heterogeneity even in the same depth range, implying that the thermal structure is not the only controlling factor of interplate coupling and that the plate configuration may play an important role. The daily GPS coordinate data are also utilized to analyze an aseismic fault slip event on the plate boundary interface east off the Boso Peninsula in the middle of May 1996. The silent rupture propagated southward over a 50km * 50km wide area during about a week. The maximum slip was about 50mm and the released seismic moment was 4.7E18Nm (Mw6.4). The estimated stress drop was as small as 0.05MPa. The silent slip occurred in the peripheral of a locked asperity, suggesting that the distribution of seismic slip and that of aseismic slip are complementary each other and that the frictional property of the plate boundary is persistent. Therefore detailed spatio-temporal mapping of variable slip behavior is necessary for comprehensive understanding of plate boundary process and it is essential for quantitative estimation of future seismic hazard.

### S51G-06 1135h

## Candidates of M7-Class Earthquake Beneath Greater Tokyo Area

Yoshimitsu Okada (81-29-863-7781; okada@bosai.go.jp)

National Research Institute for Earth Science and Disaster Prevention, Tennodai 3-1, Tsukuba 305-0006, Japan

In greater Tokyo area, the occurrence of M7-class earthquake is thought to be imminent by the following reasons. (1) In these 20 years, maximum size of shallow microearthquakes beneath Tokyo is steadily increasing. (2) In recent 80 years after Kanto earthquake, maximum size of the earthquakes in Kanto region is gradually increasing. (3) In these 400 years, it was observed twice that two M7-class earthquakes precede the M8 interplate earthquakes in the latter half of the interseismic period. Taking into consideration these background, the Central Disaster Management Council, Japan issued Guideline for Countermeasures to the Earthquakes Beneath Southern Kanto Region on August 1994, and proposed 19 fault models along the upper boundary of Philippine Sea plate as the candidates of the forthcoming M7-class earthquake. At present, we have no data of abnormal seismic activity or crustal movement to select preferable one among these 19 fault models. Here, we will try to constrain the candidates which may have relatively higher possibility of the occurrence by a elimination method. It seems to be possible to exclude some of the fault models by the following ways. (1) Adopting characteristic earthquake concept, we can exclude 5 models which overlap to the focal region of 1923 Kanto earthquake. (2) A belt like zone of serpentine are found from tomography results at 30-40km depth along the Philippine Sea plate beneath the Kanto Plain and no microearthquake activities are generated along this zone (Kamiya and Kobayashi, GRL, 2000). We can eliminate 4 models which lie in this zone. (3) Beneath the eastern Boso Peninsula, it was found that slow slips of M6.5-class are repeated every 5-6 years. We can exclude 2 models in the area (4) Since plate collision is undertaken beneath eastern Yamanashi Prefecture, we can exclude 1 model in this area. Finally, it remains 7 fault models as the possible candidates of M7-class earthquake beneath Tokyo area. They are 3 models just beneath mid-Tokyo, 3 models in southern Ibaraki Prefecture, and 1 model at western Kanagawa Prefecture. So far we have restricted us the candidates of M7 earthquake only along the upper boundary of Philippine Sea plate. Under the complex tectonic settings around Tokyo, we should be also aware of the other type earthquakes, although a deeper event with the same magnitude will cause smaller ground motions in general.

### S51G-07 1150h

## The recurrence interval of great earthquakes along the Sagami trough

Masataka Ando (81-52-789-5390; ando@seis.nagoya-u.ac.jp)

Rec. Cent. Seismology, Volcanology and Hazard Mitigation, Nagoya Univ., Furocho, Chikusa, Nagoya 464-8602, Japan

Along the Sagami trough, an oblique subuduction zone between the Philippine Sea and North American plates, great earthquakes occurred in 1923 (M7.9) and1703 (M8.6), about 50 km southwest of the Tokyo. Both events generated strong ground motions and tsunamis. Strong ground motions equivalent to seismic intensities 6 to 7 in JMA scale and 10 to 12 in MM scale struck over southern Kanto. The two earthquakes are similar more or less in the extent of the damage and the crustal deformation, possibly occurring very near each other. The extent of the damage and the crustal deformation on the southern area was greater in the 1703 event, whose tsunami reached and damaged the coast of the Kii peninsula, 300 to 400 km away from the source. The source region of the 1703 earthquake, therefore, is considered to have extended towards the ocean and much larger than that of the 1923 event. Several studies of uplift coastal terraces suggest the events like the 1703 one have occurred possibly every 1,000-2,000 years, while those like the 1923 Kanto earthquake more frequently without leaving geomorphic evidence on the terraces. Before 1703, a possible candidate for a subduction event is the M7.0-7.5 1257 or M7.0 1293 earthquake that caused serious damage to southern Kanto region. However, no other earthquakes have been found in historical documents. Historically, the Kanto area was not well civilized until 13th century and earthquakes are not well documented. In addition most historical documents recorded between 14th and 16th centuries were lost during the age of civil wars. If an average recurrence interval is 200 years, at least 4 to 5 events should have occurred before 1703 ,since the 9th century when the first earthquake was reported in this area. The incomplete earthquake history may contain at least two recurrence intervals, 200 and 400 years. However, the 400 year interval can be shortened by inserting additional earthquakes. For the purposes of hazard mitigation and study of earthquake recurrence paleoseismic research should be much more focused on excavating unrecognized great earthquakes along the Sagami trough.

### S51G-08 1205h INVITED

## Recurrence of characteristic Kanto earthquakes and unusual 1703 type earthquakes inferred from emerged shoreline topography

Masanobu Shishikura[1] (+81-29-861-3911; m.shishikura@aist.go.jp)

Shinji Toda[1] (s-toda@aist.go.jp)

[1]Active Fault Research Center, Geological Survey of Japan/AIST, SiteC7, 1-1-1 Higashi, Tsukuba 305-8567, Japan

Sagami Trough, extending NW-SE off South Kanto, is convergent plate boundary where the Philippine Sea Plate subducts beneath the North American Plate. Two major historical earthquakes, the 1703 Genroku Kanto Earthquake (M 8.2) and the 1923 Taisho Kanto Earthquake (M 7.9) occurred along the trough. As a result of the coseismic crustal movements associated with these earthquakes and repeated pre-historic earthquakes, Holocene emerged shoreline indicators (e.g. emerged wave-cut bench, fossilized mollusk etc.) are observed on 15 levels along the coast of the Miura Peninsula and the Boso Peninsula. The height distributions of the lowest two levels of them in the Miura Peninsula indicate 1.0-1.5 m of uplift during the both historical events. In the Boso Peninsula, although the whole of the peninsula was uplifted (max. 2 m) and tilted toward the northeast during the 1923 event, the 1703 event resulted in northward tilting accompanied with the uplift of more than 5 m in the southernmost area and subsidence of ca. 1 m in the central area. According to above results, it is inferred that the fault source model of the 1703 Genroku Kanto earthquake consists of a combined fault system of fault A and B. The fault A is the same as the model of the 1923 event which has already been estimated by Ando (1974). The uplift of the Miura Peninsula (both the 1703 and 1923 events) and the Boso Peninsula (only the 1923 event) can be explained by about 6.7 m slip of the fault A. The fault B is a low angle dip thrust located off the southeast of the Boso Peninsula. The unique movement of the 1703 event in the Boso Peninsula has been derived from about 12 m slip of the fault B. 14C ages of the older paleo-shorelines above two recent levels indicate that the characteristic earthquake generated from the fault A has occurred repeatedly about every 400 years. Basing on the geometry of emerged shoreline topography, four large uplift events of the 1703 Genroku type occurred several times in addition to several repeated small uplift events of the 1923 Taisho type. Recurrence interval of the 1703 type earthquake accompanied with the slip of fault B is 2000-2700 years.

