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How large is the fault slip at trench in the M=9 Tohoku-oki earthquake?

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It is widely known that coseismic slip breached the trench during the 2011 Mw=9 Tohoku-oki earthquake, responsible for generating a devastating tsunami. For understanding both the mechanics of megathrust rupture and the mechanism of tsunami generation, it is important to know how much fault slip actually occurred at the trench. But the answer has remained elusive because most of the data from this earthquake do not provide adequate near-trench resolution. Seafloor GPS sites were located > 30 km from the trench. Near-trench seafloor pressure records suffered from complex vertical deformation at local scales. Seismic inversion does not have adequate accuracy at the trench. Inversion of tsunami data is highly dependent on the parameterization of the fault near the trench. The severity of the issue is demonstrated by our compilation of rupture models for this earthquake published by ∼40 research groups using multiple sets of coseismic observations. In the peak slip area, fault slip at the trench depicted by these models ranges from zero to >90 m. The faults in many models do not reach the trench because of simplification of fault geometry. In this study, we use high-resolution differential bathymetry, that is, bathymetric differences before and after the earthquake, to constrain coseismic slip at and near the trench along a corridor in the area of largest moment release. We use a 3D elastic finite element model including real fault geometry and surface topography to produce Synthetic Differential Bathymetry (SDB) and compare it with the observed differential bathymetry. Earthquakes induce bathymetric changes by shifting the sloping seafloor seaward and by warping the seafloor through internal deformation of rocks. These effects are simulated by our SDB modeling, except for the permanent formation of the upper plate which is like to be limited and localized. Bathymetry data were collected by JAMSTEC in 1999, 2004, and in 2011 right after the M=9 earthquake. Our SDB results indicate that a fault slip of about 60 m at the trench, increasing landward by a few metres over a distance of 50 km, is needed to explain the differential bathymetry data for the time interval of 1999 – 2011. Most of this slip presumably happened during the 2011 earthquake, although very limited aseismic slip from 1999 to just prior to the earthquake cannot be ruled out. The 2004 – 2011 differential bathymetry data would indicate about 45 m near-trench slip, but this estimate is less reliable because the 2004 survey had a very short segment seaward of the trench, causing very large uncertainties in the 2004 – 2011 data.