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New insights on active fault geometries in the Mentawai region of Sumatra, Indonesia, from broadband waveform modeling of earthquake source parameters

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Global earthquake catalogs provide important first-order constraints on the geometries of active faults. However, the precision of location and focal mechanism parameters in modern global catalogs is typically insufficient to resolve the detailed geometry of many important faults. This issue is particularly critical in subduction zone region, where most great earthquakes take place. The current Slab1.0 have smooth fault geometries, and cannot adequately address local structural complexities that are critical for understanding earthquake rupture pattern, coseismic slip distribution, and interseismic coupling and etc. However, more detailed information about fault geometries can be obtained by careful relocation and modeling waveform of earthquake sequences.

Here, we refine the geometry of two active faults in the Mentawai region offshore of Sumatra, Indonesia. This region is a seismic gap in the Sumatran subduction zone, where the 2007 Mw8.4 Bengkulu and 2010 Mw7.8 Mentawai earthquake sequences have partially ruptured the frictionally locked megathrust but a great earthquake has not yet to occur. In addition, two smaller earthquakes in 2005 (Mw6.9) and 2009 (Mw6.7) with steeply dipping fault plane solutions have been identified as backthrust events by Singh et al. (2010) based on structural constraints from seismic reflection profiles. Wiseman et al. (2011) provided geodetic evidence to support the statement that these two earthquake sequences occurred on a major backthrust fault underlying the forearc islands. However, the combination of a small number of focal mechanisms in the available catalog and large uncertainties in both earthquake locations and fault plane solutions severely limits our understanding of the geometry of both the megathrust and backthrust faults.

We take advantage of the global seismic stations and conduct broadband waveform modeling for medium size earthquakes (M>4.5) to refine their source parameters, which include location, in particular for depth, and fault plane solutions. Our refined catalog shows that the 2005 and 2009 "back-thrust" sequences occurred on a steeply eastward-dipping fault that contradicts previous studies. We interpret these earthquakes as 'unsticking' of the Sumatran accretionary wedge along a backstop fault that separates accreted material of the wedge from the strong crust and mantle lithosphere of the Sunda plate. Coseismic GPS displacements for the 2009 event are well explained by the newly proposed fault geometry. We also find that the seismicity of the Sunda megathrust deviates from the Slab1.0 by up to 8km beneath the forearc islands. Furthermore, dip angles of the main plate boundary earthquakes inferred from robust teleseismic waveform inversions are systematically 5 to 10 degrees larger than the fault dip delineated by alignment of the seismicity. This discrepancy could either be explained by irregular topography of the plate interface (e.g. subducted seamounts) or the fault zone structure above the plate boundary.

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