Responses to the comments of Referee 2 on egusphere-2022-1494

Editorial template

Each comments of the reviewer are presented in the normal font.

The responses of the authors are indented and written in italic.

Comments and responses

General comment

With their study, the authors deal with the sediment discharge from alpine catchments in the French Western Alps. The study is based on a large number of historical measurement data, some of which go far back into the past. The authors subject the measured data to a careful plausibility check at the end of which the impressive number of 69 catchments remain for further in-depth evaluations. From a combination of these data with climatic data and digital relief analysis, various statistical techniques are used to examine those variables suspected of controlling sediment discharge from alpine catchments.

Overall, the study is well structured, based on a careful review of the literature, and written in good English. Furthermore, it must be highlighted here that very valuable data are included in the analyses, which are thus also made visible to the scientific community. Such long-term time series, especially with regard to sediment discharge, are rare and, if available, can only be put into value with great effort. Ultimately, however, these long-term time series are absolutely necessary in order to analyze statements about changes in sediment discharge (changes as a result of anthropogenic changes or caused by climate change). With the topic addressed, it has high relevance and fits very well with the focus of NHESS and I therefore strongly recommend its inclusion in the journal!

My congratulations to the authors on this work!

We thank very much Referee 2 for this positive comment.

Detailed comments to the chapters:

Missing of the chapter Study site

From my point of view, a chapter on the study areas is absolutely missing in the publication. At one point or another, the text refers to the variability of climate and geology, and the different slope conditions are also mentioned. However, it is difficult for the reader to understand exactly what this variability looks like! It would be desirable, for example, that a map of precipitation distribution be presented (e.g., with mean annual precipitation). Other information is of course difficult to present on maps due to the wide extent of the watersheds. Information on elevation distribution, EZG size and the different slope ratios can be found in the table in the supplement material, but here it would be worth considering whether to try to present individual important influencing variables (slope, channel lengths, vegetation cover) graphically (e.g. boxplots) rather than just using mean and median values. This would mean a good basis for the later discussion. Especially for areas with different precipitation, uncertainties in the (statistical) analyses would be more concretely discussable and explainable.

Figure 1 gives a good overview of the location of the sites (should be integrated into the chapter study sites), but due to the small size some catchments are hardly recognizable in the graph. Here I would prefer if the map would be larger in the manuscript (possibly combined with the precipitation distribution curve) and instead the photos of the catchments were moved to a separate figure.

Good comment. We will add a short section "Study area" associated to an updated Figure 1. Here the figure and below the new section:

