Rupture process of the 2004 Mw 9.0 off the west coast of northern Sumatra earthquake

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The Magnitude 9.0 off the west coast of northern Sumatra earthquake occurred on the interface of the India and Burma plates. This is the fourth largest earthquake in the world since 1900. It is not the surprizing magnitude but the heavy damage and large casualties caused by the Tsunami of this earthquake that shocked the whole world. Simulation of tsunami propogation requires the detail rupture process. Several studies on the source rupture process using the far field body waves are availble on line. On the basis of aftershock distribution, the rupture area properly extended more than 1000 km. Assuming a physically reasonable rupture propagation velocity of 2.5km/s, we shall expect the rupture duration as long as 400 seconds. Instead of analyzing usually clear P phase or direct SH phase, however, here one meets a problem to deal with different phases (P, PP and PcP) when the synthetic seismogram is constructed.

In this study, besides including P phase, we take into consider PP and PcP phases to invert the rupture process. Studies (e.g. Fukao et al., 2003, JGR) showed that the observed travel time difference (Tpp-Tp) differes from region to region with the calculated one on the basis of a 1-D velocity model because of the anomaly of P-wave velicity in the upper and middle mantle. In this study, we select four earthquakes occurring before the main shock in this area to correct the calculated PP travel time. Since the PP wave shows a 90-degree phase shift compared with the P phase, the observed PP arrivel times are hence determined by searching the maximum correlation of the Hilber transformation of P phase with the observed PP phase.

To follow the trench trace in this area, we divide the fault plane into three segments. The most sourthern segment has a strike direction of 320 degree; the middle segment rotates 20 degree clockwise, whereas the most northern segment further rotates 21 degree clockwise. This fault plane is continuous and the dip angle varies from the south to the north. We further divide the fault plane into 120 grids. The grid spacing in the strike direction is 60km and about 50km in the dip direction. Rupture velocity of 3km/s is assumed. Note that this value only controls the rupture front of the first source time window and the real rupture is not determined by it.

Our inversion results show that introduction of PP and PcP phase into the synthetic seismogram improves the waveform fittings. In about 400 seconds, the rupture propagted for about 1000km from the hypocenter in the southern part to the northern end. Slip distribution shows heterogeneity of rupture pattern. The released total moment leads to a moment magnitude of Mw 8.9. The maximum slip is about 7 meter. Three asperities can be identified in this main shock. The first and the smallest one is confined in the hypocenter area. The second asperity is located just north of the hypocenter. And the thrid one moves to shallow part in the most northern fault. There is not large slip on the third fault segment. Large slip. It seems that the bending in the northern end played an important role to stop the rupture.