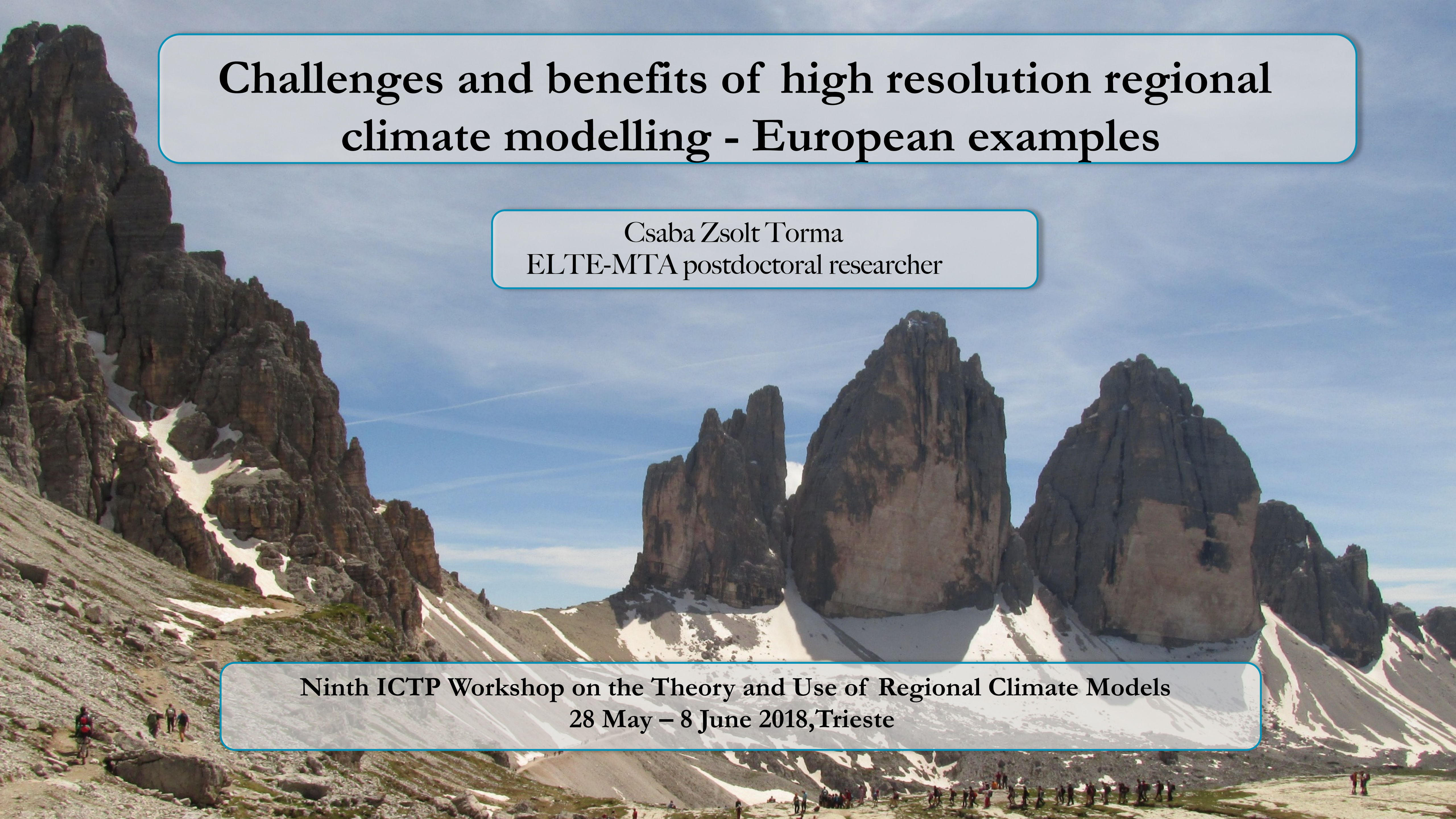


Challenges and benefits of high resolution regional climate modelling - European examples

Csaba Zsolt Torma
ELTE-MTA postdoctoral researcher

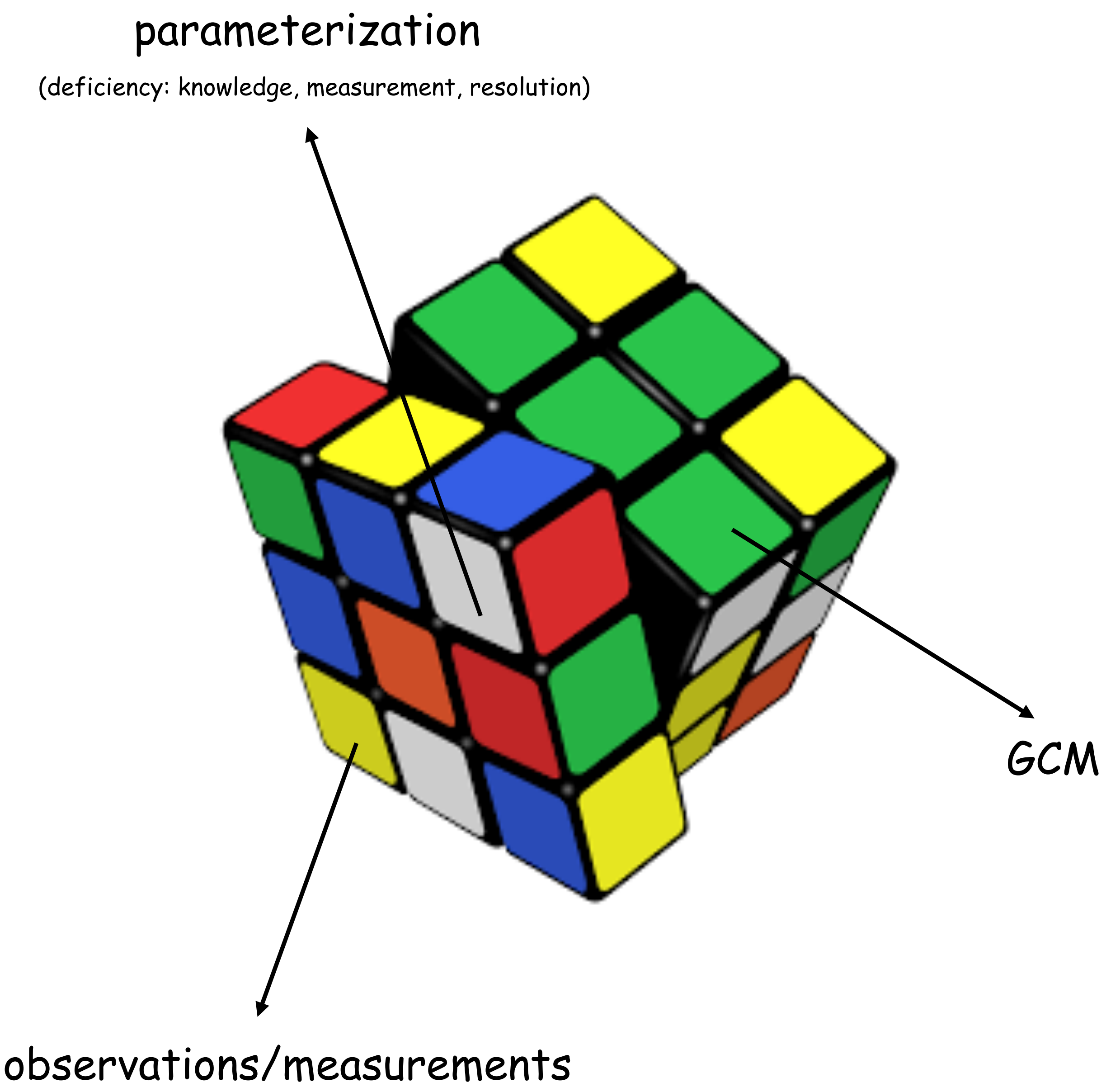
Ninth ICTP Workshop on the Theory and Use of Regional Climate Models
28 May – 8 June 2018, Trieste

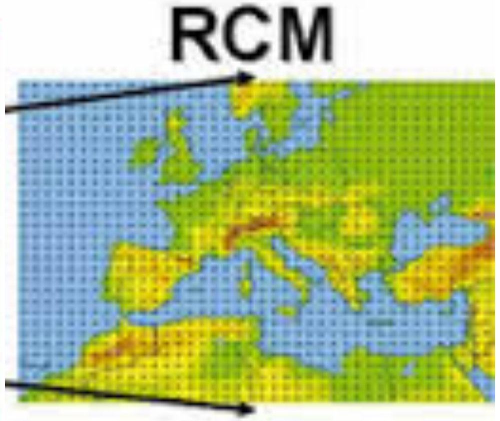
Introduction

Challenges

Benefits (added value)

Summary


parameterization
(deficiency: knowledge, measurement, resolution)
GCM
observations/measurements



