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

Akio Fujita[1*], Mikio Satomura[2], Ryoya Ikuta[2], Seiichi Shimada[3], Teruyuki Kato[4], Yasushi Harada[5]

[1]Geoscience,Shizuoka Univ., [2]Fac. of Science,Shizuoka Univ., [3]NIED, [4]Earthq.Res.Inst.,Univ.Tokyo, [5]School. Marine Sci.and Tech.,Tokai Univ.

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

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

SSS030-02 Room:105 Time:May 24 08:45-09:00

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

Yuuki Hashimoto[1], Mikio Satomura[1*], Ryoya Ikuta[1], Seiichi Shimada[2], Shozo Matsumura[2], Teruyuki Kato[3], Yasushi Harada[4], Takeshi Sagiya[5]

[1]Fac.Science,Shizuoka Univ, [2]NIED, [3]ERI,Univ Tokyo, [4]Fac. Marine Sci.,Tokai Univ,, [5]Environmental Studies, Nagoya Univ

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

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

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

Tadafumi Ochi[1*], Teruyuki Kato[1]

[1]ERI, the University of Tokyo

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.

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

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

Steady interplate coupling at the Nankai Trou

Ryoji Hirata[1*], Takao Tabei[2]

[1]Grad. School of Science, Kochi Univ., [2]Faculty of Science, Kochi Univ.

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.

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

SSS030-05 Room:105 Time:May 24 09:30-09:45

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

Hisashi Suito[1*]

[1]GSI of Japan

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

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

SSS030-06 Room:105 Time:May 24 09:45-10:00

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

Masayuki Murase[1*], Nobuhisa Matsuta[2], Kazuhiro Ozawa[2], Wen-shan Chen[3], Cheng-Horng Lin[4], Naoji Koizumi[5]

[1]Nihon University, Japan, [2]Nagoya University, Japan, [3]National Taiwan University, Taiwan, [4]Academia Sinica, Taiwan, [5]AIST, Japan

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

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

SSS030-07 Room:105 Time:May 24 10:00-10:15

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

Tatsuya Kobayashi[1*], Yusaku Ohta[1], Satoshi Miura[1]

[1]RCPEVE, Sci., Tohoku Univ.

[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]
We thank GSI for providing GPS data. This study is based on GPS data obtained by the investigation project conducted by Japan Nuclear Energy Safety Organization (JNES) to establish evaluation techniques of seismogenic faults. We thank Mr. T. Takasu for providing the GPS analysis software, 'RTKLIB ver.2.3.0'.

[References]
Blewitt et al., J. Geod., 83:335-343, 2009
Matsumura et al., Rep. NRCDP, 41, 44-64, 1988
Matsu'ura and Hasegawa, Phys. Earth Planet. Inter., 47, 179-187, 1987
Nishimura et al., JPGU, Abstract, S150-002, 2009
Okada, Bull. Seismol. Soc. Am., 75, 1135-1154, 1992
Ohta et al., EPS, 60, 1197-1201, 2008;

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

SSS030-08 Room:105 Time:May 24 10:15-10:30

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

Tadashi Yamasaki[1]*, Gregory A. Houseman[1]

[1]University of Leeds

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.

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

SSS030-P01 Room:Convention Hall Time:May 24 10:30-13:00

Time evolution of the magma chamber beneath the Izu-Ohshima Island.

Shinzaburo Ozawa[1*]

[1]Geospatial Infromation Authority of Japa

1. Introduction

The Geospatial Authority of Japan (GSI) and the Japan Meteorological Agency (JMA) set up GPS network in Izu-Ohsima Island. GSI analyze GPS data of the GSI together with the GPS data of the JMA and monitors crustal deformation of the Izu-Ohsima Island on daily basis. The GSI has employed the time dependent inversion to the detected position time series and estimated the time evolution of a volume change in the magma chamber beneath the Izu-Ohsima Island. The result shows that the magma chamber inflated and deflated alternately over time with a total volume increasing from 2004. In this research, we estimate the latest time evolution of a magma chamber using the data until the end of 2010.

