Review of Croissant et al., *Pulsed carbon export from mountains by earthquake-triggered landslides explored in a reduced-complexity model* submitted to Earth surface dynamics

Summary

I enjoyed reviewing this manuscript and found it not only interesting, but also very carefully organized and well-written. The fate of OC is clearly an important topic, and this contribution provides a new model framework that can be adapted to ask many questions about the fate of OC mobilization by landslides in mountain regions.

Below, I lay out a few points about the model setup and assumptions that left me confused and that the authors may be able to address before publication. Beyond these points, I do not have any major comments or suggestions on this well-crafted piece.

Sediment transport and fluvial OC export in the model

As far as I understand, the authors assume that OC is transported as part of the fine sediment fraction. In turn, fine sediment transport is parameterized as a function of the average sediment transport capacity, $\bar{Q}_s$. As per equation (8), did I understand correctly, that for a single landslide body, the transport of sediment and, thus, the removal of M_{OC} just scales directly with this transport capacity of the river at the point that the river passes the deposit? I would have intuitively thought that, in many cases, the river, where it passes the deposit, is already transporting near, or at, capacity – thus, the additional sediment that it can erode when it passes the landslide may not corresponds to the full transport capacity $\bar{Q}_s$. In other words, wouldn't you have to route sediment through the channel network, to determine the excess transport capacity at each of the landslides? The difference between capacity and excess capacity could be quite large? I am probably misunderstanding something, but even if I am, clarifying the assumption in the text may help some readers that have the same thought.

Further, I struggled to follow the jump from the individual equations of $M_{oc,t}$ for fluvial transport and oxidation, to equations 12-14. Here, it could help to first define $M_{ox,t}$: $M_{ox,t} = k_{ox}M_{oc,t}$ (I think). Then you can explicitly state in the text that you combine this equation with eq. 10 and integrate to obtain eq. 12. The same applies to giving an explicit definition of $M_{riv,t}$ before the integration and a statement of which equations you combine and integrate to obtain equations 13 – 14.

Finally, I got confused about the parameterization of fluvial transport in the model. In particular the link between the differential equation (8) and the linear scaling with $\overline{Q_s}$ in equations (11, 13-14) remains unclear to me. As far as I understand, you first give a differential equation for the loss of M_{oc} by river export in equation (8). The solution to this equation, similar to eq (10) for oxidation, is not given (not sure why?), but should be $M_{oc,t} = M_{oc,0}e^{-\frac{\overline{Q_s}}{M_{ls}}t}$. Then, a characteristic time is introduced. This time looks similar to the e-folding time in the solution above, but it is now expressed (1) in terms of volume rather than mass and (2) in reference to only the fine material, not the entire landslide material (M_{ls}). Moreover, this timescale is not an e-folding time, but assumed to be the time to remove the entire landslide volume – leading to a linear scaling of sediment export with $\overline{Q_s}$. This jump was not clear to me. What is $M_{riv,t}$? Analogous to $M_{ox,t}$, from equation (8), I would have thought it should be $M_{riv,t} = \frac{\overline{Q_s}}{M_{ls}}M_{oc,t} = M_{oc,0}\frac{\overline{Q_s}}{M_{ls}}e^{-\frac{\overline{Q_s}}{M_{ls}}t}$. Similarly, I would have thought that the combined loss of OC to both oxidation and fluvial transport would just be the sum of eq (8) and eq (9) with the solution: $M_{oc,t} = M_{oc,0}e^{-\left(\frac{\overline{Q_s}}{M_{ls}}+k_{ox}\right)t}$. However, this is not what equations (11, 13-14) show.

So, in summary, it would be very helpful if you could specify why riverine OC export is first introduced via a differential equation with an exponential solution, and then later modeled as an inverse function of t_0 or a linear function of $\overline{Q_s}$.

I am sorry, if this is horribly confused, but hopefully these comments can give some ideas on how to clarify the model setup.

<u>Assumptions in the model</u>

In P 18, L29 – p19, L21, you discuss the limits to the parameterization of the connection velocity. You also mention the assumption that once the toe of the landslide deposit is connected to the channel, everything is connected. Given the volumes of landslide sediments stored on hillslopes in the field, this assumption strike me as one of the more significant ones. An additional aspect here, that is sort of touched on in the paragraph, may be that, after some time, fine sediment may become limited by the removal of the coarse fraction – either because the coarse sediment shields finer sediment underneath, or because the coarse sediment at the toe of the landslides stabilizes the remaining material on the hillslope. If that was true, then OC transport may be sensitive also to the transport of coarse material and to the role of extreme events that can mobilize that coarse material. It could be possible to implement it in the model via a different version of equation (8) – such implementation may be beyond the scope of the paper, but discussing this limit and the potential to overestimate (?) OC export could be useful.

Is it worth mentioning the assumption that OC is distributed equally on all slopes (e.g. on P6)? I can imagine that very steep slopes have less OC than gentler slopes – whereas landslides are biased toward steeper slopes. Thus, may landslides be biased toward slopes that have OC stocks below the landscape-average?

On a similar note, by modelling landslides to only occur during earthquakes, the landscape has more time to rebuild the carbon stock between earthquake events. Rainfall-triggered landslides in the Southern Alps are common. Moreover, reactivation of previous slopes (which are necessary, as you say, to deliver all of the sediment to the channel and allow the connection of the entire sediment mass to the channel) may disturb the buildup of soils and biomass on the slopes. Thus, OC stock buildup may be itself a function of the erosion of material from the hillslope. Perhaps it could be valuable to add a note on how reactivation or interseismic landsliding affects the estimates of the model.

Line & Figure comments

P2, L29: I believe there should be a hyphen between ‘sediment’ and ‘transfer’?

P3, L1: Why is this relevant only for OC at the surface?

P5, L23: I suggest to explicitly state that it is sediment in the *entire* deposit that is assumed to be connected.

P6, L4: Typo; landslide ‘scar’ without ‘s’.

P6, L13 – 15. You could consider adding a reference for this statement.

P10, L22: Space missing

P11, L11: ‘soil’ without ‘s’

P16, L19: Is ‘sort’ supposed to be ‘sought’? Otherwise, I do not understand the sentence.

P31, L5: ‘is shown’

Fig 5: I wasn’t sure whether the histograms referred to the blue or the red line, or to both?

Fig. 9: The relevant parameter is runoff variability which scales with 1/k, so I suggest to replot the figure with 1/k on the x-axis – if this change is not made, I suggest to at least change the label ‘runoff variability’. Otherwise, the reader might read high values as high runoff variability.

I hope that the comments are helpful and remain with best wishes to the authors and editor,

Sincerely,

Aaron Bufe