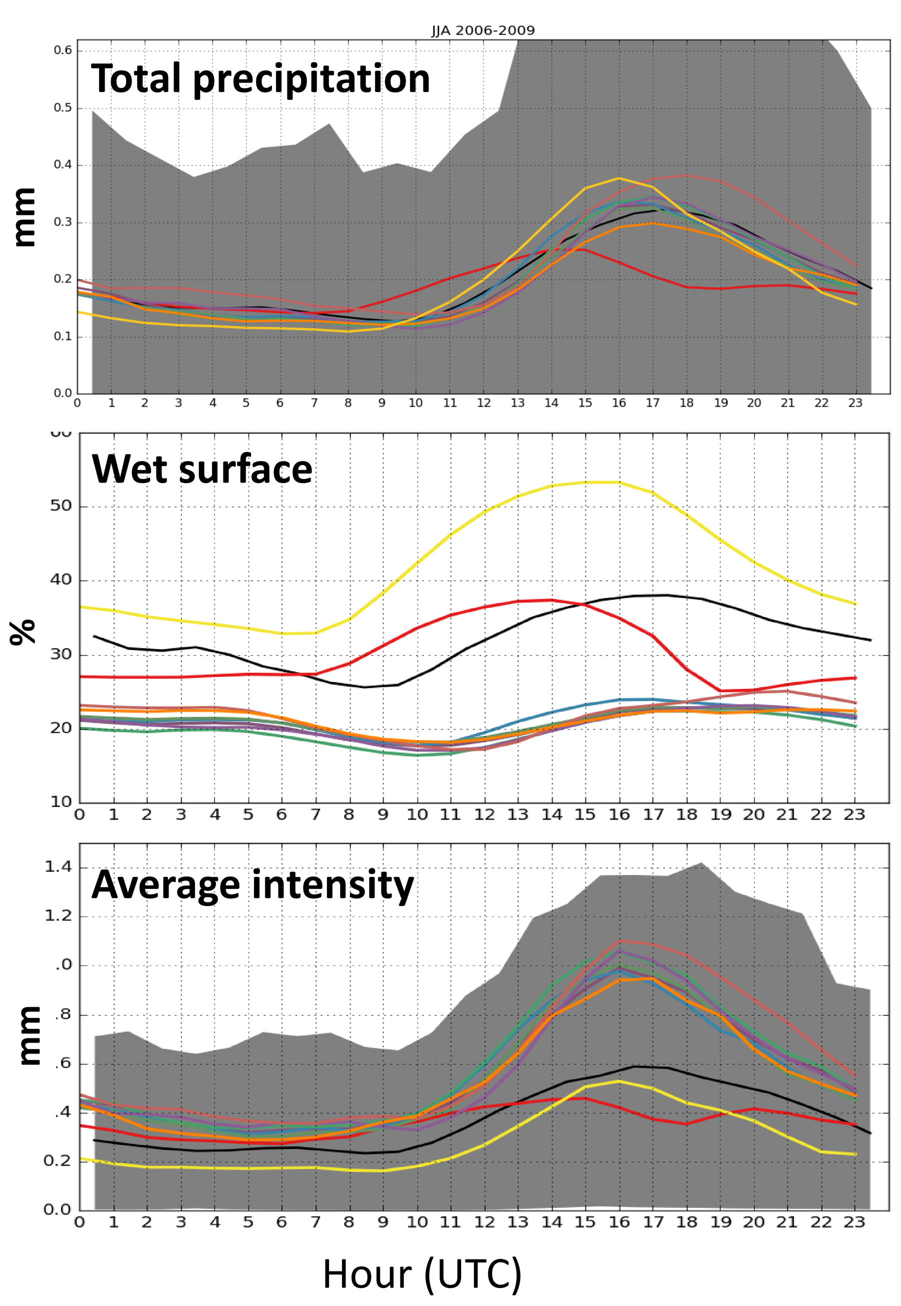

Fig. 2 Diurnal cycles of total precipitation in summer (JJA) 2006-2009, for Austria. (Top) mean precipitation, (middle) fraction of surface with non-zero precipitation, (bottom) average intensity of precipitation.

- Good representation of the peak of precipitation in average in CPCM (both CCLM and WRF)
- WRF: afternoon peak primarily driven by increased of precipitating surface
- CCLM-CPCM:
  - -15% of wet surface compared to INCA
  - afternoon peak driven by increased of mean intensity
- LBC_IFS: improved duration of the late afternoon peak