2. Analytical Procedure

We used the east-west (EW), north-south (NS), and up-down (UD) components at 9 selected GPS sites covering the Izu-Ohsima Island, relative to the 93051 site. Since the raw data include annual components, we first estimated them, using a polynomial function and trigonometric functions to fit the position time series for the period between 2004 and 2010.

Using the position time series without annual components, we applied square-root information filtering, following the time-dependent inversion technique for the period between January 2004 and December 20, 2010. We weighted the EW, NS, and UD movements with a ratio of 1:1:1/5, considering the standard deviations estimated from ordinary Kalman filtering. We employed the time dependent inversion to the position time series. The position of a magma chamber is estimated in the time dependent inversion on the assumption that these parameters are constant over time. A volume change is estimated on condition that it changes smoothly over time.

3. Results and discussion

As a result, a magma chamber inflated and deflated alternately over time with a total volume change of 1600m3 from 2004 to 2010. This result is consistent with the past studies. At present, a magma chamber is inflating from July 2010, slightly slowing down inflation in December 2010. A volume change for this period reaches 5 million m3. This volume change is second the largest volume increase following the 2007 inflation. In a meeting, we will present the latest time evolution of a magma chamber beneath the Izu-Ohsima using the latest position time series.

Keywords: Izu-Ohshima, magma chamber, GPS, time dependent inversion

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

SSS030-P02 Room:Convention Hall Time:May 24 10:30-13:00

Repeated GPS observation at active volcanoes in Hokkaido

Satoshi Okuyama[1*], Hitoshi, Y. Mori[1]

[1]ISV, Hokkaido Univ.

We carried out repeated GPS observation at Mt. Tokachi and Mt. Tarumai in June and September, 2009 respectively.

Baseline extension around the crater is observed at Mt. Tokachi since 2006, and its rate is decreased in 2010 (Sapporo District Meteorological Observatory, 2010). SAR Interferometry detected the inflation of summit lava dome at Mt. Tarumai (Ando et al. 2010). These deformations are of small spatial scale, indicating that the deformation source is at the shallow depth. To investigate the activity of deeper magma chambers, we constructed GPS networks of 5km to 20km from the summits. Analysis shows no significant displacement and we suggest three possibilities to explain this; The first possiblity is low supply rate of the magma. Since no displacement related to the deep magma chambers has been reported, the supply rate of the magma is considered to be very low. Thus longer observation period is required to stack the displacement. Secondly, most of the GPS stations are located in the forested area. Thus the data is severely deteriorated by the trees above the antennas. Thirdly, our observation period was not long enough. The length of our observation period in 2010 is one to two weeks. This fact, along with the bad circumstance stated above, prevented us from precise measurement of the displacement. Based of this, we are planning semi-continuous GPS observation at the eastern flank of the Mt. Tokachi.

MG-2120B Ver. 2.02 (FurunoDenki, runs Bernese 5.0 internally) is used for the analysis.

Keywords: GPS, Mt. Tokachi, Mt. Tarumai, Hokkaido, volcano

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

SSS030-P03 Room:Convention Hall Time:May 24 10:30-13:00

Responses to earth tide and atmospheric pressure of a laser strainmeter of 200m and 400m baseline lengths

Akio Katsumata[1*], Akio Kobayashi[1], Kazuhiro Kimura[1]

[1]Meteorological Research Institute

We have been observing crustal deformation with a laser strainmeter since December 2007 to detect slowly proceeding event such as long-term and short-term slow slip events. The laser strainmeter is oriented in north-south direction. The baseline length was 200m from Dec. 2007 to Dec. 2008, and it was extended up to 400m in March 2009. We compare responses to earth tide and atmospheric pressure between the 200m and 400m baseline.

Secular strain change is recognized. It was –4.2$*10^{-7}$strain/year for the 200m baseline, and -2.2$*10^{-7}$ for the 400m baseline. Both are greater than the value of -5$*10^{-8}$ strain/year obtained from GPS observation.

Coefficients of tidal response were estimated from detrended strain data with BATAP-G (Tamura et al., 1991). Variation of the response was obtained with moving window of forty days. The estimated values for the 200m and 400m baseline were almost coincided, and the amplitudes were about half of theoretically expected values. Difference was seen in variation of the coefficients, less than 2% for the 200m baseline and about 4% for the 400m baseline.

