Climate and hydrological variability: the catchment filtering role

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Response to Referee Comment RC-C4448-2014 – Anonymous Referee #2

The authors sincerely thank Anonymous Referee #2 for the time spent on our manuscript, his/her constructive comments, and for the interesting suggestions that will help to improve the manuscript. In particular, paper by Botter et al. (2013) was revealing, as it contains material and results of considerable interest. We have obviously referenced it in the revised version of the manuscript.

Before replying to the specific concerns of the Referee, we would like to make a premise that may allow the reader to better understand the essence of our study. We aim to estimate the frequency of occurrence of peak flows by using a derived distribution approach. Accordingly, we use a stochastic process to model rainfall and a deterministic lumped model to simulate the rainfall-runoff transformation. The above analytical approach, that has a long history of application in hydrology (see, for instance, Eagleson (1972) and Papa and Adams (1997)), presents several advantages. The most relevant one is the opportunity of analytically assessing the cause-effect relationships that take place in the rainfall-runoff transformation.

However, the analytical approach requires the use of models that lend themselves to analytical developments, which are obtained by using simplified representations. Therefore our analysis, being based on the use of an analytical model, cannot account for the overall complexity of catchment processes. This is the main reason why we use a simplified representation of hydrological processes without including detailed effects. Our target is to account for the most significant processes governing the hydrological impacts of climate change. We discuss the limitations of the analytical approach in the revised version of the manuscript.

Here below we report our detailed responses to the specific issues raised by Referee #2.

1. About a more complicated scenario where climate change also brings about changes to the landscape filtering attributes

We absolutely agree with Referee #2. There are clear interactions at the catchment scale between landscape characteristics (soils, vegetation and geology, for instance) and climatic properties. As Referee #2 states, possible climate-vegetation-soil feedbacks are not considered or investigated in our study. The initial scope of the proposed modelling scheme as well as additional simulations performed were in fact significantly more limited, as they basically centred on the variability of rainfall patterns, and to which extent such variations can actually be buffered by a given standard hydrological catchment, with typical response parameters of a semi-arid Mediterranean region. We observe that this same question was also brought to our attention by anonymous Referee #1. Accordingly, the revised version of the manuscript will describe in more detailed the scope of the paper (INTRODUCTION). To clarify the particular interest of this point, we will emphasize the limitations in the discussion/final conclusions of the paper, with explicit mention of extending the investigation in future studies, in order to incorporate the effect of watershed properties variation and role of land use changes, using a similar modelling framework.

2. On the assumption that each rainfall event, thus runoff event, can be treated as an independent event, with no "memory" of previous events

The analysis presented in the study is an "event based" approach, where, indeed, each rainfall-runoff event is treated as an independent event, with no "memory" of previous events. For the type of catchments undertaken for the scope of the paper, there are several arguments to support this assumption. In the Valencia Region, as in other many semi-arid locations around the Mediterranean, ephemeral rivers are closely related to small and fast-responding catchments. These stream flow regimes could also be named as "erratic regimes" according to the classification provided by Botter et al. (2013). Such regimes occur when rainfall inter-arrival times are somewhat longer than the typical duration of the resulting flow pulses, as the case presented in this study. As stated in Andrés-Doménech et al. (2010), antecedent dry periods for the rainfall pattern analysed are exponentially distributed with a 22-hour low bound and an 8-day expected mean value. With such a sporadic rainfall regime, antecedent moisture conditions are mainly related to the event itself and rainfall intensities during initial stages of the storm, so that the assumption of independence from the previous event is

plausible. Moreover, for this type of hydrological events, direct runoff is the dominant component of the hydrograph, and in any case, this is especially true during the peak flow stage. All these assumptions and considerations will be described in greater details in the revised version of the manuscript, in order to clearly state the hypotheses which support the subsequent developments and its range of applicability.

3. On how heterogeneity in catchment properties (soil properties, vegetation, storage, etc.) can influence the results

Again, we agree with Referee #2 about this particular concern. Investigations into this question have been contrasting and sometimes contradictory (Sangati et al., 2009), given the inherent complexity of the problem. In any case, it is clear that runoff statistics sensitivity to spatial heterogeneity is in principle less significant as the catchment area is smaller and more homogeneous. In our case, the assumption of a one hour concentration time for the hypothetical catchment under consideration is actually limiting the catchment area. Thus, the lumped modelling assumption can be considered reasonable, at least for the purpose of comparing in quantitative terms the resulting confidence interval width for peak flow distributions, resulting from either climatic input variations or known asymptotic properties of the Pareto distribution MLE estimators. Such comparison is rigorously carried out under a simple, popular, well-defined and identical catchment rainfall-runoff lumped operation.

4. About considering the entire range of stream discharge and its non-stationarity effects

This point of the discussion is in accordance with what has already been stated in response #2. As highlighted by Referee #2, the focus of the paper is on peak flows. In this respect, the Annual Maximum Series (AMS) approach may be clearer and more illustrative given the aims of this study, and thus all the additional analytical work has been conducted to present results derived from this more classic approach. To carry out this analysis, we assume that the rainfall forcing in the present climate can be modelled by a stationary model. We also assume that non-stationarity can be accounted for by changing the parameters of the rainfall model at a given time when climate change is supposed to occur. Such a change in the rainfall model parameters implies a corresponding deterministic change of rainfall statistics and therefore

non-stationarity (see also Koutsoyiannis and Montanari, 2014; Montanari and Koutsoyiannis, 2014).

Non stationarity in the river flow is assumed to occur for the presence of the above non-stationarity in rainfall and is quantified through our proposed approach. Non-stationarity in the modelling of the rainfall-runoff transformation is not considered, as a deterministic rainfall-runoff model with constant parameters is used.

In the revised paper, all the above assumptions that were not explicitly mentioned in the former version will be discussed. Also, and for a better geomorphological and hydrological identification of the type of catchments under analysis, additional references are included in the new version of the paper.

5. On the limitations of the approach

To fulfil the objective of the research and to benefit from the analytical simplicity and practical applicability, as mentioned by Referee #2, a very simple modelling approach is assumed, which necessarily involves major limitations, which were also mentioned by Referee #1. These limitations will be clearly identified in the revised manuscript. In fact, the research herein presented may constitute a first step towards a more complex analysis after relaxing of some of the initial assumptions, for instance, incorporating seasonality of rainfall stochastic properties or an extended sensitivity analysis based on variations of catchment response parameters. These aspects, among others already mentioned, should guide further research lines.

Additional references

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