migration of hypocenters were reported. But this time, the migration speed looks very faster than before.

S12A-1184 1330h POSTER

Detection and Location of Potential Sources of Background Low Frequency Surface Wave Energy

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Earth's background free oscillations were reported recently by *Nawa et al.* (1998). While the observations are now well established, and the coupling of the solid earth with the atmosphere/ocean system is widely accepted as a likely source mechanism, detailed studies on sources, and in particular the spatial distribution of the sources, have been few.

Ekström (2001) showed that coherent Rayleigh wave energy in the frequency range between 2 and 7 mHz is detectable in 94% of the 5 year period considered. Though most data of 5 year period are contaminated with surface wave energy generated from events, it implies that we can detect coherent Rayleigh wave energy from sources taking part in generating continuous free oscillation in the absence of significant earthquakes. However, his method does not provide enough resolution to determine spatial distribution of the sources.

We propose an array based method as a modification of Ekström's method. This method is designed to detect low-level Rayleigh type surface wave energy by using one local array and provide rough estimate of back azimuth and arrival time of it. Testing of this method for small earthquake events shows the detection level of the method is lower than the documented background excitation levels (*Ekström,* 2001; *Tanimoto and Um,* 1999). Combining compatible detections from several arrays (3 or more) can help both identify sources of long period energy, and obtain an estimate of the source location. We have tested this method using vertical component recordings at BDSN (Berkeley Digital Seismic Network, USA), GRSN (German Regional Seismic Network) and F-NET (Japan) arrays. We will show and discuss the results of its application during intervals without significant earthquakes.

S12A-1185 1330h POSTER

OBSERVATION OF THE FREE OSCILLATIONS OF THE EARTH AND THEIR PERMANENT EXCITATION

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Fundamental spheroidal free oscillations of the Earth appear, even on seismically quiet days, as continuous vertical straight lines on the frequency-time diagrams. The oscillations are persistent through the 10 years of data presented from the WUS (GEOSCOPE) station. Analysis of four years of TAM (GEOSCOPE) station data with simultaneous seismic-pressure recordings allows us to improve the resolution of these background oscillations. To reduce the atmospheric effect, we compute the pressure-acceleration transfer function and subtract the pressure effects from the acceleration signal. The 'cleaned' acceleration signal better resolves the free oscillation signal and allows us to isolate some very low frequen cy spheroidal fundamental modes (in the angular order range l = 2-15) and some radial modes after large earthquakes. The existence of a permanent free oscillation signal is verified, but the source of this phenomenon is not clearly defined. Before discarding a seismic source, we address the definition of "seismically quiet days". We found that severe selection criteria leads to only a few of these days. The favourite candidate for the permanent excitation of the Earth's normal modes is the coupling between the Earth and the atmosphere. We detect a small annual variation of the phenomenon, with an increased amplitude of some peaks in June- July that Terra and Tanimoto (1999), Tanimoto and Um (1999), Nishida et al. (1999, 2000) relate to solar activity. This hypothesis requires further analysis. If atmospheric forcing drives the excitation, this may be one of the rare phenomena indicating a direct solid earth-atmosphere interaction. Understanding this problem will clearly add another dimension to our understanding of the earth. It may also improve our understanding of other planets, because an atmosphere-surface coupling should also occur in other terrestrial planets. The existence of such phenomenon may allow us to study the interior structure of even tectonically quiet planets.

S12A-1186 1330h POSTER

Theoretical Calculation of Mars' Background Free Oscillations

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It has been suggested that the excitation source of the Earth's background free oscillations (BFO) is the random force exerted on the surface due to atmospheric disturbance (e.g. Kobayashi & Nishida, 1998). The previous studies also suggested a possibility for detection of the BFO on Mars. In this study we estimate the excitation level of the Mars' BFO by applying an atmospheric excitation theory to the Mars' atmospheric pressure data obtained in the Mars Pathfinder mission.

The atmospheric excitation theory used here is based on the seismic normal-mode theory and it can well predict the observed power spectrum of the Earth's BFO (Fukao et al. in press). The theory uses a power spectrum of the surface atmospheric pressure and a correlation length of atmospheric disturbance as the inputs. Since no direct observation of the correlation length is available to date, a correlation length should be assumed to calculate the theoretical power spectrum. A weakly frequency-dependent correlation length, about 1 km at 1 mHz, was assumed for Earth.

Using a simple theory of atmospheric disturbance, Kobayashi & Nishida (1998) estimated the excitation level of the Mars' BFO. A more sophisticated theory predicts values of 10^2 Pa^2s and 2 km for the pressure power at 1 mHz and the correlation length, respectively, for Mars. Using these values and eigenfunctions calculated from the Mars model of Sohl & Spohn (1997), we obtain the theoretical excitation level of about 0.5×10^{-18} m^2/s^3, which is an observable level with a high-sensitivity broadband seismometer installed at a very quiet site.

Surface atmospheric pressure on Mars was measured with a maximum resolution of 0.25 μbar in the Mars Pathfinder mission (Schofield et al. 1997). We analyze records for 5 Martian days and calculate an averaged power spectrum. It exhibits the well-known f^{-2} dependence at frequencies between 0.5 and 4.0 mHz, but a value of 10 Pa^2s at 1 mHz, which is an order of magnitude smaller than the theoretically predicted value. Using this spectrum and assuming a correlation length of 2 km, we obtain the excitation level of about 10^{-19} m^2/s^3, which seems too low to observe. We can obtain an observable excitation level when assuming a correlation length of 10 km, but such a long correlation length seems to be unlikely. If a value of 10 Pa^2s at 1 mHz is typical for the atmospheric disturbance on Mars, it is very hard to observe the Mars' BFO.

