

## ***Answer to the reviewers: “Detection of seasonal erosion processes at the scale of an elementary black marl gully from time series of Hi-Resolution DEMs”***

***by J. Bechet et al.***

First we would thank all the reviewers who underlined some weaknesses of the manuscript which we tried to improve.

### **Editor comments**

We followed your proposition about tables.

Concerning the error, we did not follow the papers you cited. As you have seen the conditions of data acquisition were quite complicated. We get some shadows (remember that we cannot go in this “natural” catchment”). In addition, no measurement of the suspended material were available for the studied period, only average data.

We based our estimation on the matching of scan for the same period and on trial and error to get reliable image of erosion deposition. For that reason we have not used sophisticated method, which led to a quite high threshold of erosion deposition detection.

We have followed most of the comments of the reviewers.

### **Anonymous Referee #1**

**Author’s response:** First we thank the reviewer for his very pertinent review that will improve the paper.

Interactive comment on Earth Surf. Dynam. Discuss., 3, 1555, 2015.

**Comments from Referees:** This paper deals the erosion processes measured from multi temporal lidar data in a small catchment located in the South East of France. The approach developed by the authors is interesting for their purpose. I am surprised that no mention of slope is made in the paper. Are there some relationships between erosion amount and slope value?

**Author’s response:** We fully agree with this we were too much concentrated on the surface slope changes and the volume transfer, and not enough by the other parameters (that we have already). We provide an elevation change versus slope angle graphs and we added add texts in method, result a discussion. In addition, we add consideration about slope aspects and flow accumulations related to changes. We thank the reviewer for this proposal, because it made a major input in our paper.

**Comments from Referees:** I think that this paper could easily concern a broader audience if the discussion part was more developed. I list also some minor points:

**Author’s response:** yes we agree.

**Comments from Referees:** Abstract: the results are not described in the abstract. Please remove sentences such as “Comparisons of the TLS sediment budget map with the in situ sediment monitoring (limnigraph and sedigraph) in the stream are discussed” by sentences with more content.

**Author's response:** we reformulate mostly the second part of the abstract as requested.

**Comments from Referees:** Page 1559 Line 8: I don't think that your model conceptual explains but it describes.

**Author's response:** changed to described.

**Comments from Referees:** P1559 l19: What is IRSTEA ?

**Author's response:** Done

**Comments from Referees:** P1560 l9: Is there a relationship between erosion intensity and the deep of sedimentary layers?

**Author's response:** yes there is an impact but in our study we were not able to make the difference, in the discussion we added some references (Mathys, 2005; catena; PhD Mathys). When the slope is perpendicular to the bedding the weathering is more important. We also add some sentences related to that problem in the discussion.

**Comments from Referees:** P1560 l10: Pinus nigra instead of Pina Negra:

**Author's response:** Done!

**Comments from Referees:** P1561: Are the hyper concentrated flows trapped in the sediment trap ? If not how do you take them into account in your measure of sediment export?

**Author's response:** This aspect is clarified on page 1565 the choices we made are explained.

**Comments from Referees:** P1563 L1: replace as by has.

**Author's response:** Done!

**Comments from Referees:** P1164: the discussion concerning the accuracy is not clear for me. Could you develop? You discuss only the vertical accuracy. What about the horizontal one? In such high relief environment, a horizontal error will produce high errors in topographic balances.

**Author's response:** we add: We do not consider horizontal error for two main reasons: (1) the effect of the slope orientation on the measures of point location very similar for each scan (the average slope does not change significantly between scans). (2) When merging scan with ICP the error between scans include its horizontal components. It does not exceed the thresholds we used for detecting erosive processes (see sections 3.5 and 4.1). Assuming the systematic errors caused by slope orientation are similar (except for identified other problems) for all scans we are not tackling in more detail this topic.

**Comments from Referees:** P1564 L21: the images are small and difficult to analyse.

**Author's response:** we added a larger version in supplementary materials.

**Comments from Referees:** P1565: Did you try to evaluate the accuracy on flat area on which erosion or deposit is negligible?

**Author's response:** we add the following sentence refereeing to Abellan et al. (2009):

These authors showed in particular that when averaging point clouds the detection of changes increased significantly.

**Comments from Referees:** P1565L13: I don't see any mention of density in table 2 or I don't understand what you mean. (Perhaps it concerns volume variation).

