Solid Earth Discuss.,
https://doi.org/10.5194/se-2020-134-RC1, 2020

Interactive comment on "Thermo-mechanical numerical modelling of the South American subduction zone: a multi-parametric investigation" *by* Vincent Strak and Wouter P. Schellart

Anonymous Referee #1

Received and published: 15 September 2020

The work by Strak and Schellart uses numerical models to study the South America subduction zone. They compare their models results with data from South America using a ranking system to find which values of the studied parameters work best to fit the natural case. The manuscript is well written and the figures are clear, however I have troubles understanding the logic behind the study because I believe there is an important flaw at the base of it (see first comment below).

Major points In this study, the South America subduction zone is treated as if its characteristics (those used to rank the models) are the same everywhere along trench. This

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Discussion paper

is a huge assumption that I believe really affects the conclusions. Fig. 3 for example shows changes in trench and plate velocity with single lines, are these averages along the whole length of the trench, or are these taken along a specific section? If the latter is true, then which section is it? This is extremely important because, as the authors show in Fig. 2, there are large variations along trench. For instance, the slab is not flat everywhere, but there are only 2 regions where this is the case. Importantly, along section BB' the slab is not flat and this is where the positive anomaly in the lower mantle is higher (meaning that the slab pile is more clear, following the reasoning of the authors). In fact, the other two sections, where the slab is flat, do not show the same large anomaly in the lower mantle. How does this reconcile with the main conclusions and, more generally, with the philosophy of the study? In other words, this study tries to find the best 2D model that fits as many criteria as possible with the natural case, but in South America the criteria themselves are not all present in one single 2D section of the subduction zone. So, what is the point of finding a model that fits everything, when even in nature this is not the case? I used the slab dip and the slab pile in the lower mantle as examples, but also the other criteria (like the subducting plate velocity and the trench velocity) are not the same all along the trench.

Another important point is that the conclusions of this study are based on the comparison between models and data according to 9 criteria. However, at the moment, these criteria are mostly qualitative. How is the progressive reduction of trench velocity computed? What is the 'acceptable' range/error of flat slab portion length to have a rank of 1 or 2? The same goes for all criteria: what the authors define 'somewhat comparable' and 'very comparable' is subjective. I suggest to add a table in which the values of these criteria are clearly stated both for the models and for the data the models are compared with. And then again, some models might better fit one section of the subduction zone, but others that do poorly in that section might be better at fitting another section. I am not sure what we can learn from this though.

About the flat slab. The authors state that there is no need to add external forces or have a buoyant body to have flat slab and that slab flatting can happen dynamically as a consequence of a progressive decrease of the slab dip (lines 438-443). Then one might wonder why are there only two portions of flat slab along the South America subduction zone. Why is the slab not flat along section BB' (Fig. 2)? Moreover, these models do not take into the presence of buoyant bodies in the subducting plate (which it cannot be denied it is the case in the Nazca plate with the ridges entering the subduction zone), so the question is how would the results and conclusions change if a more realistic subducting plate would be modelled?

40-44: I find the objectives of the paper very vague, they could fit with any paper that presents a parametric study. I suggest to be more specific about which features of the South America subduction zone the authors are trying to explain/understand with this study. For example, in the first sentence of the introduction it is stated that this subduction zone is enigmatic because of the orogeny formed with an oceanic subduction, but this study is not really addressing this issue. Instead, paragraph 2.5 is describing the features that are then compared with the results. To me, it makes more sense to move this paragraph in the introduction, but the authors should also add an explanation on what it is about these specific features that is not yet understood and what are the main research questions related to these features they are trying to answer.

243: from Fig. 3a it seems more that the gentle decrease in vT (between 2.5 and 2 cm/yr) is only until about 12 Ma, then there is a clear step to 1.5 cm/yr and the trench velocity remains more or less constant. Given that this is one of the thing that decides the final ranking of the models, how does this affect the results? Again, having a table with quantitative values for each criterion would help.

The amplitude of oscillation in vSP is also something that the authors look at in the models, however this is not described in paragraph 2.5 at all, but it starts to be mentioned only in the results and discussion. Describe the natural range.

The viscosity jump between upper and lower mantle has a major control on the slab bending, piling and flattening. And slab piling and flattening is the main focus of this study. However the viscosity jump is not a parameter that is investigated. 100 is a commonly used value, but it is also an end-member. Often, other numerical studies use 30 as a viscosity jump. How do the authors think a lower viscosity jump would affect their results? I would like to see a model with a lower viscosity jump and see the effect on slab piling and flattening.

Other minor points 128: Does the assumption of a neutrally buoyant OP affect the overriding plate deformation?

The overriding plate is 60 km thick for about 1000 km from trench. How does this compare to South America?

196-198: is it only the viscosity of the slab that is affected by the thermal weakening? Or is it also the viscosity of the mantle? One of the reasons for this question is also because in Fig. 12 there are ‘blue’, thus very weak, regions around the slab in the lower mantle. It seems to be a consequence of numerical instability, is it?

291-292: the subducting plate does not seem to be entirely consumed in Fig. 6f, why does the model stop?

Fig. 6 only show two of the models with different A, I suggest to show the dynamics of the other two models (or at least a final snapshot) in the supplementary material.

374: “the higher E’, the quicker the flat slab is attained”. Or is it simply because subduction is faster, but the amount of convergence is the same?

729: then why is the natural range in figures (blue area) only going between 6 and 10 cm/yr?

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