Clusters of deep non-volcanic tremors and friction parameter in the rate- and state-dependent friction law

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Swarms of deep non-volcanic tremors occur with a recurrence interval of 2-6 months along the subduction zone of Philippine Sea plate in southwest Japan. These episodic events are considered to be manifestations of stress relaxation process in the transition zone of the subducting plate interface. Epicenter distributions and space-time plots for tremor sources show that the Shikoku area can be divided into three major segments of tremor sources: the eastern, central, and western segments. Furthermore, the eastern and western segments consist of three and four clusters, respectively. Thus the Shikoku area consists of eight units of tremor occurrences.

Tremor swarms often exhibit occurrences with a period of about 12 or 24 hours, and they are synchronized with the Earth tides. Our previous study has shown that the periodic tremor occurrences depend on the stress rate due to the Earth tide, and that they can be reproduced by using the seismicity rate theory based on the rate- and state-dependent friction law [Nakata et al., 2008]. In this study we have investigated tremor occurrences in each of the eight clusters in Shikoku area by applying the same method as in the previous study.

The seismicity rate theory predicts the relative number of earthquakes from the time history of stress changes. For the numerical calculations of seismicity rate, we use discretized versions of seismicity rate formulae in Dieterich et al. [2000]. The stress change in tremor source region is composed of the secular change due to the plate subduction, the transient change due to the triggering short-term slow slip event, and the periodic change due to the Earth tides. Assuming that tremors occur as thrust faulting at the subducting plate interface, we calculate shear stress and normal stress from the theoretical Earth tides evaluated at the central point of the epicenter distribution on the thrust fault plane in each cluster. Although the secular stress change can be estimated from strain observations, we have no reliable observation on the transient stress change due to short-term slow slip events.

Using hourly tremor durations as data, we obtain the seismicity rate profiles that give the best fits to the observed tremor durations. In this inversion, the unknown transient stress rate is expressed as a single or two box-car functions. Another unknown is the combined parameter A$*$sigma, fault constitutive parameter times effective normal stress, in the seismicity rate theory. We determine the unknown parameters by using the simplex method in which we maximize the cross-correlation coefficient between the observed tremor sequence and the calculated seismicity rate.

We have analyzed a total of 46 major tremor swarms that occurred in the Shikoku area from 2004 to 2007. For all of the clusters, the resultant transient stress rates due to the short-term slow slip event are comparable to the tidal stress rate, and the A$*$sigma values are on the order of 1 kPa. These are consistent to the results of our previous study. However, the A$*$sigma values for the clusters in western Shikoku are 2-3 times larger than those for eastern Shikoku, indicating regional difference in friction parameter value and/or effective normal stress.