Dear Editor, dear authors,

The paper "Sediment export in marly badlands catchments modulated by frost-cracking intensity, Draix-Bléone Critical Zone Observatory, SE France" presents a very valuable data set that will be of the interest of the ESurf readership. Its conclusions regarding frost-cracking models and potential alternative proxies are relevant for the community and a timely publication. It is overall well-written and I enjoyed reading it. However, I recommend to the Editor that the manuscript is returned to the authors for Minor Revisions before publication. The suggestions I make below are mostly towards improving the clarity of the aim, hypotheses, and writing in some parts, and including a few additional figures.

We thank the reviewer for their constructive comments on the manuscript. In the following, the reviewer comments are indicated in black, our response in grey, excepts from the manuscript in grey italic, and the proposed modifications to the manuscript in red italic. Modifications in response to comments from reviewer #1 are indicated in green.

1) My main concern is that the aim and hypotheses of the study are not clear in the abstract and introduction, and hypotheses of this study are hard to untangle from the conclusions of previous studies. For example, in lines 11-14 of the abstract, it says "rainfall variability does not fully explain (…) sediment export (…) suggesting that sediment production may modulate (…) sediment export". **My first thought was that at this stage of the abstract, why ruling out the influence of other potential processes such as sediment storage**? Later, in lines 84-85, it is clear that sediment storage is not relevant due to the very small scale of the studied catchments. But because this is not mentioned in the abstract, as it is written now, it's quite puzzling to the reader to **see only one hypothesis favoured.**
2) The abstract sound like the aim is to explore what controls the sediment export anomalies, but the first paragraphs of the introduction show **that you have already, before doing any research, a pretty good idea of what controls those anomalies from previous published research** (e.g. "Rovera and Robert (…) noted the marls' sensitivity to frost weathering…" (line 50); then line 55 "(…) inferred that these catchments was mainly dependent on the number of freeze-thaw cycles occurring during the year" lines 55-61 " Bechet et al. (…) inferred a yearly cycle between transport-limited conditions in spring to supply-limited conditions in autumn"). After the first page of the introduction**, I get the impression that this is a very-well studied field site and I don't understand what the aim of this current study is.** When in line 86 it says "we hypothesize that frost-weathering processes can modulate sediment yield by controlling regolith production on hisllslopes", this sounds too similar to the conclusions of previous studies and I don't understand why this is a hypothesis that needs testing if it has already been shown to be true. **The goals of the study (lines 90-93) also need a bit more differentiation from what's already known in the study area so that the relevance of this study can come across more clearly.**

To clarify the context of the study and the current knowledge gaps, the abstract has been modified in order to better outline the main outstanding problems in these badland areas, exposed in the introduction, and the (more qualitative) outcomes of previous studies that motivate our research questions, exposed at the end of the introduction (L77-80; 84-93).

Line 9: *Long data records (30 consecutive years for sediment yields) collected in the sparsely vegetated, steep and small marly badland catchments of the Draix-Bléone Critical Zone*

Observatory (CZO), SE France, allow analysing potential climatic controls on long-term regolith dynamics and sediment export. Although widely accepted as a first-order control, rainfall variability does not fully explain the observed inter-annual variability in sediment export. Previous studies in this area have suggested that frost-weathering processes could drive regolith production and potentially modulate the observed pattern of sediment export. Here, we address this question quantitatively, by defining sediment-export anomalies as the residuals from a predictive model with annual rainfall intensity above a threshold as the control. We then use continuous soil-temperature data, recorded at different locations over multiple years to highlight the role of different frost weathering processes (i.e., ice segregation versus volumetric expansion) in regolith production.

Whereas the reviewer mentions our hypothesis L86, they ignore the previous sentence where we explained that one of the main advances of our work is the catchment-scale analysis, as opposed to the plot- or hillslope-scale analyses of previous studies. However, we note that both reviewers commented on the lack of clarity of the objectives of the study; we took these comments into account to clarify the general and specific objectives as follows:

Line 84: In this study, the general objective is to develop a similar approach at the catchment scale (0.1-1 km^2) in marly badlands, taking advantage of the exceptional long-term dataset available for the Draix-Bléone Observatory. At the catchment scale, sediment export is primarily driven by rainfall, particularly during high-intensity events (Mathys et al., 2003), but we hypothesize that frost-weathering processes can modulate sediment yield, even at this scale, by controlling regolith production on hillslopes. Coupled to this first hypothesis, this study aims to highlight and quantify the main frost-weathering process in a setting of humid climate and soft lithology, by using high-resolution soil-temperature measurements.

3) Likewise, if the aim of the paper is to explore the controlling factors on sediment production/export, when I read that the summer surface temperature show a variability of 40-50 degrees Celsius (lines 239-237), I was surprised that, considering the data set available, solar-induced thermal stresses and their effect on physical weathering have not been considered as another potential variable influencing catchment sediment export (e.g. see Missy Eppes' papers).

