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Interactive comment

Interactive comment on "Slope–Velocity–Equilibrium and evolution of surface roughness on a stony hillslope" *by* Mark A. Nearing et al.

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Reply to Anonymous Reviewer #2

Thank you for these comments on the paper. They are much appreciated.

These comments regarding the potential connections between the current work and hypotheses that been proposed, and experiments that have been conducted at other scales and in other environments is very interesting. In particular the work of Grant and his hypothesis of threshold Froude number as a controlling factor in the feedbacks between erosion, velocity and morphology is quite pertinent. We were a bit hesitant to stretch our interpretations beyond the scope of what the data show, but in this case we

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think that this discussion is interesting and useful. Thus we added two paragraphs to the paper, one in the Introduction and one in the discussion, plus we added a graph of the Froude numbers (Figure 10) as a function of cumulative runoff. These are:

In the Introduction:

"The dynamic feedback between flow, bed morphology, and erosion was discussed in a hypothesis testing study conducted by Grant (1997), in a broad way, from the perspective of mobile-bed river channels. Grant's hypothesis stated that "in mobile-bed river channels, interactions between the channel hydraulics and bed configuration prevent the Froude number from exceeding one for more than short distances or periods of time." In other words, when the kinetic energy of flow exceeds the gravitational energy flow instability is created that results in "rapid energy dissipation and morphologic change" that counteracts flow acceleration and "applies the 'brake' to flow acceleration." Grant argues that this system is consistent with the concept of minimization, because flow rate relative to flow energy is maximized at critical flow. Grant suggests that this general mechanism may be applicable in channels ranging from boulders to sand bed streams, with structures including step-pools and antidunes. It has also been suggested that supercritical flow is necessary for the development of headcuts in upland concentrated flows (Bennett et al., 2000; Byron, 1990), which then act to retard flow velocities."

In the Discussion:

"Our data are not inconsistent with the hypothesis that has been proposed for channel beds, that the feedback between bed morphology, erosion, and flow velocities is associated with, or controlled by the Froude number. Average Froude numbers calculated from the data tended to decrease as a function of the surface development, and stabilize toward the end of the experiments. Average values of the Froude number across the entire plot were less than one in all but two cases, both of which were measured during the early stage of the experiment when the surface was just beginning to evolve to its final state (Figure 10). Of course there is no way using the data presented here to know the spatial variations in the Froude number occurring on the plot at any given time, nor where the Froude number may have approached unity. With detailed measurements of the surface morphology at various times during such an experiment as this, possibly combined with distributed measurements or modeling of the flow velocity field, it might be possible to better investigate the role of energy minimization and the Froude number threshold in the development of these types of surfaces."

Regarding the comment on the methods discussion: We added a schematic figure in the supplementary information showing the sequence of the experimental measurements. We added to the text: "A schematic example of the sequence of measurements can be found in the Supplementary information." Good suggestion.

Regarding the 2 comments about the transient vs. steady-state issue: We are not sure how to address that question, or exactly what the reviewer is asking about, but from the perspective we designed the experiment the intention was to evolve the surface using the simulated erosion, and to make measurements during steady-state runoff, at two different intensities, of velocities, roughness, rock cover, etc. as the surface evolved.

Regarding the comment of the protective cover for splash erosion: The protective cover was used only during the pre-wetting of the soil to bring the soil material up to a moist condition. We re-worded this section of the methods section to make the point more clear: "Prior to the experiment the soil was placed in the box and spread evenly in an approximately 20 cm layer. The box was positioned horizontally, covered with cloth to prevent splash, and low intensity rainfall (35 mm h-1) was applied until the soil was wetted throughout. This ensured a consistent moisture starting condition for each treatment, and allowed for more rapid development of steady-state runoff with minimal erosion occurring before the first measurement of runoff velocity. After pre-wetting, the box was positioned at the target slope and protective cloth was removed."

Regarding the comment on the role of antecedent conditions: This experiment was not

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conducted in such a way as to mimic antecedent conditions of rock cover, necessarily, but the physics of the experiment is expected to be the same that one would observe in the field. The idea was to try to set up a range of physical conditions that mimicked the general process of the development of a rock pavement over a surface, and to measure how velocities will change from a standpoint of the physical modification of the surface cover and roughness. I think that we need more field work to follow up on this controlled experiment in order to bring in more “real-world” conditions as found in nature. The soil box is a great way to generate and test basic hypotheses, but we also need to see how we can translate these findings to natural conditions.

We don’t have direct measurements of flow depths in this experiment. All we have regarding the flow depth is what we can calculate based on the velocity and flow rate values, which means that we have an estimate of the average flow depth across the plot.

The Chezy and Manning roughness values are taken form the measurements of the flow at a near steady-state. That is true and we think apparent from reading the manuscript.

“Technical Corrections” were all addressed as suggested. Thanks to the reviewer for all the comments. This was a very helpful review.

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