S12A-1187 1330h POSTER

Comprehensive Processing of the Apollo Lunar Seismic Event Data

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The Apollo Passive Seismic Experiment consisted of four seismic stations deployed on the lunar surface between 1969 and 1972. Data were recorded continuously from deployment until 1977. Previous studies often used only small subsets of all the available data due to computational limitations. In our study, event data (lunar seismic signals detected in the continuous time series) in their entirety are converted into a standard format for seismological analysis. The IRIS Data Management Center provided data to us in their original format on nine 8mm Exabyte cartridges (eight event tapes and one supplementary tape). The total disk usage of the event data after conversion to two-byte integers is 13 Gb. Events have been previously classified into three types: deep moonquakes, shallow moonquakes, and impacts. The tapes from the IRIS DMC contain just under 11,000 events the bulk of the approximately 12,000 catalogued events.

Several programs to view and filter the data are used to improve data quality. Data with various irregularities (timing errors, telemetry problems) are corrected or removed. These modifications allow for modern processing techniques to be applied consistently to the remaining data. Based on our preliminary analyses we estimate 97.6 % of the data will be useable for further study.

This work will permit a range of investigations, using stacking techniques that do not require waveform coherence. The poor signal-to-noise ratio of the lunar seismograms renders conventional automatic detection methods (used for terrestrial seismic events) ineffective for these data. Using recently-developed stacking techniques and our processed version of the data, we will focus on better identification and cataloguing of moonquakes and on estimating lateral variability in scattering properties of the lunar regolith.

S12B MCC: Hall C Monday 1330h

Strong Ground Motion Prediction and Site Response Posters *(joint with PA)*

Presiding: **R J Blakely,** U.S. Geological Survey**; S A Zaragoza,** University of Nevada, Las Vegas

S12B-1188 1330h POSTER

Las Vegas Basin Seismic Response Project: 3-D Finite-Difference Ground Motion Simulations

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3-D simulations of seismic wave propagation in southern Nevada are performed in an effort to characterize strong ground motions in and around the Las Vegas Basin (LVB). These simulations utilize a 3-D geologic model constructed from a gravity-based depth-to-basement map of the 5-km deep LVB. The 3-D LVB basin model is embedded within a regional geologic framework characteristic of southern Nevada. Simulation parameters are varied to determine the sensitivity of seismic velocity, basin geometry, topography, attenuation, and regional structure on the amplitude and duration of seismic shaking. The simulations reveal significant correlation between high amplitude ground motion and model parameters. In particular, the duration of seismic shaking is heavily influenced by the geologic velocities in the upper 1 km of the basin. In some simulations, seismic energy originating from the northwest is channeled through the LVB in a northwest-southeast orientation. In addition, regions of localized high amplitude motion are observed. The simulations are compared to observed data from historic seismic events in southern Nevada.

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

S12B-1189 1330h POSTER

Las Vegas Basin Seismic Response Project: Measured Shallow Soil Velocities

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The Las Vegas valley in Nevada is a deep (up to 5 km) alluvial basin filled with interlayered gravels, sands, and clays. The climate is arid. The water table ranges from a few meters to many tens of meters deep. Laterally extensive thin carbonate-cemented lenses are commonly found across parts of the valley. Lenses range beyond 2 m in thickness, and occur at depths exceeding 200 m. Shallow seismic datasets have been collected at approximately ten sites around the Las Vegas valley, to characterize shear and compression wave velocities in the near surface. Purposes for the surveys include modeling of ground response to dynamic loads, both natural and manmade, quantification of soil stiffness to aid structural foundation design, and non-intrusive materials identification.

Borehole-based measurement techniques used include downhole and crosshole, to depths exceeding 100 m. Surface-based techniques used include refraction and three different methods involving inversion of surface-wave dispersion datasets. This latter group includes two active-source techniques, the Spectral Analysis of Surface Waves (SASW) method and the Multi-Channel Analysis of Surface Waves (MASW) method; and a new passive-source technique, the Refraction Mictrotremor (ReMi) method. Depths to halfspace for the active-source measurements ranged beyond 50 m. The passive-source method constrains shear wave velocities to 100 m depths.

As expected, the stiff cemented layers profoundly affect local velocity gradients. Scale effects are evident in comparisons of (1) very local measurements typified by borehole methods, to (2) the broader coverage of the SASW and MASW measurements, to (3) the still broader and deeper resolution made possible by the ReMi measurements.

The cemented layers appear as sharp spikes in the downhole datasets and are problematic in crosshole measurements due to refraction. The refraction method is useful only to locate the depth to the uppermost cemented layer. The surface-wave methods, on the other hand, can process velocity inversions. With the broader coverage of the active-source surface wave measurements, through careful inversion that takes advantage of prior information to the greatest extent possible, multiple, shallow, stiff layers can be resolved. Data from such broader-coverage methods also provide confidence regarding continuity of the cemented layers. For the ReMi measurements, which provide the broadest coverage of all methods used, the more generalized shallow profile is sometimes characterized by a strong stiffness inversion at a depth of approximately 10 m. We anticipate that this impedance contrast represents the vertical extent of the multiple layered deposits of cemented media.

URL: http://www.ce.unlv.edu/egl

S12B-1190 1330h POSTER

Las Vegas Basin Seismic Response Project: Preliminary Results From Seismic Refraction Experiments, Las Vegas, NV.

