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Detection of short-term slow slip events in southwestern Japan using GPS data

Takuya Nishimura[1*], Hisashi Suito[1]

[1]GSI of Japan

Slow earthquakes with a wide range of time constants occur in a deep part of the Philippine Sea plate subducting from the Nankai Trough (cf. Obara, 2010). It is important to investigate characteristics of the slow earthquakes for understanding the earthquake cycle and the process of stress accumulation. Although long-term SSEs (slow slip events) with a time constant of months to years have accompanied surface deformation detected by GPS in the Bungo Channel and the Tokai region, deformation associated with short-term SSEs was detected by not GPS but tiltmeters and strainmeters because its signal is presumably below a noise level of GPS. Recently, the noise level of the GPS data has been improved by revising the strategy of the GEONET baseline analysis. We expect that GPS becomes to detect the deformation of the short-term SSEs because the fault models for the short-term SSEs estimated from tilt data predict up to 3 mm of surface displacement. Hama et al. (2009) reported that GPS could detect the deformation of the short-term SSEs in the Tokai region. In this paper, we present results for detecting signals of the short-term SSEs in GPS data and estimating their fault models.

Because repeatabilities of daily coordinates in GEONET timeseries are 2-3 mm, it is difficult to judge an existence of 2-3 mm signals related with short-term SSEs by visual inspections. We reduce short-wavelength noises by spatial filtering which remove a common component in timeseries for clusters of GPS stations (Tabei and Amin, 2002). We found several offsets which are coincident with deep low-frequency tremors in filtered timeseries. Spatial pattern of horizontal displacement calculated from the offsets is concordant with that predicted by the fault model of short-term SSEs.

Although the National Research Institute for Earth Science and Disaster Prevention (Sekine et al., 2010) has investigated the short-term SSEs from the tilt data, we tried to detect signals of the short-term SSEs solely using GPS data. First, we calculated AIC (Akaike's Information Criterion) by fitting two functions for the filtered timeseries with shifting a 180-days-long time window. The GPS data spanned from 2005 to 2010. One function is a linear trend and the other is a linear trend with a step at the middle of the time window. Second, we calculated the AIC difference between two functions for two specific regions, that is, the Tokai and the northern Kii Peninsula regions. A candidate date for the short-term SSEs has a local minimum of the AIC difference. Finally, we visually inspected horizontal displacement for the candidate dates and recognized specific SSEs patterns for 9 events in 21 candidates. These events accompanied deep low-frequency tremors. In several cases, it is possible to estimate fault models of SSEs from the GPS displacement. Moment magnitudes for the events occurred around February 13, 2007 and March 4, 2008 are estimated to be 5.82 and 6.05 from GPS data, respectively. We, therefore, conclude that GPS can detect large short-term SSEs. However, we need to improve the method to detect them because some large events reported by Sekine et al. (2010) cannot be recognized by the present method.

Keywords: Short-term slow slip, GPS, Southwest Japan, Fault model, Philippine Sea plate