

Regionalización dinámica de la precipitación diaria sobre la Península Ibérica: análisis de la resolución espacial en la descripción del clima actual y clima futuro

Dynamical downscaling of daily precipitation over the Iberian Peninsula: a spatial resolution analysis for present and future climate conditions

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RESUMEN

Se presenta el análisis de la precipitación diaria sobre la Península Ibérica modelizada por un modelo global de clima (GCM) y un modelo regional de clima (RCM) forzado por éste, con dos resoluciones, para clima presente y el escenario A2 de emisiones de gases de invernadero para final del siglo XXI. La estructura espacial básica de la precipitación total anual, con un máximo en el noroeste de la región y un mínimo en el sureste es descrita tanto por el GCM como los RCMs a ambas resoluciones, aunque el GCM no es capaz de mostrar los valores correctos de ambos extremos, ni tampoco diversos aspectos más locales, asociados a la compleja orografía de las cordilleras de la Península, o a efectos costeros. Otro aspecto en el que se obtienen más diferencias es en la estructura espacial del número de días de precipitación. Para condiciones de cambio climático, tanto el GCM como los RCMs muestran un descenso generalizado en la precipitación total y del número de días de lluvia.

Palabras clave: Precipitación; regionalización dinámica; cambio climático; modelos regionales de clima.

ABSTRACT

The analysis of daily precipitation over the Iberian Peninsula as modelled by a global climate model (GCM) and a regional climate model (RCM) forced by the GCM, at two resolutions for present climate and A2 scenario of greenhouse gases emissions for the end of 21st century is presented. The spatial structure of total annual precipitation, with a maximum in the northwest of the region and a minimum in the southeast is described by both the GCM and the RCMs, although the GCM is not able to reproduce neither the magnitude of both extremes, nor other

more local characteristics, such as the ones related to the complex orography of the Iberian Peninsula mountain chains, or coastal features. Important differences in the spatial structure are also seen in the number of days of precipitation. For climate change conditions, the GCM and the RCMs show a general decrease in the total precipitation and in the number of rainy days.

Key words: Precipitation; dynamical downscaling; climatic change; regional climate models.

SUMMARY: 1. Introduction. 2. Methodology: PROMES regional climate model 3. Results. 4. Summary and conclusions. 5. Acknowledgements. 6. References

1. INTRODUCTION

Regional climate modeling (RCM, Giorgi and Mearns, 1999) has become in the past years a widely used tool to downscale global climate model (GCM) results into more regional scales. Due to the limited horizontal grid size of the GCMs (typically around 200 km at 2007-IPCC report) there are several atmospheric processes showing problems to be accurately described, at their natural scales. The increase in resolution obtained by the RCMs can improve such representation. One of the variables that is likely to show a more clear improvement is the precipitation. It has a very complex structure both in time and space, and atmospheric mechanisms that generate it are related both to large scale processes and to smaller scale processes like convection. A better description of orographic features or coastal characteristics is also a topic of improvement related to regional models.

One of the regions in Europe where precipitation exhibits a more heterogeneous behaviour is the Iberian Peninsula (IP). The IP presents a strong seasonal cycle and a large interannual variability (Trigo and Palutikof, 2001), with a large spatial spread in precipitation values, mainly due to Atlantic synoptic disturbances (Serrano et al., 1999), ranging in annual amounts from 300 mm year⁻¹ in the southeastern semi desert regions (Romero et al., 1999), to more than 1200 mm year⁻¹ in the northwestern part (Rodríguez-Puebla, 1998; Romero et al., 1999; Martín-Vide, 2004; Rodrigo and Trigo, 2007; Martínez et al., 2007). At the same time, climate change projections for future conditions indicate a much larger uncertainty in precipitation than in temperature (Christensen et al., 2007), although they generally indicate a tendency to a reduction in total amounts (Christensen and Christensen, 2007), together with the possibility of an increase in heavy precipitation events over the Mediterranean region for future climate scenario conditions (Alpert et al., 2002; Sánchez et al., 2004; Gaertner et al., 2007; Gao et al., 2008).

