CMIP5 Earth System Models' Extreme precipitations over Iberian Peninsula and Balearic Islands: a comparative for historical periods using statistical downscaling

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R. Monjo, F.J. Pórtoles, E. Gaitán and J. Ribalaygua
Climate Research Foundation (FIC), Spain, fic@ficlima.org

Introduction

In the Peninsular Spain and Balearic Islands, the predominant climate is Mediterranean. Extreme monthly precipitation can have values ranging from a total amount of 0 mm (in July in some areas of the southeast), to almost 1000 mm in northern areas, or even in the east, where a high amount of precipitation in only a few days is usually recorded (Martín-Vide 2004). Eastern peninsula is a particular example of Mediterranean extreme precipitation (Fig. 1).

Thanks to the CMIP5 (Coupled Model Intercomparison Project Phase 5), a set of Atmosphere-Ocean Global Climate Models (AOGCMs) have been made available for its use in climatic studies. Some of the AOGCMs have been coupled to biogeochemical components that account for the important fluxes of carbon between the ocean, atmosphere, and terrestrial biosphere carbon reservoirs, thereby "closing" the carbon cycle in the model. These models are called Earth System Models (ESMs), and they have the capability of using time-evolving emissions of constituents from which concentrations can be computed interactively. They may in some cases also include interactive prognostic aerosol, chemistry, and dynamical vegetation components (Taylor et al., 2012). In our study, 10 climate models are used. In particular: EC-EARTH, HADGEM2-CC, NorESM1-M, MIROC5, CNRM-CM5, CanESM2, MRI-CGCM3, MPI-ESM-LR, GFDL-ESM2M, FGOALS-S2.

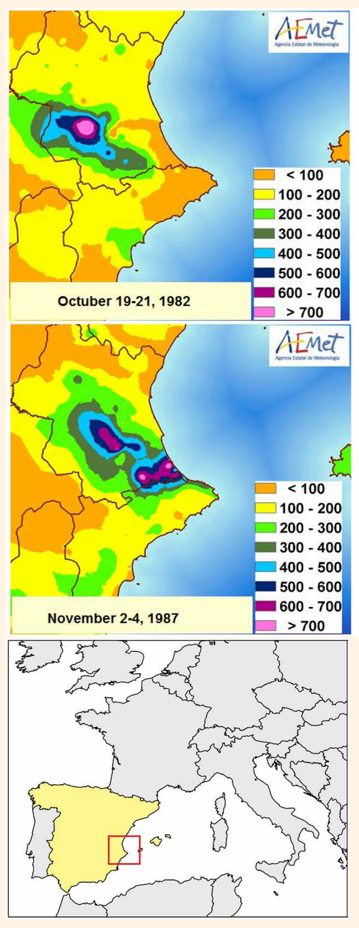

Fig. 1. Two example of extreme precipitation in eastern peninsula, and particular area in Spain. Figure thanks to Jose Ángel Nuñez (AEMET)

Data & Methodology

We have used the daily precipitation registered at 702 rain gauges (Fig. 2) of the Spanish Meteorological Agency (AEMET), with at least 40 years of records. The used time period is 1958-2000, which is common with the ERA40 reanalysis, our simulation of reference. The extreme rainfall of ten climate models are evaluated in this study, for the "historical experiment" provided by the CMIP5. Two-step analogue statistical downscaling method (Ribalaygua et al., 2012) is used:

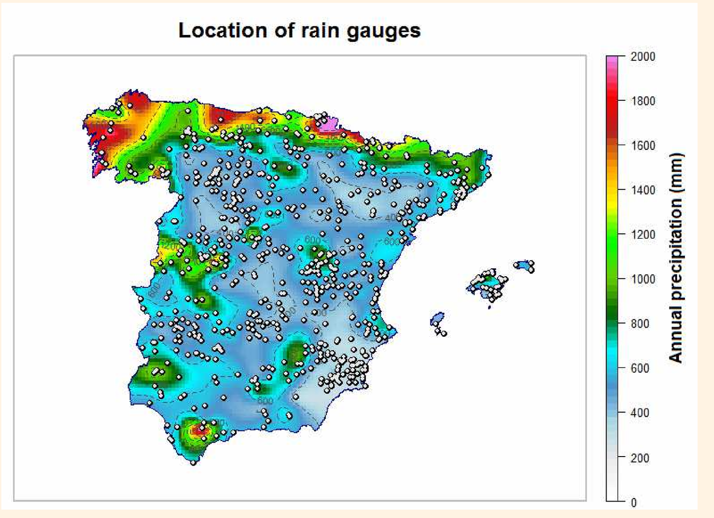

Fig. 2. Location of the 702 rain gauges with at least 40 years of records. Source: AEMET

