Solid Earth Discuss.,
doi:10.5194/se-2016-12-RC1, 2016

Solid Earth
Discussions

Interactive comment on "Numerical simulation of mantle convection using a temperature dependent nonlinear viscoelastic model" *by* M. Norouzi et al.

Anonymous Referee #1

Received and published: 22 February 2016

I previously reviewed this paper for another journal. As this manuscript seems identical (with no attempt to incorporate the recommendations I made previously) I will simply repeat what I wrote then:

Here the authors present some convection simulations using a nonlinear viscoelastic rheology with the Giesekus constitutive equation, and claim that they are relevant to understanding Earth's mantle. There are several reasons not to publish this manuscript in Solid Earth.

Most fundamentally: Does the Giesekus constitutive relationship that they use actually apply to rocks? This relationship was derived specifically for polymers. Rocks are not polymers – they are crystalline. Are there any laboratory experiments showing that rock minerals, or indeed any type of crystalline material, has nonlinear viscoelasticity

that matches the Giesekus constitute relationship? Or any field observations? Unless the authors can cite some evidence that this is actually relevant, then this manuscipt has no place in an Earth science journal.

Secondly, in a journal like SE one expects a strong link between the presented results and the actual Earth, but instead the authors present a nondimensional parameter study with no attempt to make quantitative inferences or predictions regarding the actual Earth. This is in contrast to earlier studies on mantle convection with viscoelasticity, which the authors don't seem to know about since they don't cite them (Beuchert and Podladchikov, 2010; Harder, 1991; Moresi et al., 2003; Moresi et al., 2002) (also there are many papers on lithosphere & crust deformation that include viscoelasticity). The usual view is that in the mantle elasticity is unimportant at geological time scales because the viscoelastic relaxation time is short compared to the deformation time scale (viscosity/shear modulus $\sim$1e21/1e11 $\sim$ 300 years), while in the lithosphere, viscosity can be orders of magnitude higher so elasticity can be important. It is not clear that the authors reach this regime. As it is, this paper belongs more in a journal like Journal of Non-Newtonian Fluid Mechanics.

Thirdly, the investigative method. If the authors want to demonstrate that nonlinear viscoelasticity is important then they need to show corresponding solutions for (i) nonlinear viscoelasticity (ii) linear viscoelasticity and (iii) viscous flow, and identify how and where they are different.

Fourthly, they claim that they include viscous dissipation "for the first time" but in fact there are several 10s of papers on mantle convection that include this term – basically anything study that uses a compressible approximation. Here are just a few examples to get them started: (Balachandar et al., 1993; Glatzmaier, 1988; Jarvis and McKenzie, 1980; Leng and Zhong, 2008; Tackley, 1996).

Fifthly: they claim that including variation of "g" through the mantle is an important new aspect of their study: actually the variation with depth is very small – only a few

% - as you can see in the widely-used PREM (Preliminary Reference Earth Model) (e.g. http://geophysics.ou.edu/solid_earth/prem.html). This is why it is almost always ignored.

I could go on, but that's enough for now.

REFERENCES

Balachandar, S., Yuen, D.A., Reuteler, D., 1993. Viscous and Adiabatic Heating Effects In 3-Dimensional Compressible Convection At Infinite Prandtl Number. Physics Of Fluids a-Fluid Dynamics 5, 2938-2945.

Beuchert, M.J., Podladchikov, Y.Y., 2010. Viscoelastic mantle convection and lithospheric stresses. Geophys. J. Int. (UK) 183, 35-63.

Glatzmaier, G.A., 1988. Numerical simulations of mantle convection - time-dependent, 3-dimensional, compressible, spherical-shell. Geophys. Astrophys. Fluid Dyn. 43, 223-264.

Harder, H., 1991. Numerical-simulation of thermal-convection with Maxwellian viscoelasticity. Journal Of Non Newtonian Fluid Mechanics 39, 67-88.

Jarvis, G.T., McKenzie, D.P., 1980. Convection in a compressible fluid with infinite Prandtl number. J. Fluid Mech. 96, 515-583.

Leng, W., Zhong, S., 2008. Viscous heating, adiabatic heating and energetic consistency in compressible mantle convection. Geophys. J. Int. 173, 693-702.

Moresi, L., Dufour, F., Muehlhaus, H.-B., 2003. A Lagrangian integration point finite element method for large deformation modeling of viscoelastic geomaterials. J. Comp. Phys. 184, 476-497.

Moresi, L., Dufour, F., Muhlhaus, H., 2002. Mantle convection models with viscoelastic/brittle lithosphere: Numerical methodology and plate tectonic modeling. Pure and Applied Geophysics 159, 2335-2358.

Tackley, P.J., 1996. Effects of strongly variable viscosity on three-dimensional compressible convection in planetary mantles. J. Geophys. Res. 101, 3311-3332.

Interactive comment on Solid Earth Discuss., doi:10.5194/se-2016-12, 2016.