We thank the reviewer for this interesting comment. However, several arguments can be put forward to justify our choice of focussing on frost-weathering processes rather than solar-induced thermal stresses:

- The Eppes et al. (2016) experiments were conducted on a granite boulder, a very different lithology from the marls we deal with (in terms of texture, structure, physical properties, etc); we therefore feel that these results cannot be simply transposed to our study context.
- Saprolite (widely fractured marls) contains significantly more liquid water than granite cracks, and we infer that frost weathering is therefore much more efficient in these lithologies.
- Bechet et al. (2016) demonstrated sediment accumulation on hillslopes during the winter, pointing toward winter soil production.
- Consistent with the previous point, the hysteresis cycle of monthly sediment export (Figure 4) shows that a supply-limited regime is installed by the end of the summer

period. This observation is in contradiction with potential sediment production by solar-induced thermal stresses during the summer (i.e. the, season when the highest temperatures are recorded). This argument will be add in the text as follows:

Line 340: *Together with the evidence for a transition from transport-limited to supply-limited conditions during the year discussed above, we interpret these results as indicating that frost-weathering processes modulate sediment export from the catchments by exerting a strong control on the production of mobilizable sediment. In particular, the lack of sediment supply during summer months inferred in the previous section argues against significant sediment production by solar-induced thermal stresses (e.g., Eppes et al., 2016), despite high daytime surface temperatures and large temperature variations in the marls during summer (Suppl. Fig. 1).*

Testing the volumetric expansion and ice-segregation frost-cracking models in “temperate/humid climate and soft lithologies” (Lines 77-79) is perhaps the most novel aim of this manuscript, and one that seems to adjust better to its content. However, this does not come across clearly in the abstract and introduction. I suggest rephrasing to put more emphasis on this, and carefully rewriting the current aim and hypotheses to more clearly differentiate them from the conclusions of previous studies.

This comment was taken into account; see our responses to points 1 and 2 above.

4) In section 2, a bit more context on the catchments geomorphology (range and mean hillslope angles?) and dynamics (are there any frequent small landslides? Are the streams ephemeral?) would also be useful.

Both in the Moulin and Laval catchment, convex forms are common and hillslopes are steep (mean slopes: Laval:0.58; Moulin: 0.40). Hillslopes become steeper with increasing elevation and thus range between …..We suggest to modify the text as follows:

Line 104: *The rainfall regime varies across seasons, with high-intensity rainfall events during spring/summer and lower-intensity but longer rainfall events in autumn. Only the main streams (Laval and Moulin) are permanent, although the Moulin shows very small discharge in summer; all tributary gullies are ephemeral.*

Line 113: *These black marls are susceptible to strong erosion and develop steep badland slopes (mean hillslope angles of 0.58 for the Laval and 0.40 for the Moulin catchment),with high drainage density and deeply incised gullies characterizing the catchment morphologies (Fig. 1C, D). Sediment transport occurs through gravitational processes on hillslopes, minor landslides (<1 m^3), micro debrisflows in the upper network, and bedload and suspended load in the main network.*

5) In the methods, the timing of data set acquisition is a bit unclear, see my line-by-line comments below.

As we received similar comments from reviewer #1, we modified the text (line 250) and added a supplementary table (Supplementary Table 1) to clarify the timing of dataset acquisition.

6) Figures. 3 and 4 show monthly total rainfall, but figure 6 focuses on rainfall intensity. It would be useful to show for reference a box plot of the distribution of rainfall intensity

across the months (e.g. do October and November have also higher rainfall intensity, or just higher total rainfall because it rains more days?). It would also be useful to see how panel B of Fig. 4 looks like when average monthly rainfall intensity is plotted rather than total monthly rainfall. This would also help better visualizing and following the discussion of section 5.2.

We thank the reviewer for this very interesting comment. As suggested, we have computed and plotted the monthly-averaged rainfall intensities. Because the calculation of the inter-annual monthly average of the rainfall instantaneous intensity was not relevant (variable time step), we work with rainfall intensity at 5-min constant time-step in order to compute monthly average rainfall intensity. The following figures, which show the results of this computation, will be modified / added in the manuscript and the previous Figure 4 will be moved to the supplementary material. The boxplot analysis highlights the seasonal variations of the rainfall intensity with the highest values (late spring- early summer), associated to highest variability, twice higher than winter values. Autumn mean rainfall intensity is clearly smaller than summer intensity, which contrast with the monthly cumulative rainfall (Figure 3A et 4B).

Note that the rainfall intensity that we have used for these monthly averages is computed over 5 minute time-steps, contrary to the data used for Figure 6 that was based on instantaneous intensities (i.e. computed at the variable time step of each tipping event). This is mentioned in the captions of the figures.