**Author's response:** we clarified this point in the text, but no more references to the table.

**Comments from Referees:** P1565L21: Do you mean that 40% of the sediment are not trapped?

**Author's response:** No, this is the maximum ratio measured by Mathys (2006) at the scale of one specific event, the average is 20%. This is the value we used. We clarified the text above.

**Comments from Referees:** P1566L13: Could you explain why interpolation reduces measurement errors? Generally interpolation propagates errors.

**Author's response:** in that case the interpolation reduced the number of points by averaging locally, this means that the elevation error was reduced, but the size of pixels increased reducing the noise by averaging (see Abellan et al., 2009).

**Comments from Referees:** P1568: I think that you could be clearer concerning the relationship between rainfall and erosion. What is finally the main parameter? The instantaneous amount of rain? The history of rainfall in the few days before the erosion occurs? Is the soil saturation an important parameter for erosion?

**Author's response:** We add the following sentence: The effect of rainfall is not straightforward. The erosion rate depends first on the material available, and second on the rainfall intensity. But low intensity rainfalls are participating to the cycle of erosion by implying drying and wetting plus micro-slope movements, which weathered the regolith more and transfer mass locally.

And moved the whole to the discussion as requested by the rev #2.

**Comments from Referees:** P1169L27: June?

**Author's response:** Done.

**Comments from Referees:** P1571L11: event

**Author's response:** Done.

***Interactive comment on “Detection of seasonal erosion processes at the scale of an elementary black marl gully from time series of Hi-Resolution DEMs” by J. Bechet et al.***

**Anonymous Referee #2**

Interactive comment on Earth Surf. Dynam. Discuss., 3, 1555, 2015.

Detection of seasonal erosion processes at the scale of an elementary black marl gully from time series of Hires DEMs

Bechet et al

**Comments from Referees :** I was saddened when reading in the acknowledgements that the first author had deceased in an avalanche accident. I wish the team of co-authors much strength in dealing with this loss. It is to be commended that they decided to finish this work and dedicate it to Dr. Bechet.

The ms deals with a multi-temporal dataset of highly accurate DEMs, which are subtracted from each-other to yield Dems of Difference (although this term is not mentioned). The objective is to create seasonal maps of erosion (confusingly called ablation) and sedimentation, and to extract a conceptual model from this. The data presented are interesting and worth my time.

**Author’s response:** [We have changed the terms and we use erosion only.](#)

The main conclusions about seasonality appear to be warranted, although they should be defended rather than posited, and some extra calculations are required to put them further into context. I am not well placed to comment on the quality of embedding the discussion in the context of (international) gully erosion research, but this appears to be going well. Figures are well made up (but see comments) and support the storyline. My main points for improvement of the ms follow here - a detailed list of suggestions is given below.

First, I find that the seasonality of processes is the most interesting point of the document. It deserves a clear presentation - first as a hypothesis, which has led to your data gathering scheme (i.e. multiple times per year). Then the data should be examined, and you can conclude (a bit later in the ms than you do now) that there are strong seasonal differences in what you observe. From that, the conceptual model can follow.

**Author’s response:** [We moved this part later in text. In addition, we give some more info about previous study in Draix which addressed already some of these topics. .](#)

Second, one main possible uncertainty that you have not been able to resolve is the effect of weathering on bulk density and hence on slope swelling. I think that you should get at some preliminary estimates of this effect, and that this can strengthen your interpretation. I make suggestions below.

**Author’s response:** [We will try to give more explanations, but quantification is very difficult \(see below\). Nevertheless, with the new graph giving changes in elevation with slope, it can be viewed that the expansion exists, in addition we made some consideration about the regolith expansion.](#)

Third, there is a long list of small language issues in the ms. I make detailed suggestions for improvement below. The main point would be that in my perception 'erosion' is a more common term for what you call 'ablation'.

**Author's response:** see first comment.

Most of my comments will be easily considered and if needed, corrected. However, because some restructuring of the arguments is needed along with new calculations that could lead to some changes in the argumentation, I recommended major revisions to the editor. I expect however that these will not take up too much of your time.

