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Mantle flow beneath subducting slabs from seismological observations and geodynamical models

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The classical model for mantle flow beneath subducting slabs is simple, with viscous coupling between the downgoing slab and the mantle beneath it resulting in entrained two-dimensional flow. However, recent observations of seismic anisotropy beneath slabs have revealed inconsistencies with the predictions of the simplest models in many subduction systems worldwide. We present recent observations and models of sub-slab anisotropy and mantle flow that argue for the possibility of trench-parallel sub-slab mantle flow in many subduction systems. We have used the source-side shear wave splitting technique to construct detailed data sets that sample sub-slab anisotropy beneath the Tonga, Scotia, and Caribbean subduction zones. We find that trench-parallel fast directions predominate in most of the regions we have examined, and argue that the most likely explanation is predominantly trench-parallel flow. We present a series of three-dimensional numerical modeling experiments to explore the conditions under which trench-parallel flow may dominate beneath subducting slabs. These kinematic-dynamic subduction models, implemented with the COMSOL finite element modeling software, investigate the interaction between ambient mantle flow and subducting slabs, which are often retreating or advancing in a mantle reference frame. Our numerical experiments demonstrate that trench-parallel sub-slab flow is predicted under a fairly wide range of conditions and is enhanced by rapid trench rollback and/or weak mechanical coupling between the slab and the sub-slab mantle.