Response to atmospheric pressure was estimated with BAYTAP-G and adjusted by checking corrected strains. The response was -1.8$*10^{-10}$strain/hPa for 200m baseline and -4$*10^{-10}$strain/hPa for the 400m baseline. The difference is about double. Some temporal variation was seen, however the systematic difference between the 200m and 400m baseline was not recognized in the temporal variation. The difference in the response would indicate that the site material is less hard for the 400m baseline on the average.

Response to precipitation is recognized. Contractive response was observed in rainy season for 200m baseline, and it was several nano-strain. Extensive response of several nano-strain was seen after large precipitation for the 400m baseline. The polarity of preciitation response is reversed between the 200m and 400m baseline.

The smaller secular may indicate that the case of the 400m baseline is less influence by local deformation. However the responses to tide and atmospheric pressure show softer site rock for 400m baseline.

We are grateful to Dr. Araya for his kind guidance on interferometer system for crustal deformation observation.

Keywords: long baseline laser strainmeter, tidal response, atmospheric pressure response

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

SSS030-P04 Room:Convention Hall Time:May 24 10:30-13:00

A trial of the detection of the long-term slow slip events by the strainmeters of JMA in the Tokai region

Kazuhiro Kimura[1*], Akio Katsumata[1], Akio Kobayashi[1]

[1]Meteorological Research Institute

It is not concluded whether the Strainmeters of JMA were able to find the long-term slow slip events that occurred in the Tokai region from 2000 to 2005. It is generally difficult to find a long-term change by the strainmeters, because a long-term trend of the strainmeters is not stable. Kobayashi and Yoshida (2004) pointed out that long-term slow slip events occurred in the Tokai region from 1980 to 1982 and from 1988 to 1990. JMA has been operationg the volume strainmeters in the Tokai region since 1976, three long-term slow slip events occured all over the observation period. JMA installed the Multi-components strainmeteres in the Tokai region from 1998 also, One Long-term Slow Slip Events occured in the observation periods.

From three following viewpoints ee investigated whether the strainmeters of JMA were able to find the long-term slow slip events.

1. Whether the trend change due to the three long-term slow slip events.can be recognized in the records of the volume strainmeters of JMA.
2. Whether the trend change due to the long-term slow slip events.can be recognized in the records of the multi-components strainmeters of JMA.
3. Whether the frequency of short-term SSEs detected by the strainmeter of gamagori were related to the long-term slow slip events.

Keywords: strainmeter, long-term slow slip event

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

SSS030-P05 Room:Convention Hall Time:May 24 10:30-13:00

Improvement of detection level using composite of strain changes

Kazuki Miyaoka[1*], Hisao Kimura[1], Takashi Yokota[1], Kazuhiro Kimura[2]

[1]Japan Meteorological Agency, [2]Meteorological Research Institute

Japan Meteorological Agency has installed strainmeters in Tokai region to detect precursors of the major interplate earthquake, so-called ‘Tokai Earthquake’. Several researches expect that the slow slip event, pre-slip, is observed on the plate boundary before Tokai Earthquake occurs.

We propose the new method to improve the detection level of strainmeters by using composite of strain changes. It is the method that strain data are stacked after their polarities are arranged to improve S/N by amplifying signals.

We examined the past slow slip events (SSEs) and were able to detect them at an early stage. In addition, we succeeded to detect the long-term SSE in Tokai region from 2000 to 2005 and SSE in Boso peninsula in August 2007, which have not been thought it was detected by strainmeters.

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

SSS030-P06 Room:Convention Hall Time:May 24 10:30-13:00

Groundwater level changes associated with the dynamic strain variations

Yasuhiro Asai[1*]

[1]TRIES, ADEP

From June 2006 to January 2010, groundwater level changes associated with the dynamic strain variations have been repeatedly observed at the Shizubora crustal activity borehole observatory (SN-3, SN-1 and 97FT-01 wells) in the Tono area, Gifu prefecture, central Japan.