# S52A MCC: Level 1 Friday 1330h

## Strong Ground Motion Prediction IV Posters

*Presiding:* **T Iwata,** Kyoto University; **A Pitarka,** URS Corporation

### S52A-0108 1330h POSTER

## The Origin of Supershear Rupture

Eric M Dunham[1] (edunham@physics.ucsb.edu)

Pascal Favreau[2] (pfavre@ipgp.jussieu.fr)

Jean Carlson[1] (carlson@physics.ucsb.edu)

[1]University of California - Santa Barbara, Department of Physics University of California, Santa Barbara, CA 93106, United States

[2]Institut de Physique du Globe de Paris, 4 place Jussieu, Paris 75252, France

We discuss four situations in which ruptures make the transition from sub-Rayleigh to supershear propagation velocities, and describe how all are manifestations of a diffraction effect. In 2D, the transition is often discontinuous, with an S-wave stress peak triggering rupture ahead of the main crack edge. For 3D ruptures on homogeneous faults, the rupture smoothly accelerates to supershear velocities. Ruptures breaking the free surface exhibit a stress concentration near the surface that triggers a continuous transition. We describe in detail the fourth mechanism, in which a sub-Rayleigh rupture encounters a high strength obstacle. The rupture front initially decelerates and either partially or totally encircles it. The concave front focuses waves into the center of the barrier, creating slip velocities over an order of magnitude larger than elsewhere. This releases strong elastic waves that manifest as distinctive slip pulses on the fault surface, for which we present an analytical solution. For barriers above a critical strength, the energy concentration triggers a transient supershear burst. Even unbreakable barriers can trigger the transition when the split rupture fronts converge to produce rapid stress drop and high slip velocities (split-front focusing). Scaling laws are given for the time required to break a barrier. The diffraction effect underlying the transition can be understood by considering a rupture front in which the stress breaks down over a finite length scale. The dynamic displacement and stress fields are constructed by a superposition of point shear tractions that appear behind the rupture as it passes a given point and attain their final value (the stress drop) over a finite time scale. The resulting elastic waves cross the broken part of the crack until they reach the moving crack edge, where they diffract into the surrounding medium. Head waves generated within the breakdown zone convert to S-waves at the edge, which, if they are sufficiently strong, trigger a continuous supershear transition. Otherwise, a cumulative effect is necessary to develop this S-wave peak, such as occurs for slowly accelerating 2D cracks, leading to a discontinuous transition. This model also predicts the observed secondary peak in slip velocity moving near the Rayleigh speed behind a supershear front. Rather than having been left behind by the rupture after the supershear transition, it consists instead of surface waves continually emitted from the breakdown zone that never overtake the faster-moving rupture front.

### S52A-0109 1330h POSTER

## Estimation of Dynamic Stress Parameters of the 1992 Landers Earthquake

Arben Pitarka[1] (626 449 7650; arben pitarka@urscorp.com)

Luis Angel Dalguer[2] (dalguer@egmdpri01.dpri.kyoto-u.ac.jp)

[1]URS Corporation, 566 El Dorado St., Pasadena, CA 91101, United States

[2]DPRI, Kyoto University, Gokasho, Uji, Kyoto 611, Japan

We apply a slip-weakening friction model of rupture dynamics to determine the dynamic stress-drop, strength excess and critical slip for the 1992 Landers earthquake. We follow a two step procedure. First, based on the slip distribution on the fault and the rupture time obtained from a kinematic model of the fault rupture (Wald and Heaton,1994), we compute the shear-stress change on the fault during the earthquake using a finite-difference method of fourth-order accuracy. We use a vertically heterogeneous velocity model and a single planar fault. Using the shear-stress change we derive the distribution of approximate values of the dynamic and static stress drop, and strength excess. The slip weakening distance is obtained using the approach of Mikumo (2003) which uses the slip-velocity and the time history of the shear stress. Second, based on finite-difference forward modeling of the recorded motion using dynamic modeling of the fault rupture, the dynamic stress parameters are adjusted by a trial and error scheme. The final model is the one that best fits the total slip obtained by the kinematic model, and the recorded ground motion in the frequency range of 0.1-0.5 Hz.

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### S52A-0110 1330h POSTER

## Three-Dimensional Finite-Difference Simulations of Strong Ground Motions during the 1720 Shacheng Earthquake($M_w$7.0) of Yanhuai Area, Beijing, China using a Stochastic Finite-Fault Model

Guo-Quan Wang[1] (49-89-21804207; wang@geophysik.uni-muenchen.de)

Heiner Igel[1] (49-89-21804207; igel@geophysik.uni-muenchen.de)

Haijiang Wang[1] (49-89-21804207; haijiang@geophysik.uni-muenchen.de)

[1]Institute of Geophysics, University of Munich, Theresien str. 41, Munich 80333, Germany

Three-dimensional finite-difference (3D-FD) simulations of elastic waves in the Yanhuai Basin are performed for the 1720 Shacheng earthquake ($M_w$7.0) with a stochastic finite-fault model. The goal of this study is to incorporate the stochastic finite-fault model used widely in earthquake engineering for simulation of strong ground motion (Beresnev and Atkinson, 1997, 1998, etc.) into the 3D-FD program. The basic idea of the stochastic finite-fault model is that the causative fault plane can be subdivided into several subfaults (elements), and radiation from a large earthquake is the sum of contributions from all subfaults with proper time delays, each of which acts as a small independent source. The rupture starts at a given point on the fault and propagates with constant velocity, triggering subsources as soon as it reaches them.The causative fault of the 1720 Shacheng earthquake ($42km \times 18km$) is divided into $6 \times 4$ subfaults with dimensions of $7km \times 4.5km$ in this study. An important aspect of the problem of characterizing the earthquake source is the degree of fault heterogeneity or roughness. Heterogeneity of the fault rupture process are modeled by randomizing the location of the initial rupture, and by randomizing the subevent rise times and slip distributions in this study, from which the model was named. This study emphasizes particularly on the applications of the theoretical simulation in the engineering practice. The simulated results include the distribution maps of peak ground velocities (PGV), duration of strong ground motions, 5%-damped response spectra (pseduo-velocity response spectra) for different oscillator periods (e.g., 0.7sec, 1.0sec, 1.5sec, 2.0sec, 5.0sec), and seismic intensity. We study the effects of the randomness implicated in our source model on the simulated results with a homgeneous 3D model systematically. The general finding is that the randomness produce slight effects on the distribution of PGV (less than 5 cm/s), response spectra, durations, as well as seismic intensity, and furthermore, the effects are mostly limited in the range of the horizontal projection of the fault surface on ground surface. A 3D velocity model of the Beijing Area is constructed from studies that analyzed available geological information, seismic-reflection suveys, borehole logs, and gavity data. The smallest shear-wave velocity in the model is 1.0 km/sec. A grid increment of 100m in three directions is used in this simulation, which made it possible to caputure the short period information with a resolution of 0.5 sec. It is the most interesting period range in earthquake engineering. This study highlights the possibility of using the finite-difference and stochastic finite-fault combined method into the simulation of strong earthquake ground motions,and domentrates the important effects of the basins occured in the Beijing area on the strong ground motions.

## S52A-0111 1330h POSTER

### Characterization of Dynamic Source Parameters for Strong Motion Prediction

Tomotaka Iwata[1] (81-774-38-4057; iwata@egmdpri01.dpri.kyoto-u.ac.jp)

Haruko Sekiguchi[2] (Haruko.Sekiguchi@aist.go.jp)

Hiroe Miyake[3] (hiroe@eri.u-tokyo.ac.jp)

Wenbo Zhang[1] (wenbo@egmdpri01.dpri.kyoto-u.ac.jp)

Ken Miyakoshi[4] (ken@geor.or.jp)

[1]DPRI, Kyoto Univ., Gokasho, Uji 611-0011, Japan

[2]AFRC, GSJ/AIST, Chuo 7, Higashi 1-1-1, Tsukuba 305-8567, Japan

[3]ERI, Univ. of Tokyo, Yayoi 1-1-1, Bunkyo, Tokyo 100-0032, Japan

[4]Geo. Res. Inst., Itachibori 4-3-2, Nishi-ku, Osaka 550-0012, Japan

Heterogeneous slip characterization of inland crustal earthquakes (Mw5.4-7.6) shows a scaling relation between total area of asperity, which has rather larger slip than the total area, and seismic moment from source inversion results using strong motion data (e.g. Somerville et al., 1999; Miyakoshi et al., 2002). Irikura and Miyake (2001) proposed characterized source model based on this scaling relation for strong motion prediction. The availability of the characterized source models has been proved through the strong motion simulation in near-source area in the broadband frequency band (BB) for e.g., the 1995 Kobe (Kamae and Irikura, 1997) and for the 2000 Tottoriken-Seibu (Ikeda et al., 2002), Japan, earthquakes. In those simulations, they assumed stress drops only for the asperities by forward simulation of the high frequency contents of the records. When constructing a characterized source model for BB strong motion, we need rules to set stress parameters of the characterized source model. We examine dynamic source parameters by mapping method of spatio-temporal shear-stress distribution on the fault plane from a spatio-temporal slip distribution from kinematic waveform inversion (Bouchon, 1997). The dynamic source parameters averaged over on- and off-asperity areas are estimated. Average effective stress values of on- and off- asperity areas are estimated as 10-30MPa and about 5MPa for the 1995 Kobe, the 1999 Chichi, Taiwan, the 1999 Kocaeli, Turkey, and the 2000 Tottoriken-Seibu earthquakes. Stress parameters on the asperities are slightly increasing with asperity depth. Stress parameters on the asperities coincide with the ones that were used for forward ground motion modelings. Characterization of stress parameters contributes the development of characterized source model.

## S52A-0112 1330h POSTER

### Effects of Uncertainties of Input Data on FD Ground Motion Simulations in the Cologne Basin, Germany

Michael Ewald[1] (0049 89 2180 4209; ewi@geophysik.uni-muenchen.de)

Heiner Igel[1] (igel@geophysik.uni-muenchen.de)

Frank Scherbaum

Klaus Hinzen

[1]Ludwig-Maximilians University Munich, Theresienstr. 41, Munich 80333, Germany

In FD ground motion simulations we encounter the same two major sources of error as in any computer simulation of physical events: 1) approximation error, due to uncertainties of the input data (e.g. velocity model, q-values, densities, source location especially source depth etc.) as well as the inherent errors incurred in the discretization of physical models into computational models, and 2) modeling error, due to natural imperfections of mathematical abstractions of real physical events depending on the algorithms used in the simulations. Whereas the latter is subject of numerous studies, the influence of uncertainties in the input data are rarely discussed. To investigate such effects we performed elastic and visco-elastic finite difference simulations using different models within the error margins given by the input data sets. The Cologne Basin, NW-Germany, was chosen as study area because it is seismically one of the most active regions in central Europe and an ML 5.0 event which took place on July 22, 2002 in this region provides a dataset for comparing synthetic seismograms with observed ones.