Finer resolution

- more detailed *topogr*
- more
- more
- more
- ***diffe*** te

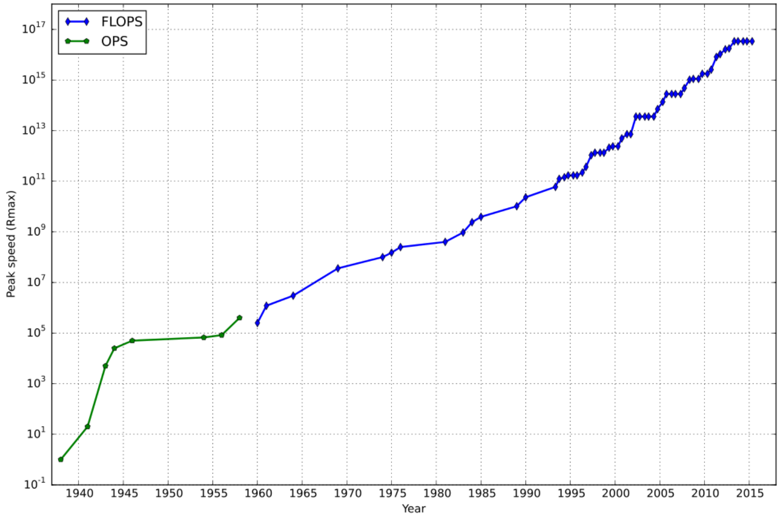
xand

„With great power comes great responsibility.“

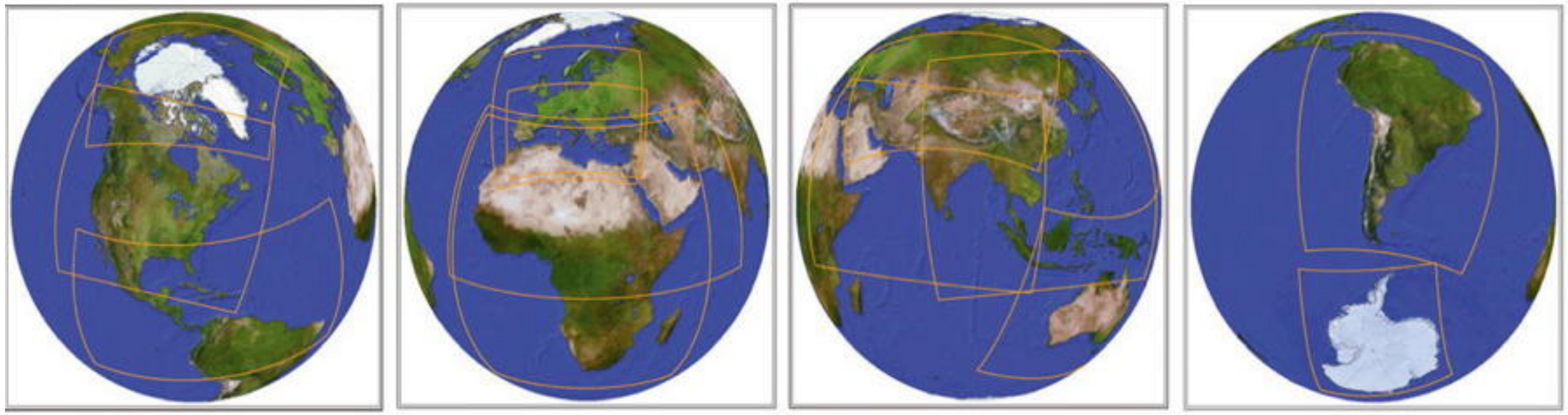
„With high resolution comes great computing needs.”

Number of processors: 200
Resolution: 480 x 480 x 23 (12 km)
1 year ~ in 4 days

IBM Blue Gene/P supercomputer
(250 000 processors)



Top supercomputers performance



CORDEX

14 regions

Resolution: 50 km and 12 km

PRUDENCE	**0,5 TB**
ENSEMBLES	**23 TB**
CORDEX (not up to date)	**1.400 TB**
CMIP5 (2.3 PB)	2.300 TB

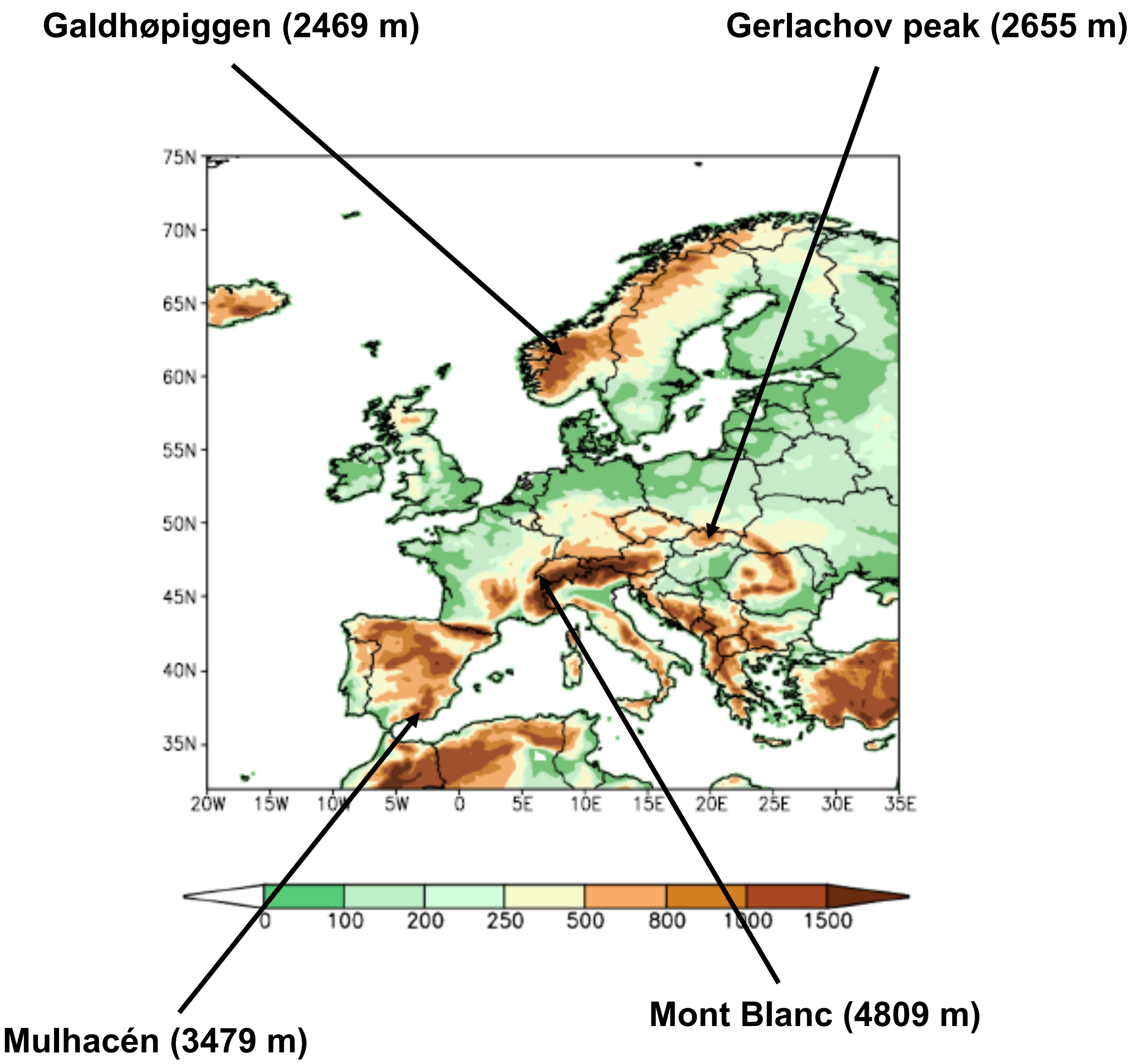
On the one hand: huge amount of data to be stored…

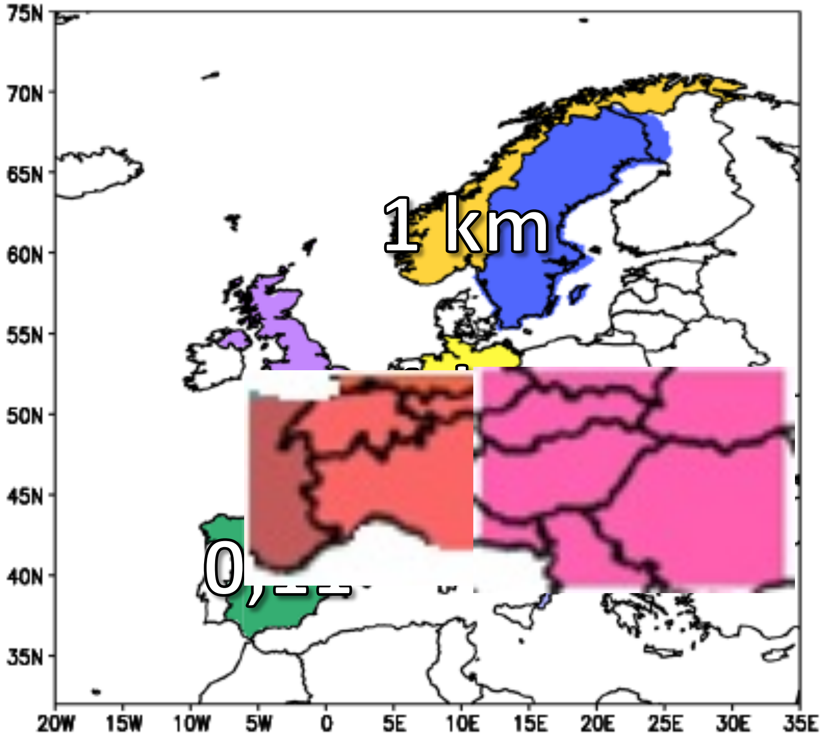
About 2kB printed information is stored on A4 sheet. Paper ~ 0.1mm thick, so*:* 20 MB/m.

