Regional climate simulations at kilometer-scale with RegCM4: Evaluation of precipitation and future projection

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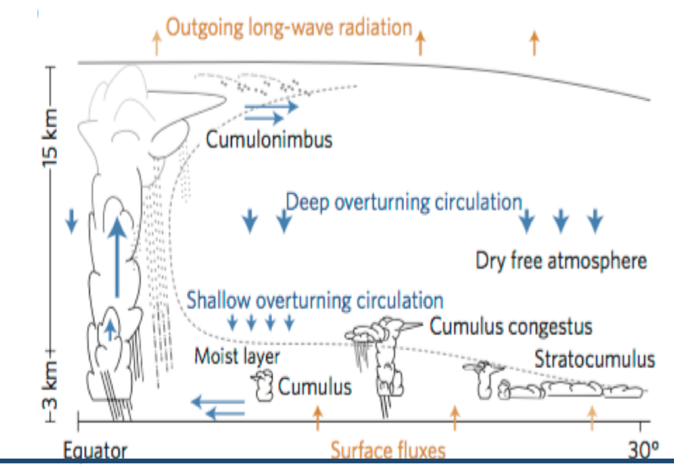
1) Introduction : Regional Climate activities in convection permitting scales)

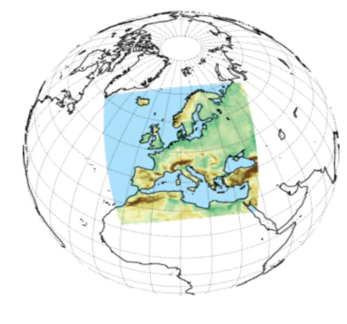
The reduction of model errors associateds with parameterized convection, a more detailed representation of present convection phenomena and the need to investigate how the convection phonomena responsible of damnaging events will change in the future, have strongly motivated the recent increase in modeling activities and projects at convection permitting scales:



Role of convection :

- ✓ Driving damaging extreme events
- ✓ It is the dominant type of precipitation in many parts of the world (tropics)
- ✓ Influences the general circulation of the atmosphere

EUCP
European Climate Prediction system



2) Overview of the work

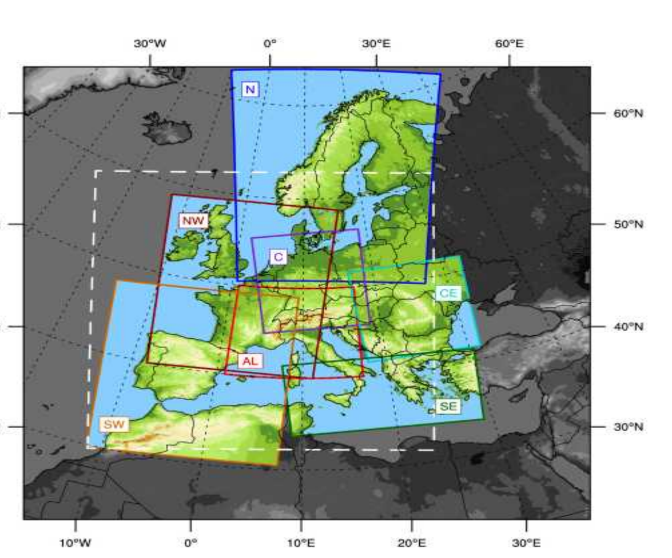


Fig.1: Set of Domains used for CP-RCM simulations in the EUCP.

We performed Convection Permitting Regional Climate Modelling (CP-RCM) simulation in the framework of European climate Prediction System project (**EUCP-https://www.eucp-project.eu/**) using the non-hydrostatic version of **RegCM4.7.0** model for the domains **AL**, **CE** and **SE** showed in **fig.1**:

1. Non hydrostatic simulation (3 km of resolution)
2. The ERA-Interim reanalysis, drives the perfect boundary simulation, cover the period 2000–2015
3. the scenario simulation , driven by the Global Climate model HadGEM, historycal (1996-2005), the near future (2041-2050) far future (2090-2099) for the RCP8.5 scenarios,