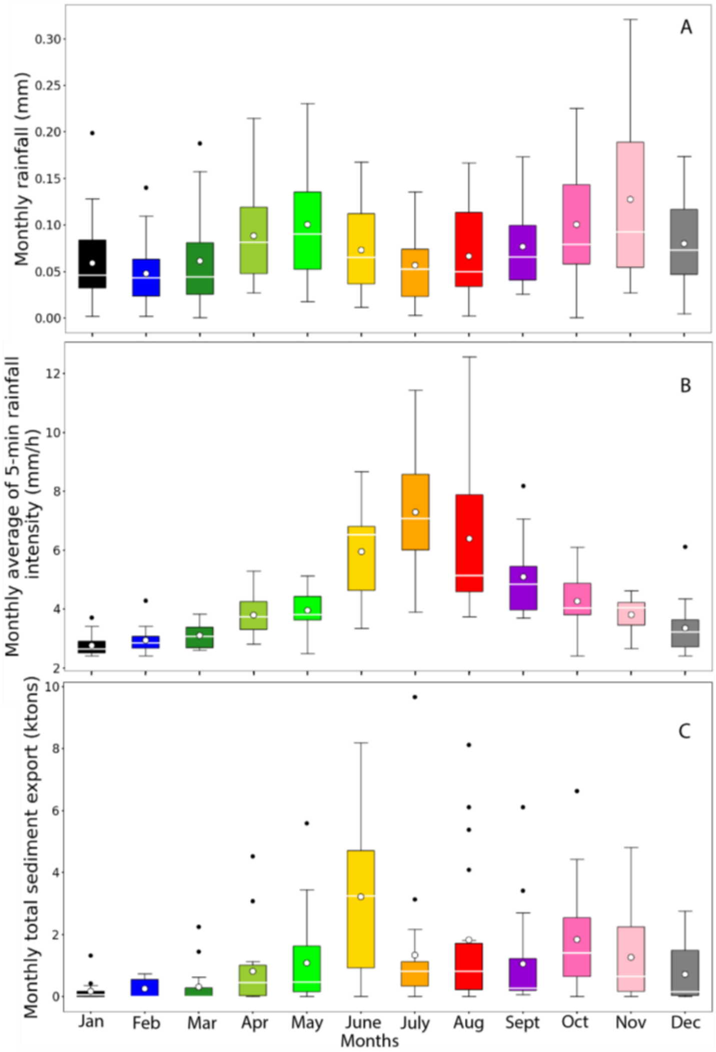


Figure 3: Boxplots of (A) monthly rainfall, B) Monthly average rainfall intensity computed at 5-minute time-steps and C) monthly total sediment export (i.e., bedload + suspended load) of the Laval catchment. White line shows median value and white dot indicates mean value. The first (Q1, 25%) and third (Q3 75%) percentiles are indicated by the box limits, whiskers show Q1 – 1.5 IQR and Q3 +1.5*IQR (inter-quartile range). Black dots are outlier values.*