**Comments from Referees :** Abstract l 22 temporal : temporary?

**Author's response:** temporal sequence of...

## ***Page 1558***

**Comments from Referees :** l 20 : It is unclear to me what SOERE RBV is. Is it a reference? Then it lacks a year.

**Author's response:** we will add: SOERE (SYSTÈMES D'OBSERVATION ET D'EXPÉRIMENTATION POUR LA RECHERCHE EN ENVIRONNEMENT) RBV (Reseau de Bassins Versants = network of catchments for the study of the critical zone, see [portailrbv.sedoo.fr](http://portailrbv.sedoo.fr))

## ***Page 1559***

**Comments from Referees :** l 15 - move the explanation of SOERE BV to earlier in the ms

**Author's response:** we will add: moved at the beginning

## ***Page 1559***

**Comments from Referees :** l19 what is IRSTEA?

**Author's response:** Done.

## ***Page 1560***

**Comments from Referees :** l23 A limestone ridge overlies the marls - this is confusing to me. A ridge is a landform, 'the marls' is a sedimentary formation. Please clarify.

**Author's response:** we change to: These the black marls are overlain by limestones creating cliffs in the upper part of the Draix catchment (Ballais, 1999). Remember that this description concerns the regional scale.

## ***Page 1561***

**Comments from Referees :** l17 it would be useful here to present the mean annual air temp and the average temperature in the three winter months instead of daily average.

**Author's response:** we changed to: *The average yearly air temperature is 10.9 C with a standard deviation of 8.7 °C (based on daily average temperature) over the period 1970-2000.*

**Comments from Referees :** l25 But... this sentence is not understandable (use 'but' only once, for instance).

**Author's response:** we changed like this: *Because considering only the freezing and thaw cycles the south-facing slopes suffer more cycles than the north-facing ones, but the gullies located in the south-facing slope are equivalent to north facing slope (Rovera and Robert, 2005).*

## **Page 1562**

**Comments from Referees :** l 11 A popcorn structure? This requires a photograph and/or some extra explanation. I have no idea what this means.

**Author's response: we changed to:** In the spring season, the regolith observed in the gullies has a popcorn structure defined as "Expansion is accompanied by the development of cracks separated by micro-humps" (Gutiérrez, 2005), and therefore a lower density compared to the unweathered black marls.

**Comments from Referees :** l 13 erosion rates of the b. m. is 8 mm yr<sup>-1</sup> (no 'of').

**Author's response:** Done

**Comments from Referees :** l14 8 mm / yr , calculated over which period? Same for next sentences

**Author's response:** The mean erosion rate of the black marls averaged over 3 years (1985-1987) is of 8 mm.yr<sup>-1</sup>, which is approximately 100 t.ha<sup>-1</sup>.yr<sup>-1</sup> (Olivry and Hoorelbeck, 1989),

**Comments from Referees :** l17 upper part of the slopes

**Author's response:** Done!

## **Page 1563**

**Comments from Referees :** l 8 Yes, indeed, give wavelength.

**Author's response:** The TLS2 laser is in the green electromagnetic spectrum wavelength (only information available from the manufacturer) with a 6 mm accuracy and a 6 mm spot size at 50m.

**Comments from Referees :** l10 from May 2007 to November 2010 (no 'the' )

**Author's response:** Done!

**Comments from Referees :** l18 are less than (no of)

**Author's response:** done!

l19 ranges from 0.3 to 3 pts cm<sup>-2</sup>

**Author's response:** Done!

## Page 1564

**Comments from Referees :** l8 As an example : this sentence is too long, has at least one error and is not clear to me. Please check and cut up into two new sentences.

**Author's response:** Performing an average on a surface area of  $4 \text{ cm}^2$ , ( $2 \times 2 \text{ cm}$ ) with densities ranging from  $0.3$  to  $3 \text{ pts.cm}^{-2}$  ( $n = 1.2$  and  $12 \text{ pts}$  in  $4 \text{ cm}^2$ ) provides an accuracy ranging from  $6.7$  to  $2.3 \text{ mm}$ . Because  $\sigma_n$  is given by  $(\sigma_1/n)^{0.5}$  assuming that the point cloud is well georeferenced.

**Comments from Referees :** l21 to l24 this is not understandable to me. What are you doing in addition to simply taking the difference between each HRDEM and the subsequent HRDEM? Are you matching a HRDEM with one from the same season a year back? Why? If that is true, change in

**Author's response:** we will clarify this sentences: Eleven difference between successive DEMs giving DEMs of Differences (DoDs) have been calculated from the 9<sup>th</sup> May 2007 to the 4<sup>th</sup> November 2010 (Figure 2). Because the occurrence of processes is strongly related to each season, the DEMs are sorted out by seasonal periods. The mapping of the different erosion and deposition areas is carried out for each season by taking into account the DoDs of the corresponding season.