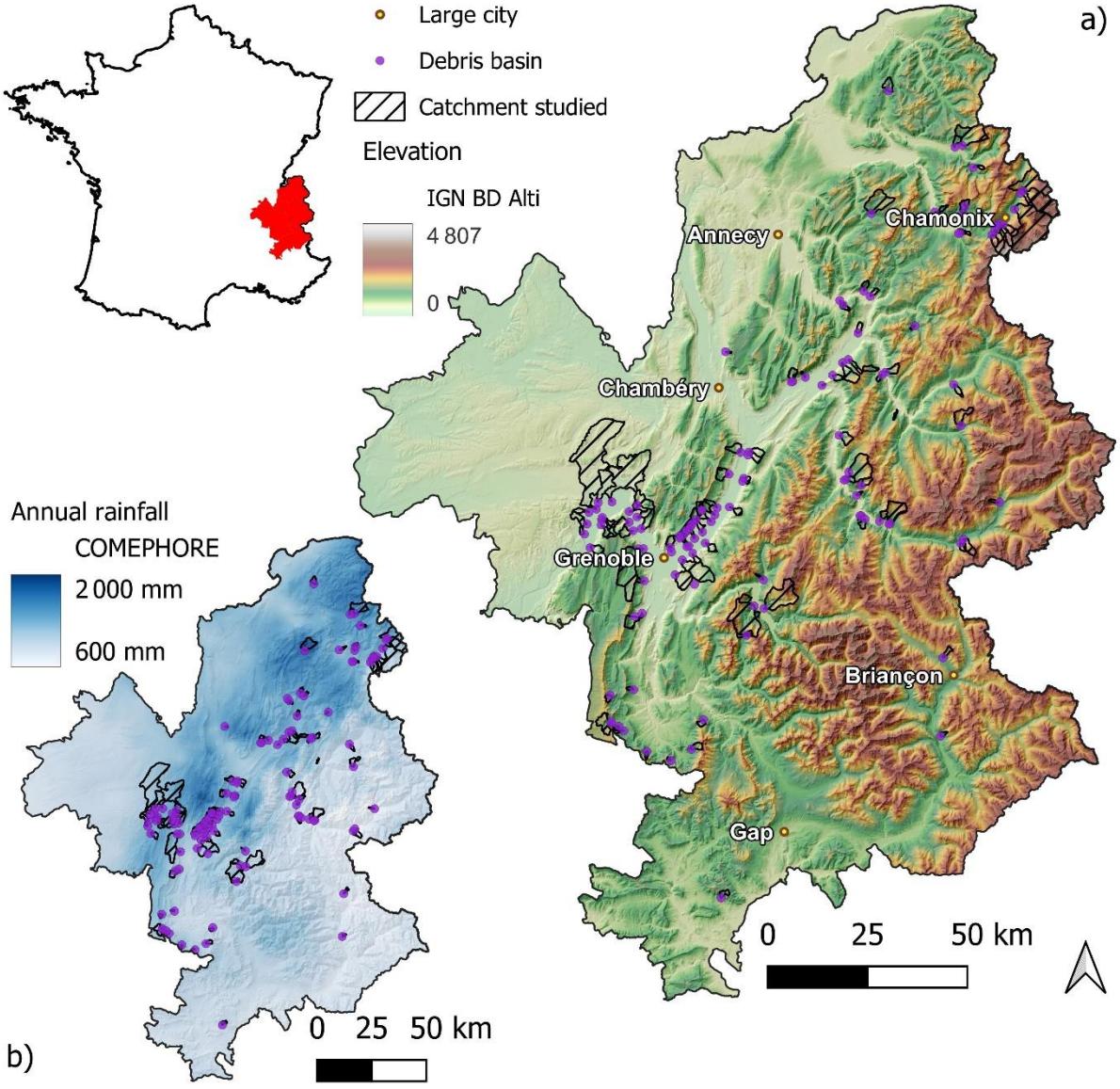

Figure 1. Spatial distribution of the studied sites: a) background image of elevation according to the IGN BD ALTI dabase and b) background image of mean annual rainfall according to the COMEPHORE data base (a link to access maps of each catchment is provided at the end of the paper

*"**2.1 Study area***

The study area is located in the northern french Alps. The studied catchments are located on a wide range of

mountain setting, from hills culminating below 800 m.a.s.l. at the north-west of Grenoble to torrents draining the glaciers of the Chamonix valley with summits above 4,000 m.a.s.l. (Figure 1a). This geology of the studied catchments cover both sedimentary, metamorphic and igneous rocks. The climate in the area is considered temperate without dry summer in the valleys, usually cold without dry summer above 1000~m.a.s.l. and even polar above 2000~m.a.s.l. (Beck et al. 2018). The annual mean precipitation ranges within 600 and 1800 mm with a clear influence of the relief, as well as a decreasing trend toward the east (Figure 1b) associated to the penetration into the massif of the humidity coming from the Atlantic sea."

However, we cannot provide a map where each catchment is visible in detail: an atlas showing the detailed maps of each catchment is accessible through a DOI in the data statement availability.

In addition, as suggested by Referee #2 we added a complementary figure that complete Table 2 with scatterplots and boxplots of the main input parameters versus the ratio of sediment contributing area R_{ZP} which is our main explanatory variable. The updated the text in the result section to refer to this new figure.

