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Interactive comment on "Density distribution across the Alpine lithosphere constrained by 3D gravity modelling and relation to seismicity and deformation" *by* Cameron Spooner et al.

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General comments The paper presents an interesting attempt to produce a 3D density distribution in the Alpine lithosphere, constrained by gravity modelling and by a wealth of geophysical data, mostly taken from the literature. The modelling results support the occurrence of differences in crustal thickness and density between the European and Adriatic domains, including the units now stacked in the Alpine belt, which are inferred to maintain a specific density characterization that reflects their provenance. Partly comparable results showing differences in thickness and density between the European and Adriatic crust were presented in a previous study, although carried out

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along a transect (TRANSALP; Ebbing et al., 2006, Tectonophysics) and not presenting a 3D picture. That work, however, should be cited at some stage. In spite of the uncertainties in precisely locating the density distribution using gravity modelling, the results are in many aspects convincing and stimulating when compared to the geological interpretation of the Alpine structure. The presentation of the results and the Discussion sections are very essential and could be expanded a little in order to compare the results with other works and to give some hints on the potential implications for the tectonic evolution of the Alps. Some issues that may be worth expanding/commenting further are listed in the Specific comments below.

Specific comments lines 47-49: modelling indicates that the crust is thinner in the Po and Molasse basins, where sedimentary depocenters are present, and in the Rhine Graben. Whereas crustal thinning occurred in the Rhine Graben in late-post Alpine timing, the Po and Molasse basins are produced by flexure, mainly due to the load of the adjacent mountain belts (Apennines and Alps, respectively). The thickness of the crust is not affected by plate flexure; the crustal thinning should therefore be considered an inherited feature. lines 207-208: perhaps some comments on the comparison of the results with previously published Moho maps (e.g., Ziegler and Dezes 2008, Geol. Soc. London; Spada et al., 2013 GJI) could be useful. lines 217-219: interestingly the two areas of negative residual anomaly in Fig. 6b seem to have some geological relationships. The western one partly follows the Ivrea zone, and the eastern one is over a basement high that existed since Late Permian-Triassic (see Masetti et al., 2012 AAPG). Perhaps the authors have some comments on this fact, that doesn't look random. lines 231-235: the average density of the crust result from the integration of a column of rocks where different units are stacked one on top of the other; the domains cropping out at surface not always continue at depth, as illustrated in many of the geological cross sections across the Alps (e.g., Schmid et al 2004). The relationship between average density distribution and tectonic domains may not always be straightforward, and this should betaken into account, lines 246-248: the Molasse foreland basin originated by flexure of the European plate under the Alpine load, and that was independent from the inherited along-strike difference in crustal density. Present-day vertical motions could represent a post-orogenic isostatic adjustment, but the Austrian sector of the Molasse is an undeformed basin, whereas a detachment connected to a thrust front located north of the basin underlies the western Molasse; an active involvement of the basement has also been suggested in the region of the Jura mountains (e.g., Mock and Herwegh 2017 Tectonics), and this could contribute to positive vertical motion. The authors also mention a difference in the density of sediments between the western and eastern Molasse basin; however, the difference in density between the two sedimentary domains is rather small: is it enough to drive a differential vertical motion? line 250-251: the distribution of earthquakes with M>6 and max. horizontal strain is rather limited spatially. They are mostly located at the thrust front of the Southern Alps which represents the active southern boundary of the Alps, as also supported by focal mechanisms (see Serpelloni et al., 2006). The difference in average crustal density observed in the model is expected at such plate boundary. The other few and sparse earthquakes are not very indicative of dynamics at crustal boundaries and likely reflect different tectonic regimes: the earthquake next to BLF is likely related to the Rhine Graben, whereas those in the Swiss Alps reflect a regional trend of extension/strike-slip that characterizes the highest regions of the central Alps, irrespective of tectonic domains. lines 282-285: the "boundaries" between different crustal "blocks" is a likely place for the occurrence intraplate earthquakes, that tend to follow pre-existing weakness zones. In the presence of an active plate boundary, like the Alps, the link between different blocks and seismicity is less obvious, as there are plate interfaces, and faults originated by the collisional process are abundant, and often seismically active (e.g., Serpelloni et al., 2016). Lines 289-290: see also Serpelloni et al 2016 Tectonophysics for distribution of seismicity in central-eastern Alps: crustal seismicity seems to follow the major faults driving the eastward escape of the Eastern Alps . lines 295-300: as mentioned before the thickness of the crust underlying the Molasse and Po foreland basins should be taken as unaffected by the load of the mountain belts. The possibility of having a contribution to subsidence driven by crustal extension in the Po Basin, as suggested by the authors, seems highly unlikely and no evidence to support it is present. Lines 306-307: see also Serpelloni et al 2016 Tectonophysics for distribution of horizontal velocity and strain rates in central-eastern Alps: the motion of Adria seems mostly accommodated by deformation at the thrust front of the Southern Alps.. line 312-316: the authors assume that the evidence for a thinner and denser crust in eastern Adria supports its subduction underneath the European plate, as originally inferred by Lippitsch et al. However, it should be considered that the long term evolution of the Alps, including the Eastern Alps, is consistent with a subduction of the the European plate below Adria. And this is certainly true until the last 20 Myr. Therefore, density alone does not justify a supposed change in the polarity of subduction along the strike of the Alpine orogen. Moreover, shortening of the Adriatic plate in the eastern Southern Alps is rather limited, as also pointed out by Kastle et al. (2019 SE), and is not enough to explain the extent of the slab observed in Lippitsch's tomography.

Figure 2. It would be useful to have also a simplified geological map of the Alps (e.g., taken from Schmid et al 2004) to give a better link between geophysical and geological data. Figure 3: A simplified geological cross section, plotted at the same scale of the profile in Fig. 3, would be useful to give a better feeling of the relationships between density domains and geological units. I am not aware of a geological cross section running along the same direction of the profile in Fig. 3, but perhaps the TRANSALP cross section, with appropriate comments, could be indicative enough (after Pfiffner 2014, Geology of the Aps; or Schmid et al 2004)

Technical corrections line 13: "orogenies" instead of "orogenys" line 43: "More recent" instead of "Newer" line 79: sufficient; however (insert semicolon) Line 127: "before" instead of "prior" line 185: "... thicker, but with a similar..." line 191: "Apennine belt" instead of "Apennine plate" line 204: "respectively, " instead of "respectively" (insert comma) line 218: "exceeds that value." instead of "exceeds that." line 297: "before" instead of "prior" Line 303: "however" can be removed line 489: before listing the labels of key tectonic features add that a-a' is the cross section in Fig. 3. line 499:

add that a-a' is the cross section in Fig. 1a line 500: location is marked in Figs 1a, 2 and 4 to 6. line 508: "depth to the Moho" instead of "depth to top surface of the Moho" line 508: "... required within the lithospheric mantle..." instead of "...required within the layer..."

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