And we used DEM for image and DoD for difference of images.

**Comments from Referees :** l17 : "from AN earlier HRDEM".

**Author's response:** Done using DEM!

l26 "these maps ....including the interpretation ... of .. process"? How can a map include an interpretation of a process - it should be a result of your work that can not be contested - not an interpretation that we can have different opinions about.

**Author's response:** we changed to: These maps represent a synthesis of the DoDs of Fig. 2, showing the erosion or deposition areas.

## Page 1565

**Comments from Referees :** l5 subtracted from

**Author's response:** Done!

**Comments from Referees :** l10 why do these volumes need to be corrected? Do you mean convert? And what does this have to do with vegetated areas? **Comments from Referees :** l12 and if the density changes throughout the year, then why always use  $1500 \text{ kg m}^{-3}$  ?

**Author's response:** Finally, an average density of  $1500 \text{ kg.m}^{-3}$  for the black marls deposits measured in the sediment trap as proposed by Mathys *et al.* (1996). This value is used to calibrate the TLS volumes. This has been performed because some vegetated areas and some occlusions exist which are not imaged by the scans (Table 2 and 3). As reminder this occurred because the access within the Roubine catchment is forbidden. This allows also to get a rough idea of the density of the eroded material. It changes throughout the year according to the seasons indicating that in summer the density is close to the bedrock value (i.e.  $2325 \text{ kg.m}^{-3}$ ) and during spring it close to the sediment  $1500 \text{ kg.m}^{-3}$ .

**Comments from Referees :** l16 results were compared

**Author's response:** Done!

**Comments from Referees :** l23 that were quantified

**Author's response:** Done!

**Comments from Referees :** l25 due to atmospheric conditions in the last section of the methods, you talk a lot about what CAN be done to quantify the errors. Has this also been done in your case? 4 results

**Author's response:** we add this sentence: The use of a high threshold value to validate DoDs values to detect process of erosion or deposition permits to escape from the problems of misalignment or atmospheric deformation (see below).

**Comments from Referees :** l22 ablation should be erosion, also in captions and elsewhere. It is not an international term, I believe.

**Author's response:** Done!

## ***Page 1567***

**Comments from Referees :** Two main comments about the 5 'seasons'. I believe that your recognition of possible seasonality is a main attraction of this work. I think you should therefore not posit that seasons make a difference, but you should formulate it such that we see how you came to believe this, and to what extent you are sure about it. One weakness that you could highlight in this respect is that the winter season is characterized by only one observation / pattern. Second, does your method account for the fact that in some cases there may be a difference in altitude (or distance to the scanner) that is caused by expansion of the slope as it undergoes weathering but not erosion? You did discuss the large differences in bluk density between bedrock and regolith/soil, so this effect may be significant. This may be particularly important in the winter season. Please comment.

**Author's response:** We discussed this point, but we did not have enough data to solve fully the problem. This study underlines the necessity to take into account micro processes, because the Lidar accuracy is high enough to catch some of them. We try to clarify improve this point as far as we can with our data, making some assumptions about regolith expansion. But mainly, we suspect swelling process and we demonstrated it experimentally in the paper of Bechet et al., (2015 HESS). But remember that the sediment transfer is supported by the sediment trap data. The slope angle-erosion graphs also add information about this point, which is discussed now in the text.

## ***Page 1568***

**Comments from Referees :** l7 . This is probably etc. : please save interpretation for the discussion section.

**Author's response:** ok, you are right!

**Comments from Referees :** l8 This sentence is superfluous: for gullies with any flow accumulation, if there is not enough rainfall or rain intensity, there will be no transport.



**Author's response:** It seems there is a misunderstanding, the flowacc with less than 100 m2 are only working for high intensity rainfall. It sounds clear for us!