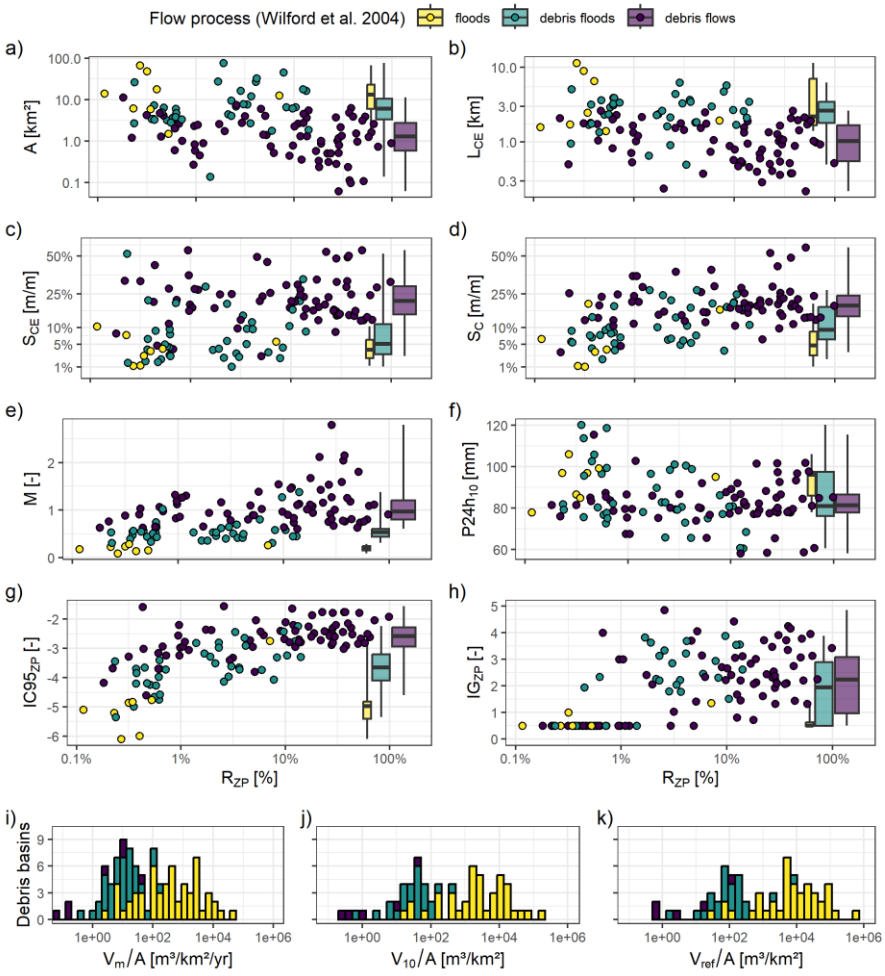

Figure 7. Scatter plot of the main calculated variables against the ratio of sediment contributing area R_{ZP} : a) catchment area A, b) channel length L_{CE} , c) channel slope S_{CE} , d) fan slope S_C , e) Melton index M , f) daily precipitation with return period of 10 years P 24h_{10}, g) quantile 95% of the Connectivity Index extracted in the sediment contributing area $IC95\%_{ZP}$, h) Geological Index of D'Agostino and Marchi (2001) extracted in the sediment contributing area $IG\%_{ZP}$; and histogram of the output variables: i) mean annual specific sediment production V_m/A, j) specific event magnitude with a 10 year return period V_{10}/A and k) reference specific event magnitude V_{ref}/A.

Material and methods

Precipitation

With regard to the Precipitations section (I would use Precipitation as the heading here), the data basis remains somewhat unclear. The resolution of the reanalysis data is with 1km very good for a spatial analysis. But the question remains (since it is reanalysis data, which is a model result, at least if I am correct), if it makes sense especially with respect to the analysis of extreme events to use only pixels in a catchment area or if one should not analyze something more large-scale. The background is that the atmospheric conditions are certainly well represented by the reanalysis, but the spatial distribution is certainly not accurately predicted. In order to be able to estimate the occurrence of especially convective events for a space here, I would find it better to buffer the catchment areas a bit and thus extend the analyses a bit beyond the areas.

Indeed, we agree with Referee #2 that this point was not sufficiently clear. Actually, the COMEPHORE database is a combination of rain gauge and radar data and does not use atmospheric conditions to provide precipitation values. It is considered to represent adequately the spatial extent and intensity of local precipitation events (see https://doi.org/10.1007/s00382-021-05708-w and https://doi.org/10.1007/s00382-020-05558-y). This type of reanalysis is very different from a global reanalysis that assimilates mostly satellite data and results mainly from numerical weather models (e.g. ERA5-Land). A comparison of ERA5-Land and COMEPHORE in the East of the Pyrenees clearly illustrates this aspect in the following Copernicus report: https://www.spaceclimateobservatory.org/sites/default/files/2021-10/FLAude_D3.1-2.Recommendations%20on%20C3S%20data.pdf . In the study area of our study, COMEPHORE was shown to be adequate for the reproduction of the hydrological processes of small catchments (from 10 km^2 to 200 km^2), see the following technical report in French: https://hal.inrae.fr/hal-03671653 We agree that the characteristics of COMEPHORE are important to consider in our study and they will be detailed in Section 2.4.1 "Precipitation" where the following sentence will be added:

> *"The COMEPHORE product exploits ground measurements from rain gauges and radars. It is considered to represent adequately the spatial extent and intensity of intense and local precipitation events (see Appendix A in Caillaud et al., 2021, for an extensive description of its strengths and limitations)."*

Geological index

The weighting used is certainly suitable. The question remains, however, to what extent the geological maps used actually show bedrock and loose material. For the discharge of an area, it is ultimately not so relevant whether granite or limestone predominates as geology, but rather whether sufficient loose material is available. This can be moraine material or thicker slope debris covers. A distinction should be made, however, between bedrock and loose material. The authors

should make this a little clearer in this section, which information was really used from the geological map.

