Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS030-01 Room:105 Time:May 24 08:30-08:45

Monitoring of Short-term Slow Slip Event by GPS data in Tokai Region

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In the south-western part of Japan, there occur episodic tremor and slip beneath Nankai trough. These short-term slow slip events (S-SSEs) especially in Tokai region are known to be very small and hard to detect by GPS. Our study is a trial for monitoring these S-SSEs by GPS data.

The S-SSEs in Tokai region have been detected by strain meters and Hi-net tilt meters (Hirose and Obara, 2006), and the fault parameters were estimated from these data. Though the tilt- and strain-meters are very sensitive to short term variation, the records by tilt meter and strain meters are not so stable for weeks or months because of local movements of ground water around sensors affect them. For example, Hirose and Obara [2006] clipped the time series of tilt-meter corresponding to the time of tremors, and then they estimated the fault parameter from the clipped tilt records.

On the other hands, Satomura et al.,[2008;JPGU] successfully detected surface deformation accompanying deep low frequency tremors and estimated the amount of the slip by forward modeling using the fault parameter obtained by tilt-meter analysis. Although the amount of the slip was not equated with that estimated by tilt-meter, the pattern of the displacement matched very well between observed and calculated one.

One of the advantages of GPS data is its small middle- or long-term variations comparing to tilt- and strain-meters. The records of GPS antennae during the term without S-SSE or far from the sources are quiet. GPS record should be a powerful tool for automatic temporal and spatial detection of S-SSEs without any assumptions like coherences between several stations or correspondence with tremors.

We conducted feasibility study for the automatic detection of the S-SSEs using GPS. The aimed event was the S-SSE occurred in January 2006 beneath western Mikawa. The moment magnitude of it was estimated to be Mw 5.5 by JMA. We confirmed that the GPS data covering Tokai region were successfully inverted to the slip just around the source of the tremor at the corresponding time.

The used data were obtained at 69 stations of GEONET and 35 stations by GPS university consortium of Japan from December 1, 2005 to December 31, 2006. Positioning was done by GAMIT ver.10.35 software. The calculated positions were processed by the method by Satomura et al.,[2008;JPGU] to reduce fluctuation and then inverted by a method based on theory by Yabuki and Matsuura.,[1992;GJI]. The maximum slip of about 1 cm was detected around the focal area of the tremor.

The next step is to extend the temporal and spatial expansion of the GPS data eastward to Suruga Trough, westward to Bungo Channel, back to 2002 and forward to 2010. We will try to detect the spatio-temporal distribution of the SSEs beneath south-west Japan automatically.

Keywords: deep low-frequency slight tremor, short-term slow slip, GPS, inversion

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Change in dilatation obtained by means of GPS and presumption of asperities for the Tokai Earthquake (2)

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Tokai Earthquake is presumed to occur in the near future along the boundary of subducting Philippines Sea Plate and Amurian Plate in the Tokai district. Therefore, very dense GPS network has been constructed in order to detect the precursory signal of the earthquake.

A slow slip event was found to occur under the Lake Hamana between 2000 and 2005 by the GPS observation results. This slow slip event occurred at deeper area of the presumed source area and it might change the conditions of the locking status on the source fault of the Tokai Earthquake.

We processed the GPS data to obtain the detailed dilatation velocities in the last report (Ukei et al., 2010). The results corresponded well with the model calculated from the asperity model by Matsumura (2007). We processed more data than the last report to get more reliable results.

We processed 95 GPS stations data which is 29 more than the last one. The duration was 3 years from January 2004 to December 2006. GAMIT ver.10.35 was used referring to ITRF2005.

The results obtained showed the clear dilatation velocity change before and after the stop of the slow slip, and also showed better correspondence with those calculated from the asperity model than the last results.

We also obtained the slip distribution from the velocity data by using inversion method by Yabuki and Matsu'ura (1992) on the plate boundary obtained by Ohta et al. (2004). This results showed that the homogeneous back-slip in the source area of the Tokai Earthquake. It is inconsistent with the results from dilatation velocity data.