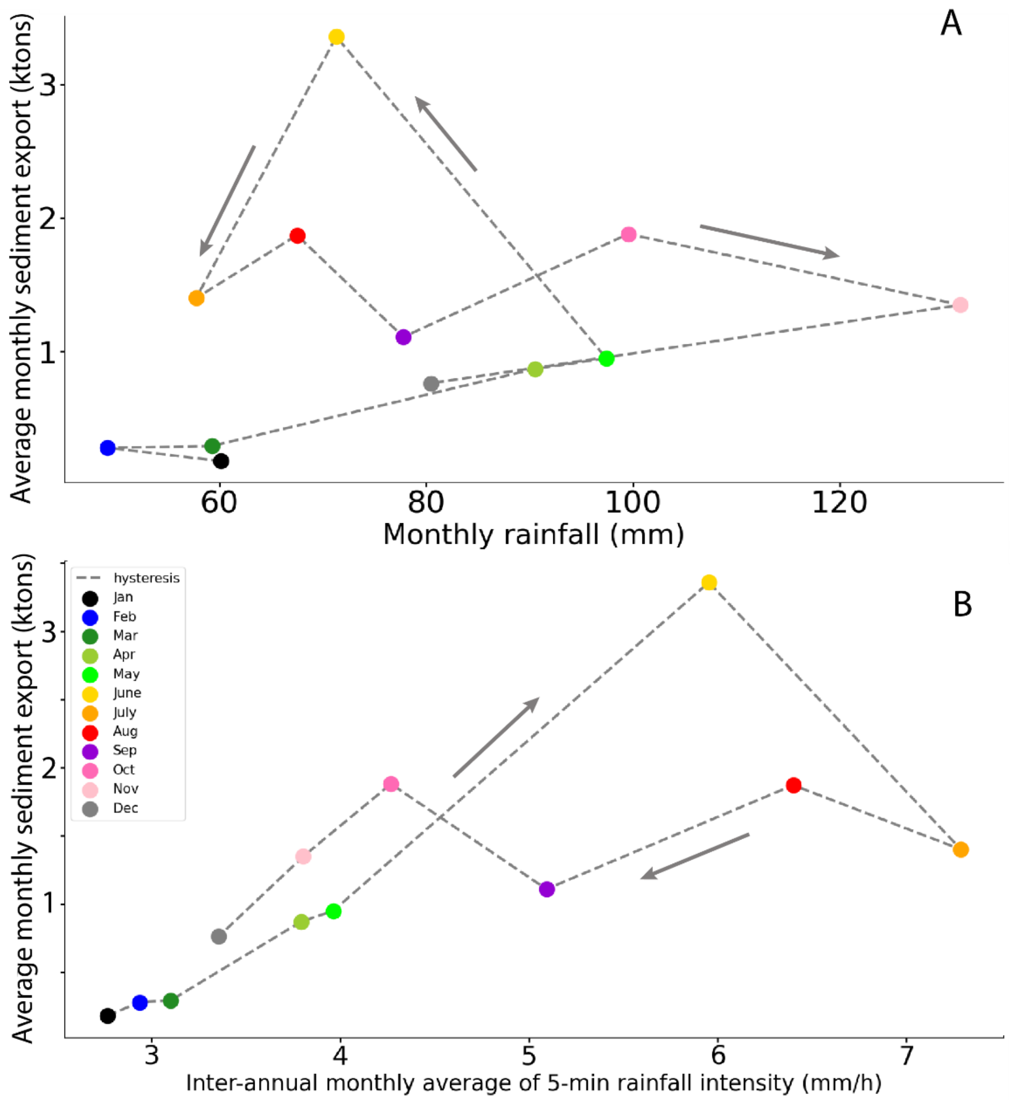


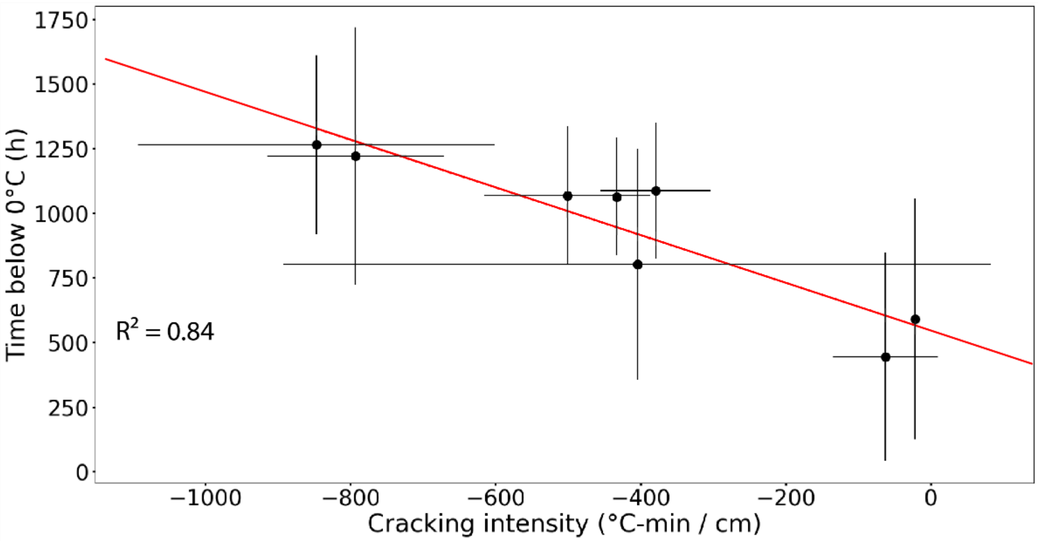
Figure 4: Hysteresis plot using interannual monthly average values from the Laval catchment between 2003 and 2020. (A) Monthly sediment export (ktons) versus monthly rainfall. Dashed line highlights the hysteresis cycle with two separate maxima: high sediment export and moderate rainfall in June versus high total rainfall and moderate sediment export in October/November (B) Monthly sediment export (ktons) versus monthly average rainfall intensity. Dashed line illustrate the hysteresis cycle with a maxima of sediment export in June preceding a stationary stat around 1.5 ktons of sediment export between July and November.

In light of this observation, we suggest to modify and add details about these results in the text of the manuscript part 4.1 and 5.2 (see in the new version of the manuscript) and in part 3.2.1 as follows:

Line 155: *First, we compared monthly sediment export and monthly rainfall to understand the seasonal dynamics of sediment transport in the Laval and Moulin catchments (Figs. 3 - 5). The analysis was performed for the period 2003 - 2020, during which sediment export was the most precisely recorded. In this time interval, rainfall amount was summed for each month to obtain monthly rainfall. When gaps were present in the data (around 6% of the time), daily cumulative reconstitutions of these missing periods were possible thanks to the network of tipping-bucket* *rain gauges installed around the catchment. Monthly averaged rainfall intensity was also computed by averaging non-zero values of 5-minute constant time-step rainfall intensities.*

7) Finally, showing a direct correlation of time spent below 0 degrees and frost-cracking intensity would add value to the paper and convey one of its most important outcomes more easily.

The direct correlation between the time spent below 0°C and the frost-cracking intensity is already illustrated by the correlation matrix (Figure 7; significant value of -0.92). We are not sure that adding a figure showing this correlation would add much but we suggest adding it as a supplementary figure, which we refer to in the discussion:



Supplementary Figure 5: Regression analysis between frost-cracking intensity and the time below 0°C, the two temperature indicators that best predict the sediment export anomaly (Fig.7). Horizontal and vertical error bars refer to the difference between measurements at uphill and downhill locations (temperature measurements for 2017 and 2019 were only available for the downhill location; for these years the average difference for the other years was taken). Red line shows ordinary least-squares (OLS) linear regression giving a coefficient of determination $R^2 = 0.84$.

