The first multi-model ensemble of regional climate simulations at kilometer-scale resolution
Part I: Evaluation of precipitation

Nikolina Ban

CORDEX-FPS convection and EUCP WP3 teams

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universität innsbruck

EUCP
European Climate Prediction system

Introduction

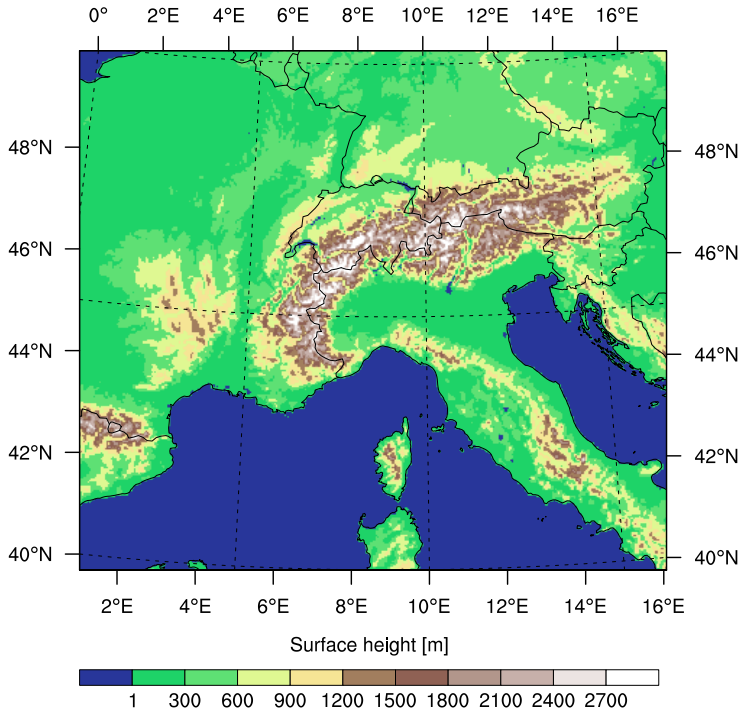
- With recent advances in computing power, a number of studies started to show improvements in model performance when the grid spacing is increased to kilometer-scale and parametrization of deep convection is switched off (so-called convection-permitting, convection-resolving, convection-allowing)
- However, these studies have been conducted over diverse geographical regions with different models

CORDEX FPS: Convective phenomena at high resolution over Europe and the Mediterranean (led by Erika Coppola and Stefan Sobolowski)

- One of the main aims: Provide a collective assessment of our modeling capacity at the kilometer-scale resolution

Group Abbreviation	Group Name	Model	Grid Spacing	Intermediate step grid spacing/ Model/Domain
IPSL	Institut Pierre-Simon-Laplace (FR)	WRF381BE	3	15/WRF/EURO-CORDEX
BCCR	The Bjerknes Centre for Climate Research (NO)	WRF381BF	3	15/WRF/EURO-CORDEX
AUTH	Aristotle University of Thessaloniki (GR)	WRF381BG	3	15/WRF/EURO-CORDEX
CICERO	Climate and Environmental Research (NO)	WRF381BJ	3	15/WRF/EURO-CORDEX
FZJ	Research Centre Jülich (DE)	WRF381BB	3	15/WRF/EURO-CORDEX
IDL	Instituto Dom Luiz (PT)	WRF381BH	3	15/WRF/EURO-CORDEX
UCAN	Universidad de Cantabria (ES)	WRF381BI	3	15/WRF/EURO-CORDEX
UHOH	University of Hohenheim (DE)	WRF381BD	3	15/WRF/EURO-CORDEX
WEGC	University of Graz (AT)	WRF381BL	3	15/WRF/EURO-CORDEX
ICTP	International Centre for Theoretical Physics (IT)	RegCM4	3	12/RegCM4/Europe
KNMI	Royal Netherlands Meteorological Inst. (NL)	HCLIM38-AROME	2.5	12/RACMO/Europe
HCLIMcom	HARMONIE-Climate community (DK, NO, SE)	HCLIM38-AROME	3	12/ALADIN/Europe
CNRM	Centre National de Recherches Meteorologiques (FR)	CNRM-AROME41t1	2.5	12/ALADIN/Med-CORDEX
GERICS	Climate Service Center (DE)	REMO	3	12/REMO/Europe
UKMO	Met Office Hadley Centre Exeter (UK)	UM	2.2	No*
ETHZ	ETH Zürich (CH)	COSMO-CLM	2.2	12/COSMO-CLM/Europe
CMCC	Centro Euro-Mediterraneo sui Cambiamenti Climatici (IT)	COSMO-CLM	3	12/COSMO-CLM/Euro-CORDEX
KIT	Karlsruhe Institute of Technology (DE)	COSMO-CLM	3	12/COSMO-CLM/Europe
GUF	Goethe University Frankfurt (DE)	COSMO-CLM	3	12/COSMO-CLM/Euro-CORDEX
BTU	Brandenburg University of Technology (DE)	COSMO-CLM	3	12/COSMO-CLM/Euro-CORDEX
JLU	Justus-Liebig-University Giessen (DE)	COSMO-CLM	3	No