We investigated the relationship between the peak amplitude of co-seismic groundwater level changes (at SN-3 and SN-1) and peak-to-peak amplitude of dynamic strain variations (at 97FT-01), and found that the co-seismic groundwater level changes were caused by dynamic strain variation of maximum shear strain with peak-to-peak amplitudes above a threshold of approximately $2.71X10^{-7}$ - $3.65X10^{-7}$ strain in SN-3, and $4.13X10^{-7}$ - $6.17X10^{-7}$ strain in SN-1.

Keywords: Co-seismic groundwater level changes, dyanmic strain variation, Ishii type borehole strain meter

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

SSS030-P07 Room:Convention Hall Time:May 24 10:30-13:00

Long-term Tilt Changes at Rokko-Takao and Rokko-Futatabi Stations

Atsushi Mukai[1*], Shigeaki Otsuka[2]

[1]Nara Sangyo University, [2]Kobe Gakuin University

The tilt changes observed at Rokko-Takao and Rokko-Futatabi stations have the seasonal changes associated with groundwater discharge at Rokko-Takao station. We investigated the effects of groundwater migration in the surrounding crust on the crustal movements by using the observational data of tilt and groundwater discharge. The groundwater discharge follows the tilt changes with a lag about a month. It is considered that the tilt changes might be caused by the loading of groundwater accumulated in the shallow layer due to precipitation in the rainy season. The groundwater would migrate to underground and result in the increasing of groundwater discharge. Rokko-Futatabi station is located in the 0.6km southeast of Rokko-Takao station. The long-term tilt change at Rokko-Futatabi station follows the tilt changes at Rokko-Takao station with a lag about 2 months. These tilt changes suggest the movement of the loading area due to the groundwater migration.

Rokko-Takao and Rokko-Futatabi stations were established by Kyoto University. These stations are located in the emergency evacuation roads for the Shin-Kobe tunnel administered by Kobe City Roads Corporation. In Rokko-Takao station, three water tube tiltmeters WT1, WT2 and WT3 as well as three extensometers, three strainmeters and groundwater discharge meter were installed. The tiltmeters can observe tilt on the ground in the N69^{o}E direction. In Rokko-Futatabi station, a water tube tiltmeter WTL as well as an extensometer and groundwater discharge meter were installed. This tiltmeter can observe tilt in the N9^{o}W direction. The crustal movements have been observed every 10 minutes at both stations.

We calculated the tidal constants by applying the tidal analysis program BAYTAP-G (Tamura et al., 1991) to the tilt changes observed during 6 years from 2005 to 2010. The observed tilt tides in major tidal components have agreement with the theoretical tides with some discrepancies in the amplitudes by about 10% and in the phases by about 10 degrees. These results of tidal analysis show that the inhomogeneous structure of the crust in the Rokko mountain range causes little disturbance in the tilt changes due to the tidal force and the major parts of the observed tidal tilts can be represented by the tides predicted using the lateral homogeneous crust. However, the inhomogeneous structure of the crust might have considerable effects on the tilt changes due to the groundwater loading, because the lateral scale of the groundwater loading is less than that of the tidal force. The tilt changes at Rokko-Takao station have seasonal variations, which show the northeast dip around August every year and precede the increasing of groundwater discharge by about a month. It is considered that the accumulation of groundwater due to precipitation in the rainy season occurred in the northeast area of the station and the loading of the groundwater caused the northeast dip of tilt. The groundwater would migrate to underground and result in the increasing of groundwater discharge at Rokko-Takao station. The seasonal variations of tilt at Rokko-Futatabi station show the north dip around October every year and follow the tilt changes at Rokko-Takao station by about two months. This lag suggests that the loading area of groundwater migrates to the southeast direction. In this study, we will consider the effects of the groundwater on the strain changes as well as those on the tilt changes.

Keywords: tilt change, groundwater discharge, loading of groundwater

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

SSS030-P08 Room:Convention Hall Time:May 24 10:30-13:00

Continuous GPS observations using prepaid mobile data communication

Tomotsugu Demachi[1*], Kenji Tachibana[1], Yusaku Ohta[1], Satoshi Miura[1], Sadato Ueki[1], Akiko Hasemi[2], Yasuo Kanome[2], Takeshi Matsushima[3]

[1]RCPEVE, Tohoku Univ., [2]Sci., Yamagata Univ., [3]SEVO, Kyushu Univ.

