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Geoscientific Model Development Discussions

# *Interactive comment on* "On the sensitivity of 3-D thermal convection codes to numerical discretization: a model intercomparison" *by* P.-A. Arrial et al.

**Anonymous Referee #2**

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General comments:

1) The authors presented an interesting piece of work in this paper. Using two different numerical codes/methods, CitcomS and RBF, the authors systematically explore the sensitivities of solutions of 3D spherical thermal convection to initial perturbations for relatively small Ra. This work reminds us the complexity of non-linear thermal convection in spherical geometry even at relatively small Ra. It also shows the importance and need of good benchmark studies, as mantle dynamics community has built more numerical codes and tools – the cases presented here can be used in future studies for benchmarks.



2) Some of interesting results from this study can be summarized as follows. It appears that results from RBF and CitcomS agree reasonably well in general, but for certain Ra and initial conditions, convection converges to different state. The study presents two such examples: A) low order symmetry case of cubic initial condition and B) high order symmetry case of dodecahedral initial condition. For cubic condition, while both RBF and CitcomS gave the same convective patterns for a large range of perturbation amplitude, the transitional states that occur for a small range of perturbation amplitude are different for these two methods. For dodecahedral initial condition, the first stationary and steady state dodecahedral pattern is nearly the same for these two methods, the second stationary state differs between the two methods and is also dependent on the initial perturbation amplitude.

Specific comments:

1) Can the authors add some comments on any possible or significant differences between CitcomS and RBF for RMS velocity, <T> and Nu in Figure 10 BEFORE the transition? Figure 8 seems to suggest that the RMS velocity is nearly the same between the two methods before the transition starts. Can we say the same for the difference cases in Figure 10?

2) It would be useful for the authors to make some general comments on how readers may evaluate convection results in general, even if they may be rather speculative. Should we take the current results as indication that convective patterns, RMS velocity, and averaged temperature and heat flux are not reliable and code-dependent? or we only need to be concerned for models with certain parameters and states (e.g., relatively small Ra, isoviscous convection, . . .)? My reading of the paper is that CitcomS and RBF for isoviscous thermal convection in spherical geometry mostly agree with each. However, it would be helpful for the authors to be more specific about this topic. I suspect that RMS does not work for variable viscosity (e.g., temperature-dependent viscosity) yet. Would variable viscosity convection show similar complexity or transitional states, depending on initial state or Ra? How about Ra reaching Earth-like?

Technical corrections:

1) Page 2038, line 17, " . . . in 3-D spherical geometry (Moresi and Solomatov, 1995, Zhong et al., 2000; Tan et al. 2006)." Moresi and Solomatov (1995) was for 2-D Cartesian model Citcom, and CitcomS was first published in Zhong et al. (2000). Perhaps, it is better to move "Moresi and Solomatov, 1995" to the next line as the reference to Citcom.

2) Figure 5. It was stated in the figure caption that delta=0.09 for both methods, but in figure legends, delta=0.08 for CitcomS and 0.09 for RBF. Clarify them.

3) It seems that Fig. 10 was referenced before Fig. 9 in page 2044. Reorder them?

4) Figure 12 caption includes two b). Also, in line 23 of page 2046, figure 12e was incorrectly referenced for 5-cell pattern, but the 5-cell pattern is in figure 12d.

5) Page 2047, line 13, add "to" before "highlight".

6) Page 2047, line 16, replace "finite volume" with "finite element".

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