Comment on gmd-2021-367
Carsten Burstedde (Referee)

Referee comment on "Towards Automatic Finite Element Methods for Geodynamics via Firedrake" by D. Rhodri Davies et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2021-367-RC7, 2022

This is a comprehensive and detailed paper on implementing mantle convection simulations in Firedrake. I am in favor of publishing it, due to the attention to reproducibility, the careful matching of benchmarks, and its general model and tutorial value. I have only minor suggestions:

The Newton terms are omitted, the Nitsche terms are omitted form the discussion of system solution. Yet these would be rather interesting since these take some effort to derive and many will not have taken the trouble to do so before, especially in light of concrete benchmarks. Conversely, what is presented in terms of equations in the paper is rather well known. Thus my question, would it be practical to add these equations/derivations? Or is it rather that due to the automatic differentiation available in Python, there is no need to present them in detail?

Figure 6b is the first that disagrees with established values. Is it understood why? Maybe the results obtained here are actually better?

Chapter 7, realistic convection simulation: what is the spatial and temporal resolution?

Line 220, it is also required that finite element of different spaces pairings are stable, which depends crucially on the choice of these spaces. The paper omits this point entirely, maybe some comments can be added. Related, discontinuous pressure discretizations may be worth attention.

Line 255: The (imposed) Tinhom values produce a term linear in q that moves to the right
hand side of (10). How is this handled?

Line 290, 298: It is not clearly described how the temperature equation could possibly become nonlinear in T. Maybe the authors are referring to the fully coupled systems, where the parameter $u$ depends itself on $T$?

Line 550: Using petsc fieldsplit is more advanced and even more interesting than what is lined out earlier in the paper. It would be valuable to discuss the corresponding numerical approach and technique in more detail, which may help readers to move in this direction themselves.

Line 836, may mention precondition work by Bangerth used in the Aspect code.