Recently, expanded service area for mobile phone and offer of flat-rate charge plan by each vender have made it possible for mobile data communication to use for seismic data transmission between remote observation site and data center (e.g., Hirahara and Hori, 2009; Okubo, 2009; Matsushima and Uehira, 2010). Kyushu University (2010) used prepaid mobile data-communication device (b-mobile3G hours180, Japan Communications Inc.) for transferring GPS observation data files. Compared to mobile data communication and wired internet connection service (FLET's Service, NTT), prepaid mobile data-communication device is convenient and inexpensive.

In early Apr. 2010, Japan Communications Inc. released new prepaid SIM card named as "b-mobileSIM U300" for mobile data communication. This SIM card provides service of flat-rate data communication for a year with transmission speed of over 300kbps (both upload and download). We installed the data-communication device with b-mobileSIM U300 in two volcano GPS sites (Suwanosejima volcano and Sakurajima volcano-Gongen) and new five GPS sites (Yamanome junior high school, Ichinoseki city museum, Hondera elementary school (Ichinoseki city, Iwate prefecture), Tamugino (Tendo city, Yamagata Prefecture), and Higashine city hall (Higashine city, Yamagata Prefecture). These networking systems are based on Kyushu University (2010). In the two volcano sites, we are operated the networking systems for an hour in every day using motor time switch, because of these devices are operated by limited DC power supplies through solar cell. In other five sites, we can use commercial AC power supplies, so that data connections are always available. Our inexpensive mobile networking system makes it possible to data connection between remote area GPS sites and data center at all times. We think that this mobile system is useful for immediate GPS observations when disastrous large earthquakes and volcano eruptions occur.

Keywords: continuous GPS observation, prepaid mobile data communication, data transfer

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

SSS030-P09 Room:Convention Hall Time:May 24 10:30-13:00

Development of a Remote GPS Monitoring System (REGMOS-Hybrid) using Next Generation Mobile Satellite Phones

Yoshifumi Hiraoka[1*], Masanori Yokokawa[1], Moriyuki Nemoto[1], Sigeyuki Murayama[2], Minenori Takeyama[2]

[1]GSI of Japan, [2]Techno Vanguard Co., Ltd.

In 1998, we developed a remote GPS monitoring system (REGMOS) utilizing a mobile satellite phone service of a communication common carrier in Japan. REGMOS is a system which is supplied power from a photovoltaic power generator to acquire GPS data, and transfers the data using a mobile satellite phone service. The greatest feature of the REGMOS functions is that the communications control unit (TCU) monitors the power supply, GPS and mobile satellite phone terminal, and resets each device when trouble occurs in the GPS, mobile satellite phone terminal and the TCU.

We have installed this system on active volcanoes where there is no infrastructure, and in areas where the infrastructure has been shut down due to earthquakes, and have been acquiring GPS data. However, since the transmission speed of this system is 4.8 kbps, the communication time was taking too long to transfer data, which often caused trouble where telephones were interrupted during transfer. In recent years, there has been an increase in the demand to acquire image data or data by other sensors, in addition to the GPS data using REGMOS as a platform. For that reason, improvements in the speed of communication have become a large issue, so that a stable transfer of the increased data can be performed.

Under such circumstances, from February 2009, high-speed data transmission by Inmarsat became available around the world except for the polar zones. Therefore, we introduced data communication by a Broadband Global Area Network (BGAN) which is a communication service of Inmarsat, and developed a new remote observation control system (REGMOS-Hybrid) which can acquire and transfer data, such as images, ground temperatures, inclines and etc. including GPS. In September 2010, a new system was installed on Mt. Tarumae and has been monitoring volcanic activity. In this lecture, we would like to introduce the structure of the REGMOS-Hybrid system, and report on the data of the GPS, images and etc. which have been acquired on Mt. Tarumae till now.