Keywords: Tokai District, GPS, Crustal movements, Asperity, Tokai Earthquake, Slow slip

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SSS030-03 Room:105 Time:May 24 09:00-09:15

The whole picture of temporal development of the plate coupling in the Tokai region, 1996–2010

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In the Tokai area, central Japan, the continuous crustal deformation due to the interaction between subducting Philippine Sea Plate and overlying continental plate have been observed by many methods such as GPS and leveling. We developed these data in order to know full picture of the plate coupling process macroscopically.

We developed the GPS data from 1996 to 2010 as following: we cut the time series of daily GPS coordinates into two-year-length time series and removed annual and semi-annual components to obtain mean annual velocity. Using this value, we estimated plate coupling on the plate interface using the geodetic inversion method. The results showed that the plate coupling had three phases: 1) strong slip deficit in the offshore region before 2000, 2) forward slip beneath the inland region in addition to the stronger slip deficit in the same region as 1 between 2000-2004, and 3) the same distribution as 2 but the smaller size than 2 since about 2006. Phase 2 might indicate the slow slip event.

We also developed the leveling data from 1996 to 2008. We picked it up to make five-year-length time series and estimated mean annual velocity in the interval, because unlike the daily GPS coordinates, the leveling observations were taken place usually only once a year. Although the interval of the analysis was slightly different, the overall trend resembled the results using GPS data mentioned above. The estimated coupling distribution by GPS data could make the leveling data, and vice versa.

These results showed that GPS and leveling data were consistent each other and suggested that the result of geodetic inversion became more accurate if the geodetic inversion using both GPS and leveling data was made.

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SSS030-04 Room:105 Time:May 24 09:15-09:30

Steady interplate coupling at the Nankai Trou

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The Philippine Sea plate is subducting beneath southwest Japan at the Nankai Trough causing elastic shortening of the crust in the direction of plate convergence. To better understand interplate megathrust earthquake cycle, distribution of plate coupling on the plate interface at the interseismic stage should be monitored. The biggest problem may be a modeling of plate interface that changes abruptly its strike and dip-angle. Instead of conventional rectangular faults, we use a number of triangular elements to reproduce the plate interface in this study. We invert three-dimensional GPS velocities to estimate interseismic slip deficit rates at the Nankai Trough plate interface.

At first we calculate horizontal velocities relative to the Amurian plate and vertical velocities with respect to the ellipsoid at 430 GEONET stations in southwest Japan. We use final coordinate solutions of GSI (F3 solutions) during the period of January 2004 to December 2009. Next plate interface in depth of 4-60 km is reproduced by 533 triangular elements without any gap or overlap. In the inversion analysis, we employ Poly3D (Maerten et al., 2005) and apply a boundary condition of zero-coupling at the margin of the model space and a constraint of smoothness for spatial variation of slip deficit rates between the elements.

The result shows that the regions of the highest slip deficit rate (nearly 100% of plate coupling) are estimated off Sikoku and Kii peninsula. These regions are in accordance with the asperities of the 1946 Nankai earthquake and consistent with the results of the previous studies. Nearly 70% of coupling is estimated beneath the Bungo channel where long-term slow slip event (L-SSE) has been detected every 6-7 years. Cumulative slip deficit in one interval of the L-SSE (6-7 years) is roughly equivalent to the maximum slip of the 2003 and 2010 L-SSEs (about 30cm) if plate convergence rate (70 mm/yr from a global plate model) and plate coupling (70% in this study) are assumed. Moreover recent studies have revealed that crustal deformation field in southwest Japan involves lateral motion of the forearc block along the Median Tectonic Line (MTL). Assuming that the shallower portion of the MTL fault plane is locked but aseismic forearc block motion is going on along the deeper portion of the MTL, we calculate contributions of the MTL and remove them from the observed GPS velocity field. Reanalysed results show that slip deficit rates that have been overestimated especially in the western part of the model space are improved.

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Detectability of interplate fault slip on the Pacific plate, based on GEONET

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The detectability of interplate fault slip on the Pacific plate is investigated using the GPS Earth observation network system (GEONET) in Japan. The detectability is calculated in term of two characteristic parameters; threshold of the data and number of stations.

