3D migration of fluid and its implications for the spatial variation of slow earthquakes

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In recent years, slow earthquakes have been studied extensively because of its importance for better understanding of interplate slip behavior in the subduction zone. At least in southwest Japan and Cascadia where relatively dense seismic and geodetic observations are available, we can clearly see the spatial variation of the activities of slow earthquakes. In southwest Japan, non-volcanic tremor may not be active around Kii Channel and Ise Bay, where the geometry of subducting Philippine Sea Plate changes significantly. In Cascadia, the amount of slip due to slow slip events is largest beneath Port Angeles where we can see the bend of the subducting Juan de Fuca Plate. These observations suggest a possible relationship between slab geometry and the activities of slow earthquakes. Considering that fluid may play an important role in generating slow earthquakes, one explanation for it is that fluid released from the subducting slab migrates in 3D due to complex slab geometry and it leads to the along-arc variation in porosity.

To investigate 3D fluid migration due to complex slab geometry, we construct 3D subduction zone models based on finite element approach. The model domain is divided into crust, subducting slab, and mantle wedge. Mantle wedge is subdivided into a thin serpentinite layer just above the slab and the remaining part. We assume that the serpentinite layer has permeability anisotropy so that the fluid can move nearly parallel to the slab surface and reach the region where slow earthquakes occur. We first compute matrix flow and temperature. Matrix flow is computed only in the mantle wedge and temperature is computed for the whole model domain. Next, we compute fluid migration in the mantle wedge. We assume that fluid migrates as porous flow. 3D fluid migration arises from the combined effects of permeability anisotropy and complex slab geometry.

For a simple oblique subduction case, we find that fluid moves nearly parallel to the maximum-dip direction of subducting plate, not subparallel to the direction of plate motion. For the case with slab geometry similar to that of Cascadia, the fluid concentrates around the bend of the slab, which results in the increase of porosity there. This may help explain the observed along-arc variation in the slow slip events in Cascadia. Our results show that 3D fluid migration may have a strong impact on the spatial variation of slow earthquakes.

Keywords: 3D fluid migration, subduction zone, slow earthquakes

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