Model Simulations



In total, we analyze 22 simulations with ~3km grid spacing (no convection parametrization) and 21 simulation with > 12 km grid spacing (parametrized convection).

6 different models are represented in the ensemble.

10-year long simulations (2000-2009) driven by ERA-Interim reanalysis.

Observations

EURO4M-APGD (Isotta et al. 2014)

- Daily precipitation data available at a horizontal resolution of 5 km over the Alpine region for a period 1971-2008

RdisaggH (Wüest et al. 2010)

- Gridded hourly precipitation data, available for a shorter period (2003-2010) and over the area of Switzerland with the horizontal grid spacing of 1 km

COMEPHORE (Fumière et al., 2019)

- Hourly observational dataset with a resolution of 1 km available over the area of France, based on radar and raingauge data

GRIPHO (Fantini, 2019)

- Hourly gridded precipitation dataset, available over Italy at a horizontal resolution of 3 km for the period 2001-2016

Analysis

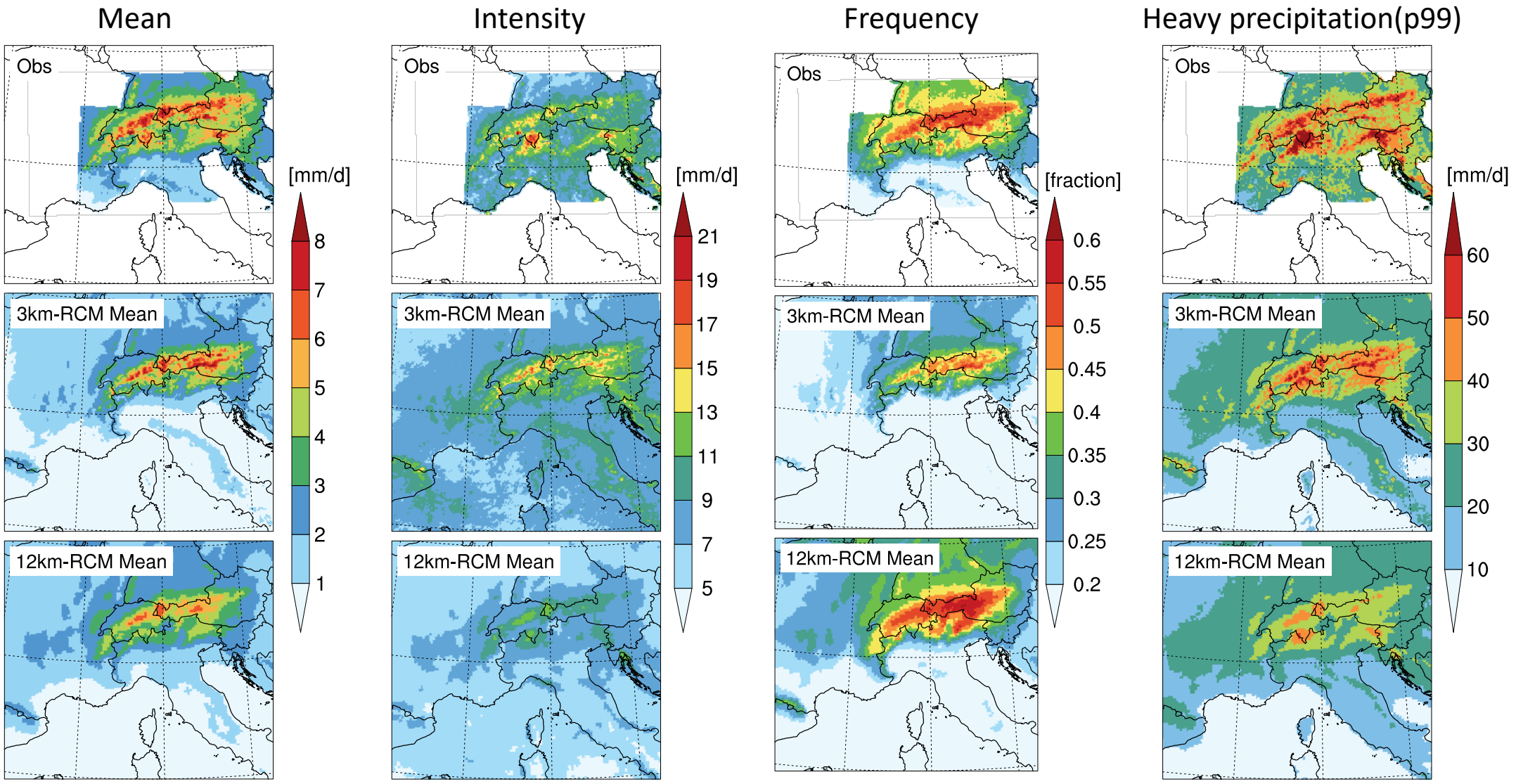
ABBREVIATION	DEFINITION	UNIT
Mean	Mean Precipitation	mm/d
Freq	Wet day/hour[a] frequency	[fraction]
Int	Wet day/ hour[a] intensity	[mm/d] / [mm/h]
pXX	XX percentile[b] of daily/hourly precipitation	[mm/d] / [mm/h]