## S52A-0113 1330h POSTER

### Source and Path Modeling of the 2001 Geiyo Earthquake and the Strong Ground Motions

Yasumaro Kakehi (81-78-803-5738; kakehi@kobe-u.ac.jp)

Faculty of Science, Kobe University, Nada, Kobe 657-8501, Japan

Intraplate earthquakes occurring within subducting slabs (slab earthquakes) can give large damage to the cities located above. In this study, detailed source process of the 2001 Geiyo earthquake (Mw = 6.8), which is a normal fault event occurring in the subducting Philippine Sea plate beneath southwest Japan, is investigated from the inversion of high-density strong ground motion waveforms. For the inversion, the S-wave part velocity waveforms (0.1 - 0.5 Hz) at the NIED K-NET and KiK-net stations are used. Analysis of the waveforms at the 13 stations surrounding the source area indicates a bending fault model, which is roughly composed of the two segments with different strike and dip angles, respectively. The slip distribution on the fault plane obtained from the waveform inversion is rather heterogeneous. The Philippine Sea slab in this area is composed of the high-velocity slab mantle and the overlying low-velocity slab (oceanic) crust with thickness of 6 km. The rupture, which started within the slab mantle, not only spread in the high-velocity slab mantle but also invaded into the low-velocity slab crust. Large slip is seen both in the slab mantle and in the slab crust. The rupture propagated almost unilaterally from the north to the south. Comparison of the observed waveforms at the northern (backward-directivity side) and the southern (forward-directivity side) clearly shows the directivity effect on the strong ground motion waveforms. The detailed irregularities of the complex rupture process appear more clearly on the backward-side waveforms. The Green's functions are calculated using flat-layered underground structure models. An aftershock with Mw 5.2 is used as a path-calibration event, and the station-specific shallow sediment layer models are constructed by trial and errors by comparing the observed and synthetic waveforms of this event. The total seismic moment of the 2001 Geiyo earthquake is 2.3 x 10E+19 N*m. The previously estimated seismic moment based on the underground structure model without the shallow sediment layers was 3.1 x 10E+19 N*m. This shows that source inversion without considering shallow sediment layers can inappropriately attribute the amplification effect by soft layers to the source and overestimate the source factor.

## S52A-0114 1330h POSTER

### A method for synthesizing strong ground motion by using filters for representing site, path and source characteristics.

Shigeo Kinoshita (81-45-787-2319; kkk001@yokohama-cu.ac.jp)

An observed ground motion can be decomposed to site, path and source characteristics. Many studies were devoted to investigate these characteristics. On the basis of the results of those studies, we propose a new method to synthesis the ground motions at free field by means of the convolution of source, path, and site effects. The method based on filter theory assumes that source spectrum is the amplitude function of source filter driven by an impulse. This assumption introduces the causality of source filter. Thus, each filter has the impulse response of one-side function. As the results, site and path filters are constructed by minimum-phase filters. This means that the impulse responses of these two filters are calculated from only the amplitude functions of filters by using the Kramers-Kronig relation. On the contrary, source filter has the characteristics of a quasi-linear phase filter. The statistical characteristics of synthetic ground motion are calculated and compared with those of observed earthquakes, by using the convolution of impulse responses obtained from these three filters.

## S52A-0115 1330h POSTER

### Source Model of the 2002 Miyagi-Oki Interplate Earthquake (Mw=6.4) Obtained by Strong Ground Motion Simulation Using Empirical Green's Function Method

Wataru Suzuki[1] (suzuki@egmdpri01.dpri.kyoto-u.ac.jp)

Tomotaka Iwata[1] (iwata@egmdpri01.dpri.kyoto-u.ac.jp)

[1]Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan

Previous studies show that strong motion records of crustal earthquakes can be successfully simulated using aftershock record as empirical Green's function with rectangular source model which is smaller than total fault size estimated from aftershock distribution. We call the area strong motion generation area (SMGA). It is also revealed that the SMGA corresponds to the asperity deduced by kinematic waveform inversion, and its size can be expected from scaling relation between the size of the asperity and the seismic moment. Asano et al. (2003) analyzed shallow intraslab earthquakes in the similar manner and derived that the size of SMGA is smaller than that expected for crustal earthquake of the same seismic moment, and the ratio of the derived and the expected sizes decreases with focal depth. This may implies that the deeper earthquake has the larger stress drop on the asperity. In November 3, 2002, an earthquake of $M_w = 6.4$ (depth was about 45km) occurred in Miyagi-Oki region, north east of Japan, where high percentage of occurrence of interplate events is expected by the long term forecast. This event was thought to be interplate earthquake from moment tensor solution and aftershock distribution. We simulate broadband strong motion records of this interplate earthquake using empirical Green's function method proposed by Irikura (1986). Comparing observed and simulated waveforms, we derive the size and location of the SMGA by forward modeling. The obtained size of the SMGA is smaller than that expected from the relationship between the size and the seismic moment for crustal earthquakes, and is consistent with the relation among the size and the seismic moment and the depth derived from Asano et al. (2003). This result supports the idea that stress drop on the asperity mainly depend on its depth. We would like to thank K-NET and KiK-net for providing strong motion data, F-net for moment tensor solution, and JMA for information of hypocenter.

## S52A-0116 1330h POSTER

### Dynamic Rupture Process of the 1999 Chi-Chi Earthquake

Wenbo Zhang[1] (+81-774-38-4058; wenbo@egmdpri01.dpri.kyoto-u.ac.jp)

Tomotaka Iwata[1] (+81-774-38-4057; iwata@egmdpri01.dpri.kyoto-u.ac.jp)

Kojiro Irikura[1] (+81-774-38-4061; irikura@egmdpri01.dpri.kyoto-u.ac.jp)

Arben Pitarka[2] (Arben_Pitarka@urscorp.com)

Haruko Sekiguchi[3] (haruko.sekiguchi@aist.go.jp)

[1]Wenbo Zhang, Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan, Uji, Kyo 611-0011, Japan

[2]Arben Pitarka, URS Greiner Woodward Clyde, USA, Pasadena, CA 91101, United States

[3]Haruko Sekiguchi, AFRC, Geological Survey of Japan, Tsukuba 305-8567, Japan

Earthquake source dynamics provides key elements for the prediction of strong ground motion and for understanding the physics of earthquake processes. This research investigates the characteristics of dynamic source rupture process of the 1999 Chi-Chi earthquake by using a 3D finite difference method with variable grid spacing. A new algorithm is proposed to deal with a non-planar fault model. This approach does not require aligning the fault plane to the finite-difference grid for implementation of FDM and provide a method to deal with a more realistically irregular geometry fault model. We apply this approach to the 1999 Chi-Chi earthquake with a curved fault surface and rebuild the dynamic source rupture process for this larger earthquake. Our results show that for the Chi-Chi earthquake, the behaviors of the most of the subfaults followed a slip-weakening friction law during rupture. And the distributions of the dynamic source parameters estimated from the kinematic results are quite heterogeneous. For the dynamic rupture process, this study reveals the rupture propagation jumping phenomenon which is difficult to be simulated in kinematic modeling. That is when the propagation front encountered a zone with a high strength excess, the rupture would pause to accumulate more energy to break it. Meanwhile, if there are low strength excess zones around the barrier, the propagation front would jump over the barrier to break the low strength excess zones and leave the high strength barrier unbroken. Such phenomenon of the high strength excess barriers intend to delay the propagation front can be seen clearly in the dynamic model. Using a thick fault zone model, the dynamic model discovers that the slip on the hanging-wall side is larger than that on the food-wall side and the northern parts have the longer source duration that the southern parts and these northern parts have an extreme large slip. Based on the dynamic source rupture model, the strong ground motions near the fault surface breaks are simulated in frequency range of 0.05 to 0.5 Hz. In general, the synthetic velocity waveforms agree well with the observed records for most stations. The dynamic source model successfully simulates the distinctive velocity pulse for the stations in the forward rupture direction. Also our dynamic source model successfully reproduced the waveforms as well as the distinctive velocity pulses for the station nearby or on the fault surface breaks. These results demonstrate that our dynamic source model can reproduce the main features of long period ground motions; hence, lead us to a better understanding on the source rupture process of the Chi-Chi earthquake.

