Developing objective detection algorithm for deep short-term SSE at the southwest Japan using tilt and strain data

*Suguru Yabe[1], Norio Matsumoto[1], Tadafumi Ochi[1], Takanori Matsuzawa[2]

1. National Institute of Advanced Industrial Science and Technology, 2. National Research Institute for Earth Science and Disaster Resilience

Slow earthquakes have been detected along the deep plate interface in the southwest Japan. Signals of slow earthquakes are termed differently according to their observed frequency band. High-frequency seismic signals at 2- 8 Hz are termed "tremor", whereas geodetic signals are termed "slow slip events (SSEs)". SSEs in the southwest Japan have usually moment magnitudes (Mw) less than Mw 6.3 and duration of about a week. Signals of such SSEs are easily masked by the noise in GNSS data. Thus, tilt and strain data are used to detect these SSEs. Tiltmeters were deployed at Hi-net stations by National Research Institute for Earth Science and Disaster Resilience (NIED). Since 2009, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (GSJ, AIST) constructed strain observatories at the southwest Japan to improve detectability of SSEs. Japan Meteorological Agency (JMA) also constructed strain observatories at the Tokai region. Strainmeters can detect strain changes less than 10^{-9}, which is small enough to capture SSE signals. Therefore, tilt and strain data are useful to detect and analyze SSEs in this region. However, due to high sensitivity of these sensors, they are also affected by local crustal deformation around the observatories caused by rainfalls and local groundwater movements, etc. Contaminations of such non-tectonic signals in strain and tilt data make it difficult to use these data for objective detection of deep SSEs so far. In this study, we developed a new objective detection algorithm for SSEs using tilt and strain data. The developed method is similar to geodetic matched filter technique developed by Nishimura et al. (2013) and Nishimura (2014) to detect SSEs using GNSS data. We consider that observed data is the summation of a linear trend and tectonic signals of SSEs. We use a three-week time window. We assumed that an SSE occurred in one week at the middle of the time window, and two-week data except for one week in the middle of the time window are used for data fitting. We solve the problem of temporal changes in data quality due to contaminations of non-tectonic signals by introducing a prior distribution of log-normal distribution to the variance of data fitting. The likelihood is calculated by numerical integration of conditional probability and prior probability. Fault parameters (location, size, and slip) are determined by grid search maximizing the calculated likelihood. Newly introduced prior distribution reduces weight on irregular data caused by non-tectonic signals, and likelihood becomes large when tectonic signals are consistently recorded at multiple stations. Signals are detected using Akaike Bayesian Information Criterion. We applied the developed method for eight-year (2013 –2020) strain and tilt data of GSJ, JMA, and NIED. We compared our detection results with SSE catalogs by GSJ and NIED, which are based on visual inspections of the same data as well as an SSE catalog updated from Nishimura et al. (2013) and Nishimura (2014) based on GNSS data, showing that detectability of our method is better for smaller events than NIED catalog (visual inspections for tilt data only) and GNSS catalog.

Acknowledgement
We appreciate JMA and Prof. Nishimura for providing their strain data and SSE catalog, respectively.

Keywords: Strain, Tilt, Slow Slip