[a] A wet day (hour) is defined as a day (hour) with precipitation $\geq$ 1 *mm/d* (0.1 *mm/h*)

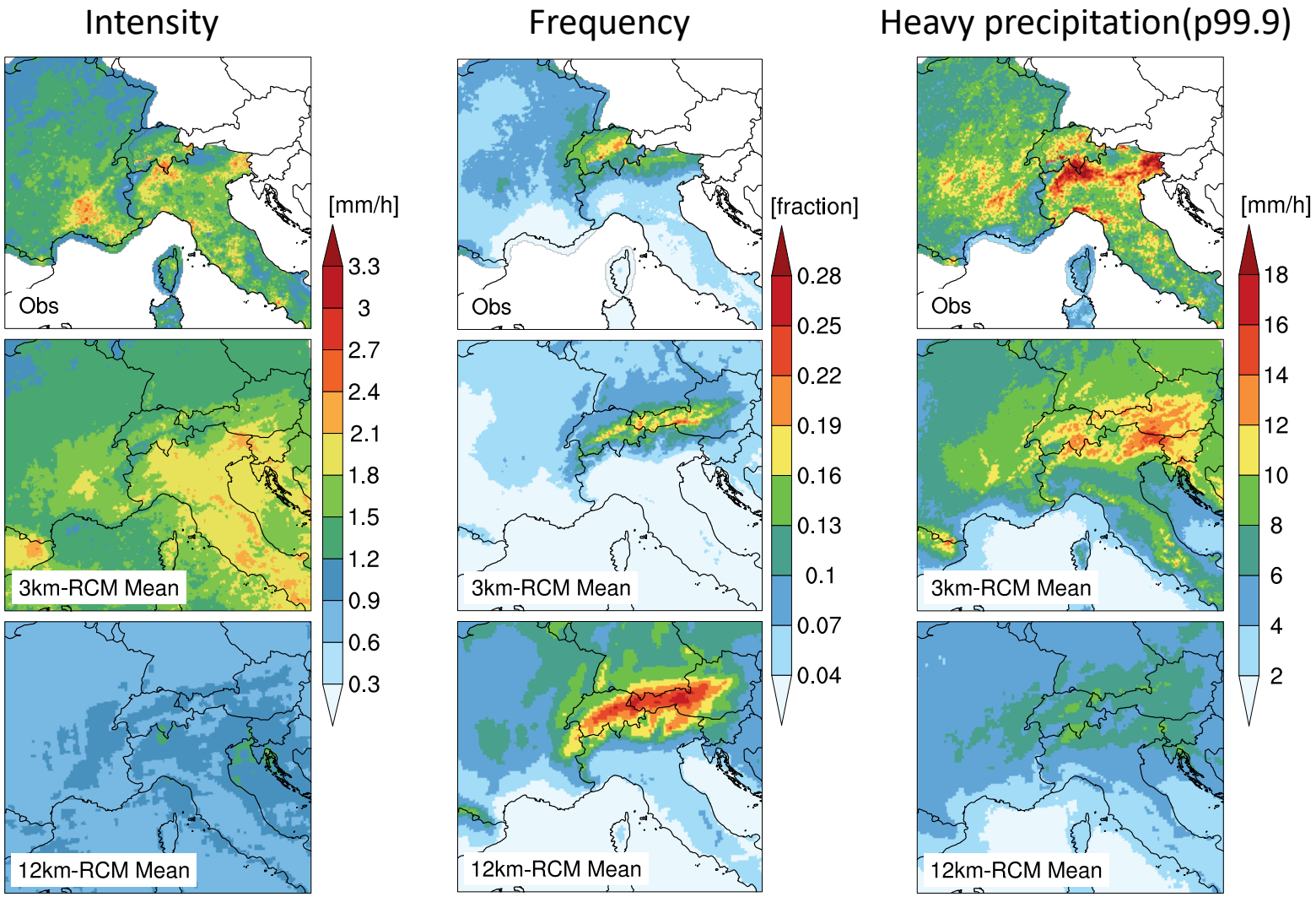
[b] Percentiles are calculated using all events (wet and dry) following Schär et al., 2016

