Climate change and extreme precipitation: the response by a convection-resolving model

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Among expectations from global warming, caused by anthropic greenhouse gases emissions, many studies have pointed out the increase in precipitation above a certain threshold, also known as extreme precipitation increase. This feature is common to most climate models, including those with a very coarse resolution. It is not incompatible with a decrease in total precipitation, i.e. the accumulation for all precipitating days. It is also in agreement with Clausius-Clapeyron law, which states that temperature is a limiting factor for atmosphere moisture. However IPCC global models represent poorly the probability distribution function of precipitation beyond 99% percentile. Therefore a model consensus is not enough to definitely state that extreme precipitations will increase during the 21^{st} century. Regional climate models, in particular those running at 12 km horizontal resolution like in EuroCordex, attempt to represent phenomena closer than the observed ones. However both GCMs and RCMs do not explicitly represent the physical phenomenon responsible for heavy rainfall, i.e. convection.

The climate of the South-East part of France, named Mediterranean climate, is characterized by heavy rainfall in autumn and early winter. It is still debatable whether these phenomena have increased or not during the 20^{th} century. In this region, the eastern part of the Massif Central mountain (so-called Cevennes) undergoes the maximum daily rainfall rates with observed values above 300 mm/day in the SOND season, based on the last decade records. Almost every year, dramatic flash flood events are reported there, and the link to climate change is often pointed out.

In order to explore the role of an explicit representation of the convection in the simulation of heavy precipitation, two experiments have been carried out. In each experiment we have used ALADIN (Déqué and Somot, 2008), a hydrostatic model with 12 km resolution on a domain covering France and surrounding areas, and AROME (Seity et al., 2011) a non-hydrostatic model with 2.5 km resolution on a smaller domain centered on South-East France. ALADIN provides lateral boundary conditions to AROME. Both models are operational forecast models at Météo-France, and may be used for long climate simulations as well (e.g. in Cordex).

The first experiment is a validation against the hourly 1kmx1km 1997-2006 rainfall reanalysis over France COMEPHORE (Tabary et al., 2012) based on radar and rain gauges. ALADIN is driven by the ERA-interim reanalyses, and drives in turn AROME. We have selected 0.5°x0.5° boxes where the maximum daily rainfall exceeds 300 mm in the daily 8kmx8km reanalysis over France SAFRAN (1989-2014). This domain corresponds broadly to the above-mentioned Cevennes region. For COMEPHORE, AROME and ALADIN, all the grid points of this domain for SOND 1997-2006 are aggregated, and a cumulative distribution function (cdf) is calculated. This operation is done for hourly as well as for daily rainfall. Figure 1 shows the tail of the cdfs (in fact 1-cdf). The probability estimated is the absolute probability, not a conditional one. Thus, a probability of 0.00001 for hourly data corresponds to a return period of 35 years at a given grid point. For daily data, this probability corresponds to 24 times this length. The ALADIN daily cdf is poorly sampled at the very tail, with 1220 days and 124 grid points in the “Cevennes” domain. For AROME (3097 grid points) and COMEPHORE (22500 gridpoints) the sampling used to evaluate a 0.00001 probability is better. One can see that the high resolution model AROME is closer to observations than ALADIN, even though AROME underestimates rainfall for probabilities less than 0.001.

It is not surprising that a model at lower resolution produces less extreme events than a model with higher resolution. The interesting question is: do the two models behave similarly in a global warming scenario. If yes, one can use Cordex model responses as a proxy, with a statistical adjustment (e.g. quantile mapping) when realistic amounts are needed in an impact study. If no, we need to run regional models at the highest possible resolution, when the impact study is connected with extreme precipitation. The second experiment consists in two pairs of simulations with ALADIN and AROME. The driving condition is an RCP8.5 scenario with CNRM-CM5 model (CMIP5 experiment). The first time slice, named reference, is 1989-2000. The second, named scenario, is 2089-2100.

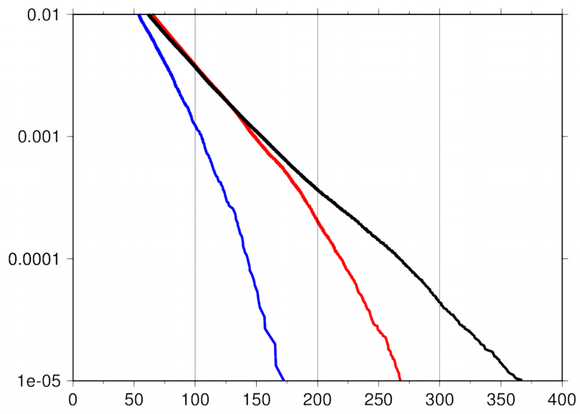

Figure 1: Tail of the complement to one of the cumulative distribution function for daily (left) and hourly (right) precipitation (mm) in the Cevennes area for the validation experiment: COMEPHORE (black), AROME (red) and ALADIN (blue); probabilities are shown in logarithmic scale.

Figure 2 shows the tail of the cdfs for hourly and daily precipitation, AROME and ALADIN, reference and scenario. For hourly precipitation (right panel), the expected behavior is obtained: both models increase the extreme precipitation. For daily precipitation (left panel), an opposite behavior is observed: AROME decreases the extremes whereas ALADIN increases them, in agreement with the usual behavior of GCMs and RCMs.

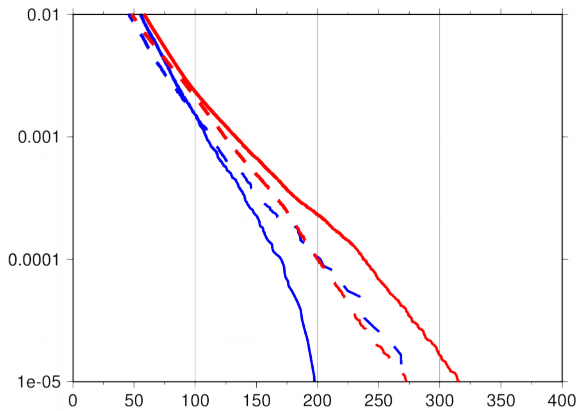

Figure 2: As Figure 1 for AROME (red) and ALADIN (blue); reference time slice (solid line) and scenario time slice (dash line).

We should avoid to generalize this result: the analysis period is only 12 years, and on other parts of the domain both models increase the extreme daily precipitations. But we want to report here that one must be careful when using GCMs or hydrostatic RCMs to evaluate the response of climate change on extreme precipitation events.

References:

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