(Responses in blue).

Carretier et al. present a timely development of their Cidre model that supports the rapidly developing field of new lab techniques for sampling cosmogenic concentrations in individual sediment grains. The model allows the numerical exploration of the landscape processes that influence the residence time of sediment grains in mountain catchments and the impact these processes have on the population statistics of cosmogenic concentrations in exported sediment. This is very useful for generating hypotheses that are becoming increasingly testable with field data.

One uncertainty that I have relates to the relationship between relief and CN production in the model and how erosion rate is defined relative to the topographic surface. It would be great if there was a figure clarifying the coordinate system for the attenuation path of cosmic rays emulated together with the surface lowering/mass removal processes.

Thank you for this suggestion. We added a Figure 1 showing the different vertical coordinates of grains as well as topographic changes during a time step in a net eroding cell and another net depositing cell. We hope that is useful. We also realized that we had used the same letter to describe cell elevation (z) and the grain's depth, causing confusion. We changed the grain's depth to z' for its center and z'_b for its basis.

Are the rays attenuated vertical or perpendicular to the topographic surface in the model? Is this important if the model is to be applicable to topographies steeper than those modelled in the paper (>30O)? I am thinking that steeper slopes do not lower their surface uniformly, so if cosmic rays are attenuated vertically, how might the production rates vary depending on the hillslope model used? E.g. non-linear hillslope diffusion model vs Cidre's model where detachment rates are proportional to slope and mass removal is modelled with non-local effects above a threshold. Some clarification would be great for us visual learners.

The rays are attenuated vertically, namely perpendicularly to the surface of each cell and thus not perpendicular to the real surface topography approximated buy the mesh of square cells. This is not perfect; we agree and this is a concern we have. For the moment, the good match between derived and true catchment-average erosion rate shows that in average this approximation holds. For much steeper landscapes we will have to evaluate it. The DiBiase paper (2018) about the necessity to apply simple shielding correction or not depending on the topographic slope is also to be considered in the future.

Concerning the relationship with the hillslope model, there is no particular problem (steeper slope can still erode uniformly, at dynamic equilibrium in particular). The non-local hillslope model in Cidre separates the grain detachment from grain deposition, whereas the non-linear model of Roering is formulated as a difference of incoming and outgoing fluxes on a cell. Both model lead to the same evolution (cf Carretier et al., Esurf, 2016), but handling grains is far much easier in the Cidre formulation because the probabilities for a grain to be detached and then deposited are simply linked to the detachment and deposition rates on each cell. That said, the tricky part is to decide how to distribute the CN production between the grain's initial position and its final position during a time step. As the CN production rate depends on elevation and depth, this choice is important to predict the correct final CN of a grain. The strategy we explain in the manuscript ("using the mean elevation and depth of its travel during the time step.") is the best we have found to predict the correct CN concentration. The last time step before a grain becomes dead is even more critical: the CN production rate has to be "multiplied by the ratio between the depth of the grain on the starting cell of this time step and the eroded thickness on that cell during this time step" (section 3.2). If not, the final CN concentration can be wrong by more than 20% in fast eroding landscapes (because a grain can be suddenly exhumed from depth and leave the model with a two low CN concentration).

Other minor comments are included in the pdf attached.

Revisiting the grammar throughout the manuscript would do the work better justice but the paper is well structured and easy to follow. I have highlighted some of the sentences below that would benefit from clarification/rewording. The conclusion would also be made more impactful if there was a more holistic summary of the work.

Thank you very much for pointing unclear statements or proposing rephrasing. Concerning the conclusion, to keep it as short as possible, we added the sentence “The catchment-average erosion rates are approximated to within 5% uncertainty in most of the cases with a limited number of grains.”

Minor comments below:

Line2: remove ‘the’ from ‘the relief evolution’

Done.

Line3: suggest change to ‘Models can be used to explore the statistics of CN concentrations in sediment grains’

Thank you, done.

Line7: change to ‘The concentrations of various CNs can be tracked in these grains.’ Line10: not clear what a ‘grain-by-grain distribution’ is. Rephrase sentence?

Thank you, done. We cut the second part line10.

Line12: Rephrase, e.g. ‘We illustrate the robustness and limitations of this approach by deriving the catchment-average erosion rates from the mean 10Be concentration of grains leaving a synthetic catchment, and comparing them to the erosion rates calculated from sediment flux, for different uplift scenarios.’