❖ Prior to the analysis, all high-resolution simulations have been interpolated to the common 3 km grid, while the intermediate simulations have been interpolated to the common 12 km grid.

Multi-model mean of **daily** precipitation in the summer season



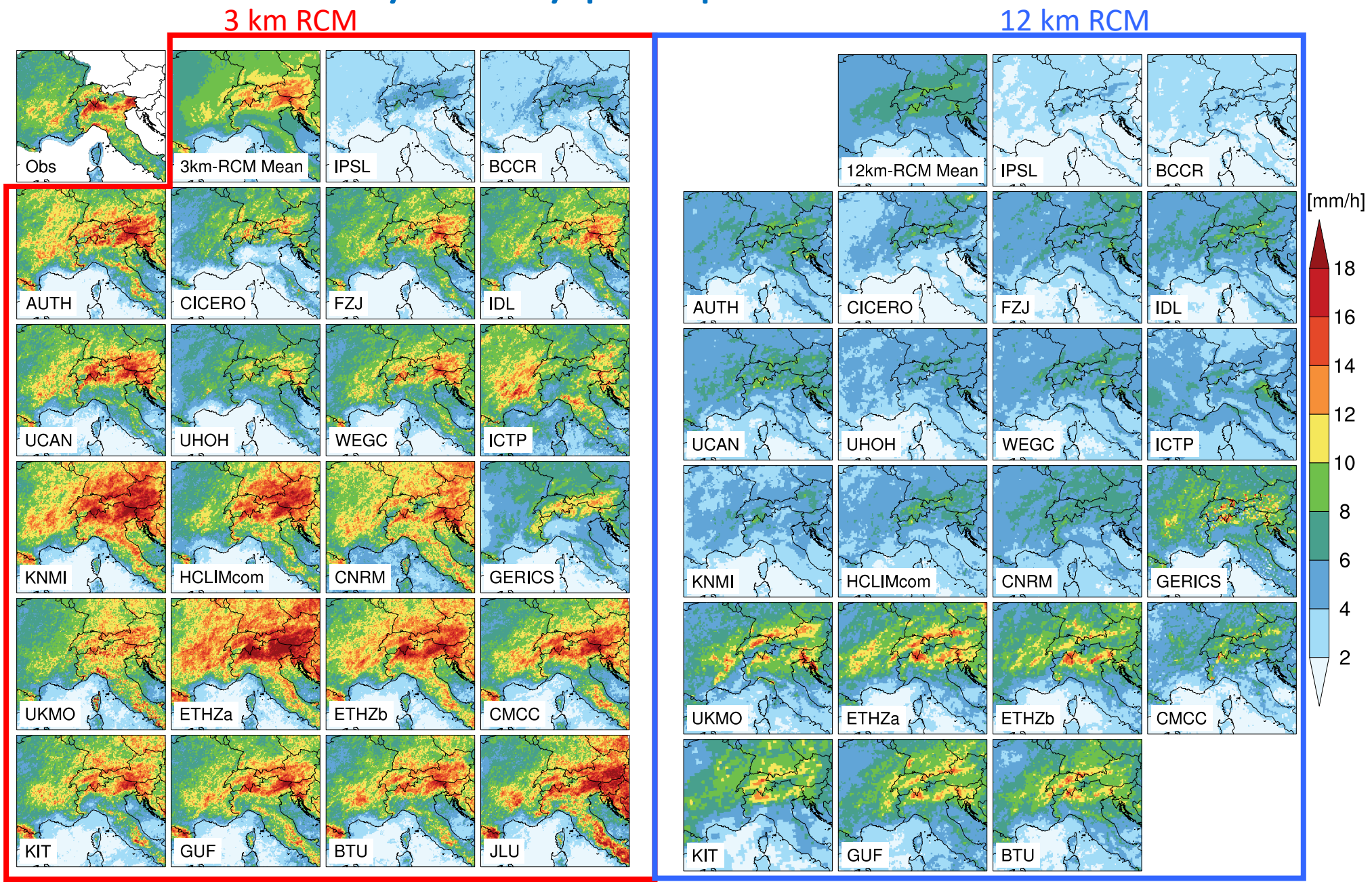
Multi-model mean of h**ourly** precipitation in the summer season