Keywords: GPS, Remote Monitoring System, Mobile Satellite Phones, Volcanism

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

SSS030-P10 Room:Convention Hall Time:May 24 10:30-13:00

The expressions for deformation fields due to a moment tensor in a poroelastic half-space

Akinori Hashima[1*]

[1]Dept. Earth Sciences, Chiba University

According to the recent studies on postseismic deformation, the top of the crust has poroelastic properties in which the elastic deformation of the crust and the pore fluid flows couple. In order to infer exactly the internal processes such as fault slips from the ground deformation, it is necessary to formulate the effect of poroelastic deformation. So far, solutions on poroelastic deformation have been separately obtained for different sources as displacement discontinuities and water injections. In this study, using a moment tensor as the general internal source, we derived general expressions for poroelastic deformation in a poroelastic layered half-space.

As a beginning, we derived the expressions for displacement potentials due to a moment tensor in an infinite isotropic poroelastic space in cylindrical coordinates. First, displacements due to a moment tensor was easily obtained by differentiating the existing expressions for displacements due to an impulsive force with respect to source coordinates. In general, poroelastic solutions are time-dependent. Thus, we performed Laplace transformation to replace the time-dependent parts by Laplace variable for the later derivation. Next, these expressions were transformed from Cartesian coordinates to cylindrical coordinates for the parallel-layer structure problem. Finally we applied Hankel transformation to the displacements and decomposed them into the expressions for static displacement potentials. In the case of poroelastic problems, we have three displacement potentials for solid displacements corresponding to elastic problems and one potential for pore pressure (Biot potential). As for the potentials obtained here, the three displacement potentials satisfy the Laplace equation, and Biot potential satisfies diffusion equation.

The solution obtained above is the particular solution of the inhomogeneous differential equation in the mathematical context, which corresponds to the direct effect due to the internal source. Adding the particular solution to the mode solution of the layered structure (homogeneous solution) and applying the propagator matrix method, we can obtain the solution for the layered half-space due to the source. We extend the propagator matrices in the elastic problem to those in the poroelastic problem and solved the deformation in the poroelastic layered half-space. The expressions obtained in this study are the Laplace transformed solution and the solution in the time domain can be numerically obtained by the inverse Laplace transformation.

Keywords: poroelasticity, Internal deformation, Layered half-space model, Moment tensor, Mathematical formulation, Pore pressure

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

SSS030-P11 Room:Convention Hall Time:May 24 10:30-13:00

A real-time algorithm for detecting transient deformation signals using a particle-based Network Inversion Filter

Jun'ichi Fukuda[1*], Paul Segall[2]

[1]ERI, University of Tokyo, [2]Stanford University

We present an online, or real-time, method for detecting transient crustal deformation signals due to transient fault slip episodes using data from large-scale geodetic arrays. Our method builds on the Network Inversion Filter (NIF) approach to time-dependent fault-slip inversion [Segall and Matthews, 1997; McGuire and Segall, 2003]. In the NIF, fault slip-rate is assumed to be steady in time in the absence of requirement from data. Deviations from steady-state slip-rate are parameterized by a temporal smoothing parameter. Fukuda et al. [2004, 2008] extended the NIF by treating the temporal smoothing parameter as a time-varying stochastic variable. The time-dependet posterior probability distribution of the temporal smoothing parameter is estimated as a function of time with an online particle-based filter, Monte Carlo mixture Kalman filter (MCMKF). When the data reflect steady-state fault slip rate, the temporal smoothing parameter tends toward a low value. However, if the data reflect transient fault slip, larger values are favored. This indicates that the temporal smoothing parameter can be used as an indicator for transient slip rate changes. Integrating the posterior probability distribution of the temporal smoothing parameter for values exceeding a maximum value associated with effectively steady deformation provides a measure of the probability that a transient signal had been detected, thereby allowing us to quantify the statistical significance of potential transients in real-time. In this presentation, we outline the theoretical basis for the method and show results from the application of this method to real data sets.

