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Earth Surface Dynamics Discussions

Interactive comment on "Particle size dynamics in abrading pebble populations" *by* András A. Sipos et al.

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This is a stimulating article, which makes an interesting link between a statistical description of pebble collisions, the physics of their attrition and the evolution of the size distribution of river or beach pebbles. I found particularly promising the distinction between reducing or increasing the variability of grain sizes related to attrition as a function of a parameter, r, which can be related to river energy. However, in order for this paper to be read and used by those, like me, who do not eat the Fokker-Planck equation for breakfast every morning, I recommend substantial additions described below. I have no substantive criticism of the results presented. My suggestions are intended to broaden the scope of this article for non-physicists.

At the first order, the authors could increase the impact of their findings by better relying on and linking it more closely to geological and experimental observations. The authors claim that their model "fits" the geological observations, but I see no clear evidence of such a fit in their paper. Several assertions lack references (see specific comments), in particular concerning the relative role of selective transport and attrition in the evolution of grain size along a river. In fact, selective transport has been mainly advanced to explain or model downstream fining in rivers (e.g. Paola et al., 1992; Ferguson et al., 1996; Fedele and Paola, 2007; Whittaker et al., 2011 - see list of papers at the end of this review). In parallel, several authors have shown evidence of attrition to explain the variation in grain size (e.g. Brewer and Lewin, 1993; Attal and Lave, 2006; Dingle et al., 2017). These studies are worth mentioning and discussing to show that the results presented in this manuscript are consistent with geological observations.

Theoretical results could also be confronted with experimental data, which are rare and valuable. In addition to Kuenen (1956), Attal and Lavé (2009) presented pebble attrition experiments on a 1:1 scale, representing Himalayan rivers conditions. These experiments show in particular that the mass loss by attrition increases with particle velocity but is weakly dependent on particle size. As the parameter r can represent the degree of dependence between the attrition rate and the particle size, a discussion on the possible value of r in the experiments of Attal and Lavé (2009) would allow to link the theory, these experiments and the prediction of the evolution of the relative variability (focusing or dispersing) in a natural case like that of Himalayan rivers.

Statistical physics is used here in a very clever way to describe the phenomenon of attrition. However, statistical physics (and the Fokker-Planck equation) has also been used to describe the transport of grains in a river. In this case, advection-diffusion emerges from a combination of probability densities that describe the distribution of the transport distances of the particles and that of their residence time at rest (e.g. Lajeunesse et al., 2018; Nikora et al., 2002). Longer residence times for larger particles (selective sorting) may explain some of the anomalous scattering observed in tracer data (Phillips and Jerolmack, 2014; Carretier et al., 2019). In a natural system that combines both the statistical physics of transport and abrasion, how could the proposed theory be verified on the basis of field observations? What experiments or observations need to be carried out to distinguish between these two components? Again, linking this proposed theory with predictions that could be made by geologists or experimenters would increase the scope of this paper. I recommend significantly increasing the discussion in this direction.

In the discussion, always with the aim of linking this theory with the field, I suggest discussing the following points: The pebbles impact each other but also the bedrock (which could represent a much larger volume for the population y). How would this change the result? The lateral contribution of the hillslopes modifies the initial distribution fo(x) in the real case (e.g. Attal and Lavé, 2006; Sklar et al., 2017). Can we find a natural case where the proposed theory could be tested (canyon with one particular lithology at some localized point upstream, providing tracer pebbles that could be followed downstream for example)?

The structure of this manuscript is confusing: the conclusions are described in several details in the introduction. This has the merit of setting reader's minds, but when reading it for the first time, I wondered whether it was a reminder of previous work or new findings. To guide the reader, I think it is important to write clearly what the addressed question is in the introduction.

Specific comments

Page 2 Geological observations: extend this part based on above comments.

Page 2 Line 27-29: gives references.

Page 2 "as we can see": not obvious to me.

ÂăP3 L14: " in (Domokos and Gibbons, 2013) " wrong citation format for this reference throughout the text: in Domokos and Gibbons (2013)

P4 Equation for Xt, Yt: number the equations. Give the numbers of these equations in the original paper and the corresponding notations, to help the reader.

P5 L9 Useful assumption to avoid dealing with the diffusion term in the F-P equation, but the experiments of Attal and Lave (2009) show that fragmentation can be significant.

P5 L21 "setting this is not the case": Why?

P5 L31 “that the that the”

P6 L10: Is the correspondence with Sternberg's law demonstrated in this paper or in a previous paper?

P7 L6-10. I think it would be useful to discuss the meaning of the two populations. Are they particles of the bedload? Of the suspended load? Both? Does the collision model reflect a dynamic where the grains are in suspension? In saltation? I imagine that the physics of collisions is different in these cases.

P8 L7. Could you give a "hands-on" explanation of the nature of diffusion related to fragmentation in this case?

P8 L25 Summary or summation ?

P8 L26-30 Explain why you are testing these other kernels whereas you announce in the introduction that the kernel finally used is "the right one".

P L12: Proportional TO projected ? (could you give a reference?)

P9 L21-27 Give references or explain better the values deduced for r. Again, do these r values depend on the type of transport (suspension, saltation etc.)?

P9 L 26-27 Important to make the link with the field. Expand on this aspect.

P9 L32 what is V? (Volume I think but I have not seen its definition above).

P11 L10 justify why you take a log-normal law for fo. Does the result change if you take another law?

P11 L11: "The applied time step is fixed at ∆t = 0.01." Already said above.

P11 Figure 4: Indicate c: continuous and d: discrete in the caption. Because the by-product of abrasion is removed, I would have expected that the distribution tends toward a Dirac at x=0 in all the cases. Why is it not the case? (“hands-on” explanation please;). In the focusing case, what determines the final x value of the Dirac?

P12-12 3.3 Very interesting discussion. In Figure 4 it could also be argued that the tail of the distribution between 2E-7 and 2E-6 is a power law, while the outliers represent a subsampling of the actual distribution, as often observed in seismology (for magnitude) or hydrology (for peak discharge). Could the persistence of these outliers indicate some fractional derivative component not taken into account in the Fokker-Planck equation?

P14 “(a) existing geological observations”: not demonstrated in my opinion.

Good luck with the revision,

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