→ 12 km RCM mean shows a large underestimation of precipitation intensity, and overestimation of precipitation frequency

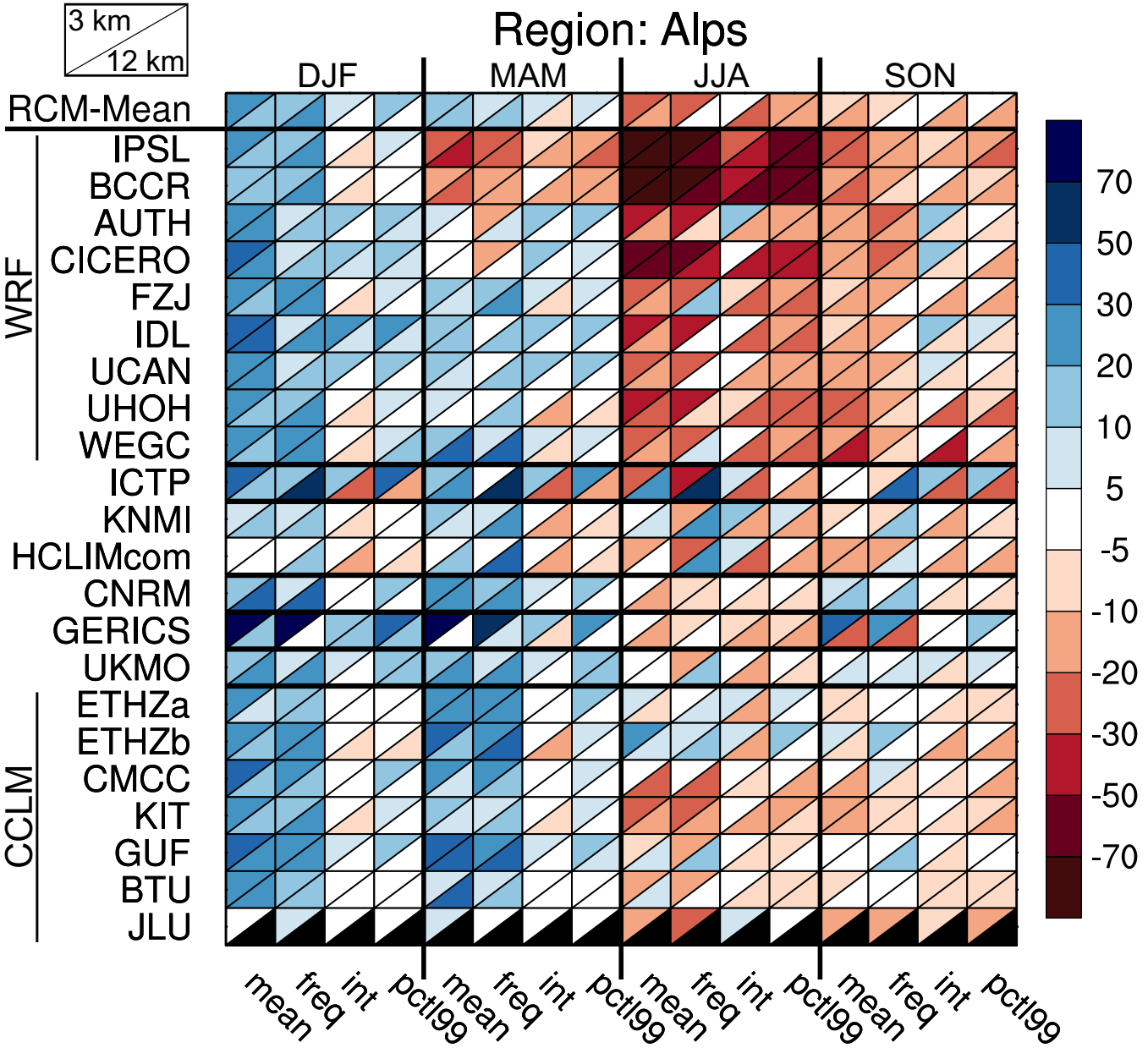
→ 3 km RCM mean show better performance in reproducing the spatial patterns of precipitation

Heavy hourly precipitation in the summer season



→ Large variability between the models, but a clear difference between the 3km and 12 km RCMs

