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Interactive comment on “Mantle flow below the central and greater Alpine region: insights from SKS anisotropy analysis at AlpArray and permanent stations” *by* Laura Petrescu et al.

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General comments

Dear Referee 2,
in the following you will find our answers and/or description of changes we applied to our manuscript following you useful suggestions. Within 2-3 days we upload the revised version of the manuscript so you can follow our changes.

Specific comments

REF2: Vertical resolution is the problem of SKS splitting. The authors calculated the Fresnel zone and concluded strong anisotropy in the asthenosphere. It is useful. Another method is to make quantitative compression between delay times and lithospheric thicknesses. If lithospheric anisotropy dominates, a strong positive correlation should be clear. Otherwise, asthenospheric anisotropy is required. In this case the delay times should be as accurate as possible, so the stacked averages are better because individual measurement usually overestimates the delay times.

ANSW: In the Discussion section “Depth and source of SKS anisotropy in the Alpine region” to clarify we added the following paragraph: “A quick comparison between LAB depth variations in the Alpine region and delay times does not yield a clear correlation, which should also support a non-lithospheric source signal. Most S-receiver function based LAB estimates generally indicate LAB depths in the 90-140 km range beneath the Alps (Geissler et al., 2010; Miller and Agostinetti, 2012; Bianchi et al., 2014)Âă decreasing to 80-100 km north of the European Front (Geissler et al., 2010). In contrast, Plomerova et al. (2010) infers lithospheric thicknesses of up to 230 km beneath the Alps and 100 km north of the Front. LAB estimates thus vary between studies and the actual boundary remains elusive especially in on-slab locations, where slabs plunge almost vertically, but a large-scale decrease towards the north is a common feature. However, delay time variability (Figure 4a) does not mirror this large-scale decrease, providing further support for an asthenospheric source.”

REF2: If the circular patterns of fast polarizations are result of subduction-driven mantle flow, since the subducting slab is steep here, how to explain similar fast orientations in the high (slab) and low velocity regions at 100 and 200 km depths.

ANSW: In future developments of this work we’ll certainly try to distinguish the more feasible location of the anisotropy we detect and also if a contribution from the slab can be ascertained. At present, tomographic images do not report a unique and coherent shape of the slab. Moreover, for the particular condition of the coexistence of Apennines, Alps and Dynaric slabs, mantle flow directions here may be similar above and below (in front and behind?) the Alpine slab and consequently difficult to be distinguished. Alternatively, the dipping slab(s) and entrained asthenopsheric mantle could explain part of the circular fast azimuths, if the lithospheric mantle is characterized by a dip-parallel foliation containing the a- and c-axes of olivine. This situation has been envisaged by Song and Kawakatsu, 2012, GRL, to explain the trench-parallel anisotropy along subduction zone forearcs. This is now cited in section 5.4

Technical Comments:

Line 124: Grid search method is used here. So it is necessary to clarify the steps for fast polarizations and delay time. A short description to the uncertainty estimation is also necessary.
ANSW: We now modified the text to include this information: "Grid search parameters are 0.025 for δt and 1o for φ, and error calculations are based on the Silver and Chan (1991), under the assumption of Gaussian noise."

Line 135: Describe or show the reference for standard circular means.
ANSW: Yes, we used the standard circular mean described in Davis J. C. (2002), Statistics and data analysis in geology - 3rd edition, Wiley ed. We add the reference.

Line 194: 1.0 - 2.0 s
ANSW: Changed as suggested

Line 254: I think Figure 6 is missing. So I cannot check it.
ANSW: Unfortunately, this is true. In our first submission in fact we missed figure 6. We then uploaded a correct manuscript, but we do not know why you probably received our first version. Hope you can check now in this revised version. We apologize for this.

Figure Comments:

Figure 2: Label the epicentral distances in the inset. The study region does not seem to be in the center.
ANSW: Inset figure modified as suggested.

Figure 4d: Label the stations in the map above.
ANSW: Labels added.

Figure 5: In the map view, there are many NE-SW fast orientations around (6E, 46N), but they are invisible in profile D. Why?
ANSW: Coloured squares are station measurements, not individual event SKS measurements. However, in profile D, at 200 km distance, roughly corresponding to the 6E,46N location, coloured squares indicate a large scatter in the fi direction, as expected.

Figure 7: Here are comparison of seismic tomography at 100 and 200 km depths with seismic anisotropy at stations. Maybe you can try to project the SKS splitting to 100200 km depths and calculated the regional averages respectively.
ANSW: 100 200 km piercing point maps are really similar to the 150 km we decided to use. The position of a measurement at the piercing point at 100 km or 150 km differs by about 12 km. This means that different maps at different depths of the piercing points would show substantially the same pattern at the scale we are working in this paper.
Concerning the computation of the regional average directions computed from the measurements at piercing points, we chose to provide a sketch of the possible mantle flow patterns (see Figure 8) which we considered significant and helpful based on the average values at stations. However, for other aims, we are also working on what you are proposing, see the abstract EGU2020-13880, "Surface and deep deformation of

the great Alpine region from GNSS and seismic anisotropy measurements” by Simone Salimbeni et al.

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