Several recent studies have analyzed precipitation features over specific European subregions from RCM results: Christensen et al. (2001) for Scandinavia; Frei et al. (2003) over the Alps; Rowell (2006) over Great Britain; Gibelin and Déqué (2003), Sánchez et al. (2004), Giorgi and Lionello (2008) over the Mediterranean Sea, Zanis et al. (2009) for Greece, or Hagemann et al., (2009) over several European catchments. But there is a lack of such detailed analysis focused specifically over the Iberian Peninsula, despite the numerous points of interest described before. The most detailed description of climate change features over the

IP is found in several studies that have included IP as a whole when splitting Europe in subregions (usually 8) to analyze European climate from regional climate models (Christensen and Christensen, 2007; Jacob et al., 2007; Déqué et al., 2007; Tapiador et al., 2007).

We want here to focus on the following issues: the differences between the GCM and the RCM, and the dependency on spatial resolution of RCM results in the description of daily precipitation characteristics over the Iberian Peninsula for present climate conditions and for climate change projections by the end of the 21st century. The idea behind this is an effort to quantify to what extent and with which degree of coherence GCM/RCM models are able to describe the main features of precipitation. As the RCM has simulated climate over the Iberian Peninsula with two horizontal resolutions (50 and 25 km of horizontal grid size), we will be able to point out the strong and weak characteristics of precipitation description of the IP climate in relation with the horizontal resolution (as both RCM configurations use the same parameterizations, which is not the case of the GCM compared with the RCM).

2. METHODOLOGY: PROMES REGIONAL CLIMATE MODEL

PROMES regional climate model (Gallardo et al., 2001; Sánchez et al., 2004) has been applied, with a horizontal resolution of 50km (RCM50), for present climate (1961-1990) or current conditions (named CT hereafter) and under A2-SRES future (2071-2100) emissions scenario (Nakicenovic and Swart, 2000), forced by HadAM3H global climate model (Pope et al., 2000). These PROMES RCM simulations have been compared successfully against other regional models under the same conditions at PRUDENCE European project (Christensen et al., 2007). Seasonal temperature and precipitation have been analyzed for current climate (Jacob et al., 2007) and climate change conditions (Christensen and Christensen, 2007; Déqué et al., 2007) over several subregions, one of them being the whole Iberian Peninsula. We use daily precipitation results obtained from RCM50, together with a higher resolution simulation (25km horizontal grid size) performed with the same PROMES-RCM model (RCM25) in a domain centered over the IP and nested in RCM50. The corresponding results of the GCM (with a horizontal resolution of 1.875 x 1.25 degrees) used to force RCM50 are also shown. To compare model results against observations on daily scales, ECA (European Climate Assessment) observational daily database (Haylock et al., 2008) is chosen.

3. RESULTS

3.1 Total annual precipitation results.

3.1.1) Present climate (CT):

Total annual mean precipitation over the Iberian Peninsula for present climate conditions (1961-1990) is shown in Fig. 1. There are some differences between the two RCM runs: precipitation in RCM25 is higher at the northern and northwestern coast. This increase compares positively with ECA data, particularly at the northwestern coast, where a large improvement is achieved in RCM25 with respect to RCM50 and GCM runs. The latter showed not only a large negative bias over the northwestern parts, but also a displacement to the south of the maximum precipitation. In general, the higher resolution generates higher precipitation maximum, in coincidence with previous numerical studies (Durman et al., 2001). In general, these higher maximum values compare favorably with direct analyses from observational data (Esteban-Parra et al., 1998; Martín-Vide, 2004). At places like the Pyrenees, the higher maximum precipitation in RCM25 departs more from ECA data, though the sparse distribution of meteorological stations used in generating ECA precipitation (Haylock et al., 2008) may underestimate precipitation over certain mountainous areas. Simulated precipitation is also higher in RCM25 at the eastern Mediterranean coast, particularly at its central and northern parts. The behaviour of the different simulations is unusual in this respect, as the run with less precipitation over this area is RCM50, not the GCM run. This particular behaviour may be linked to the precipitation characteristics, as this is an area with a large influence of strong convective events. Comparing with ECA data, the best simulation would be RCM50 over this area. Another noteworthy feature is the negative bias of both RCM runs over the southwestern part of Iberian Peninsula. In this case, higher resolution doesn't generate more precipitation there. The GCM results are nearer to ECA data there. This suggests that model-related differences (like different parameterizations in PROMES model of cloud-precipitation processes) may be the reason for such precipitation differences. Some tests with different physical parameterizations (Dominguez, 2009) seem to confirm this hypothesis.