3) Purpose of the work and data

We aim to provide a first analysis of RegCM4 convection permitting simulations (3 km) with the driving 12 km convection parametrized simulation forced by the GCM-HadGEM, for two 10-year scenario projections, **1996-2005** (historical) and **2090-2099** (far future-rcp8.5) and for two domains, ALP and SE (Fig.1). The assesment of the RegCM4 historical simulations consist of a comparison with different observational datasets. The results for Alpine domain (**ALP**) (Fig.1) have been compared with high-resolution (sapce and time) observation-based precipitation datasets available over different areas covering *France, Germany, Netherlands, Alps, Spain, Italy and Switzerland* (EURO4M-APGD, COMEPHORE, SPAIN02, REGNIE, GRIPHO, RdisaggH). The results for South East Europe domain (**SE**) (Fig.1) have been compared with a merging of european-wide EOBS dataset with GRIPHO dataset (Fantini 2019). *The results are shown for historical and future for SE domain while for the ALPS we show and discuss only the historical simulation (**1996-2005**)*

4) Analysis and Methods : Statistical Indices

A number of statistical indices are employed (tab.1) to evaluate the model ability to reproduce the precipitation climatology as well as assess the impact of projected climate change. The indices are calculated on a seasonal basis considering December-January-February (DJF) for winter, March-April-May (MAM) for spring, June-July-August (JJA) for summer and September-October-November (SON) for autum.

Index	Definition	Unit
Mean daily precipitation	*Mean daily precipitation*	mm/day
Frequency	*Wet day/hourly frequency (defined as fraction of number of wet days per season)*	[fraction]
Intensity	*Wet day/hourly intensity (wet day is defined as a day with precipitation of at least 1 mm)*	[mm/d - mm/h]
Heavy Precipitation	*99th or 99.9th percentile of daily or hourly precipitation (defined as the 99th percentile of all events)*	[mm/d - mm/h]
Probability density Func. (PDF)	*Normalized frequency of occurrence of precipitation events within a certain bin*	

Tab.1: Statistical Indices analysed in the work

5) Results: South East Europe (Hstorical period)

Daily Analysis
Season: DJF (1996-2005)

