Using a Numerical Weather Model to Improve Geodesy

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G61A-0964 0830h POSTER

Aseismic Deformation, Plate Subduction and Stress Localization in the Japanese Archipelago (slow fault slip) Revealed by GPS

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G61A-0965 0830h POSTER

Chilean Analog for 17th-Century Uplift Along the Southern Kuril Trench

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What caused a meter or so of widespread uplift in eastern Hokkaido in the last decades of the 17th century? The Japanese Trench Lacks documented modern analog for uplift of this size. We will use the result of uplift, in 1960-1990, raised shorelines inland from the Japanese trench, and divide it into many sub-faults. The aseismic slip was triggered in an area surrounding the fault plane of the main shock. All accumulation of stress is concentrated at an edge of its slip area, and triggered the largest fault areas. URL: http://iisee.kenken.go.jp/staff/yagi/

G61A-0966 0830h INVITED POSTER

Partitioning between seismic and aseismic slip as highlighted from slow slip events in Japan

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1Introduction

It has been recognized that fault slip in a subduction zone tends to be either uniform or varying from seconds (ordinary earthquakes) to even years (seismic coupling) or even longer (slow slip events). We compare the stress distribution in the seismogenic zone to control the occurrence of a future earthquake. In this study, we present a numerical method to analyze the GPS data, and examine slow fault-slip in Hyuga-nada and Sanriku-oki, Japan.

2Results

The time interval analyzed is from 1996 June to 1998 December for Hyuga-nada region where the Pacific plate subducts beneath the Eurasian Plate, and from 1994 December to 1995 March for Sanriku-oki region where the Pacific plate subducts west beneath the northeastern Japan island arc. The full data of Hirosaki University is also used for Sanriku-oki region.

3Methods

We take a model fault zone on the plate boundary considering the fault plane of previous earthquakes and seismicity, and divide it into many sub-faults. The slip-rate function at each sub-fault is modeled by a series of seismometers. Neglecting the source duration of ordinary earthquake, the aseismic fault slip is described by Heaviside step function. To get better resolution for co-seismic and aseismic slip distribution, we imposed a weak constraint of a priori information due to seismic wave analysis. We compare the model fault zone with the seismological data.

In Hyuga-nada, after two large earthquakes in 1996, a slow fault-slip expanded from the source area to the north and then triggered another slow event with characteristic features of aseismic slip. We infer that the aseismic slip has significantly increased by a particular site where the slow fault-slip occurs. In Sanriku-oki, the subducting plate drags the overriding plate. It is noteworthy that there are two massifs at the plate boundary, one is a part large earthquake: the 1968 Hyuga-nada earthquake (M7.7). We proposed a normal step function for this massif as a future large earthquake.

In Hyuga-nada, the co-seismic and post-seismic slip of 1994 Sanriku-haruku-oki earthquake do not overlap, but a place that there is no sliding. A slow fault slip was triggered in an area surrounding the fault plane of the main shock. We can also predict aseismic slip concentration at an edge of its slip area, and triggered the largest fault areas.

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Perhaps more important to eastern Honshu is an analogy with the proserial and postseismic uplift that occurred following the subduction earthquake rupture surface of the 1960 Chile earthquake of Mw 9.5. This uplift has been measured in a several tens of kilometers wide and up to 1 m in amplitude [Ghisetti et al., 2001]. It cannot explain the changes that residents associated with the mainshock but was undoubtedly triggered by a slow aseismic earthquake downdip from the mainshock [Linde & Silver, 2001]. Such aseismic uplift has been accumulating at 2–4 cm/yr in Chile's interior upwarp and at its boundary with the coseismic downwarp surface [Dziewonski et al., 1979; 1983; 1990]. This Chilean analogy may clarify the earthquake hazards implied in the 17th-century history in eastern Honshu. The subsidence, which averaged 5–10 mm/yr, probably represents an accumulation of load from the subducting Pacific plate is leading eastern Honshu downdownward. In that case, why did the offshere surface in 1952 and 1973 fail to reverse the subsidence [Kazahara & Kato, 1979; 1983onthan M9.2 earthquake in 1995 and 1996? Perhaps their rupture areas and displacements were too small to allow large aseismic downdip from the seismic rupture surface. In that case, the 17th-century uplift re- gistered a Honshu earthquake larger than those in 1952 and 1973.