## S52A-0117 1330h POSTER

### Modeling of Long-period Ground Motions from Moderate-size Earthquake in Kinki Area, Japan

Nobuyuki Yamada[1] (+81-774-38-4187; yamada@egmdpri01.dpri.kyoto-u.ac.jp)

Tomotaka Iwata[1] (+81-774-38-4057; iwata@egmdpri01.dpri.kyoto-u.ac.jp)

[1]DPRI, Kyoto Univ., Gokasho, Uji 611-0011, Japan

The Kobe and Osaka metropolitan areas are located on the Osaka sedimentary basin in Japan where has repeatedly suffered from heavy damage caused by subduction zone earthquakes with M8 class, although it has more than 100km from the source region. As very high probability is estimated for occurrence of the next earthquakes, it is an emergent subject to characterize source and propagation-path models for predicting strong ground motions. Especially, estimation of response of high-rise buildings that were not existing during the last subduction earthquakes in this area, against the ground motions is one of the quite important issues for seismic disaster mitigation. We have started to simulate long-period (2 to 10s) ground motions of M5 class earthquakes, occurred in the source area of the hypothetical subduction earthquake at strong-motion and broad-band seismic stations in the area using a 1D crustal structure model. Although simulated velocity ground motions with a starting velocity model seem to be able to reproduce the S-wave and some later phases at the bedrock stations between the source and Osaka basin, frequency characteristics and duration of the simulated ground motions are different from those of observations. We are improving the crustal structure model by introducing a 3D crustal structure with referring to ground motion simulations.

## S52A-0118 1330h POSTER

### Parallel 3D Simulation of Seismic Wave Propagation in the Structure of Nobi Plain, Central Japan

Akira Kotani[1] (kotani@eri.u-tokyo.ac.jp)

Takashi Furumura[1] (furumura@eri.u-tokyo.ac.jp)

Kazuro Hirahara[2] (hirahara@eps.nagoya-u.ac.jp)

[1]Earth Research Institute, University of Tokyo, 1-1 Yayoi 1-chome, Bunkyo-ku, Tokyo 113-0032, Japan

[2]Graduate school of Environmental Studies, Nagoya University, Chikusa, Nagoya 464-8602, Japan

We performed large-scale parallel simulations of the seismic wave propagation to understand the complex wave behavior in the 3D basin structure of the Nobi Plain, which is one of the high population cities in central Japan. In this area, many large earthquakes occurred in the past, such as the 1891 Nobi earthquake (M8.0), the 1944 Tonankai earthquake (M7.9) and the 1945 Mikawa earthquake (M6.8). In order to mitigate the potential disasters for future earthquakes, 3D subsurface structure of Nobi Plain has recently been investigated by local governments. We referred to this model together with bouguer anomaly data to construct a detail 3D basin structure model for Nobi plain, and conducted computer simulations of ground motions. We first evaluated the ground motions for two small earthquakes (M4 5); one occurred just beneath the basin edge at west, and the other occurred at south. The ground motions from these earthquakes were well recorded by the strong motion networks; K-net, Kik-net, and seismic intensity instruments operated by local governments. We compare the observed seismograms with simulations to validate the 3D model. For the 3D simulation we sliced the 3D model into a number of layers to assign to many processors for concurrent computing. The equation of motions are solved using a high order (32nd) staggered-grid FDM in horizontal directions, and a conventional (4th-order) FDM in vertical direction with the MPI inter-processor communications between neighbor region. The simulation model is 128km by 128km by 43km, which is discritized at variable grid size of 62.5-125m in horizontal directions and of 31.25-62.5m in vertical direction. We assigned a minimum shear wave velocity is Vs=0.4km/s, at the top of the sedimentary basin. The seismic sources for the small events are approximated by double-couple point source and we simulate the seismic wave propagation at maximum frequency of 2Hz. We used the Earth Simulator (JAMSTEC, Yokohama Inst) to conduct such large simulation. The parallel simulation using 256CPUs of the Earth Simulator took computer memory of 260GByte and wall-clock time of 8.3hours. Comparisons between the observed waveforms and computed simulations for two earthquakes agree well, so that it is indicating the effectiveness of the 3D model. We therefore conducted another simulation to estimate the pattern of strong ground motion during large earthquakes such as for the 1945 Mikawa earthquake. We employ the fault rupture model of Kikuchi et al (2003), which is derived from the inversion of regional records, and the pseudo dynamic source time function of Nakamura and Miyatake (2000). The simulated wavefield from the Mikawa earthquake is dominating in large surface waves at amplitude over 10cm/s and a relatively long period of 6-8s in the center of the Nobi plain. We also find directivity effect of the fault rupture from south to north in the PGV distribution and waveforms. This explains the major pattern of seismic intensity distribution and the strong motion damage during the earthquake.

## S52A-0119 1330h POSTER

### Estimation of Hierarchical Structured Strong Motion Generation Patch Causing Seismic Damage

Shinichi Matsushima[1] (+81-3-3508-8011; matsu@ohsaki.co.jp)

Hiroshi Kawase[2] (kawase@arch.kyushu-u.ac.jp)

Toshiaki Sato[1] (satom@ohsaki.co.jp)

[1]Ohsaki Research Institute, Inc., Uchisaiwai-cho, Chiyoda-ku, Tokyo 100-0011, Japan

[2]Grad. School of Human Env. Studies, Kyushu Univ., Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan

Seismic damage is strongly influenced by the characteristics of strong motion at the natural period of about 1 second. For predicting near fault strong motion in this period range, it is important to adequately evaluate the heterogeneity of the slip distribution of the source rupture process as well as the effects of the complex subsurface geology. The characteristics of velocity pulse waves, directly leading to seismic damage, derived from forward rupture directivity effects are significantly affected by the size and the slip velocity function of the strong motion generation patches (SMGPs). So, it is necessary to evaluate these parameters accurately (Kawase et al., 2000). We developed a technique for estimating rupture process assuming a distinctive SMGP by waveform fitting considering the 3-D subsurface geology using 3-D reciprocal Green's functions and examined the validity of the technique by numerical experiment (Matsushima et al., 2001). In this study, we extended the technique to resolve multiple SMGPs and applied this technique to resolve the size and slip velocity functions of the SMGPs of actual earthquakes. We used data of the Off Miyagi, Japan, earthquake of 1978 recorded at stations of Public Works Research Institute of Japan. By using the sharp velocity pulses, with dominant period of about 1 second, in the data as target, we found that we need relatively small patches hierarchically existing inside the asperities derived from previous source inversions (e.g. Yamanaka and Kikuchi, 2003).

## S52A-0120 1330h POSTER

### Comparing Observed and Predicted Directivity-Amplified Ground Motion

Jeffrey K. Howard[1] (1-916-227-0536; jhoward@water.ca.gov)

Chris A. Tracy[1]

Robert G. Burns[1]

[1]California Department of Water Resources, Division of Safety of Dams, 2200 X St., Suite 200, Sacramento, CA 95818, United States

Near-source strong motion can have forward directivity amplification ("directivity") from constructive interference of body shear waves radiated ahead of the rupture front, and "fling" from co-seismic tectonic movement. In theory, directivity-amplified waves vibrate normal to fault strike (FN). "Fling", which is fault parallel (FP) motion in strike slip rupture and may add to FN motion in dip-slip rupture, is thought to be longer-period motion. Somerville et al. (1997) proposed empirical factors for spectral attenuation formulas to predict directivity-amplified spectral acceleration in FN and FP directions. Abrahamson (2000) revisions retained the implicit assumption that FN and FP represent directions of maximum and minimum response. We compared observed near-source motion to predicted directivity-amplified motion. We isolated the suspected velocity waveform(s) of 25 near-source time histories with strong forward directivity amplification, estimated the waveform polarity, rotated the record accordingly, and computed the rotated spectral response amplitude (i.e., the presumed maximum response amplitude and FN direction) for periods up to 2 seconds. Predictions were based on average results (median or +1 standard deviation) of three attenuation formulas modified by Somerville-Abrahamson factors. We compared velocity pulse-aligned spectra polarity and amplitude with other reported directions of maximum spectral response, actual FN direction and spectral amplitude, and predicted amplitude. Our initial findings are: 1) Records rotated to the velocity waveform polarity commonly yield the largest overall spectral response for periods between 0.5 and 2.0 seconds. 2) More than half the records so oriented have spectra that met or exceeded +1 s.d. SA predictions for some portion of this period range. 3) The velocity waveform rotation is generally close to FN for strike-slip faulting, but can deviate significantly from FN in dip-slip faulting. 4) The periods of maximum spectral amplitude do not seem predictable. A re-analysis of the velocity waveforms using refined procedures was performed and comparisons were made up to periods of 3 sec. Results will be presented at the Fall Meeting.

