Reviewer 1:

This work presents an interesting investigation of floods across Europe. It aims to build on previous work by considering more factors as potential flood drivers (e.g. soil moisture at various depths, leaf area index, ET, and a metric precipitation variability.)

A1: We thank the reviewer for emphasizing the novelty of our study of investigating the mechanisms of high-flow generation.

The study concludes that:

1. This study provides a quantitative mapping of the importance of drivers of high river flow in near-natural European catchments.
2. […] that antecedent precipitation anomalies are the most important driver of high flows in most catchments.
3. […] In some other catchments snowmelt and soil moisture are found to be the most relevant drivers.
4. […] Moving beyond the state of the art we find a remarkable diversity of second-most important drivers across Europe. This includes vegetation-related drivers such as evapotranspiration.
5. […] Overall, observed daily high flow dynamics can be explained similarly well using drivers from the daily, weekly and monthly time scales. This indicates that mechanisms acting at different time scales contribute similarly and jointly to high flow events.
6. […] While the most important drivers are similar across time scales, we find interesting variations for the second-most relevant drivers where evapotranspiration and surface soil moisture become more relevant towards longer time scales while deep soil moisture gets less relevant. Furthermore, for more extreme high flows we find a greater diversity of most important drivers across the considered catchments.
7. […] Therefore, while moderate high flows are strongly associated with antecedent precipitation, the most extreme events can only be fully understood when considering a comprehensive selection of drivers.
8. […] The spatial variations in the relevance of considered high flow drivers can be attributed to vegetation and terrain characteristics of the catchments.
9. […] Our findings thereby illustrate that it is beneficial for flood monitoring and prediction to jointly consider several time scales and a comprehensive set of drivers physically related to streamflow dynamics.
10. […], Identifying the relative importance of high flow generating mechanisms can reveal regional patterns of causes of floods in Europe and inform future model development.
11. […] Moving beyond the state of the art we find a remarkable diversity of second-most important drivers across Europe. This includes vegetation-related drivers such as evapotranspiration.

All aspects 1-11, listed above are potentially relevant for publication in HESS. However, all these aspects also require some substantial consideration before I can recommend them for publication in HESS. My main concerns is:

The chosen method that relies on removing the seasonal cycle sounds potentially useful, but it is unclear to me how this should assign a dominant driver. In places where particular processes are underlying the flood response (e.g. snowmelt in NE Europe, this process is not considered important anymore in the analysis), and processes that physically can have no meaningful effect on floods at the given timescale (e.g. ET at daily timescale) are sometimes identified as most important process. The paper should manage to explain the attribution method (and the logic of removing the seasonal cycle) better to ensure the reader can trust these findings. The whole paper hinges on these findings, so it would be good if the reader can be better convinced of the presented approach.

A2: We thank the reviewer for pointing out his/her concern on our approach to remove mean seasonal cycles from the considered data streams. While our initial motivation for this was to investigate anomalies as society is probably adapted to (seasonal) mean conditions but the abnormal mechanisms are not exclusively addressed, we understand the reviewers comment that absolute quantities (e.g. water masses) might be more informative to study, and are more straightforward impact-relevant. Hence, we have updated our methodology and omitted the removal of mean seasonal cycles.

We update Figures 2-6 and section 2.2.3 accordingly. The results are actually not affected largely compared to results when removing mean seasonal cycles. Overall, there is a tendency for increased relevance of soil moisture at short time scales, and the attribution results related to vegetation types and terrain characteristics are clearer.

Some comments on the main conclusions

[1] Since the method seems to ignore relevant drivers and attribute irrelevant drivers, point 1 may not be not shown robustly

A3: We think that our updated methodology (see response A2) can address this point. If the reviewer would like to suggest additional relevant flood drivers to add to the extensive selection currently analyzed, we would be happy to implement.

[2-3] this seems in line with earlier work. Is there anything that we learn here that we did not know from previous studies? This may be useful to better highlight.

A4: The reviewer refers to a sentence in which we indicated an agreement with previous studies in the results and discussion section, while the subsequent sentences refer to new insights related to [4, 7, 8]. We agree that antecedent precipitation, snowmelt, and soil moisture are commonly illustrated as highly important flood drivers in previous studies. Obtaining similar results also helps to validate our methodology.

[4] If ET is really important (at daily timescales) this needs to be physically argued. Otherwise it is hard to be convinced by this finding.

A5: We agree with the reviewer that ET is expected to affect the water cycle and floods rather at longer time scales during which the daily fluxes can aggregate. This is already described in section 3.1. In order to avoid confusion we will adapt this sentence in the conclusions section to clarify that ET is relevant at weekly to monthly time scales, which is illustrated in Figure 4.

[5, 7] these are potentially very relevant and interesting findings, but they are only very briefly discussed and not very quantitatively shown in the paper. Can there be more explicit graphs/analyses that support these findings?

A6: We thank the reviewer for the positive feedback on our new findings.

We have implemented an additional analysis to support point [5]. We repeat the correlation analysis with all drivers from all three considered time scales to find the most relevant driver and time scale. This is done for each catchment. Then we aggregate these results across all catchments. We find that while preceding precipitation is still the main driver, the most relevant time scale varies between catchments, such that at the continental level all three considered time scales are found to be similarly relevant. This result will be included in our manuscript as an additional supplementary figure.

Moreover, when performing the multimodel inference analysis for each catchment considering the eight most important predictors across time scales found from the previous correlation analysis, we find that antecedent rainfall at daily or weekly is the main driver in different catchments. This highlights again the necessity of considering multiple time scales in high flow analyses.