**Comments from Referees :** l19 very often: often

**Author's response:** Done!

**Comments from Referees :** l21 characterized by relative drought

**Author's response:** Done!

## ***Page 1569***

**Comments from Referees :** l 8 The difference is in an - this is a new sentence

**Author's response:** Done!

**Comments from Referees :** l12 I would prefer the dimnsions of 8m3 to be changed into volume per time. This is going to be important because not all your seasons are equally long. 14 rainfall was

**Author's response:** we corrected a few mistake in the numbers and added m3/year and mm/y.!

## ***Page 1570***

**Comments from Referees :** At l6 you conclude that you are underestimating - and then you give the reasons, before hypothesizing that you are underestimating, Better turn this around: first hypothesize, then give your reasons for it, and then conclude that you have a lot of confidence in your hypothesis.

**Author's response:** we modified accordingly!

**Comments from Referees :** l16 I am glad to see your attention for the swelling due to weathering. But before you discount this, why don't you provide a back-of-the-envelope calculation of the difference this would make? Roughly speaking, most of the year's weathering happens in winter, right? So, assuming equilibrium between weathering and erosion (which you implied before when you said that slopes do not change shape), why not take the annual volume of material captured in your sediment trap, divide that over the slope area (perpendicular to the slope, not aerial area). That should give you a first order estimate of the swelling? In imaginary numbers: if you have 10 kg leaving your catchment in a year, and you have 1000 m2 of slope area, then on average you have 0.01 kg/m2 slope area that has been eroded, and hence been weathered first. Weathering 0.01 kg/m2 from a bulk density of bedrock (2500 kg/m3) into a bulk density of sediment (1350 kg/m3) , would correspond to a swelling of the slope by (0.01/1350)-(0.01/2500) m / m2. My numbers are surely wrong, but perhaps the approach is valuable. Alternatively and more locally, you have the local erosion for your pixels over a whole year - assuming again that this is of an order with the local weathering, you could maybe do local erosion [m] \* local slope gradient [m/m] \* (density regolith / density bedrock) [-] .

**Author's response:** your proposal will probably not be able to capture the order of magnitude of the swelling, because it affects the regolith in several ways as we observed in experiment in Bechet, J., Duc, J., Jaboyedo , M., Loye, A., and Mathys, N.: Erosion processes in black marl soils at the millimetre scale: preliminary insights from an analogous model, Hydrol. Earth Syst. Sci., 19, 1849–1855, doi:10.5194/hess-19-1849-2015, 2015. But we gave some answer taking into account the calibration of the erosion... In

addition, we add some discussion about the density, and comments about the new figure slope-angle-elevation difference. But, it is clear that it opens a full topic of research for both field and experimental contexts.

## ***Page 1571:***

**Comments from Referees :**

l11 rainfall event

**Author's response:** done!

l12 from a transportlimited pattern (at ....spring) to a supply-limited one (in summer).

**Author's response:** ok!

**Comments from Referees :** l22 sentence may be wrong

**Author's response:** we propose: ... (Mathys et al., 2000). That threshold is lower if the dry period is smaller than 5 days.

## ***Page 1572***

**Comments from Referees :** l19 inter-rill erosion

**Author's response:** done!

**Comments from Referees :** 23 moving a few m through solifluction in one winter? That is very surprising to me. I am not aware of so rapid solifluction. Please illustrate this statement with literature or process knowledge. Are you thinking about mudfl

**Author's response:** you are right we use MDFs for the large movements! We adapted in that way: In winter, the upper regolith probably only moves on short distance at centimetre scale by small mass movements (Bechet et al., 2015) and at meter scale by MDFs.

## ***Figure***

**Comments from Referees :** Figures F1 - no comment

**Comments from Referees :** F2 - I love this figure. Very crucial to the paper, and it illustrates the richness of your data. However, individual maps are rather small. Could you please rearrange the titles of each so that you can zoom in a bit more to the maps? They deserve as much space as you can give them.

**Author's response:** We will rearrange and provide a supplementary material large in addition to the video.

**Comments from Referees :** F3 ablation=erosion. In legend: deposit - deposition. Also here, I think you can blow up the maps a bit larger.

**Author's response:** Done, for the size this is up to the journal, we can also move a version in supplementary material!

**Comments from Referees :** F4 do not show the zero values for cumulative [recipitation or intensity. You have used a threshold so this is not fair. In the caption, are you talking intensities per minute over a 1 minute period? Or five? or ten?

**Author's response:** The threshold are indicated now and we add the additional data and information.

**Comments from Referees :** F5 perfect.