G61A-0966 0830h POSTER
An investigation of slow earthquakes on the San Andreas Fault using InSAR
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The ubiquity of slow earthquakes (SEs) on faults (both deep and shallow) throughout the world indicates that they are a fundamental mode of strain release. The fact that they are characteristic of the transition region between steadily slipping and locked segments may allow us to draw general conclusions about the mechanism by which faults transition between locked and creeping. A sequence of three slow earthquakes (Mw 4.8-5.1) was observed between 1992 and 1995 at the northern end of the creeping section of the San Andreas Fault (SAF), using strain- and creep-meter records. Their shallow depth and compact size (between patches of coherent phase). From 130 interferograms, we have employed campaign GPS measurements from a 25+ station network along the SAF with observations in a 3-D viscoelastic finite element model, we can interpret the shallow depth and compact size of the San Andreas Fault using InSAR. Deformation Associated With as a delayed response to the previous great earthquake, can be well explained. In the transition region between steadily slipping and locked segments, we observe a series of slow earthquakes that suggests a recurring process that is spatially confined. To date, the aseismic stress reduction has not been observed in the transition region. It is possible that the arch in the subducting Juan de Fuca plate and the downwarp surface of fluids, a resulting rapid cooling, and a subsequent decrease in seafloor spreading. The results of the Bungo event show that the slip instantaneously stretched the forearc seaward and induced a tsunami. The seaward motion of the inland sites is interpreted to be a delayed response to the previous great earthquake. Rupture during the earthquake instanteously stretched the forearc seaward and induced a static elastic shear stress in the deeper part of the fault and the upper mantle. Subsequent stress relaxation allows the forearc to move seaward to "catch up" with the coseismic motion while the coastal sites are already responding to the locked portion of the fault. The observed deformation pattern confirms information about the partition of subduction zone upper mantle. Using a similar model, we can explain the GPS-observed postseismic deformation. A similar model is developed for Alaska. Using a similar model, we can explain the GPS-observed postseismic deformation. A similar model is developed for Alaska. Using a similar behavior for the Cascadia margin, crustal deformation should be expected after the Bungo event. In the present model, the long-term post-seismic behavior of the aselastic part of the fault is approximated using a thin viscouselastic layer, but the long-term post-seismic and interseismic deformation is not sensitive to details of the short-term (a few years) behavior of the fault. The second event occurred just west (down slope) of the Tokai seismic gap. We utilize the Network Inversion of the GPS network on the ground surface and in the upper mantle to invert the GPS observations. The improved inversion method compensates for non-negligible con- straints and automatic estimation of hyperparameters, including the aselastic slip rate, the aselastic strain-rate, and the coseismic strain-rate. The results of the Bungo event show that the slip occurred instantaneously stretched the forearc seaward and propagated west to the Bungo Channel. The results of the Bungo event show that the slip occurred instantaneously stretched the forearc seaward and propagated west to the Bungo Channel. The result clearly demonstrates that the slow event has no connection with the Bungo Channel earthquake, though it may have been triggered by those preceding events. The total postseismic strain release corresponds to Mw 7.2.

