Solid Earth Discuss., 6, C653–C655, 2014
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Solid Earth
Discussions
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Interactive comment on "Using the level set method in geodynamical modeling of multi-material flows and Earth's free surface" *by* B. Hillebrand et al.

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Received and published: 10 July 2014

General comments:

1. The authors claim that level sets are not commonly used for geodynamical modeling. I have to disagree with that. In the last few years, there have been numerous papers discussing the advantages and drawbacks of level sets in a geodynamical context and/or applying it to a specific geodynamical problem. As a simple Google search would have shown, some examples include:

âĂć Hale et al. (2007), Using the level set method to model endogenous lava dome growth, JGR, 10.1029/2006JB004445, âĂć Gross et al. (2007), Interface modeling in incompressible media using level sets in Escript, PEPI, 10.1016/j.pepi.2007.04.004,

âĂć Bourgouin et al. (2007), Studying the influence of a solid shell on lava dome growth and evolution using the level set method (2007), GJI, 10.1111/j.1365-246X.2007.03471.x, âĂć Braun et al. (2008), DOUAR: A new three-dimensional creeping flow numerical model for the solution of geological problems (2008), PEPI, 10.1016/j.pepi.2008.05.003, âĂć Kadlec et al. (2008), Interactive 3D computation of fault surfaces using level sets. Vis. Geosci., 13, 133-8, âĂć Suckale et al. (2010), It takes three to tango: 1. Simulating buoyancy-driven flow in the presence of large viscosity contrasts, JGR, DOI:10.1029/2009JB006916, âĂć Suckale et al. (2010), It takes three to tango: 2. Bubble dynamics in basaltic volcanoes and ramifications for modeling normal Strombolian activity, JGR, DOI:10.1029/2009JB006916, âĂć Samuel and Evonuk (2010), Modeling advection in geophysical flows with particle level sets, G3, DOI: 10.1029/2010GC003081, 2010, âĂć Hale et al. (2010), Dynamics of slab tear faults: Insights from numerical modeling, Tectonophys., 10.1016/j.tecto.2009.05.019,

The Computational Infrastructure for Geodynamics also now offers software (ASPECT) that includes a level-set component. It is regrettable that the authors do not refer to the ongoing debate about the role of level sets for Geodynamic modeling and advances made on that question over the last few years.

2. Given the importance of accurately modeling interfaces in geodynamic problems, I think it is valuable to write papers that are predominately methodological like this one instead of focusing exclusively on a single application. That being said, a methodological paper should provide a detailed analysis of the chosen implementation in comparison to the state of the art in the field. Again, numerous mathematical papers discuss the pros and cons about level-set implementations, but unfortunately the authors do not take note of that. For example, it is well known that the reinitialization procedure can lead to significant artifacts including spurious mass loss and interface distortions (e.g. Adalsteinsson and Sethian, 1999; Sethian, 1999a; Chopp, 2009 and many others). The authors also state that it is not necessary to use high-order schemes when implementing the advection equation for the level set. That statement is surprising in light

of the conclusions from the two main textbooks about the level set method (Level Set Methods and Dynamic Implicit Surfaces by Osher and Fedkiw and Level Set Methods and Fast Marching Methods by Sethian), that recommend not only high-order methods, but shock capturing techniques. It is difficult to judge the quality or applicability of the implementation suggested by Hillebrand et al. without a more detailed justification of their implementation and error analysis.

References: âĂć Adalsteinsson, D., and J. A. Sethian (1995), A Fast Level Set Method for Propagating Interfaces, J. Comput. Phys., 118(2), 269-277. âĂć Adalsteinsson, D., and J. A. Sethian (1999), The Fast Construction of Extension Velocities in Level Set Methods, J. Comput. Phys., 148(1), 2-22. âĂć Chopp, D. L. (2001), Some Improvements of the Fast Marching Method, SIAM J. Sci. Stat. Comput., 23(1), 230-244. âĂć Chopp, D. L. (2009), Another look at velocity extensions in the level set method, SIAM J. Sci. Comput., 31(5), 3255-3273.

3. Finally, the benchmarks are nice, but in several of these benchmarks, the main computational challenge does not seem to be the tracking of the interface, but dealing with the material jumps across the interface. Smearing is one strategy for dealing with these, but has significant drawbacks (as again, discussed in the mathematical literature) and does not necessarily avoid spurious oscillations (e.g. Liu et al. 2003). A more detailed error analysis of the different components of this code would be helpful for judging the accuracy of this implementation.

References: Liu, X.-D., R. P. Fedkiw, and M. Kang (2000), A boundary condition capturing method for Poisson's equation on irregular domains, J. Comput. Phys., 160(1), 151-178.

Interactive comment on Solid Earth Discuss., 6, 1523, 2014.