Line 356 : *However, our study suggests that the time spent below 0°C, which correlates well with the frost-cracking intensity (Supplementary Figure 5), may be used as a simpler proxy to predict frost-weathering intensity.*

LINE-BY-LINE COMMENTS:

For every line-by-line comment we suggest directly a modification of the manuscript, if needed.

8) Lines 9 and 11: when saying "long data records" and "long-term" please add in parenthesis an actual timescale bracket. Otherwise it's a bit vague and different people understand different things by "long-term".
   See the modification made in response to comments 1 and 2.

9) Line 43: "very large quantity of sediment" – again, this sounds a bit vague and open to interpretation, add some order of magnitude or range in parentheses
10) Lines 42-44: to follow this sentences better and to provide more context, it would be useful for the reader to know what's the magnitude and frequency of these floods typically

We added in this part quantitative value associated to a typical big flood (in the top 10 of the floods for bedload records since 1995) from spring 2014. For one flood event, the total sediment-yield (suspended load and bedload) was around 5960 tonnes, giving a total specific sediment–yield of 6930 tonnes/km². We suggest to add this quantitative information in the introduction part and give more context on magnitude and frequency of these floods in the section 2.

Line 42: *Because of the ample availability of sediment and the efficient network connectivity (Jantzi et al., 2017), floods in these catchments can transport a very large quantity of sediment (Delannoy and Rovéra, 1996). As an example, during one flood event on 17/06/2014, 6390 tonnes/km² were exported and the suspended sediment concentration reached 440g/L).*

Line 115*: The Draix catchments record some of the highest specific sediment yields observed worldwide: average annual sediment yields for the Laval and Moulin catchments are around 12,000 and 570 tonnes, equating to specific sediment yields of around 14,000 and 5,700 t/km^2/y, respectively. This sediment budget results from 22 floods per year on average (for the Laval), ranging between 13 and 45 floods / yr and associated with very heterogeneous sediment yields from 0 up to around 6500 t/km² per event (Smetanova et al, 2018). Considering only the unvegetated parts of the catchments as contributing to the sediment yield and the measured sediment density of 1.7 kg/m^3, the average erosion rate is around 8 mm/yr for both catchments (Mathys, 2006).*

11) Line 51: "distinct evolution between S-facing and N-facing slopes" – distinct how? In the time, the magnitude of the response,….?

We cite Rovera and Robert (2005) in order to head the reader towards the details of the study and make our writing more fluent. We suggest to lightly modify the manuscript as follows:

Line 50: *Rovéra and Robert (2005) first investigated periglacial erosion processes in the Draix-Bléone CZO; they noted the marls' sensitivity to frost weathering, in particular to freeze-thaw cycles, and the resulting faster ablation on north facing than south-facing slopes*

12) Line 55: how many years of observations does this time-series contain?

Line 55*: Based on a two-year time series of twelve high-resolution digital elevation models from a 0.13 ha catchment in the Draix-Bléone CZO, Bechet et al (2016) showed…*

13) Line 62: what other similar sites? Please provide a couple of examples or delete this part of the sentence

'Other similar sites' refer to Spanish badlands mentioned in the previous paragraph.

Line 62: *Overall, existing observations from the Draix-Bléone CZO and similar sites (e.g., Regüés et al., 1995; Nadal-Romero et al., 2007) lead to consider frost weathering as a potentially important process controlling regolith production in marly Alpine badlands.*

14) Line 87: what is meant by "high-resolution" – give some more specific indication of the resolution.

More details on the -soil temperature series are given in part 3.1 (Line 134), thus we made a minor modification to the introduction.

Line 86: *To test our hypothesis, we used high-resolution soil-temperature measurements* ***(every 10 min)*** *from different locations and compared calculated temperature indicators,*

15) Line 89: what winter season and "following year"? Would be handy to know the exact year.

Our response is similar to the previous point: more details are provided in the third part of the manuscript but we add some detail here.

Line 88-89: *'…including the number of freeze-thaw cycles, the time spent below 0 °C, the mean negative temperature and the frost-cracking intensity, during a winter season to the sediment-export anomaly (i.e., the residual of sediment yield that cannot be explained by rainfall variability) in the following year (e.g., for the 2007-2008 winter season, we used the sediment export for the year 2008).*

16) Line 109: is the mean elevation of one catchment 850 and for the other, 1250 (and if so, for which), or does the elevation of both catchments range from 850 to 1250 m of elevation? Please rephrase to make this clearer.

Line 109: *Elevations range from 850 to 1250 m a.s.l. for the Laval and from 850 to 925 m a.s.l. for the Moulin catchment.*

17) Line 114: and how much would the average erosion rate be if the whole catchment is considered? Most studies do not remove vegetated sectors when providing catchment-averaged erosion rate estimates.