PRUDENDCE data printed: **25 km** high paper tower
ENSEMBLES: **1.100 km**
CORDEX: **70.000 km**
CMIP5 : 115.000 km

On the other hand
uploading/downloading data with100 Mb/s:

PRUDENCE: 12 hours
ENSEMBLES: 23 days…

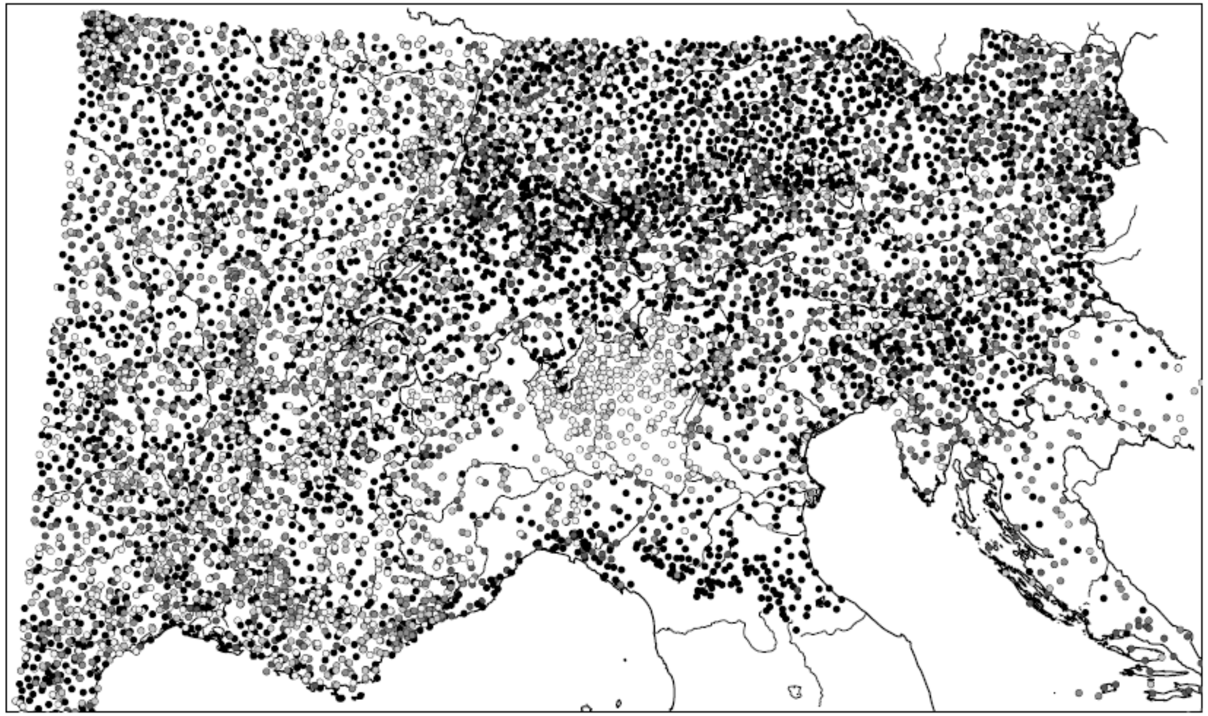


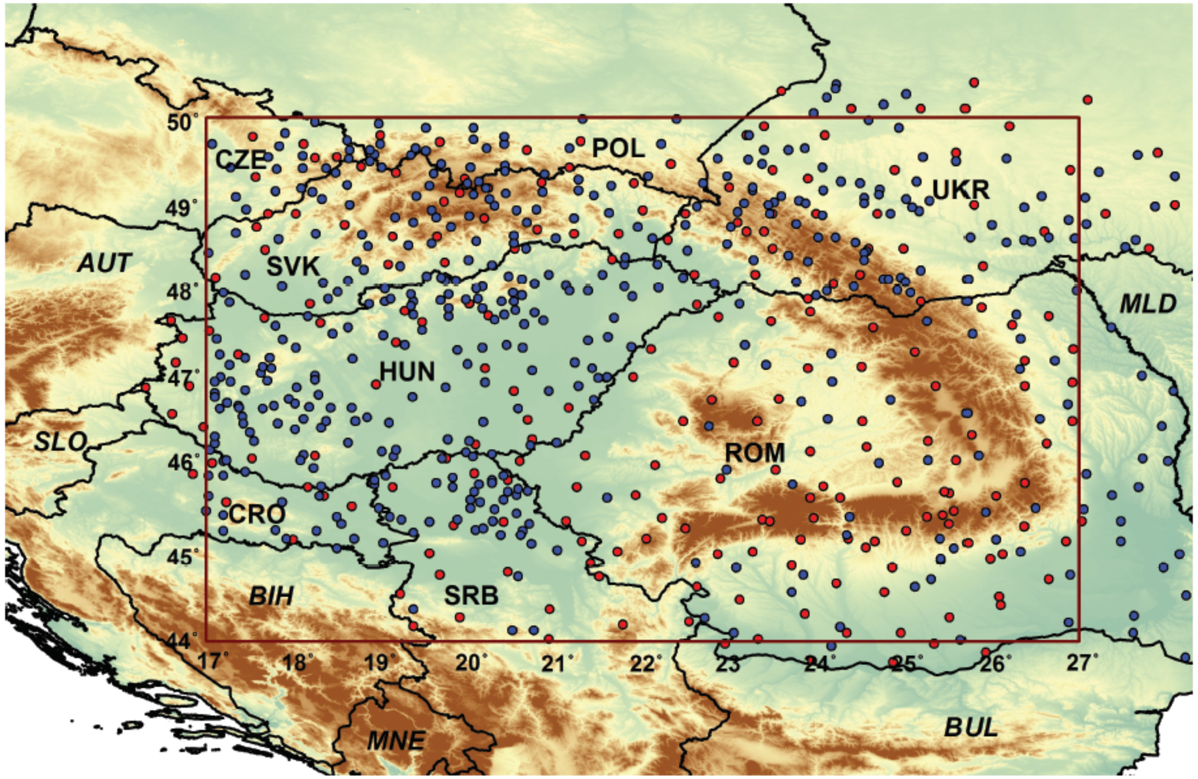


(Fantini et al., 2016)

Finer orography

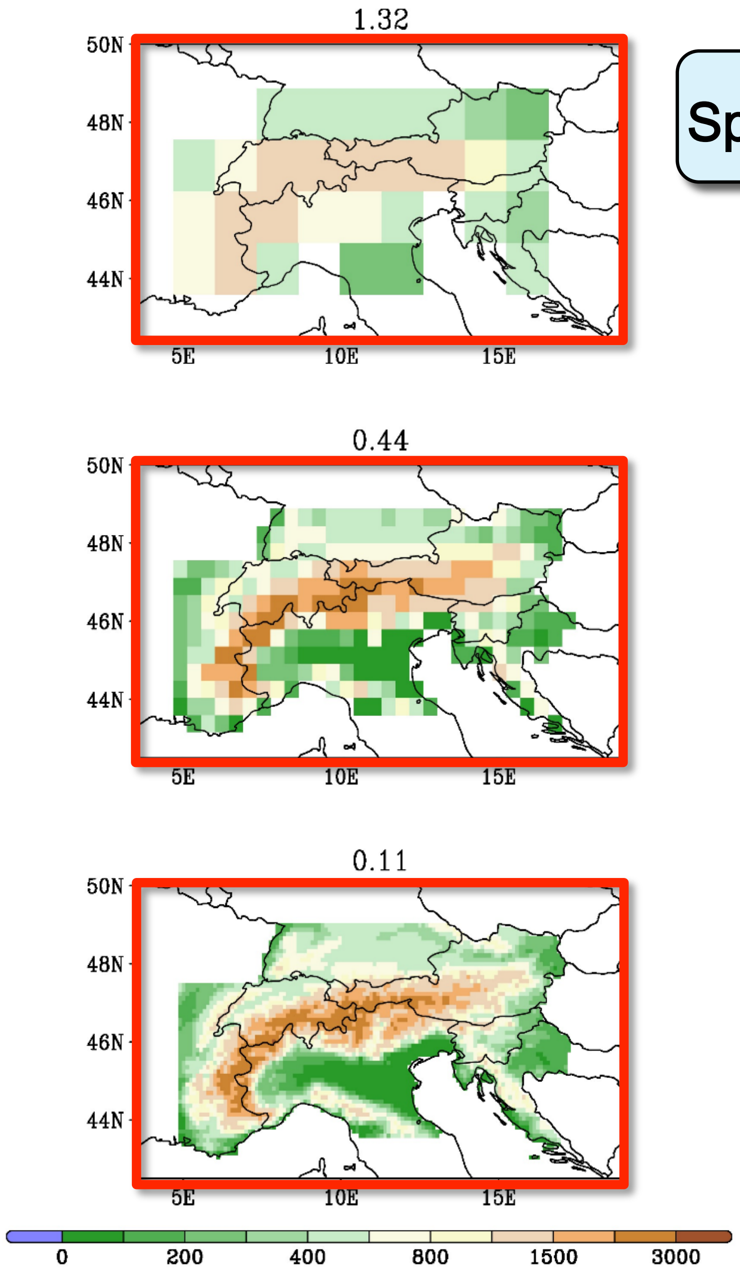
Resolution: 1’ (~2 km)





reference dataset: EURO4M-APGD (Isotta et al., 2014)
period: 1971-2008
resolution: 5 km
Number of stations: 5500

reference dataset: CARPATCLIM (Szalai et al., 2013)
period: 1961-2010
resolution: ~10 km
Number of stations: 904