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## S52A-0121 1330h POSTER

### Towards High-Frequency Ground Motion Prediction Using a Dynamic/Pseudo-Dynamic Approach

Hiroe Miyake[1] (mhiroe@pangea.stanford.edu)

P. Martin Mai[2] (mai@seismo.ifg.ethz.ch)

Mariagiovanna Guatteri[3] (Mariagiovanna_Guatteri@swissre.com)

Gregory C. Beroza[1] (beroza@pangea.stanford.edu)

[1]Department of Geophysics, Stanford University, 397 Panama Mall, Stanford, CA 94305-2215, United States

[2]Institute of Geophysics, ETH, Zurich, CH-8093, Switzerland

[3]Swiss Re. America, 175 King St., Armonk, NY 10504, United States

The past several years have seen substantial progress in physically based approaches to earthquake source modeling for the prediction of strong ground motion (e.g., Mai et al., 2001; Guatteri et al., 2002, 2003). We explore the use of this approach for predictions of wave generation from the source at higher frequencies, where important engineering needs exist. To do this we apply two physical constraints. We assume that wave generation is controlled by the product of maximum slip velocity and effective pulse width.

The Kostrov-like slip velocity function ($t^{-1/2}$) has a too steep spectral decay ($f^{-1/2}$) to reproduce the high-frequency content observed in seismograms. Previous dynamic rupture simulation (< 2 Hz) in Guatteri et al. (2003) shows that maximum slip velocity of each subfault correlates well with the static stress drop. Moreover, the rise time in the heterogeneous slip distribution varies inversely with the time after rupture initiation, as long as the slip-weakening constitutive law is adopted. Using these characteristics of the dynamic faulting, we construct high-frequency source description that satisfies the above constraints. Once the high frequency slip velocity functions are obtained, ground motions are simulated by convolution of the slip velocity and Green's functions using the discrete wave-number method (e.g., Bouchon, 1981) in the low-frequency range, and by the ray-theory calculation using isochrone integration (Spudich and Frazer, 1984) in the high-frequency range. We examine the variability of the ground motions and response spectra, particularly in the near-fault region within 5 km of the fault. Even assuming the same slip distribution, variations in hypocentral location result in strong variations in the intensity of strong ground motions, indicating that the influence from the hypocenter location cannot be neglected for ground motion prediction in empirical attenuation relations.

## S52A-0122 1330h POSTER

### Determination of source, path, and site parameters from Yokohama High-concentration Seismograph Network

Kenichi Tsuda[1] (1-805-893-5750; kenichi@crustal.ucsb.edu)

Ralph Archuleta[1] (1-805-893-8441; ralph@crustal.ucsb.edu)

[1]Institute for Crustal Studies, University of California Santa Barbara, Institute for Crustal Studies, University of california SAnta Barbara, Santa Barbara, CA 93106, United States

The data from the Yokohama high-density accelerometer array have been used to try to separate path, source and site effects. The Yokohama array has 150 surface accelerometers and 9 borehole accelerometers located in a 20 km x 20 km region. The main objective of this study is to measure the variance of site effects for closely spaced sites on similar surficial geology. Since 1998, the array has recorded more than 30 earthquakes, 13 of these events were recorded at all borehole stations, and selected for our analysis (9 deep events and 4 shallow events). Using the data from these 13 events we estimate the seismic moment and corner frequency for each event, Qo, frequency dependence of Q, and the frequency dependent site effect. We use Boatwright's (1978) representation of the omega-squared spectrum for the source. The quality factor is assumed to be constant for frequencies less than 1.0 Hz while having a power law relation for frequencies greater than 1.0 Hz. Using a Heat Bath algorithm, we estimate the parameters for the source and path using only the borehole stations. Initially the borehole response is assumed to be unity and path attenuation fixed while Mo is determined by inverting the data for f. . . 1Hz. The difference between the observed and predicted spectrum at each borehole is then used as the site response of the borehole records and Qo, Q(f) and fc are determined by inverting the borehole data from the 9 deep events, keeping Mo fixed to the previously determined values. We iterate until changes in the residuals between observed and predicted spectra are negligible. Once stable values of Mo, fc and Q(f) are obtained, we invert only the source parameters (Mo and fc) using the 9 borehole stations for each of the 9 events individually. The same procedure is applied for 4 shallow events. Knowing Mo, fc, and Q(f), we can then determine the site response for the 150 surface stations by averaging the ratio between predicted and observed amplitude spectra. The Q results show a very weak function of frequency for deep events: Q(f)=285f**0.055, however, events shallower than 20 km have a stronger dependence:Q(f)=80f**0.265.The results for site response correlate with the averaged S-wave velocity for upper 30m for the low frequency range.

## S52A-0123 1330h POSTER

### Rupture Directivity in a Foam Rubber Physical Model

Rasool Anooshehpoor[1] (775-784-1954; rasool@seismo.unr.edu)

James N Brune[1] (775-784-4974; brune@seismo.unr.edu)

[1]University Of Nevada, Reno, Seismological Laboratory 174 1664 N. Virginia Street, Reno, NV 89557-0141, United States

Understanding earthquake rupture dynamics, especially forward rupture directivity (focusing of seismic energy in the direction of rupture propagation), is crucial in determining the seismic hazard for critical structures located near major active faults. We use foam rubber modeling experiments to provide constraints on parameters that control rupture dynamics, and consequently, forward directivity effects. Numerical models currently in use have too many unconstrained parameters to allow confidence in predictions, and may not even be realistic from a physical point of view. The foam rubber model allows us to develop a deep physical understanding of an actual physical model. This in turn will allow us to better specify which physical parameters used in numerical models are critical, and establish a realistic range for their values, and to better understand and qualify particular numerical models. Three-dimensional numerical simulations of earlier experiments with excellent results provided incentive for additional funding from PEER to increase the number of recording channels in the model from 32 to 76. In particular, we have increased the number of recording sites on the fault plane from 12 to 35 to provide a better picture of the slip distribution on the fault during rupture. At the time of meeting we will present waveforms for selected events.

## S52A-0124 1330h POSTER

### Simulation of Strong Ground Motion by Dynamic Rupture With Locally Variable Time-Step Finite-Difference Method

Tae-Seob Kang[1] (82-2-872-2713; tskang@seismic.snu.ac.kr)

Chang-Eob Baag[1] (82-2-880-6735; baagce@snu.ac.kr)

[1]School of Earth and Environmental Sciences, Seoul National University, San 56-1, Sillim-dong, Gwanak-gu, Seoul 151-747, Korea, Republic of

Characteristics of strong ground motion depend on the complicated processes of earthquake rupture along fault surface, propagation path, and site conditions. The earthquake rupture includes dynamic processes of rupture nucleation, propagation, and healing that are governed by friction properties on the fault. Seismic wavefield radiated by the fault processes propagates through the heterogeneous geological media and undergoes near-surface modulations such as either amplification or deamplification. Complete understanding of these effects requires a numerical modeling technique with multi-scale resolution. That is, a high resolution modeling with dense grid and time steps is required in the vicinity of the fault rupture in order to deal with the dynamic rupture processes. On the other hand, modeling of the wavefield propagating through the media outside the rupture zone requires relatively low resolution. However, even in the latter case, large velocity contrast between the media such as sedimentary basins surrounded by host rock forces modeling parameters to be discontinuous in order to avoid an oversampling in both time and space. Recently, we proposed a 3-D fourth-order staggered-grid finite-difference technique combining discontinuous grids with locally variable time-step (LVTS). Discontinuity of modeling parameters is generalized in full three-directions; thus a region of modeling parameters with fine scale can be localized within a domain, and/or the boundary between the regions can be extended to the free surface. These properties allow the LVTS scheme to be efficiently used for modeling of both rupture dynamics and radiated wavefield in the heterogeneous media. Simulation results of earthquake ground-motion including high-resolution rupture dynamics are presented. This approach makes possible to understand the combined effect of dynamic fault processes and heterogeneous media surrounding the fault region. Also, if this type of simulation results is compared with observed data, it will provide a better understanding for the physical conditions influencing source dynamics from ground-motion records.

## S52A-0125 1330h POSTER

### Ground motion prediction for huge subduction earthquakes in Osaka basin, Japan, using an advanced stochastic Green's function

Hidenori Kawabe[1] (+81-724-51-2418; kawabe@rri.kyoto-u.ac.jp)

Katsuhiro Kamae[1] (+81-724-51-2369; kamae@kuca.rri.kyoto-u.ac.jp)

[1]Kyoto University, Noda Sennan-gun Kumatori-cyo, Osaka 590-0494, Japan

The hybrid technique combined theoretical calculation with stochastic one is powerful in predicting broadband strong ground motions from future large earthquakes. Kamae et al. (1998) has demonstrated its powerfulness through some simulations of near-source strong ground motions in the 1995 Kobe earthquake, Japan. Then, in the stochastic calculation for high-frequency ground motions, the stochastic simulation method by Boore (1983) has been applied taking into consideration the amplitude characteristics on corresponding sedimentary site. However, in application of the stochastic calculation to prediction of ground motions inside the basin, we need to consider not only amplitude characteristics but also phase ones at target sites. We found that the characteristics of the frequency dependent envelope as well as the Fourier spectra at sedimentary sites inside the basin change depending on the source direction, source distance, source depth and local geological conditions. In general, seismic waves in the basin structures elongate the duration time of ground motion by the effect of the seismic waves secondarily induced at the basin edges and so on. In this study, after characterizing empirically phase and spectral amplitude, we examine the possibility for stochastic simulation of strong ground motions at sedimentary sites using empirical frequency dependent envelope functions and amplitude spectra at each site. Then, frequency dependent envelope functions in Osaka basin are specified by the source direction, source distance, source depth and local geological conditions. This method is verified by reproduction of recordings with long duration in Osaka basin due to some earthquakes. Finally, Strong ground motions from future huge subduction earthquakes (e.g. Nankai earthquake, Tonankai earthquake) are predicted by the hybrid technique using this advanced stochastic simulation technique for high-frequency motion.