We considered only the unvegetated part of the catchment for the erosion rate computation because it has been shown that the vegetated parts do not contribute to the sediment-yields. As a witness, the vegetated Brusquet catchment has a specific sediment yield about two orders of magnitude less than the Laval catchment sediment yield, or about 0.5% (Carriere et al, 2020). In that sense, we suggest to not modify the given erosion rate but we add details on this part as follows:

Line 117: *It has been shown that erosion is strongly focused in the unvegetated parts of the catchments; the specific sediment yield of the adjacent vegetated Brusquet catchment is two orders of magnitude smaller than that of the Laval catchment (Carrière et al., 2020). Considering only the unvegetated parts of the catchments as contributing to the sediment yield, and the measured sediment density of 1700 kg/m*^{3}*, the average erosion rate is around 8 mm/yr (Mathys, 2006).*

18) Line 120: please clarify the measurement periods and years for each of these data sets. You say later on line 135 that soil temperature was recorded between 2005-2019, but the recording periods of sediment yield and rainfall are unclear. It would actually be useful if these study periods are mentioned in the abstract or introduction as well, earlier in the paper.

Reviewer #1 made similar comments; we therefore add a paragraph at the beginning of Section 3 to clarify the recording periods and we supply a supplementary table detailing measurement periods for soil temperature.

We used two different time periods for our analyses:

- 2003 to 2020 for the monthly sediment export analysis (4.1, 5.2: Figs. 3 - 5)
- 2005 to 2020 for the temperature indicator analysis (4.2, 5.3 : Figs. 6 - 9)

Because these two results are not directly correlated, we used the longer time range available for the sediment-export data to analyse the hysteresis cycle. However, when comparing annual sediment export with the temperature indicators (Fig. 6) we only used the data in the timespan 2005-2020 in order to be consistent with the time range of the soil temperature datasets.

19) Line 134: it is a bit unclear how many soil temperature sampling sites there were: was it four on each catchment (south-facing top, south-facing bottom, north-facing top, north-facing bottom?). In figure 1D, only 3 sites are marked as SF-top, SF-bot, and NF, so it's a bit confusing if for the NF, there were also top and bottom sites, and whether there was only one monitored hillslope per catchment, or one in each catchment (so 8 monitored sites in total?). Also, what is the elevation of this monitored hillslope with respect to the mean elevation of the catchment?

The paragraph starting line 134 contains the answers to these questions. In line 135 we mention that probes are implanted '*on opposite slopes in an inner meander of the Moulin Creek'*. Thus, there are 2 hillslopes in only one catchment. Additionally, line 136 clarifies the location of each probe site: '*probes located in bare black marls at uphill and downhill locations on north- and south-facing slopes'*. Confusion might come from Figure 1D; therefore we will add 'top' and 'bot' behind 'NF' in the revised version of the manuscript.
The mean elevation of the Moulin catchment is about 917m (Mathys, 2006) and the probes are located in the lower part of the catchment at an elevation around 867m.

Line 134: *Soil temperature has been recorded using several PT100 soil-temperature probes located on opposite slopes (867m elevation) in an inner meander of the Moulin Creek between August 2005 and December 2019 (i.e., four sites in total; Fig. 1D).*

20) Line 139-141: You say earlier that soil temperature was monitored between August 2005-December 2019. But then here you say "we specifically analysed soil temperatures during the winter season, from October 18th to 31st" – I guess this means that data was recording throughout the year but for this study you only focus on the winter temperatures? Or does this mean that only winter temperatures were recorded? Please clarify.

This is correct, as mentioned in line 139, we only used winter temperatures to study frost weathering because negative temperatures do not occur during spring, summer and early fall.

21) Line 148-153: show this relationship of air and soil temperature in the supplement – it's hard to follow a description of data that is not shown anywhere.

As suggested also by reviewer #1, we added figures and details in the supplementary material (Supplementary Figures 2 and 3) .

22) Line 152: what proportion of the winter season is snow-free?

In the Draix-Bléone catchments, snow fall occurs almost every year but these very small events accumulate less than 10 cm snow depth in general. Additionally, this thin layer rarely remains more than 1 day on south-facing slopes because of direct solar radiation, whereas it can stay a few days on North-facing slopes. Because these conditions are not very frequent, snow-cover periods have not been recorded. Only soil-temperatures records, on north-facing slopes, in the subsurface give approximate indications of snow-cover periods (e.g., Figure 2B).

Line 105*: The rainfall regime varies across seasons, with high-intensity rainfall events during spring/summer and lower-intensity but longer rainfall events in autumn. Snow fall occurs almost every year but in small amounts (<10cm) and it melts quickly. The mean annual temperature is 10.3 °C, with an annual variability between mean daily temperatures of approximatively 0.5 °C in winter and 20 °C in summer.*

23) Line 158: what previous studies? Please cite them.

Line 158: *We selected this range of thresholds based on inferences from previous studies (Mathys, 2006) and then used the value providing the best correlation to predict annual sediment-export values.*

24) Line 162: is that really your aim? The whole study seems focused to explore only one controlling factor, not test for other potential controlling factors.

This concluding sentence explains the general goal of the sediment-export anomaly calculation. To be consistent with the modifications made in the introduction, the following clarification has been added in the text:

Line 162: *With the aim of quantifying the impact of frost weathering on sediment production, and of identifying the most relevant frost-weathering process, our objective is to identify a controlling factor to explain this sediment-export anomaly*

25) Lines 210-211: these years of measuring periods of precipitation and sediment export should have been mentioned on the methods.

As we received comments from reviewer #1, we added a paragraph at the beginning of the Section 3.2.1 (Line 155).

