Japan Geoscience Union Meeting 2014
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SCG64-P01 Room:Poster Time:April 30 18:15-19:30

Deep Triggered Non-Volcanic Tremor in the Slow Earthquake Active Regions in South Chile and Ecuador

CHAO, Kevin[1*] ; OBARA, Kazushige[1]

[1]ERI, the University of Tokyo

Deep non-volcanic tremor has been observed at many major plate-boundary faults and intraplate faulting systems. Recent studies have shown that the tremor triggered by surface waves of teleseismic earthquake occurs on the same fault patches as the spontaneously occurring ambient tremor. The observations suggest that the triggered tremor can be used as a proxy to estimate the background tremor activity. Here we search for tremor triggered by teleseismic earthquakes in south Chile and Ecuador where the ambient tremor and slow slip event have been observed respectively. In south Chile, we analyzed a temporal array data between 2004 and 2006 and observed clear triggered tremor following the 2004 Mw9.0 Sumatra, 2005 Mw8.6 Nias, and 2006 Tonga earthquakes. Triggered tremor sources are located at the central of the ambient tremor zone. The results indicate both Love and Rayleigh waves promote the tremor triggering potential. The tremor triggering threshold is around 2 kPa, similar to which in Parkfield. In Ecuador, we can only use single station to infer the existence of triggered tremor due to lack of seismic stations in this region. During the period between 2004 and 2012, we observed triggered tremor following the 2010 Mw8.8 Chile and 2007 Mw8.0 Peru earthquakes. Since there is no other station within 500 km near that station, we roughly estimate that the triggered tremor sources are located within 50 km from the station based on the attenuation of tremor from previous studies and the estimation of the time difference between P- and S-waves of triggered tremor. We infer that the triggered tremor source might be located at the region where the slow slip event has been observed. The apparent tremor triggering threshold in Ecuador is about 40 kPa. The high threshold infer a low background tremor rate or simply due to the network capability.

Keywords: non-volcanic tremor, triggered tremor, south America

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Shallow low-frequency tremor activity in the Hyuga-nada, revealed by ocean bottom seismographic observation

YAMASHITA, Yusuke[1*] ; YAKIWARA, Hiroshi[2] ; UCHIDA, Kazunari[1] ; SHIMIZU, Hiroshi[1] ; HIRANO, Shuichiro[2] ; MIYAMACHI, Hiroki[2] ; UMAKOSHI, Kodo[3] ; YAMADA, Tomoaki[4] ; NAKAMOTO, Manami[1] ; FUKUI, Miyo[1] ; KAMIZONO, Megumi[1]

[1]Institute of Seismology and Volcanology, Kyushu Univ., [2]Nansei-Toko Observatory for Earthquakes and Volcanoes, Kagoshima Univ., [3]Graduate School of Fisheries Science and Environmental Studies, Nagasaki Univ., [4]Earthquake Research Institute, Univ. of Tokyo

In order to reveal the detail of microseismicity from the shallower part of the plate boundary to seismogenic zone in the Hyuga-nada region, we have conducted Ocean Bottom Seismographic observation from May 19 until July 6, 2013. We used 12 Ocean Bottom Seismometers (OBSs) with a three-component short-period seismometer. During this observation, we observed many low-frequency tremors (SLFT) which mainly occurred from end of May to end of July 2013 [*Yamashita et al*., 2013 AGU fall meeting]. We report the detail of SLFT activity in the Hyuga-nada region based on the semi-automatically analysis using envelope correlation method (ECM)[*Obara*, 2002].

The differential arrival times between OBS stations using ECM were obtained from the lag times with maximum cross-correlation coefficient between the pair of the root mean square (RMS) envelopes which were converted from composite horizontal components waveform with applying a 2-8 Hz bandpass filter. RMS envelopes were smoothed by using 5 s window and performed down-sampling with a 20Hz. The length of RMS envelops for calculating of cross-correlation coefficients was set for 150 s. If the maximum cross-correlation coefficient for a pair was larger than 0.85, and more than or equal to 6 pairs, we searched minimum RMS residual position by a grid search algorism. These processing were performed automatically for the continuous RMS envelope records every 75 s (i.e., overlapping two moving window for 75 s). After the calculation, we carefully examined the candidate tremor events to distinguish "regular" earthquakes, T-phase signals, or background noise.

Based on the result of SLFT location by ECM, we identify two migration episode of the SLFT: 1st episode started in east off Tanegashima Island from end of May, 2013, migrated northward along strike of subducting plate, veered away to the north-west in the around S08 station, then reached under the S06 station on July 12 - 14. 2nd episode started in the south of S08 station on July 17, migrated northward and veered away to the north-west in the around S08 station, reached around the S07 station, veered away to the east, reached around the S09 station.

