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Tsunami source model of the 2011 Tohoku earthquake and comparison with the 1896 Sanriku and 869 Jogan earthquakes

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The 11 March tsunami from the off Pacific coast of Tohoku earthquake (M 9.0) was recorded instrumentally on coastal and offshore gauges. The ocean bottom pressure (OBP) and GPS wave gauges within the source area, in particular, showed two-stage tsunami waveforms, i.e. a gradual increase of water level followed by an impulsive tsunami wave. The coastal run-up and inundation heights were also measured by many researchers, and the large peak appeared around Miyako in Iwate prefecture. Our previous result of tsunami waveform inversion (Fujii et al., 2011, Earth Planets and Space) assuming a simultaneous rupture of subfaults indicated that the largest slip ($\sim$48 m) occurred near the trench axis off Miyagi. However, the computed coastal tsunami heights from this model did not reproduce the distribution of the measured tsunami heights. Here we introduced multiple time-window analysis assuming a constant rupture velocity, and estimated the slip distribution both in space and time. We also used tsunami waveforms recorded at more gauges than the previous study. In total, we used 11 OBP gauges, 10 GPS wave gauges and 32 coastal tide or wave gauges. The new result indicates that the fault slip propagated from the epicenter and took about 3 minutes to reach the northern and southern ends of the source area. The large slip along the Japan trench axis is more extended than the previous result, with the maximum slip of 37 m. The northern rupture includes the source area of the 1896 Sanriku earthquake, although very large slip occurred just to the south of the 1896 source. This offshore slip is responsible to the second-stage tsunami, i.e. the large impulsive peak. Large slip on the plate interface (< 30 m) around the epicenter is responsible to the first-stage tsunami, i.e. initial water rise and large tsunami inundation in Sendai plain. This slip on the plate interface is very similar to a model of the 869 Jogan earthquake, which we previously proposed, and produces large (> a few km) tsunami inundation on the Sendai plain. Thus the 2011 Tohoku earthquake was a simultaneous rupture of the 869 Jogan type earthquake and 1896 Sanriku-type tsunami earthquakes. While each type had been proposed and considered, simultaneous rupture and resulting larger slip were not considered for previous tsunami hazard assessments, including that for nuclear power plants.