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Interactive comment on "Gravel threshold of motion: A state function of sediment transport disequilibrium?" *by* Joel P. L. Johnson

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In this manuscript, the author discusses the implications of the idea that the threshold of motion is an evolving function of sediment supply. This leads to a re-definition of the threshold as a state variable in analogy to thermos dynamics. The concept is interesting and provides a fascinating change of view. My major concern is that the author does not make the above-stated re-definition explicit and uses the term threshold of motion somewhat interchangeable between the new and the old version. That makes a sometimes confusing read and can be rectified by clarifying the writing and making explicit statements. Further, I think the model is insufficiently put into physical context, and the various mechanisms that can relate sediment supply to the threshold of motion are scattered amongst the different parts of the manuscript. This can be streamlined and clarified. Some further comments to this effect follow in the next few paragraphs.

The physical explanations that have been proposed for the observed dependence on the threshold mostly relate to properties that the author summarized as bed state controls. Recking argued that the observed variability could at least partly be connected to changes in interlocking and armoring (see e.g., his figure 6), and Bunte et al. related the variability to bed stability, which is also dependent on properties such as interlocking. There are two possible explanations that are directly dependent on transport conditions: collective entrainment, in which moving particles mobilize stationary ones by knocking them out of their position. This mechanism has been advocated recently by Ancey and co-workers in a series of paper and demonstrated in 2D-experiments (e.g., Ancey et al. 2008; there are newer articles also available), but is highly debated by researchers working on 3D systems. The second one is the effect of fine material (sand) on the mobilization of gravel (e.g., Curran and Wilcock 2005). Although the latter could be argued to be a bed state control (the sand falls into pockets between gravel grains and therefore reduces roughness). I think the physical mechanisms that lead to the equations derived in the paper need to be better worked out and discussed, and the difference between bed state controls and direct controls of sediment supply need to be clarified. I am also not sure whether the equations actually differentiate between these two mechanisms.

The mechanism described by the author (during erosion, grains in pockets that are least stable move first, while during deposition grains stop in pockets that are most stable) could arguably be also classified as a bed state control, as it is depends on the availability of pockets of a certain degree of stability.

Further, the described mechanism in my mind only holds if either the supplied grain size distributions systematically change, or if deposition / erosion lead to systematic compaction or loosening of the bed. Consider a bed of a single grain size. By depositing a single grain, clearly it fills a pocket, but it also creates new pockets. It can be plausibly argued that the average state of the bed (roughness etc) does not change systematically in this way.

Finally, if the mechanism holds as described, there would be a feedback to roughness: deposition in stable pockets reduces the number of stable pockets, which means a smoother bed and higher flow velocity, which in turn makes each of the pockets less stable (similar to the effect of adding sand to a gravel bed, see Curran and Wilcock 2005). This would be a feedback limiting the variability of the threshold.

31 Please give some references for the statement here.

48/50 Two consecutive sentences that are both starting with 'in practice'.

55 maybe add 'typically' here

57 yes, but slope is a proxy for other parameters such as roughness, rather than a direct control

53-74 Turowski et al. 2011 demonstrate both the large temporal variability of the threshold and its control by grain and bed properties for several mountain streams. Chen and Stone 2008 explained some of the variability of measured bedload transport rates with local sub-sampling of the overall grain size distribution, leading to spatially varying thresholds of motion. This is also related to recent work on patch dynamics.

77 I am not sure whether I totally agree. See major comment.

93 comma missing after (vertical position)

136 Individual grains each have a different threshold...

142-143 inconsistent: does tau*_c follow a probability distribution (implying it is a random number) or is it constant?

145 and following: overuse of future tense: Progressive erosion entrains... grains tend to preferentially deposit...

147-148 This makes intuitive sense. Are there any data on this?

148-149 I am not entirely convinced by these arguments. It assumes that deposition

systematically changes bed-averaged roughness. See major comment.

158-160 Unclear why it was necessary to make this point. Please elaborate.

207 unit missing after 4.

208 does the use of 'initial' imply here that slope was changed during the experiments?

227 What does 'very low' mean here?

260 The hiding function exponent...

294 Which experiments? New paragraph, reference is unclear.

300-312 Curran and Wilcock 2005 should be cited somewhere here.

304 change 'with no' to 'without'.

332 Undefined abbreviation RMSD.

352 Please give the full reference.

462 Turowski et al. 2011 should be discussed in this chapter.

489-492 So, how does the model relate to the data, then?

584 There needs to be at least a brief description of Phillips' concept; it cannot be assumed that the reader is familiar with that paper.

589-605 The comparison with thermodynamics is interesting, but I wonder in how far it is novel. In the end, in river morphodynamic modelling, channels have been treated using concepts similar to state variables and state functions, they just have not been explicitly called such. Note that recently Furbish and co-workers applied concepts from statistical mechanics to bedload transport (e.g., Furbish et al. 2012, series of 4 papers in WRR and JGR).

610 This statement involves a redefinition of tau*_c, and this should be made crystal clear.

Fig. 4, caption: typo in matching, 3rd line.

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