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Earth Surface Dynamics Discussions

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

Anonymous Referee #3

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This is an interesting and timely study presented by van Dongen et al., assessing the influence of the grain size used in detrital 10Be sampling and how it may bias measured concentrations and subsequently estimated catchment averaged denudation rates. The authors present new CRN data from a series of catchments in the Chilean Coastal Cordillera which span across a notable climatic gradient, to test the effect of precipitation on 10Be grain size dependence. They combine this with an analaysis of other metrics in these catchments (e.g. hillslope angle, lithology, abrasion) which are likely to produce grain size fractions with variable 10Be concentrations. Finally, a similar analysis is performed on a global dataset of 10Be samples and reported grain size fractions to test whether grain size dependencies exist. Overall, I found the paper interesting and relatively well written. I think there are some important messages

concerning the conditions under which grain size dependency may bias 10Be sampling which can be drawn from the manuscript. With some clarification and moderate changes, I would support publication of the manuscript.

General comments:

One of my first thoughts on reading this manuscript is the overlap with that of Binnie et al. (2007) Geology, although there is no reference to this study. One of the main finding from this earlier study was that denudation rate and slope gradient are broadly linear up to threshold hillslope gradients of ∼30 degrees. Beyond this, denudation rates are much more variable because of a transition from transport-limited to detachment-limited denudation processes – i.e. steepening the hillslope beyond this has limited effect on catchment averaged denudation rate. In general, I felt there were a number of key references missing in the first few sections of this manuscript. I think it needs to be made clearer how the findings from this study are new/different from previous work.

Production rates: In terms of CRN production rate varying measured concentrations – I'm not sure what the total relief across the Cordillera catchments are (could you possibly add this into Table 1?) or the CRN production rate that was used (please also add this in somewhere) for each catchment but it seems unlikely that this would have a significant impact unless there is some considerable relief?

Lithology: Just a quick query about quartz content of lithologies – I'm presuming most of these lithologies are fairly quartz rich such that this shouldn't bias any results (I'm thinking mostly about the mixed category)? Line 130 states some variations in mineralogy exist – do you have any maps/indication as to whether this is significant in terms of biasing quartz distribution across the catchment?

Catchment size: I'm not entirely convinced by the interpretation on L326. Looking at Figure 7b, there does appear to be some increase in negative grain size dependency in larger catchments but only really in sedimentary lithologies. Is the scale correct on the horizontal axis in Figure 7b (I thought only catchments <5000 km2 were considered)?

In these larger catchments, I'd expect that these sedimentary rocks would abrade more quickly into finer grain size fractions, especially given these greater travel distances – perhaps these coarser and lower concentration grains are actually more locally produced (lower production rate if from lower elevations too possibly?). In the sections following Line 332, there is a counter argument that in really large catchments (the exact size would depend on lithology/abrasion thresholds I presume) the effects of grain size dependency are likely to be less, as the majority of material should be abraded into sand? I think this comment rests upon whether the horizontal scale in Figure 7b is correct or not. It might be helpful to define what you consider as a large catchment here (>1,000 km2 etc.)?

Lupker et al. (2012) considered multiple grain size fractions in samples taken from a number of Himalayan catchments at the mountain front and found no systematic trend or differences in 10Be concentrations as a function of sand grain size (which makes up the majority of the sediment load). With increasing catchment area, one would expect the concentrations measured in the sand fraction to be more representative of the total catchment. As catchments get larger, there are also likely to be different erosional processes operating within in which may influence 10Be concentrations (see Dingle et al., 2018). For example glacial shielding (which will offset any difference in production rate as a function of elevation), glacial erosion, sediment recycling and 'hotspots' of erosion which may be driven by spatial variations in climate which can occur across sufficiently large catchments (e.g. localised storms), or parts of the catchment which undergo higher rates of rock uplift and are more susceptible to landsliding. There are then also issues relating to temporary storage (even just within the channel itself, or within large landslides) within increasingly larger catchments. I think you touch upon this in Line 59.

