Testing a real-time GNSS-based earthquake and tsunami early warning system

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The goal of GNSS-based earthquake early warning (EEW) is to estimate magnitude, without saturation, and fault finiteness for the largest, most damaging earthquakes. This is especially important for tsunamigenic earthquakes, where slip on a finite fault can be used to guide local tsunami hazard warning in real-time. Because large events (M>6.5) are infrequent, geodetic algorithms are not regularly exercised and tested. It is therefore necessary to assess the performance of such algorithms using synthetic earthquakes and geodetically-recorded earthquakes worldwide. We will discuss the testing and performance of the Geodetic Alarm System (G-larmS) using both real and synthetic earthquake data. G-larmS has been in continuous operation since 2014 using event triggers from the ShakeAlert EEW system and real-time position time series from a triangulated network of GPS stations along the west coast of the United States. G-larmS uses high rate (1 Hz), low latency (<~5 s), accurate positioning (cm level) time series data from a regional GPS network and P-wave event triggers from the ShakeAlert EEW system. It extracts static offsets from real-time GPS time series upon S-wave arrival and performs a least squares inversion on these offsets to determine slip on a finite fault. During its 3 years of operation, G-larmS has only been tested in real-time by the 2014 M6 Napa, California earthquake. We therefore develop a catalog of 1300 Cascadia megathrust scenarios and 4000 individual ruptures on 25 faults in California built from realistic 3D geometries in order to test the system. Synthetic long-period 1Hz displacement waveforms were obtained from a new stochastic kinematic slip distribution generation method (Fakequakes). Waveforms are validated by direct comparison to peak P-wave displacement scaling laws, peak ground displacement GMPEs obtained from high-rate GPS observations of large events worldwide, and NGA-West2 spectral acceleration GMPEs at 10s period. In addition to the synthetic catalog, we also run real-time simulations for the recent M7.6 Melinka, Chile earthquake and the 2011 M9 Tohoku-Oki earthquake. We use the resulting finite fault sources to simulate tsunami hazards and demonstrate the usefulness of geodetic-algorithms for tsunami early warning.

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