Interactive comment on "Three-dimensional thermal structure of subduction zones: effects of obliquity and curvature" *by* A. K. Bengtson and P. E. van Keken

A. K. Bengtson and P. E. van Keken

keken@umich.edu

Dear Ikuko,

Thank you for your comments and questions. We have improved the manuscript following your suggestions and provide our response below.

Peter van Keken and Amy Bengtson

In the models, the flow and thermal fields in the mantle wedge are influenced by where the back-arc vertical boundary is placed relatively to the slab (i.e., the distance from the back-arc vertical boundary wall to the slab). Could the higher mantle temperature

in the northern- and southern-most regions in Fig. 5a, for example, be caused by the proximity to the back wall? Also, in the case of oblique subduction at a curved margin (Fig. 5b), the mantle that overlies the northern slab has travelled a significantly longer distance from the back wall than that overlies the southern slab before it comes in contact with the slab. Could this also be contributing to the cooler condition at the slab surface in the north?

Those are great questions - they address the role of boundary conditions on wedge flow and thermal structure. There are three reasons why we consider that the location of the boundaries has a secondary effect on the thermal structure of the slab. First, when we developed the subduction zone benchmark (van Keken et al., PEPI, 2008) we had an extensive discussion about this. Using a direct comparison between the codes that were supplied by Claire Currie (the PGC code that is also used in Wada and Wang, 2009), Scott King (Conman) and ours (Sepran) we found that the role of the arc-side boundary condition on slab thermal structure relevant for arc volcanism (100 km depth) was unimportant as long as the model was deep enough (>250 km depth) and the slab exited through the lower boundary (i.e., the lower boundary has at least a small portion of the wedge). We attributed this to the fact that the wedge flow is dominated by the suction force towards the point where the slab couples with the wedge. In the case of temperature-dependent viscosity the drag by the slab draws in the warmest fluid along the most efficient route and we think that this also helps minimize the influence of the arc-side boundary. These considerations, in part, led to the development of the benchmark geometry, which is also used here, with some modifications. In the case of the curved geometry used here the closest proximity to the arc boundary is at the edges, and the slab is further away from the arc boundary condition in the interior. We therefore expect that any consequences of the distance to the back wall are mitigated by the dominance of the slab drag and resulting suction force.

Second, from the comparison shown in Fig. 6 we see a similar shift at the Moho as

we do at the slab surface. If the slab surface would be colder primarily because it gets in contact with a cooler wedge we would not see the same shift at the Moho, at least not until at much greater depths as the temperature effect at the slab surface needs to diffuse down into the slab. Since the Moho and slab are both colder at the same depths it is clear that this is due to advection of material in the slab through the cross-section, which is not captured in the 2D model.

Third, we repeated the model for the Southern Marianas in Syracuse et al. (2010) for a wedge that was 100 km longer. This mimics the conditions that some wedge material may see by extending the path that it travels from the boundary before it sees the top of the slab. For the time-dependent models with olivine dislocation+diffusion creep evolved to 40 Myr we found a difference of 1.5 K along the slab surface at 4 GPa, suggesting the effect of the boundary condition on slab surface is minimal in these models.

Page 920 Line 13 For consistency and clarity, it is better to use "curved trench" instead of "curved subduction". Page 920 Line 24 ")" is missing. It should be "Wada et al., 2012)". Page 921 Line 19 I suggest "rheology" instead of "properties" since T- and stressdependent properties of the wedge can include properties such as thermal conductivity and density. We have modified the text following these suggestions.
Page 920 Line 22 It should be "van Keken et al., 2011" instead of "van Keken et al., 2012". We had intended to list van Keken, Kita and Nakajima, this volume here; it got confused in the type setting of the discussion paper and I didn't catch that it didn't make it into the references.

Page 922 Line 27 Could you specify what "geochemistry" (e.g., geochemistry of arc lavas). Page 923 Line 18 Could you clarify what "either domain" is referring to? Page 923 Line 22 Remove "T is the temperature". Page 924 Line 4 Change "potential mantle temperature" to "mantle potential temperature". Page 926 Line 15 "that it should be taken" is unneeded. Perhaps, change "structure" to "the trench" for clarity. Page 927 Line 9 Shouldn't "parallel to strike" be "normal to the strike (of the trench)"? Page 927

Line 24 Insert "a" in front of "curved trench" Page 927 Line 27 (Fig. 2) Is "the normal velocity on the sides" referring to the velocity normal to the side (i.e., vy)? If so, "v=0" in Fig. 2 should be "vy=0". Could you clarify what "v=0 slab and wedge sides" means in Fig. 2? Page 928 Line 18 Could you clarify what "the intersection" means? Page 928 Line 26 The sentence "Variations are : : :" applied to the case with theta = 0. Could you specify this in the sentence? Fig. 1. Caption Line 3 "angle" is unneeded. Fig. 3 and Fig. 4 The figures are switched (and thus not matching with the captions). Fig. 5 Does the arrow length represent anything? Units are missing from the colour bar. We have modified the manuscript using these suggestions and corrections.