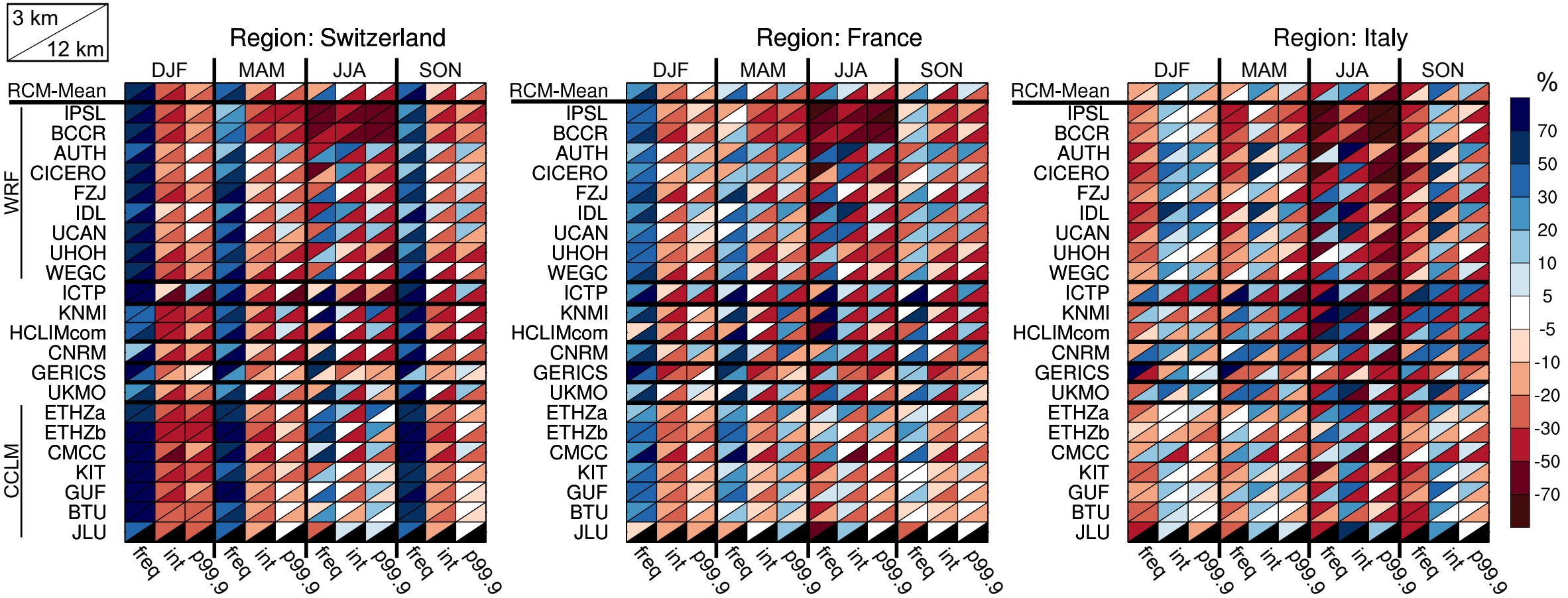
Relative bias for daily precipitation



→ Both models show precipitation overestimation in cold seasons, and precipitation underestimation in warm seasons

→ The largest dry bias is found for the WRF group of models in the summer season

Relative bias for hourly precipitation



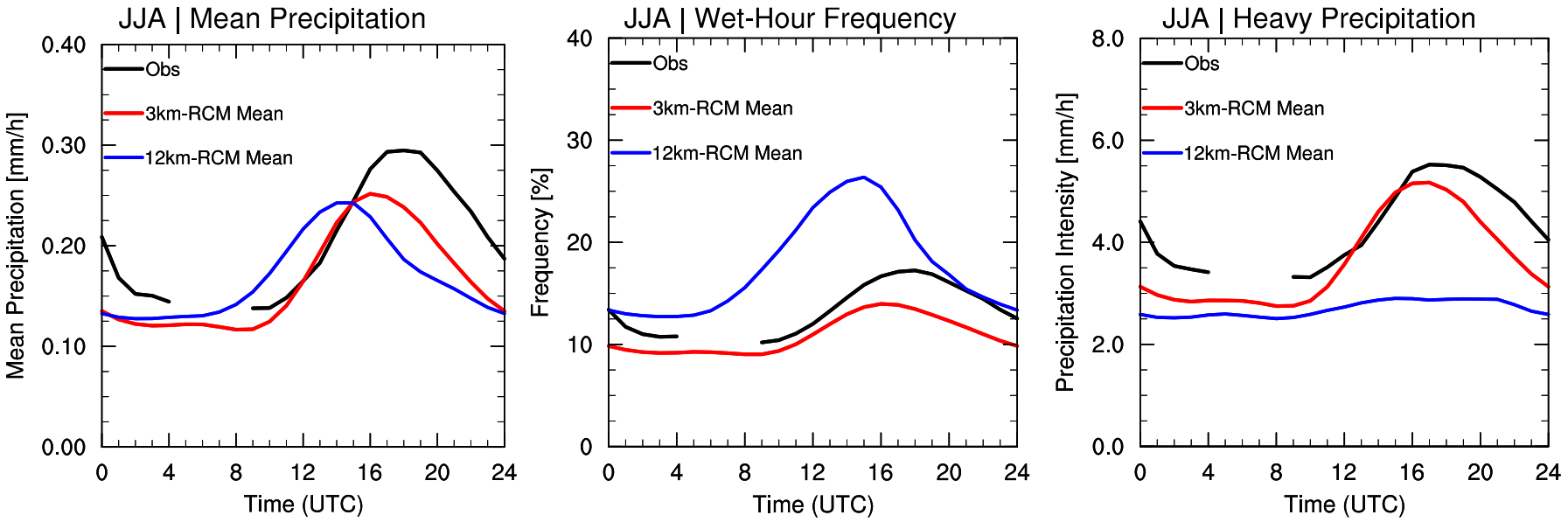
→ Overestimation of precipitation frequency and underestimation of precipitation intensity in almost all seasons and especially over Switzerland

