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Earth Surface Dynamics Discussions

Interactive comment on "A reduced-complexity model for sediment transport and step-pool morphology" *by* M. Saletti et al.

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The paper presents a new reduced-complexity model for the evolution of bed topography and particle motion in steep, coarse-bedded streams, with a focus on step-pool topography. The model includes only one particle size, which is capable of only the simplest of stepwise motions on a rectangular grid. Entrainment and deposition are controlled by particle protrusion as measured by height relative to the average of the surrounding bed, with entrainment modeled in a somewhat more detailed way than deposition, which occurs simply when a particle lands on a location lower than its average surroundings. Entrainment can be either deterministic when protrusion exceeds a fixed threshold, or probabilistic. The only other major ingredient in the model is the (optional) inclusion of a jamming condition, which again is the simplest possible one: the chance arrival of particles across a whole channel cross-section, leading to imme-

diate stoppage. There is no explicit role for the flow, which appears only indirectly via the entrainment threshold.

In my opinion, this is a true "Saint Exupery" model: there is nothing left to take away. The authors have done exactly what the first formation of a model for a self-organized pattern like step-pool topography should do: to find out the absolute minimum set of conditions necessary to produce it. With only simple particle interactions and the crudest possible representation of the flow, under the right conditions the model evolves what looks to me to be pretty convincing step-pool topography. I enthusiastically endorse this for publication. It is a beautiful example of reduced-complexity modeling that sheds new light on how this important feature of steeplands streams, important both in terms of sediment transport and stream ecology (e.g. the pools are important shelter zones for fish), develops and responds to changes in sediment supply and water discharge. It will attract the interest of the large community that studies mountain rivers, as well as the growing community of people interested in applying granular physics (whence the basic insight about jamming) to sediment transport. It will also inspire further research, some of which will have the unfortunate aim of adding detail in the interest of making the model "more realistic". Nonetheless, this paper will stand as the one that revealed the essence of the phenomenon.

Comments: 1. One thing that is left to the reader to infer is the relation between particle entrainment/deposition and changes in bed topography. I assume this is as simple as I imagine: that when a particle is deposited, the elevation (Zij in the paper) is incremented by a unit amount, and vice versa for erosion. But this should be stated explicitly.

2. The authors' choice of probabilities for a particle moving straight downstream as opposed to stepping left or right (2.2.2) seem a bit arbitrary. Are there any observations of particle paths in steep streams that could be used to constrain these? How much does the choice of weights matter for the observed model outcomes?

3. The authors state (2.3) that, in the jamming model, once the jamming condition is met, all the particles across the jammed section are ‘locked’ in place. A little later the text says the process is ‘permanent’. I took this to mean that they were deposited and could never move again, but reading on and thinking about the results reported later, I don’t see how this could be right. This is an important point, since the inclusion of jamming is an important part of the paper, so it must be explained clearly. I think what the authors mean is that all the particles in that section are considered to be deposited, i.e. stop moving, regardless of the local relative elevation. But then, I assume, the jammed particles can be entrained again according to the same criterion used for all the other particles, i.e. there is nothing special about particles that were deposited through jamming. Whether this is correct or not, the authors should explain clearly what if any conditions are needed to re-entrain particles deposited through the jamming criterion.

4. In section 2.2.2, it appears that deposition occurs if a particle in motion collides with another particle in transport. This seems inconsistent with the original simple condition for deposition, which is simply that the particle arrives in a pocket (relative elevation deficit). This should be clarified. Also, when there is a collision between two moving particles, are both deposited, or only one? It would also be interesting, and in my view still in keeping with the aim of a simplest-possible model, to see whether changing the entrainment condition to account for particle collision (e.g. by letting the entrainment probability increase upon arrival of a moving particle) would change the model behavior.

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