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Proper estimation of stress fields in the source region of the 2011 Off the Pacific Coast of Tohoku earthquake

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A various observation data revealed that coseismic slip of the 2011 Off the Pacific Coast of Tohoku earthquake exceeded a few tens of meters near the Japan Trench. This suggests that a prominent spatial variation in stress fields may be found there. In this study, we report that the spatial variation in stress fields can be identified on the basis of proper data-set selection in the stress tensor inversion.

A single earthquake as well as a set of nearly identical focal mechanisms cannot constrain the stress tensor, so that we need an adequately diverse set of focal mechanisms in the stress tensor inversion. Using synthetic focal mechanism dataset, Hardebeck and Hauksson (2001) showed that when the mechanism diversity is low, the stress tensor inversion returns an incorrect solution in which a direction of the maximum principal stress (S_1) is about 45 degree from the strike of the reference fault. The same situation may occur in the present study area, because most of earthquakes are low-angle reverse-faulting types occurring along the plate interface.

In order to overcome the problem, we try to divide the dataset into earthquakes along the plate boundary (On-fault earthquake) and other events (Off-fault earthquake). Here we defined the on-fault earthquake that satisfies all the following three criteria: (1) Thrust mechanism categorized in the triangle diagrams of Frohlich (1992), (2) Kagan's angle (Kagan, 1991) relative to a reference mechanism (strike=195, dip=15, rake=90) is less than 35 degree, (3) focal depth is within +-10 km of the inferred plate interface. We applied these criteria to F-net moment tenser solutions during the period from February 1997 to the occurrence of the 2011 Tohoku-oki earthquake. The strike and dip angles of on-fault earthquakes are consistent with the geometry of subducted Pacific slab, suggesting that the above criteria work well. Off-fault earthquakes show a diversity of focal mechanisms.

We divided the study region into several small subareas and applied the stress tensor inversion method (Michael. 1984) using off-fault earthquakes. The inversion results show that the plunge of S_1 is subhorizontal within a subarea where a large coseismic slip occurred. Considering the 95% confidence regions, the angle between S_1 axis and the plate interface (A) is about 10-40 degree. In contrast, the dip angle of S_1 becomes higher in other subareas and the angle A in Ibaraki-oki is nearly perpendicular. This suggests that the shear stress was relatively high around the large coseismic slip area, while those in other areas were very low.

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