Rapid and robust characterization of the earthquake source for tsunami early warning

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Introduction

Effective tsunami early-warning after an earthquake is difficult when the distances and tsunami travel-times between earthquake/tsunami source regions and coast lines at risk are small, especially since the density of seismic and other monitoring equipment is low in most regions of the world. For tsunami warning worldwide, seismic monitoring and analysis currently provide the majority of information available within the first ten minutes of an earthquake. This information is used for direct tsunami hazard assessment, and as basic input to real-time, tsunami hazard modeling. It is thus crucial that key earthquake parameters are determined as rapidly and reliably as possible, in a probabilistic, time-evolving manner, along with full uncertainties.

High-seismic activity on the east African rift (EAR) system, in the years 2009-2010, resulted in an increase of seismic monitoring and earthquake early-warning. In simulation for the devastating Mw9.0 Tohoku earthquake, tsunami, Early-est determines: the epicenter within 3 min after the event origin time (OT), discriminants showing analysis at the INGV tsunami alert center (CAT, “Centro di Allerta Tsunami”).

Early-est earthquake parameters are determined as rapidly and reliably as possible, in a majority of information available within the first tens of minutes after an earthquake. Distances and tsunami travel-times between earthquake/tsunami source regions only available 10-20min or later after origin time. The program fmamp is a demonstration showing earthquake parameters for the 25 October 2010, Mw7.8 Mentawai tsunami earthquake.


Rapid focal mechanism determination

The use of P first-motion data is critical in Early-est for determining focal mechanisms during the first few minutes after an earthquake. As P waves are the first seismic wave to arrive at a station, they are used to determine the origin time of an earthquake. Picking is done with FilterPicker is a general purpose, broad-band, phase detector and picker which is applicable to real-time seismic monitoring and earthquake early-warning. Picking is done with FilterPicker is a general purpose, broad-band, phase detector and picker which is applicable to real-time seismic monitoring and earthquake early-warning.

Mwpd: large earthquake magnitude within 10 min

We previously presented a duration-amplitude procedure for rapid determination of a tsunami-earthquake at origin time + 5→10min earlier than the conventional P-wave magnitude (Mwp). Mwpd extends Mwp for very large and long duration events. Mwpd gives similar results for most large earthquakes using currently available, real-time seismogram data.


Robust, simultaneous association and location using a probabilistic, global-search

The Early-est associate/locate module efficiently and robustly associates picks, and detects and locates seismic events over the whole Earth to 700km depth using the non-linearized, out-of-time importance-sampling approach (Lomax, et al., 2009). Robust, simultaneous association and location using a probabilistic, global-search. Time evolution of Early-est event characterization : The 2010, Mw7.8 Mentawai tsunami earthquake

The 2010 Mentawai tsunami earthquake generated a large, destructive, local tsunami. Early-est characterizes this event with an epicenter constrained in the first minutes after the origin time (OT) and Mwp, Mwpd(RT), and T50Ex measures available at OT+3→4min. All three discriminant for tsunami potential, T50Ex at OT+4→5min, and T0 and Td at OT+5→6min indicate a tsunami-earthquake, and allow us to follow a likelihood based on stacking of multiple TS events over a source at 4.5º for each pick, given a velocity model, a pick time, and assuming a source point in the model and seismic phase type that may have produced the pick, the phase travel-time from source to station Tx can be calculated and an implicit origin-time OT for the source and phase can be computed.


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