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Effects of background mantle flow on subduction dynamics: insights from laboratory models

Benjamin Guillaume (1,2), Francesca Funiciello (1), Claudio Faccenna (1,2), Carlo Doglioni (3,2)

(1) Univ. "Roma TRE", Dipartimento di Scienze Geologiche, Rome, Italy (benjamin.guillaume@uniroma3.it, +39 06 57338201), (2) Consiglio Nazionale delle Ricerche-Istituto di Geologia Ambientale e Geoingegneria, Rome, Italy, (3) Dipartimento di Scienze della Terra, Università "La Sapienza", Rome, Italy

Flow within the mantle is a combination of processes acting at the regional scale, such as subduction-induced poloidal and toroidal mantle circulation, and at the global scale, a westward net rotation of the Earth's lithosphere being indicated by global analyses of surface features connected to the deep mantle (e.g., hot spot tracks). The magnitude of the relative eastward global mantle flow is still debated, Authors proposing values ranging between 0.2 to 1.2°/Myr. The slowest values imply that the net rotation is only an average motion of the lithosphere, dominated by the westward component of the Pacific plate. The fastest values would rather indicate that the lithosphere is entirely "westerly" polarized relative to the underlying mantle, which would move easterly, exerting a first-order control on the global geodynamics and modifying the force balance in subduction zones.

To test the influence of a background mantle flow on the subduction behavior, we designed a new experimental set-up allowing performing 3D dynamically self-consistent laboratory models in which a trench-perpendicular horizontal flow is systematically changed within the upper mantle. Such apparatus is composed of a large Plexiglas box (equivalent to 10000 × 10000 km2), limiting boundary effects, in which a rigid horizontal interface located in the center of the box simulates an impermeable upper-lower mantle discontinuity. The lithosphere and the upper mantle are reproduced by using silicone and glucose syrup, respectively. These materials have been widely tested in previous studies, and selected upon their rheological and physical properties, which scale with the natural prototype. Background mantle flow is produced by the horizontal motion of a piston beneath the intermediate horizontal plane, triggering a homogeneous horizontal background flow in the upper mantle.

We performed a total of 15 models by fixing plate widths to 660, ∼2000, and ∼4000 km and by imposing a horizontal background flow with a velocity corresponding to 0, 4, and 8 cm/yr in both directions (from the foreside and backside of the subduction system). For each model, we analyzed and quantified the trench velocity and curvature, and the slab shape evolution using a high-resolution laser scanner. Preliminary results show that both the magnitude and direction of the background flow strongly control the geometry of the slab, and the trench velocity and curvature. In particular, subduction is inhibited when background mantle flow comes from the foreside region and promoted when the flow comes from the other direction.