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Interactive comment on "The rarefied (non-continuum) conditions of tracer particle transport in soils, with implications for assessing the intensity and depth dependence of mixing from geochronology" *by* David Jon Furbish et al.

Anonymous Referee #1

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This paper presents a detailed and rigorous treatment of when, why, and how to use probabilistic models to describe the transport of particulates in the landscape. In terms of understanding how soil particles migrate in natural settings, this work exposes and explores a number of ideas and concepts that benefit both theory and field practice.

Going forward I have a number of questions and suggestions that the authors may like to consider in making revisions to their work.

1. The authors present a full derivation of the governing transient Fokker-Planck equa-

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Discussion paper

tions. From a completeness point of view this derivation is appreciated but I feel that some of the main points the authors would like to make (e.g., the theoretical and practical advantages of probabilistic transport treatment over continuum treatments) get lost in the detail. I note that the actual theoretical, modeling, and practical calculations in the paper are all focussed on steady state problems, thus I would suggest that, while we may loose the full theoretical framework, just focusing on steady state problem might streamline the theory in the paper and shed a more focussed light on the take-home points the authors would like to make. One possible way to do this might be to put the rigorous developments of the equations into appendices and adapt the material currently in appendices A,B and C for the main text.

2. The authors do an excelled job of demonstrating the validity and utility of their probabilistic approach. The comparison and contrast of the theoretical (analytical) and numerical (random walk) solution for the mixing in a soil column provide convincing arguments that, for this class of problems, the probabilistic approach and its associated numerical model is an appropriate and flexible research tool. In my mind, there is little doubt that the proposed method is an excellent choice for analysis of mixing in soil columns.

Throughout the authors correctly note that their models are not continuum models and suggest critical differences between their probabilistic approach and treatments based on conventional (continuum) advection-diffusion equations. Never the less the governing equations used in the analysis in the paper, conservation of the expected number of 10Be atoms, conservation of particles with finite OSL age, and conservation of expected OSL age, are in “standard advection-diffusion forms”. So essentially the difference between the probabilistic treatment and a continuum treatment, reduces in the construction of the velocity and diffusion terms and the definition of the dependent variables. Thus my question is: In a continuum treatment, that takes the soil particle properties and associates them with bulk soil properties, what are the possible forms of the dependent variables? Perhaps, explicitly identifying differences between prob-

abilistic and continuum dependent variables, will provide additional illustration of the advantage of the probabilistic model?

3. In a more general context of land-scape process one might argue that a probabilistic transport model is always valid; if properly posed, such an approach will always reduce to a continuum model where appropriate. Never the less, in the spirit of reduced complexity modeling, can the authors comment on or provide guide-lines as to when a continuum approach would be reasonable. There is a hint of this on page 26 but could the authors expand and generalize?

4. There are a number of places in the paper where important concepts are presented. In some cases I feel that a figure may help to better illustrate the key ideas. In particular it may help to use a figure to illustrate the distinction between rarefied and continuous particle conditionsâĂŤsuch a figure could be used in expanding guidelines for when to use a probabilistic model, see point 3 above.

5. The current paper is quite long but if the authors can streamline as I have suggested above they may also be able to add a summary/conclusion section.

Smaller points

Abstract: Line 1 put comers around “due to disturbance driven particle motions” Line 2 is it “ the Fokker-Planck equation” or “a Fokker-Planck” equation? Line 6 The sentence starting “The analysis,” may read better is it were split into two sentences

Page 4: Line 14 “target grains represent a subset of the total population of quartz grain sizes”, what is the range of the total population

Page 10: Line 10 This line is a little confusing, why is eq. (14) an “advection equation”

Page 25: Line 7 “the formulation reveals that the expected particle OSL age (and the variance) satisfy a diffusion-like equation”, what is the evidence for this?

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