Solid Earth Discuss., 7, C1854–C1856, 2016
www.solid-earth-discuss.net/7/C1854/2016/

Solid Earth
Discussions
Open Access
EGU

SED
7, C1854–C1856, 2016

Interactive comment on "A simple 3-D numerical model of thermal convection in Earth's growing inner core: on the possibility of the formation of the degree-one structure with lateral viscosity variations" *by* M. Yoshida

S. Zhang (Referee)

siqi.zhang@mq.edu.au

Received and published: 15 January 2016

Although this isn't exactly my area of expertise, I do find the topic of this paper interesting. Degree-one like inner core structure has been proposed by recent seismological studies. This paper carried out a series of 3D thermal convection simulations to explore the possibility of generating this kind of structure by an "endogenic factor". While exploring the major uncertainties of the model parameters such as rheology and the thermal conductivity of the inner core, the author concludes that an "endogenic factor" is less probable. The lateral viscosity variation considered here is a good addition to previous works, and this improves our understanding of the core evolution, which is worth publishing. However, the numerical treatment borrowed directly from mantle convection simulations requires a few changes to be suitable for inner core convection. And some details of those treatments carried out in this paper are oversimplified or improper to me (listed below). I would like to suggest some corrections or justifications before the paper can be published.

Some detailed comments are listed below:

1. This study uses mantle convection simulations to deal with convection within a growing inner core. In contrast to mantle convection studies, the author uses a time-dependent inner core radius to get dimensionless equation Eq. (2-4) to account for a growing inner core. However, the Eq. (2-4) is build based on an Eulerian specification that is fixed on space. With a growing inner core radius, the grid is actually slowly expanding through time. So strictly speaking, mass, momentum, and energy are no longer conserved with this expending mesh. One could argue that the growth rate is small enough to make it negligible, and there are also some previous studies using a similar treatment. However, considering the significant accumulating growth of the inner core during the whole simulation, I still feel this requires some improvement or at least a more detailed justification.

2. p. 3820, l. 12-14. As the small sphere is imposed, it created an additional inner boundary, what's the boundary condition here? And how is it made consistent with reality? The temperature difference across the inner core seems to be constant during the whole simulation. What is the justification for that? As the inner core radius grows significantly through time, and it cools as well, I don't see any particular reason that this will stay almost the same.

3. Ep.(8) and p.3823, l. 1-4 "The heat source associated with solidification of the inner core are ignored because these effects play a secondary role in the growth of the inner core (Buffett et al., 1992)". This isn't correct. Buffett et al., (1992) keeps the latent heat

SED

7, C1854–C1856, 2016

Interactive Comment

and gravitational energy terms in their equation, and most other research keep them as well. For example, in core evolution models from Gubbins et al. (2003), Nimmo et al. (2004), the latent heat plus gravitational energy is larger than the specific heat term for present day Earth. These research also show once the inner core starts to freeze, the core temperature dropping rate decreases significantly. So this isn't a secondary effect that can be ignored.

4. The gravity acceleration seems to be treated as a constant in this study. Different from the mantle, the gravity acceleration should be almost linearly increasing from 0 at the centre to ~4.4 m/sˆ2 at the present day ICB (e.g. PREM model). I would expect depth dependent g will have some influence on the convection that should be considered.

5. Although model uncertainties of CMB heat flow and inner core age are mentioned in the discussion, the heat flow is assumed to be constant in this study. Moreover, only low CMB heat flow and a slowly growing inner core with an age of ~4.5Gry are tested in this study, which are extreme cases rather than "realistic" ones. As mentioned in the discussion of this paper, there are many studies that suggest larger CMB heat flow and younger inner core age. And the CMB heat flow may have a significant variation through the whole Earth's history. Whether the fast growing inner core leads to a different flow pattern or not needs to be explored. So, I would like to suggest an additional test model with fast growing inner core.

Technical correction:

p. 3821, l. 15 "g" should be g0

I hope these comments/suggestions will be found useful by the author when preparing a revised version of the article.

Interactive comment on Solid Earth Discuss., 7, 3817, 2015.