Fist step: analogue approach (Zorita and von Storch, 1999). The similarity between two days was measured using a Pseudo-Euclidean distance between four large-scale fields as predictors: (1) speed and (2) direction of the geostrophic wind at 1000 hPa and (3, 4) the same at 500 hPa.

Second step: we downscale a group of m problem days. For each problem day (i) we obtain a "preliminary precipitation amount" (p_i) averaging the rain amount (r_{ij}) of its n most analogous days. The average is weighted by the probability (π_{ij}) of each analog. The In the other hand, we sort the $m{\times}n$ amounts of rain (r_k) and then we gathered those amounts in m new values (p_h'). Every quantity is then assigned, orderly, to the m days previously sorted by the "preliminary precipitation amount". Finally, empirical return period is obtained with a double logarithmic adjust for the extreme of the ECDFs.

$$p_i = \sum_{j=1}^{n} r_{ij}\pi_{ij}$$

$$p_h' = \sum_{k} r_k \pi_k$$

Results

Maximum daily precipitation expected for a return period of 5 years

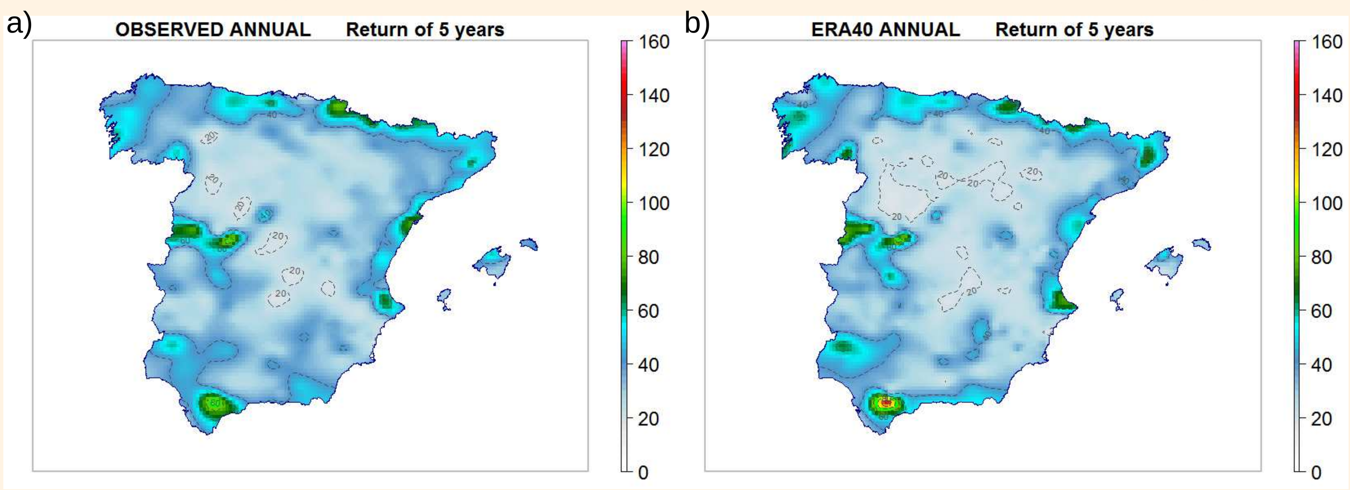

Fig. 3. a) Observed maximum daily precipitation for a **return period of 5 years**. **b)** the same but simulated for ERA-40.

