10th ACES International Workshop, Awaji Island, September 25-28, 2018

Dynamic rupture simulations of the 2016 Mw 7.9 Kaikoura earthquake: Revealed importance of non-planar fault geometries and heterogeneous traction

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The coseismic rupture of the 2016 Kaikoura earthquake propagated over the distance of 150 km along the NE-SW striking fault system in the northern South Island of New Zealand. The analysis of In-SAR, GPS and field observations (Hamling et al., 2017) revealed that the most of the rupture occurred along the previously mapped active faults, involving more than seven major fault segments. These fault segments, mostly dipping to northwest, are distributed in a quite complex manner, manifested by fault branching and step-over structures. Back-projection rupture imaging shows that the rupture appears to jump between three sub-parallel fault segments in sequence from the south to north (Kaiser et al., 2017). The rupture seems to be terminated on the Needles fault in Cook Strait. One of the main questions is whether this multi-fault rupture can be naturally explained with the physical basis. In order to understand the conditions responsible for the complex rupture process, we conduct fully dynamic rupture simulations that account for 3-D non-planar fault geometry embedded in an elastic half-space. In order to conduct a number of parameter studies, we employed an efficient spatio-temporal boundary integral equation method, called the fast domain partitioning BIEM (FDP-BIEM), implemented for high performance computer environment such as the K-computer and the Oakforest-PACS.

The fault geometry is constrained by previous In-SAR observations and geological inferences. The regional stress field is constrained by the result of stress tensor inversion based on focal mechanisms (Balfour et al., 2005; Townend et al., 2012). The fault is governed by a relatively simple, slip-weakening friction law. For simplicity, the frictional parameters are uniformly distributed as there is no direct estimate of them except for a shallow portion of the Kekerengu fault (Kaneko et al., 2017). Our simulations show that the rupture can indeed propagate through the complex fault system once it is nucleated at the southernmost segment. The simulated slip distribution is quite heterogeneous, reflecting the nature of non-planar fault geometry, fault branching and step-over structures. We find that optimally oriented faults exhibit larger slip, which is consistent with the slip model of Hamling et al. (2017). We conclude that the first order characteristics of this event may be interpreted by the effect of irregularity in the fault geometry.

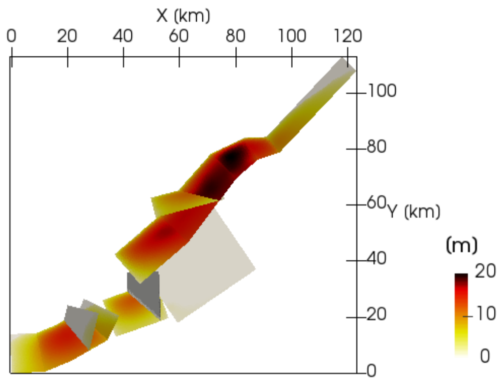

Figure 1. Simulated slip distribution of the 2016 Kaikoura earthquake. Non-planar fault geometry is assumed.