Line 155*: First, we compared monthly sediment export and monthly rainfall to understand the seasonal dynamics of sediment transport in the Laval and Moulin catchments (Figs. 3 - 5). The analysis was performed for the period 2003 - 2019, during which sediment export was precisely recorded.*

26) Line 219: are there any general trends of increasing or decreasing precipitation or sediment export across the sampling years?

There is a large variability but no significant increasing or decreasing trend for precipitation or sediment export over the period we used (2003-2019).

27) Lines 342-343: why focusing only on small or marly catchments? It would be good to add some context and mention other studies that have shown that frost-cracking is an important control or modulator in sediment production (e.g. Hales and Roering's works on New Zealand, Delunel et al., 2010).

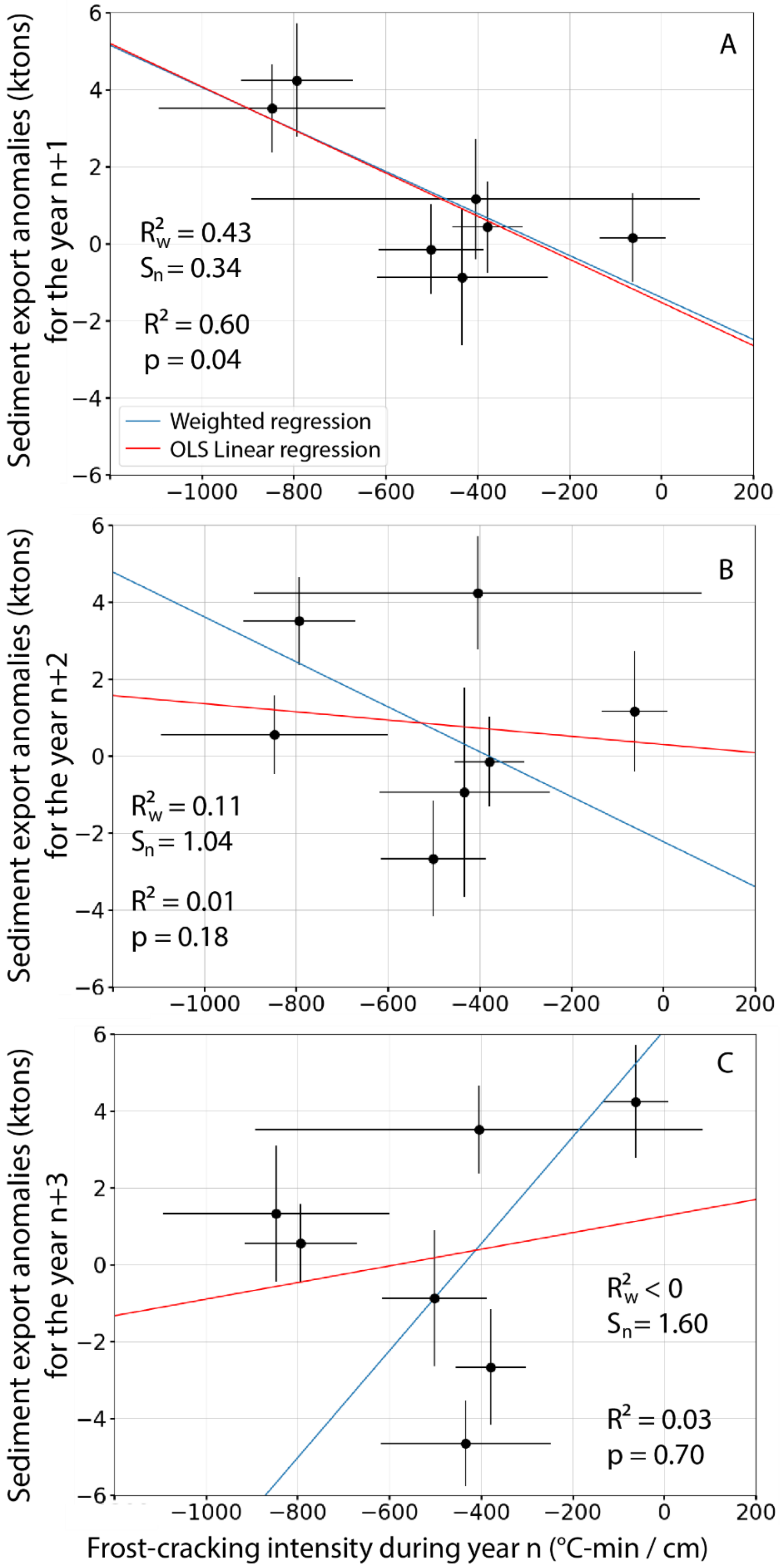
We are not sure that we fully understand this comment in the sense that Rengers et al (2020) studied a chalk hillslope rather than a marly catchment (Line 341). This part of the discussion also does not seem the right place to cite these other studies. However, we agree that they are relevant and therefore we will refer to them in the introduction as follows:

Line 76: *Frost-cracking has thus been identified as the major control on rock weathering in high Alpine environments (Hales and Roering, 2007; Delunel et al, 2010; Bennett et al., 2013; Draebing and Krautblatter, 2019).*

28) Lines 365-369: please include these figures in the supplementary info, it's hard to follow and blindly believe data that you can't see.

