Finite element modeling of the 2011 Christchurch, New Zealand, Mw 6.3 earthquake

Charles Williams¹, Bill Fry¹, Brad Aagaard², John Beavan¹, Russell Robinson¹, Caroline Holden¹, Stephen Bannister¹, Martin Reyners¹, Susan Ellis¹, John Ristau¹

¹GNS Science, Lower Hutt, New Zealand
²USGS, Menlo Park, California, USA

Contact e-mail: C.Williams@gns.cri.nz

On February 22, 2011, a Mw 6.3 aftershock struck near the city of Christchurch, following a Mw 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. Initial Coulomb stress modeling indicates that the aftershock occurred on a fault that experienced a slight Coulomb failure stress increase from the Mw 7.1 event.

To refine our understanding of the causes of this event as well as implications for future events, we are developing finite element models that make use of seismic velocity information to infer elastic material properties. Our preliminary models consist of a single fault plane using geodetically derived (GPS and InSAR) fault slip estimates for the Mw 6.3 event. The models use several different velocity structures: 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 homogeneous model with properties corresponding to an average of a New Zealand-wide velocity model at 8 km depth; 3) a 1D model based on a profile at Christchurch; 4) a full 3D model. Our initial results show virtually no difference between the predicted surface deformations of the first two models, while there are significant differences between models 1 and 3, as well as models 1 and 4. There are also measurable differences (~ 20 mm in predicted InSAR line-of-sight displacement) between models 3 and 4, indicating that lateral variations in the material properties are influencing the predicted deformation field.

For each of these deformation models, we have calculated Coulomb stress changes on a target fault with the same orientation as the fault for the Mw 6.3 event, and a range of rake angles. We have also superimposed the stresses inferred for the Mw 7.1 event using an elastic dislocation model. In both cases, we find little to no correlation between elevated Coulomb stresses and the location of aftershocks following the Mw 6.3 event. Our present work focuses on improving our aftershock locations (which will refine the source fault geometry as well as the Coulomb target fault parameters) and including finer scale features in the 3D seismic velocity model. We expect that these refinements will provide a clearer picture of how stress is being redistributed in the Christchurch region.