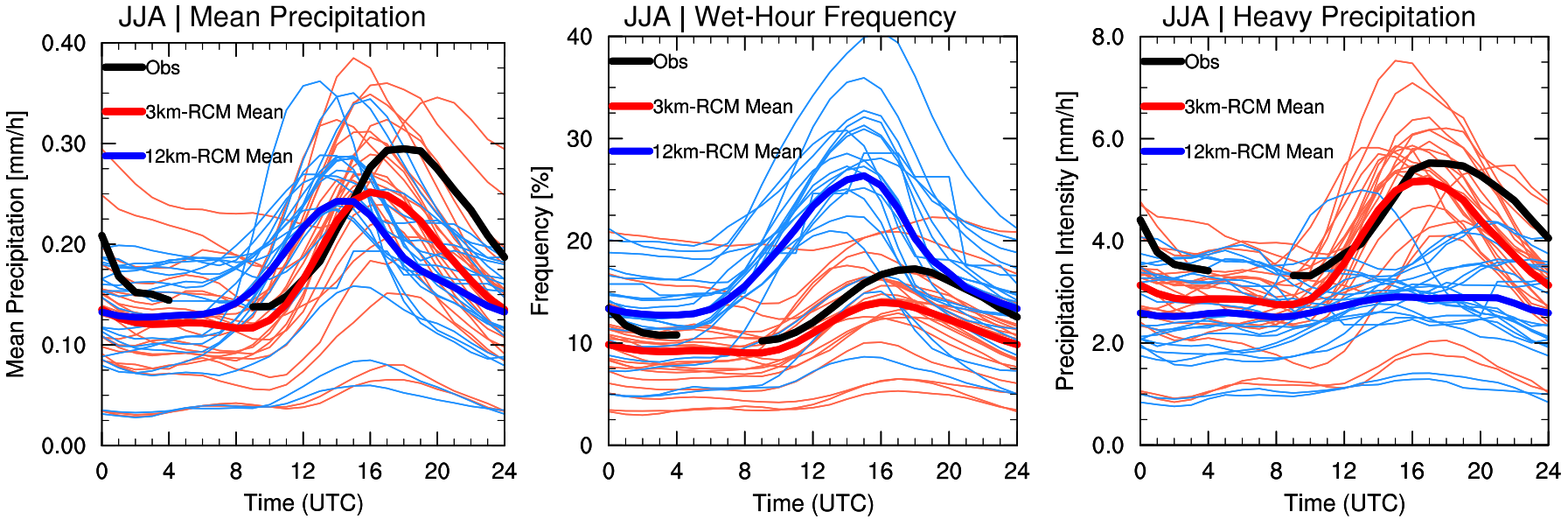
→ The biases are more pronounced in the 12 km models

→ The ensemble mean shows a reduction in biases for km-scale simulations, although some exceptions exist

