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Near-field and far-field effects of elastic structure on coseismic deformation of the 2011 Tohoku earthquake, Japan

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Coseismic deformation due to the 2011 Tohoku earthquake, Japan, was detected by dense GPS network of over 1200 stations and several seafloor stations. Using these observations, we investigated effects of elastic structure on coseismic deformation with a 3-D finite element model incorporating geometry of the regional plate boundaries and elastic structures. First, we computed displacement fields for different elastic models with the same coseismic slip distribution to understand the effect of elastic structures. We assumed the three structure models: (a) Homogeneous model, (b) two-layered model considering crust-mantle structure (rigidity of 35 and 65 GPa, respectively) (Layered model), (c) crust-mantle model with cold subducting slab (85 GPa) (Slab model). We found the two contradicting effects: (1) In the far field (mostly at onshore stations), the amount of displacement decreases with the increase of the average rigidity. (2) In the near field at offshore stations, the amount of surface displacement increases with the increase of rigidity across the faults. This is because the stiffer (less deformable) footwall requires more movement of the hanging wall to accommodate the slip. Next, we inverted the observed displacements to obtain slip distribution for three elastic structures. The patterns of inverted slip distribution are basically similar for all three models but the amount of maximum slip is not simply related to average rigidity of structure models. The maximum slip increases from 39 m in Homogeneous model to 40 m in Layered model and then falls to 38 m in Slab model. These changes show that crust-mantle layering is more effective on far field while slab effect is more important in the near field.