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Interactive comment on "Global scale modeling of melting and isotopic evolution of Earth's mantle" *by* H. J. van Heck et al.

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Review comments for a discussion paper by van Heck et al. given by Takashi Nakagawa

Main

This paper was described for the implementation of partial melting process and fractionation of isotope in a convecting mantle into numerical code of thermo-chemical mantle convection code 'TERRA' and shown some numerical examples with authors' implementaion. The technical procedure for implementing the partial melting and isotope fractionation seems to be similar to that from Xie and Tackley [2004]. However, authors tried to reveal the mechanism on their pseudo-isochron with Rudge [2006] be-

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cause Rudge [2006] tried to figure out what happened the pseudo-isochron provided from Christensen and Hoffman [1994] and Xie and Tackley [2004]. Applying Rudge's approach, it is a good attempt. As a result this paper would be taken an advantage from Xie and Tackley [2004] and Christensen and Hoffman [1994]. It would be interesting to me. In spite of authors' great effort for implementation of partial melting process into numerical mantle convection simulations, there were several unclear statements that should be addressed by authors for their revised paper. The biggest issue for this paper is the treatment of initial condition of their mantle convection simulations because authors' statement is not quite clear. The second biggest issue is how tracers can hold the information of melting. In the paper, I did not find out how to hold the information of melting in each tracer. Can the tracer erupt to the surface to create the oceanic crust at the surface? Looking at Figure 1, the basaltic stuff can be only created from depletion of ambient mantle material but not erupted to the surface to create the oceanic crust. If so, that is quite disadvantage with Xie and Tackley [2004] and a series of publication on the degassing of noble gas done by Peter van Keken. Since the eruption event is very important for addressing with degassing of He, Ar or other noble gasses as well as greenhouse gases, the authors should clarify how to address with melting information for each tracer. In conclusion, I would recommend revising this paper with more clarifications in the section 2 (Model description) as readers could understand more comprehensively.

Detail

l.18 to l.19 of Page 3: A statement of 'This makes melting a first order ... numerical code' is not quite clear to me. The paragraph including this sentence describes about how the partial melting is important for the geochemical heterogeneity in a convecting mantle. I feel a bit odd for such a statement in this paragraph. To connect the next paragraph much smoother, this type of statement should be described in the last sentence of the paragraph.

A paragraph starting from l.24 of Page 4: I did not quite understand this paragraph

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entirely. As far as I understood, the authors describe the necessity on the benchmarking of thermochemical mantle convection with isotope tracking. Rudge [2006] actually tried to find analytical solution for understanding pseudo isochron provided from mantle convection simulations. However, this is a bit odd either before the paragraph starting with ' In this paper. . .'. I recommend dropping this paragraph from revised version because authors stated the last sentence in the paragraph starting from 'In this paper. . .' as 'Though this, we validate our implementation' That seems to be enough but not clear to the reader. I also recommend adding some reason on validation of authors' implementation, that is, 'with analytical approach (Rudge, 2006)' to the last sentence of introduction section.

Title of section 2.1 should be 'Numerical mantle convection simulations' As far as I understand, TERRA has been only used for mantle convection simulations.

Equations 1 to 3: It seems to me that authors solved isochemical mantle convection numerically? Tracking tracers for basaltic and ambient mantle compositions, it is equivalent to solving the advection equation. Please add the advection equation for chemical composition.

l.3 to l.11 of Page 7: I do not quite understand what authors' initial condition of mantle convection on temperature, composition, melt fraction and velocity is. With authors' statement, assuming 3.6 Ga in the Earth's mantle, the initial condition of mantle convection would be very vigorous and huge amount of partial melting occurred. It seems to me that authors uses their initial condition is well-developed thermal or thermochemical convection without melting. Is that correct? Alternatively, is the initial condition similar to Xie and Tackley? Owing to such an unclear statement in this paragraph, I recommend describing the initial condition assumed by authors more specifically.

Section 2.6: This is an explanation of how to address the partial melting for TERRA. I think that this section should be described in the earlier than trace elements fractionation because trace element fractionation is strongly related with the melting process.

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Thus, Section 2.6 should be moved before the section 2.4. Moreover, as I mentioned before, I do not find out how to hold the information of melting in each tracer particle. If so, please provide information clearly. Otherwise, authors should say 'tracers can only track the solid composition' and 'the partial melting can only address with the thermo-dynamical formulations'. Because the entire explanation of section 2.3 is not quite clear to me.

Regarding section 2.6 again, it seems to me for authors not to implement the erupting process in authors' partial melting process. However, as I mentioned before, the eruption process is important for addressing the degassing process of noble gas release into the atmosphere. Please explain the reason not to address the eruption process in the code.

Looking at Eq. (7), do tracers track the temperature as well? I did not understand how to derive Eq. (7) from Eq. (6). It seemed to be based on formulation by Xie and Tackley [2004]? Is it true? In conclusion, I did not understand what the authors wanted to describe in the section 2.6. Please clean them up for more comprehensive explanations.

Figure 2: Is the solidus temperature used by authors comparable for melting experiments in the upper mantle? Solidus temperature is quite important for understanding melting process. It would be needed to explain the applicability of authors' soludis temperature with melting experiments.

Eq. (8): I guess that this is based on the partition of isotope composition into the melt. However, this is not quite understandable by itself. Please provide the formulation of partitioning of trace elements such like provided by Christensen and Hoffman [1994] then show the authors' numerical assumption.

Section 4 (Discussion): It would be good to discuss the model limitation of authors' simulations but it would not be enough. I guess that authors could discuss the comparison with other numerical model addressed with the isotope fractionations. Please

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discuss it because it is important for readers to understand what happens in authors' simulations.

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