## S52A-0126 1330h POSTER

### Strong Ground Motion Prediction By Composite Source Model

Jan Burjanek[1] (+420-221912535; burjanek@karel.troja.mff.cuni.cz)

Kojiro Irikura[2] (irikura@egmdpri01.dpri.kyoto-u.ac.jp)

Jiri Zahradnik[1] (jz@karel.troja.mff.cuni.cz)

[1]Department of Geophysics, Faculty of Mathematics and Physics, Charles University, Prague, V Holesovickach 2 Praha 8, Prague 18000, Czech Republic

[2]Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, Kyoto, Kyoto 611-0011, Japan

A composite source model, incorporating different sized subevents, provides a possible description of complex rupture processes during earthquakes. The number of subevents with characteristic dimension greater than $R$ is proportional to $R^{-2}$. The subevents do not overlap with each other, and the sum of their areas equals to the area of the target event (e.g. mainshock). The subevents are distributed randomly over the fault. Each subevent is modeled either as a finite or point source, differences between these choices are shown. The final slip and duration of each subevent is related to its characteristic dimension, using constant stress-drop scaling. Absolute value of subevents' stress drop is free parameter. The synthetic Green's functions are calculated by the discrete-wavenumber method in a 1D horizontally layered crustal model. An estimation of subevents' stress drop is based on fitting empirical attenuation relations for PGA and PGV, as they represent robust information on strong ground motion caused by earthquakes, including both path and source effect. We use the 2000 M6.6 Western Tottori, Japan, earthquake as validation event, providing comparison between predicted and observed waveforms.

URL: http://geo.mff.cuni.cz/students/burjanek

## S52A-0127 1330h POSTER

### Finite Moment Tensors of Southern California Earthquakes

Thomas H. Jordan[1] (tjordan@usc.edu)

Po Chen[1] (213-821-2370; pochen@usc.edu)

Li Zhao[1] (zhaol@usc.edu)

[1]Department of Earth Sciences, University of Southern California, Los Angeles, CA 90089, United States

We have developed procedures for inverting broadband waveforms for the finite moment tensors (FMTs) of regional earthquakes. The FMT is defined in terms of second-order polynomial moments of the source space-time function and provides the lowest order representation of a finite fault rupture; it removes the fault-plane ambiguity of the centroid moment tensor (CMT) and yields several additional parameters of seismological interest: the characteristic length $L_c$, width $W_c$, and duration $T_c$ of the faulting, as well as the directivity vector $\mathbf{v}_d$ of the fault slip. To formulate the inverse problem, we follow and extend the methods of McGuire et al. [2001, 2002], who have successfully recovered the second-order moments of large earthquakes using low-frequency teleseismic data. We express the Fourier spectra of a synthetic point-source waveform in its exponential (Rytov) form and represent the observed waveform relative to the synthetic

in terms two frequency-dependent differential times, a phase delay $\delta\tau_p(\omega)$ and an amplitude-reduction time $\delta\tau_q(\omega)$, which we measure using Gee and Jordan's [1992] isolation-filter technique. We numerically calculate the FMT partial derivatives in terms of second-order spatiotemporal gradients, which allows us to use 3D finite-difference seismograms as our isolation filters. We have applied our methodology to a set of small to medium-sized earthquakes in Southern California. The errors in anelastic structure introduced perturbations larger than the signal level caused by finite source effect. We have therefore employed a joint inversion technique that recovers the CMT parameters of the aftershocks, as well as the CMT and FMT parameters of the mainshock, under the assumption that the source finiteness of the aftershocks can be ignored. The joint system of equations relating the $\delta\tau_p$ and $\delta\tau_q$ data to the source parameters of the mainshock-aftershock cluster is denuisanced for path anomalies in both observables; this projection operation effectively corrects the mainshock data for path-related amplitude anomalies in a way similar to, but more flexible than, empirical Green function (EGF) techniques.

## S52A-0128 1330h POSTER

### Characterizing Near-Field Rupture Directivity Effects at Low to Intermediate Frequencies

Yoshimitsu Fukushima[1] (yf@ori.shimz.co.jp)

Gene A Ichinose[2] (626-449-7650; gene_ichinose@urscorp.com)

Paul G Somerville[2] (paul_somerville@urscorp.com)

Kazuki Koketsu[3] (koketsu@eri.u-tokyo.ac.jp)

[1]Ohsaki Research Institute, Fukoka Seimei Bldg. 2-2-2 Uchisaiwai-cho Chiyoda-ku, Tokyo 100-0011, Japan

[2]URS Corporation, 566 El Dorado St, 2nd Floor, Pasadena, CA 91101-2560, United States

[3]Earthquake Research Institute, Univ. of Tokyo, 1-1-1 Yayoi Bunkyo-ku, Tokyo 113-0032, Japan

Analysis of near-fault ground motions of recent large crustal earthquakes have shown that the forward-rupture direction is significant in recorded strong motions. There are only a few near-fault observations and therefore they are under-represented in empirical relationships. Ground motion predictions based on simulations using point source or far-field approximations may be underestimating the ground motion levels because they cannot fully capture near-fault directivity effects. We show that the "directivity pulse" results in amplifications at low frequencies and does not result in a shift of the corner frequency and addition of high frequency radiation as predicted by the ($\omega^{-2}$) model. We examined the directivity effects using a finite-fault simulation with a simple uniform slip model. The rupture parameters include sub-fault grid spacing, rupture velocity, source-time function, and dislocation rise-time. The waveform synthetics are computed using the reflectivity method and a layered earth model. These simple slip models generated directivity effects at low and intermediate frequencies that fit reasonably with observed near-fault ground motions from the 1992 Landers, 1994 Northridge, and 1995 Kobe earthquakes. Amplifications in near-fault Fourier accelerations for the forward-rupture directions were amplified by a factor of 10 to 50 between 0.05 to 0.6 Hz relative to the reverse-rupture directions. These amplifications were most dominant on the fault normal component for strike-slip and dip-slip faults near the terminal edge of the rupture. The amplification for dip-slip ruptures are significant between $\pm 45°$ from the forward rupture direction. Directivity effects resulting from the simulations are consistent with observations made by Somerville et al. [1997] and analytical models by Bernard et al. [1996]. This amplification is not an artifact of the simulation parameterization or rupture parameters and we show examples where changes in these parameters caused changes at only higher frequencies ($f > 0.5$ $Hz$).

## S52A-0129 1330h POSTER

### BROADBAND GROUND MOTION SYNTHESIS OF THE 1999 TURKEY EARTHQUAKES BASED ON: 3-D VELOCITY INVERSION, FINITE DIFFERENCE CALCULATIONS AND EMPRICAL GREENS FUNCTIONS

Rengin Gok[1] (gok1@llnl.gov)

Dogan Kalafat[2] (kalafato@boun.edu.tr)

Lawrence Hutchings[1] (hutchings2@llnl.gov)

[1]Lawrence Livermore National Laboratory, 7000 East Avenue L-206, Livermore, CA 94550, United States

[2]Bogazici University Kandilli Observatory and Earthquake Research Institute, Cengelkoy, Istanbul 81220, Turkey

We analyze over 3,500 aftershocks recorded by several seismic networks during the 1999 Marmara, Turkey earthquakes. The analysis provides source parameters of the aftershocks, a three-dimensional velocity structure from tomographic inversion, an input three-dimensional velocity model for a finite difference wave propagation code (E3D, Larsen 1998), and records available for use as empirical Green's functions. Ultimately our goal is to model the 1999 earthquakes from DC to 25 Hz and study fault rupture mechanics and kinematic rupture models. We performed the simultaneous inversion for hypocenter locations and three-dimensional P- and S- wave velocity structure of Marmara Region using SIMULPS14 along with 2,500 events with more than eight P- readings and an azimuthal gap of less than 180°. The resolution of calculated velocity structure is better in the eastern Marmara than the western Marmara region due to the dense ray coverage. We used the obtained velocity structure as input into the finite difference algorithm and validated the model by using $M < 4$ earthquakes as point sources and matching long period waveforms ($f < 0.5$ Hz). We also obtained Mo, fc and individual station kappa values for over 500 events by performing a simultaneous inversion to fit these parameters with a Brune source model. We used the results of the source inversion to deconvolve out a Brune model from small to moderate size earthquakes ($M < 4.0$) to obtain empirical Green's function (EGF) for the higher frequency range of ground motion synthesis ($0.5 < f > 25$ Hz). We additionally obtained the source scaling relation (energy-moment) of these aftershocks. We have generated several scenarios constrained by a priori knowledge of the Izmit and Duzce rupture parameters to validate our prediction capability.