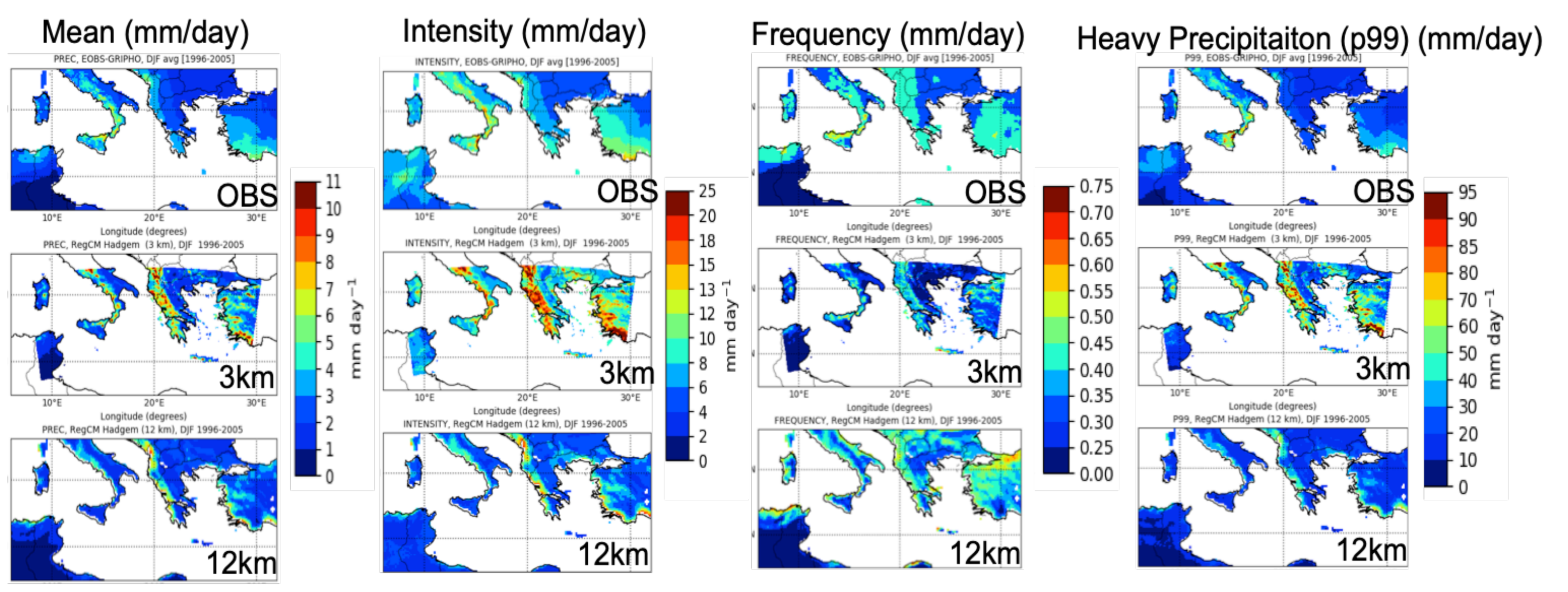


Fig.2: *Seasonal Mean (DJF) of analysed indices (from left to right: mean precipitation, precipitition intensity, precipitation frequency, and heavy precipitation defined as 99th precentile) calculated for daily precipitation in the winter (DJF).*

Hourly Analysis
Season: SON (1996-2005) **Season: JJA (1996-2005)**

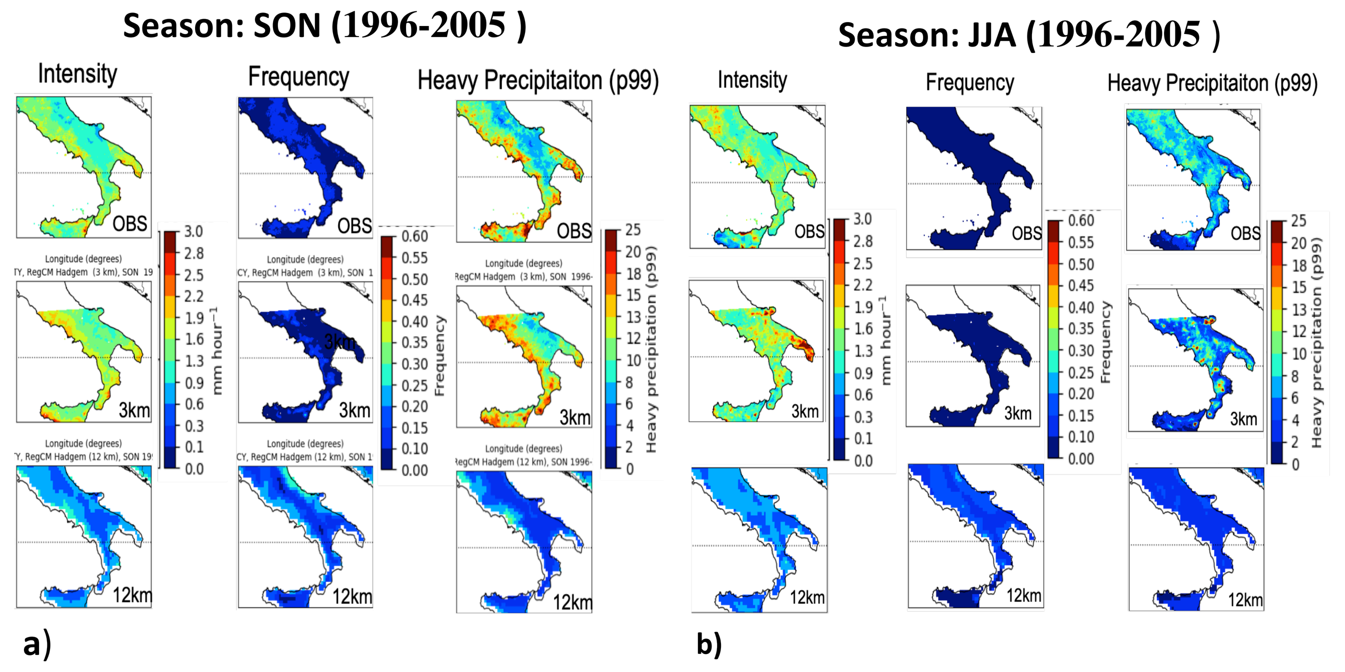


Fig.3 a,b) as Fig.2 but respectively for autumn (SON) and summer (JJA) hourly precipitation (mm/h). *We focused on the South of Italy whiche is the only area included in the SE domain where are available hight resolution (spatial and temporal.) observations from GRIPHO dataset (Fantini, 2019)*