These migration episodes suggest that undetected short-term slow-slip event may have occurred at the same time in the shallow part of the Hyuga-nada region. Around the focal area of SLFT, the Kyushu-Palau ridge is subcudting: the SLFT activity was only found on the south side (i.e., Ryukyu arc side). In particular, the depth of plate boundary around the S08 station is southwestward deepening down to 10 km depth [*Park et al*., 2009]. Therefore, the episodic slow-slip extended to northward with SLFT activity, and shifted to northwest-ward caused by the Kyushu-Palau ridge which act a segment boundary to controle the interplate slip phenomena.

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Keywords: Shallow low-frequency tremor, Ocean Bottom Seismographic observation, Hyuga-nada

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The Slow Slip Event off the Boso Peninsula on January 2014 and the associated earthquake swarm

KIMURA, Hisanori[1*]

[1]National Research Institute for Earth Science and Disaster Prevention (NIED)

Introduction

Off the Boso Peninsula, at the southeastern Kanto, central Japan, slow slip events (SSE) accompanied with earthquake swarms recurs with time interval of 4-7 years. SSEs have occurred in 1983, 1990, 1996, 2002, 2007, and 2011 and the latest SSE recurred from Dec. 2013 to Jan. 2014 with interval of 2 years and 2 months. In this study, detailed activity of the earthquake swarm and a fault model of the Boso SSE were determined.

Data and Methods

High precision hypocenter distribution was determined for earthquakes shallower than 30 km off the Boso Peninsula, from Jan. 1, 2005 by Double Difference method incorporating waveform correlation analysis. Hypocentral parameters determined by NIED Hi-net (automated hypocenters were partly included) were used as initial hypocenters.

A rectangular fault model with uniform slip was determined using genetic algorithm inversion for fault location and geometry and the weighted least squares method for slip amounts, following a method of Obara *et al*. (2004) based on tilt data recorded by high sensitivity accelerometer co-installed in NIED Hi-net station. In this analysis, slip direction was fixed to the direction of relative plate motion.

Results

Most earthquakes occurred around the northern edge of the seismic region where seismic swarms associated with the previous Boso SSEs occurred. Seismic swarms first occurred at the eastern offshore area and then migrated to the western onshore area. Migration from offshore to onshore regions is common feature among the previous Boso SSEs. Distribution of earthquake swarms is similar to that of the 2007 SSE, although spatial distribution and number of events are slightly smaller than the 2007 SSE.

The maximum crustal tilting of about 0.4 μ radian with northwestward direction was observed at KT2H station and the fault model was determined to be located off the Boso Peninsula with size of M_W6.1. Location of SSE slip overlaps with locations of the 2007 (Sekine *et al*., 2007) and initial stage of the 2011 (Hirose *et al*., 2012) SSEs. Tilting direction is similar to tilting direction of the 2007 SSE, however, its amount is about a half of the 2007 SSE (M_W6.4) and the SSE size is also smaller. Smaller number of earthquakes is likely to reflect smaller size of the SSE. In the 2011 SSE, west-northwestward tilting of about 0.3 μ radian was observed for the first two and a half days and size for this period was estimated as M_W6.2. Its direction and amount are similar to those of the 2014 SSE and the SSE size is also close.

Discussion

Recurrence interval of the 2014 SSE was shortest for the last about 30 years. The size of the 2011 SSE was estimated to be comparable to previous SSEs and a possibility that the 2011 SSE was hastened by the stress increase caused by the 2011 Off Tohoku Earthquake and its afterslip has been proposed (Hirose *et al*., 2012). On the contrary, size of the 2014 SSE is likely to be smaller than previous SSEs. This result infers that the SSE slip is smaller supposing the same source area and the SSE recurred with shorter interval with smaller stress accumulation. Further analysis is necessary to reveal the detailed source process of the Boso SSE for monitoring of the stress accumulation.

Acknowledgements:

In this study, seismic data obtained by Earthquake Research Institute (ERI) and Japan Meteorological Agency (JMA) were used.

Keywords: Slow Slip Event, plate boundary, earthquake swarm, Kanto region

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A long-term slow slip event in central Shikoku in 2013

KOBAYASHI, Akio[1*]

[1]Meteorological Research Institute

A long-term slow slip event in central Shikoku is investigated using the GEONET GNSS data. We estimated the steady deformation rate at each GNSS station from the daily coordinates for the period from January to December 2012. Then the steady deformation rates were subtracted from all the coordinate data. The artificial offsets of the coordinate were corrected using data set shown on the web site of the Geospatial Information Authority of Japan. We can see south-eastern displacements less than 1 cm at GNSS stations in central Shikoku for one year from October 2012. These unsteady displacements are also seen in the time series of the baseline lengths between central Shikoku and Chugoku district.

We estimated slip distribution on the plate boundary, assuming the unsteady displacements were caused by a slip on the plate boundary. The estimated slip is distributed in central Shikoku. Center of the slip is located slightly southeast of the belt of deep low-frequency earthquakes. The size of the slip is equivalent to Mw 6.2, which is smaller than other long-term SSEs along the Nankai Trough.