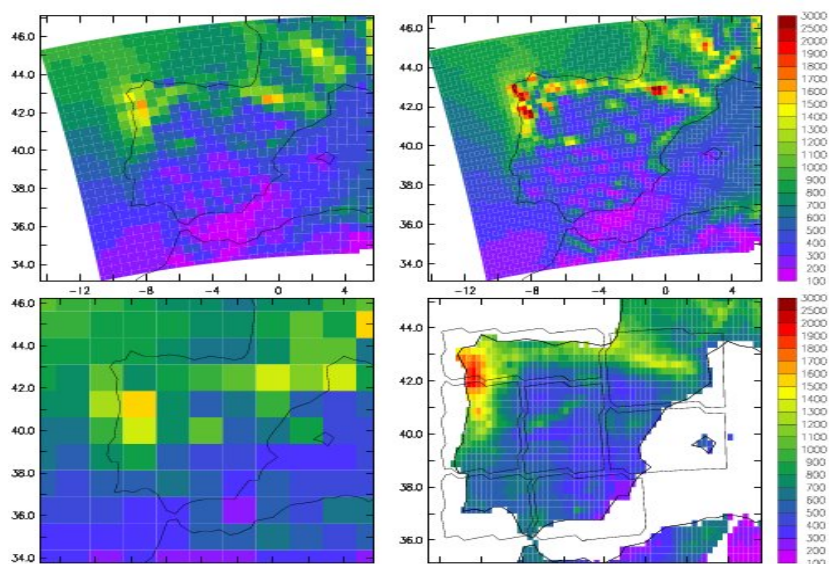


Figure 1. Accumulated annual precipitation (mm year^{-1}) for present climate conditions (1961-1990) as obtained by the RCM50 (up-left) and RCM25 (up-right), and the GCM (bottom-left) and observational ECA database (bottom-right). On the last figure, seven subregions are shown for a more detailed analysis. The subregions are named as follows: NW (northwest), NE (northeast), CW (center-west), CC (center-center), CE (center-east), SW (southwest) and SE (southeast).

In Fig. 2 monthly climatological timeseries (30 year averages) for the three models and also for ECA are shown for the seven subregions defined in the bottom-right frame at Fig. 1. Although RCM25 gives systematically higher values of precipitation than RCM50, the main features of both RCMs are quite similar, especially in CW, CC and SW. Larger differences are found in CE. Meanwhile, differences between RCMs and GCM are substantial for most of the months and regions. Models are able to describe the observed summer minimum/winter maximum of western subregions, and the spring-autumn double maximum behaviour of Mediterranean subregions (Rodríguez-Puebla et al., 1998, Lana and Burgueño, 2000).

