Reviewer 2:

This paper presents a study about identifying different drivers of extreme flows over Europe by using observations from 250 near-natural catchments. It is well-written though;

B1: We thank the reviewer for appreciating our manuscript.

It basically uses some traditional and simple statistical approves say regression or correlation things to conduct some basic analysis between extreme flow and potential drivers or factors.

B2: While based on regressions, our multimodel inference methodology illustrated in Figure 2 is (i) powerful as it can reduce the risk of overfitting, and the effects of collinearities between predictor variables, and (ii) novel as it has not been used a lot in past high-flow analyses but has been successfully used in ecological studies such as Groemping et al., 2007, Fernández-Martíne et al., 2020, Jiao et al., 2021, considering the advantage mentioned in (i). We will clarify these points in the introduction.

Also, the paper did not transfer any new findings or new approach development. And no in-depth physical mechanisms have been introduced. Given that, it is not recommended for publication in this high-ranking journal.

B3: We disagree with the reviewer here. As stated in response B2 above, our statistical approach is a reliable tool to better understand the potential drivers of high flow events, which are so far often studied but no definitive conclusions. We do provide new insights aside from previous studies as stated in the conclusions section. Our study finds that (i) an interplay of multiple drivers induces extreme high flows, and (ii) drivers of high flow are relevant and need to be considered at different time scales. In addition, note that reviewer #1 recognizes the value of our study by mentioning e.g., “these are potentially very relevant and interesting findings“ and “This work presents an interesting investigation of floods across Europe.”

The reviewer gives a good point about physical mechanisms which we might write less clearly throughout the manuscript. We will list the hypotheses of each driver's physical process related to high-flow generations in the introduction, and expand the interpretation of physical mechanisms in the results and discussion section.

Concerns:

Line 15, it goes “Therefore it is imperative to understand their underlying physical mechanisms”. After reading the paper, there is no information or analysis about the physical stuff.

B4: We note that physical linkages between high flows and the considered drivers have been discussed in several places in the manuscript, namely in sections 2.1.2, 2.2.4, 3.1, and 3.2.

In order to address the reviewer’s concern we will introduce a table to synthesize and expand the physical mechanisms of potential high flow drivers as listed below.

Precipitation is a direct water input that contributes to soil moisture and runoff. But proportions of precipitation that can be partitioned into soil moisture and runoff depend on the soil moisture content as well as the precipitation intensity. For the precipitation intensity, we quantify such influence using the distribution of the rainfall over the considered time scale.

Snowmelt is another direct water input for runoff, and the input rate of snowmelt depends on the properties and amount of the snow, and meteorological conditions, e.g., temperature, radiation, and precipitation.

Soil moisture can contribute directly to runoff through the drainage and resulting baseflow, and additionally modulates the conversion of rainfall into streamflow.

Evapotranspiration (ET) affects soil moisture and thereby indirectly runoff. ET is controlled by meteorological conditions and also vegetation dynamics such as changes in leaf area index. Vegetation removes water from the soil through transpiration or interception evaporation on the vegetation surface.

Line 20. The paper goes like “And in these 11 articles the focus is mainly on regional and/or modelling studies, and they use some drivers for an explanation of the results rather than including them in the actual analysis.”, which induces a justification of the current like “This leaves a knowledge gap in the joint understanding of a variety of observation-based controls of high river flows across continental-scale areas.”. In fact, many existing studies have focused on identifying the possible contribution of extreme flow over the globe, including Europe as well. This paper should give a better explanation of why the current study should be done and why it is important.

B5: The current study is important because it jointly considers a comprehensive suite of potential high flow drivers (not only limited by hydrological processes but also combined with ecological processes) across different time scales to determine the main controls of high flows across Europe. Moreover, we for the first time analyse and attribute spatial changes in the relevance of vegetation and terrain characteristics on identified main controls. To do this, we take advantage of state-of-the-art datasets which benefit from recent advances in Earth observations and land surface modelling. We will clarify these points in the introduction section.

The section of 3.2 attribution analysis is quite loose and hard to explain. tree over fraction is the most important in explaining spatial patterns of the relevance of precipitation. This result is not new.

B6: Note that tree cover fraction does not only explain spatial variations in the relevance of rainfall for the occurrence of high flows, but also spatial variations in the relevance of snow melt and soil moisture. To our knowledge, we firstly illustrate the tree cover fraction as a main control out of other terrain or basin characteristics in influencing multiple drivers generating high flows.

While about the elevation and slope, the paper has no in-depth explanation about the potential relationship of the streamflow. And the basin area is of important to affect the effect of elevation and slope to flow. This also needs more physical explanations. Also see Fig. 6, the correlations of different time scales seem to be not consistent, even the direction (some positive or negative), this should be fully discussed.

B7: We agree with the reviewer that in previous results, except for the tree cover fraction, other attributes seem to have inconsistent patterns of regulating directions. For this, we have re-computed the attribution analysis of Figure 6 after keeping the seasonality in all our considered data streams (streamflow and potential drivers of high flows), to implement a suggestion from reviewer #1 by considering the potential seasonal influence of high flow drivers (see response A2). Interestingly, the updated figure confirms the previous results of tree cover fraction as the main control, and shows more consistent patterns for other second-order drivers across time scales such as basin areas. The new figure shows that rainfall is more relevant for high flows in small catchments where the entire area can be affected by extreme rainfall at the same time. Soil moisture is more relevant for larger catchments as these are typically not simultaneously affected by strong rainfall. Further, soil moisture is more relevant in low-elevation catchments where soils can easily be water logging, while rainfall and snowmelt

are more relevant in high-elevation catchments. Finally, soil moisture is more relevant in catchments with strong slopes, as this favors lateral flow, while the opposite is observed for precipitation.

We will update Figure 6, and include these arguments in section 3.2.

This paper in fact did some basic statistical analysis, while all paper gives an impression about trying to link the physical mechanisms to the changes of flows. Yet, this is no physical analysis across the paper and no physical explanations but some statistical analysis.

B8: As recognized by the reviewer, we are linking physical mechanisms to drivers of high flows in order to explain their relevance. We do this through a data-driven approach which detects emergent relationships from observation-based data and interpret in a process-oriented way. Therefore, our approach nicely complements model-based analyses which can more explicitly study physical processes but are limited by a potentially inaccurate and/or incomplete representation of processes in the model.

We will clarify this point in the conclusions section.

References:

Groemping, U. Relative importance for linear regression in R: the package relaimpo. J. Stat. Softw. 17, 1–27 (2007).

Fernández-Martínez, M. et al. The role of climate, foliar stoichiometry and plant diversity on ecosystem carbon balance. Glob. Change Biol. 26, 7067–7078 (2020).

Jiao, W., Wang, L., Smith, W. K., Chang, Q., Wang, H., & D'Odorico, P. (2021). Observed increasing water constraint on vegetation growth over the last three decades. Nature Communications, 12(1), 3777.