Slip inversion based on tilt change data for short-term slow slip events in western Shikoku, southwest Japan

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In the southwest Japan subduction zone, so called episodic tremor and slip (ETS) episodes repeatedly occur at the deeper portion of the megathrust source area along the Nankai trough (e.g., Obara and Kato, 2016). An ETS episode is a phenomenon that low-frequency tremor and a short-term slow slip event (SSE) occur simultaneously (Rogers and Dragert, 2003). The western Shikoku area is one of the most active ETS areas in the world: each episode has a week-long duration and their recurrence interval is about six months.

ETS activity provides useful information for understanding the strain balance not only at the ETS zone but also at the source area of the megathrust earthquakes. Both an earthquake and an SSE are phenomenon that releases accumulated strain by fault slip. It is thought that slow slip and high-speed slip (earthquakes) occur next to each other on the plate boundary fault and they interact with each other. When an SSE occurs and the accumulated strain is released, stress at the source area drops but stress at the peripheral region (locked region) increases. Therefore, strain balance between the accumulated strain and released strain by SSEs is important information for considering the stress level at the locked region, the evaluation of the occurrence probability and the estimation of the rupture area of megathrust earthquakes. Although Sekine et al (2010) discuss the strain balance between the accumulated strain by relative plate motion and the released strain by short-term SSEs in southwest Japan, their discussion is a rough sketch in terms of spatial resolution because they model an SSE with a rectangular fault. In order to discuss the strain balance in a smaller scale than discussed in Sekine et al (2010) , it is necessary to estimate the spatial slip distributions of short-term SSEs systematically and to make their catalog as complete as possible. In this study, we develop a method to estimate the spatial slip distribution of a short-term SSE and apply this method to observed tilt change data in western Shikoku.

This method is intended to apply to tilt change data such as a high-sensitivity accelerometer installed at NIED Hi-net stations (Obara et al, 2005), which has been widely used to detect short-term SSEs in southwest Japan (e.g., Hirose and Obara, 2005). Using the tilt change data, Hirose and Obara (2010) estimated spatiotemporal slip distributions of the short-term SSEs. However, there is a limitation in the application of their method to the tilt change data because it requires high S/N time-series data without large disturbances. Then, our method does not use information on temporal change but only use information on spatial variation of tilt changes. It is expected that this will increase the number of data sets that can be applied. Our inversion method estimates a slip distribution from tilt change vectors with a least squares method based on the analytic formulae of crustal deformation due to fault slip in a homogeneous elastic half-space (Okada, 1992) with spatial smoothness constraints. The slip on the plate interface is modeled by a superposition of spline functions of degree 1. This enables to express the spatial slip distribution that is not able to be expressed in conventional methods which assume a rectangular fault (e.g., Hirose and Obara, 2005). The direction of the surface projection of a slip vector is fixed to that of the relative plate convergence of the Philippine Sea plate (Miyazaki and Heki, 2001).

We apply this method to tilt change data for short-term SSEs in western Shikoku in November 2003 and April 2004. The previous study estimates the spatial slip distribution of April 2004 SSE (Hirose and Obara, 2010), but could not estimate that of November 2003 SSE because of the limitation in the data quality. We successfully obtain the spatial slip distributions for both of the SSEs Estimated moment of both events are similar sizes with those in Hirose and Obara (2005). For both of the slip distributions, slip in the western part of the modeled area is larger than that in the eastern part. This slip distribution for the April 2004 SSE is consistent with that of Hirose and Obara (2010). In addition, we can estimate the slip distribution of November 2003 SSE that could not be estimated in the previous study (Hirose and Obara, 2010) by using our method. This indicates that we can obtain more slip distributions of the short-term SSEs in the area that will be useful to discuss the strain balance around the plate boundary.