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Identification of possible tsunami earthquakes along the Mexican Subduction Zone

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Tsunami earthquakes are defined as events that generate tsunamis of much greater amplitude than those expected from their seismic magnitudes (Kanamori 1972), and the source process is still controversial. This is because tsunami earthquakes are relatively rare and have not been observed yet with recent seismic and geodetic networks.

On April 18th, 2002, the earthquake with M_W 6.7 was located about 55 km from the coast of Guerrero, Mexico. The earthquake occurred near the trench of the northwest Guerrero seismic gap, which has not broken in a large earthquake since 1911 (Singh et al., 1981; UNAM Seismology Group 2015). The rupture of the 2002 event most likely began at a subducted seamount, and propagated unilaterally towards NW, parallel to the trench for ~ 60 km and for a duration of ~ 60 s. The moment rate function was highly rugged with two dominant pulses separated by about 50 s. Although relatively small in magnitude, the earthquake has all the characteristics of a tsunami earthquake: the slip occurs very close to the trench; the rupture speed is slow (~1 km/s); the high-frequency radiation is deficient, the moment-scaled radiated energy is lower ($E_S/M_0 = 1.43x10^{-6}$) than those of typical interplate earthquakes. This event was also characterized by a large centroid delay time from the origin time, whch was about 30 s (Duputel et al., 2013). Also, it produced anomalously low accelerations and generated a small tsunami (Iglesias et al., 2003). Therefore, this event can be categorized as a tsunami earthquake.

Okal and Borrero (2011) conducted a detailed seismological study of the large Colima, Mexico earthquake. The event occurred on June 3rd and its aftershocks on June 18th and 22nd in 1932. The aftershock on June 22nd generated a tsunami more devastating than that of the main shock, despite much smaller seismic magnitudes. They confirmed a deficient energy-to-moment ratio derived from high-frequency P-waves recorded in Pasadena, approximately $E_S/M_0 = 6.607x10^{-7}$. Their study suggests that this aftershock had the characteristics of a tsunami earthquake.

Therefore, in the previous two examples, we have observed that the moment-scaled radiated energy(E_s/M_0) plays a fundamental role in characterizing a tsunami earthquake. Newman and Okal (1998) also demonstrated that the scaled energy is a powerful discriminant for tsunami earthquakes.

Shapiro et al. (1998) apply a method based on the ratio of the total radiated energy to the high-frequency energy, ER, computed from at the broadband seismometer at CUIG, located in Ciudad Universitaria, Mexico City. Using this information, Iglesias et. al., (2003) showed a relation between ER and E_S/M_0, which suggests that events with high values of ER should also have low values of E_s/M_0.

In general, if ER is greater than 100 for an event, then E_s/M_0 is less than $3x10^{-6}$. For instance, E_s/M_0 values were calculated as $1.5x10^{-6}$, $0.6x10^{-6}$, and $2.6x10^{-6}$ for the tsunami earthquakes of Nicaragua (2 September 1992, M_W 7.6), Java (2 June 1994, M_W 7.8), and Peru (21 February 1996, M_W 7.5), respectively (Venkataraman, 2002). ERs for two tsunami earthquake were 1180 and 512 in Peru in 2002 (Iglesias et al., 2003).

The seismic magnitude scales of moment magnitude,

M_W and surface wave magnitude, M_S, body wave magnitude, m_b have a fundamental role in identifying a size of earthquakes and expecting a scale of tsunamis. A tsunami earthquake is generally identified as an event with a larger M_W than ordinary earthquakes with the same M_S, whereas M_S usually saturates when a very large earthquake has an ordinary source process (Polet and Kanamori, 2000).

In this work, we identify possible tsunami earthquakes that occurred in the Mexican subduction zone. First, we select the events with ER greater than 100. Next, we compare E_S/M_0 of some possible tsunami earthquakes with ordinally and tsunami earthquakes. Finally, we use the comparisons of M_S, m_b, M_W to determine if these events share common characteristics with tsunami earthquakes. It was previously suggested in a study using bathymetric data (Geersen et al, 2019) that lower-plate topography and sediment thickness may be related to the risk of a tsunami earthquake. Therefore, we will also compare the location of the possible tsunami earthquake events with residual gravity values in the surrounding area to help understand any possible correlation between the source of the events and the geological structure.

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