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Resolving slip evolution of deep tremor in western Japan

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Recent studies have shown that deep tectonic tremors in many subduction zones consist of numerous low-frequency earthquakes (LFEs) that occur as shear slips on the plate interface. LFE hypocenters are determined relatively accurately, and in western Japan, they are concentrated in a narrow zone around the anticipated plate interface [Ohta and Ide, 2011]. Therefore, the location of LFEs may constrain the instantaneous location of tremor sources and illustrate its migration behavior, as demonstrated by a matched filter analysis with template LFEs [Shelly et al., 2007]. Nevertheless, it is yet unclear whether tremor occurs at exactly the same location as LFEs. Since tremor behavior on the plate interface are various and spatially characteristic [Ide, 2010], there might be some tremor activity undetectable using template LFEs. Moreover, while the previous method using matched templates has achieved to draw the discrete picture of the slip behavior of potential tremor, it is not sufficient to explain the entire rupture process. To understand the underlying physics of tremor and other slow earthquakes, it is essential to highly resolve the spatial and temporal behavior of the rupture of these events.

This study determines spatiotemporal slip distribution associated with deep tremor in western Japan, without the spatial limitation of template LFEs. We first estimate the location of the plate interface based on the precise hypocenter locations of LFEs in a target region and prepare ”synthetic template waveforms” by stacking the seismograms of these LFEs at every grid point arranged on this interface. These synthetic template waveforms can be used in a matched filter analysis to continuous waveforms, to grasp a crude image of tremor source. Furthermore, we use the synthetic waveforms as substitute of Green’s functions, and invert continuous tremor waveforms by a non-linear slip inversion method.

We apply the method to 3600 s continuous velocity seismograms recorded at Hi-net stations in the western Shikoku, on 16 March, 2008 from 23:00-24:00, to obtain the detailed slip history of about 1200 s tremor sequence. The slip episode migrates from south to north and consists of three stages: (1) the southern part for 80 s, (2) the central part for several hundred seconds, and (3) the northern part for 60 s. Average migration velocity is between 10-50 m/s, and the first and third stages correspond to unknown VLF events, whereas the second stage includes a much longer slip episode. These differences may be associated with the heterogeneities of material properties on the plate interface.

Keywords: deep tremor, slow earthquake, subduction zone, Nankai Trough, slip distribution