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Interactive comment on "The Subduction Dichotomy of Strong Plates and Weak Slabs" *by* Robert I. Petersen et al.

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Referee #1 enumerates 2 points to address.

The first that slab weakening is imposed at the, too shallow, depth of 10km below the overriding plate. Our paper presents two figures which compare two sets of models that address this concern. Figure 8 show three models with equal strength 80km thick plates and maximum slab viscosity of 1e25, 1e24, 1e24 Pa s. The figure shows that from the surface to a depth to several hundred kilometers the slabs have a substantially similar morphology. Contrastingly figure 9 shows three models in which the strength of the 80km thick plates is varied while the slab strength at depth is equal across models. The maximum viscosity of the surface plates in 1e23, 1e24,and 1e25 and the subducted slab strength is 1e23. In this figure the the morphology of the subducted slabs differ in the shallow part of the mantle (to several 100km) while the portion of the slab lying above the lower mantle across all models is substantially similar. We would assert that the shape of subducted slabs in the shallow upper mantle is controlled by plate strength and the shape of the subducted slab deep into the upper mantle is controlled by the subducted slab strength if not fully independently then at least to a very high degree. While we believe that it would be an interesting exercises to systematically modify the depth of weakening to discover the degree to which these mechanisms are, in fact, independent the results of this study do not suffer due to the chosen depth of weakening.

The second point raised by the referee questions the cohesion parameter of 150 MPa. The use of 150MPa limits yielding below the crustal layer increasing plate strength. As our models do not use an imposed weak zone, nor do they limit the weak crust to the subducting plate, as is found in other studies, the high cohesion serves to strengthen the overriding plate. Yielding is focused in the hinge of the subducting plate. This is can be seen in the figures that plot viscosity, e.g. figure 8, figure 10 models 14 and 16, and figure 11. The value that we use for this parameter, 150 MPa, is the same as that used by other studies that generate a distribution and fragmentation of tectonic plates similar to Earth (Mallard et al., Nature 2016).

The referee compares our model 18, a model with no weakening, to tomographic observations below Tonga, suggesting that no weakening in required to support observations. Pysklywec et al, EPSL 2003 (doi:10.1016/S0012-821X(03)00073-6), using the tomography model of van der Hilst et al., Nature 1997 (doi:10.1038/386578a0), model an avalanche scenario for the Tonga slab using an initial condition that is similar to the evolved state of model 18 as shown in figure 8. In other regions tomographic interpretations suggest piling or buckling or slabs. Under the Izu-Bonin and Mariana convergent zones van der Hilst and Seno, EPSL 1993 (doi:10.1016/0012-821X(93)90253-6), have suggested that the subducted plate has piled. Ribe et al., EPSL 2007 (doi:10.1016/j.epsl.2006.11.028), draw comparisons between analytic and

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numeric models of viscous sheet buckling instabilities and tomographic models of this Cocos plate beneath Central America, and of the Australian plate beneath Java. They identify large wedge-like structures which they interpret as "'piles' of folds generated by buckling instabilities in the transition zone". Therefore, the same strength of slab that can match observations of Tonga cannot match observations of Marianas, and this is why we model systems with a weakening mechanism with a range of various magnitudes. It is this range that gives rise to models that behave as both "strong" slab systems comparable to the Tonga trench and to "weak" slabs systems that buckle and pile comparable to the Cocos, Australian, Izu-Bonin and Mariana subduction systems.

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