Tsunami source of the 2011 Tohoku earthquake

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For the 2011 Tohoku earthquake, many models of slip distribution based on seismic waves, geodetic and tsunami data have been proposed. The maximum slip is located at around 38˚N near the epicenter off Miyagi prefecture, and the northern edges of most models are at around 39.5˚N. The coastal tsunami height was largest around Miyako city at 39.5˚N, which is roughly 100 km north of the maximum slip.

Satake et al. (2013, BSSA) made inversion of tsunami waveforms recorded on bottom pressure, GPS and costal wave and tide gauges to estimate the spatial and temporal distribution of coseismic slips. Their result indicates that a very large slip (maximum 69 m) occurred near the trench axis, and it propagated toward the north along the trench. They concluded that the delayed slip in the northern source region (39.5 –40˚N) near the trench axis was the main cause of the largest tsunami in Iwate prefecture.

Tsunami waveform inversion reconstructs the temporal and spatial distribution of sea surface (seafloor) displacement, but cannot give the cause. Tappin et al. (2014, Marine Geology) claimed that the cause of the large tsunami on the Iwate coast is a submarine landslide. Their analysis indicates that the submarine landslide occurred at 135 seconds after the origin time at around 39.5˚N along Japan Trench, with a length of 40 km, a width of 20 km, a slope thickness of 2 km, a vertical offset (rotation) of 100 m. The total landslide volume was estimated as 500 km^3. Fujiwara et al. (2017, GRL), based on the differential bathymetry mapping before and after the earthquake, found no larger-scale (> 20 m) horizontal displacement of the seafloor was detected on the north (39.5˚N), while they detected such displacement near the epicenter (38 –38.5˚N). Yamazaki et al. (2018, JGR) started from a source model based on seismic waves, and modified it to reproduce the tsunami observations (waveforms and runup data), and reached a source model similar to Satake et al., extending to 39.5˚N along the trench axis. They further confirmed that this model can explain the observed seismic and geodetic data, indicating that the slip at 39.5˚N near the trench axis was not resolvable from seismic or geodetic data.

Near the trench axis off Iwate prefecture, the 1896 Sanriku tsunami earthquake occurred. The coastal tsunami heights on Sanriku coasts were similar for the 1896 and 2011 events, while amplitudes of the 2011 tsunami waveforms were much larger in Hokkaido (Hanasaki), Southern Tohoku (Ayukawa) and Kanto (Choshi). Such differences can be reproduced by a model that the 1896 tsunami source was slightly far from the trench axis, on 3.5 –7 km depth (compared to 0 –3.5 km in 2011). Both the 1896 and 2011 tsunami earthquakes were generated near the trench axis off Iwate prefecture, but their depth was slightly different (Satake et al., 2017, Geoscience Letters).

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