The approach used here consists of coupling a Lanscape Evolution Model (LEM) developed by the 1st author with well-known cosmogenic nuclide (CN) production and decay laws, in order to track individual particles (grains) journey from their source to their sink (here, when they leave the model grid). This allows the authors to evaluate statistically how the 10Be signal carried by a population of grains in riverine sands is representative of the average denudation rate of the upstream catchment. For now, I guess the aim of the authors is to demonstrate the model's ability to achieve the desired goal (i.e., to retrieve denudation rate variations with a limited number of grains and a reasonable computational time), not to address very specific questions on real or synthetic cases. To this respect, this paper is extremely interesting and the Lagrangian approach used here allows to account for the large variability in individual grains histories. The effect of grid size, resolution, time step, and number of grains are tested and the results seem extremely robust. It may however reach its limits for a larger landscape (here the grid is only 10km x 10km, except for fig 7 where it is 20km x 20km), and/or with low denudation rates, for which a large number of grains would be needed.

I only have some minor to moderate comments. There are some points that are unclear to me concerning the LEM itself, independently of the CN part. Some sentences are not very clear and may need to be rephrased. Finally, I think that some outcomes deserve a deeper discussion: the influence of the grains' origin (Quartz source located close or far from the outlet) and the strong amplitude reduction of the 10Be-derived erosion rate for short period precipitation oscillations.

Thank you for these comments. We address the different points in our responses to the detailed comments.

See detailed comments in the pdf file.

Line 3:" A model could help...": awkward sentence. I suggest something like "to address this, a model can be designed to explore the statistical properties of CN concentrations in sediment grains."

Thank you. We rephrased as: "Models can be used to explore the statistics of CN concentrations in sediment grains"

Line 59: Why hillslope erosion is not simulated by a diffusion equation? Equation 3 should look like:

$\epsilon\epsilon_h = \nabla ? (\kappa\kappa \nabla h)$

This is actually a pure diffusion equation if the transport length (the denominator in the deposition law) equals dx. The hillslope model in Cidre derived from the non-linear diffusion model popularized by Roering'papers, but rewritten as an erosion-deposition model. Instead of calculating the divergence between and incoming sediment flux and an outgoing flux obeying a specified transport capacity, this is the detachment flux and the deposition fluxes that are specified and the outgoing flux derives implicitly from their balance. Both formulations predict similar evolutions, what is detailed in Carretier et al. (Esurf, 2016), but the erosion-deposition model is much more stable numerically (no problem with a sediment flux going to infinity when the slope is close to the critical slope Sc) and much more adapted to the coupling with grains (Carretier et al. Esurf, 2016; EPSL, 2020).

To recall it, we added in section 2.1: "Note that the hillslope equations derive from the non-linear diffusion model (Roering et al., 1999), but written as an erosion-deposition model. Both formulations lead to the similar topographic evolution but the model used in Cidre is numerically more stable and more adapted to the coupling with grains transport (Carretier et al., 2016)".

I don't understand how drainage divides get eroded with equations 2 and 3 since basically erosion is null when the slope is null. Am I missing something?

We are not sure to understand the concern. The slope is not null from a pixel of the drainage divide to any downstream cell, so erosion can affect a cell of the divide. If the slope is null, the pixel belongs to a flat surface, for which indeed, there is no erosion.

Line 75: You use MFD to distribute the incoming water flux from the donor node to the receiver nodes, but then you only use the "steepest-descent slope" when you compute the erosion potential of the donor node.

Somehow it means that the water that is given to the other nodes does not contribute to erosion. Why not computing the erosion potential of a donor node as the sum of the contribution of each receiver node proportionally to their slope?

This is a good remark and we have been thinking a lot to that question. The way you propose was actually the algorithm in a former version of Cidre, before the mass balance was reformulated as erosion-deposition models for rivers and hillslopes. The former version was much more unstable numerically because it summed on a donor cell the non-linearities linking the erosion potentials and the water discharges in all downstream directions. The idea of calculating only one detachment potential for the donor cell according to the steepest downstream slope is that the detachment (wet or dry conditions) is mainly driven by gravity in the steepest direction. Then the water and eroded material can spread towards all the downstream directions for different reasons (approximation of shallow water equation, subcell surface rugosity etc…). The sediment routine, even the MF algorithm, is a necessary simplification in LEMs, but the exact parametrization is still a matter of research (e.g. Coatléven and Chauveau, Esurf Discussion, 2023).

Line 81: "Sediments that leave the cell are spread downstream". Do you mean "distributed to downstream cells"?

Yes. We reworded as you propose.

Line 88: Composed instead of comprised

Done.

Line 89: "They are localized by the cell number where they are located": not clear to me. Do you mean they have an index corresponding to the cell number where they were initially sown?

We rephrased as:"They are localized by the index corresponding to the cell number where they are located".

Line 98: "For a grain on a cell, it is detached if the eroded layer on that **time step** is **thicker** than or equal".

Done.

Line 110: Sediment deposition volume instead of flux; I would keep the term "flux" for something that is moving.

OK. Done.

Line 197 and 206: "Outgoing water flux" instead of "leaving water flux"

OK. Done.

Line 202:" Erode the bedrock but multiply the eroded volume by (1-sediment volume/potential erosion of sediment)" Awkward sentence. Could you rephrase it please? If the volume to be eroded is greater than the volume of sediment available, the bedrock is eroded by the remaining quantity. Is it correct?

Yes. We rephrased as: "Erode a volume of bedrock according to Equation 3 weighted by (1-sediment volume/potential erosion of sediment)"

Line 214: what do you mean by "draw the next cell"?

We rephrased as: "draw the next cell of the grain…."

Lines 215-216: Shouldn't this be in a while loop (with lines 213-214)?

We guess it could be written as a while loop equivalently.

Line 223: Do you mean user-determined output times?

We rephrased it as:"the time fits the user-defined output time".

Line 299: How do you define the "residence" time? This term is not clear to me. I would say that the "residence time" of sediments is the time spent in a given system (river network for instance) whatever they are exposed to cosmic rays or not. On the other hand, the exposure time should be the duration during which the sediments are exposed, even partially, to cosmic rays whatever the system they reside in. Could you please be more specific on what you call the residence time?

We rephrased as: “The long residence time at shallow depth”. The residence time here is the time spent by grains in the soil of the hillslopes.

Line 301: Figure 3A instead of 3B

Thank you!

Line 322: Having seen this, I think it would be interesting to see the effect of a variable Quartz source distribution (i.e., more abundant in the upstream or downstream parts of the catchment for instance) on the resulting 10Be-derived erosion rate. Maybe add this topic in the Discussion section also?

Yes! There are many other questions we want to address with this new tool, this one is a good one, but we leave this for a more thematic paper (less suitable for GMD).

Line 362: You do not discuss the amplitude. It seems that the amplitude is largely underestimated for the short period oscillations. Why is it so?

Thank for this comment. We added: “Indeed, when a grain reaches shallow depths ($<$1 m) during a low erosion rate period, its ^{10}Be concentration is relatively high. If the grain is then rapidly exhumed, it will reach the surface with a concentration that is too high compared with what it would have been with a high rate of erosion. Once detached, if we use this concentration to determine an erosion rate, we underestimate the erosion rate. This memory effect causes the cosmogenic signal to be damped out.”