Recent progress and future of earthquake slip inversion

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Slip inversion is a popular analysis method for earthquake sources and a number of slip models, spatio-temporal slip distributions of seismic slip, have been constructed using seismic and various geodetic data for a couple of decades. Each model has different level of reliability, which depends on the quality and quantity of available data. There are small number of well-resolved earthquakes, such as the 1989 Loma Prieta, the 1992 Landers, the 1994 Northridge, the 1995 Kobe, the 2002 Tottori earthquakes, whose slip models are consistently determined by several research groups. On the other hand, slip models of an earthquake presented by different groups can be quite different, even for a large event. Typical reasons of large errors are small number or uneven distribution of stations, inaccurate record timing, and unresolved underground structure. In spite of these uncertainties, slip models have provided useful information for physics of earthquake. One example is the existence of slip pulse, which is first suggested by Heaton (1990) and confirmed by many slip models. Slip pulses imply the existence of velocity-dependent friction law or strong heterogeneity in stress field, and may be one reason for observed predominance of unilateral rupture for large earthquakes (McGuire, 2002). Slip models can constrain constitutive relations on fault planes (Ide and Takeo, 1997) and spatial difference of fracture energy (Ide, 2003).

The size of earthquakes analyzed by slip inversion ranges from M1 (South Africa gold mine, Yamada et al., 2005) to M9 (the 2004 Sumatra earthquake). Although the resolution of slip inversion is relatively low for small events, we can find a sequence of several independent ruptures similar to large earthquakes. Therefore it is almost established that heterogeneity is ubiquitous in the rupture process of earthquakes, and as the next step we require studies characterizing the degree and scaling of heterogeneity. Some pioneering studies have discussed such heterogeneity and found no strong evidence for breakdown of geometrical similarity of earthquakes. Another direction is to study the growth process of an earthquake. Uchide and Ide (this meeting) developed a multiscale slip invesion and applied it to the 2004 Chuetsu earthquake. They found successive small rupture pulses at the beginning of the rupture whose slip rate and rupture velocity are comparable to those of large earthquakes.

Slip models are useful to construct a typical earthquake model, which is applied for dynamic simulations to understand the nature of strong motion generation. It should be noted that the dynamic simulation depends on a characteristic scale of the model and we do not know well what determine the scale or even whether such a scale exist. Development of analysis methods including Green's function calculation and stable broadband inversion will enhance our knowledge about earthquake rupture.