Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS01-15 Room:302 Time:May 19 16:15-16:30

Investigating the Relation Between Trench-breaching Rupture and Shallow Afterslip

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Afterslip commonly occurs in fault areas of coseismic stress increase (i.e., negative stress drop), peripheral to the areas of stress drop. It is thus logical to expect afterslip to avoid the area of largest coseismic slip. Seafloor geodetic measurements made after the 2011 M 9 Tohoku-oki earthquake are thus intriguing. They appear to indicate rapid afterslip of the shallowest, near-trench part of the megathrust which, according to many models, is also the area of very large or largest coseismic slip. If we assume some coseismic stress increase near the trench is needed to drive the shallow afterslip, then we must infer that the same stress increase must have acted to resist coseismic rupture. If true, the coseismic slip should peak at some distance landward of the trench but decrease to a smaller value when it breaches the trench. Such an inference or any counter argument has important implications to fault mechanics. To investigate this problem, we are currently making the follow efforts. (1) To constrain the pattern of ongoing shallow afterslip, we need to make corrections to seafloor geodetic measurements to account for the effect of mantle viscoelastic stress relaxation. To model the short-term mantle relaxation, we have developed a 3D finite element model with transient mantle rheology. The results necessitate a correction for a systematic landward motion of the entire frontal forearc, arguing more strongly for the presence of shallow afterslip. (2) To understand how well the near-trench or trench-breaching rupture is resolved by observations, we have compiled near-trench slip distributions of coseismic rupture models based on the inversion of various geodetic, seismological, and tsunami observations. The compilation indicates that the near-trench slip is poorly resolved. (3) We are developing a rupture scenario that features large slip to explain main coseismic observations yet acquires some stress increase in the shallowest part of the megathrust to drive afterslip.

Keywords: subduction earthquake, fault mechanics, earthquake deformation, seafloor geodesy, post-seismic deformation, Tohoku-oki earthquake