Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2019-62-RC2, 2019

Geoscientific Model Development Discussions

Interactive comment on "A lattice-automaton bioturbation simulator for the coupled physics, chemistry, and biology of marine sediments (eLABS v0.1)" *by* Yoshiki Kanzaki et al.

Anonymous Referee #2

Received and published: 5 June 2019

This paper presents an extension to the LABS model. In the new model, the authors implemented the calculation of water flow and oxygen and organic matter concentration filed. It is useful for theoretical investigations into the interplay between biological, physical and chemical factors influencing sediment bioturbation. The manuscript is well written and organized. This is an important work that merits publication, and GMD is an appropriate journal for this work. However, the manuscript needs substantial improvement of the presentation before it can be recommended for publication. The two main problems are (1) clarity in the presentation of the model and (2) generality of the results.

1) The distinct advantage of eLABS is the addition of water flow, which could couple the overlying water with sediment continuously. However, it is too rough for the model description and therefore its validity cannot be judged. For example, the proper treatment of the moving boundary when the sediment was moved by organisms is essential to get the flow field. Only constant flows imposed in the head or tail of the organisms may not sufficient. The pressure and velocity along the moving sediment is also important. The accuracy of boundary condition also largely depends on the grid resolution, especially in this case that the sediment occupied only one grid. Therefore, grid refinement is necessary to check the error bar. Similarly, the treatment of the boundary condition of oxygen on the moving sediment has to be careful to ensure the mass conservation. One could check the mass conservation of oxygen by turn off the oxygen consumption rate. The implicit and explicit finite-difference method as well as the boundary condition could be presented in the appendix to guide readers easier. Before considering the effects of biological, physical and chemical factors on bioturbation, the verification of numerical implement could also be put in the appendix.

Organic matter is generally located in the solid particles and oxygen in water. How to calculate the rate with Eqs.(4) and (5) when OM and O2 are not at the same cell?

2) The model was run only once for one case study, which loose its generality. Lattice-automaton contains stochastic processes. It is better to consider different initial distribution the sediment and random generator for animal move. The ensemble averaged effects of biological, chemical and physical parameters on oxygen fluxes and rates of mixing in ocean sediments could provide a mechanistic explanation for empirical relationships observed in the modern ocean sediments, which is much more useful. Otherwise, it becomes meaningless due to large uncertainty and randomness. According to the model setup, the running will lead to a steady state. It the time is within geology years, one could compare the results in the steady state, which is comparable with the observed empirical relation.

–other notes–

Page 5 /line 28: Non-local mixing of water (bio-irrigation) by infauna is already represented in LABS. In the original LABS, there is only non-local mixing of sediment and no bio-irrigation is presented.

6/1-2: Many readers may not familiar with “marker and cell method”. It is better to give some details. The references cited here (Hoffmann and Chiang 2000; Manwart et al 2002; Meysmann et al. 2005,2006b,2007; Volkenborn et al. 2012) are not properly.

6/11: For fluid the name “no-vertical-flux boundary conditions” is not used. Instead, slip boundary condition is common used. “Non-slip boundary” should be replaced by “No-slip boundary”. “left and right boundaries are continuous” could be simply replaced by “periodic boundary condition”.

7/7: The shear velocity is usually resulted from a turbulence flow in the overlying water. Within the lowest portion of the planetary boundary layer a semi-empirical log velocity profile is used. However, in this paper, there is any external flow in the water and shear velocity lose its meaning.

9/32: Does “biodiffusion coefficients in the present study are obtained by calculating average values...” mean that Db is depth independent. Actually, Db depends on the sediment depth.

11/5: The unexpectedly larger of biodiffusion coefficient at $\sim$7 to 8 cm depths results from only one sample run. If one runs more samples and average them, I think the “unexpectedly” will be disappear. It is not from non-local mixing.

12/3: The authors mentioned that “advective water flow has only insignificant influences on bioturbation”. In fact, people are more interested in the effect of bioturbation on the advective water flow and thereafter the bioirrigation, which might significantly change oxygen flux.

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