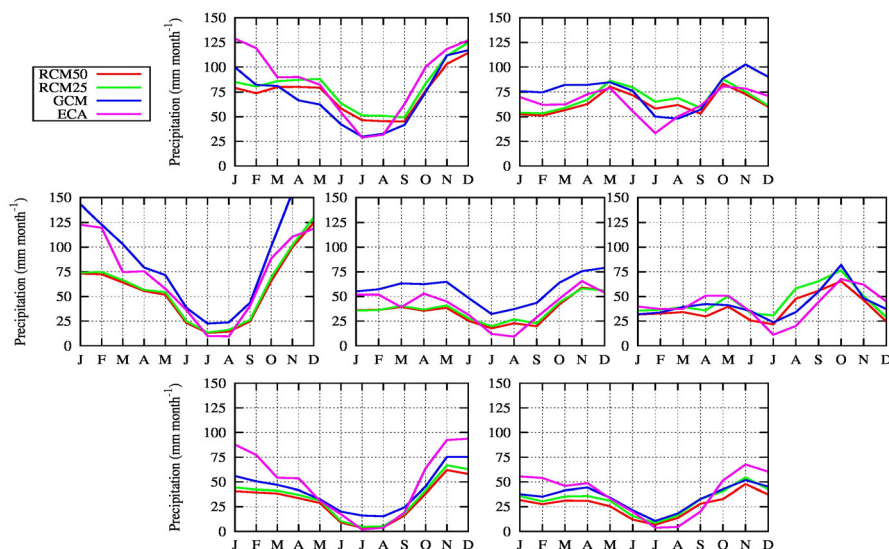


Figure 2. Climatological monthly precipitation (mm month^{-1}) timeseries for present climate period at each of the seven subregions described in bottom-right picture of figure 1. Their relative position is here the same as there: NW and NE in the upper row, CW, CC and CE in the central row and SW and SE in the bottom row.

3.1.2) Future climate conditions (A2):

Regarding the impact of anthropogenic climate change on future annual precipitation, Fig. 3 shows the projected precipitation change for the three runs. The general effect is very clear, as a yearly precipitation reduction is obtained in all simulations. There are some important differences between the GCM and the two RCM runs. The minimum future precipitation change is located, in the GCM, over the northwestern part of the Iberian Peninsula and at the northern coast. The two RCM runs (more strongly the RCM25 run) locate the minimum precipitation change over the northern plateau, south of the northern mountain range. This difference points to the influence of the orography on this result, as the RCM represents much better the orography. The GCM shows the maximum precipitation change over the southwestern part of the Iberian Peninsula, in contrast to the RCM runs. This difference between models could be related to the above explained negative bias in the RCM runs: if less precipitation is simulated in them, the change (in absolute value) is limited in comparison with the GCM run. Generally, the precipitation reduction in RCM25 is stronger over the mountains than in RCM50, in good correspondence with the differences between the two runs for present climate conditions. Along the same line, RCM25 shows a stronger reduction at the eastern coast. The uncertainty in the precipitation projection linked to the model formulation seems to be larger than the uncertainty linked to the

model resolution, though all simulations point in this case towards a clear precipitation reduction.

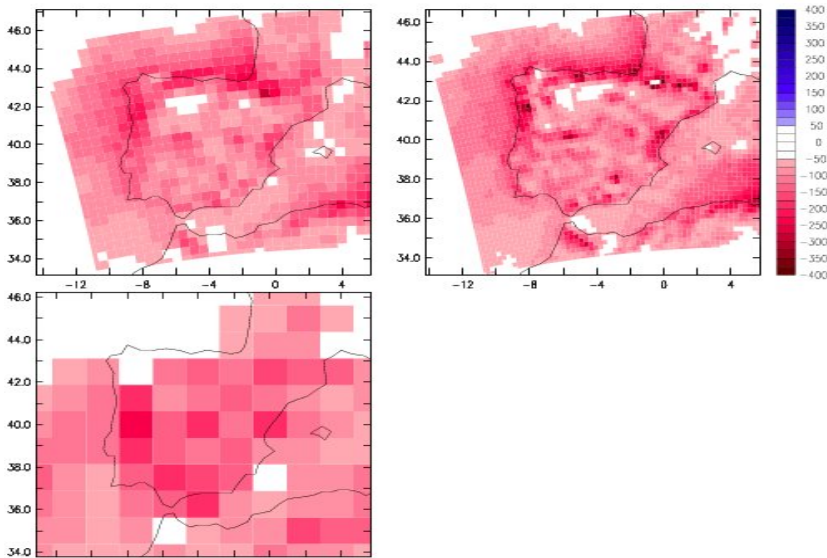


Figure 3. As figure 1, but for climate change projections: (2071-2100) period under A2 emissions scenario minus (1961-1990) current climate period (total annual precipitation amounts in mm year^{-1}).