It is expected to detect the interplate fault slip with a moment magnitude of greater than 6.5 in the wide area of the plate interface when the threshold and number of station are 3mm and 3, respectively.

Keywords: GPS, interplate fault slip, detectability

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Large aseismic creep detected by precise leveling survey at the central part of the Longitudinal valley fault, Taiwan

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Longitudinal valley faults in eastern Taiwan are commonly considered collision boundary between the Eurasian plate and Philippine sea plate. Yuili fault, one of the active segments of the longitudinal valley faults, is reverse fault with east dip. We established about 30km leveling route from Yuli to Changbin to detect the vertical deformation in detail (Murase et al. 2009). The installation interval of benchmarks near the fault area is about 100 m. Others were installed every about 300m.

The precise leveling surveys were conducted in August 2008, August 2009 and August 2010. The overview of the deformation detected in the period from 2008 to 2010 is as follows. It was detected about 3.0 cm/year uplift, referred to the west end of our route, at about 2km region across the fault. Uplift was gradually-reduced with the distance from the fault, and was 1.5 cm/year at the east coast. In the observation period, there is no significant earthquake in Yuli fault. It suggests the detected deformation as a cause for the aseismic creep motion of the Yuli fault. The deformation detected in the period from 2009 to 2010 denotes the same tendency and rate of that from 2008 to 2009. It suggests that the creeping occur at the same location of the fault with constant rate. From these deformation, the preliminary creep distribution was estimated in the Yuli fault. We adopted a two-dimensional reverse fault model to estimate the creep distribution. The fault geometry was optimized using the genetic algorithm in order to conform to the leveling data. The goodness of the fit of the examined models is determined on the basis of Akaike's information criteria (AIC; Akaike,1973).

In August 2010, we installed more three routes in Yuli and conducted them. Since it was first time to conduct the leveling survey in these new routes, we will be able to detect deformations next year. In this meeting, we will present an overview and our purpose of our observation in the new routes.

Keywords: creep, precise leveling survey, Taiwan

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Preliminary results of rapid determination of coseismic fault model using RTK-GPS

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[Introduction]

Detection of coseismic crustal deformation by Real-time Kinematic GPS (RTK-GPS) has been studied in the recent years [e.g., Nishimura et al., 2009, Blewitt et al., 2009]. Rapid estimation of seismic fault model by GPS data is important for understanding of earthquake size. The advantage of the GPS data that are detected directly displacement relative to the assumed reference sites or reference frame. It is useful for detection of "tsunami" earthquake, which may cause slow displacement. In this study, we developed an algorithm for estimation procedure for coseismic displacement using RTK-GPS coordinate time series, and we tried to determine coseismic fault model based on these information.

[Method]

For the automatic detection algorithm for coseismic displacement, we use to the methods using short-term average (STA: 60 s) and long-term average (LTA: 600 s) [e.g., Matsumura et al., 1988], which is used for automatic detection of P-, S-, and later phases of seismic waves. We define D value as |LTA-STA|-SD(LTA), where LTA and STA are the mean coordinates for 600 and 60 seconds time window, respectively, and SD(LTA) is the standard deviation of LTA. We assume that permanent displacement is detected if D exceeds a threshold K=D'+4s, where D' is a mean coordinate for the period without any earthquake and s is its standard deveation.

Once D > K at the time Td, the next procedure is started to estimate coseismic displacements, which is defined by the difference between the postseisimc coordinate averaged over the time period of 20 seconds just before D becomes the maximum (Dmax), and the preseismic one averaged between 7 and 5 minutes before Td. We use only horizontal components for the procedure. This algorithm judges earthquake occurrence when D exceeds K at more than 4 sites within 100 square kilometers, and 30 seconds. This reduces misdetection. Also changing the definition of K value into D'+2s after judgement of earthquake occurrence helps to detect relatively small displacements.

