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Rapid source inversion of W phase for tsunami warning

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W phase is a long period phase arriving before S wave. It can be interpreted as the superposition of the fundamental, 1^{st}, 2^{nd}, and 3^{rd} overtones of Rayleigh waves and has a group velocity of 8 km/s at 1000 s and 8.6 km/s at 100 sec. At a distance of 50° the W-phase energy is mainly contained within a time window of 700 s after the P arrival. Since the amplitude of long period waves better represents the tsunami potential of an earthquake, the use of W phase has a merit in assessing the tsunami potential at an earliest possible time.

We inverted the displacement seismograms windowed over a short duration after the P arrival. The duration is given by $15 \times \Delta\ s$ (Δ in degrees). Thus, at a distance of 50°, we use the record only up to 23 min after the origin time which is the distinct advantage of using W phase for tsunami warning purposes. If many stations are available at shorter distances, the time can be considerably shortened. The bandwidth of W phase is approximately from 0.001 to 0.01 Hz, and we band-pass filter the data from 0.001 to 0.005 Hz in most cases.

Having extracted W phase from the vertical component records, we concatenate them in time in the order of distance to obtain a single W-phase time series. This time series constitutes the data column vector. We synthesize similar concatenated W-phase time series by mode summation for each of the moment tensor elements. These time series constitute the column vectors of the matrix which maps the unknown moment tensor to the data. We then perform a linear inversion to retrieve the moment tensor of the source represented as a point source.

For rapid inversion, we pre-computed the Green's functions by mode summation for each of the moment tensor elements for a distance range of $0^\circ \leq \Delta \leq 90^\circ$ with an interval of 0.2° and for a depth range of 0 to 700 km. The depth intervals range from 2 km for shallow events to 10 km for the deeper ones. The practical calculation is straightforward and the time overhead is negligible.

In order to evaluate the reliability of this inversion procedure, we carried out a systematic comparison with the Harvard and Global Centroid Moment Tensor solutions for all the events with $M_w \geq 7.0$ which occurred worldwide since 1990 (~ 240 events) by using the FDSN broad-band data. The agreement is excellent and holds the promise of the use of W phase for rapid assessment of tsunami potential. A practical procedure for operational use of W phase for tsunami warning purposes will be discussed.