Comparing current climate and A2 scenario precipitation by regions (Fig. 4), a decrease of precipitation is projected for all the regions and for most of the months. Results are quite similar again for RCM50 and RCM25, and only appreciable differences are found in CE region. Although changes in the GCM are qualitative similar to those in the RCMs, in some cases precipitation has important differences between both kinds of models. Some examples are spring in the CC, summer in the NW or autumn in the NE. It's noteworthy that six out of seven regions reach in May their largest decrease of precipitation in A2 when compared with current climate. These decreases are especially important for north-western subregions, which could be related to the changes in the strength of the annual cycle spectrum for the A2 scenario obtained by Tapiador and Sánchez (2008) for that area.

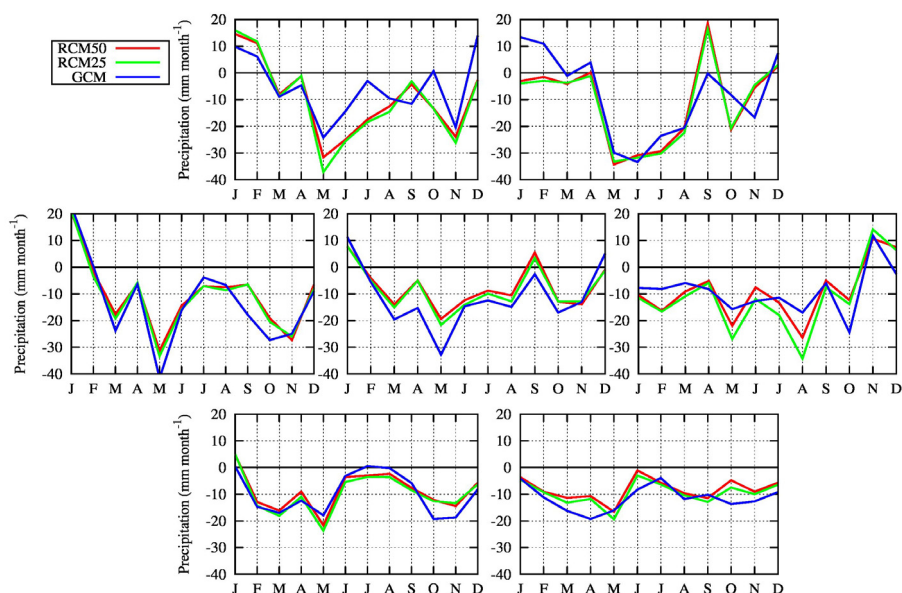


Figure 4. Same as figure 2, but showing the difference between future climate scenario (A2) and present climate conditions (CT), in mm month^{-1} .

3.2. Number of rainy days

The number of rainy days (defined by a 0.1 mm day^{-1} threshold) for present climate (Fig. 5) and its change for A2 scenario (Fig. 6) shows a different picture than the total precipitation amounts. ECA results exhibit a much smoothed pattern (Hofstra et al., 2009), which is not obtained by other observational analysis (e.g. Burgeño et al., 2005). GCM and both RCMs overestimate ECA values, although the higher values in the northern half of the IP and the lower values in the southern part structure are reproduced by the models. Again, the GCM is unable to describe features related to orographic (central mountain chains) or coastal characteristics (Mediterranean area). RCM25 shows in the southern area more similar values to ECA than RCM50, whereas in the Cantabric region both model versions give much higher values of rainy days than ECA. With respect to climate change projections (Fig. 6), an overall decrease in the values are obtained by the three simulations, although the GCM shows some increases in the annual amounts at specific points. RCM50 and RCM25 present a very similar structure.

