Comments of Referee #2

This manuscript uses the non-vertical propagation of SK(K)S phases along with previous shear wave splitting observations to model anisotropy beneath the Alps. The authors find that beneath the northern portion of their study region, anisotropy can best be modeled with a b-up olivine alignment indicative of flow in the asthenosphere. In the southern half of the study area, the slab seems to be in the way complicating the observations and producing less well-fit model results.

1) Are there any restrictions placed on the delay time errors used in the high quality splitting dataset like the 20deg restriction placed on fast direction? a. What are average errors on dts and Phis of the original splitting dataset? and the restricted dataset?

- *No, we did not further restrict the dataset for delay times errors. As in the investigated intervals Δt is expected to be 0, the conclusion unfortunately does not really benefit from delay time changes. Also, usually the determination of an amplitude, as in the case of Δt, is less precise.*
- *As we combined only the "good" quality SKS and SKKS measurements of three datasets and used the permanent stations of restricted areas, it is difficult to trace back to an "original dataset" and average errors cannot be representative for the whole shear-wave splitting datasets of Barruol et al. (2011), Qorbani et al. (2015) and Salimbeni et al. (2018). Nevertheless, a version of the dataset (not limited by the study area) before implementing a restriction on φ led to average errors of 9.04° and 0.25s in comparison to 8.14° and 0.23s afterwards.*

2) The manuscript would benefit from an expanded discussion of the 1-layer of anisotropy assumption.

a. I think a supplemental figure of baz for the stations before restricting the dataset would help. It is important to make sure that by restricting the dataset you are not removing some of the BAZ variability.

- *As stated in Barruol et al. (2011) referring to the distribution of shear-wave splitting parameters: "Swiss stations do not show clear evidence of backazimuthal variation of these parameters in the SKS period range (i.g., between 5 and 20s) yet the azimuthal coverage is uneven. The seismic rays are mostly incident within the NE and SW quadrant." Effects of multiple or dipping layers have not been resolved. We rephrased and slightly extended the discussion on single-layer anisotropy:*
- *Indeed, the Central Alps have been well-characterized by single-layer anisotropy before, as azimuthal variations per stations are comparably small (Barruol et al., 2011). Evidence for a two-layer case (90° periodicity) or a dipping layer 360° periodicity), causing upper mantel anisotropy, have not been resolved in the area.*
- *Due to the small size of the effects that we seek, they would not become visible in such a plot readily; they emerge by combining different data points.*

b. There seems to be large variances in dt, which can be indicative of layered splitting

- *The determination of Δt is usually less precise. Also, the range of the majority of observed δΔt does not necessarily require more than one layer to be considered (Fig. 4 third row). We added the following to the single-layer discussion:*
- *Strong backazimuthal changes in the delay time could be an indication of multiple anisotropic layers but considering that the determination of delay times is usually less precise, the larger scattering at individual stations for different events is also not surprising. Overall, the majority of observed δΔt per station remain in a range, comparable to the expected variations from non-vertical incidence (Fig. 4 third row).*

3) Why are there fewer BAZs represented at stations above the slab (e.g. figure 5)? Slab stations seem to have fewer 225-360deg baz splits. If this is due to dataset error restriction, it could be an indicator of layers of anisotropy. Layered splitting measurements often have larger errors at BAZs where the largest variations in phi and dt occur.

- *The smaller variation of fast axes in the southern window is intriguing. It is not due to the dataset restrictions, and neither is it easily explained by 2-layer anisotropy.*

4) How are the BAZs of 45 and 135 around which things are stacked chosen? Is it based on average fast directions? Or because of BAZ coverage? Or some initial assumption about olivine axes?

- *The intervals are chosen based on different factors, mentioned in the manuscript. They are related to the backazimuthal distribution itself and the expected variations. SWS parameters e.g. cannot be obtained for backazimuths parallel or perpendicular to φ. Excluding those backazimuthal ranges leads to the baz windows that we used.*

5) Figure 5 – change the colors of the cross section lines. It is very hard to see B-B'

- We agree and used slightly darker colors now.

6) Does the 70% of fully aligned olivine assumption make sense given the observed delay times? Wouldn't a ~100km layer with 70% alignment yield far larger delay times than the 1-2s dts that are measured?

- *Given the calculations for Fig. 2 both, the b-up and c-up case, a 100km thick layer of 70% aligned olivine lead to reasonable delay times considering the histogram in Fig. 3. However, as delay times relate to a tradeoff between the layer thickness and the strength of anisotropy, other combinations might explain the distribution similarly good.*
- *We see that this connection might have been not obvious and extended our explanations:*
- *Assuming a 100km thick layer of 70% aligned olivine with a horizontal a-axis (Nicholas and Christensen, 1987) and …*
- *… Delay times (bottom, right) range between ~0.48 - 2.88s, with an accumulation between ~0.96 - 1.92s, not unlike the expected values in Fig. 2.*

7) It would be helpful to add a discussion of how b-up and c-up olivine relate (or translate) to the more traditionally used A-, B-, C-, D-, E- type fabrics. a. A-, C- and E-type fabrics have all been proposed for the asthenospheric mantle and all have general properties where phi aligns with strain. But A-type and C-and E-types have different b-up and c-up relationships to shear strain. So how do you distinguish between them, or do you have to assume A-type?

- *We agree, in a subduction zone other olivine types are likely present. As we think that could be another factor why the southern area might deviate, we added the following to our explanations:*
- *If this area can be understood as hydrated (Giacomuzzi et al. 2011, and for further reading Hearn, 1999), serpentine, known to react highly anisotropic (see Katayama et al., 2009 or Salimbeni et al., 2018, based on Bezacier et al. 2010), and variation in the olivine type (Jung, 2009), must be considered. Indeed, evidence for different olivine types were found, e.g. B-type near Cima di Gagnone (Skemer et al., 2006); C-type around Alpe Arami (Skemer et al. 2006, based on Mockel, 1969; Buiskool Toxopeus, 1976; Frese 2002); A-, B-, and E-type at Val Malenco (Jung, 2009). However, until now we just applied our method using the San Carlos olivine of Abramson et al. (1997) in different orientations. Future studies might take the effect of different olivine types in their b-up and c-up variation on shear-wave splitting parameters into account. The diversity hinders also the comparison with surface motions derived by Sanchez et al.*

(2018). They are slightly stronger (0.35 - 0.78mm/a), and mainly oriented towards NNW in the southern subarea (Fig. 9 bottom row).

- *… effects from serpentinite and various olivine types might occur…*

8) Figs 8 and 9 and text – It would be useful to discuss and show a null test of the models. It looks to me like a flat line model would match the data just as well as the varying BAZ model.

- *In Fig. 4 and the northern subarea in Fig.7 (former Fig. 8) it is clear, that this Null hypothesis would be rejected by the data. Yet in the southern subarea (former Fig. 9) simple model do not seem to explain the data.*

9) P1L1 and throughout – "e.g." is used throughout the text in cases where it is not needed.

- *We tried to reduce it and removed it.*

10) P1L2 – "constraint" to "constrain"

- *We changed to:*
- *… constrain their nature.*

11) P4L18 – "till" to "until"

- *We change it to:*
- *… until 20 Ma …*

12) P14L33 – "first site" to "first sight"

- *We change it to:*
- *At first sight …*