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January 9, 2018

To the Associated Editor of ESurf

Dear R. G. Hilton

We are pleased to submit a revised version of the manuscript "Colluvial deposits as a possible weathering reservoir in uplifting mountains", by Sébastien Carretier and co-authors.

We want to thank you and the three reviewers for very useful and constructive comments. They identified the points that "hurt" and we hope that the changes we made help to clarify them.

The added, moved or modified text is in red in the revised manuscript. We added 3 figures in the Supplementary Material (S3, S4, S5). In the following we respond to the comments point-by-point, beginning by your comments.

Best regards,

Sébastien Carretier on behalf of the co-authors

Associated Editor (R. G. Hilton)

I have now had the opportunity to read your manuscript in detail, before examining the comments made by the three referees. My apologies for the delay in posting these comments online. The referees and I are in broad agreement ? this is a worthwhile contribution, providing novel insight into the role of colluvium (and alluvium) in setting weathering fluxes at the river catchment scale in mountains. The modelling framework has caveats, but in general these are well explained, and the numerical experiments provide impetus for future field, laboratory and modelling based studies into the links between tectonics, climate and the carbon cycle. The work is a very good fit for Earth Surface Dynamics.
The three reviews contain very thoughtful and detailed comments. These need to all be considered thoroughly in your revision. In some cases, moderate to major modifica- tions may be necessary, some are quick fixes. Please provide a detailed point-by-point reply to the referees? comments. While all the referee comments are valid and need to be considered, the ones which come to the front, based on my own reading of the paper and the reviews are:
- revising the abstract to better explain the numerical experiments which have been run, and thus provide more context to the wider implications. As it is, it tends to simplify and generalise a bit too much some of the discussion elements, and caveats.

Thanks. We rewrote the abstract as (new text in italic):
The role of mountain uplift in the evolution of the global climate over geological times is controversial. At the heart of this debate is the capacity of rapid denudation to drive silicate weathering, which consumes CO_2. Here we present the results of a 3D model that couples erosion and weathering during mountain uplift, in which, for the first time, the weathered material is traced during its stochastic transport from the hillslopes to the mountain outlet. *At this stage, the model does not simulate the deep water circulation, the precipitation of secondary minerals, variations in the pH, below ground pCO2 and the chemical affinity of the water in contact with minerals. Consequently, the predicted silicate weathering fluxes represent probably a maximum. We explore the response of weathering fluxes to progressively cooler and drier climatic conditions, we simulate weathering fluxes accounting for the decrease in temperature with or without modifications in the rainfall pattern based on a simple orographic model. The predicted silicate weathering rates are within the range of silicate and total weathering rates estimated from field data. In all cases,* during mountain uplift, the erosion rate increases and the climate cools, which thins the regolith and produces a hump in the weathering rate evolution. *This model thus predicts that the weathering outflux reaches a peak and then falls, consistently with predictions of previous 1D models.* Nevertheless, lateral river erosion drives mass wasting and the temporary storage of colluvial deposits on the valley borders. This new reservoir is comprised of fresh material which has a residence time ranging from several years up to several thousand years. During this period, the weathering of colluvium sustains the mountain weathering flux at a significant level. The relative weathering contribution of colluvium depends on the area covered by regolith on the hillslopes. For mountains sparsely covered by regolith during cold periods, colluvium produce most of the simulated weathering flux for a large range of erosion parameters and precipitation rate patterns. In addition to other reservoirs such as deep fractured bedrock, colluvial deposits may help to maintain a substantial and constant weathering flux in rapidly uplifting mountains during cooling periods.

- In the main text, making it more clear what experiments were run, and why these were run (i.e. justifying them).

We extended a lot section 2.7 "Description of experiments" in order to describe and justify the experiments.

- explaining better the role of physical breakdown of particles (during weathering, but also during transport) and its absence from the model (?)

In the Discussion section, we added:
"*We also neglected the fragmentation of clasts during hillslope and river transport by physical weathering and crushing. This fragmentation should increase the weathering contribution of sediment trapped in the valleys as smaller grains weather faster.*"

- commenting on glacial/periglacial processes (given that even without cooling the lapse rate of 6 degrees/km would mean sub-zero temperatures at >4.1km elevation). This is in terms of some classic papers on this from a weathering perspective, and in terms of particle production (e.g. frost shattering etc,.).

This should be the topic of an entire paper ... Nevertheless, in the Discussion section, we added:
"*Glacier erosion and associated physical weathering is not modelled. Glaciers would provide fresh sediment eroded from high elevations to the fluvial system. This is already the case in our simulations with cold climate but glaciers may generate more and finer sediment. In addition, frost-cracking at high elevations produces sediment. Both phenomena should increase the weathering contribution of sediment stored in valleys.*"

`A final additional minor comment which I have, which I did not see made by the referees, regarded the relief of the simulations. 7 km seemed quite high. Comparisons to the Andes and Himalaya are broadly fair, but these regions have longer-wavelength topography which contribute to these peak elevations. Mountain ranges with faults at sea level, such as Taiwan and the Southern Alps, tend to have much lower peak elevations (>4 km). This comment also relates to the glacial/periglacial processes issue.`

You are right. As we explain extensively bellow in response to similar comments from referees, we designed experiments with high elevations because we thought that temperature gradient should control the regolith pattern evolution, which is partly the case but not crucially. The drawback of such a choice is that simulations should include a glacier erosion and frost-cracking model, but they do not. Nevertheless, we explain in the Discussion that both phenomena should rather increase the weathering flux from sediment temporarily stored in valleys at lower elevations. This deserves to be studied in the future, and we are very careful about non-intuitive behaviour, but adding these phenomena may actually reenforce our conclusions.

`Thank you for submitting to ESurf, and I look forward to seeing the revised manuscript.`

Thanks !