Spatial resolutions: 1.32° (~150 km), 0.44° (~50 km) és 0.11° (~12 km)

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

10.1002/2014JD022781

Key Points:

- RCMs produce substantial added value over complex topography regions
- High resolution improves precipitation spatial patterns simulation and extremes
- RCMs are important tools for climate studies over complex topographical regions

Supporting Information:

- Figures S1–S8 and Table S1

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Added value of regional climate modeling over areas characterized by complex terrain—Precipitation over the Alps

Csaba Torma[1], Filippo Giorgi[1], and Erika Coppola[1]

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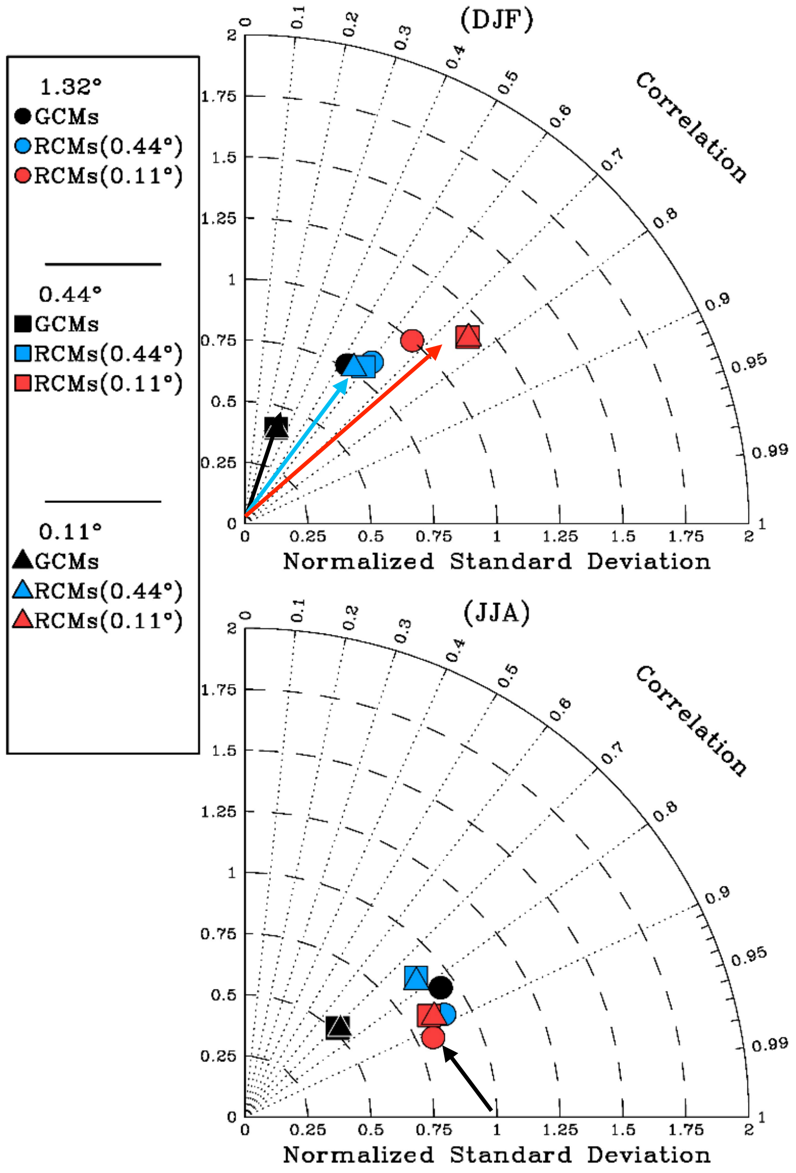
Abstract We present an analysis of the added value (AV) of downscaling via regional climate model (RCM) nesting with respect to the driving global climate models (GCMs). We analyze ensembles of driving GCM and nested RCM (two resolutions, 0.44° and 0.11°) simulations for the late 20th and late 21st centuries from the CMIP5, EURO-CORDEX, and MED-CORDEX experiments, with a focus on the Alpine region. Different metrics of AV are investigated, measuring aspects of precipitation where substantial AV can be expected in mountainous terrains: spatial pattern of mean precipitation, daily precipitation intensity distribution, and daily precipitation extremes tails. Comparison with a high-quality, fine-scale (5 km) gridded observational data set shows substantial AV of RCM downscaling for all metrics selected, and results are mostly improved compared to the driving GCMs also when the RCM fields are upscaled at the scale of the GCM resolution. We also find consistent improvements in the high-resolution (0.11°) versus medium-resolution (0.44°) RCM simulations. Finally, we find that the RCM downscaling substantially modulates the GCM-produced precipitation change signal in future climate projections, particularly in terms of fine-scale spatial pattern associated with the complex topography of the region. Our results thus point to the important role that high-resolution nested RCMs can play in the study of climate change over areas characterized by complex topographical features.

Torma et al., 2015 (Journal of Geophysical Research: Atmospheres)
https://goo.gl/9VmUeE



1976-2005

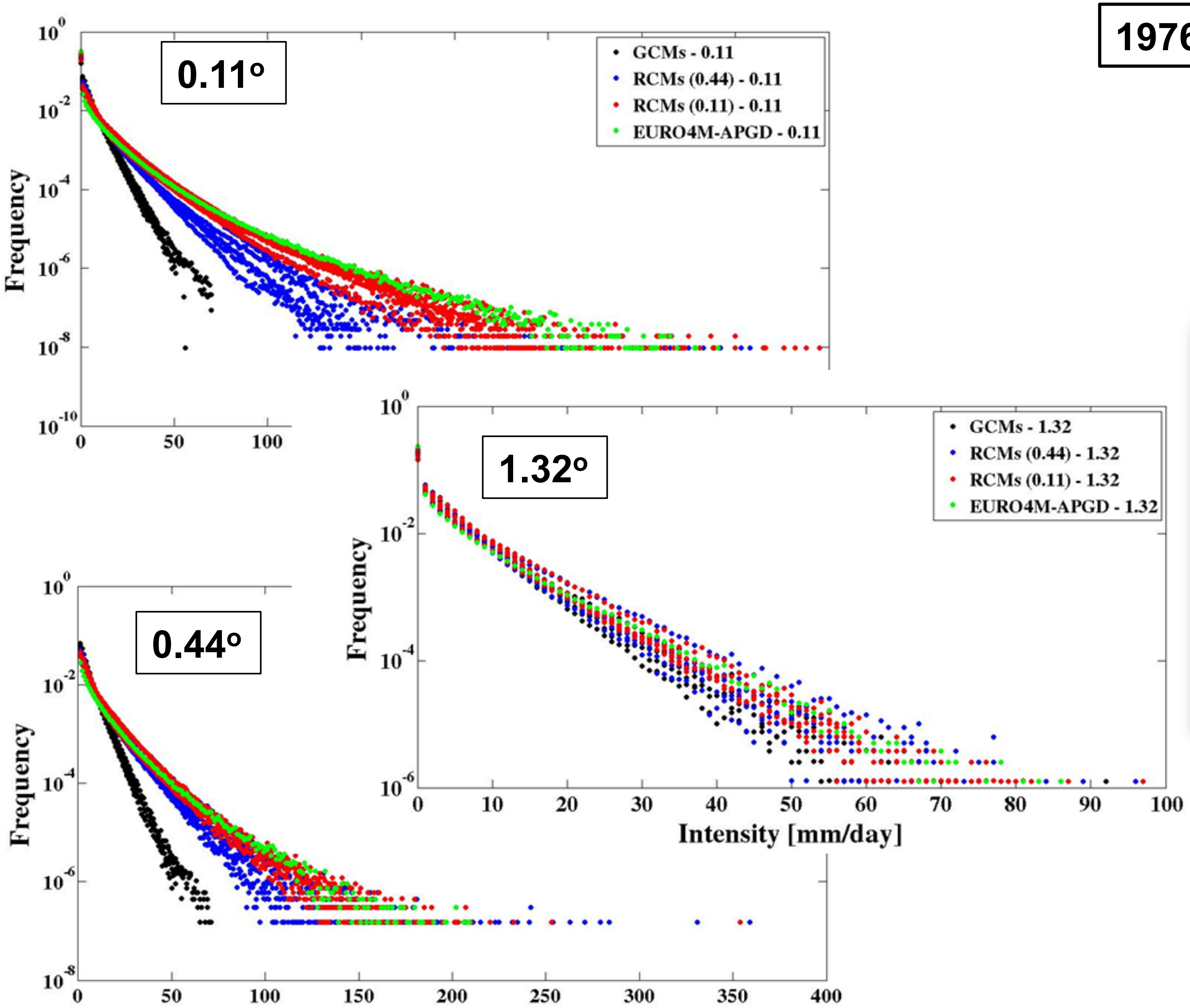
Areal averages over the Alps

Ensembles means: GCM(4), RCM(5)

