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3D Dynamic Rupture with Slip Reactivation and Ground Motion Simulations of the 2011 Mw 9.0 Tohoku Earthquake

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Seismological, geodetic and tsunami observations, including kinematic source inversion and back-projection models of the giant megathrust 2011 Mw 9.0 Tohoku earthquake indicate that the earthquake featured complex rupture patterns, with multiple rupture fronts and rupture styles. The compilation of these studies reveals fundamentally three main feature: 1) spectacular large slip over 50m, 2) the existence of slip reactivation and 3) distinct regions of low and high frequency radiation.
In this paper we investigate the possible mechanisms causing the slip reactivation. For this purpose we perform earthquakes dynamic rupture and strong ground motion simulations. We investigate two mechanisms as potential sources of slip reactivation:
1) The additional push to the earthquake rupture (slip reactivation) comes from the rupture front back propagating from the free-surface after rupturing the trench of the fault, a phenomena usually observed in dynamic rupture simulations of dipping faults (e.g. Dalguer et al. 2001). This mechanism produces smooth slip velocity reactivation with low frequency content.
2) Slip reactivation governed by the friction constitutive low (in the form given by Kanamori and Heaton, 2000) in which frictional strength drops initially to certain value, but then at large slips there is a second drop in frictional strength. The slip velocity caused by this mechanism is a sharp pulse capable to radiate stronger ground motion.
Our simulations show that the second mechanism produces synthetic ground motion pattern along the Japanese cost of the Tohoku event consistent with the observed ground motion. In addition, the rupture pattern with slip reactivation is also consistent with kinematic source inversion models in which slip reactivation is observed. Therefore we propose that the slip reactivation observed in this earthquake is results of strong frictional strength drop, maybe caused by fault melting, pressurization, lubrication or other thermal weakening mechanisms that reduces further the frictional strength to lower levels due to the extremely high slip.