Very good remark: the geological map we used actually maps superficial formations, especially the many kind of quaternary deposits that are key sediment source to many torrents. As such, moraine accumulations or gullies entrenching fluvial deposits are captured. This will be specified in the text (as well as a detail on the catchments without mapped sediment contributing area). The new elements are underlined:

"The definition of the lithological classes was performed mainly on the basis of national geological maps which account for superficial formations as fluvial and glacial loose deposits (BD Charm-50 © BRGM, see https://www.geocatalogue.fr/Detail.do?id=4156. In catchment without mapped sediment contributing area, where even the river channel was too narrow to clearly appear between the mapped vegetation patches (an evidence of weak sediment transport activity), a minimum value of 0.5 was arbitrarily assigned.

Results

From my point of view, the analysis of extreme events (magnitude and frequency) is too short. I would suggest that the authors try to include some analysis of this very important aspect in the results. Even though the data certainly have limitations in this regard and the focus of the study certainly has a different emphasis, this information would be very helpful for understanding sediment discharge. This again especially against the background of being able to discuss the uncertainties in the model result.

We are sorry but we are not sure to fully understand the request from Referee #2. The whole point of the statistical fit is to estimate the frequency – magnitude relationship of each basin. Each fit is shown in the Supplement in a very long Figure S5. The type of statistical fit (exponential or GPD) we used are quite standard. The paper being yet long and approaching many other topics that are newer, we prefer to stay concise on this part. Maybe we are missing the essence of the question that the Referee #2 would like to raise?

Discussion

The discussion takes up important aspects of the results section, but in my view parts of the discussion are more like conclusions. In my opinion, the authors should carefully revise the text and separate the discussion from the conclusion.

Conclusion

Parts of the discussion can be incorporated here as Conclusion, which would also add some value to this section. So far, this part is more of a summary in my view. Here, too, I recommend that the authors carefully revise the section.

We respond here to the two comments above that are connected. Considering the several addition we made to the discussion, it now probably more looks like a classical discussion where the authors interpret and comment the results both in a broader perspective (comparing with other works) and with eventual more advices and comments that are not strictly "results" but more personal ideas on how to use the "results". In the new extended and rework form of the Discussion, we prefer to keep the elements in it where we explain the doubts we have on our analysis, the perspective we see to push further the work and how we suggest to reuse the results.

We agree that the conclusion (that will be rather called "Concluding remarks") rather look like a synthesis but we fell it is consistent and follows well the previous Discussion. We trust the Editor to advice on whether another approach of what to put in the Concluding Remarks is necessary or not.

Some minor suggestions (but there are maybe more):

Thanks a lot for these suggestions and pointing these typo!. We addressed the remarks, corrected and typos and provide responses below only if we thought it necessary.

L23: approaches

L31: replace for instance with for example

L59: please rephrase the sentence: "The paper presents….."

L71: erratic? Perhaps better episodic?

L74: of an alluvial fan

L78: how did you assume 25%?? Is this based on expert information?

Yes, this is now specified

L81: remove mean

L104-105: The sentence should be rephrased

L118: I would suggest to remove "if crude in its results"

L133: remove on

L151: what do you mean with "geometries"? Do you mean areas? Please use area also in the following sentences

L153: what is meant by "but goes essentially in the same spirit"? Please specify.

We will be more precise: "the definition is thus not exactly the same than that used by Haas et al., 2011; Altmann et al., 2021, who used automated threshold conditions on the land cover, the hillslope

gradient, the distance to the channel and the channel slope and but goes essentially in the same spirit: identifying in mountain catchments connected, active sediment sources on aerial pictures – to identify the bare soil – and topographical maps – to check the connectivity."

L251:remove "that"

L252: replace "corresponds" by tends to or consists of

L300: in your catchments I would think, that you mainly have bare sediments and not soil. I would suggest to use sediment or material instead of soil (also in the following text)

Well, as pointed by the other referee, we also sometime have bare rock. We will specify that in the paper "soil" encapsulate all of them:"i.e. unvegetated soil, sediment or rock".

L328: I think also for this statement a map or other figure about the climate variability in a "study site" section could be helpful/necessary

L356: What do you mean with weakly active hydrosystems? Please make clear

L366: provide multiple estimations

L367: Using one single equation

L370: Debris-flow

We thank very much Referee #2 for his/her time helping us to improve this work!