Numerical simulations of stagnant slabs assuming various mantle viscosity structures

Yoku Torii[1]; Shoichi Yoshioka[2]

[1] Earth and Planetary Sci, Kyushu Univ.; [2] Dept. of Earth and Planetary Sci., Kyushu Univ.

1.Introduction

Recent results of seismic tomography shows various shapes of subducted slabs. Some of them penetrate straight into the lower mantle, and others lie horizontally in the mantle transition zone. Here, it is a matter to reveal mechanisms to make slabs flatten and stagnate. As one of the possible factors, positive thermal buoyancy force associated with phase transition from ringwoodite to perovskite + magnesiowustite at a depth of 660km boundary has been considered to play an important role to prevent slabs penetration into the lower mantle. By 2-D numerical simulations, Christensen and Yuen(1984) demonstrated that stagnant slabs could be realized as long as the value of the Clapeyron slope is less than -6MPa/K. According to the recent studies of high pressure and high temperature experiments, however, the value of the Clapeyron slope is about -1MPa/K (e.g. Fei et al., 2004). If such value is accepted, we cannot expect the positive buoyancy force around the 660km discontinuity. Therefore, in this study, we focused on the mantle viscosity structures, and attempted to carry out numerical simulations of stagnant slabs assuming various mantle viscosity structures, setting 0 to -1MPa/K as the value of the Clapeyron slope.

2.Model

We adopted a 2-D Cartesian numerical model of Yoshioka and Sanshadokoro[2002], in which the effects of the phase transition at the 660km discontinuity are taken into account. The slab with a thickness of 100km descends gradually along a pre-assigned path (guide) at a certain subducting velocity to a depth of 400km. The slab was set to behave freely down below. The area, to a depth of 50km from the Earth's surface on the backarc side, was assumed to be a rigid body and a fixed conductive layer, corresponding to the continental crust. As to the temperature in the model space, the temperature at the top boundary was assigned 0 degrees and the initial temperature was assumed to be stratified with depth, considering cooling of the oceanic plate. Mantle materials with this temperature flow through the right-side boundary. We assumed that there is no heat flow from the left and bottom boundaries. In addition, we used the boundary condition that normal stress is zero at the bottom and both-sides boundaries. We solved both momentum and energy conservation equations simultaneously as a coupled problem, assuming Bussinesq approximation. A temperature and depth dependent viscosity proposed by Christensen(1996) was used in this study.

3.Results and discussion

On the basis of Christensen's equation for viscosity, we simulated the model, assuming that there are some local viscosity jumps in the mantle. For example, we considered athenosphere and the low viscosity layer that could exist just below the depth of 660km, and high viscosity in the lower mantle. The result shows that the effect of the mantle viscosity structure alone couldn't realize stagnant slabs shown by tomographic images. However, if the viscosity of the lower mantle was raised by 1 order the slab was easily deflected at the 660km boundary. The slab stagnated temporarily around the upper and the lower mantle boundary, if the lower mantle viscosity was increased by 2 orders. We should also found that to deflect slabs, the viscosity of the top of the lower mantle needed to be raised up to the close order of viscosity of the slab. In consequence, slabs seem to be deflected or stagnated around the 660km boundary more easily if viscosity jump exists at the depth and there is a mechanism to decrease viscosity of slabs such as grain-size reduction associated with phase transformation.