Assessing the Utility of Strong Motion Data to Determine Static Ground Displacements During Great Megathrust Earthquakes: Tohoku and Iquique
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Static Displacements from Strong Motion
Strong motion accelerometers can record broadband, large amplitude shaking on-scale in the near-field of large earthquake ruptures; however, numerical integration of such records to determine static displacement is typically unstable due to baseline changes (i.e. distortions in the zero value) during strong shaking. We modify the technique by fitting a quadratic to the end of the velocity time series, in an effort to recover static displacements:
1. Convert to m/s. Perform zeroth-order correction, i.e. remove mean.
2. Integrate to velocity.
3. Fit a quadratic to velocity, constrained to zero at first motion.
4. Integrate twice to obtain displacement time series.

Strong Motion Records From Tohoku
Several strong motion instruments along the western coast of Chile recorded the near-field shaking from the 1 April 2014 Mw 8.2 Iquique earthquake. We used the same correction technique to generate static displacements (shown in blue) from these acceleration time series, and compare them to displacements predicted from a seismological finite fault model in an elastic half-space (orange).

Can Strong Motion Observations Yield Reliable Static Displacements?

Percent Correctable (Reliable Displacement)
Kik-Net Borehole ~85%
Kik-Net Surface ~65%~80%
Chile Surface ~90% ~75%~80%

Percent of Remaining Matching GPS/FFM Prediction

In the worst case from these three datasets (surface instruments from KIK-Net), nearly 50% of the strong motions produced accurate coseismic static displacements, suggesting that a network of strong motion instruments can yield an accurate displacement field for large megathrust earthquakes. In addition, these corrected records contain the displacement time series, which may be used for constraining the coseismic rupture evolution from the near-field.

At The Limit - 2014 Iquique Foreshocks
This method is limited to instances of strong shaking that can be captured on an accelerometer. Low amplitude shaking from small events or at stations far from the source will not have reliable strong motion-derived static displacements. The minimum static displacements that we resolved from the Mw 8.2 Iquique dataset were ~20 cm.

The foreshock sequence preceding the Mw 8.2 Iquique earthquake began on an Mw 6.7 earthquake on 16 March 2014, west of the Mw 8.2 centroid (yellow star). Although this earthquake generated shaking detected on the strong motion instrument at station GO01, its static displacements are too small to be confidently resolved by strong motion integration.

Slow or aseismic slip events also do not generate strong shaking, and are not recorded on strong motion instruments, despite potentially large displacements accumulating. These must be inferred from geodetic measurements, such as in the case of the foreshocks leading up to the 2014 Iquique earthquake.

The observed GPS displacements from 16 March 2014 through 1 April 2014 are not completely accounted for by displacements from foreshock seismicity. Following Ruiz et al. (2014), we infer that aseismic slip must have occurred on the megathrust plate boundary to account for the extra observed displacement.

These maps show the GPS displacements immediately before the 1 April 2014 Mw 8.2 Iquique main shock (blue), the cumulative displacements in an elastic half-space of the foreshocks (green), the difference vectors (obs-pre; orange), and the displacements predicted for the slow slip patch shown (pink). Note that it is difficult to account for the extra displacements at stations UTAR and CRSC unless the slow slip patch is updip of the foreshock sequence.