PDF (mm/h)-South Italy

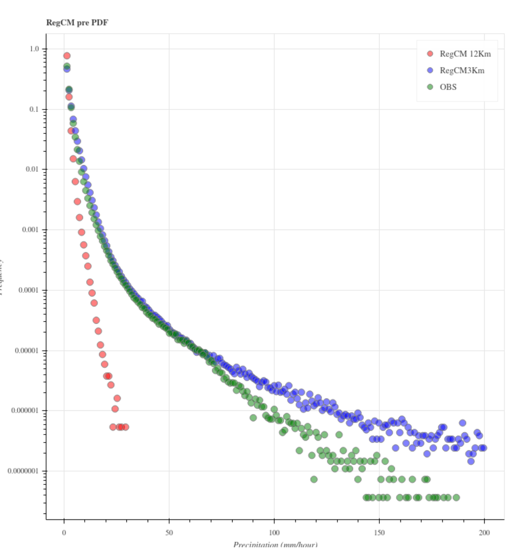


Fig.4:Probability density function (PDF) of hourly precipitation (mm/h) over South Italy for observed data GRIPHO (green), the 3km simulation (blue) and 12km simulation (red) over the period 1996-2005

The difference between the two simulation (3km vs 12km) are pronounced at hourly precipitation analysis (Fig.3a,b) and Fig.4. The qualitative improvement of the convection-permitting simulation in the precipitation intensity, frequency, extremes (p99) and spatial distribution is clear than for the daily timescale (fig.2)

5) Results: South East Europe (Future period)

CHANGE-Season: SON (2090/2099-1996/2005) **CHANGE-Season: JJA (1996/2005-2090/2099)**