Every simulations, on each grid

Finer resolution RCMs show better agreement regardless the season

Simulations are separated as different resolutions



1976-2005

Daily time series

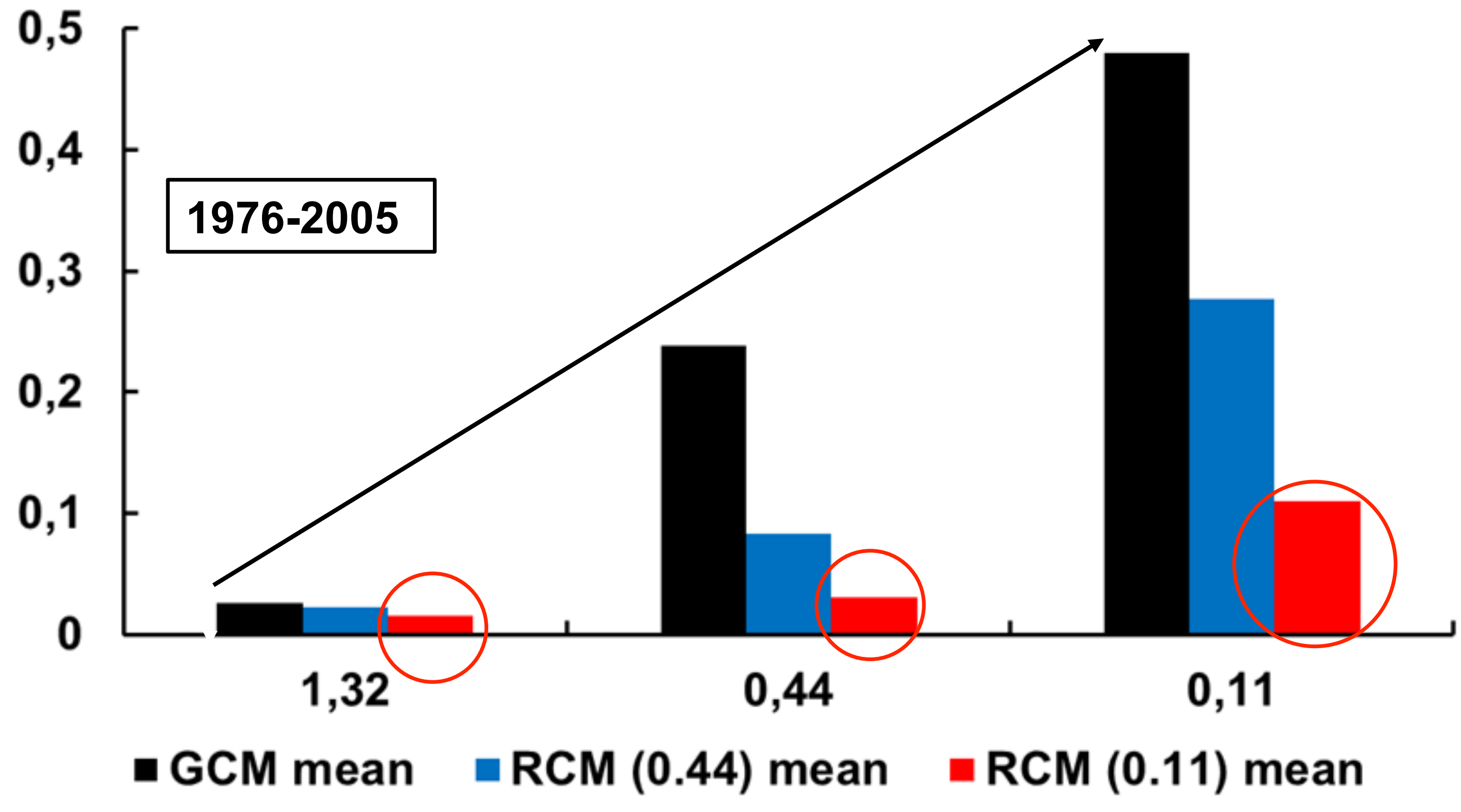
All simulations on every grid points are depicted

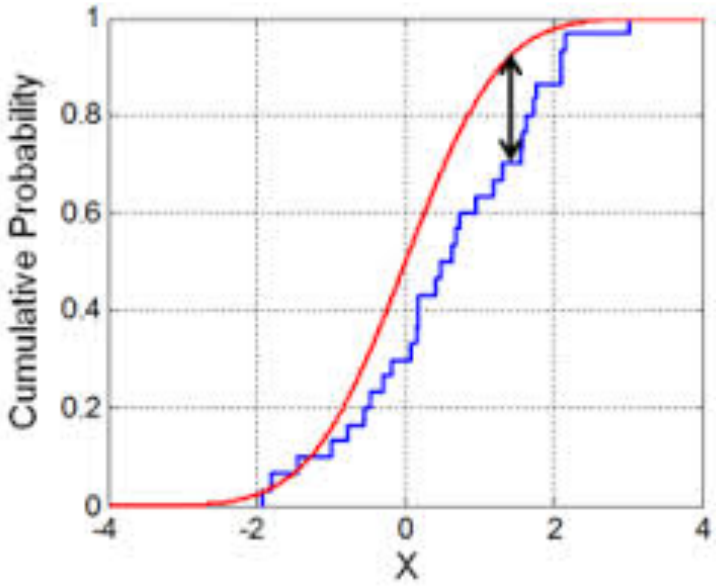
RCMs show better agreement with OBS on each grid (compared to GCMs)

More accurate extremes

Kolgomorov-Smirnov distance

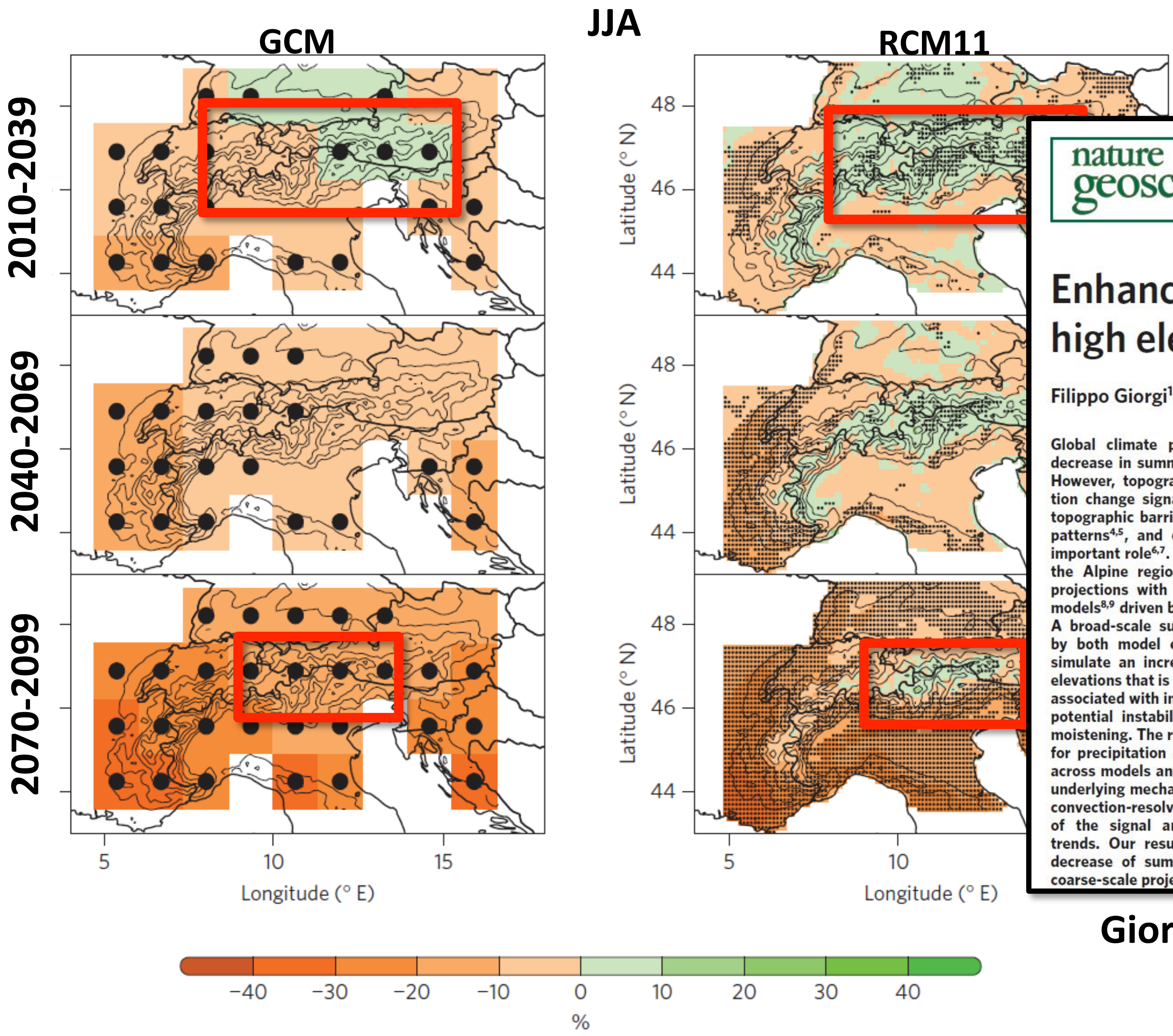
$$d_{KS}(F,G) = sup_{t\in\mathbb{R}}|F(t) - G(t)|$$





K-S distance is inversely proportional to resolution

K-S distance is minimal: RCM11 (on each grid)



Contrary to global trends

nature geoscience
LETTERS
PUBLISHED ONLINE: 11 JULY 2016 | DOI: 10.1038/NGEO2761

Enhanced summer convective rainfall at Alpine high elevations in response to climate warming

Filippo Giorgi[1]*, Csaba Torma[1], Erika Coppola[1], Nikolina Ban[2], Christoph Schär[2] and Samuel Somot[3]