## S52A-0130 1330h POSTER

### Directional Site Amplification Effect on Tarzana Hill, California

Vladimir Graizer[1] (vgraizer@consrv.ca.gov)

Anthony Shakal[1] (tshakal@consrv.ca.gov)

[1]California Geological Survey, 801 K Street, MS 13-35, Sacramento, CA 95814-3531, United States

Significantly amplified ground accelerations at the Tarzana Hill station were recorded during the 1987 Mw 5.9 Whittier Narrows and the 1994 Mw 6.7 Northridge earthquakes. Peak horizontal ground acceleration at the Tarzana station during the 1999 Mw 7.1 Hector Mine earthquake was almost twice as large as the accelerations recorded at nearby stations. The Tarzana site was drilled to a depth of 100 m. A low shear-wave velocity near the surface of 100 m/sec increasing to near 750 m/sec at 100 m depth was measured. The 20 m high hill was found to be well drained with a water table near 17 m. Modelo formation (extremely weathered at the surface to fresh at depth) underlies the hill. The subsurface geology and velocities obtained allow classification of this location as a soft-rock site. After the Northridge earthquake the California Strong Motion Instrumentation Program significantly increased instrumentation at Tarzana to study the unusual site amplification effect. Current instrumentation at Tarzana consists of an accelerograph at the top of Tarzana hill (Tarzana - Cedar Hill B), a downhole instrument at 60 m depth, and an accelerograph at the foot of the hill (Tarzana - Clubhouse), 180 m from the Cedar Hill B station. The original station, Tarzana - Cedar Hill Nursery A, was lost in 1999 due to construction. More than twenty events, including the Hector Mine earthquake, were recorded by all these instruments at Tarzana. Comparison of recordings and response spectra demonstrates strong directional resonance on the top of the hill in a direction perpendicular to the strike of the hill in the period range from 0.04 to 0.8 sec (1.2 to 25 Hz). There is practically no amplification from the bottom to the top of the hill for the component parallel to the strike of the hill. In contrast to accelerations recorded during the Hector Mine earthquake (high frequency part of seismic signal), displacements (relatively low frequency part of seismic signal) demonstrate almost no site amplification from the bottom of the hole to the surface at periods greater than 1.5 sec, in either direction. The directional effect at Tarzana hill seems to be azimuth dependent. Relatively higher amplification at the perpendicular component is produced for the earthquake sources located north of the station. We were not able to see any differences in hill response before and after development (a relatively small part of the hill was developed). The source of the site amplification that produces large motions at Tarzana is still under investigation with "the usual suspects" like topography and shear wave velocity profile not providing the explanation. New data recorded at Tarzana in recent years clearly show that the Tarzana effect is a very localized high-frequency effect observed only at the top of the hill. Drilling at Tarzana was co-funded by CSMIP and by the National Science Foundation through the Resolution of Site Response Issues from the Northridge Earthquake Project (ROSRINE).

## S52A-0131 1330h POSTER

### Stochastic Strong Ground Motion Simulation of the 7 September 1999 Athens (Greece) Earthquake

Zafeiria Roumelioti[1] (00302310991420; zroum@lemnos.geo.auth.gr)

Anastasia Kiratzi[1] (00302310998486; Kiratzi@geo.auth.gr)

Nikos Theodoulidis[2] (00302310476081; ntheo@itsak.gr)

[1]Department of Geophysics, Aristotle University of Thessaloniki, P.O. Box 352-1, Thessaloniki 54124, Greece

[2]Institute of Engineering Seismology and Earthquake Engineering, P.O. Box 53, Thessaloniki 55102, Greece

The stochastic method for finite faults is applied to simulate the strong ground motion from the 7 September 1999, M 5.9 Athens earthquake. The method includes descritization of the fault plane into certain number of subfaults, each of which is assigned an $\omega^2$ spectrum. A slip distribution model, derived from previous studies of this earthquake, is used to specifically account for the source effect. The contributions from all subfaults are then empirically attenuated to the observation sites, where they are summed to produce the synthetic acceleration time history. The method is first calibrated against its ability to reproduce the recordings of 19 strong-motion stations, at epicentral distances ranging from 16 to 61 km. The calibrated model is then used to calculate synthetics at a large number of grid points covering the area around the fault plane. Simulated peak values are subsequently used to produce synthetic peak ground acceleration and spectral acceleration maps at hard rock conditions. Both the peak ground acceleration and spectral acceleration maps imply energy directivity towards east, where most of the damage was concentrated. The directivity effect is most prominent at large periods (>2 sec) and in the frequency range 0.2 - 0.3 sec. Independent geotechnical studies showed considerable site-effect at periods <0.5 sec within the meizoseismal area. This result, coupled with the results of the present study, imply that the damage distribution pattern of the 1999 Athens earthquake can be explained by the destructive combination of two factors: the source directivity and the site effect.

## S52A-0132 1330h POSTER

### Physical Interpretation of Fling Step and Long-Period Rupture Directivity Pulse

Yoshiaki Hisada[1] (+81-3-3340-3442; hisada@cc.kogakuin.ac.jp)

Jacobo Bielak[2] (bielak@cs.cmu.edu)

[1]Kogakuin Univ. Dept. of Architecture, Nishi-Shinjuku 1-24-2, Tokyo 163-8677, Japan

[2]Department of Civil and Environmental Engineering Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, United States

The long-period pulse and the fling step are the most prominent near-source effects, such as the 1995 Kobe and 1999 Taiwan earthquakes, respectively. In order to compute those near-source ground motions efficiently, we have recently proposed a new form of the representation theorem, in which the dynamic and static Green's functions in fault integrations were evaluated separately (Hisada and Bielak, 2003). Using this theoretical method, we found that the long-period pulse and the fling step were mainly composed of the dynamic and static Green's functions, respectively. The directivity pulse consists of mainly the dynamic Green's functions (i.e., the body and surface waves), while the fling step is composed of static Green's functions. Therefore, the long-period pulse attenuates on the order from the inverse of r to the inverse of the square root of r, where r is the distance between an observation station and an asperity of the fault, whereas the fling step attenuates rapidly on the order of the r squared. In this paper, we use this methodology to simulate the near-fault ground motion observed during the 1992 Landers earthquakes. The results show successfully the strong presence of the fling step and the directivity pulse on the near-fault ground motions.

URL: http://kouzou.cc.kogakuin.ac.jp/

## S52A-0133 1330h POSTER

### Synthetic Strong Ground Motion Validation and Prediction

Yuehua Zeng[1,2] (775-784-4231; zeng@seismo.unr.edu)

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[1]Institute of Earth Sciences, Academia Sinica, 128 Academia Road, Sec. 2, Nankang, Taipei 115, Taiwan

[2]Seismological Lab, University of Nevada, Reno, NV 89557, United States

In this paper, I first validate a ground motion simulation procedure against ground motion observation from the Imperial Valley, Loma Prieta, Landers, Northridge, Kobe, and Kocaeli earthquakes. The ground motion simulation procedure follows Zeng et al. (1994) using a composite source model. In that model, the source is taken as a superposition of circular subevents with a constant stress drop. The number of subevents and their radius follows a power law distribution equivalent to the Gutenberg and Richter's magnitude-frequency relation for seismicity. The heterogeneous nature of the composite source model is characterized by its maximum subevent size and subevent stress drop. As rupture propagates through each subevent, it radiates a circular crack rupture pulse. In addition to wave propagation through a layered earth, the model has been improved by including scattering waves from small scale heterogeneity structure of the earth, site specific ground motion prediction using weak motion site amplification, and nonlinear soil response using geotechnical engineering models. In the current validation study, the fixed and free model parameters have been systematically cataloged and the statistical distribution of those free parameters has been carefully identified. A critical component of the study is to define the function of goodness-of-fit. In this investigation I emphasize on goodness-of-fit based on ground motion response spectra. Other forms of goodness-of-fit based on seismic waveform, shake duration, accumulative energies, etc., are also examined. Based on the result, I then conduct broadband ground motion prediction from scenario earthquakes. The objective of this simulation is to argument the existing empirical strong ground motion database on magnitude, distance, and frequency range. The result will be used to test the function forms used in developing the Next-Generation-Attenuation relation initiated by PEER/SCEC/USGS.

