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Seismic anisotropy and texture development during early stages of subduction

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Shear wave splitting measurements are frequently used to infer upper mantle flow trajectory, based on the fact that, under strain, olivine develops lattice-preferred orientation (LPO) textures in the convecting mantle. However, such inferences ought to be made carefully, since the relationship between splitting fast polarisation and olivine LPO depends on several factors, one of them being the deformation history of the volume of mantle in question. This is especially the case in regions such as subduction zones, where complex and time-dependent mantle flow occurs.

Here, we present an integrated model to simulate strain-history-dependent LPO development and measure the resulting shear wave splitting in a subduction setting. We do this for a subduction model that approximates the geometry of the double-sided Molucca Sea subduction system in eastern Indonesia. We test a single-sided and a double-sided subduction case, and compare the results to shear wave splitting observations of this region.

Since the subduction zone is fairly young, early textures from the slab's descent from the near-surface to the bottom of the mantle transition zone – which we simulate in our models – have not yet been overprinted by subsequent continuous flow. It further allows us to test the significance of the double-sided geometry, i.e. the need for a rear barrier to achieve trench-parallel sub-slab mantle flow.

We simulate olivine LPO evolution in polycrystalline aggregates as they move and deform along pathlines extracted from a 3-D mantle flow model. Interactions between crystals are described using the visco-plastic self-consistent (VPSC) approach. Unlike previous studies, we consider the entire subduction history from subduction initiation onwards. After calculating elastic properties associated with LPO textures, we estimate the resulting splitting parameters (fast direction φ, delay time δt) for synthetic SKS phases.

Our models demonstrate that complex, backazimuth-dependent behaviour in φ appears in even apparently simple models of subduction zone mantle flow. We also show that although a rear barrier amplifies trench-parallel sub-slab anisotropy due to mantle flow, it is not essential for producing trench-parallel fast directions. In a simple model of one-sided subduction and deformation dominated by the motion of dislocations belonging to the (010)[100] slip system, trench-parallel fast directions result from a combination of simple shear and deformation by axial compression in the sub-slab mantle.