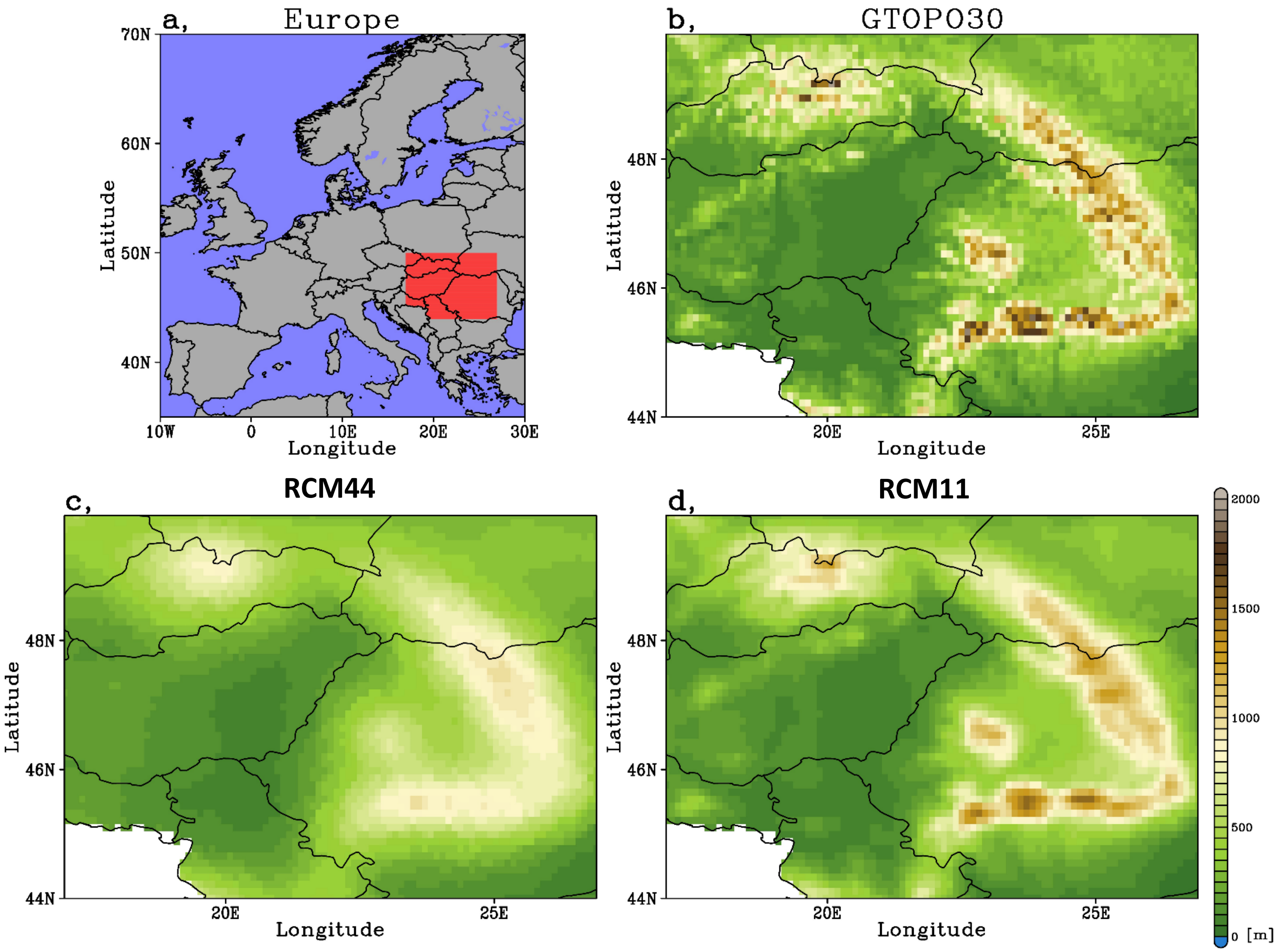
Global climate projections consistently indicate a future decrease in summer precipitation over the European Alps[1–3]. However, topography can substantially modulate precipitation change signals. For example, the shadowing effect by topographic barriers can modify winter precipitation change patterns[4,5], and orographic convection might also play an important role[6,7]. Here we analyse summer precipitation over the Alpine region in an ensemble of twenty-first-century projections with high-resolution (~12 km) regional climate models[8,9] driven by recent global climate model simulations[10]. A broad-scale summer precipitation reduction is projected by both model ensembles. However, the regional models simulate an increase in precipitation over the high Alpine elevations that is not present in the global simulations. This is associated with increased convective rainfall due to enhanced potential instability by high-elevation surface heating and moistening. The robustness of this signal, which is found also for precipitation extremes, is supported by the consistency across models and future time slices, the identification of an underlying mechanism (enhanced convection), results from a convection-resolving simulation[11], the statistical significance of the signal and the consistency with some observed trends. Our results challenge the picture of a ubiquitous decrease of summer precipitation over the Alps found in coarse-scale projections.

a modulation would in fact point to the added value of using high-resolution models in regional climate projections. As shown in a previous study[15] the EURO-CORDEX and MED-CORDEX RCMs can reproduce well the observed fine-scale summer precipitation patterns over the Alps (for example, Supplementary Fig. 2), in particular improving the corresponding patterns in the driving GCMs. A number of studies demonstrated the added value of RCMs in reproducing different characteristics of topographically forced precipitation[9,15–17]. However, whether the added value in reproducing present-day climate also results into more credible projections is still an open issue[18].

Here we use an ensemble of projections with 6 RCMs at ~12 km grid spacing driven by 4 different GCMs (Supplementary Table 1) and analyse three future twenty-first-century time slices (near term, 2010–2039; mid-century, 2040–2069; late century, 2070–2099) under the RCP8.5 greenhouse gas concentration pathway[19] with respect to the present-day period 1975–2004 (see Methods). The domain of analysis encompasses the Alpine chain and surrounding areas (Supplementary Fig. 1), and is defined by the coverage area of the observation data set[14].

Figure 1 shows the ensemble mean of the percentage change in summer precipitation for the three twenty-first-century time slices in the driving GCM and the RCM ensembles. The GCMs produce a large-scale drying signal over the region, which grows in magnitude throughout the twenty-first century and extends to the entire Alpine

Giorgi et al., 2016 (Nature Geoscience)
https://goo.gl/4y8ZjA



Driving field:

ERA-Interim

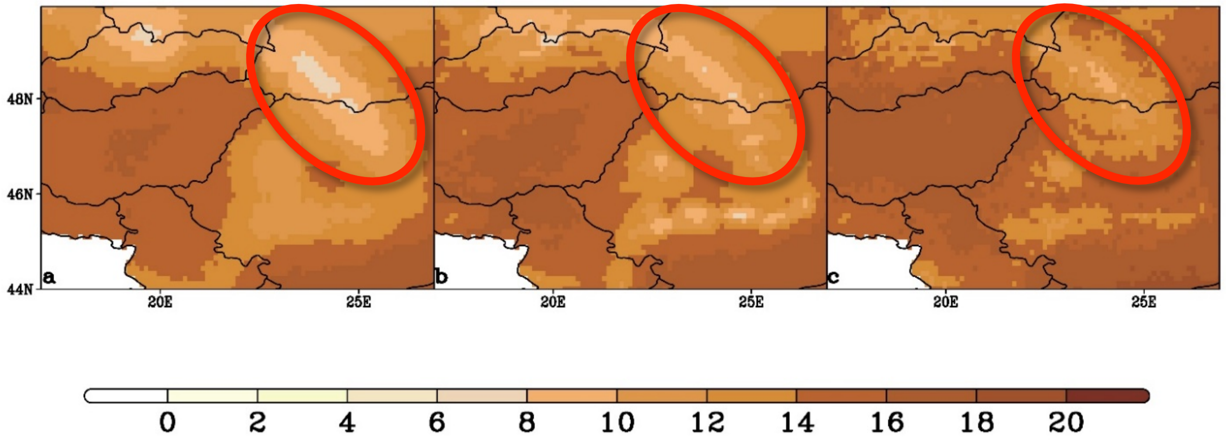
1989-2008

RCMs:

CCLM
REMO
RACMO
ALADIN
RegCM4.3
RCA4
WRF
HIRHAM5
PROMES

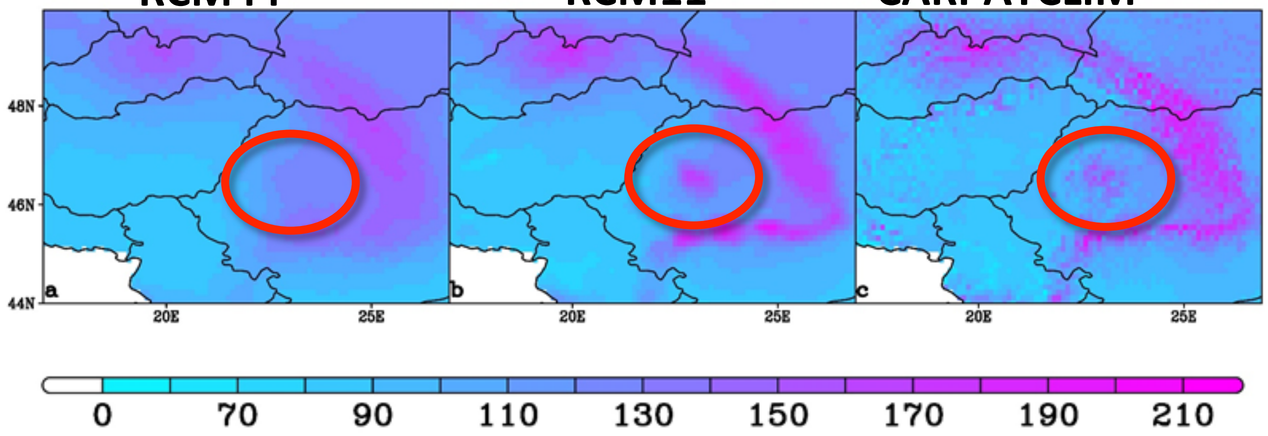
CDD

RCM44 | RCM11 | CARPATCLIM



Frost days (T_{min} < 0 °C)