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In May and September 2002, seismic refraction data were acquired in the Las Vegas basin. Located in the southern Basin and Range province, the cities of Las Vegas, North Las Vegas, and Henderson sit atop a fault-bounded basin with a depth of up to 5 km and basin dimensions of roughly 60 km wide (east-west) by 50 km in length (north-south). Previous isostatic gravity, seismic reflection, and aeromagnetic studies indicate that a series of sub-basins exist beneath the unconsolidated basin fill, with the deepest sub-basin occurring 5 km west of the fault block bounding the eastern edge of the basin (Frenchman Mountain). The basin is significantly deeper along its northern extremity, following the path of the fault block bounding the northern edge of the basin (Las Vegas Valley Shear Zone), and along the western edge of Frenchman Mountain. Recent, paleoseismic studies have indicated that faults in the Las Vegas region have the potential for an earthquake of M6.5 to 7.0. It is estimated that a M6.9 earthquake in the basin could produce about 11 billion dollars in damage and a significant number of deaths and/or injuries. In addition, an equivalent or larger event in the Death Valley fault zone, 150 km distance, would also be devastating to the metropolitan area of approximately 1.5 million residents. Therefore, it is essential to understand the seismic hazard posed to the Las Vegas region.

This project is part of a larger collaborative effort to characterize the basin and its response to ground shaking. The University of Nevada, Las Vegas with assistance from the University of Texas at El Paso, students from UNLV and UTEP, volunteers from the community and several students from Centennial High school deployed 432 portable seismic recorders ("Texans") throughout the valley. Shot point locations were located at three quarries in the valley, one to the north, one to the east and one to the southwest. The profiles cross the Las Vegas Valley Shear zone as well as a prominent NW/SE trending step in the basin floor across which the basement drops from 2 to 4 km in depth. In addition, the profiles cross several Quaternary fault scarps, which have recently been identified as tectonic in origin. Preliminary analyses of the seismic refraction data indicate that the basin has an average P-wave velocity of 4.5 km/s and is in agreement with the estimated basin depths from isostatic gravity studies (2 to 5 km depth). Both tomographic inversion and forward modeling techniques are being used to analyze these data. These data will be used to produce a velocity model of the basin and image the basin/bedrock contact. In addition, these data will be integrated into a community model, which is being produced by the Las Vegas Basin Seismic Response working group to further assess the site response of the basin.

S12B-1191 1330h POSTER

Las Vegas Basin Seismic Response Project: Developing a Community Velocity Model for NTS and Las Vegas

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We are developing a three-dimensional reference seismic velocity model for Las Vegas and surrounding basins. We will use this model to help determine the importance of the basin response to any possible large seismic source, and the contribution of this response to seismic hazards in the urban area. Assessment of seismic-shaking amplification by deep sedimentary basins needs detailed characterization of basin geometry, fill velocities, and geotechnical velocities. We are compiling velocity information from sources in the literature, results of previous seismic experiments, earthquake monitoring, and geotechnical, petroleum, and ground water projects. We are developing for public release in early 2003 a model-assembly code and web interface that generates elastic-property grids for input to finite-difference codes. The model assembler is rule-based. It incorporates location and geological information to specify basin depth, seismic velocities, and densities for bedrock, sedimentary basins, and volcanic rift-basins. It adds the results of more detailed studies where they are available, such as those from Langenheim's gravity analysis of Las Vegas basin. This community velocity model is a part of a regional model we are developing for the western Great Basin. With a new parallel computer facility, we are validating the obtained rule-based models by generating synthetic seismograms and comparing them to recordings of old NTS explosions and past earthquakes (as the Little Skull Mountain earthquake) at broadband seismic stations and urban strong-motion stations.

URL: http://www.seismo.unr.edu/ftp/pub/louie/lv

S12B-1192 1330h POSTER

RENO AREA BASIN SEISMIC RESPONSE: GROUND MOTION SIMULATION IN RENO, NEVADA

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A three-dimensional seismic velocity model is being constructed for the Reno Basin and surrounding region for the purpose of modeling basin effects on the ground motion from potential earthquakes. The model specifies seismic velocities, density, and attenuation on a three dimensional grid (120 km x133 km), down to a depth of 40 km. The background model is based on Western Great Basin geology. Published velocity models and new geophysical data are incorporated to constrain the model. Ground motions from recent earthquakes (Mw4.4 12/02/2000 Truckee event; Mw5.2 08/10/2001 Mohawk Valley) are simulated by a fourth order, 3D staggered grid elastic finite difference code (e3d; Larsen, Schultz, and Grieger), and compared with data recorded by local network and nearby broadband IRIS instruments. These e3d synthetics have an upper frequency limit of 0.3 to 0.6 Hz. 1D synthetic Green's functions, computed in a layered elastic solid using the generalized reflection and transmission coefficients, are also compared to both the real seismogram data and the e3d synthetics. Depending on the station, data are above the noise level at frequencies as low as 0.2 Hz, giving a lower frequency limit for comparison. Success is achieved in matching arrival times. Current work focuses on validating and improving the velocity model.

S12B-1193 1330h POSTER

Shallow Shear-Velocity Transect Across the Reno Basin

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Earthquake shaking is amplified by many soils and in alluvium-filled basins, increasing the hazard to people and structures. Average shear velocity to 30 meters depth (V30) is one predictor of amplification and forms the basis of the NEHRP site classification scheme. In late 2001 we completed the first-ever complete shallow shear-velocity transect across an urban basin, using 45 Texans from the PASSCAL Instrument Center. Our study plots average shear velocities to 10, 30 and 100 m depths at 300-meter intervals along a 16-km-long transect crossing the Reno, Nevada basin, east-west through its heavily populated center. The refraction microtremor method of Louie that we employed enabled us to complete the transect with a crew averaging 3.5 people in just 9 field days. Ambient noise on a 300-m rolling Texan array is transformed to p-f space, picked for Rayleigh-wave dispersion, and modeled for Vs with depth. We have tested a method compensating for variations in apparent velocity sensed by our linear geophone arrays due to shear-wave arrivals from directions that are not down-line. We compare our shear-velocity profile against a gravity-depth profile of the same transect from an earlier study. Unlike the Los Angeles basin, the Reno basin's greatest depths appear to be overlain with stiffer, older sediments at the surface. Weaker soils appear to occur east of downtown Reno in the broad floodplain of the Truckee River. Extending the geologic-map classifications of Wills and others from the SCEC Phase III report to Reno would result in almost the entire transect being classified as NEHRP D. Our measured shear velocities differed from those predicted in 37 of 45 locations along the transect, showing NEHRP class C instead of D. The calibration of geological maps to correspond to the NEHRP soil hazard class in this region should be the subject of further study.

