Detection of annual-scale variations in interplate coupling by combining intraplate earthquakes and geodetic data: Application to the Tohoku-oki and Nankai

Kazutoshi Imanishi[1] and Akemi Noda[2]

[1]Geological Survey of Japan, AIST, [2]Japan Meteorological Agency

k.imanishi@aist.go.jp

Accurate estimates of interplate coupling are crucial for understanding the timing and magnitude of large earthquakes at plate boundaries. While these estimates are typically based on geodetic data, the analysis combining seismic data can enhance spatio-temporal resolution.

In this study, we propose a method to infer spatio-temporal variation in interplate coupling by examining whether the focal mechanisms of intraplate earthquakes near the plate interface align with the stress field caused by the geodetically derived steady-state plate coupling. We define a misfit angle as the angle between the slip direction of an earthquake's focal mechanism and the tangential traction predicted by a stress tensor resulting from the plate coupling model. When the plate coupling persists, earthquakes will exhibit smaller misfit angles. Conversely, deviations from the locked state, such as those caused by large earthquakes or slow slip events, will result in larger misfit angles for earthquakes in the surrounding area. By setting up grids in both the temporal and spatial domains and calculating the average misfit angle for each grid cell, we can estimate the spatio-temporal variations in the plate coupling state.

We applied this method to the Tohoku-Oki plate boundary. A steady-state plate coupling model was estimated by analyzing surface velocity data from GNSS daily coordinates during the period from March 1998 to February 2008. Using the F-net moment tensor catalog, we extracted focal mechanism solutions of intraplate earthquakes near the plate interface from 1997 to 2023. The misfit angle exhibits complex behavior both temporally and spatially, capturing variations in the locked state that were not detectable using geodetic data alone. Focusing on the large slip area of the 2011 Tohoku-Oki earthquake, we observe that the misfit angle shows annual-scale fluctuations, with an overall increasing trend since around 2008. This observation suggests that prior to the occurrence of the Tohoku-Oki earthquake, there was a complex deviation from the locked state, possibly involving multiple occurrences of slow slip events.

Motivated by these results, we applied this method to the Nankai Trough. We will demonstrate how we detected spatio-temporal variations associated with long-term slow slip events.

Acknowledgements: We used the F-net moment tensor catalog provided by NIED and the GEONET F3-Solution published by GSI.