For highlighting point [7], we provide more detailed information in section 3.1, as well as a new supplementary figure. Therein, we compare the mean fraction of high flow variance explained by only antecedent precipitation, as shown in the legend of Figure 3, with the mean explained fraction of variance of the full regression models considering all flood drivers. We find that the R^2 values are clearly higher for the full models, particularly for the more extreme floods, which quantitatively illustrates point [7].

[8] Ok, but what do we learn from this attribution? Can this be stated?

A7: We learn from this which are the main landscape characteristics and which modulate the relevance of flood drivers in space. This way, the main high flow drivers such as preceding precipitation and soil moisture affect high flows in different ways in different catchments. For example, the tree cover fraction and slope modulate the precipitation infiltration rate, and consequently the relevance of precipitation for flood events. We will clarify this point in section 3.2, as well as in the conclusions section.

[10] Can it be made a bit more explicit how models can benefit?

A8: Our main result is that a diversity of drivers and time scales needs to be considered to comprehensively understand, and accurately predict floods. This informs model development by suggesting alternative drivers and time scales to be more explicitly taken into account in flood modelling in the future. And furthermore, our attribution findings stress the relevance of vegetation such that hydrological model development should ensure to appreciate and include the information of temporal and spatial vegetation dynamics. We will add these arguments to the conclusions section.

[11] This diversity of drivers hinges on my main concern of the paper listed above.

A9: Please refer to response A2.

Further comments

- Considering ET and LAI as drivers of soil moisture on daily timescales seems nonsensical. How would these processes physically affect floods as ET and LAI will be tiny components of the total water balance during flood conditions on such timescales. Are their effects not already captured in considering soil moisture (which integrates the effects of E(T), as also is acknowledged in section 3.1)

A10: While we understand the reviewer's comment, we prefer to include the same set of drivers in the analyses for all time scales for consistency. As suggested by the reviewer, and described in response A5, ET is indeed not relevant at the daily time scale.

- It is unclear to me why the model selection leads to a set of near natural catchments, instead of just a set of catchments with simple to model behaviour (independent of the degree of human interference). I would be careful in qualifying these as near-natural.

A11: As we are using a versatile, conceptual model we assume that this scheme can reproduce streamflow whenever it is mainly controlled by meteorological variations instead of human interference. In addition, the streamflow dataset that we employ in our study describes the contained catchments as near-natural (Stahl et al. 2010). We will clarify this point in section 2.2.1.

- The choice of coarse spatial resolution of forcing data is understandable, but maybe problematic in the more mountains catchments. What are the potential consequences of this coarse data.

A12: The role of the spatial mismatch between the 0.25 degree flood driver data and the catchment-specific streamflow has been discussed in section 3.3 the limitations. The reviewer raises another valid point that this mismatch could be more problematic in mountainous regions. Figures 3 and 4 show that the spatial coherence of high flow drivers does not largely differ between mountainous areas like the Alps and their more flat surroundings. This suggests that the use of potential drivers with a 0.25° spatial resolution seems to be sufficient for our purpose. In addition, Figure 6 shows that basin area and terrain slopes play second-order roles in regulating the mechanisms of high flow generation. We will further clarify these points in section 3.3.

- Why are seasonal cycles removed, as these seasonal cycles might be important underlying drivers of the extreme events (i.e these are the ~sum of a seasonal cycle + an individual event on top of that). In places where processes are dominantly driven by a particular seasonal cycle (e.g. snowmelt in NE Europe and large parts of Scandinavia, suddenly snow is not important anymore. How can you explain this to a reader?

A13: Motivated by the reviewer's comments, we have updated the methodology to keep the seasonal cycles. Please refer to response A2.

- Previous work across Europe also aggregates data across various time windows (e.g. Bloschl et al., 2017).

A14: This is true, but these studies do not compare the relevance of drivers considered at different time scales. To our knowledge, our study is the first analysis to do this systematically with a comprehensive set of drivers.

- When daily values are used, should rainfall on the date of the flood be chosen, or on the day before, or does this depend on the catchment size?

A15: This is an interesting point. After careful consideration we decided to keep our approach of considering the flood drivers on the day/week/month before the flood day. This enables us to understand and pinpoint flood drivers which are useful for predicting flood events, and we would not expect to have data on the flood day. We clarify this point in section 2.2.3.

- Figure 2: The font color of soil moisture layer 1 is hard to read.

A16: Adapted.

- Figure 3-4: this color classification is hard to read. It would also be useful to guide the reader in what the conclusion is of the Figure (within the caption).

A17: We will enlarge the colored points in the legend in Figures 3 and 4 to improve readability. Further, we will add a summary sentence of the findings in each figure to the caption.

- "Another interesting result is that the explained variance of high flows of the dominant drivers is similar across time scales. This indicates that studying drivers at different time scales is relevant to understand high flow dynamics, whereas daily, weekly and monthly time scales are similarly important. Multilayer soil moisture has a higher explained variance for events of the 99th percentile, suggesting the soil water storage is more relevant for the more extreme high flow generation." This is an interesting statement, but I think it requires some more analysis to conclude this. Right now this result is based on hand wavy interpretations of the results, and no formal quantitative comparison.

A18: Please refer to response A6 about new analyses that we provide to quantitatively study high flow drivers across different time scales. The second sentence in this statement will be revised to reflect the slight changes in the results in Figure 5 in relation to keeping the seasonal cycles.

References:

Stahl, K., Hisdal, H., Hannaford, J., Tallaksen, L. M., van Lanen, H. A. J., Sauquet, E., Demuth, S., Fendekova, M., and Jódar, J.: Streamflow trends in Europe: evidence from a dataset of near-natural catchments, Hydrol. Earth Syst. Sci., 14, 2367–2382.