

Seismic evidence for subduction-induced mantle flows underneath Middle America

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Laboratory experiments and geodynamic flow simulations demonstrate that poloidal- and toroidal-mode mantle flows develop around subduction zones, driven by the downdip motion and rollback of subducting slabs. To date, inferring deep mantle flow circulation patterns in actual subduction environments using shear wave splitting or surface wave tomography remains elusive, due to limited depth or lateral resolution of these techniques. Here, we use a new 3-D azimuthal anisotropy model constructed by using full waveform inversion, to infer deep subduction-induced mantle flows underneath Middle America. At depths shallower than 150 km, poloidal-mode mantle flow is perpendicular to the trajectory of the Middle American Trench. From 300 to 450 km depth, return flows surround the lateral edges of the descending Rivera and Atlantic slabs, while escape flows are inferred through slab windows beneath Panama and central Mexico. Underneath Nicaragua and Costa Rica, trench-parallel flows are delineated at depths greater than 300 km in the sub-slab region and 50~km in the mantle wedge, suggesting the upward tilting of toroidal-mode mantle flows due to pressure gradients created by fast rollback of the Cocos slab (25 mm/yr). Furthermore, at 700 km, the study region is dominated by the Farallon anomaly, with fast axis directions perpendicular to its strike, suggesting the development of lattice-preferred orientations by substantial strains due to penetration of the Farallon slab through the 660-km discontinuity into the lower mantle. These observations provide depth-dependent constraints on seismic anisotropy for future mantle flow simulations, and call for further investigations about the deformation mechanisms and elasticity of minerals in the transition zone and uppermost lower mantle.

