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Interactive comment on "Cosmogenic ^{10}Be in river sediment: where grain size matters and why" *by* Renee van Dongen et al.

Anonymous Referee #2

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Summary and general comments: This work provides an empirical analysis of variability in 10Be concentrations across detrital sediment sizes, using a case study from Chile and a global compilation of previous work. The authors assess the relative importance of mechanisms that likely contribute to this variability, including slope, travel distance, lithology, and precipitation. The results have implications for understanding sediment production on hillslopes, and provide useful information for study design in landscapes that may be susceptible to 10Be "grain size dependency" (i.e. systematic variation in 10Be concentrations with sediment size). This contribution is significant and relevant to a broad range of surface process and landscape evolution literature. It's great to see an empirical treatment of potential for bias in 10Be studies and the mechanisms that control 10Be across grain sizes, and I found this paper to be both timely and interesting.

I agree with the authors that their results suggest slope and travel distance are primary factors in grain size dependence (aside from the potentially larger role of lithology), and the fact that the effects of precipitation are measurable only at extremes (arid and humid) is quite interesting. I like the way the authors frame their synthesis in terms of thresholds, which is an intuitive and useful approach and is supported by the data. I found the figures to be mostly helpful, with the exception of Figure 6 (see more detailed comments below). The figure captions could be expanded a bit to help readers interpret the figures.

The main weaknesses I see are as follows (see specific comments below for more details):

1. The introduction and literature review needs a bit more attention, both in terms of clarity and including a broader range of relevant previous work.

2. The Chilean case study claims to isolate precipitation as a controlling factor on 10Be grain size dependency, but catchment area and slope vary significantly across these sites – this should be addressed in the discussion.

3. I'd love to see the effect of lithology explicitly teased out of the state-factor analysis (Figure 9 and associated text). The relative importance of MAP, slope, and travel distance is less meaningful without first quantifying how much of the variability might be attributed to lithologic controls. This should be relatively simple to do based on the current analysis. I think that the (potentially larger) role of lithology still needs additional work, and the details are certainly beyond the scope here – the discussion/conclusions could stress this point as a call to action from the community.

I also have questions about the normalized grain size approach and the consideration (or lack thereof) of changes in 10Be production rate across catchments. These are outlined in my specific comments below.

Overall, I found this paper to be reasonably well-written and easy to read. The analysis and interpretations are thoughtful and well-reasoned, and the results are both interesting and novel. With some relatively small changes, I'd be happy to see it go forward.

Specific comments:

Section 2.1: There's a ton of information here, and there's a lot of relevant literature to point to. This section is essentially a literature review, but it leaves out some key papers – more references are needed in general, and a bit more care in the way the references are cited would be helpful. For instance, the first reference (Sklar et al., 2017) addresses the breadth of the first sentence, but the placement of the reference makes it seem like the paper is about mineralogy – there are other (earlier) papers that would be better references for this specific role in influencing sediment size. Re: weathering and climate, work by Riebe et al. (Sierra Nevada) and Dixon et al. (NZ Southern Alps) should probably also be included (unless line 79 refers only to the dependence of grain size on climate, rather than the dependence of weathering on climate – the text should be clarified on this point regardless).

In general, it's not clear if the literature reviewed here deals only with grain size variability, or with the variability in erosion, weathering, lithology, climate, etc. that influence hillslope processes (and therefore grain size), even in studies where grain size is not explicitly addressed. Section 2.1 should probably be expanded a bit to more clearly explain how these mechanisms relate to grain size. It also needs more citations to acknowledge the body of literature behind each of these topics.

The metrics identified at line 120 as the controlling factors on grain size and 10Be dependence aren't introduced in the previous section explicitly. This section could be much improved either 1) by taking a more linear path to get to these factors (which would require a restructure of the introduction) or 2) by adding a bit more explanation here re: why these particular factors are important (e.g. provide some specific mechanistic examples). They're not exactly simple state factors, there are a lot of complicated interactions. Slope should influence erosion rate and susceptibility to landslides. Precipitation should also influence erosion rates and weathering intensity (though there's literature on both sides of this argument, which is not acknowledged here). I'm not concerned about your choice of metrics – these are great things to quantify – but a bit more massaging of the text would help clarify exactly what you hope to learn in designing the study this way.

The case study in the Chilean Cordillera claims to isolate precipitation as a controlling factor on 10Be variability across grain sizes. While these sites span relatively similar lithology and tectonic uplift, catchment area and slope vary significantly across these sites. These factors should also be considered in the analysis and discussion.