Frequency-intensity distribution of total precipitation

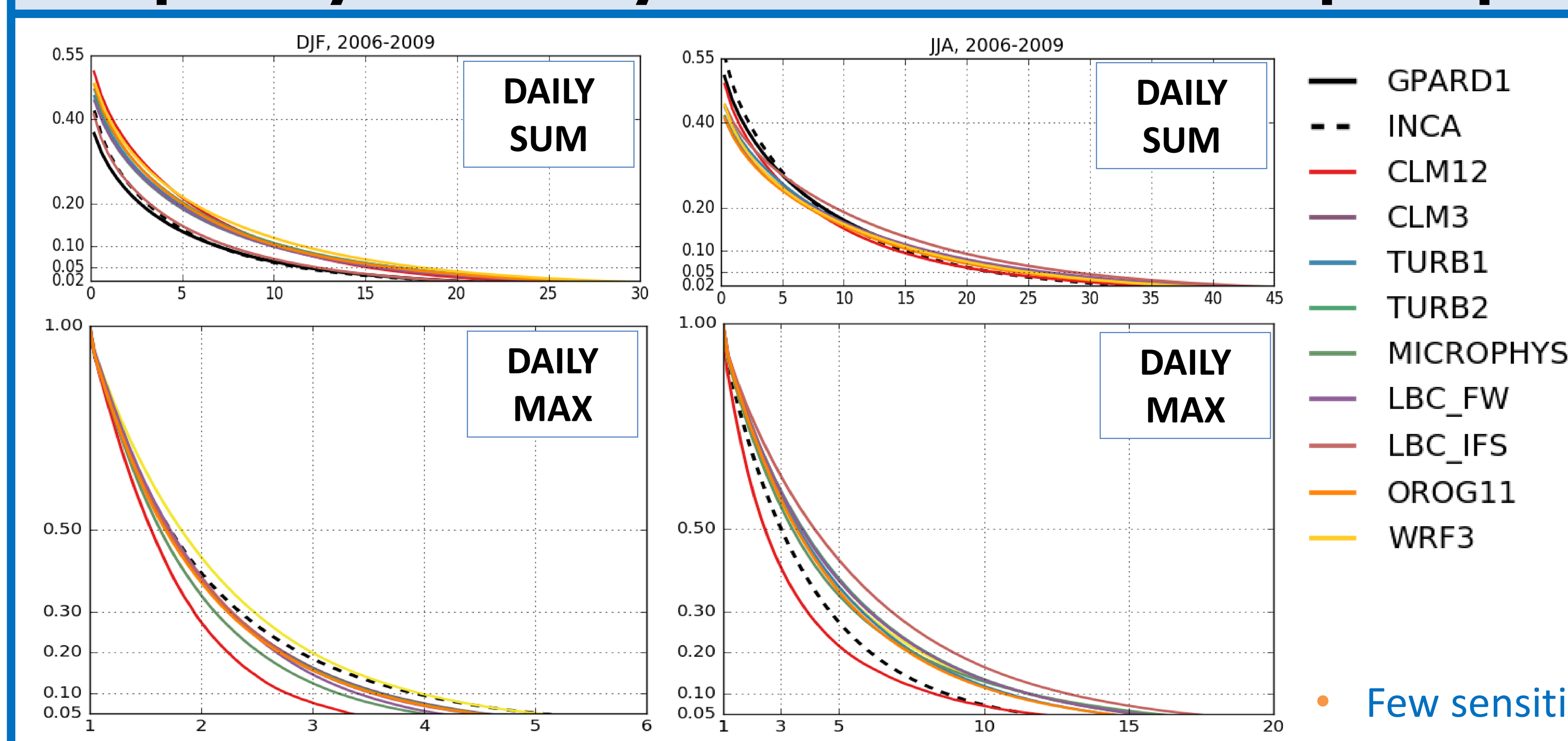

Fig. 3 Daily sum (top) and maximum (bottom) of hourly total precipitation, winter (left) and summer (right) for 2006-2009, Austria.

- LBC_IFS: excellent agreement in winter with GPARD1 and INCA
  → role of the driving data (large-scale forcing, frontal activity in the Alps)
- Added-value: daily max, extremes
- CPCM: too many dry days in summer
- Few sensitivity to TURB, OROG11, MICROPHYS, LBC_FW