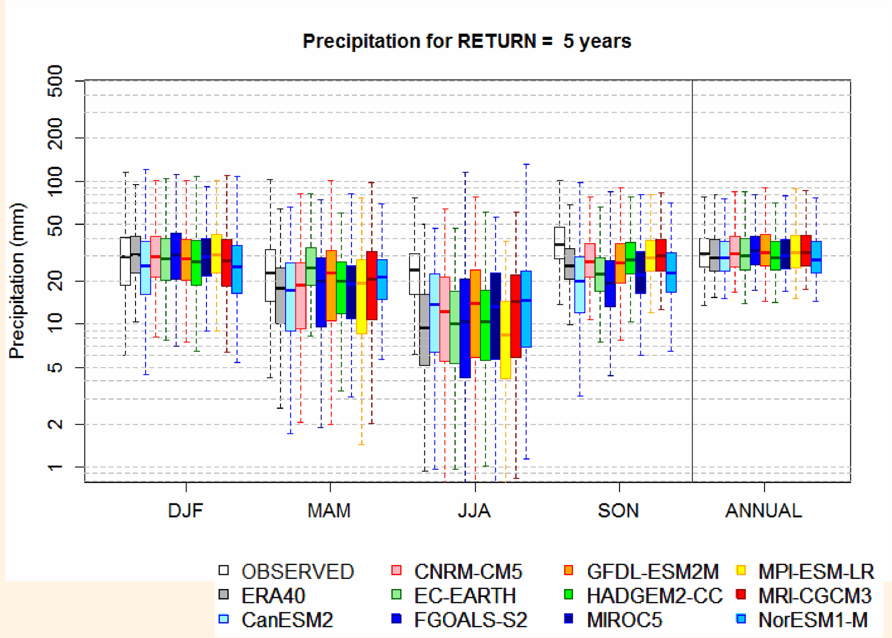

Fig. 4. Comparison of several simulations of the daily precipitation with a return period of 5 years, **separated for seasons**.