### S52A-0134 1330h POSTER

## Focal Mechanism Influence on Probabilistic Estimation of Strong Ground Motion

Vincenzo Convertito[1] (+39 081 676 876; converti@na.infn.it)

André Herrero[2] (+39-081-676-811; herrero@na.infn.it)

[1]Università Federico II of Naples, Via Cinthia, Naples, ITA 80126, Italy

[2]Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, Rome, ITA 00143, Italy

One major challenge of the modern seismology is the mitigation and the reduction of the consequences on structures and society due to the occurrence of future earthquakes. Probabilistic seismic hazard analysis (PSHA), in the last years has assumed a fundamental role in this research field. In fact, using the past seismicity and information regarding the tectonic environment, it allows to estimate the most probable strong ground motion level at a particular site for a given time period. Moreover, from an engineering point of view, using de-aggregation techniques, it permits to infer the design earthquake. The aim of the present work is to illustrate a new methodology for improving the probabilistic peak ground motion estimation and, consequently, the seismic hazard through the modification of attenuation laws. In fact, attenuation laws are usually used in tectonic environment different from that they have been retrieved. This may conduct to unrealistic estimates of the strong ground motion thus influencing the PSHA result. The proposed modifications are carried out by means of theoretical and empirical considerations and, in particular, regard the source focal mechanism. A corrective multiplicative coefficient is formulated in order to use a-priori information on the most probable focal mechanism expected in a given seismogenic source region. This information can be inferred, for example, by the actual tectonic stress regime or by historical seismicity, and are often available in the present-day catalogues. The proposed methodology is used also to extend the design earthquake to the focal mechanism. In fact, a specific probability density function of the focal mechanism parameters can be formulated and introduced into the general formulation of the PSHA. This probability density function allows the analytical formulation of available a-priori information. An application to a site located in the southern Apennines (Italy) along with the formal treatment of the proposed methodology is shown.

# S52B MCC: Level 1 Friday 1330h

## Earthquake Hazards of Greater Tokyo: Eighty Years After Kanto II Posters *(joint with G, T)*

***Presiding:*** **Y Okada,** National Research Institute for Earth Science and Disaster Prevention (NIED)**; T Nishimura,** Geographical Survey Institute

### S52B-0135 1330h POSTER

## Characteristics of Seismic Activities in and around the Boso-Peninsula, in Central Japan, with Dense Seismographic Array Observation

Toshihiro Igarashi[1] (81-3-5841-5745; igarashi@eri.u-tokyo.ac.jp)

Naoshi Hirata[1] (hirata@eri.u-tokyo.ac.jp)

[1]Earthquake Research Institute, University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo 1130032, Japan

We investigated seismic activities in and around the Boso Peninsula, which is located east of Tokyo, Japan. A velocity structure beneath the Boso area is very complex, consisting of three layers: an overriding plate in land, northward subducting Philippine Sea plate, and westward subducting Pacific plate. The area includes a part of the source region of the 1923 Kanto Earthquake (M=7.9) and other older large earthquakes. Several slow-slip events were also detected by continuous GPS observations. First, we investigated whether or not exist repeating earthquakes, which was found in Tohoku district, in northeastern Japan (Igarashi et al., 2003), also beneath the Boso Peninsula. It is suggested that the repeating earthquakes occurred when a small asperity was periodically broken due to stable sliding of the plate boundary surrounding the asperity. If this is the case, the repeating event can be a kind of sensors to detect an aseismic slip in the area. We used the same algorithm for detecting them as Igarashi et al. [2003] did in Tohoku area. We found that many repeating earthquakes occurred on the subducting Pacific plate boundary and some of them around the subducting Philippine Sea plate. The repeating earthquakes in the Philippine Sea plate occurred on the edge of source regions of large interplate earthquakes or slow events. This suggests that the repeating earthquake is related with the degree of the plate coupling. Furthermore, we expect the repeating earthquake to be a clue to understand the location of asperities and also next large earthquake. Next, we investigated other small earthquakes. Seismicity beneath the Boso Peninsula is reported to be lower than that around the area, and large events did not occur in recent 50 years. The entire Japans Island is covered with a highly dense seismographic network. However, an interval of seismographs in the Boso Peninsula is relatively wide for populous area. And a thick sediment also prevents to detect a small event there. An accurate crustal structure and relationships between seismicity and configuration of boundary have not been well understood. Therefore, we need a dense seismographic array in the Boso Peninsula to clarify the seismic velocity structure of deeper part of the crust and subducting plate, detect micro earthquakes, and image the seismic fault of earthquakes that may destroy the metropolitan area. These seismographs are installed along the line of the northeast-southwest direction. Station intervals are about 2 km to 10 km. We install 30 stations during this fiscal year, data from which are continuously transmitted to the Earthquake Research Institute, the University of Tokyo, in Tokyo, by using the Internet and a satellite communication system. The new array enables us to detect smaller events beneath the array than the current networks, to clarify whether the lower seismic activity is real or not beneath the peninsular. Observed waveforms have many converted phase, which seem to appear on a common boundary. We expect to estimate the location of the upper plate boundary of the subducting plate by the conversion point, resulting in characterization of seismic activities in this region.

### S52B-0136 1330h POSTER

## Correlating Seismicity and Subsidence in the Tokai Region, Central Japan

Stefan Wiemer[1] (stefan@seismo.ifg.ethz.ch); Jochen Woessner[1] (woessner@seismo.ifg.ethz.ch); Akio Yoshida[2] (ayoshida@met.kishou.go.jp); Kohji Hosono[3] (hosono@eqvol.kishou.go.jp); Shin'ichi Noguchi[4] (shin@bosai.go.jp); Hiromi Takayama[5] (hirtakay@mri-jma.go.jp.)

[1]Swiss Seismological Service, ETH Zurich, Hoenggerberg, HPP, Zurich 8093, Switzerland

[2]Kakioka Magnetic Observatory, Japan Meteorological Agency, Kakioka 315-0116, Japan

[3]Seismological and Volcanological Department, Japan Meteorological Agency, Tokyo 163, Japan

[4]National Research Institute for Earth Science and Disaster Prevention, 3-1,Tennodai, Tsukuba 305

[5]Meteorological Research Institute, Japan Japan Meteorological Agency, Tsukuba 305, Japan

We investigate the correlation between seismicity rate changes as well as changes in the earthquake size distribution (b-value) of earthquakes and transients in geodetic data in the Tokai area of Central Japan. As a first target, we analyze the period of accelerated subsidence in the period 1988 - 1990. Three largely independent seismic catalogs cover this region: NIED, JMA and JUNEC, offering a unique opportunity to verify seismicity anomalies based on independent sources. We spatially and temporally map out seismicity rates, finding that a significant decrease in the earthquake rate of $M > 2.0$ events coincides with the accelerated subsidence period; however, this anomaly disappears when including smaller magnitudes in the analysis. This relative quiescence of larger events can readily be explained when interpreting the transient in seismicity in the framework of a change in the earthquake size distribution, or b-value. The background b-value of about 0.8 increased in the period 1987.5 to 1989.5 to a value of b=1.2 and is confirmed in all three data sets. This b-value transient occurred in the immediate vicinity of a patch of low b-value in the centre of Suruga Bay (b=0.5) that could be interpreted as a major locked patch or asperity. We also analyze stress tensor inversions of NIED focal mechanism data, finding an increase in thrusting type earthquakes for the anomalous period show. While a unique interpretation of the relationship between subsidence, b-value and stress tensor inversion results is not possible, we propose that an increase in the locking strength, a slow stick event, is consistent with all observations. We are now investigating the seismicity transients accompanying the recent slow slip event that started in the year 2000. Our ultimate goal is to construct a quantitative model that relates micro-seismicity and deformation data in the Tokai region.

### S52B-0137 1330h POSTER

## Effects of Differences in Subsurface Structural Models on Synthetic Ground Motion During The 1923 Kanto Earthquake

Hiroaki Yamanaka[1] (+81-45-924-5513; yamanaka@depe.titech.ac.jp)

Nobuyuki Yamada[2] (+81-774-38-4187; yamada@egmdpri01.dpri.kyoto-u.ac.jp)

[1]Tokyo Institute of Technology, 4259 Nagatsuta Midori-ku, Yokohama 226-8502, Japan

[2]DPRI, Kyoto Univ., Gokasho, Uji 611-0011, Japan

In this study, two 3D grid models for subsurface structure of deep sediments in the Kanto plain, Japan, were constructed for strong motion simulation from geological investigations by Suzuki (1999) and S-wave profiles obtained with microtremor array explorations by Yamada and Yamanaka (2001). We tested the performance of the 3D structure models from comparison between the simulated long-period ground velocities during the 1923 Kanto earthquake using a 3D finite difference technique. The differences between the strong motions are small at sites in the focal region, because the source effects are dominant. However, they become large at sites out of the focal region due to site effects. As these sensitive depend on the 3D structure model, we need considerations of setting up the source model for strong ground motion prediction.

### S52B-0138 1330h POSTER

## Detailed Structure of Plate Boundary Revealed by Seismic Reflection Survey and Spatial Relation With Interplate Seismic Activity Indicated by Converted Waves, East off Boso Peninsula, Japan

Hisanori Kimura[1] (81-29-863-7663; kimura@bosai.go.jp)

Keiji Kasahara[1] (kasa@bosai.go.jp)

[1]National Research Institute for Earth Science and Disaster Prevention, Tennodai 3-1, Tsukuba, Ibaraki 305-0006, Japan

Tokyo metropolitan area of Japan is located near Sagami trough where Philippine Sea(PHS) plate subducts beneath Kanto district and large earthquakes including Kanto Earthquake, 1923 took place repeatedly. Thus, for the purpose of damage mitigation in Tokyo metropolitan area, it is important to study the characteristics of plate boundary and relation with seismic activity. The area eastern off Boso peninsula is one of regions where interplate earthquakes are occurring at shallower part around Kanto district. We researched