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Interactive comment on "A global,spherical,finite-element model for postseismic deformation using ABAQUS" *by* Grace A. Nield et al.

Anonymous Referee #2

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Review of "A global, spherical, finite-element model for postseismic deformation using ABAQUS" by Nield and co-authors.

The manuscript represents an implementation of postseismic viscoelastic relaxation problems in a widely used finite-element commercial package. The study addresses common problems associated with meshing the domain, which is difficult around faults, and benchmarks the results against semi-analytic solutions attained with another widely used, but open-source, package. The study is accompanied with supplementary material that allows the community to reproduce and expand on these results quickly.

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Discussion paper

The study makes a number of simplifying assumptions about the rheology of the Earth that permits direct comparison with the semi-analytic code visco1d. However, once the code is benchmarked, these assumptions should be relaxed and more realistic constitutive laws that include a power-law stress/strain-rate relationship at steady state and a similar power-law constitutive behavior for transient creep - all compatible with laboratory observation of olivine creep - should be implemented and described. More realistic distributions of physical properties associated with thermal activation of viscoelastic flow in a realistic thermal field should follow.

A remaining issue is the meshing around more complex fault assembly that include multiple surfaces is not included in the model. As many earthquakes are now imaged to such a level of accuracy that these details are often well constrained, including complex fault geometry would be a relevant addition.

Finally, the iterative procedure to include self-gravity should be replaced by directly solving the appropriate equations based on advection of pre-stress.

I follow with a few detailed remarks.

55: An example of finite-element modeling of post-seismic relaxation with a spherical geometry is

Agata, R., Barbot, S.D., Fujita, K., Hyodo, M., Iinuma, T., Nakata, R., Ichimura, T. and Hori, T., 2019. Rapid mantle flow with power-law creep explains deformation after the 2011 Tohoku mega-quake.ÂăNature communications,Âă10(1), pp.1-11.

105: Since it seems so easy to add more realistic rheology with the method, it should actually be done in this study. More realistic rheology involves a power-law stress/strain-rate relationship, see

Hirth, G. and Kohlstedt, D.L., 2003. Rheology of the Upper Mantle and the Mantle Wedge: A View from the Experimentalists: Inside the Subduction Factory, v. 138.

Karato, S.I. and Wu, P., 1993. Rheology of the upper mantle: A synthesis. Science, 260(5109), pp.771-778.

Recent development include the inclusion of transient creep compatible with nonlinear steady-state creep:

Masuti, S., Barbot, S.D., Karato, S.I., Feng, L. and Banerjee, P., 2016. Upper-mantle water stratification inferred from observations of the 2012 Indian Ocean earthquake. Nature, 538(7625), pp.373-377.

Inclusion of realistic rheology seems more important and relevant than including self-gravitation.

130: It is unfortunate that Abaqus cannot simply solve the appropriate governing equations for self-gravitation and that these iterations are necessary. How can that be improved? Is there a way to solve a user-defined set of equations? Are the governing equations with self-gravitation not readily included in Abaqus? How is advection of pre-stress included?

180: The horizontal and vertical resolutions of the mesh seem inadequate to resolve the near field. The fault is 200x20 km and the mesh size around it is 10x5 km, representing just 20x4 mesh elements along the fault. It is actually surprising that the numerical result match the analytic solution so well with such a coarse mesh. This is perhaps an area of improvement.

215: We need to see a convergence test in terms of mesh resolution for these cases. This may not necessitate more figures, but this needs to be discussed. I suspect that the resolution of the mesh in the near field can be improved, with valuable gains on the misfit. I suspect that the discrepancies that accumulate at long period during postseismic relaxation may be reduced with a more appropriate mesh in the near field.

250: If linear rheology models are assumed, several simulations can be run with separate parts of a complex fault geometry model - each fault at a time - and the results subsequently combined.

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