Figure 6: I find this figure difficult to read. There is some benefit to having all 4 metrics displayed at once, but I think it would be preferable to split this information into more figures/panels. It's just too much to take in, the trends and details get lost. Maybe move this figure to the supplemental material, and provide a clearer set of plots. I found figure S4 to be really useful because everything was split out into separate plots. Providing separate plots with the absolute grain size and normalized grain size would be useful, as I don't find the normalized grain size to be intuitively as useful – maybe that actually means moving Fig. S4 into the main text?

The normalized grain size is calculated using the arithmetic mean of grain sizes from the same catchment, but what does that mean (average) really mean (signify)? Is it the average of grain sizes in which 10Be was measured, or the average grain size present on the streambed? If no pebble counts were reported (as I'm sure they weren't for all of these studies), is the average of sizes in which 10Be was measured really all that useful? I realize you're trying to find a way to compare across a huge swath of literature, with highly variable sampling approaches, and you need a way to compare across studies. If the goal of the compilation is to understand how 10Be varies across sediment size, the actual (rather than normalized) sediment sizes are potentially quite important, and that information gets lost in Fig. 6.

Results from different lithologies (starting at line 265) – to me, these observations suggest that lithology is a fundamental control on grain size dependency. If you're going to do multi-variate analysis to attribute grain size variability to each factor, can you tease apart the variability attributable to lithology first, and then discuss trends attributable to other factors? Ideally you'd do a multi-variate analysis for all 4 factors, but lithology isn't a continuous dataset, so this isn't really possible – teasing out the affects of lithology first would at least give you an idea of the relative importance of each factor including lithology.

Figure S5 suggests (or at least asserts – providing a calculation to back it up would be useful) that the altitudinal variation in 10Be production is not sufficient to explain the positive trend in 10Be with grain size. What about the other catchments? If coarse grains originated only at low elevations (i.e. were not transported from upper parts of the catchment), could that explain negative grain size dependency? Could this be a sediment transport story, rather than a landslide/depth shielding story? By ignoring the spatial variation in 10Be production, you're essentially assuming that sediment originates from all elevations – this assumption may not always be valid for all grain sizes, and it should probably be stated somewhere in the text.

Technical comments:

Line 44: modeling studies (Lukens et al., 2016) help constrain how big this bias could be (under- or overestimating erosion rates by a factor of 3 or more) – this might be worth mentioning here as context for the potential scope of the problem.

Line 107: "Furthermore, fluvial processes can affect grain size fractions in a way that not all parts of a catchment are equally represented at a given sample location" – this is certainly true, but needs to be more clearly explained and certainly needs references. (You do this at the end of the paragraph, maybe this sentence just needs to move.)

Line 113: "grain size" here refers to mineral grains, yes? Be careful/specific when discussing mineral grains vs clast sizes. These are different problems to consider, and arise for different reasons (lithologic controls vs. weathering/geomorphic process/etc.). I've run into a fair bit of confusion from readers/reviewers in my own work for just this reason, and the only advice I can give is that clarity and consistency of language around this distinction is paramount – I'd suggest changing "grain size" here to "mineral size".

Line 118: misplaced comma towards the end of the line (should go after "depth")

Line 123: "process" should be plural

Line 246: "Uncertainties in 10Be concentrations tend to be higher for samples from steeper hillslope angles (>10°), which is related to generally lower concentrations, i.e., higher denudation rates." This sentence is confusing. On my first read I thought you were suggesting that hillslope angle controlled 10Be uncertainties. Too many ideas in one sentence, break it up for the sake of clarity. Steeper hillslopes are eroding faster, which means they have lower 10Be concentrations. Uncertainties are larger for very low 10Be/9Be ratios.

Line 248: "nearly similar" is redundant, nix the "nearly"

Line 277: "Only in the arid. . ." Awkward sentence structure – consider flipping it around (Trends in 10Be only exist in the arid and mediterranean catchments)

Line 287: missing comma before figure reference

Line 289: Are the soil pit 10Be measurements also from Schaller et al. 2008? If so, cite them here. Referencing Figure 8 here would also be appropriate.

Line 317: "threshold slopes. . . where hillslopes cannot get any steeper" It's a nitpicky point, but I'd quibble with this language. Conceptually, yes, slopes steeper than the threshold "shouldn't" exist, but they certainly do at local scales. Your plots have slopes steeper than the threshold, even at basin-averaged scales, so your own data attest to the fact that hillslopes CAN get steeper.

Line 356: “We thus think” = awkward

Line 357: missing “the” before “mixed soil layer”

Line 370: don’t start a sentence with “And”

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