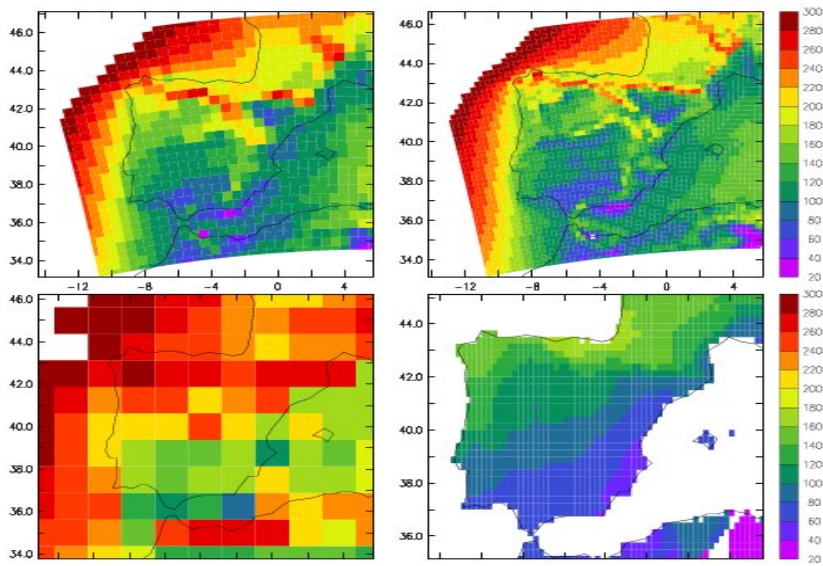


Figure 5. As figure 1, but for the number of rainy days (defined by the threshold of 0.1 mm day^{-1}).

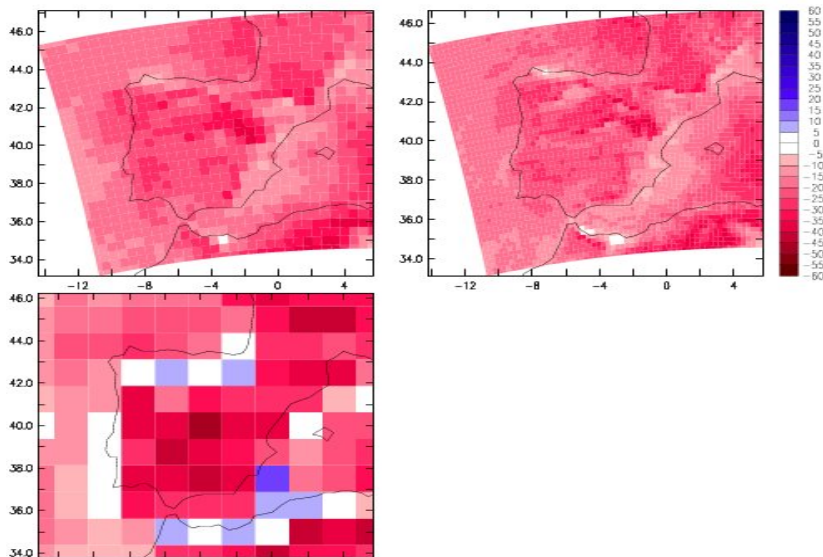


Figure 6. As figure 5, but for change of the number of rainy days for future climate conditions (A2) with respect to present climate conditions (CT).

4. SUMMARY AND CONCLUSIONS

Daily precipitation results from an RCM at two resolutions (50 km and 25 km) and the forcing GCM for present and future climate conditions over the Iberian Peninsula have been analyzed. The GCM and both RCM50 and RCM25 are able to describe the general features of current climate annual precipitation amounts regarding their spatial and temporal structure. Nevertheless, also important differences are found, as the GCM is not able to describe some regional features related to orography and coastal areas, where it underestimates the total values of precipitation. For climate change conditions, both the GCM and the RCMs exhibit a decrease in total precipitation, although the magnitude of this decrease is smaller for the GCM results. The subregional monthly climatic timeseries show remarkably similar results for the GCM and the RCMs, both for present climate and for climate change projections. The spatial average of higher and lower values of RCMs compared with the GCM over the seven subregions, giving rise to smoothed values, can explain this better agreement of timeseries compared with the spatial structure of this field. The number of rainy days exhibits larger differences between the GCM and the RCMs, whereas the ECA observations present a very smooth spatial pattern. Models project a decrease in this variable, although the GCM presents some isolated points where a small increase is obtained.

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