Subduction-induced mantle convection on Earth: Poloidal versus toroidal flow

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Subduction of oceanic lithosphere results from two different modes of subduction: (1) trenchward motion of the subducting plate and (2) oceanward retreat of the trench and subduction hinge resulting from rollback of the slab. The first mode is the textbook example of how subduction is commonly perceived. It is described as poloidal mantle flow and can be explained with simple thermal convection models. The second mode is harder to explain as it primarily induces toroidal-type flow in the ambient mantle [1,2], which does not directly contribute to the heat loss from the Earth's interior. Subduction models have shown that ~70% of the negative buoyancy force of the slab is used to drive this toroidal flow [2,3]. A global compilation of current trench migration velocities and subducting plate velocities in different global reference frames is presented to obtain a quantitative estimate of the relative contribution of each subduction mode to the total subduction flux on Earth.

Preliminary investigations indicate that about one quarter of the subduction flux results from trench migration, indicating its significance in the global mantle convection budget. Laboratory and numerical subduction models have investigated trench migration and slab rollback processes. Mass conservation requires that rollback induces a return flow of material behind the slab toward the mantle wedge side. It was shown that this return flow is predominantly toroidal and occurs almost entirely (95-100%) around the lateral slab edges [1,2]. From the global trench migration calculations and the penetration depth of slabs into the mantle, one can thus approximate the total upper mantle mass flux associated with slab rollback. A rough estimate is made by assuming that all slabs continue down to the 660 km discontinuity and have a constant lateral migration velocity with depth. For the 40 mature subduction zones considered, this toroidal mass flux is estimated to be three times larger than the poloidal mass flux resulting from trench-perpendicular trenchward subducting plate motion.

References

[1] Schellart W.P. (2004) *JGR* **109,** B07401.
[2] Stegman D.R. et al. (2006) *G-cubed* **7,** Q03012.
[3] Schellart W.P. (2004) *GRL* **31**, L07611.