URL: http://www.seismo.unr.edu/hazsurv

S12B-1194 1330h POSTER

3-D Finite-Difference Modeling of Earthquakes in the City of Rome, Italy

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The goal of this study is to estimate 3-D amplification effects from regional and local earthquakes in the city of Rome. Mainly, two distinct seismogenic districts may affect the city of Rome: the (1) Alban Hills region, located about 25 km from downtown Rome, and (2) the Central Apennines, located 80-100 km from Rome where the most recent event occurred on January 13, 1915 (M=6.8) which was felt in Rome with a VII degree intensity. To address the seismic hazard in Rome from such sources we have simulated 0-1 Hz viscoelastic wave propagation in a three-dimensional model of the Tiber Valley, Rome, for an M5.5 scenario earthquake (1 Hz) in the seismogenic area of Alban Hills about 25 km from downtown Rome and an M7.0 earthquake (0.5 Hz) about 100 km east of the valley using a fourth-order staggered-grid finite-difference method. We used a basin model ($\sim$ 6 km by 6 km by 0.050 km) which includes sediments with shear-wave velocities as low as 250 m/s in the Tiber River sediments, constrained by more than 3000 borehole measurements. We have also

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estimated the amplification of the 3D model due to a 1-Hz vertically-incident planar SH wave.

Our results suggest that the strongest ground motion amplification in Rome is restricted to the Holocene alluvial areas with a significant concentration close to the edges of the Tiber River valley, in agreement with the results by Tertulliani and Riguzzi (1995). In particular, the fill deposits in the Tiber River generate amplification by up to a factor of 2 with respect to the surrounding volcanics, largest near the contact between the alluvial sediments and the surrounding volcanic deposits for the incident plane wave source. We find 1-Hz peak ground velocities of up to 30 cm/sec for the M5.5, Alban Hills earthquake, largest near the northwestern edges of the Tiber River. The largest 0.5-Hz peak velocity is 24 cm/s for the M7.0 earthquake with extended durations up to about 1 min. The lower maximum frequency for this scenario is dictated by computational limitations.

S12B-1195 1330h POSTER

STEP: Likelihood Testing of an Online Time-Dependent Hazard Mapping Application

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Short Term Earthquake Probabilities (STEP) is a time dependent hazard mapping routine currently producing daily forecasts for California. Using real-time seismicity information we produce the probabilistic forecast of ground motions exceeding .1g in the next 24 hours. The maps are automatically generated every 5 minutes and are available on the Web. In the forecasts we include probability increases of two types: aftershocks and potential foreshocks. We have expanded upon a model originally developed by Reasenberg and Jones that has been used by the USGS to issue forecasts of the chance of experiencing a potentially damaging event. To this model we have added three main components; Spatial information with the application of an appropriate attenuation relationship and site amplification terms; Spatial variability of the parameters of the Gutenberg-Richter relationship and modified Omori law within an aftershock sequence; The online availability of up to date hazard information to the public, media and scientists. Likelihod ratio testing of our results has shown a statistically significant improvement over the time independent USGS National map as well as a good fit to the data. Additionally, by testing three different models of time dependent seismicity we have optimized the design and implementation of STEP for California. Within this testing framework we have an ideal tool to test other proposed time dependent hazard mapping techniques.

S12B-1196 1330h POSTER

3D Simulation of Earthquake Ground Motion in the Cologne Basin, Germany

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The Cologne Basin in the North-West of Germany is seismically one of the most active regions in central Europe. Combined with its dense population and highly concentrated industry it is a region of elevated seismic risk. In order to obtain information about the effects of the underground structure on ground motion parameters in this area we performed 3D elastic and visco-elastic earthquake scenarios simulations for some of the largest events within the last 200 years in the Lower Rhine Embayment. The simulations were carried out in a frequency range of 0 - 1.0 Hz and have shown strong effects of the sedimentary basin on peak amplitudes, shaking duration and waveforms. Due to the sparse distribution of strong motion stations in the study area, it was difficult to compare synthetic seismograms with observed ones. In the past 10 years further seismic stations were placed inside the basin. An ML 4.9 event occurred in the study area on July 22, 2002 with the epicentre near the city of Aachen. Here we compare observations with synthetic seismograms calculated for this event and discuss the implications for the shaking hazard assessment using 3D simulations.

S12B-1197 1330h POSTER

Seismic Attenuation Characteristics in the Canadian Cordillera

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This paper investigates the seismic attenuation characteristics in the Canadian Cordillera. Isoseismals obtained from past moderate earthquakes (e.g. Prince George Earthquake of 21 March 1986, Ms 5.2) in the southern part (50°N - 60°N) of the Canadian Cordillera are elongated along the strike of the mountains. This suggests that attenuation of ground motion along the mountains may be slower than across the mountains. About 20 earthquakes in this area with magnitudes ranging from 3.0 to 4.5 recorded between 1994 and 2002 were considered in this study. Records from 14 stations, mostly consisting of broadband three-component instruments, operated by the Geological Survey of Canada and BC Hydro were used. The epicentral distances ranged from 250 km to about 650 km. Signal to noise ratios were calculated and signals with high noise levels were removed from this database. Attenuation of peak vertical and horizontal velocities and accelerations at different frequency ranges were examined and compared in the directions along and across the mountains. A significant difference between the two directions was only observed at the frequency range of 5 Hz to 10 Hz. This roughly corresponds to the frequencies humans are most sensitive to, which may in part explain why felt intensity contours are elongated. At this frequency band, across motions attenuate faster than along strike motions, but remain higher than along strike motions until epicentral distances of about 300 km.

