Monitoring of temporal change in the interseismic plate coupling using misfit angles of focal mechanisms relative to the slip-deficit induced stress field: The Nankai trough case

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The activity of shallow inland earthquakes in the Kinki region, southwest Japan, increased from about 50 yr before to 10 yr after the occurrence of large interplate earthquakes along the Nankai trough (Utsu 1974; Hori & Oike 1999). This observation indicates that the shallow inland earthquakes occur in response to the interseismic plate coupling, facilitating further research on the causal relationship between the inland earthquake activity and the interplate coupling state.

Here we propose a method to monitor the temporal change in the interseismic plate coupling by examining whether the focal mechanisms of inland earthquakes align with the stress field caused by the slip-deficit or not. We expect that earthquakes will preferentially occur on faults whose slip direction is close or in agreement with the slip-deficit induced stress field when the stress buildup due to the plate coupling dominates the regional background stress. Therefore, the misfit angle of focal mechanism solutions (i.e., the angle between the observed slip direction and the tangential traction predicted by the reference stress tensor) is a useful indicator (e.g., Terakawa et al., 2016; Otsubo et al., 2018).

The procedure is summarized as follows:
(1) The stress tensor caused by the slip-deficit is computed every 0.1˚ at the depth of 10 km.
(2) Search the grid point closest to the hypocenter of each focal mechanism, defining a reference stress tensor there.
(3) Calculate the misfit angle of each focal mechanism. Here the smaller angle for each pair of nodal planes is used in subsequent analysis.
(4) Calculate the moving average of the misfit angles for 1-year time window. The error is computed using a bootstrap resampling with replacement over 1000 iterations.

We applied the method to inland earthquakes in the Kinki region and the western Shikoku to evaluate a temporal change in the plate coupling along the Nankai trough. We merged the JUNEC catalog (Ishibe et al. 2014) and the JMA catalog to produce the consolidated one, which spans from 1 July 1985 to 31 December 2019. For the calculation of the slip-deficit induced stress tensor, we adopt the slip-deficit model of Noda et al. (2018). The results show that the average misfit angles fluctuate every 3-5 years. The amplitude of the fluctuation is about 20˚, which is significant even if errors are taken into account. This result may reflect that the interplate coupling periodically becomes strong or weak. Although such cyclic fluctuations have not been reported in the Nankai trough, Uchida et al. (2016) found a quasi-periodic slow-slip behavior (1-6 years period) in the Tohoku subduction zone, which results in the cyclic fluctuations in the interplate coupling. Furthermore, we observe that the average misfit angles tend to decrease since 2012, suggesting a possibility that the plate coupling becomes stronger with time. The recent occurrence of moderate earthquakes, such as the 2013 M_j6.3 Awaji Island, the 2015 M_j5.1 southern Tokushima, and the 2018 M_j6.1 northern Osaka earthquake, may support the hypothesis.

Further studies are needed to verify the above results, but it is likely that the present method has a

capability to detect subtle temporal change in the plate coupling and could be incorporated into earthquake forecasting strategies.

Keywords: stress, monitoring, plate coupling, Nankai trough