We will add in the supplementary material a figure and numerical results about the correlation between the FCI indicator and sediment export anomalies of the years n+1, n+2, n+3. We also modify the text as follows because some numerical results were slightly different than previously due to the initial choice to take the mean temperature value of each hillslope face.

Line 361: *These correlations between sediment production computed during a winter season and sediment yield for the directly following year (spring to autumn), together with the strongly varying dynamics of transport during the year discussed in the previous section, favour the hypothesis of rapid sediment export from the studied catchments, in contrast to the 3-year residence time of sediments in these catchments inferred by Jantzi et al. (2017). In order to test this hypothesis, we performed correlations between the frost-cracking intensity in a particular winter season (n) and the sediment-export anomaly of the first (n+1), second (n+2) and third (n+3) year after that season (i.e., in the n+3 case, if we consider the 2006-2007 winter season for the frost-cracking intensity, we compare it to the sediment-export anomaly for 2010) (Supplementary Figure 5). In all configurations, the correlation is weaker than the direct annual correlation that we observed (R^2 = 0.76) and the correlation weakens with increasing residence time (Suppl. Fig. 6); correlations for the years n+2 and n+3 are not significant . The ratio observed in sediment distribution during the spring/summer (74% suspended load / 26% bedload) and the rapid export of these fine sediments probably make the suspended load invisible in the estimation of sediment storage in the catchment, rendering the calculation of residence time complex.*



Supplementary Figure 6: *Regression analysis between frost-cracking intensity on the south-facing slope for the years (n =) 2007, 2008, 2009, 2010, 2014, 2015 and 2017 and the sediment-*

export anomalies of A) the year n+1, B) the year n+2, C) the year n+3 (See text for explanation). Horizontal error bars refer to the difference between measurements at uphill and downhill locations (temperature measurements for 2017 were only available for the downhill location, thus uncertainty on frost-cracking intensity was computed as the average of the uncertainties from the others years); vertical error bars are ±2σ uncertainty in export anomaly. Red line shows ordinary least-squares (OLS) linear regression whereas ***blue*** *line shows weighted linear regression following York et al. (2004). Weighted determination coefficients* R^2_w *and associated normalized goodness-of-fit indicator* $S_n = S / (n-2)$ *are indicated for the weighted regression. Standard* R^2 *and associated p-value indicate significance of the ordinary least-squares (unweighted) regression.*

29) Line 413: the phrasing "later in the year"/ "an initial"/"followed by" is a bit confusing in the context of a hysteresis cycle. This would be clear if rephrasing to something like "from June to September", etc.

Line 409: *The annual hysteresis cycle (Fig. 4) shows an anti-clockwise pattern between June and August, and a clockwise pattern later in the year (September to December), suggesting a spring / early summer transport-limited regime followed by an autumn supply-limited regime in these catchments.*

FIGURES:

In general, all figures are on the lower-resolution side; higher-resolution, vectorized versions would be better for publication.

Figure 1: Some text is hard to read well because it's too pixelated, small, or a too fine font. In panel A, almost all text except the key and scale bar numbers are impossible to read. The cardinals are also impossible to read in all panels, I suggest just substituting for a bigger, bolder arrow pointing North. In panel B, all text is too small to be read easily, but the river names particularly. Panel C would be easier to read if the letters were bolder, or a white box is placed in the background and text switched to black. The black text in panel D is hard to read as well, it needs to be bolder, or have some outline in white, or a white box behind it.

We are surprised that the reviewer received low-resolution figures because we used the highest resolution possible for the insets of Figure 1. To improve the readability we increased the font, bolded some labels and changed the north arrow.

Figure 2: Does (A) have the same x-axis as B? If yes, please clarify in caption, if not, please add labels on axis.

We modify the caption as follows:

Figure 1: Example of raw temperature series (1 measurement every 10 min). (A) Typical soil-temperature series recorded with four probes at different depths (from south-facing uphill location; time scale as in B). (B) Example of soil-temperature series (from south-facing downhill location) biased because of climatic conditions (snow cover), buried or loosened probes. A full year of temperature measurements is shown in Supplementary Figure 1. High

temperature values are observed at -1cm even in winter when black marl heats up during sunny periods.

Figure 3: How have outliers been identified? Please explain on methods.

As we detailed in the caption to Fig. 3, the boxplot graphical representation indicates the mean, the median and the 1st and 3rd quartile (colour box limits). To define whiskers and outlier points we followed the Interquartile range (IQR) method of outlier detection, which commonly uses a scale of 1.5. This number controls the sensitivity of the whiskers range and is set to be close from what the Gaussian distribution with a 3σ range would give .

As these are standard methods we do not feel they need to be explicited in the methods section. However, we will add a short explanation to the figure caption:.

Line 578: *Black dots are outlier values (i.e., with values <Q1 - 1.5 IQR or > Q3 + 1.5 IQR).*

Figure 8: Choose a different colour for the weighted regression line that is not the same as the data points and error bars.

We will plot the data points in black and leave the weighted regression line in blue for Figures 7 and 8 in the revised version of the manuscript.