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Earthquake Source Characterization for Broadband Ground Motion Simulation

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Source modeling for strong ground motion prediction keeps developing through observations and physics-based simulations. M9-class megathrust earthquakes and crustal earthquakes associated with shallow slip posed issues and affected the current status of source modeling for broadband ground motion simulations. This presentation includes multiple choices of source modeling with realistic 3-D velocity models to reproduce extreme ground motions.

As for the M9-class earthquakes, many source models for the 2011 Tohoku, Japan, earthquake are derived by dense observation of teleseismic, strong motion, geodetic, and tsunami open data. The similarities and differences of source models from strong motion records are shown in Figure 1. Long-period source models in a period range of longer than around 10 s inverted large slip near the hypocenter and along the Japan Trench. On the other hand, short-period source models in a period range of shorter than around 10 s provided several strong motion generation areas or strong-motion pulse generation areas with large stress drop near the hypocenter and along the down-dip edge of the fault. Both types of source models are partly overlapped in near the epicenter regions, and complementary in the southern regions. Source models from back projection, array analyses, envelope inversion, and seismic intensity inversion generally agreed with the above mentioned source characteristics. Similar to the 2010 Maule, Chile, earthquake, the 2011 Tohoku earthquake could consist of M9-class long-period and M8-class short-period source models. However, new findings of complex rupture along dip direction and multiple ruptures over the fault indicate the diversity of earthquake sources. The resolving power of the strong motion dataset along the Japan Trench is not enough for the 2011 Tohoku earthquake, and further offshore strong motion observation is highly expected.

As for crustal earthquakes with shallow slip, during the 2016 Kumamoto, Japan, earthquake, significant near-fault extreme ground motions were observed. Shallow slip source modeling improvements to reproduce permanent displacement and long-period components of near-fault ground velocity pulses need to be discussed, including the 2023 Kahramanmaraş, Turkey, earthquake, and other recent earthquakes. Some source models propose adding larger and shallower slip areas above strong motion generation areas with smoothed ramp slip velocity functions. However, the latest 3D velocity structure model is revised by the dense microtremor array measurements after the 2016 Kumamoto earthquake. Comparable studies of different velocity structure models and source modeling parameters are useful for broadband ground motion simulations. Additionally, deep borehole array measurements along active faults can constrain design basis ground motion.

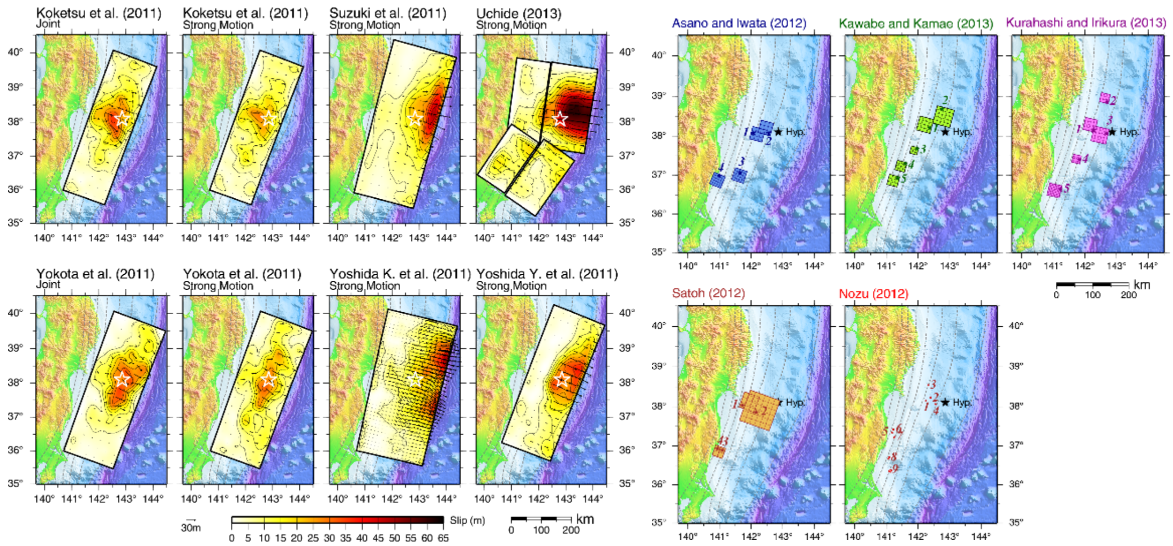

Figure 1. Inverted slip models to reproduce long-period components and source modeling to reproduce shorter-period ground motion for the 2011 Tohoku earthquake (Miyake et al., 2016).