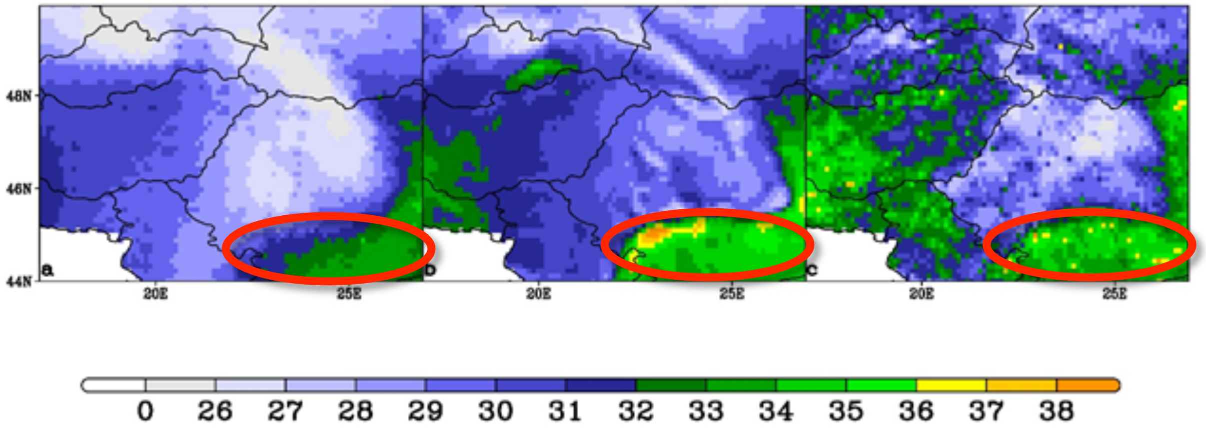
RCM44 | RCM11 | CARPATCLIM



1989-2008

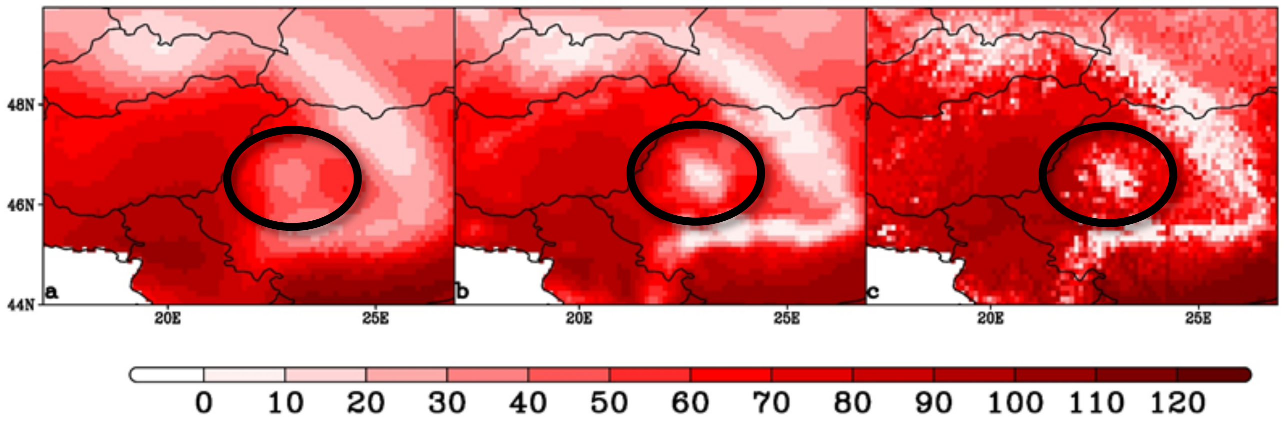
R95

RCM44 | RCM11 | CARPATCLIM

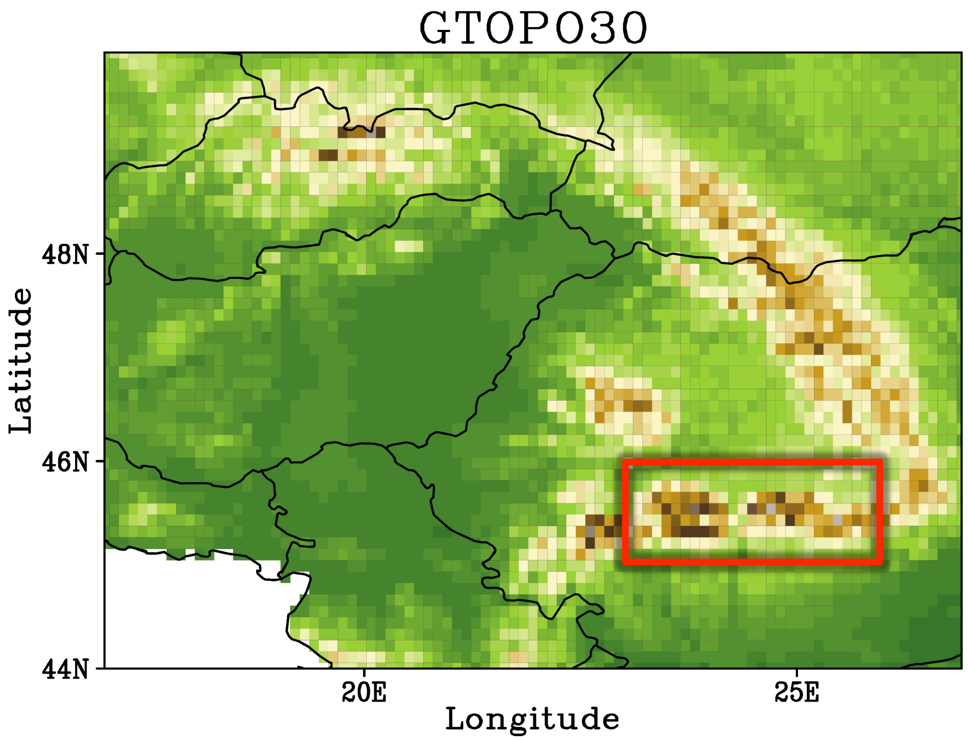


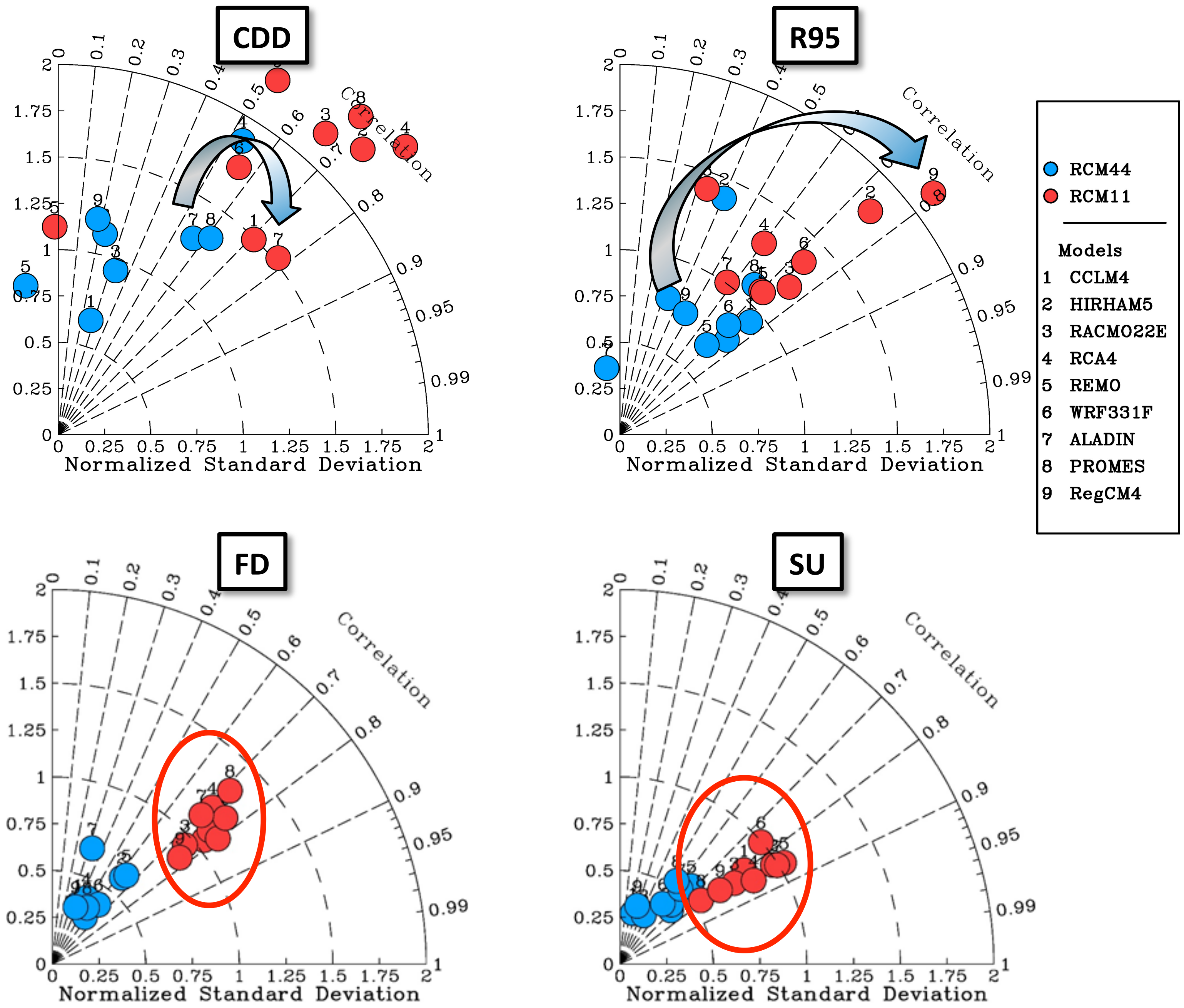
Summer days (T_{max} > 25 °C)