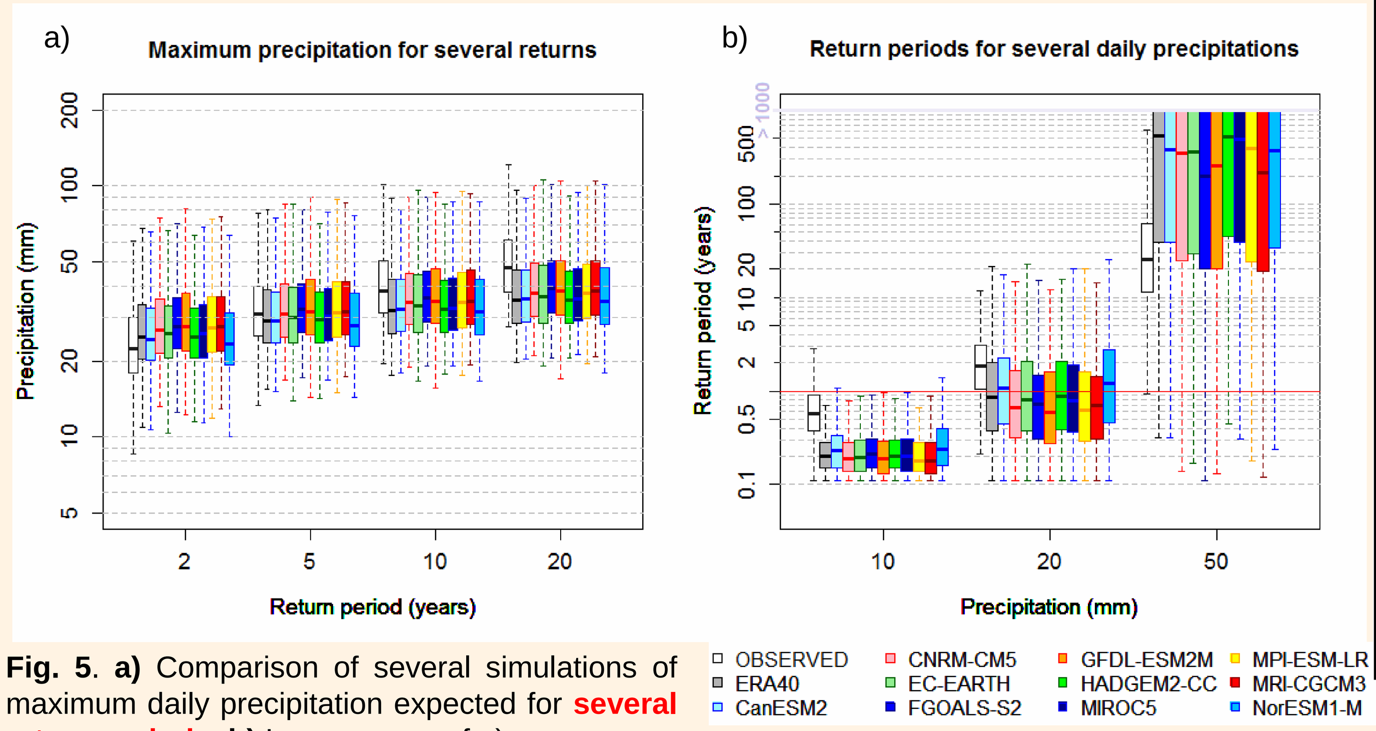

Fig. 5. a) Comparison of several simulations of maximum daily precipitation expected for **several return periods**. **b)** Inverse case of a)

