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Earth Surface Dynamics Discussions

Interactive comment on "Designing a suite of measurements to understand the critical zone" *by* S. L. Brantley et al.

Anonymous Referee #2

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Review of Brantley et al., "Designing a suite of measurements to understand the critical zone" for Earth Surface Dynamics Discussions

This manuscript is an interesting contribution from a diverse team who are seeking to understand processes and fluxes in the Critical Zone (CZ). It is not a 'standard' paper, in that it considers aspects of experimental design, as the title suggests, which the authors hope will allow CZ research priorities to be achieved. I quite liked this take, we don't really discuss these themes much (usually while writing proposals and designing/doing the research, rather than putting these decisions through peer review) - perhaps we should do more of this. In that regard, this is a relatively novel and quite refreshing perspective. While not having a large new dataset present (although there is new data which could be used more), this novelty clearly makes it relevant and inter-

esting to the readership at Earth Surface Dynamics. It fits the journal remit well (linking atmosphere, pedosphere/lithosphere and hydrosphere) and in particular seeks to enhance theory–observation links. In my opinion it should eventually be published here, and should form an important paper for discussing CZO design and implementation, while also very relevant to others working on similar questions at non-CZO sites.

However, I have three important comments which I feel need to be addressed before it is ready for publication:

1. Making it clear why the expansion being undertaken: The paper discusses the expansion from Shale Hills CZO (0.08 km2) to the Shavers Creek (160km2). It outlines how Garners Cr was selected as a site to help inform how the increased size of the sample network might work. However, it was never really made clear what the scientific objectives for Shavers Creek were. Later in the article, nitrate export from farm land was mentioned briefly. I think some addition information is needed to explain why, in this case, the expansion in being undertaken.

This is important because, from reading this article one may conclude that it is simply the 'next step' to install a sampling network downstream of a small (<1km2) CZO. A nested catchment approach can be very powerful to examine solute fluxes (for example see recent work by Torres et al., 2015, in the Andes). However, it may instead be preferable to install monitoring at a completely different larger catchment, which is not necessarily draining the same geographic area as a CZO. For example, the SH CZO has shown us that these things are crucial (x,y,z) in terms of sedimentary rock weathering, now lets test this in a larger, sedimentary-rock dominated catchment system (where existing work may also be available). Or, one could imagine the case opposite to that posed here, where we have good data and information at a catchment $\sim$1000km2, and we wish to install measurements at a 1st order site. I think some reflection on that could be helpful, and help provide a broader context for the discussions and decision making steps being explained in the paper.

2. Making is clear how we can use experimental catchments across scales: Linked to the previous comment, I think the paper also needs to summarise what complementary information can be gained from monitoring at small scales (0.08km2), to medium (100km2) and larger (>1000km2) catchments. To me, it seems that small scale (most of the current CZOs), intensively monitored catchments are very helpful for informing us about processes (what controls them, their rates, variability etc.,). However, larger catchments allow us to identify the dominant water/solute/sediment fluxes, and target the major players (perhaps in terms of major processes, major sources etc.,). This is key for upscaling and thinking about larger scale river geochemical fluxes (and what they tell us about the changing dynamics of erosion and weathering).

A lot of work has been done on geochemical fluxes at Earth surface at the larger catchment scale (>100 km2) and at I think some discussion of that literature could be very useful here. This could be linked to point 1 above, to a revised introduction. Perhaps deal with these general themes first, before explaining the Shale Hills – Shavers Creek case (and its associated scientific priorities and objectives).

3. More analysis of the geochemical data: The article includes some new data (soil/solute data) from the Garner run catchment and other nested sample locations. Not much is made of this data, which is a pity. In addition to discussing experimental design, I think this work would be useful to the community with an expanded discussion of these datasets (and much clearer links to the objectives of the paper, i.e. how this data helps inform the future sampling efforts) in place of some of the 'will be done' parts of the discussion. See more detailed line-by-line comments below.

Having completed my review, I also looked over comments by Reviewer #1s which were published earlier in the month. I see quite a few parallels with my main comments above, and I hope together they can be used to improve the manuscript further.

I've also identified other comments as I worked through the paper, and list them here as they appear in the manuscript (with page and line, Px-Ly):

P06-L9: 'much' is true, but not in the context of other work on geochemical transfers at earth surface, 164 km2 is still a small catchment. Perhaps remove 'much'

P06-L16: It would be useful to have a little bit more about what these measurements seek to tell us

P06-L25: The abstract didn't really specify what the scoping measurements were and what they show in terms of CZ science. I think this would strengthen the abstract to include these findings and conclusions

P07-L1: Given the potentially broad readership, it would be useful to perhaps have a little more about the CZ, what it is, the overarching questions which the community is seeking to address.

P07: somewhere in the intro, could it be useful to spell out what the point of data collection is? Is it to build empirical models for forecasting, or to test physically numerical models? Its both I imagine depending on the question. But could be useful to explain somewhere in the intro. In fact, my comments 1 and 2 above suggest the introduction can be refocused somewhat, which may help this.

P08-L11: perhaps change to "Different disciplines may focus on. . ."