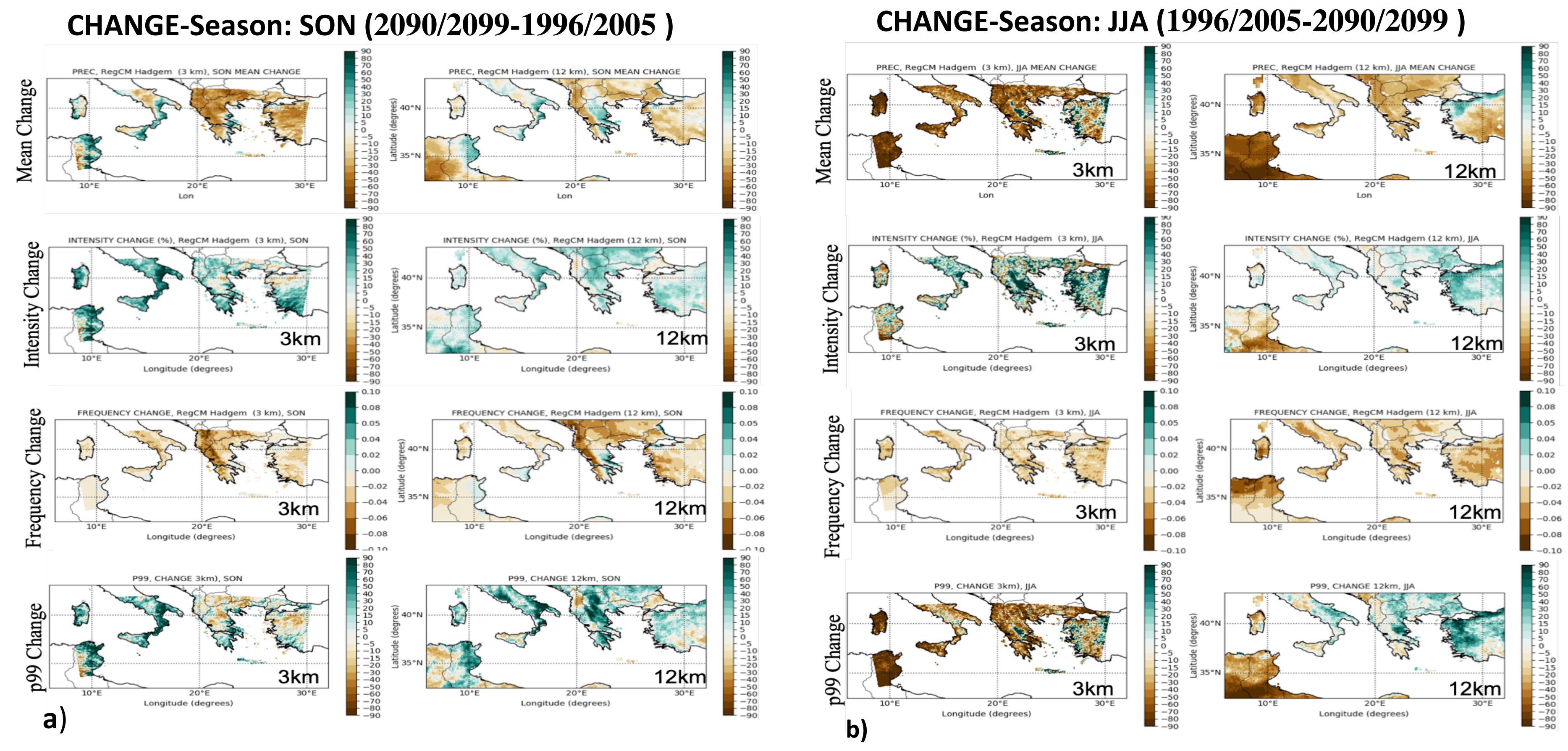


Fig.5 a,b) Seasonal Mean of the indices analysed over 2090-2099 respectively a) for autumn (SON), b) for summer (JJA). From top to bottom: mean precipitation (mm/day), precipitation intensity (mm/h), precipitation frequency, and heavy precipitation defined as 99th precentile (mm/h).

