3D Modeling of Deformation and Stress Changes Due to the 2011 Christchurch, New Zealand, M_W 6.3 Earthquake

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On February 22, 2011, a M_W 6.3 aftershock struck near the city of Christchurch, following a M_W 7.1 mainshock near the town of Darfield on September 4, 2010. Although much smaller than the mainshock, the aftershock caused significantly more damage to the city. We investigate the coseismic deformation and Coulomb stress changes associated with this event, focusing on the sensitivity of the results to the level of detail in the spatial variation of the elastic properties.

Our preliminary models consist of a single fault plane using geodetically derived (GPS and InSAR) fault slip estimates for the M_W 6.3 event. We consider four different descriptions of the elastic properties: (1) a homogeneous model with a Poisson's ratio of 0.25, for comparison with the half-space solution used to infer fault slip; (2) a 3D New Zealand seismic velocity model (Eberhart-Phillips et al., 2010); (3) a homogeneous model with properties corresponding to the local average of the 3D seismic velocity model at 8 km depth; and (4) a 1D model corresponding to a vertical profile in the 3D seismic velocity model at Christchurch. Our initial results show negligible differences between the predicted surface deformations of the two homogeneous models, while there are moderate differences in the displacements in the near-field (~60 mm) between the models with homogeneous properties and those with 1D and 3D variations in elastic properties. This indicates that the vertical variations in elastic properties have a moderate influence on the predicted deformation field, and the effects of lateral variations in the elastic properties are much less with maximum differences of about 20 mm between the deformation predicted by the models with 1D and 3D elastic properties.

For each of these deformation models, we have calculated Coulomb stress changes (Harris and Simpson, 1992; King et al., 1994) on a target fault with the same orientation as the fault for the M_W 6.3 event, and a range of rake angles. We have also superimposed the stresses inferred for the M_W 7.1 event using a homogeneous elastic dislocation model. In both cases, we find little to no correlation between elevated Coulomb stresses and the location of aftershocks following the M_W 6.3 event.

Our present work focuses on refining the rupture model to improve the accuracy of the deformation models. Double-difference aftershock relocations will result in tighter constraints on the fault geometry as well as the Coulomb target fault parameters. Adding finer scale features to the 3D seismic velocity model, especially in the top few kilometers, may further reduce the misfit between the simulated deformation and GPS and InSAR observations.