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Comment on egusphere-2022-934

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Referee comment on "ChronoLorica: introduction of a soil–landscape evolution model combined with geochronometers" by W. Marijn van der Meij et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-934-RC2, 2022

Review of *ChronoLorica – Introduction of a soil-landscape evolution model combined with geochronometers* by van der Meij et al.

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Van Der Meij et al. present an introduction to an adaption of an established soil landscape evolution model by including new processes controlling Optically Stimulated Luminescence (OSL) and cosmogenic geochronometers. The authors introduce this new model as a start into delving into broader scale questions of landscape dynamics.

Overall, I am very supportive of this paper. I think that coupling luminescence (and cosmogenics) into a large-scale landscape evolution model is a great idea. In particular, as the authors note, this approach has the potential to uncover new predictions and hypotheses that would be hard to develop outside of a modeling framework. Also it is really admirable the work done to build such a comprehensive model incorporating the wide array of processes involved in a soil-focused landscape evolution model. I have some comments below on specific things, but I want to acknowledge ahead of time that the model is pretty broad and these comments may not change the broader results.

Main Comments:

Soil transport in ChronoLorica

One thing that I wondered about is whether the treatment of soil horizonal and vertical transport is internally-consistent. An example may be the comparison between the soil creep function and the bioturbation function along with the particle transport formulae of Anderson (2015) and Furbish et al. (2018b). There isn't enough detail in this section for me to fully understand how the model is working, but I wonder are the ddCR and ddBT values consistent with that input into Anderson/Furbish? If so, how is this done?? The second point on this is that it isn't clear what the justification is for exponential decay functions for soil creep and bioturbation. It would be helpful to back this up with

references. Perhaps with some of the Young's pit studies?
As another comment on this: On line 119, the authors say they use the formulae of Anderson (2015) and Furbish et al. (2018b) to model downhill transport of soil particles. However, these papers disagree with each other on the base principles of how soil moves downhill with the Anderson study assuming a continuum-style flux of soil (basically soil treated as a fluid) and the Furbish et al. study explicitly treating the soil particles as non-fluid with the advection-diffusion style equations describing the ensemble averaged conditions of soil particle transport using statistical mechanics. The advection/diffusion equations describe the flux of probability of the expected value of the ensemble average. The particle transport was handled with different random-walk equations. This in effect means that if you use Furbish theory, you cannot calibrate your OSL/cosmo field data against the advection/diffusion model because the model and data are two fundamentally different things. The model being a theoretical average of a uncountable number of theoretical soils. In contrast if you use the Anderson approach, you will be wrong because soil doesn't follow continuum mechanics as in the base assumptions of that paper.
OSL physics
One thing that this paper made me think was that it would potentially be useful for the authors to directly simulate the luminescence. It seems like the authors get into a high level of detail with the cosmogenic physics but not the OSL physics. I think this is worth exploring in the model because the model is intended to be an explicit coupled soil-landscape-geochronometers model, yet the physics of cosmogenic is treated very in depth but the OSL isn't. Right now the model feels very focused on the cosmo
One thing that brought this up is the assumption that the burial age equals the OSL age, which I think isn't always an easy assumption in soils! As a particle travels through various soil layers, the background dose rate, DR(z), can change due to a variety of processes, but particularly with soil density and water content which affects the density of the natural background radiation intensity and the cosmogenic radiation flux. I didn't see any content or discussion on how this could affect the OSL geochronometer results, but I could imagine that the burial age and the OSL age could vary a lot (it does from my field experience with OSL in soil). I think it is important for the authors to explore this assumption and show, perhaps with a sensitivity analysis that it does or does not matter. As an admission, I assumed constant DR with soil depth in past work and I think Furbish et al. (2018b) made a case for why this does not matter but I don't remember fully. I'm bringing this up because treatment of specific soil layers seems to be an important benefit of Chronolorica
One could model the change in luminescence (and assumed an idealized luminescence geochronometer, the luminescence grows in at $dL(z)/dt = DR(z)/D0 * (Ls - L(z))$ where L is luminescence, z is vertical height in the soil, t is time, DR(z) is dose rate, D0 is a dose e-folding scale, and Ls is the luminescence at saturation. A really good source for this type of modeling is Brown, N. D. (2020). Which geomorphic processes can be informed by luminescence measurements?. Geomorphology, 367, 107296 Where the author gives the equations that could be directly incorporated into the model.

Minor Comments:
Line 41: if helpful, Gray et al 2019 has a section on soil mixing and methods that might be helpful for this review paragraph: Gray, H. J., Jain, M., Sawakuchi, A. O., Mahan, S. A., & Tucker, G. E. (2019). Luminescence as a sediment tracer and provenance tool. Reviews of Geophysics, 57(3), 987-1017.
Line 64: Hmm. The comparison with field studies is a bit weird as SLEMs are hypothetical scenarios but are not actually reality in the way that field studies are.
Line 198, 459: 10 mm seems high for light penetration in soil. See: Ciani, A., Goss, K. U., & Schwarzenbach, R. P. (2005). Light penetration in soil and particulate minerals. European journal of soil science, 56(5), 561-574.