Solid Earth Discuss., 3, C83–C87, 2011
www.solid-earth-discuss.net/3/C83/2011/

Solid Earth
Discussions

Interactive comment on "3-D thermo-mechanical laboratory modelling of plate-tectonics" *by* D. Boutelier and O. Oncken

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Received and published: 21 April 2011

We received three reviews, each providing interesting points that we had ignored or insufficiently reported on in the submitted manuscript. We thank the reviewers for their work that helped us produce a better paper.

One point common to the three reviews is the fact that using an inviscid asthenosphere is a simplification that we should not continue doing if we expand our area of interest to the whole plate. We now explicitly present our modelling setup as a milestone within a developmental path which will include appropriate implementation of the viscous interaction between the lithosphere and asthenosphere. We agree with the reviewers that this assumption should be abandoned. However, we are building on legacy 2D mechanical and thermo-mechanical set-ups [1-4] and therefore we decided to keep

the inviscid sub-lithospheric mantle simplification while developing the 3D set-up. The implementation of the viscous interactions between lithosphere and asthenosphere will come later. It is important to note that we do not have a choice in the order of the implementations. Viscous interactions between the lithosphere and asthenosphere have been tested in a pseudo-2D set-up [5], but flow was either controlled or it was strongly influenced by the boundary conditions. Similarly, the reviewers have been doing dynamic experiments with flow in the mantle due to sinking of the lithosphere in a large three-dimensional tank to avoid side effects [6,7]. It is therefore imperative that the set-up is first expanded to 3D before the viscous interactions between the lithosphere and asthenosphere are implemented. This task is not the easiest as the whole thermo-mechanical experimental setup had to be entirely redesigned in order to achieve a good control of the surface temperature together with use of optical strain monitoring system.

A second point raised by the reviewers is that we exerted a kinematic control over the experiment, while the reviewers have all produced numerical or analogue simulations where the negative buoyancy of the subducted lithosphere is the sole driving force of plate convergence [6-8]. This point is tightly linked to the previous one. The dynamics of the plate requires that the force balance is made at the scale of the plate. Then, the viscous interactions between the lithosphere and asthenosphere, either driving or resisting, cannot be ignored. Since we did not reproduce the viscous interaction, we decided to impose a constant rate in the presented series of experiments. However, we know that subduction and collision processes are dynamic and their modelling should include velocity variations [9]. We took this in consideration when developing the driving system, which can either impose a constant velocity or constant force. We thank the reviewers for raising this point as it allowed us to develop on the importance of the thermo-mechanical approach. Indeed, collisions are dynamics and there are velocity variations that certainly affect the evolution of stress and therefore strain in the model. Furthermore, velocity variations also affect the temperature distribution in the model, and consequently the strength evolution. We will investigate this aspect once the viscosity of the sub-lithospheric mantle has been properly scaled and the constant-force driving system has been fully tested. However, both the implementation of the viscous interaction and constant-force driving system are minor modifications of the experimental set-up presented in this study. Furthermore, none of these next developmental steps require changes in our modelling strategy.

Finally, there is a last point that has been raised by the reviewers which is whether we can really consider that we have free boundary conditions. This comment comes from reviewers who have been investigating the role of flow in the mantle [6-8] which was shown to be strongly influenced by the boundary conditions. Therefore, it appears that our model flow in the mantle may be influenced by the boundary conditions (i.e. walls). However, at the moment this is not a problem since we do not include flow in the mantle. Therefore the boundary conditions really matters for the lithosphere only [10]. Our plates can either be placed in the middle of the tank and then the lithosphere is free to move laterally (i.e. free boundary condition), or it can be placed near the wall and the lithospheric plate can only slide parallel to the wall (i.e. free-slip boundary condition). Depending on the problem we investigate we will choose one conditions or the other. When implementing the flow in the mantle we will face another choice. We will have to reduce the width of the lithospheric plates if we wish to implement mantle flow around the slab that is not influenced by the walls. However, this would limit our ability to implement along-strike variations of the physical properties of the plates. Therefore we may be able to implement flow in the mantle but compromise and accept that it may not be entirely free of the influence of boundary conditions. Another solution is to build another even bigger experimental tank.

We thank the reviewers for these constructive comments, that have been answered in the replies as well as in the body of the text, in the appropriate sections.

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Interactive comment on Solid Earth Discuss., 3, 105, 2011.