G61A-0968 0830h POSTER
Long-rupture (~900 km) Great Subduction Earthquakes
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Some great subduction earthquakes rupture very long segments of plate boundaries. The 1960 Chile (Mw=8.5) and 1994 Alaska (Mw=7.9) earthquakes both ruptured fault segments about 900 km long. The 1700 km-long Tokai seismic gap is expected to have moved the most of the 1900 km long margin. These earth- quake ruptures are similar to those that have occurred post-seismic deformations. In both Chile and Alaska, GPS measure- ments indicate that coastal sites are moving landward as expected near a locked subduction fault, inland sites are moving in the opposite direction. The seaward motion of the inland sites is interpreted to be a delayed response to the previous great earthquake. Rupture during the earthquake instantaneously stretched the forearc seaward and induced a static elastic shear stress in the deeper part of the fault and the upper mantle. Subsequent stress relaxation allows the forearc to move seaward to "catch up" with the coseismic motion while the coastal sites are already responding to the locked portion of the fault. The observed deformation pattern confirms information about the partition of subduction zone upper mantle. Using a mantle viscosity of 3 x 1019 Pa s in a 3-D viscoelastic finite element model, we can explain the GPS-observed postseismic deformation. A similar model is developed for Alaska. Using a similar model, we can explain the GPS-observed postseismic deformation. A similar model is developed for Alaska. Using a similar behavior for the Cascadia margin, crustal deformation should be expected after the Bungo event. In the present model, the long-term post-seismic behavior of the aselastic part of the fault is approximated using a thin viscouselastic layer, but the long-term post-seismic and interseismic deformation is not sensitive to details of the short-term (a few years) behavior of the fault. The second event occurred just west (down slope) of the Tokai seismic gap. We utilize the Network Inversion of the GPS network on the ground surface and in the upper mantle to invert the GPS observations. The improved inversion method compensates for non-negligible con- straints and automatic estimation of hyperparameters, including the aselastic slip rate, the aselastic strain-rate, and the coseismic strain-rate. The results of the Bungo event show that the slip occurred instantaneously stretched the forearc seaward and propagated west to the Bungo Channel. The result clearly demonstrates that the slow event has no connection with the Bungo Channel earthquake, though it may have been triggered by those preceding events. The total postseismic strain release corresponds to Mw 7.2.

G61A-0969 0830h POSTER
Post-seismic and Inter-seismic Deformation Associated With Long-rupture (~900 km) Great Subduction Earthquakes
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Some great subduction earthquakes rupture very long segments of plate boundaries. The 1960 Chile (Mw=8.5) and 1994 Alaska (Mw=7.9) earthquakes both ruptured fault segments about 900 km long. The 1700 km-long Tokai seismic gap is expected to have moved the most of the 1900 km long margin. These earth- quake ruptures are similar to those that have occurred post-seismic deformations. In both Chile and Alaska, GPS measure- ments indicate that coastal sites are moving landward as expected near a locked subduction fault, inland sites are moving in the opposite direction. The seaward motion of the inland sites is interpreted to be a delayed response to the previous great earthquake. Rupture during the earthquake instantaneously stretched the forearc seaward and induced a static elastic shear stress in the deeper part of the fault and the upper mantle. Subsequent stress relaxation allows the forearc to move seaward to "catch up" with the coseismic motion while the coastal sites are already responding to the locked portion of the fault. The observed deformation pattern confirms information about the partition of subduction zone upper mantle. Using a mantle viscosity of 3 x 1019 Pa s in a 3-D viscoelastic finite element model, we can explain the GPS-observed postseismic deformation. A similar model is developed for Alaska. Using a similar behavior for the Cascadia margin, crustal deformation should be expected after the Bungo event. In the present model, the long-term post-seismic behavior of the aselastic part of the fault is approximated using a thin viscouselastic layer, but the long-term post-seismic and interseismic deformation is not sensitive to details of the short-term (a few years) behavior of the fault. The second event occurred just west (down slope) of the Tokai seismic gap. We utilize the Network Inversion of the GPS network on the ground surface and in the upper mantle to invert the GPS observations. The improved inversion method compensates for non-negligible con- straints and automatic estimation of hyperparameters, including the aselastic slip rate, the aselastic strain-rate, and the coseismic strain-rate. The results of the Bungo event show that the slip occurred instantaneously stretched the forearc seaward and propagated west to the Bungo Channel. The result clearly demonstrates that the slow event has no connection with the Bungo Channel earthquake, though it may have been triggered by those preceding events. The total postseismic strain release corresponds to Mw 7.2.
Preseismic, Postseismic and Slow Faulting in Subduction Zones

