Review of Slab Break-offs in the Alpine Subduction Zone by Emanuel D. Kästle, Claudio Rosenberg, Lapo Boschi, Nicolas Bellahsen, Thomas Meier, and Amr El-Sharkawy

The manuscript compares different body-wave tomography studies of the Alps, which have different geodynamical interpretations. They use a recent surface wave tomography from Kästle et al. (JGR 2018)as a basis for discussion of these interpretations. The authors conclude on the presence of slab break off in the western and eastern Alps, and a continuous slab in the central Alps.

I have some major comments to the manuscript.

1. The first one is that the discussion does not bring much new on the table as compared to the Kästle et al. tomography (JGR 2018). The different tomographies and their interpretation are present in various manuscripts, and as I see it, the discussion of the present MS is already quite similar to the one in Kästle et al., 2018. For an in-depth discussion, the tomographies, including the surface wave tomography, would need to be transposed to similar scales and the Kästle et al. model should be added to Figure 2. I have for my own use, made a composite figure that combines Figures 1 and 2. It would seem at a first glance that the Kästle model overall has more agreement with the Zhao et al. model and/or the Koulakov model than with the Lippitsch et al. model – but it is really difficult to compare when the regional average at each depth has not been subtracted at each depth.
2. The second issue concerns the resolution of the surface wave models. The Alpine slab geometry is fully 3D, and in the western part of the Alps it may well be the most complex mantle geometry in the world at such a small scale. Indeed the structures are laterally small, and the crust particularly complex because of the Ivrea body and the proximity of the very deep Po Plain. At ~100 km depth, the wavelengths used are of the order of 400km (periods of approx. 100s). Care should therefore be taken at interpretation of spatially narrow (~50km-100km) areas of velocity reductions at this depth. I read the original Kästle (JGR 2018) paper and there are indeed checkerboard tests, albeit at much shorter periods. If we assume great-circle propagation, I would assume that checkerboard tests would perform well also at long periods, however these tests don't take into account the very complex wave propagation across the Alps. There is quite a lot of research that has taken place to better understand the complexity of surface wave propagation in heterogeneous structures, and even though the large amount of data used helps to improve resolution, it is optimistic to interpret anomalies as small as 10%-25% of the wavelength. Using dedicated small scale arrays is one option, but a limit of 10%-20% of the wavelength still applies (see for example Bodin et al., 2008). Also, recent work by Kolinsky et al. demonstrate that the surface wave propagation in the greater alpine area is complex, also at long periods. While these problems can probably be neglected for relatively large scale structures, they cannot be ignored for small scale structures, which should consequently be treated with utmost care and possibly not be interpreted.
3. The Ivrea body makes all types of tomography very difficult indeed, as errors on the very complex 3-D crustal model can leak into the mantle in various forms. A good example of such problems is Beller et al. (GJI, 2018) who observe an anomaly which could be the continuation of the European crust, or alternatively low velocity mantle material, indicating slab breakoff. With crustal material that extends to at least 80km, surface wave inversions may additionally have crust/mantle tradeoffs that go as deep as 100-120km.
4. In the eastern Alps, the size of the structures is bigger, so better resolved. The slab breakoff is in that case attributed to a decrease of positive velocity anomaly at approximately 100km

depth, decrease that is found to a larger or smaller extent in many parts of the model. What I don't quite understand is why this velocity decrease is taken as a slab breakoff, when such a decrease is present, but not interpreted, in other parts of the model. Perhaps this can be explained by further text – it may be an issue of 3D geometry only? At a minimum the reader needs more help.

5. The Kästle model (JGR 2018) could at that time not take advantage of the more recent models which include AlpArray data, but a re-inversion using an updated and more detailed crustal model would at this point be a valuable addition to the 2018 article. As an example, the interpretation of surface wave dispersion by Lyu et al. (GJI, 2017), using a very detailed crustal model and higher resolution due to the use of a set of dense networks, does not indicate a slab breakoff. Note that the Lyu et al. paper made the transposition of surface wave data onto a body wave tomography type representation and would make for an interesting comparison for this MS.

Minor comments

a. I disagree that the uplift is due to slab breakoff. Indeed, a recent article by Sternai et al. (Earth Science reviews 2019) demonstrates convincingly that the uplift has too small lateral extent to be explained by any of the present models. Note that this MS is recent so may not have been known to the authors.
b. If possible, it should be made easier to compare figure 1s and 2, in terms of the denominations. For people not very aware of Alpine 3D geometries, it is quite hard to figure how to compare items with different names. It will in any case help to combine the models of Figures 1 and 2, but aligning vocabulary might be useful?

Attempt at composite image Figures 1 and 2