Thank you, done.

Line33: ‘but without taking the evolution of the relief into account.’ Could you specify why this is important?

We reworded as: “but without taking the evolution of the relief, and thus of the CN production rate into account”.

Lines47, 226, 261 etc: I think the clarity of the manuscript could be improved by better defining what is meant by the ‘true rate’ and using this term consistently throughout the manuscript.

We added at the first occurrence: “In the following we call the 'true' average catchment erosion rate the ratio of the sediment outlux over the catchment area calculated in Cidre.”

Line68: What slope threshold and transport length do you use?

0.83 and 1, respectively. We indicated these values in Table 1 to which we refer when designing the reference simulation in section 4.1

Line85: Rephrase ‘they are not useful in terms of presenting the algorithm to calculate the CN concentrations in the grains’.

We rephrased it as: “because the algorithm to calculate the CN concentrations in the grains does not vary according to these processes”.

Line92: Rephrase: ‘For example, they can be set randomly on the grid and at depth, or with a higher density in some regions, in order to simulate the different proportions of some minerals depending on the underlying rock type.’

We rephrased it as: “For example, they can be set randomly on the grid and at depth if the grains are quartz grains and the proportion of quartz is constant in the underlying rock. Alternatively, grains can be set with a higher proportion in some cells or at some depths for which the rock has higher quartz content.”

Line189: I like the pseudo code!

Thank you!

Line268: Clarify: ‘In the second period, the mean erosion rate decreases to the new dynamic equilibrium value with a maximum elevation of 340 m.’

We rephrased as: “In the second period, the mean erosion rate decreases to match the lower uplift rate value at the new dynamic equilibrium. The maximum elevation is 340 m during this new equilibrium period.”

Line273: different wording? ‘where grains were dead...’

Reworded as: “where grains left definitively ...”

Figure 1 caption: Clarify: ‘Radioactive decay slightly decreases the mean 10Be concentration calculated by Cidre, and thus the apparent inferred erosion rate neglecting radioactive decay, which is inversely proportional to the 10Be concentration, is slightly overestimated.’

We rephrased as: “The apparent inferred erosion rate is inversely proportional to the 10Be concentration (Equation 14), but because it is calculated by neglecting radioactive decay, the apparent inferred erosion rate is slightly overestimated.”

Line297: interesting!

Thank you!

Line329: Why did you chose to test this variable? Include a sentence earlier in the manuscript e.g. paragraph starting line45.

We added: “As LEMs can be sensible to cell size, we tested the result of decreasing the cell size ….”

Line348: ‘When the number of grains is multiplied by four, this decreases the variability (Figure 8B).’ Could you expand on the significance of this? Perhaps in the discussion.

Actually, this test was just to verify a statistical fact: the more the grains, the better the average estimate (if the distribution is not heavy tailed).

Line399: rephrase ‘In a Lagrangian formulation, the approach by discrete grains has advantages.’

We rephrased as: “In a Lagrangian formulation of CN concentration evolution, the approach by discrete grains has advantages”

Line433: rephrase ‘and still faces the difficulty of modelling stochastic processes in a landscape evolution model’

We cut the sentence: “Nevertheless, linking a CN detrital signal with landscape evolution is not straightforward.”

Line437-439: Could this be expanded on a little? I think it is an interesting part of the discussion. Could you also look at connectivity?

We are a bit afraid of expanding this part of the discussion. We agree that this is the interesting scientific part as you noticed and we are excited by the possibility to revisit the issue of paleo-denudation rates using Cidre. However, this manuscript is for a Journal describing algorithms and codes in geosciences. We are afraid that a deeper thematic discussion here may not be suitable. We left this for applications coming soon.

Line456: Reword?: ‘We present a new coupling of landscape evolution model Cidre with a model of CN concentrations in individual grains.

OK thank you for your proposition.

Line458: Clarify: ‘The algorithm is tested by deriving the mean catchment erosion rate from the 10Be concentration of grains leaving an uplifting catchment.’ – how does this test the algorithm?

You are right. We reworded as: “The algorithm is tested by comparing the catchment-averaged erosion rate derived from the 10Be concentration of grains leaving an uplifting catchment and the true catch-ment-averaged erosion rate calculated by Cidre.”