Daily rainfall of return of 5 years. Time: ANNUAL

Daily rainfall of return of 5 years. Time: AUTUMN

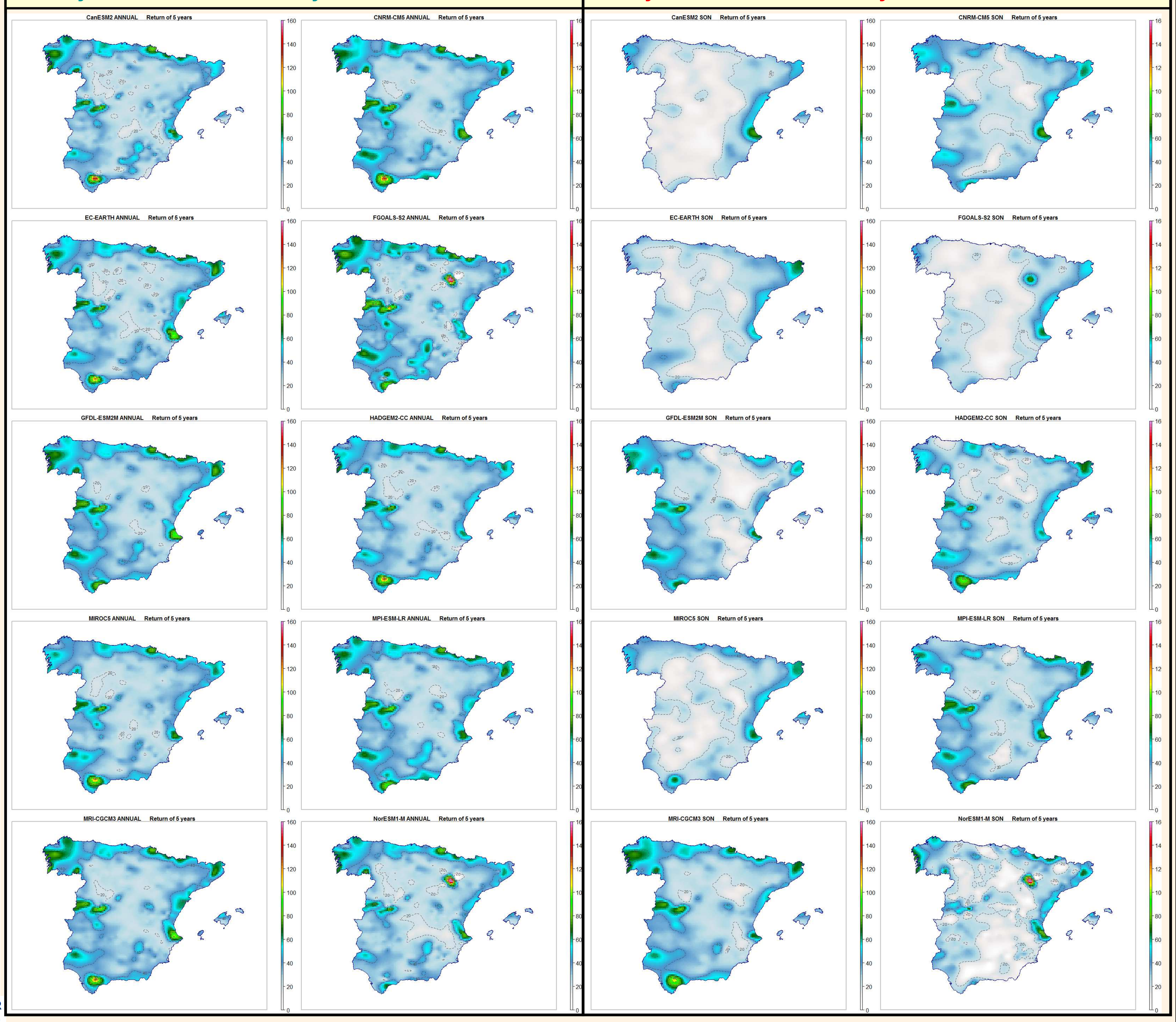

Fig. 6. Spatial distribution of daily precipitation expected for a return of 5 years, simulated for the 10 climate: **(left)** Annual period, **(right)** autumn period

Discussion

Results show that simulations subestimate the expected maximum precipitation for return periods higher than 10 years (Fig. 5 and Fig 7). This is a limitation of our methodology, because simulations are performed using a weighted average. If we use only the n analogues of a problem day, the extremes of the simulated preliminary precipitation is very smooth. For this reason, we try to simulate better the observed probability distribution using a population of precipitation of m problem days, and then of the amounts of the $m{\times}n$ analogues. Indeed, in our methodology the $m{\times}n$ amounts are sorting before the weighted average, and then the new m values of precipitation have a better similarity to the observed probability distribution. However, since we choose m = 30 days, this is not enough to analyse precipitation amounts with a return period higher than 10 years.

Another important limitation is the time-period used for this study: only 40 years. For a good analysis would be necessary to have at least 100 years of data, because of the large natural variability of rainfall.

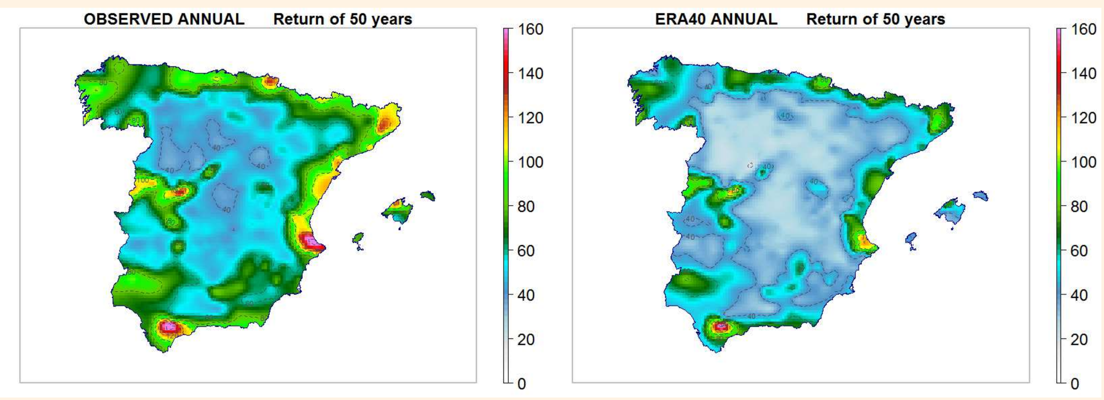

Fig. 7. Observed maximum daily precipitation for a **return period of 50 years**. **b)** the same but simulated for ERA-40.

Conclusions

- Results show a good simulation of extreme daily precipitation for low return periods: 2 to 5 years.
- Methodology has a limitation for return periods higher than 10 years.
- Regarding the spatial analysis, most of simulations using the climate models show great agreement with the observations for annual time-period and for returns lower than 10 years. But for the autumn and summer periods climate models have important discrepancies.
- If we compare the simulations using the climate models with the simulation using ERA-40, then the CanESM2 and FGOALS-S2 show better results.

Acknowledgments

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Reference

Ribalaygua J, Torres L, Pórtoles J, Monjo R, Gaitán E, Pino M.R. (2012) Description and validation of a two-step analogue/regression downscaling method. Theoretical and Applied Climatology, *in review*.