S12B-1198 1330h POSTER

Seismic Microzoning of Bucharest - a GIS-supported Study of Earthquake Hazard

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The Romanian capital Bucharest is situated close to one of the seismically most active areas in Europe. In the past centuries strong earthquakes frequently caused serious damages. The last major event occurred at March 7th 1977. It caused 1,570 fatal casualties and nearly 33,000 destroyed flats. Lateral variations in seismic intensities are strongly influenced by local site effects that depend on the geometry and dynamic properties of shallow Quaternary units.

The main objective of the study is to quantify the modification of a seismic signal by local site conditions. Thus, the first step of the working process is the generation of a digital underground model of Bucharest. Geotechnical drilling data are digitally processed by a database and a GIS. The vectorial point features are converted to spatial raster maps by suitable interpolation algorithms. Coordinates and geological attributes (i.e. thickness of geological strata and depth of ground water table) are attached to every raster-cell. Based on this information maps of average shear-wave velocities, fundamental ground period and liquefaction hazard can be generated by a raster-based GIS-module.

Next, a numerical analysis of site effects is performed by the use of a ground response analysis software. Ground amplification and spectral shake parameters are computed at discrete locations. Spatial information can be generated by interpolation or - on base of the underground model - by regression analyses.

Finally, the microzoning is verified by spatial correlations with the distribution of historical earthquake intensities. Cell-by-cell analyses show that the thickness of poorly consolidated Quaternary sediments has a noticeable influence on the damage to buildings. The result of this study is a classification of the study area according to spectral shake parameters which have a strong influence on the damage to buildings. Hence, microzoning is an important tool for the estimation of the seismic risk.

URL: http://www.agk.uni-karlsruhe.de/projekte/projekte_ing/mikrozonierung/index.html

S12B-1199 1330h POSTER

Three-Dimensional Finite-Difference Simulations of Strong Ground Motions in the Beijing Metropolitan Area

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The metropolitain area of Beijing is situated in a seismically active region. In connection with a project aiming at "Preparing Beijing for the 2008 Olympic Games", the present study focuses on the calculation of ground motion following earthquakes in the Beijing Basin. A 3D velocity model of the Beijing Area was constructed from studies that analyzed available geological information, seismic-reflection suverys, borehole logs, and gavity data. Beijing is located in a sedimentary basin of which the maximum depth is approx. 1 km. These low-velocity sediments are likely to amplify ground motion for earthquakes inside and outside the basin. To estimate the influence of the 3D structure on the ground motion, 3D-FD simulations of elastic waves were performed for the 1665 Tongxian earthquake (Mw 6.5) and the 1679 Sanhe-Pingu earthquake (Mw 8.0) using an extended rupture model. The scenario earthquakes are simulated in a block of size 210 km x 200 km x 20 km. The simulations are performed on high-performance computing facilities, which makes it possible to simulate the seismic wavefield with a dominant frequency exceeding 1 Hz. From the resulting ground motion at the surface contour maps of the peak ground velocities (accelerations), shaking duration, and 5%-damped response spectra at certain periods (e.g., 0.8 sec, 1.0 sec, 2.0 sec, 5.0 sec, 10.0 sec) are calculated. Our simulations highlight the effects of the basin structure on strong ground motion, and illustrate the possibility of using the 3D-FD method in connection with large scale seismic hazard assessment.

S12B-1200 1330h POSTER

Fundamental characteristics of strong-motion radiation patterns

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Since strong motions around frequency of 1 Hz strongly affect the degree of structural damage, it is a major concern for us to simulate strong motions in this frequency range accurately for use in disaster mitigation. One of the important characteristics that control strong motions in this frequency range is the radiation pattern. However, the fundamental characteristics of radiation patterns of strong motions in this range are complex (Liu & Hemlberger, 1985, Vidale, 1989).

In this study, we investigated the fundamental characteristics of high frequency strong-motion including 1 Hz using dense strong-motion network data for an aftershock event (Mj5.5, depth=9km) of the 2000 Tottori-ken Seibu, Japan, earthquake.

First we calculated Fourier amplitude ratios of radial and transverse components (R/T) in order to remove local site effects from the data and compared them with those of the synthetics. For frequencies lower than 1 to 2 Hz the R/T of the synthetics matches that of the data fairly well, but for frequencies higher than 2 Hz the difference became notable. This result is consistent with recent statistical studies (Satoh, 2002).

Then we calculated amplitude ratios of radial to transverse components (R/Tt) and orbit shapes for the theoretical velocity time histories and compared them with those of the data observed at a rock station having an epicentral distance of 20 km, to investigate their frequency and time dependence. The dominant direction of oscillation of the data was clear for frequencies lower than 2 to 5 Hz but for higher frequencies the oscillation became isotropic. The results for the synthetics for frequencies between 0.5 to 2 Hz during the S-wave matched those of the data fairly well.

We can conclude that the frequency range of transition from determinant to random phenomena of radiation patterns is approximately 1 to 5 Hz. We need to incorporate a radiation pattern model based on this result for development in strong motion simulation methods.

We acknowledge NIED for the use of KiK-net data. Some figures were made using GMT. This study was supported by the project "Study on the master model for strong ground motion prediction toward earthquake disaster prevention" funded by Special Coordination Funds for Promoting Science and Technology, from MEXT (2000-2004).

S12B-1201 1330h POSTER

3D Finite-Difference Modeling of Strong Ground Motion in the Upper Rhine Graben - 1356 Basel Earthquake

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The disastrous Basel earthquake of October 18, 1356 (I_0=X, M ≈ 6.9), appeared in, today seismically modest, Basel region (Upper Rhine Graben). The lack of strong ground motion seismic data can be effectively supplied by numerical modeling. We applied the 3D finite differences (FD) to predict ground motions which can be used for microzonation and hazard assessment studies.