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

SSS030-P12 Room:Convention Hall Time:May 24 10:30-13:00

Crustal deformation around southern part of Yamagata-Bonti fault zone derived by GPS observation

Yasuo Kanome[1*], Akiko Hasemi[1], Seiichi Shimada[2], Teruyuki Kato[3], Takumi Kosukegawa[1], Takashi Kusaka[1], Takashi Matsuoka[1], Shinji Suzuki[1]

[1]Yamagata Univ, [2]NIED, [3]Earthq. Res. Inst., Univ. Tokyo

1. Introduction

The Yamagata-Bonti fault zone runs along the western margin of the Yamagata basin. In order to investigate crustal deformation around southern part of this fault zone with higher spatial resolution than GEONET, we installed a temporal GPS observation station at Yamagata University.

2. Observation and analysis

We used 4000SSE Geodetic Surveyor and L1/L2 Geodetic antenna with ground plane (Trimble Navigation Ltd.) . Sampling interval is 30s, and elevation mask is set to be 15degree. The data acquisition period was from April to December of 2008-2010. We retrieved the antenna during snow season because we did not use a radome. (We continue observation this winter with a radome.)

The data was analyzed by GAMIT/GLOBK. We downloaded rinex files of 5 GEONE stations surrounding the temporal station (Yamanobe, Shirataka, Kaminoyama, Tendo, and Miyagikawasaki) from GSI, and determined locations of 6 stations. The data of 21 IGS stations in and around Japan were also used.

3. Result

Displacement rate obtained was 2+/-0.2 mm/yr eastward and 14+/-0.2 mm/yr southward on the average of 6 stations. Subtracting these averages, we examined relative movement. We found that the stations in the west of the fault move toward northeast and those in the east toward southwest. The rate of relative movement was about 3mm/yr. This direction shifts from that of the crustal shortening (E-W ~NW-SE direction) predominant in northeastern Honshu.

Seismicity is active near the surface trace of the southern part of the Yamagata-bonti fault since 1997. P-axis of this earthquake mechanism solution is oriented in NE-SW direction, that is consistent with the crustal displacement obtained in the present study.

We checked the influence due to the difference of the analysis software and adding a temporal station by comparing our result with GEONET F3 solution from 2008 to 2009. The differences of displacement rate and a direction were found to be very small between our result and F3 solution.

4. Future plan

Recent studies indicate that the Yamagata-bonti fault zone is divided into northern and southern segments that generate earthquakes separately. Therefore it is important to compare crustal deformation between the segments. This study showed that the data from a temporal station was very effective to grasp the crustal movement around the southern segment. We plan to set temporal GPS stations near the northern segment to investigate crustal movement in detail.

Keywords: GPS, crustal deformation, active fault, Yamagata-Bonti fault zone

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

SSS030-P13 Room:Convention Hall Time:May 24 10:30-13:00

Changes in the interplate coupling beneath NE Japan estimated from velocity gradients and small repeating earthquakes

Takeshi Iinuma[1*], Naoki Uchida[1], Toru Matsuzawa[1], Ryota Hino[1], Akira Hasegawa[1]

[1]AOB-RCPEVE, Tohoku Univ.

1. Introduction

A number of studies have attempted to estimate the spatial variations of interplate coupling on subducting plate interface beneath northeastern Japan based on the surface velocity fields deduced from Global Positioning System (GPS) observations (e.g., Ito et al., 2000, Nishimura et al., 2004, Suwa et al., 2006, Hashimoto et al., 2009). These studies estimated several common strong coupling zones, but, there are significant differences among their results due to the differences of the plate interface models and inversion methods. Especially, each study estimated significantly different coupling strengths at the deep portion beneath the Tohoku district and at Fukushima-Oki region. We can not ignore such differences to consider the strain accumulation process. Iinuma et al. (2010, 114th Meet. Geod. Soc. Japan) have reported that the regions of the large displacement rate gradient correspond to the rupture zones of recent interplate large earthquakes, where the coupling strengths must be strong in interseismic periods, based on the GPS observations. They also reported changes in the displacement rate gradients at several regions that suggest temporal changes in the interplate coupling at such regions. We carried out further analysis in order to confirm whether the temporal changes in the interplate coupling strength really occur or not.

