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Solid Earth
Discussions

Interactive comment on "Effects of basal drag on subduction dynamics from 2D numerical models" *by* Lior Suchoy et al.

Anonymous Referee #1

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General comments Suchoy and co-authors use numerical models to study the effect of basal drag on subduction dynamics and uses them to explain the lack of plate velocity-size correlation. The manuscript is well written and the models are well constructed. Overall, I think this is an interesting study that deserves publication after minor revisions.

Specific comments Many times in the introduction the authors talk about the viscosity of the asthenosphere and the ratio between lithosphere-asthenosphere viscosity as 'high' or 'low' or 'too low'. Since this is a crucial part of the paper, I think the author should describe this in a more quantitative manner (i.e., mention some estimates with actual numbers suggested by the cited literature). This is true also throughout the rest of the manuscript, even in the results where the viscosity values are easily to extract from the

models (e.g., lines 223-224). The same for the conclusions: e.g. line 441-443 "Models with a low-viscosity asthenosphere do reduce the contribution of trench motion to plate convergence to more Earth-like values, as observed in previous studies". How low? Which values range are we talking about?

Following the previous point, I would be curious to see the evolution of the viscosity of the asthenosphere in Fig. 4 (or in the Supplementary). The reason for this is that I have a few doubts on (1) the effect of the used methodology and (2) the effect of plate velocity on the viscosity of the asthenosphere and a figure that shows it would likely clear them out. In particular: (1) Regarding the methodology. The viscosity of the asthenosphere is weakened by multiplying the computed viscosity by a factor of 0.5. However, the computed viscosity is a combination of diffusion, dislocation and Pierels creep, thus, it is strain dependent. When lowering the viscosity by a factor 0.5, the stresses in the asthenosphere will be lower too and the viscosity will want to be higher again at the next time step. Is that what happen? Or does it more or less stabilize? (2) Several times the authors say that because the velocity of a plate increases then the basal drag increases too. However, wouldn't the viscosity of the asthenosphere decrease with high plate velocities due to larger deformation? If so, the basal drag would decrease too or is there something else in Eq. 1 that also changes to compensate a decrease of EtaAst?

I do not fully understand the reasoning in the Discussion about the correlation between plate size and age at the trench (Fig. 8B). A larger plate would have ridges further away from trenches (e.g., Pacific vs. Cocos) and therefore more likely to have older lithosphere at trenches, could it not be 'that simple' without the need to use the basal drag as explanation?

The authors should discuss how their results and conclusions could be affected by viscous anisotropy? From Becker and Kawakatsu, GRL, 2011: "One of the major limitations of our study is that we only considered a few instantaneous flow examples for which the influence of anisotropy may overall be negligible. This only indirectly addresses more complex, evolving scenarios such as changes in plate motions, or plate boundary dynamics, where mechanical anisotropy may well be relevant." Viscous anisotropy has the potential to have an important effect when looking at plate velocities during the Cenozoic as the authors do here because changes in plate motion direction would change the orientation of the anisotropy and could contribute to change the asthenosphere viscosity (hence, basal drag). I understand that this cannot be included in the calculations, but I think it deserves to be mentioned and discussed.

I think the first paragraph of Conclusions belongs to the Discussion. Consider moving it there.

Eq. 1 and 2. How is the lithosphere defined? Is it defined by the 1100 degC isotherm? Please specify it, since it matters for parameters like hLit, hAst, and Sslab. (I found the answer later on in the lines 144-145, but the authors might want to either repeat it or move it here where the variables of the equations are explained). At what depth is Sslab taken? And is it an horizontal section or perpendicular to the slab? Given the importance of these calculations for the study, I would suggest to have a figure with a schematic cartoon of a model showing where and how all the variables used in Eq. 1 and 2 are taken. It could go in the main manuscript, in the supplementary material, or merged with Fig. 2.

Table 1. Why is the slab pull force (and the basal drag) for the Cocos plate one order of magnitude larger than for the Pacific? Shouldn't it be the opposite? Please check your calculations. U is the plate velocity, what is deltaU (used in Eq.1)? S should be Splate (as referred to in the text). Is Vslab = Sslab*Ltrench or Sslab*Ltrench*Wslab?

Fig. C1: at the moment this figure is confusing. A better layout could be with each column showing a parameter. And also using more distinct colormaps for age and subduction velocity (now they are very similar). Also the colours of the different subduction zones are different from those used in the other figures (Fig. 1, 8, C2). When possible, I would suggest to keep them the same.

Technical corrections Line 331: odd sentence, rephrase. Line 338: Other approximations in addition to what? Line 401: "tend to be mostly fall around..." delete 'be' or 'fall'

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