Likelihood model of crustal earthquakes in southwest Japan using GNSS strain rate data

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In Japan, the Headquarters for Earthquake Research Promotion has developed a nationwide probabilistic earthquake model called "National Seismic Hazard Maps for Japan" since the destructive 1995 Kobe earthquake. This model covers both subduction and crustal earthquakes based on a history of past large earthquakes from seismological, historical, and geological data. The model for crustal earthquakes relies on geological and geomorphological data of active faults and never use geodetic data, whereas contemporary deformation of the Japanese Islands is observed by one of the best GNSS network in the world. Here, we attempt to develop a preliminary likelihood model of shallow crustal earthquakes using GNSS velocity data.

We follow a procedure of Shen et al.(2007) to calculate the likelihood model. The GNSS velocities at continuous GNSS stations from April 2005 to December 2009 are used for the model in southwest Japan. Elastic deformation due to interplate coupling along the Nankai trough is removed using the block model of Nishimura et al. (2018). Strain rate field is calculated at a grid point of 0.2 deg x 0.2 deg by a method of Shen et al.(1996). The strain rates are converted to geodetic moment rates by a formula in Savage and Simpson (1997). Distance Decay Constant, thickness of a seismogenic layer, rigidity, and b value of the Gutenberg-Richter law are assumed to be 25 km, 12 km, 30 GPa, and 0.9, respectively. They are uniform in the modeled region. It is well-known that geodetic strain rates are much larger than seismological ones because geodetic strain includes both elastic and inelastic strain. Elastic strain rates presumably equal to seismological ones on long-term average. We compared seismic moment rates released by shallow historical earthquakes since 1586 and geodetic moment rates. Their ratio is 0.24 and 0.14 in the Chubu, Kinki and Chugoku region and whole southwest Japan. This difference indicates a regionality of the ratio between elastic and inelastic strain. Applying 0.14 for calculating elastic rates and the stationary Poisson process of the earthquake occurrence, probability of M>6 earthquakes for 30 years ranges from 4.3 % to 0.2 % in southwest Japan (Figure 1). We verify this likelihood model by using shallow (Depth<20 km) M>5 earthquakes occurred in 2010-2019. Total number of earthquakes was 36, which is roughly concordant to a predicted number of the model (2.73 per year). Cumulative histograms of geodetic strain rates integrated over area and earthquake count are very similar. About 58 % of the earthquakes occurred with 25 % of the area with highest strain rate. The verification suggests our preliminary likelihood model has the predictive power reasonably.

Keywords: earthquake probability, long-term forecast, Geodetic data, GNSS

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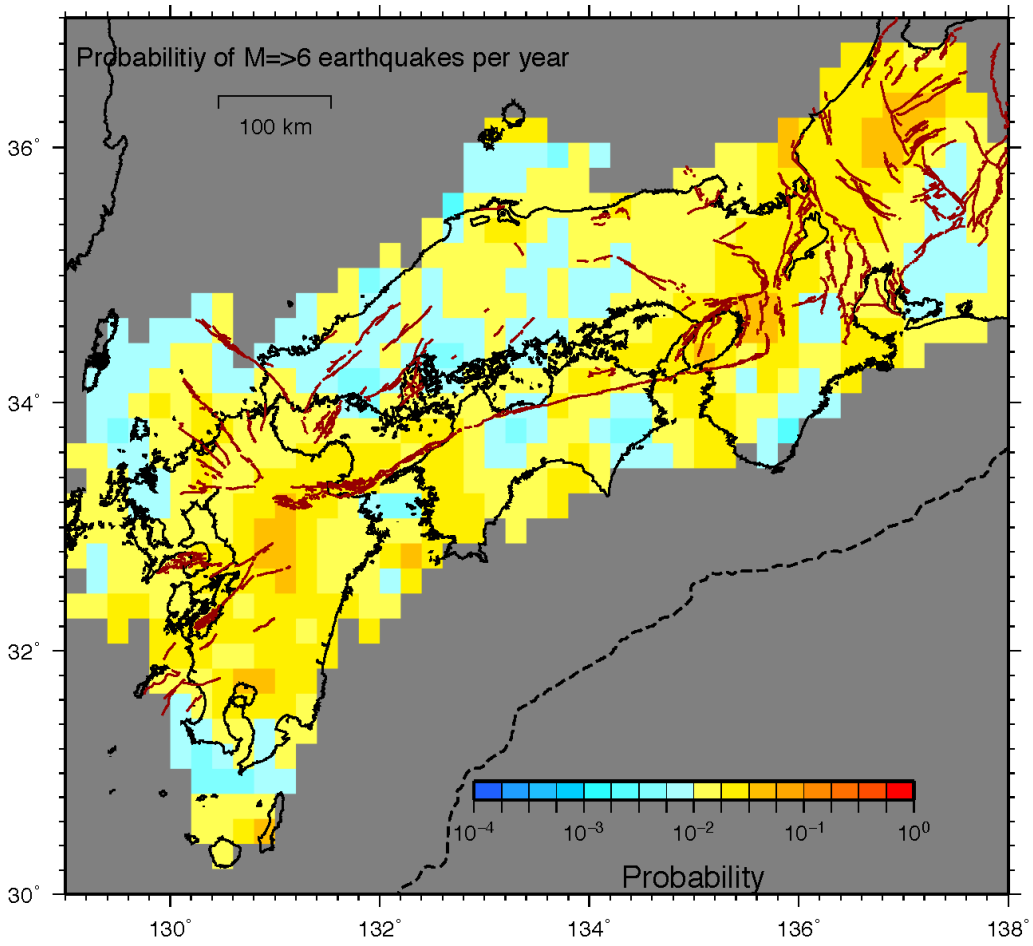

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