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Characterizing Seismic Anisotropy across the Peruvian Flat-Slab Subduction Zone: Implications for the Dynamics of Flat-Slabs

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Although 10% of subduction zones worldwide today exhibit shallow or flat subduction, we are yet to fully understand how and why these slabs go flat. An excellent study location for such a problem is in Peru, where the largest region of flat-subduction currently exists, extending ∼1500 km in length (from 3 °S to 15 °S) and ∼300 km in width. Across this region we investigate the pattern of seismic anisotropy, an indicator for past and/or ongoing deformation in the upper mantle. To achieve this we conduct shear wave splitting analyzes at 40 broadband stations from the PULSE project (PerU Lithosphere and Slab Experiment). These stations were deployed for 2+ years across the southern half of the Peruvian flat-slab region.

We present detailed shear wave splitting results for both teleseismic events (such as SKS, SKKS, PKS, sSKS) that sample the upper mantle column beneath the stations as well as direct S from local events that constrain anisotropy in the upper portion of the subduction zone. We analyze the variability of our results with respect to initial polarizations, ray paths, and frequency content as well as spatial variability between stations as the underlying slab morphology changes.

Teleseismic results show predominately NW-SE fast polarizations (trench oblique to sub-parallel) over the flat-slab region east of Lima. These results are consistent with observations of more complex multi-layered anisotropy beneath a nearby permanent station (NNA) that suggests a trench-perpendicular fast direction in the lowest layer in the sub-slab mantle. Further south, towards the transition to steeper subduction, the splitting pattern becomes increasingly dominated by null measurements. Over to the east however, beyond Cuzco, where the mantle wedge might begin to play a role, we record fast polarizations quasi-parallel to the local slab contours.

Local S results indicate the presence of weak (delay times typically less than 0.5 seconds) and heterogeneous supra-slab anisotropy beneath all stations. Splitting is however is weakest and nulls most prevalent above the incoming Nazca Ridge where the slab is at its most shallow. This suggests the main source for the local S anisotropy may be from a thin mantle wedge layer sandwiched between the slab and upper plate. The deepest local S events sample a large volume of dipping slab material and provide increasing evidence for distinct anisotropy within the subducting slab itself that has fast polarizations parallel to the slab strike.

Our detailed shear wave splitting study therefore reveals the presence of complex and multi-layered anisotropy across the Peruvian flat-slab region. We are able to characterize different sources of anisotropy in the sub-slab mantle, slab, asthenospheric wedge and the over-riding plate, each with their own implications for the regional subduction dynamics.