Diurnal cycle of summer precipitation

-SWITZERLAND-

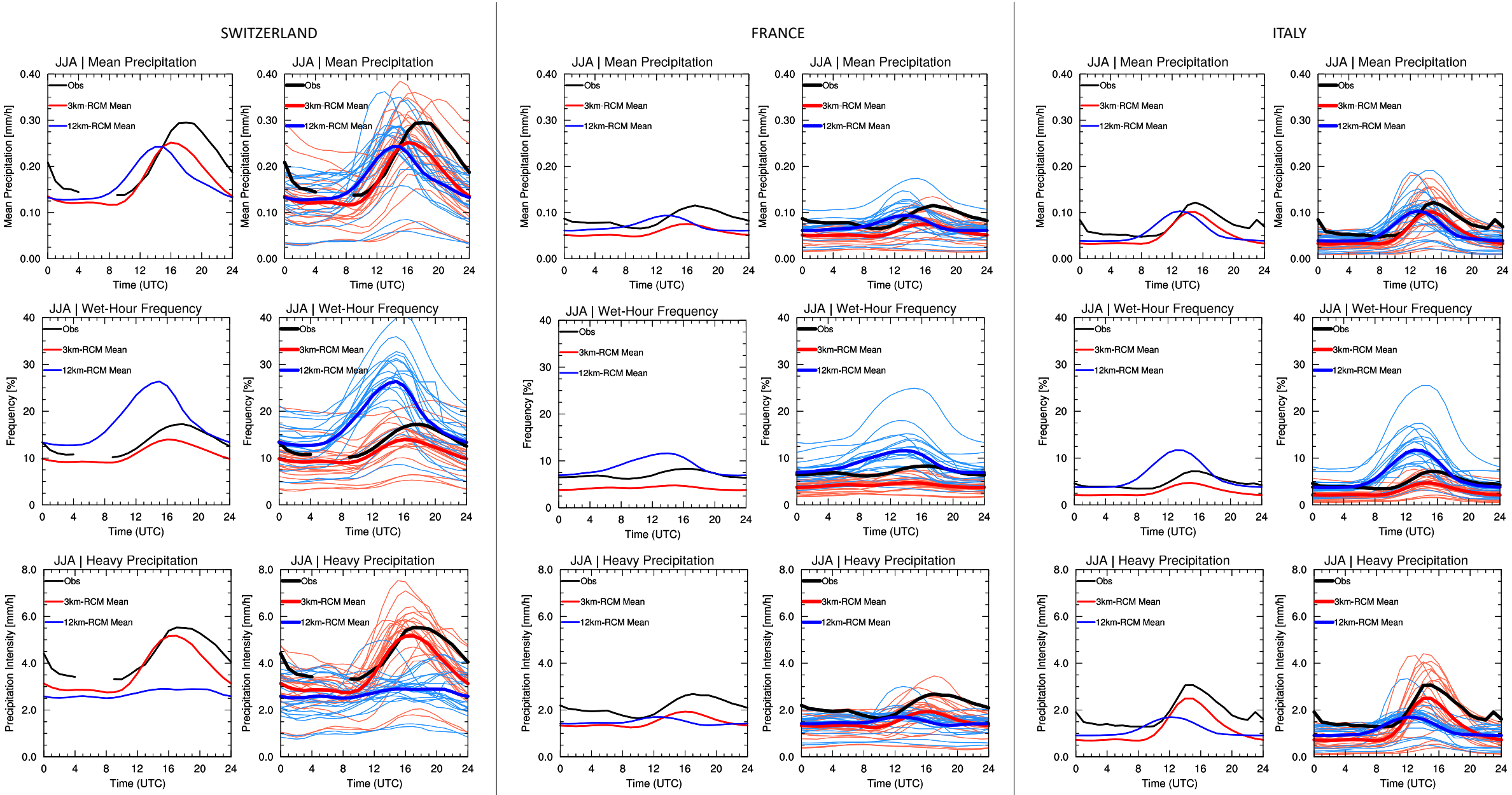




→ The ensemble mean of km-scale simulations shows superior performance to the ensemble mean of coarse resolution simulations over Switzerland (current slide) and France and Italy (next slide)

→ However, a large spread exists even within the km-scale ensemble

Diurnal cycle of summer precipitation



Summary

Although some differences and biases still persist at the km-scale resolution, this approach in an ensemble framework offers a promising way forward for improving climate simulations. In particular, the improvements in spatial representation, frequency, and heavy precipitation are pronounced compared to coarser resolution counterparts.

A few notes:

- Some of the models are run for the first time at such a high-resolution and no prior calibration or tuning has been performed, as is the case for many coarse resolution models (e.g. GCMs and ESMs).
- High-resolution simulations depend on the driving data, so their performance is only as good as the input.
- High-resolution simulations also need high-resolution observations for evaluation that are not easily accessible and come with their own shortcomings (e.g., in areas of high/steep topography the models may well be more reliable than the observations).
- High-resolution simulations are still using parameterizations which were designed for coarser resolutions, and the assumptions associated with them may not hold at km-scales.

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