PDF (mm/day)-South Italy PDF (mm/hour)-South Italy

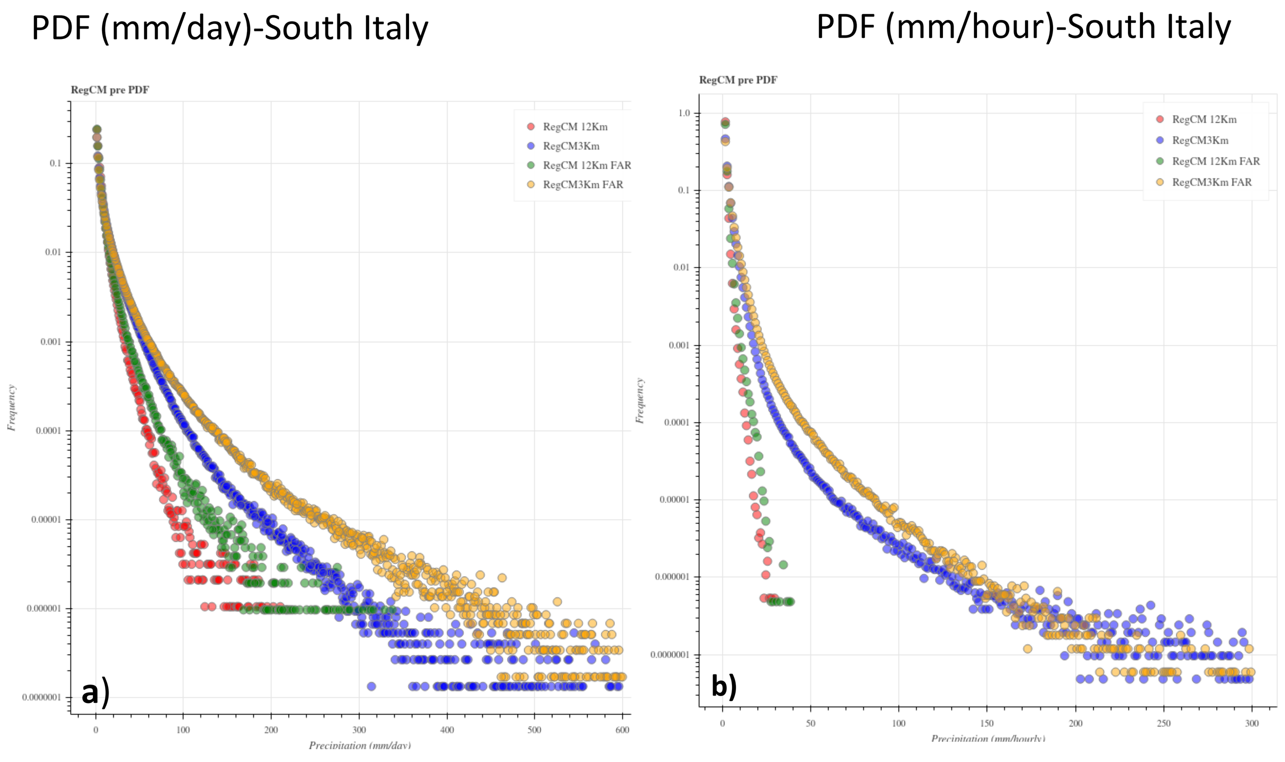


Fig.6 a,b):Probability density function (PDF) of daily (a) (mm/day) and hourly (b) (mm/hour) precipitation over South Italy for 3km simulation (blue) and 12km (red), over the reference period (1996-2005) and over the future decade (2090-2099) (green for 3km simulation and yellow 12km simulation)

For end-of-century (EOC) (2090-2099) rcp8.5 scenario, except for the p99.9 change in summer (Fig.5b), both simulations projections changes are similar (Fig.5). The 3 km simulation shows much stronger patterns of change, with drier conditions of the mean precipitation and frequency change, wetter intensity change (Fig.5) and an increase of extreme for a threshold of 400 mm (Fig.6a) at daily time scale and 150 at hourly time scale (Fig.6b)

6) Results: Alps (Historical period)