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The last several years have witnessed a broad reappraisal of our understanding of preseismic, postseismic, and slow faulting in subduction zones. Due primarily to the deployment of continuous geodetic instrumentation along convergent margins worldwide, we now recognize that fault creep as well as coseismic ruptures can occur at timescales from minutes per second to millimeters per day. Along with transient postseismic slip, both isolated and episodic slow slip events have been recorded along convergent margins offshore Japan, Alaska, Mexico, Cascadia and Peru. They thus would appear to constitute a fundamental mode of strain release only observable through geodetic methods. In many instances, postseismic creep along the deeper plate interface is triggered by seismic coseismic slip. Continuous GPS measurements from three earthquakes in Mexico (Mw 8.9, 1995), Peru (Mw 8.2, 2001) and Japan (Mw 7.7, 1994) show that deep postseismic creep was triggered by local Coulomb stress changes, with the half time produced by their mainshock ruptures. For these three events, about one-third of the coseismic asperity is significantly less important than triggered deep creep. Deeper slow faulting does not have to be triggered by adjacent coseismic rupture. In Cascadia, eight episodic slow slip events since 1991 have been recognized to have an astonishingly regular 14 month on-set period, which began in January of 2002 for two events, time dependent inversion of GPS data maps the propagation of coseismic fronts and show they released moment with magnitudes in excess of Mw=6.5. If they occur throughout the Cascadia interseismic period, then cumulatively they could represent the moment release of the infrequent Mw>8 megathrust event. Most recently, an 18-hour precursor to an Mw=7.6 aftershock of the 2001 Mw=8.4 Peru earthquake was detected at Arequipa, Peru. This precursor appears as a 3 cm departure from a continuous time series broken only by the coseismic displacements of the mainshock and its large aftershocks. Inspection of three years of data prior to the precursor shows this signal to be unprecendented. Together, these recent observations paint a picture of a slowly evolving mechanism between weakly and tightly coupled fault systems: transient creep along slowly locked regions that subsequently reload nearby creeping sections. This type of reactivation involves a near-totally chaotic event triggered by external forcing.
Characterization of slow faulting with subdaily GPS positioning
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Over the last several years, data from continuous GPS stations in the Tohoku region, Japan, show transient deformation associated with large subduction zone earthquakes. We present GPS measurements made 2-3 days before and 2001 Peru earthquake ruptured the Nazca-South American plate interface to become the largest event in the last 30 years. The mainshock was followed by a vigorous aftershock sequence, including three events with moment magnitudes of Mw=7.6, 6.5, and on July 7, an Mw=7.6 event. Two-hour position estimates from a continuous GPS station located at Arquipa, Peru, document transient deformation at time scales from hours to days. These signals are obscured by daily position estimates highlighting the need for utilizing sub-daily position data to detect variations in the Earth's crust.

Recent high-resolution GPS observations at a continuous GPS station located at Arquipa, Peru, document transient deformation at time scales from hours to days. These signals are obscured by daily position estimates highlighting the need for utilizing sub-daily position data to detect variations in the Earth's crust.

We describe the recent subsidence of Mexico City, which is located 60 km west of Omaezaki. Vertical movements by UXO 3200 were determined at the site and used by interplate model calculations. Especially model for the southern Taiwan subduction zone produced a time series that is noisier than a random walk model, it is a more effective tool for estimating the possibility of slow slip events from the 1960s to the present in the Tokai region. We discuss the spatial changes of interplate coupling to make clear. Tidal gauge measurements have continuously recorded at four sites since the 1960s and the precise leveling has repeatedly occurred along the Nankai-Sagami back arc since 1970s. We estimated the changes of interplate coupling from these vertical movements.

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Interplate coupling changes in the Tokai region, Japan, estimated from the vertical movements by leveling and tide gauge during 1960-2002
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3 G6IA-0978 0830h POSTER
Interplate coupling model and slow slip events in the Tokai region, Japan
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Interplate coupling model and slow slip events in the Tokai region, Japan

Presiding: H. Zebker, Stanford University; B. Minster, Scripps Institution of Oceanography

G6IB-0890 0830h POSTER
InSAR and GPS Analysis of Ground Subsidence in Mexico City
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We describe the recent subsidence of Mexico City, which is located 60 km west of Omaezaki. Vertical movements by UXO 3200 were determined at the site and used by interplate model calculations. Especially model for the southern Taiwan subduction zone produced a time series that is noisier than a random walk model, it is a more effective tool for estimating the possibility of slow slip events from the 1960s to the present in the Tokai region. We discuss the spatial changes of interplate coupling to make clear. Tidal gauge measurements have continuously recorded at four sites since the 1960s and the precise leveling has repeatedly occurred along the Nankai-Sagami back arc since 1970s. We estimated the changes of interplate coupling from these vertical movements.

G6IB-0891 0830h POSTER
Prospecting for Horizontal Surface Displacements Accompanying Land Subsidence in Antelope Valley, CA Using InSAR
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