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Dynamics of the subducted lithosphere with asymmetric structure inferred from 2-D numerical models of the plate-mantle system

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We have performed numerical simulation to understand various dynamics of subducted slabs. We have first constructed self-consistent dynamic models of the subduction in the integrated plate-mantle system. We incorporate hysteresis-dependent yielding to generate thrust-type plate boundary into the rheology model. In our model, plate-like motion of the surface viscous layer is generated without imposed velocity. We systematically investigate effects of yield strength and underlying low viscosity layer beneath on the generation and longevity of the plate-like motion. We also analyze driving forces working on the plate to explain sensitivity to the yield stress of the plate boundary and interior in order to generate the plate-like motion.

We have next developed a new simulation code for variable viscosity convection to perform high-resolution calculations saving computing time. In mantle convection simulation, most of the CPU time is consumed to solve hydrodynamic equations. In our code, we define dual layers of the grid to solve a system of transport equations and hydrodynamic equations. In the layer for the hydrodynamic equation, the mesh is has variable spacing. This reduces required operations to decompose a coefficient matrix of the hydrodynamic equation by less than 1/10.

We applied our new code to computations to understand dynamics of the subducted lithosphere interacting with phase transitions at 410 and 660 km depths. We consider effects of (1) freely-movable trench, (2) temperature- and pressure-dependent thermal expansivity, (3) viscosity jump at the 660 km phase boundary, and (4) viscosity decrease due to the grain-size reduction with the phase transition. The rollback of the slab is generated because of its negative buoyancy in the early stage of the subduction. This causes a shallow dip angle of the slab in the transition zone. The shallow-angle collision of the slab with 660 km phase boundary reduces a force to bend the slab upward so that it enhances effects of the phase boundary. The horizontally-lying slab is therefore formed with the Clapeyron slope of -1 MPa/K when the T- and p-dependent thermal expansivity and viscosity jump are introduced. We however could not produce megalith-type slab.