Daily Analysis **Season: SON (1996-2005)** **Hourly Analysis**

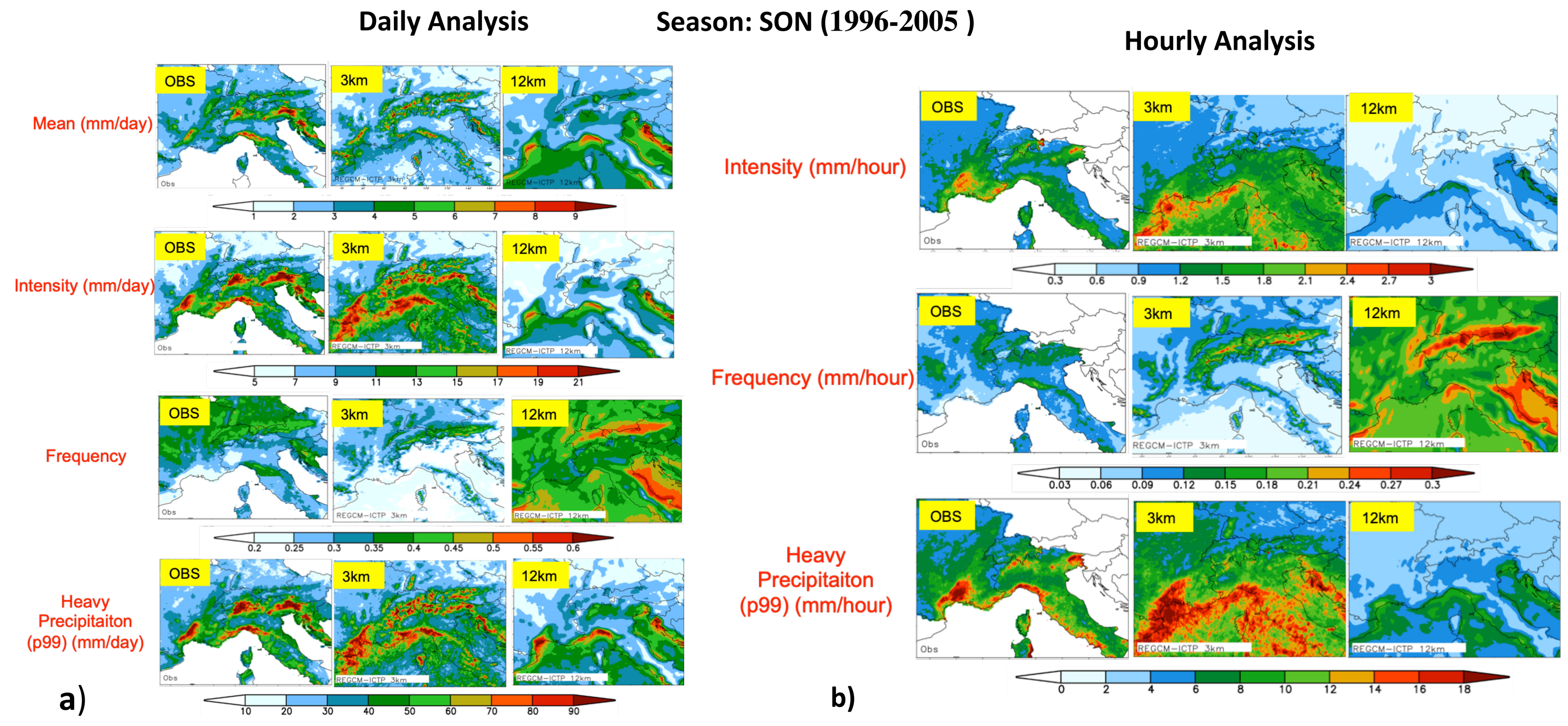


Fig.7: *Seasonal Mean of analysed indices over the Alpine region for autumn (SON), respectivley a) Daily and b) hourly. From top to bottom: mean precipitation (mm/day), precipitation intensity (mm/day-mm/hour), precipitation frequency, and heavy precipitation defined as 99th precentile (mm/day-mm/hour)*

Season: JJA (1996-2005)

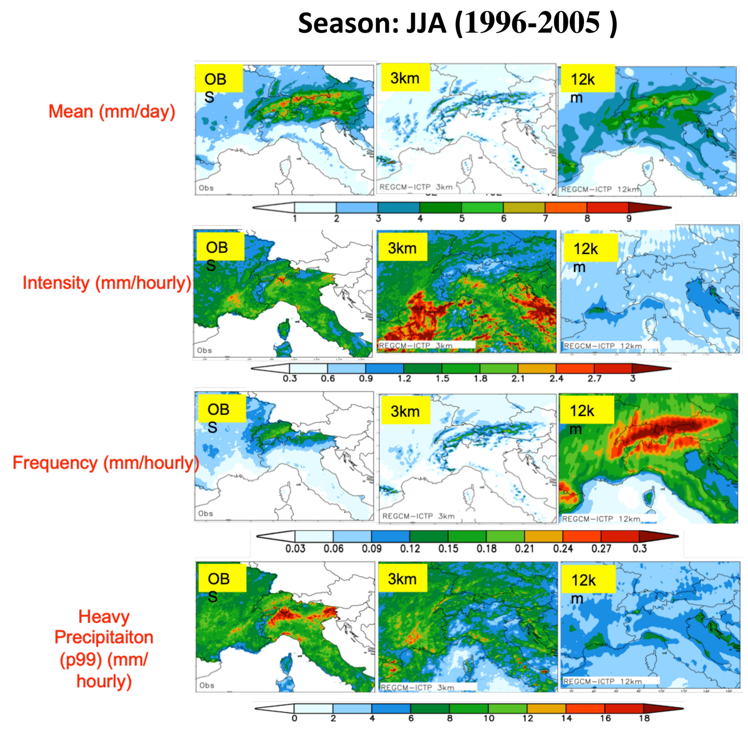


Fig.8:) as Fig.7 but for summer (JJA). *Seasonal Mean of analysed indices over the Alpine. From top to bottom: mean precipitation (mm/day), precipitation intensity (mm/hour), precipitation frequency, and heavy precipitation defined as 99th precentile (mm/hour)*

Conclusions

In general, the spatial patterns of precipitation are represented quite well, both at 3 km and 12 km and for both of the domains (SE, ALPS) (Fig. 2,3,7,8). The amplitude of the precipitation tends to be too strong in the convection-permitting model, in particular over the topography, but in general, the small-scale spatial variability of precipitation is enhanced in the convection-resolving simulation (3km). Although some differences and biases still persist at convection permitting scale resolution, an evident improvement of RegCM 3 km simulation respect 12 km in spatial representation, frequency and extremes are more marked compared to coarser resolution counterparts at hourly time scale (Fig.3b, 7b, Fig.4 and Fig.8).

The preliminary results for the future projections (2090-2099), over SE domain (Fig.5), indicate that the km-scale simulation refines and enhances the projected patterns of change from coarser resolution simulation and even modify the signal in some cases, e.g. in summer extreme change (Fig.5b). Moreover, the convection permitting simulations shows a general decrease of the mean precipitation in winter and summer over SE domain (Fig.7), an increase of the intensity and of the extreme precipitation in winter but a decrease of the amplitude of extreme in summer.