The FD method is formulated for topography models on irregular rectangular grids. It is a 3D explicit FD formulation of the hyperbolic partial differential equation (PDE). Elastodynamic PDE is solved in the time domain. The Hooke's isotropic inhomogeneous medium contains discontinuities and a topographic free surface.

The 3D elastic FD modeling is applied on a newly established P and S-wave velocities structure model. This complex structure contains main interfaces and gradients inside some layers. It is adjacent to the earth surface and includes topography (Kind, Faeh and Giardini, 2002, A 3D Reference Model for the Area of Basel, in prep.). The first attempt was done for a double-couple point source and relatively simple source function. Numerical tests are planned for several finite-extent source histories because the 1356 Basel earthquake source features have not been well determined, yet. The presumed finite-extent source is adjacent to the free surface. The results are compared to the macroseismic information of the Basel area.

S12B-1202 1330h POSTER

Estimation of Site Effects and Q Factor Using a Reference Event

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The site effects and the quality factor were inverted by applying the spectral ratio technique with the variation of using one of the earthquakes as a reference event instead of a reference site. The spectral ratios were written as logarithmic summations that allowed us to retrieve the absolute site amplification and Q. We tested this inversion scheme by first inverting synthetic data that contained different levels of noise, and then by changing the seismic moment and the corner frequency of the reference event. Finally, we used data from two strong motion networks (K-Net and KiK-Net) that recorded the aftershocks of the 2000 Tottori, Japan, earthquake to estimate the site effects at those sites. Since the KiK-Net stations had instruments located at the surface and at depth, we performed two inversions: one using the surface records and the other using the borehole records. Our results indicate that there is amplification at the borehole sites although it is smaller than the amplification at the surface sites.

S12B-1203 1330h POSTER

A Study on Simulating High-Frequency Strong Vertical Motions

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In this paper, we propose an extended stochastic simulation method to simulating high-frequency strong vertical motions. The stochastic simulation method is a useful tool to compute strong ground motions (Boore, 1983). However, it generates only horizontal-component (actually, the average of two horizontal components) earthquake motions. We have observed that although microtremor HV ratios are smaller than earthquake motion HV ratios, their spectral shapes are similar, and suggested that the difference between the two ratios is controlled by local geological conditions (Zhao *et al.*, 2000). This implies that earthquake motion HV ratios can be obtained from microtremor HV ratios using a correction factor common for geologically similar sites. We first show that the HV ratios of earthquake motions can be derived from microtremors. Then, we simulate vertical earthquake motions using correction factor *CF* from microtremors to the 1995 January 17 Hyogo-ken Nanbu Earthquake (M_J=7.2).

In contrast to a small variation of the HV ratios with respect to frequencies at rock site, we can clearly observe a large variation of the HV ratios at hard and soft sediment sites. The correction factor *CF* is computed by the equation derived from the least square fitting. At all the sites the corrected microtremor HV ratios are similar to the earthquake motion in 0.5-10 Hz, indicating that the correction factors are estimated appropriately. These results indicate that a correction factor of about 2 is suitable for soft sediment sites and a correction factor of about 1.2 is suitable for the rock and the hard-sediment sites limited within the Osaka basin. In the case of 1995 Hyogo-ken Nanbu earthquake, strong horizontal ground accelerations were calculated using the stochastic simulation method in conjecture with the ω^{-2} source spectra (Boore, 1983), vertical accelerations were computed by the same method except for using modified source spectra, where the ω^{-2} source spectra are divided by the corrected microtremor HV ratios. It should be mentioned that the modified source spectra are required only for the convenience of simulating vertical component. The source model is composed of three asperities (Kamae and Irikura, 1998). We replaced them with three point sources, which are located at the center of the asperities. We used 2 times the seismic moment and 2.5 times the stress drop. The radiation coefficients were assumed to be 0.64. Subsurface structure models of sediments at the three sites were derived from results of the reflection and the microtremor array surveys. Simulated horizontal and vertical accelerations are well reproduced in peak acceleration and duration in the S wave portion. Also, rich high-frequency contents in vertical motions are well reproduced. The result suggest that the stochastic simulation method can extended to include computation of vertical earthquake motions as well horizontal using microtremor HV ratios.

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S12B-1204 1330h POSTER

Near Surface Characterization and Estimated Site-Response at POLARIS Seismograph Stations in Southern Ontario

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Shallow seismic and ground penetrating radar (GPR) surveys have been collected in southern Ontario, Canada near current and planned seismograph stations for the POLARIS network. All five of the sites are characterized by glaciolacustrine overburden, consisting of silt, sand, and/or clay, on the order of a few metres to ten's of metres. Bedrock at all of the sites is mapped as Paleozoic limestone and shale, and is located at depths ranging from a few metres to ten's of metres. The objectives of these surveys are to obtain shallow velocity models (P and S-wave) at each site for earthquake site-response determination, and to investigate the utility of GPR data for siting underground vaults. The seismic surveys were acquired using 24- or 48-channel systems, with several different sources (an in-hole shotgun or a sledge hammer). The use of a twelve pound sledge hammer to strike a steel I-beam perpendicular to its length, oriented in-line with the geophone spread, was found to produce strong SH waves. In order to constrain the velocities at both very shallow (< 4 m) and deeper (4-30 m) depth intervals, two geophone spreads were collected, one with a one metre geophone spacing and another with a five metre geophone spacing. Velocity models derived by refraction analysis provide the basis for classification of each site according to the NEHRP scheme. In addition, a comparison of the response at each site is being undertaken by visco-elastic finite-difference modeling of the ground motion induced by incident wavefields of various types (both regional and teleseismic). Where possible, these results are compared with empirical site-response determined from regional events using the H/V method. The site response obtained for each station will be used in the future for calibration of the POLARIS network. In one case, the GPR data led to the discovery of a probable underground drainage channel that would have been an inappropriate location for a seismograph vault.

