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3D dynamic rupture simulation of a subducting reverse fault and its branch fault

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The Mw 9.0 Tohoku-Oki earthquake hit the northeast Japan on March 11, 2011 generating huge strong motion and tsunami and the area with the largest slip amount was located near the Japan Trench. Exploring the dynamics of the Tohoku-Oki earthquake is important for understanding physics of mega-thrust earthquakes and estimating the probability of rupture extensions or tsunami geneses to prevent future disasters. We model a shallow dipping mega-thrust earthquake on a bi-material interface with a free surface by using a 3D finite element method to solve elastodynamic equations and a slip-weakening friction law on the fault plane. As a preliminary study, we simulate in the relatively simple situations with a planar fault and a homogeneous prestress. Reflected body waves from the free surface strongly affect the normal and shear stress on the fault, and both the normal and the shear stress decrease just after the rupture reaches the trench. The slip on the fault reflects at the trench and rapidly propagates downward at the P-wave velocity. This downward reflected slip is consistent with the west-northwest directivity of the Tohoku-Oki earthquake. Final slip distribution with largest slip at the trench is also consistent with some kinematic slip models. Deformation style of the free surface changes depending on the dip angle and material contrast. The amount of vertical motion of the hanging wall is larger for the case of more compliant hanging wall and much larger than that of the footwall. Our simulations suggest that the huge tsunami is generated due to large amount of the surface deformation which is enhanced in the wedge part of the compliant hanging wall.

Keywords: dynamic rupture modeling in a subduction zone, branch fault, plastic yielding, FEM