25-Second Determination of 2019 M7.1 Ridgecrest Earthquake Coseismic Deformation from Global GNSS Seismic Monitoring

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We have developed a global seismic monitoring capability based on low-latency measurements from ~ 1,000 Global Navigational Satellite System (GNSS) receivers to rapidly characterize large earthquakes and, where relevant, tsunami. The system complements traditional seismic monitoring by allowing moment release to be quantified via the Peak Ground Displacement (PGD) algorithm of Crowell (2013) as fault rupture unfolds. Position time series from stations distributed across six continents are continuously estimated within an earth center of mass-fixed reference frame and streamed as local north, east and vertical coordinates into a variety of seismic monitoring algorithms and also rebroadcast for third-party use. Average positioning latency, which includes satellite observable acquisition, telemetry, and processing, averages about 1.4 seconds on our production system and 0.5 seconds on a development system. Ongoing efforts during summer, 2019 will up the number of global stations to ~3,000.

This system captured the 2019 Ridgecrest California M7.1 earthquake and determined its coseismic deformation of up to 70 cm on 12 nearby stations within 22 seconds of event nucleation. Those 22 seconds comprise the fault rupture time itself (roughly 5-10 sec), another ~5s for propagation delay between various regions of slip and GNSS stations, another 5-10s for dynamic displacements to dissipate such that coseismic offsets 'settle down,' plus another 1.4 seconds for telemetry and data analysis latency. Comparison of coseismic deformation estimated within 25 seconds to that determined with post-processing using several days of post-processing show that the real-time offsets were accurate to within 10% of the post-processed "true" offsets.

PGD runs nearly instantaneously. It is worthwhile noting that while ultrafast determination of GNSS coseismic offsets could not help ShakeAlert improve its initial magnitude assessment made several seconds after nucleation, the GNSS-based high-M6 PGD magnitude at ~25 seconds could have nonetheless triggered or revised an alert before S-waves reached the LA Basin. This highlights how GNSS can improve magnitude estimation for large events whose duration and extent of rupture precludes accurate assessment using only the first few seconds of P-wave amplitudes.