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Interactive Comment

Interactive comment on "An updated interparcel mixing algorithm in the Lagrangian advection scheme with shape matrix (LASM) v0.2" *by* L. Dong et al.

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Dear Referee 2,

Thank you for your comments! The following is our answers for your concerns. The manuscript will be modified accordingly.

1. Question: One could have hoped that the updated mixing was derived from more physically based arguments than in the original LASM. However, I have troubles to see that this is generally the case. There seems to be a number of parameter settings that a set on an ad-hoc basis.

Answer: It is normal that every practical numerical scheme contains some kinds of artifacts. For example, the flux limiters or filters used in many Eulerian advection schemes to ensure positivity and monotonicity make those schemes nonlinear, which should be linear. The interparcel mixing added in LASM is inherited from the earlier Lagrangian schemes, such as STOCHEM (Stevenson et al. 1998) and ATTILA (Reithmeier and Sausen 2002). But because the parcels in LASM have shape, which is not the case in other Lagrangian schemes, some artifacts are needed to adjust the shape of some parcels that are not approximated well by the linear deformation matrix. The performance of the mixing was verified by some test cases, such as the deformation test case. It will be studied further when LASM is applied to real GCM.

2. Question: Another major issue is the cost of the scheme and in particular the cost of identifying the computational grid (or procedure) needed to perform the interparcel mixing. How can this parallelize on modern computers? How is the multi-tracer efficiency? A discussion of these issues is requested.

Answer: The search of the grid cells that are covered by a parcel is performed by a dual-tree algorithm, which is provided by a C++ machine-learning library (MLPACK). The time complexity of the search operation is O(log n), where n is the number of total grid cells. This number can be greatly reduced when run in parallel after the domain is decomposed into small ones. The multi-tracer efficiency of Lagrangian schemes is very high compared with Eulerian and semi-Lagrangian schemes, because different tracer species share a lot of information (e.g., trajectory, remapping coefficients). This statement has been verified by HEL (Kaas et al. 2013), see Fig. 13 there. This is also true for LASM.

3. Question: It is stated that the neighboring parcel shapes are unaffected by the mixing with them. But from a physical point of view one should expect that any mixing will tend to make the shape of the neighboring (as well as the actual) parcel more isotropic, i.e., the shape is actually influenced by the mixing.

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Answer: The shape of the neighboring parcel is not changed, but the tracer density is affected by the mixing, so the mass is transferred among parcels. This resembles the diffusion in a Eulerian scheme, where the mesh cells are fixed. Only the degenerated parcel shape is changed to be more isotropic, and that parcel has the maximum weight (i.e., 1) when calculate the mean density. The reason for mixing in this way is to minimize the effects.

4. Question: A mass fixer is introduced. It should be discussed in a little more detail how this works. I presume it is only relevant for the Eulerian representation (i.e. on a regular grid) and not in the Lagrangian space of the parcels?

Answer: The mass fixer is turned off in this study, since the total mass on the parcel is conserved. Yes, it is only relevant for the Eulerian representation. We are working on another remapping strategy, where the remapped quantity is the tracer mass, so the total tracer mass is the same in both Eulerian space and Lagrangian space, and the mass fixer will be removed at that time.

5. Question: Page 767, Line 10-20:It is unclear why a mass fixer in the grid representation is influencing the mass in parcel space. Couldn't one just fix the mass in Eulerian space without affecting that in parcel space. Or maybe I misunderstood. Please explain in more detail.

Answer: Sorry for the poor writing. The mass fixer has nothing to do with the parcel space. That part just wants to say that the mass fixer is turned off in this study. We will improve the expression in the revision.

6. Question: Page 769, Line 19-20: "... and respects the local flow properties". But the ATTILA mixing also respects local flow properties in terms of local deformation rate?

Answer: ATTILA does not respect the local flow properties. It only mixes the parcel centroids within one Eulerian grid cell. CLaMS (McKenna et al. 2002a) and HEL do respect the local flow properties. We will improve the expression too.

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7. Question: Page 770, line 11: The re-shaping takes place after the mixing, and is independent of the degree of actual mixing. But what if no or insufficient mixing has actually occurred for parcel i because there were no or only rather distant neighbors. Then the parcel is re-shaped (to be more circular) even without being mixing. This seems physically inconsistent. If no mixing has taken place the physical parcel should keep its irregular shape until it can actually be mixed.

Answer: Currently, the reshaping is controlled by the elongating degree (γ_i) of parcel i. The case you mentioned should be concerned. Thanks for pointing it out! On the one hand, we should add the mixing degree as another control factor for reshaping. On the other hand, the parcels without neighbors or have very distant neighbors should be avoided. In this study, the distance among parcels is restricted and each parcel has plenty of neighbors, because the flow is 2D or even non-divergent. We are planning to add some kind of auto-refinement algorithm to avoid such case when apply LASM in 3D with strong divergence, so the parcels will be well-distributed.

8. Question: Page 773: The γ_m value of 5 is apparently chosen on an ad-hoc basis. Such a large value implies that the domain of influence of a parcel is also large.

Answer: We have tested several values for γ_m, and 5 is a moderate value. γ_m does not imply that the domain of influence of a parcel is also large. It just measures how long a parcel is.

9. Question: Page 774, line 15: It is unclear what is learnt from the right panel in Fig. 4. It could be deleted.

Answer: That figure is used to show that there is no ill parcels when use new mixing algorithm, compared with the old ones (the left one).

Best regards, Li

Interactive comment on Geosci. Model Dev. Discuss., 8, 761, 2015.