Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

SSS011-P06 Room: Convention Hall Time: May 27 17:15-18:45

Scaling laws of inner fault parameters: Characterization of heterogeneous slips on earthquake faults

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Earthquake source process is now characterized by the following two kinds of parameters: outer fault parameters and inner fault parameters. The classical outer fault parameters characterize the average source process represented by seismic moment and its related values, such as total fault plane length and width, the average amount of slips on a fault and rupture velocity. In contrast, the inner fault parameters characterize heterogeneous rupture process on a fault plane, such as the position of asperities, the number of asperities and the shape of a large slip area. Some scaling relations of the inner fault parameters as well as the outer fault parameters are now available for understanding the complexity of earthquake source processes. In this study, we introduced some new inner parameters to characterize fault plane heterogeneity as representative features of many earthquakes that have been analyzed in a routine manner. We mainly used the slip distribution of events around the world in 1994-2009 by the unified scheme of Kikuchi and Yamanaka (EIC notes) as our data set.
The first new parameter is the area size of large slips here called S50. This value is defined as the total area of slips larger than the half of the maximum slip on a given fault plane. The relation between the value of S50 and seismic moment Mo shows a self-similar scaling law: logS50 = -12.0 + 0.553*log Mo. We also examined the ratio between S50 and the area size of non-negligible slips. We confirmed that their ratio shows a slightly positive correlation.
The second is a parameter called dL that represents the distance between hypocenter and centroid location. Although the result may indicate the spatial resolution of slip distribution in the present analysis because the ratio between the distance dL and seismic moment Mo does not show any clear scaling laws for events of Mo less than 10^28 dyn*cm, a clear positive correlation can be observed for events larger than 10^28 dyn*cm. This scaling law is particularly notable for inland and intra-plate earthquakes, indicating that a large event may be possible only if an area of large slips is located apart from its epicenter.
The third is the parameter called m that represents the degree of spatial concentration in slip over a fault plane. The result may indicate simple spatial concentration for subduction-zone earthquakes while complex spatial concentration for intra and inland earthquakes. That is, the ratio between the degree of spatial concentration m and seismic moment Mo shows a slightly positive correlation for subduction-zone earthquakes but not for inland and intra-plate earthquakes.
At last, we compare the large slip areas inverted by strong motion waveforms (K-net) with those by teleseismic data for common events. The areas of small slips inverted by strong motion waveforms are systematically larger than those by the teleseismic while areas of large slips are almost similar. This indicates that the evaluation of areas of large slip or asperities is reliable regardless of data set types while we may underestimate areas of small slips by teleseismic data.

Keywords: fault parameter, slip distribution, scaling law, waveform inversion, self-similar relation