S12B-1205 1330h POSTER

Ground Motion Prediction for Moderate-Magnitude Earthquakes: Near-Source Effects During the 1997-98 Umbria-Marche (Central Italy) Seismic Sequence

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We present evidence of near-source effects on strong ground motions recorded during moderate-magnitude ($5 \leq M \leq 6$) earthquakes from the 1997 Umbria-Marche (central Italy) sequence. We studied the Colfiorito M_w 6.0 (September 26, 1997, 09:40 UTC) and the Sellano M_w 5.6 (October 14, 1997) normal-faulting earthquakes. These earthquakes provided recordings at epicentral distances less than two-three fault lengths. The recorded acceleograms are affected by the source-to-receiver geometry, the finiteness of the fault and the rupture history. We evaluated these effects by comparing recorded ground accelerations with those simulated with a stochastic-deterministic method. We have developed a hybrid technique to simulate strong ground accelerations from extended faults, which generalizes the point-source stochastic method to capture the essence of near source effects while maintaining its conceptual simplicity. A white-noise time series is windowed with a deterministic acceleration envelope computed with a simplified isochron formulation. The spectral function that filters the windowed noise is a 'point-source-like' amplitude spectrum which depends on parameters (corner frequency, distance from the fault, radiation pattern) evaluated from the deterministic computation. Despite of the simplified description of the rupture history on the extended source, we were able to explain the variability of recorded PGA and to reproduce the near-source effects both in time and frequency domain. We emphasize the importance of modeling finite fault effects for moderate-magnitude earthquakes to evaluate ground-shaking scenarios in seismic regions where no strong motion data are available. We remark the difficulties to parameterize (either empirically or analytically) the directivity and the radiation pattern effects.

S12B-1206 1330h POSTER

Surface Wave Investigation and Analysis Earthquake-Induced Liquefaction Sites in Asia

S

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This ongoing investigation is greatly expanding the worldwide data-set of shear wave velocity characteristics at liquefaction sites, most of which are located in Asia. Doing so allows for a re-evaluation of the shear wave velocity assessment methodologies for liquefaction presented in the literature since 1992, methodologies that are data deficient in the zone of high shear wave velocity and high ground motion intensity data.

To expand this data set, we are using the Spectral Analysis of Surface Waves (SASW) method, a relatively new non-invasive field approach for evaluating the shear wave velocity characteristics of potentially liquefiable ground. In our test procedure, we line-array small-lightweight sensors on the surface and gather vertical-motion vibrations produced with a small frequency-controlled electro-mechanical shaker. Real time computation of cross power spectra (CPS) between separated and precisely-spaced sensors are transformed into phase velocity-frequency dispersion space and ultimately shear wave velocity-depth space. SASW is particularly useful for lightweight reconnaissance surveys and profiling difficult materials such as gravely sand where conventional truck-based penetration methods are not practical. The dispersive nature of surface waves is the basis of the SASW method. After we have determine the dispersion characteristics of surface waves at a site, we utilize the Haskell-Thompson matrix inversion technique to estimate the shear wave velocity profile. Then, the velocity of the observed liquefied layer is used to relate the stiffness properties of the ground to an estimated intensity of the earthquake motions at the site.

In Japan and Taiwan, we profiled 182 liquefaction test sites using this method, producing detailed shear wave velocity profiles in the upper 20-30 meters of the soil column. Further testing is planned for 2003. Nearly all of the post-war documented liquefaction sites in the Japan and Taiwan, evaluated with conventional penetration apparatus, were re-tested in our study. These liquefaction events, dating from the most recent large damaging events in Japan and Taiwan (2001 Geiyo and 1999 Chi Chi, respectively), extend back to the 1948 Fukui City earthquake, represent the majority of the worlds documented sites of liquefaction occurrence. Considerable effort was directed towards earthquake events and sites that produced liquefaction related damage in relatively stiff native soil from high intensity motions (e.g. Hyogo-Nambu 1995; Hokkaido Nansei-Oki 1993; Chi Chi; Fukui; Kushiro 1993). The data from this study allows us to finally recast the shear wave velocity-liquefaction assessment method in light of a global data set.

S12B-1207 1330h POSTER

Ground Motion Levels From Deeper Versus Shallower Fault Rupture

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Somerville (2000) found a systematic difference in the level of earthquake ground motions for three M 7.2-7.6 earthquakes with large surface ruptures, and three M 6.7-7.0 earthquakes on buried faults. He found that the acceleration spectra of the smaller events are much larger than the 1994 UCB code spectrum for soil site conditions in the intermediate period range of 0.5-2.5 seconds, but similar to the UCB code spectrum at longer periods. He pointed out that this is contrary to all current earthquake source models and ground motion spectral scaling with magnitude.

We have tested the results by Somerville using dynamic rupture modeling. We compare a 45^o-dipping, 5 km buried thrust fault to a 30^o-dipping thrust fault that breaks the surface in a halfspace model with uniform dynamic rupture parameters on the faults. The seismic moments of the two dynamic ruptures amount to $3.4 \cdot 10^{19}$ Nm (M 7.0) in the first, and $5.3 \cdot 10^{19}$ Nm (M 7.1) in the latter case. The increased seismic moment for the surface rupture is due to the time-dependent normal-stress interaction of the wavefield with the free surface. We find that, compared to those for the buried rupture, the surface rupture shows larger spectral accelerations for periods between 0.33 and 5 seconds. Thus, our dynamic simulations can not confirm the observations from Somerville (2000), and we conclude that his results are not a first-order dynamic effect related to the depth of burial of the fault. Finally, we test whether dynamic rupture modeling can explain the differences by in ground motion levels from a combination of smaller fault areas and larger slip velocities for buried faults relative to those for scenarios with surface rupture (Somerville et al., 2002).

