

Interactive comment on “Advection and dispersion of bedload tracers” by Eric Lajeunesse et al.

Anonymous Referee #2

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Summary: This manuscript develops an analytical model for the spreading of a plume of bed-load tracers. From the Erosion and Deposition model developed by Charru et al. (2004) they further develop analytical solutions for the mean, variance, and skewness of the spreading tracer plume. This model demonstrates and analytical solutions demonstrate that the spreading of bed-load tracers occupies two scaling regimes. The manuscript further demonstrates that the first three moments of the tracer plume can be set against each other to effectively remove their dependence on time. They conclude with a useful description of how these results may be tested within a field setting.

General comments: Determining time in a river can be a somewhat abstract exercise and multiple authors have attempted it with varying degrees of success. This difficulty

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greatly impairs the utility of field tracers by requiring researchers to monitor both the hydrology and the sediment tracers themselves. However, this manuscript may have provided a framework that greatly increases the utility of field tracers. As the key insight of this manuscript results from setting the expressions for the mean, variance, and skewness against each other and effectively removing time from the problem. This is very clever and to my knowledge has not been done before despite its apparent simplicity (in many ways it would not have made any sense to compare these without the model and framework presented in this manuscript). This framework, if shown to be a reasonable predictor of natural rivers, could take tracers from something of a novelty measurement to a standard tool in bed load and mountain river monitoring campaigns.

I think that this manuscript does a good job of presenting the theory and model development, and I appreciate the authors discussion on how this result can be tested using tracer data as it is rare in the field of sediment transport that theory papers present easy to test hypotheses. These results will likely be of great interest to the bed load transport and mountain river scientific communities.

I have very few comments and they are related primarily to improving the clarity of several variable definitions. The manuscript would benefit from providing a physical description or picture of the flight length and flight duration. From Lajeunesse et al. (2010) these quantities represent the distance a particle travels from erosion to deposition and the duration of this movement, respectively. Those definitions are akin to the descriptions of 'steps' from the many papers that treat bed load probabilistically. In this manuscript though they seem to represent quantities that are much more akin to length and timescales that particles spend on the surface. Making this distinction very clear at the outset would help reader comprehension. Even if these quantities do not quite have an observed definition in the field it would help if the authors could expand on what they think they represent.

In conclusion, I recommend that the manuscript be published in ESurf with a few very minor changes focused on enhancing the clarity.

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[In the spirit of ESurf's open discussion period I have elected to read Reviewer 1's comments after the completion of my own review - I did not see anything within Reviewer 1's comments that should prevent this manuscript from being published, however the authors will need to provide greater clarification of their derivations to avoid the issues pointed out by reviewer 1.

A few comments on field tracers and what has been previously observed. To my knowledge all current field datasets report different relations for both the mean and variance scalings, but this is not surprising as these studies all use different metrics for time in a river (some variation of cumulative hydrologic forcing) and the fitted relations almost always stem from regression. Some of these regressions are physically justified, but the main point here is that a lot of different relations could be fit to the available datasets. That no one has really observed multiple mean and variance scaling regimes is not surprising. Without apriori knowledge of multiple scaling regimes and the locations of the break points it is unlikely that one would ever try to fit a complex function to these data due to the variability. With this current paper, there is no a reason to attempt more complicated models for the field data.

A final comment on the length of observation in field studies and a contribution that this manuscript makes. Even for the longest observed field studies (9 yrs as pointed out by Reviewer 1) it is not clear how long the rivers in those studies are actually 'on' (actively able to transport sediment). In a sense, a decade in a desert stream with few floods could be the same as a month in a tropical river that floods weekly. In terms of dynamics, maybe 9 yrs of data represents the entire scaling regime and maybe it still only represents the entrainment regime, because most of the time gravel rivers are effectively 'off'. This is key result of the current manuscript, as it provides a way to compare tracer studies by removing time, one of the more nebulous variables.]

Specific comments:

In several locations the term 'pebble' is used in place of what are likely cobbles. I

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understand what the authors mean, however more traditional geologists may find the use of the term confusing and misinterpret the size of the particles in question. I leave it up to the authors to choose.

Description of equation 1 - It is not immediately clear what the unit surface is? Is this the projected area of a grain (D^2) or the measurement window?

P. 4 Ln. 18 - The introduction of the 'flight length' should include a definition. Although it is defined in the cited papers, a short definition would benefit the readers comprehension of the concept. Something like the flight length represents the distance a particle travels from erosion to deposition.

P. 6 Ln. 16 - It now becomes clear to me that I am not sure exactly what τ_f (the flight time) refers to physically. Is it the time of an individual flight (from erosion to deposition in the surface layer, on the order of seconds) or does it refer to a longer timescale that represents the time that the particle remains in a more mobile state?

P. 7 Ln. 24 & P. 11 Ln. 1 - 'pebbles' likely a typo for pebbles. Though I would suggest cobbles per the earlier comment. Bradley and Tucker (2012) or Bradley (2017) would be worth citing here as it represents the largest deployment to date.

P. 7 Ln. 26 - is 'the size' supposed to be the standard deviation?

P. 8 Ln. 10 - 'this' should be 'these' if the conditions are indeed plural.

P. 11 Ln. 6 - The preceding lines set up the notion that tracers maintain their conditions between floods (they don't move and in a sense are frozen), but this line suggests that this also applies to the actual floods. It is just a little confusing, during the flood isn't that when tracers might be mobile and thus changing their conditions? Please clarify what is meant in this line and if floods should be included.

Pg. 11 Ln. 10-12 - Based on Paola et al. (1992), Phillips et al. (2013) have partially validated that the hydrograph intermittency is proportional to this same quantity. You might cite them here as a validation for the frameworks potentially broad applicability.

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Pg. 12 Ln. 7 - It is not immediately clear to me what this line is saying. Could you reword this sentence to clarify its meaning. What I gathered from it is that the plume of tracers will remain in the entrainment scaling regime so long as the size (variance or range?) is less than the length (mean?) position. Is this what is meant?

References: Bradley, D. N., and G. E. Tucker (2012), Measuring gravel transport and dispersion in a mountain river using passive radio tracers, *Earth Surface Processes and Landforms*, 37(10), 1034-1045, doi: 10.1002/esp.3223.

Bradley, D. N. (2017), Direct observation of heavy-tailed storage times of bedload tracer particles causing anomalous super-diffusion, *Geophysical Research Letters*, doi: 10.1002/2017GL075045.

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