Temporal effects: One of the key aspects I feel this manuscript currently overlooks is a discussion on how representative the Cordillera samples are. These catchments are small (<10 km) and experience landsliding – how likely is it that these samples

are influenced by the stochastic nature of sediment delivery from these landslides (e.g. Niemi et al., 2005 – I noticed that this paper wasn't referenced anywhere). Do you have truly 'representative' samples and how stable are these concentrations in different grain sizes in time? Is material generated by these deposits likely to be well mixed into the suspended/bed material load (especially given such short transport distances), or is it likely to overwhelm the catchment-averaged signal depending on factors such as the time since the last event/time since significant mobilisation of landslide material.

Grain size: It took me a while to get my head around what the normalized grain size statistics actually represent, especially given the ranges may have varied between the studies looked at (e.g. where only >2 mm was stated, values were forced into 2-4 mm). If I have this right, the grain size fractions presented in each study could influence the normalized grain size you calculate if these fractions were inconsistent between studies? It would be really nice to see metrics plotted against absolute grain size (maybe somewhere in the SI) given you have this information available. Another point which I think Reviewer 2 has also commented on – what is a representative grain size of a catchment (thinking about Line 28-29 in the abstract in particular), and is this what is being sampled on the river bed (e.g. Figure S2 shows that some of the catchments capture more of the CDF than others)? Interesting that your bedload GS in Chile is much more bimodal than in either Italy or the SGM datasets (Figure 1).

Specific comments:

Line 52 – Which other studies? Add some references

Line 87-94 – I found this paragraph a little wordy. "when the transport capacity of the water is too low" - too low for what? Please be more specific.

Line 95-97 - "Any process that transports different grain sizes, from areas in a catchment with contrasting. . ..". You could also say the same for grains of the same size from different parts of the catchment. I feel that this paragraph could do with a little more work generally. For example, in Line 107 you discuss variations in 10Be concentrations

in soil as a function of whether the landscape is eroding quickly or not. There is the argument that in more rapidly eroding landscape you would only expect larger variations in concentrations (due to removal of material from depths greater than the attenuation length) if a concentration profile is fully developed. In rapidly eroding landscapes, you may just end up with upper layers characterized by relatively (uniformly) low concentration material? The jump to the metrics you propose to look at in L117 onward feels quite big. It would be nice to see a clearer build up to this in the paragraph beforehand (Line 70 onwards) so that it is obvious why these metrics have been chosen.

Line 174 – what happens if you remove these studies (stated only as >2 mm) from your statistics? I appreciate this may remove a large number of points but might be interesting to see.

Line 246 – Are these uncertainties relating to error/uncertainty in the laboratory measurements or variability in measured concentrations? Either way, uncertainty and variability are different so please clarify!

Line 250 – While no pattern in MAP, I wonder whether the frequency of large storms is a factor that is likely to be important? Is it fair to assume that all sediment generated by landsliding in these catchments is immediately evacuated from the catchment and there is no preferential mobility of coarser/finer material (i.e. it might take a large storm to mobilise the coarsest material which may only happen a few days of the year?).

Line 254 – Is 54.8% really 'significant'? In general I found some of the statistics a little weak and definitions of coarse/fine not fully stated. For example, on line 234 and Figure 4, you state that only the AZ and LC catchment show consistent trends between 10Be and grain size. When I look at Figure 4 I see a lot of scatter/variability!

Line 264 - 'Partly accentuated and partly muted' - this is a very confusing sentence!

Line 278 – 'In both catchments the 10Be concentrations of river sediment correspond to concentrations measured deeper within soil profiles' – looking at AZ and LC in Figure

8 it looks like the river concentrations correspond to the concentrations measured in the upper 1m of the soil profile (AZ), not material from greater depths. In LC, it looks like all of the river grain size fractions are consistent with concentrations measured below 1m in the soil puts, suggesting no grain size dependence. Instead this seems to suggest that all of the sampled sediment is overwhelmed by material excavated from depth? Could the fact that the river sediment concentrations are lower than those in the soil pit (line 288) simply reflect the fact that the concentrations measured in the soil pits are not representative of the entire catchment?

Line 300 – I find this sentence undermines the study slightly...maybe consider rephrasing 'our new samples from the Chilean Coastal Cordillera demonstrate minor variations in 10Be concentrations'.

Table 2 – what is the superscript b referring to in the last column title?

Figure 2 – Line 707 – 'constant' or maybe uniform?

Figure 6 – I suspect this is one of the key figures for the paper but find it difficult to follow. There is a lot of information in there.

Figure 9 – 'results given for all lithologies combine' – should be 'combined'

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