P09-L26: In fact, this is not a new research design, and has been hugely successful for understanding geochemical fluxes and revealing the dominant processes in too many studies to mention. However, what is now key, which is a point not made clearly here, is a sample design which allows you to answer what you want to know now (what you might have funding for) and parallel projects (or projects you may not have even thought of). For instance, if one is interested in carbon (inorganic and organic) fluxes, it makes sense to try and collect samples for BOTH suspended load and dissolved load, and archive/store these in a way that they can be used by others (in parallel projects or at the same time). Or, say if I wanted to use Li isotopes to look at weathering processes, collecting a sample set which also allows the samples to be used to examine organic

matter fluxes and origins. There has been much progress in the 'large river' community with this in mind, which we've seen in the last few years (e.g. Ganges, Amazon, Mackenzie). To me, this is a critical need which CZOs really contribute to, and it doesn't come across clearly on reading the manuscript (also see main comments above)

P10-L9: could this heading be better as 'Existing measurement network" or something like that?

P10-L20+L24: 'extremely' and 'exceedingly' don't seem to be needed here.

P11-L24: Do you propose this to be a first step everywhere there is a CZO which may wish to upscale? Could be worth discussing briefly. See main comments above.

P12: when you mention 'small number's, it would be useful to clarify what is meant in terms of spatial or temporal frequency (+ at other points in the discussion)

P13-L5: 'Data Assimilation' – this wasn't a very clear title. I found it a little hard to navigate the paper overall, and I wonder if these subheadings could be more clear.

P15-L15-20: I think the first thing to discuss is why this sub-catchment was picked – comes a bit later, but in the context of what the paper is trying to do, this would be better to come straight up.

P16-L19: Some of the 'will' be done parts of the paper are interesting (relating to my overall feeling about the manuscript, and this occurs in a few other places too). I think more can be made on what has been measured and found so far, and how that might inform these future campaigns.

P17-L1: Could be nice to see the slope probability distributions for the two sub catchments and then Shavers' Creek, to get an idea how they sample the geomorphic variability.

P18-L1-17: Seems like a link to a recent paper by Prasciek et al., (2015) could be a useful way to support these discussions – they argue the rate at which a glacially

sculpted landscape is modified relates to the tectonic uplift (and river incision) rate.

P20-L2: First mention of the goals of upscaling to Shavers Creek. This needs to come in the opening exchanges – see main comment above.

P25-L21: because of the very high SiO2 proportion in these rocks, and low [Ti], does this lead to larger uncertainty when quantifying these normalised concentrations (i.e. if [Ti] is very low)?

P26-L3: More discussion on the preliminary results would be good. I note that the conclusion comments on the dust deposition for example, but this idea is not discussed in enough detail here. How does this compare to known dust inputs at Shale Hills?

P27-L1-26: while I argue in my opening comments that this paper is an interesting take (discussing the rationale behind measurement set up), it seems that much of this section would be better in the paper which actually provides the results of these investigations.

P30-L10: Does the reader really need this detail? A lot of this description can be summarised in a few lines which document the challenges and uncertainties in the methods.

P31-L20: How do these measurements compare to the geochemical measurements? seems these were shallower than these GPR depths?

P32-L1-20: This section highlights some really important issues which CZOs can help inform us off. However, I think it would be useful to comment and summarise on work which has sought to do this at a larger scale (100 to >1000km2 catchments), using runoff vs concentration trends, and runoff vs ion/ratio trends, to better understand processes and sources of ions and water (e.g. Tipper et al., 2006; Calmels et al., 2011; Maher, 2011; Torres et al., 2015)

P33-L26: were these samples for dissolved chemistry filtered, would be useful to clarify

P34-L9+P35-L7: To me, this dataset analysis needs more discussion and warrants more space in the manuscript. The Shale Hills data could be added to the plots, and discussed in much more detail (see main comment above and comment on the figure). How do we then use these datasets to make decisions about new sample networks?

P36-L16-28: these aspects need more discussion in the main text.

Fig. 3 – nice to see this analysis. However, not that much is made of this in the paper. Could you do a little quantitative comparison? For example, slope probability (and or elevation probability plots) for the whole Shavers creek, vs Shale Hills and Garner run?

Fig. 5. Can you add more to the caption which explains what the legend describes and whether these have been installed?

Fig. 6. Not much was made of this topographic analysis, but to me, it makes sense as a way to inform of sampling locations etc.,

Fig. 8. More can be discussed on this in the main text. It would be useful to compare to Shale Hills profiles.

Fig. 9. Could be useful to have a zoomed in inset which shows the transition of soil-bedrock boundary in more detail. I feel like the main text didn't explain quite how this line was decided on.

Fig. 10. Like fig. 8, much more can be discussed in the main text. Also, given the drainage area changes a lot, it would be useful to plot a water discharge normalised to drainage area (i.e an instantaneous runoff depth, say mm/hr). On panel A, my guess is that if you did that, you'd find the yellow points form part of the decrease seen in the other catchments?

References mentioned here not cited in the manuscript:

Calmels et al., 2011, Contribution of deep groundwater to the weathering budget in a rapidly eroding mountain belt, Taiwan. Earth Planet. Sci. Lett. 303, 48–58.

Maher, 2011, The role of fluid residence time and topographic scales in determining chemical fluxes from landscapes. Earth Planet. Sci. Lett. 312, 48–58.

Prasicek et al., 2015, Tectonic control on the persistence of glacially sculpted topography, Nature Communications, DOI:10.1038/ncomms9028

Tipper et al., 2006, The short term climatic sensitivity of carbonate and silicate weathering fluxes: insight from seasonal variations in river chemistry. Geochim. Cosmochim. Acta 70, 2737–2754.

Torres et al., 2015, Geomorphic regime modulates hydrologic control of chemical weathering in the Andes–Amazon, Geochim. Cosmochim. Acta 166, 105–128.

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