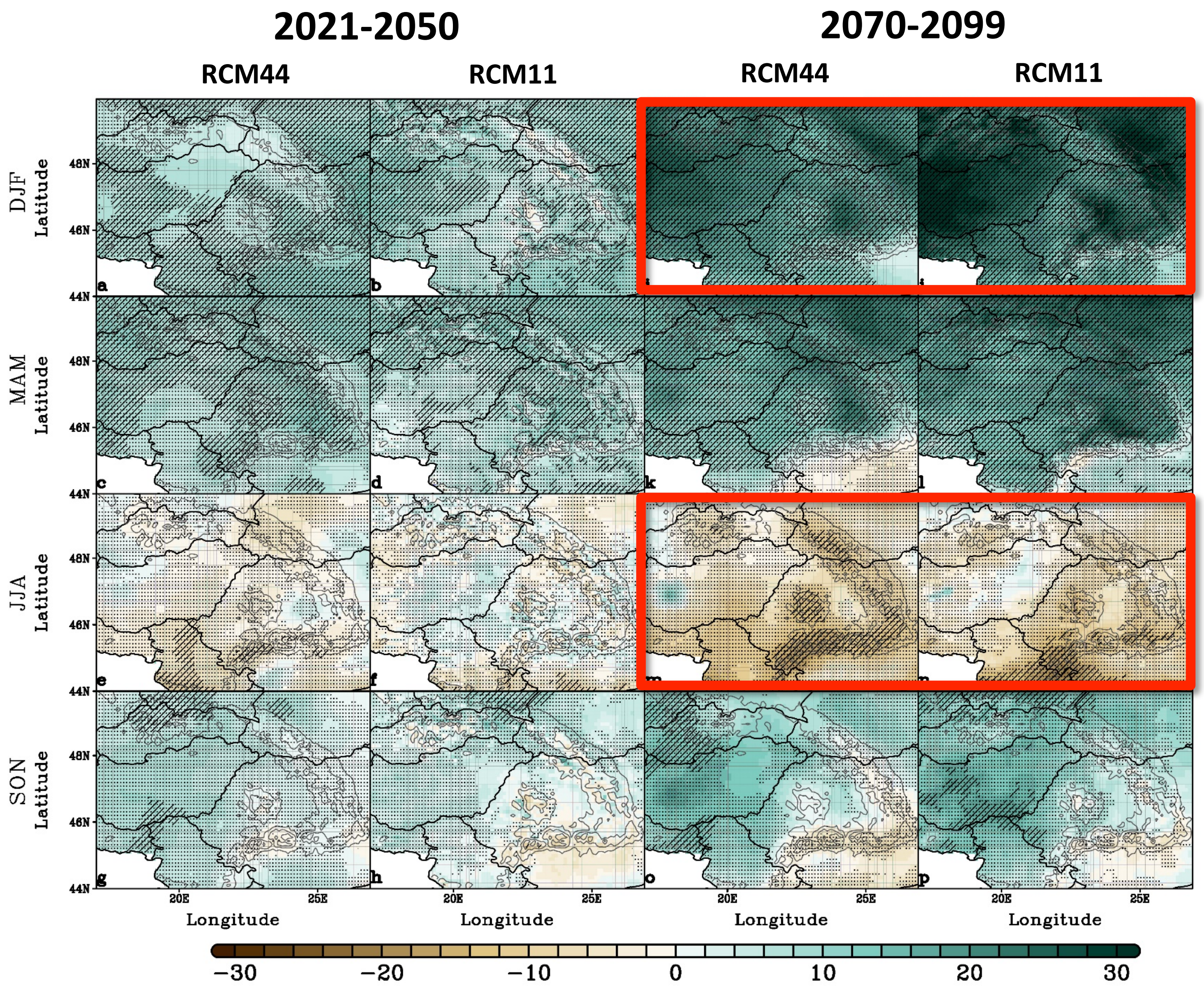
RCM44 | RCM11 | CARPATCLIM



More accurate extremes

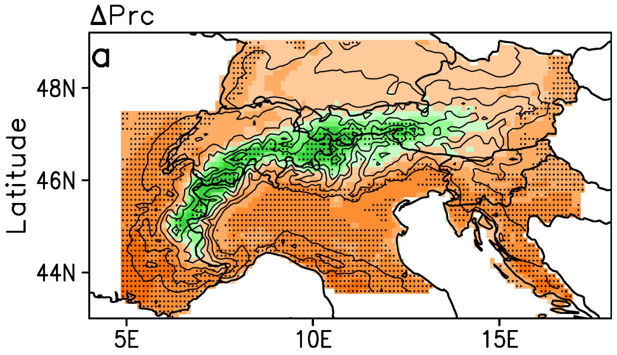




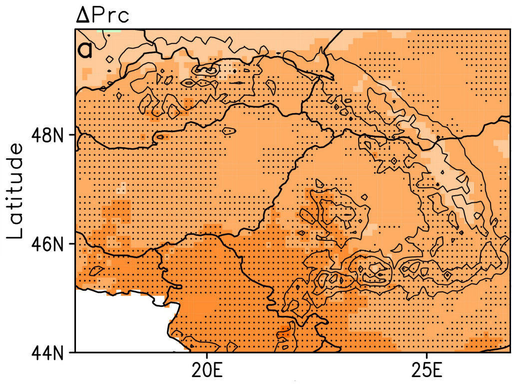


/: significant (p=0,1)
. : most modells (n=>5)
agree on the sign of the change

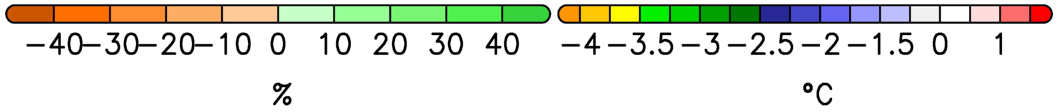
RCMs show more precipitation in DJF and less during JJA by the end of the 21st century

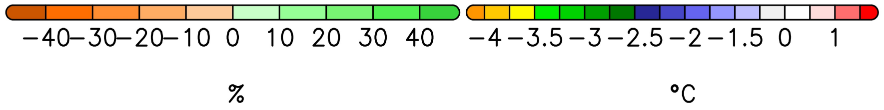


(2070-2099) – (1975-2004)



$$\mathrm{PI} = \theta_{e500} - \theta_{e850}$$





- Simulation of the climate system is challenging but comes with benefits

- High resolution RCMs can capture extremes better compare to GCMs over regions with complex topography

- Fine resolution datasets based on reliable measurements are essential in climate science

References:

Isotta et al. 2014: The climate of daily precipitation in the Alps: development and analysis of a high-resolution grid dataset from pan-Alpine rain-gauge data. Int. J. Climatol., 34 (5), 1657-1675.

Fantini A., Raffaele F., Torma Cs., Bacer S., Coppola E., Giorgi F. (2016): Assessment of multiple daily precipitation statistics in ERA-Interim driven Med-CORDEX and EURO-CORDEX experiments against high resolution observations, *Clim Dyn*, doi:10.1007/s00382-016-3453-4

Szalai, S., Auer, I., Hiebl, J., Milkovich, J., Radim, T.. Stepanek, P., Zahradnicek, P., Bihari, Z., Lakatos, M., Szentimrey, T., Limanowka, D., Kilar, P., Cheval, S., *Deak, Gy., Mihic, D., Antolovic, I., Mihajlovic, V., Nejedlik, P., Stastny, P., Mikulova, K., Nabyvanets, I., Skyryk, O.,* Krakovskaya, S.,Vogt, J., Antofie, T., and *Spinoni, J., 2013:* Climate of the Greater Carpathian Region. Final Technical Report. http://www.carpatclim-eu.org.

Torma, Cs., F. Giorgi, and E. Coppola 2015: Added value of regional climate modeling over areas characterized by complex terrain-Precipitation over the *Alps., J. Geophys. Res. Atmos., 120, 3957-3972,* DOI:10.1002/2014JD022781.

Giorgi F., Cs. Torma, E. Coppola, N. Ban, C. Schär, S. Somot 2016: Enhanced summer convective rain at Alpine high elevations in response to climate warming., *Nature Geoscience*, doi:10.1038/ngeo2761