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Rapid detection of large subduction zone earthquakes using quasi-finite-source Green's functions in moment tensor inversion

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Rapid detection and characterization of large, potentially tsunamigenic, earthquakes along subduction zones is critical for earthquake and tsunami early-warning in highly seismic regions. Techniques, such as the W-phase moment tensor (Kanamori and Rivera, 2008), are improving the determination of large and potentially damaging events in the far field, however there are still no methods that can rapidly detect and calculate the seismic moment and mechanism of such events in the near-field. In this case tsunami warnings are published based only on location and a magnitude estimate. In the near-field the dimensions of the rupture is comparable to the distances to seismic stations necessitating the consideration of variations in distance, and azimuth, due to source finiteness, and ideally distributed slip, kinematic rupture models. However kinematic rupture model inversions are too slow to be applied in the time frame needed for local tsunami early-warning, and we therefore focus on a source finiteness adjusted rapid point-source approach.

Here, we are implementing the automatic, continuous scanning GridMT method of Kawakatsu (1998), to monitor long-period seismic waves for the Cascadia subduction zone (CSZ) in the vicinity of the Mendocino Triple Junction in northern California. By continuously performing the cross-correlation of data and Green's functions (GFs), and inverting for the seismic moment tensor for virtual sources distributed over a spatial grid, the algorithm automatically detects, locates, and determines the scalar seismic moment and focal mechanism of any events occurring within the monitoring region. This method offers the great opportunity to better identify and to rapidly characterize any large damaging and potentially tsunamigenic earthquakes along the CSZ within the time frame that it takes for the complete low-frequency wavefield, including surface waves, to propagate through the Berkeley Digital Seismic Network.

In order to better take into account the rupture finiteness in the near-field we are proposing the use of quasi-finite-source GFs in the GridMT point-source moment tensor algorithm. These adapted GFs are obtained by averaging single-point GFs of multiple virtual sources located along the subduction zone. This allows us to consider any type of rupture length and position along the slab. In addition, this method can also accounts for rupture directivity to better model the data.

We present results of the performance of the system for large synthetic earthquakes along the CSZ and we show that we can obtain the complete earthquake information for any event in realtime using a single stage of processing. For this reason it will be faster and more reliable than the currently implemented cascade-type monitoring procedures involving discrete prior-process dependent steps. And finally, this technique shows improved results in terms of event characterization (centroid location, moment magnitude, focal mechanism) compared to a single point GF, thereby enabling potential tsunami early-warning capability.