Drought decreases streamflow response to precipitation especially in arid regions

We would like to thank the reviewer for the time taken to review our manuscript. In the following pages, we respond to the comments of the reviewer. Our responses are shown in blue, the revised text is shown in *italics*, and line numbers mentioned in this response refer to the current version of the manuscript and they are indicated within brackets [xx].

Reviewer 1

The manuscript by Matanó and co-workers focusses on the response of catchment streamflow to precipitation, and how this response is changed by drought conditions. The authors analyze data from a large number of catchments globally, that allows for general conclusions on catchment behavior during drought. I enjoyed reading the manuscript, not in the last place because some of the findings have potential implications for our understanding of catchment functioning. However as with many studies on catchment observations, analysis can be complicated by the fact that these are not made under controlled conditions. In my view, some of the main conclusions of the manuscript are subject to a wrong interpretation of sensitivity, and to a lack of consideration of the natural variability in P that might affect the interpretation of changes in Q/P. These issues are discussed in more detail below.

- We thank the reviewer for taking time to read our manuscript. We are pleased that the reviewer found the topic interesting and recognized the potential significance of our findings. We also appreciate the reviewer's constructive comments. Particularly, the reviewer highlights the need for:

In summary, while the manuscript deals with an interesting and relevant topic, it currently suffers from a lack of clear definitions and consistency. In order for the manuscript to become a significant contribution to the understanding of drought impact on streamflow, in my view the authors will need to: a) investigate the real sensitivity of Q to P (from a linear fit as in the second figure) and to what extent drought years might differ from the relation as given by non-drought years, and b) exclude the possibility that shifts in Q-P behavior are attributed to catchment processes whereas in reality they are simply induced by changes in P (for instance due to circulation changes).

- We agree with the reviewer that a clear definition of the yearly Q-P ratio is essential for the interpretation of the results and we will further expand on it in the Introduction and Methodology sections.

  [74] Here, we analysed the temporal dynamics of the *annual* streamflow *response* to precipitation (computed as the ratio between annual streamflow and precipitation) in approximately 5000 catchments across the world. *The*

annual Q-P ratio indicates the fraction of precipitation that is converted into streamflow, providing insights into the catchment's water balance.

[109] We then computed yearly streamflow-to-precipitation (Q-P) ratio timeseries for each catchment. *This measure represents the annual runoff ratio and is dynamically influenced by climatic and hydrological conditions. By considering an annual timescale, the ratio inherently accounts for evapotranspiration and storage processes within the catchment. However, it is important to note that, first, since the ratio is a lumped representation of these processes, it does not separate their individual contributions. Second, in some catchments, storage processes extend beyond a single year, which may influence the annual runoff ratio.*

Regarding the first reviewer's point (a), we acknowledge that the term 'sensitivity' used in the manuscript is not appropriate, as it implies a proportional change in streamflow divided by the proportional change in precipitation (Sankarasubramanian et al., 2001; Schaake, 1990). Instead, we computed the yearly ratio of streamflow to precipitation. Our focus is indeed on understanding whether and how the yearly fraction of precipitation to streamflow is influenced by different drought types (e.g., anomalies in precipitation, soil moisture, or storage). Therefore, we will replace the term "sensitivity" with "response" throughout the manuscript, as this better reflects the measure we are using. Examples of these changes are as follows:

[76] Specifically, we addressed the following questions: (1) how do drought characteristics (types, duration and severity) influence *yearly* streamflow *response* to precipitation in general and in different hydro-climatic regions across the globe? and (2) when and where do abrupt changes in streamflow *response* to precipitation occur and how do those changes align with drought periods?

[145] We used a mixed-effects panel data model (Gelman and Hill 2007) on 4487 catchments with a stationary streamflow-to-precipitation ratio to explore the influence of drought conditions on the variability of *yearly* streamflow *response* to precipitation over time.

- Concerning the second reviewer's point (b), this is precisely the main objective of our study: to investigate the influence of different drought typologies (i.e., meteorological, soil moisture and hydrological drought) on the response of streamflow to precipitation. We recognize that the wording in the manuscript may have unintentionally suggested that the Q-P relationship is solely a catchment property. This was not our intention. We will revise the introduction and methodology to clarify that our study does not consider the Q-P relationship as an

inherent catchment property but rather as a dynamic relationship influenced by climatic and hydrological conditions (revision for instance suggested above for the definition of the Q/P ratio).

Further, the reviewer's analysis shows a significant correlation between Q/P and P. However, for the scope of our study, this does not pose a problem. On the contrary, it validates our approach of accounting for the effect of meteorological drought on the annual Q-P relationship. Indeed, in our study, we explicitly use precipitation anomalies as one of the predictive variables, ensuring that the effect of climate is accounted for.

Finally, we thank the reviewer for pointing out the issue with the conceptual framework in Figure 1. We agree that figure 1a might be misleading, as we cannot directly reconstruct the individual values of Q and P from their ratio. As we only analyse the relationship between these two variables (predicted variable), we could only plot how those relationship (Q/P) change in relation to drought and no-drought years. We will revise Figure 1 accordingly, ensuring it reflects the methodology used in our study.

References

Sankarasubramanian, A., Vogel, R. M., & Limbrunner, J. F. (2001). Climate elasticity of streamflow in the United States. *Water Resources Research*, *37*(6). https://doi.org/10.1029/2000WR900330

Schaake, J. C. (1990). From Climate to Flow. In *Climate Change and U.S. Water Resources*.