2. Data and analysis

We used daily site coordinate time series of GEONET (F3 solutions) that are provided by the Geographical Survey Institute of Japan. We extracted displacement rate field from the time series by fitting the function that consists of long-term trend, annual and biannual trigonometric curve, and steps due to the earthquakes and antenna replacements. The long-term trend is estimated for each one-year time window being shifted by one week. The gradient of the surface velocities is calculated at each belt-like region configured along the direction of the plate convergence. The gradient of horizontal velocities is large when the interplate coupling at shallow part (less than about 50 km in depth) beneath the profile is strong, and the sign of the gradient of the vertical velocity is sensitive to the existence of the coupling at deep part.

We also used the slip rate and number of the interplate small repeating earthquakes to infer the temporal change of coupling. The small repeating earthquakes are identified based on the similarity of the seismograms by calculating the coherence of waveforms. We considered an earthquake pair to be repeating earthquakes when the averaged coherences at 1-8 Hz were larger than 0.95 at two or more stations. The analysis time window was 40 seconds, starting from the first P-wave motion. We then linked a pair (group) of repeaters with another pair (group) if the two pairs (groups) shared the same earthquake. The small repeating earthquakes also have a good sensitivity in coupling in wide depth range. They are thought to be occurring due to the stress accumulation by the surrounding aseismic slip and thus we can infer the aseismic slip or coupling change from the activity.

3. Results and Discussion

We found that many small repeating earthquakes occurred when the horizontal velocity gradient is small at the belt-like regions where the offshore interplate coupling is relativity low along the Japan Trench, such as offshore Ibaraki Prefecture and southern Iwate Prefecture. Both high activity of the small repeating earthquakes and small gradient of the horizontal surface velocities suggest the week interplate coupling and occurrence of the aseismic slip. This suggests that at the weak coupling area along the trench the accumulated strain due to the interplate coupling at the shallow plate interface is released by episodic slow slip event. This imply that the *stable sliding* at the plate interfaces shallower than the seismogenic zone (about 20 ~ 50 km in depth) near the Japan Trench is not perfectly *steady* but *episodic*.

Keywords: Interplate Coupling, GPS, Small Repeating Earthquakes, Northeastern Japan, Slow Slip Event, Crustal Deformation

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

SSS030-P14 Room:Convention Hall Time:May 24 10:30-13:00

Coseismic Deformation and Fault Model of the 2008 Mw 6.8 Zhongba Earthquake

Shuoshuai Sun[1*], Masato Furuya[1]

[1]Department of Natural History Sciences

An earthquake with magnitude of 6.8 struck Zhongba County, western Tibet, China, on 25th August 2008, whose focal mechanism was normal faulting according to the GCMT project. Although normal faulting earthquake often takes place in Tibetan plateau, it remains uncertainty why normal faulting earthquakes present in the present Tibetan plateau despite the on-going northward compression associated with the Indian plate motion. We use interferometric synthetic aperture radar (InSAR) observations to estimate the fault slip distribution of the Zhongba Earthquake, and infer the fault source model so that we will be able to gain any insights into the origin of normal faulting earthquakes.

Keywords: Earthquake, Normal Fault, InSAR, Fault Source Model

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

SSS030-P15 Room:Convention Hall Time:May 24 10:30-13:00

Fault model of an earthquake at Laos(May 2007, Mw6.3); Possibility of a conjugate rupture.

Nobutaka Serizawa[2*], Masato Furuya[1]

[1]Hokkaido University, [2]Hokkaido University

On May 16, 2007, an earthquake with moment magnitude (Mw) 6.3 took place near the northern border of Laos.
Using L-band ALOS/PALSAR data, we apply interferometric synthetic aperture radar technique in order to detect the associated co-seismic crustal deformation.
We compared the InSAR image with Global CMT solution and USGS to search the location of the source.
At the 2010 JPGU meeting, we presented a preliminary fault model that consisted of a rectangular source with a uniform slip.
But The observed data shows complex deformaition signals that can't be explained by a simple uniform slip fault.
Also, the special distribution of the deformaition signal suggests that the earthquake was accompanied with a conjugate rupture.
Here, we present a non-planar fault source that is based on a triangular dislocation element.

Keywords: coseismic deformation, SAR, InSAR