Height-dependency of total precipitation

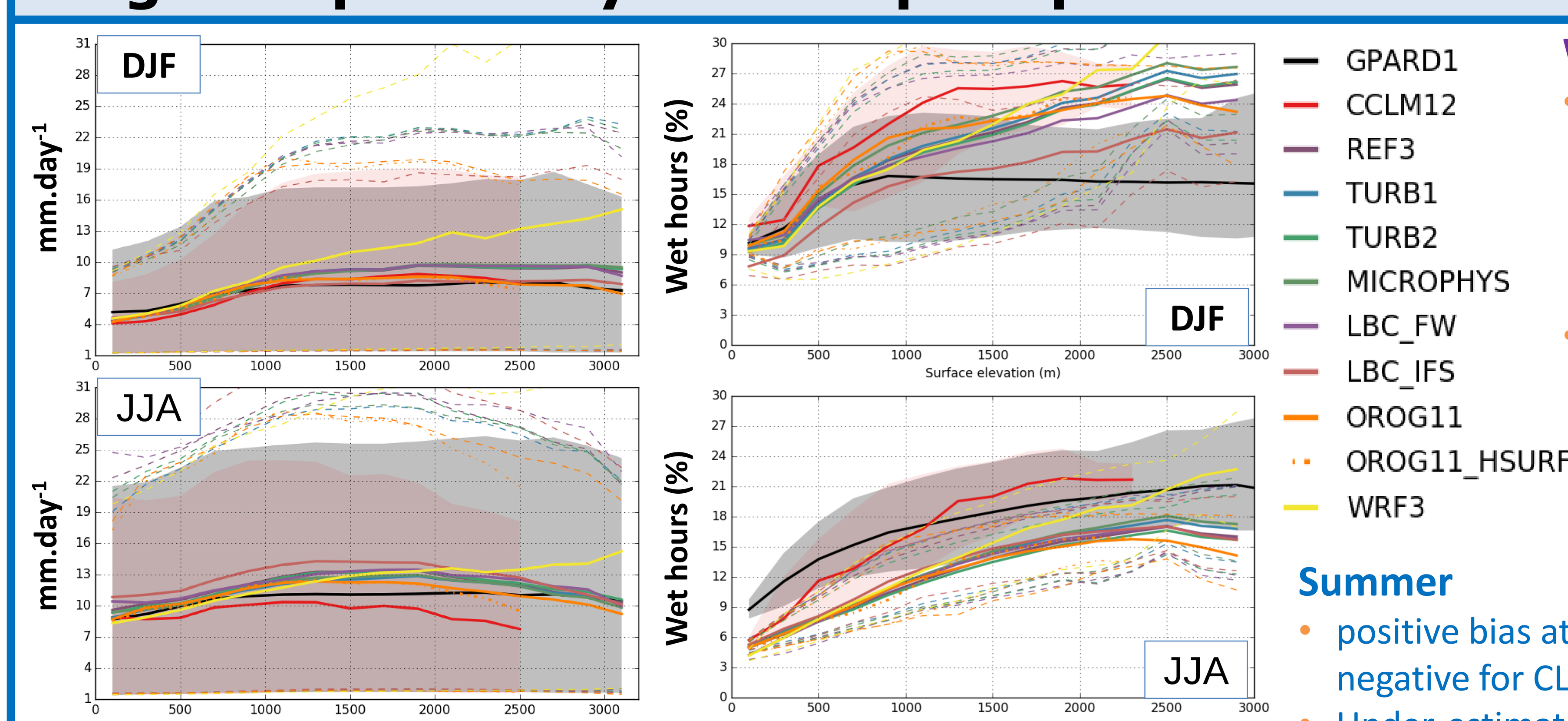

Fig. 4 Left: Mean, 10[th] and 90[th] quantiles of daily precipitation per range of surface elevation (200m height classes), for wet days (> 1 mm.day^{-1}). **Right**: same as left, but for the frequency of occurrence of wet hours (>0.1mm.hour-1)

Winter

- strong height-dependency of daily extreme values and occurrence of hourly precipitation
- OROG11 and CLM12: influence of the orography in winter
  → too strong interaction with the large-scale flow

Summer

- positive bias at all elevations for CPCM, negative for CLM12
- Under-estimation of the frequency of occurrence of hourly precipitation in CPCM, especially in low-lands (<1000m)

Conclusions

- Strong agreement between the simulations driven with CCLM12
  - sensitivity to the parameters tested for turbulence and microphysics small compared to the sensitivity to the driving data (role of the internal variability in CLM12)
  - The influence of the parameters tested is small compared to the influence of the large scale forcing (in winter) and the convective processes (in summer)
- Summer: good representation of the mean diurnal cycle in CCLM and WRF at 3km, but based on different processes and compensation of biases:
  - WRF produces too large areas of too weak precipitation
  - CCLM produces too small but too intense precipitation

References

- Prein , A. F., Rasmussen, R., & Stephens, G. (2017): Challenges and Advances in Convection-Permitting Climate Modeling. BAMS, doi: 10.1175/BAMS-D-16-0263.1.
- Prein, A. F., Langhans, W., Fosser, G., Ferrone, A., Ban, N., Goergen, K., ... & Brisson, E. (2015). A review on regional convection‐permitting climate modeling: Demonstrations, prospects, and challenges. Rev. of geophysics, 53(2), 323-361.
- Ban, N., Schmidli, J., & Schär, C. (2014). Evaluation of the convection‐resolving regional climate modeling approach in decade‐long simulations. Journal of Geophysical Research: Atmospheres, 119(13), 7889-7907.
- Kirchengast, G., T. Kabas, A. Leuprecht, C. Bichler, and H. Truhetz (2014): WegenerNet: A pioneering high-resolution network for monitoring weather and climate. BAMS, 95, 227-242, doi:10.1175/BAMS-D-11-00161.1
- Haiden, T., A. Kann, C. Wittmann, G. Pistotnik, B. Bica, and C. Gruber (2011): The Integrated Nowcasting through Comprehensive Analysis (INCA) System and Its Validation over the Eastern Alpine Region, Wea. Forecasting, 26, 2, 166-183, doi: 10.1175/2010WAF2222451.1

Acknowledgments: The computational results presented have been achieved in part using the Vienna Scientific Cluster (VSC). The authors gratefully acknowledge the computing time granted on the supercomputers JUROPA and JURECA at Jülich Supercomputing Centre (JSC).