Earth Surf. Dynam. Discuss.,
https://doi.org/10.5194/esurf-2020-98-RC2, 2021

Earth Surface Dynamics Discussions

Interactive comment on "Rarefied particle motions on hillslopes: 1. Theory" *by* David Jon Furbish et al.

Rachel C. Glade (Referee)

rcglade@lanl.gov

Received and published: 1 February 2021

Furbish et al. present a novel theoretical analysis of hillslope sediment transport in steep landscapes. They carefully and thoughtfully lay out the pieces of the problem mathematically, incorporating both probabilistic and physical elements of the rarefied (non-continuum) transport of particles. They link their findings to concepts in granular gas theory, including both fundamental and recent discoveries in that field. This paper represents a substantial step forward in the field of geomorphology, with implications not only for hillslopes but for other environments as well. I believe their precise, careful approach will stand as an example for future theoretical studies in geomorphology.

As far as I can tell the math in the study is sound, and I appreciate the care with

which each equation is presented and explained. The paper is generally enjoyable to read, and I appreciate the easter eggs and asides hidden throughout. That said, I think the paper could be lightly restructured to better highlight 1) where this study fits into previous work 2) testable predictions arising from theory. These two recommendations serve multiple purposes, the primary goal is to increase the readability of the manuscript and allow readers to better grasp the novelty/practicality and implications of the work in a coherent way.

Previous work and background: The authors could do a better job of first explaining (briefly) the state of the field before launching into their theory development. The first paragraph of the paper is nice, and does a good job of briefly highlighting previous studies on non-local transport. I think a new second paragraph could better lay out the fundamental problem: what does "rarefied" mean and why is it necessary to take into account rarefied transport on hillslopes? Defining the Knudsen number could be of use in this early part of the paper. This is a relatively minor change, but I think it would greatly improve the readability of the paper, especially for those who are not already well-versed in the concept of rarefied motions.

Testable predictions/theory overview: The main text currently stands at 98 equations (not including the appendices!). I strongly suggest the authors include a summary of the key equations in the discussion/conclusions section of the paper, perhaps in a table. Along with this summary, it would be helpful for the discussion to highlight key predictions testable in experiments or the field (this can be brief). This will help bring the reader full circle to remember what the theory aims to describe, and will also help connect this paper with the second paper, which tests theoretical predictions.

Other comments: This paper has many moving parts. Consider adding a figure early in the paper that visually defines the main pieces of your analysis in the context of hillslopes- heating, cooling, etc. The parts could be referenced in the various sections of the paper that deal with each aspect of the theory.

It would be helpful to have a summary sentence at the top of each section reminding the reader of where we are throughout the paper. Linking these with an overarching figure as describe above would also help.

Abstract You might consider starting with a more visual sentence about boulders/sediment rolling down steep hills- might help draw the reader in and parse the rest of this fairly technical abstract.

Page 4 Line 9 only on hillslopes, or in any system?

Page 4 line 16 Can you very briefly explain what "survival function" means physically, as you do for f_r?

Figure 2 This figure is very helpful. Consider moving it to section 2.

Page 7 line 11 Change "treat" to "treating"

Page 8 line 6, 7 Change "Becomes" to "become." Either way is technically correct but the latter sounds better.

Page 8 line 19 What is transport of energy in this context?

Page 12 line 25 Does total energy actually increase? Or just kinetic energy?

Page 15 line 3 "k3" should be "kd"

Page 16 line 7 "defined below." below or above? I thought we just read about this.

Figure 3 It's a little difficult to understand how to read this figure. Do the arrows indicate a translation of the uniform distribution to the right or left? If so, then it is difficult to understand the triangular region in part C (even with the explanation in the caption). Upon re-reading I think I understand part C. Does the triangular region make part C no longer a uniform distribution? This might help the read understand. . .

Page 20 line 24 "deposition occurs. . ." is this because energy is being added to the system?

Page 21 line 2 This thought experiment feels unfinished. What should we take away from it regarding hillslopes?

Page 22 line 5-7 This connection to a recent discovery in granular gases is really neat. Can you add a bit about how it impacts hillslope transport explicitly?

Page 23 line 1 Add a couple sentences of intro explaining what this section means and where we're going now.

Please also note the supplement to this comment:
https://esurf.copernicus.org/preprints/esurf-2020-98/esurf-2020-98-RC2-supplement.pdf

---

Interactive comment on Earth Surf. Dynam. Discuss., https://doi.org/10.5194/esurf-2020-98, 2020.