Second answer to reviewers

Quantifying pluriannual hydrological memory with Catchment Forgetting Curves

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Report #1

> I think the authors did a decent job in revising some details of the paper. The paper seems mostly ready for publication. However, please check the minor suggestions below in submitting the final version.

Thanks for the additional comments on this second version and for the appreciation of the work done. We have addressed your suggestions below.

> **Abstract**
> A climatic anomaly can potentially affect **on** the hydrological behaviour of a catchment for several years. Remove ""on".

"on" has been removed.

> I think elasticities "quantifies" (i.e. not "measures").

We now use "quantifies".

> CFCs are parameterized using a Gamma distribution derived from the calibration of Gamma distributions. Without context what these gamma distributions represent, this is hard to understand for a reader.

The sentence was removed from the abstract.

> L10 It would help to specify is that was your expectation.

Our expectations are specified in the following sentence : "As expected, French catchments overlying large aquifers exhibit a long memory, i.e. with the impact of climate anomalies detected over several years."

> L15-16 "Our work thus15 underlines the need to account for catchment memory in order to produce meaningful and geographically coherent elasticity indices." is not really supported since for 85% of the catchment the method did not improve anything significantly?

It's true that only 15% of our catchments have significant multi-year memory (as now stated in the abstract). However, it's enough to produce some irrelevant spatial patterns of elasticity indices, as highlighted by Figure 9, if this memory is not taken into account.

> **Introduction**
> L24 "fora Turc-Budyky explanation framework" is awkwardly phrased. Do you mean for an explanation o the Turc-Budyko framework. However, before revising this sentence. What does this Turc-Budyko framework have to do with runoff response given the antecedent catchment wetness. The wetness described in such a framework is the climatic wetness (or aridity) that does not directly describe the state of soils (but only indirectly relates).

We deleted the sentence about soil conditions here, to actually be closer to the moisture defined in the Turc-Budyko framework. We now say: "(The response of a catchment to incoming precipitation depends largely on its *wetness* (see e.g. Andréassian and Perrin (2012) for an explanation within the Turc-Budyko framework)."

> I remain to struggle with understanding why section 1.2 needs to be this long, and not to the point. By containing unnecessary much information about water age versus catchment hydrometric response, the reader can be strongly distracted from the main contribution of this paper. I would strongly recommend to drop the part on "water age" and just state in a single sentence that this work focusses "on quantifying the response of catchments in terms of flow volume, independent of the water age of this flow."

We do not agree on this point. We believe that this is an important distinction to make and that this idea cannot be summarized in a single sentence, and for this reason it deserves a full sub-section (in the previous review, referee #2 agreed on this aspect):

25 We really want to avoid the CFC being too quickly interpreted as a travel time distribution, which could be quite tempting at first because both notions have a temporal aspect.

> The new addition "This distinction may also be linked to the different perceptual storages of water in a catchment. "Mobile storage", which controls transport in a catchment is more linked to water age, whereas "dynamic storage" which controls streamflow dynamics is more in line with our definition of catchment memory (see e.g. Staudinger et al., 2017)" is a rather unclear description of something that seems not to be directly relevant to the paper.

This new reference was suggested by referee #2, and we agreed on the relevance of this addition. Similarly to the previous comment, we think that this section is necessary to avoid any misunderstanding of what we quantify in this study. This reference

30 helps us to introduce a vocabulary that can be found in other papers, in order to help the reader establish relevant links to these studies that follow a very close conceptualisation of the hydrological response.

> L289: "It thus appears that the hydrological behaviour of the driest catchments is more dependent on past climatic conditions than that of humid catchments". Please rephrase this sentence as right now it makes an wrong comparison.

We now say: "It thus appears that past climatic conditions have more influence on the hydrological behaviour of the driest catchments than on that of humid catchments."

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> L388: break this into two sentences.

We now say: "Future work could also design dynamic CFCs by investigating how climate anomalies might change the shape of CFCs over time."

Report #2

> I gave a fresh read to the revised paper, and I think it addresses most issues of the previous submission.

40   Thanks for the additional comments on this second version and for the appreciation of the work done. We have addressed your suggestions below.

> Some additional points to consider are the following:
>
> Introduction. About water age, the authors write "Because we do not use any tracers in this study, we cannot check any hypothesis about water age and we will not discuss this topic further". But it is not really true that the topic is not discussed further, as below they write: "Spectral analysis can be used to provide insight into catchment memory. It is regularly used for stream chemistry (see e.g. Kirchner et al., 2000), in order to understand travel time distributions.", and again "has a long history when it comes to water quality modeling or tracer analysis, as past pollution inputs can influence water quality in rivers for several years or decades". Please rephrase.

We have rephrased the sentence as follows: "Because we do not use any tracers in this study, we cannot check any hypothesis about water age and we will not provide any related interpretations in our analysis afterwards;"

> By reading the review, it appears that many past studies used the terminology "catchment memory". It should be
45   made clear that this is the terminology used in the current study, and adopted to describe analogous concepts in earlier work.

We fully agree that many past studies used the same terminology "catchment memory", and this is what our introduction aims to review. We tried to make that clearer by saying: "In addition to the "memory" terminology, the scientific literature sometimes addresses this concept also through "flow persistence" (see e.g., Svensson, 2015; Quinn et al., 2021) or "flow predictability" (see e.g., Bierkens and van Beek, 2009; van Dijk et al., 2013)."

> 50   Line 209: Figure 1 shows an example... It should be Figure 1b (or refer to panel b).

We now refer to Figure 1a and Figure 1b specifically.

Methods should present how elasticity and memory results from different catchments are going to be assessed. Such as, that they will be interpreted on the basis of catchment attributes, and which catchment attributes are going to be used. Otherwise this only appears in the results. Hence, methods should present and motivate the "few hydroclimatic characteristics commonly identified as the main drivers in the literature".

Catchment descriptors were already presented in section 2.1. We moved them to a different section called "Identification of hydro-climatic drivers of catchment memory" at the end of section 2 where we now present in more detail where they come from and how they are used to understand the memory drivers.

I find that having here having the results and discussion section combined is a bit problematic, because one needs the overall results picture because making interpretations. For example, statements such as "Our conclusion is that catchment size is not a first-order determining factor of memory and elasticity, and this likely reflects some more regional relation between catchment size and hydrology" would be more appropriate in the synthesis section. I therefore suggest to limit the interpretation to the minimum necessary in the results section, and expand the synthesis section (currently very short), to provide a comprehensive critical elaboration of the results. Otherwise, the risk is that the main message of the paper will be relegated to the last paragraph of the synthesis section, which provides a summary, but with no interpretation.

We deliberately made a short synthesis that can provide the main *take-home messages* of the paper. This statement about the effect of catchment size is actually already mentioned in this synthesis section: "Catchment area, often referred to in the literature, does not seem to play a first-order role". However, we have extended the hydrological interpretation of the results in this section.

References

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