[Result]

We tested this algorithm to 1 Hz RTK-GPS time-series of the 2008 Iwate Miyagi Nairiku (Inland) earthquake. Our algorithm success to estimated coseismic displacement at 20 sites out of 27 sites within about 80 seconds. This estimation result corresponds to crustal deformation from post processing analysis [Ohta et al., 2008] within 2 cm. This meansIt is suggested our algorithm is adequately useful for crustal deformation detection. Displacement detection and estimation limits are 5 cm, 3 cm respectively. We then estimated parameters of a rectangular fault in an elastic half space [Okada, 1992] using a nonlinear inversion program method with a priori constraints [Matsu'ura and Hasegawa, 1987] to reveal the consistent result with that obtained by Ohta et al. [2008] using GPS data from post processing. We took initial coordinate value of coseimic fault was first detected site coordinate valueIn this time, we still not success the full automatic coseismic fault determination because of we need to assume initial fault parameters in an evenhanded fashion. We will show full-automatic coseismic fault model estimation procedure in this meeting.

[Acknowledgements]

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Viscosity structure in the lithosphere inferred from observed post-seismic deformation

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Satellite-based geodetic observations (GPS and/or InSAR) can provide precise constraints on the mechanisms that drive stress-relaxation following an earthquake [e.g., Hager et al., Annu. Rev. Earth Planet. Sci., 19, 351, 1991; Massonnet & Feigl, Rev. Geophys., 36, 441, 1998]. Among several post-seismic deformation mechanisms, visco-elastic relaxation may be the dominant component of long period and long wavelength deformations observed following earthquakes. The choice of rheological model is important if these deformation fields are to be modelled. Several transient rheological models have been proposed to explain observed post-seismic deformation, which appears to require greater viscosities as deformation progresses [e.g., Freed & Burgmann, Nature, 30, 548, 2004; Ryder et al., GJI, 169, 1009, 2007; Hearn et al., JGR, 114, B08405, 2009]. Alternatively, the variation of viscosity with depth may be important in explaining observed post-seismic displacement rates [e.g., Hetland & Hager, GJI, 166, 277, 2006; Riva & Govers, GJI, 174, 614, 2009].

In this study, we examine the effects of depth-dependent viscosity in the lithosphere to infer how the signature of viscous relaxation can be distinguished in the surface displacement data. Using a parallelized 3-D finite element code, oregano_ve, we solve the linear Maxwell visco-elastic response to a strike-slip fault in a rectangular block, assuming a viscosity beneath the faulted elastic layer which decreases exponentially with depth. Slip on a strike-slip fault is implemented using the split node method [Melosh & Raefsky, BSSA, 71, 1391,1981]. We compare the surface displacement histories predicted for the post-seismic viscous relaxation of a uniform viscosity (UNV) model and depth-dependent viscosity (DDV) models at different points on the surface.

Our numerical experiments show that a UNV model can well approximate DDV model behaviour, but the apparent UNV viscosity which best fits a DDV displacement history depends on distance from the fault; smaller viscosities are required at greater distances from the fault. The differences between UNV and DDV displacement histories also depend on distance from the fault. In the near-field, where elastic stress is greater, the UNV prediction can approximately mimic the DDV prediction. On the other hand, in the far-field where elastic stress is less, the mismatch can be significantly greater; the DDV model predicts a relaxation mode in which greater viscosities are inferred in later phases. The model behaviour described in this study demonstrates an important signature of DDV structure in the far-field, and suggests that the signature of other relaxation mechanisms such as aseismic-slip and/or poroelastic relaxation would possibly be captured from the mismatch in the near-field.

In this study, we also attempt to apply the model to the InSAR dataset of Ryder et al. [GJI, 169, 1009, 2007], obtained following the 1997 Manyi (Tibet) earthquake. The preliminary result of the DDV structure in the crust shows that effective elastic layer thickness is greater than depth extent of the fault. Furthermore, it is implied that horizontal variation of viscosity (smaller viscosities in the near-field) and/or relaxation mechanisms other than viscous creep in the near-field are also required to explain observed post-seismic displacement patterns. Thus, the geodetic data are not always explained only in terms of the DDV structure, but the DDV model predictions provide an important opportunity to discuss the effective elastic layer thickness in relation to the slip distribution on the fault, which offers a key to understanding of the stress-accumulation in the earthquake cycle, and the necessity of other relaxation mechanisms in the systematic way.