Keywords: long-term slow slip, GNSS, crustal deformation, central Shikoku

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Rate and state simulation of Yaeyama slow slip events in the southwestern part of the Ryukyu Arc, Japan

OKUDA, Ryosuke[1*] ; HIRAHARA, Kazuro[1] ; MIYAZAKI, Shinichi[1] ; KANO, Masayuki[1] ; OHTANI, Makiko[1]

[1]Graduate School of Science, Kyoto Univercity

Slow slip events (SSEs) are recurring on the plate interface beneath the source regions of the interplate large earthquakes. It has been proposed that the activity of SSE possibly changes before the occurrence of large interplate earthquakes. Hence, it is essential to know the frictional properties for producing SSEs to predict the occurrence of large earthquakes. Our final goal is to optimize frictional parameters on the fault related to SSE through a data assimilation method which combines the observational data and the forecast ones derived from a simulation model, and then to give information on the occurrence of large interplate earthquakes. In this paper, as a first step of such a data assimilation, we construct a simulation model reproducing the observed spatio-temporal slip evolution of SSE.

In this paper, we consider the Yaeyama SSEs. Around the Yaeyama islands in the southwestern part of the Ryukyu Arc, Japan, GPS observations have caught the frequent recurrence of SSE activity. Around there have occurred almost no large earthquakes that affect the SSE activities during the observational period, which leads to a relatively simple simulation model of SSE. Those are the reasons that we select SSE on this area.

Heki and Kataoka(2008) reported the following features of Yaeyama SSEs; 1) SSEs recur on a plate interface at depths of 20-40km, 2) the average recurrence interval is 6.3 months, 3) its standard deviation is 1.2 months, 4) the slip rate released by SSEs is 11.0 cm/yr, in spite of the estimated convergence rate of 12.5 cm/yr.

We construct a simulation model which reproduces the above mentioned features of SSE. We set a dipping fault embedded in a homogeneous elastic half space. The friction on the fault is assumed to obey a rate-and state-dependent friction law, and the slowness law of state evolution (Dietrich, 1979). To simulate SSE, following Kato(2003), we set an asperity at depths of 20-40 km on a stable sliding plate interface, whose frictional properties are characterized by frictional parameters A, B and L. The asperity has the rate weakening frictional property of $A-B<0$ and its radius is nearly equal to or less than the nucleation radius determined by frictional parameters. We also consider the possible presence of a locked zone, namely an asperity, at the shallow portion of the plate boundary close to the Ryukyu Trench, which might cause the 1771 Meiwa tsunami (Nakamura, 2009). Dating of tsunami stones suggests a possible recurrence of 150-400 years of large tsunami (Araoka et al., 2013), and the large tsunami events close to the Ryukyu Trench might have recurred in several hundred years.

It is found that the interval of SSE can be adjustable by changing the friction parameters. For example, if a single asperity with the size of 80 km has frictional parameters of A=50 kPa, B=56kPa, and L=2.2 mm, the interval is about 6 months. Further, if we add another asperity with 40 % slip deficit rate of the convergent rate of 12.5 cm/yr just above the SSE asperity zone, the slip rate released by SSEs reduces to the observed rate of 11.0 cm/yr. The released slip rate depends on the location, size and assigned slip deficit rate of the shallow asperity. The locking state at the shallow portion is important to give information on the occurrence of possible tsunami earthquake, and we need the further investigation. For reproducing the observed fluctuation of recurrence intervals of SSE, we need to consider the interaction among multiple asperities or the hierarchical asperity model where a large asperity has small asperities with different properties inside itself.

Keywords: slow slip events, Yaeyama, a rate- and state-dependent friction law

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Array observation of short span strainmeter in the Kii peninsula

KANO, Yasuyuki[1*] ; HOSO, Yoshinobu[1] ; ONOUE, Kensuke[1]

[1]DPRI, Kyoto Univ.

Crustal deformations have been observed associated with deep low-frequency tremors occurring below the Kii peninsula and Shikoku. Strain measurements by an extensometer at Kishu operated by DPRI, for example, show that the sources with epicentral distance of 30 - 40 km causes strain changes of $10^{?9}$ to $10^{?8}$ occurring within several days. Although the traditional extensometer observations can detect these strain changes, it is difficult to make detailed analyses because of the limited number of stations. We designed a short-span extensometer with 1.5 m-long standard measure. Strong coupling of the instrument to the ground is important for stable observations, so three anchor bolts fixed to the base of the instrument are cemented into a 50-cm-deep hole. We observed crustal deformation associated with deep low-frequency tremors by the short-span extensometer installed at Nakaheji. We detected strain change associated with low frequency events occurred on March 2013. We are preparing another sites for installation of the strainmeter around the western Kii Peninsla to constract array of strainemters. The array observation contributes to improve the detection capability of crustal deformation by eliminating noise caused by weather disturbance and to have better understanding of slow slip events such as slip distribution.

Keywords: strainmeter, slow earthquakes, array observation