

Interactive comment on “Thermal structure and intermediate-depth seismicity in the Tohoku-Hokkaido subduction zones” by P. E. van Keken et al.

T. Yamasaki (Referee)

t.yamasaki@leeds.ac.uk

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1. GENERAL COMMENTS

This is an interesting study that develops a 2-D thermal model beneath Tohoku and Hokkaido subduction zones for testing whether or not the blueschist-out phase boundary corresponds to a depth below which the upper plane slab seismicity is delimited and whether or not thermal shielding due to the subducted fore-arc crust modifies locations of the phase boundary. The method used in this study is fairly standard, but it is attempted to predict a realistic thermal structure as much as possible, using a finite element model that is composed of very fine meshes, that has geometries of

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the subducting slab and overriding crust interpolated from its 3-D structures and that has a combined diffusion-dislocation creep rheology in the mantle wedge. The phase boundary predicted from the calculated thermal structure shows a good correlation with the slab seismicity beneath Tohoku and Hokkaido regions. Contrarily, a significant inconsistency is found beneath the junction between the two regions, implying that the shielding effect has less impact than expected in Kita et al. (2010a). This is very important outcome, identifying the problem which should be investigated furthermore in the future. I therefore would like to see this work published, but there are some comments that the authors should consider and address in the manuscript before publication.

2. SPECIFIC COMMENTS

(2-1)Page 1072, lines 18-19: Please explain what physical parameter value is interpolated by means of a method described in Appendix A.

(2-2)Page 1072, lines 19-20: Why “a simplified Moho” is used in this study, not using the Moho structure that is well imaged in receiver function and tomographic studies (see lines 4-7 on page 1071)?

(2-3)Page 1072, lines 23-25: “a combined diffusion-dislocation creep rheology” is adopted for the mantle wedge. It is essential to show rheological parameter values of dislocation and diffusion creeps used in this study. Please also explain a grain-size distribution in the numerical model and whether or not the grain-size has a time-dependent evolution (because grain-size is the principal parameter controlling diffusion creep).

(2-4)It is also essential to show thermal parameter values used in this study.

(2-5)Please explain the mechanical and thermal boundary conditions on all the four boundary surfaces.

(2-6)Please explain whether or not steady-state solution is obtained for the thermal structures demonstrated in this study.

(2-7)Page 1074, lines 19-23: Suggest explaining where in the model space “strong

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thermal gradients” are obtained. Only the statement “below this depth” is not enough.

(2-8)Page 1075, line 4: Please explain how P in Eq. $T = 617 - 52P$ is evaluated, showing density values used in this study. I do not know how much ambiguity can possibly be present for the assumed boundary and how the ambiguity (if it is present) helps us to fix the inconsistency between the phase boundary and the seismicity beneath the junction between the northern Japan and Kurile arcs.

(2-9) The slab geometry may possibly be defined so as to obtain the upper plane seismicity just below the slab surface, which would explain the inconsistency found beneath the junction.

(2-10)Fig. 7a: The predicted surface heat flow is much lower than that observed in the junction between the northern Japan and Kurile arcs. Several possible factors can be considered, including (i) much more fore-arc crust has been subducted than expected from seismic tomography, (ii) thermal conductivity of the sliver may be lower, or (iii) 130 Ma age may be appropriate for the subducting Pacific plate (e.g., see Fig. 7b: lower seismic plane, where thermal influence from the wedge mantle seems to be minor, almost exactly corresponds to the ~ 600 degree isotherm), but 30 Ma age may be too young for the other side boundary.....

(2-11)Fig. 7b: Please explain the condition under which the thermal structure is calculated: what the full coupling depth is and whether or not the subducted fore-arc crust is present?

(2-12)Fig. 7c: Suggest showing the model result obtained under a condition that the fore-arc crust is subducted (so-called modified cross-section in the manuscript) and the full coupling is assumed below 80 km depth, with which the effect of the subducted fore-arc crust can be understood in a systematic way, and deleting the model with “full coupling at 90 km”.

(2-13)Page 1077, lines 9-11: Suggest providing physical interpretation on deepening

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the blueschist-out boundary with deepening the full coupling, explaining why “the match with seismicity does not improve significantly”. The blueschist-out boundary is deepened only in a direction parallel to the slab surface, though the seismicity deepens in a direction perpendicular to the slab surface.

(2-14)Page 1078, lines 11-14: Does the following statement simply come from the model result that the predicted phase boundary does not fit with the seismicity distribution?: “....the suggestion that the presence of fluids (presumably released by the blueschist-eclogite phase change and at least partially transported back up the slab) is more important than dehydration embrittlement itself.”

(2-15)Page 1078, lines 14-16: What effects “a negative Clapeyron slope” has for resolving the inconsistency? Please explain.

(2-16)“4 Discussion”: Suggest improving the discussion so as to clearly explain the relevance of 3-D subduction dynamics to the inconsistency particularly found beneath the junction between the northern Japan and Kurile arcs. What is necessary for resolving the inconsistency may be to avoid heating the subducting slab (a cold source is only the subducting slab itself). However, the arc-parallel deformation predicted from 3-D geodynamic modelling may bring about only additional heating of the slab as it is well known that a hotter material has more mobility. In addition, the authors should know that the arc-parallel deformation may also disturb that good correlation between the phase boundary and the seismicity beneath the other regions.

3. TECHNICAL CORRECTIONS

(3-1)Reference “Yamasaki and Seno (2003)” has not been cited in the text. Suggest deleting it from the reference list.

(3-2)Reference “Kita et al. 2010” in Fig. 7 is not included in the reference list. Suggest supplying the publication detail or amending the year to be “2010a”, “2010b”, “2006”, or “2012”.

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(3-3)Fig. 3: Suggest drawing the modified crustal structure (overriding crustal structure with the subducted fore-arc crust), as well as the unmodified crustal structure (overriding crustal structure without the subducted fore-arc crust).

(3-4)Figs 4-7: Suggest drawing lines (may be green-coloured) for indicating Moho in the subducting slab in Fig. 4b, Fig. 5, Fig. 6, and Fig. 7c.

(3-5)Fig. 4: Clarify the meaning of “the arc” (volcanic arc?). Check the scaling of heat flow (ticks are not uniformly distributed) in Fig. 4a. Please provide the interpretation on a solid line in Fig. 4b that obviously is not temperature contour.

(3-6)Figs 5 and 6: Green-coloured line is suggested for indicating the top of the slab, keeping along with Figs 4b and 7b.

(3-7)Fig. 7: Check the scaling of heat flow (ticks are not uniformly distributed) in Fig. 7a. Please provide the interpretation on a solid line in Fig. 7b that is clearly not temperature contour. Green-coloured line is suggested for indicating the top of the slab in Fig. 7c.

Tadashi Yamasaki

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