S12B-1208 1330h POSTER

Unusual Strong Ground Motion Amplification at the Coyote Lake Dam, California

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Comparison is made of strong ground motions recorded at the Coyote Lake at the two stations: Coyote Lake Dam Southwest Abutment and Coyote Lake Dam Downstream. An unexpectedly high peak acceleration of 1.2 g was recorded on the 285-degree component at the abutment site during the 1984 Morgan Hill earthquake. After this earthquake the California Strong Motion Instrumentation Program installed the downstream site about 700 m from the abutment site. The records of the four earthquakes (the M5.8 Coyote Lake of 8/6/79, the M6.2 Morgan Hill of 4/24/84, the M7.0 Loma Prieta of 10/18/89 and the M4.8 Gilroy of 1/16/93) were digitized and processed. Of the four events recorded at Coyote Lake Dam the last two (Loma Prieta, and Gilroy) were recorded simultaneously at the abutment and downstream sites. Site geology for the abutment station is described as "fill (about 1.5 m) over carbonate rock", and for the downstream station as "alluvium". The abutment station lies within the Calaveras fault zone, and the downstream station is located less than 250 m from the fault zone.

The ground motion recorded during the M7.0 Loma Prieta earthquake of 10/18/89 demonstrates relatively high amplitudes on the 285-degree component at the abutment site. Amplitude of this component is more than 3 times higher than that of the 195-degree component. This component is also more than 2 times higher than the motion on the corresponding component at the downstream site in the period range between 0.3-0.8 seconds. This difference can not result from source directivity, because the two horizontal components at the nearby downstream station have almost the same amplitude. It is also unlikely that fault-zone trapped waves are important, because the source is well outside of the fault zone, and the azimuth to the site is almost perpendicular to the fault zone. Note that the 285-degree component is almost perpendicular to the orientation of the dam.

The relationship of the abutment/downstream recordings of the M4.8 Gilroy earthquake of 1/16/1993 is almost completely different from that of the Loma Prieta earthquake. The amplitudes of motion are more than 20% higher at the downstream site than at the abutment site. The abutment-to-downstream spectral ratios are less than unity in the period range from 0.3 to 0.6 sec.

The epicenter to station azimuth for the Loma Prieta earthquake is 73 degrees, and it is 325 degrees for the Gilroy event. These two earthquakes are located on different sides of the Calaveras fault zone, suggesting significantly different geology for the wave propagation paths to the stations. Combination of differences in source-station orientation, and complex 3-D structure around the fault zone and stations may be responsible for such large differences in the ratios of ground motions at the two nearby Coyote Lake stations.

S12B-1209 1330h POSTER

On the Effects of Non-Planar Fault Geometry on Strong Ground Motion

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We quantify the effects of complex fault geometry on low-frequency (<1 Hz) strong ground motion using numerical modeling of dynamic rupture. Our tests include the computation of synthetic seismograms for several simple rupture scenarios with planar and curved fault approximations of the 1994 Northridge and the 1992 Landers earthquakes. We use the boundary integral equation method (BIEM) to compute the dynamic rupture process, which includes the normal stress effects along the curved fault geometries. The wave propagation and computation of synthetic seismograms are modeled using a fourth-order finite-difference method (FDM).

The near-field ground motion is significantly affected by the acceleration, deceleration and arrest of rupture due to fault bending, as well as the the variation in directivity of the rupture. We compare 1-Hz near-fault peak velocities for 40^o-dipping, thrust faults buried 5 km with dimensions 24 km by 16 km. Compared to that for a planar fault, such as most approximations of the Northridge earthquake, a 6-km-long hanging-wall or footwall splay with a maximum offset of 1 km can change peak velocities by up to a factor of 2-3 above the fault. This change is caused in part by a variation in directivity, in part by differences in the rupture dynamics for the scenarios. In particular, the curved faults cause a gradual arrest of rupture, while the planar fault rupture stops abruptly with a resulting increase in moment. Our tests suggest that the differences in waveform are larger on the hanging wall compared to those on the footwall. The results imply that kinematic ground motion estimates and slip inversion may be significantly biased by the omission of dynamic rupture effects and of relatively gentle variation in fault geometry, even for long-period waves.

S12B-1210 1330h POSTER

Dynamic and Pseudo-Dynamic Source Characterization for Strong Ground Motion Prediction

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In the absence of sufficient data in the very near source, prediction of the intensity and variability of ground motions from future large earthquakes depends on our ability to develop realistic models of the earthquake source. With the objective of making these simulations more accurate, we developed a dynamic source characterization based on stochastic-dynamic source models (Guatteri et al., 2002). The dynamic source parameters (fracture energy and stress drop) are specified as spatial random fields such that they are consistent with the statistical properties of slip heterogeneity found in finite-source models of past earthquakes. We find that including spatial and temporal variations in slip, slip rise time, and rupture propagation that are consistent with dynamic rupture models exerts a strong influence on near-source ground motion. We investigate the relationships between dynamic and kinematic source parameters to develop approximations that may adequately describe dynamic rupture, without having to do full dynamic simulations. The result is an approximate approach to develop a physically based source characterization (pseudo-dynamic) that may improve both the source model design in probable earthquake scenarios for ground motion simulations and the incorporation of source effects in future attenuation models. A physically based source description and output that consists of strong motion time series for a suite of earthquake rupture realizations, rather than a single number of models, merge naturally with a probabilistic approach for seismic hazard analysis.

S12B-1211 1330h POSTER

Spectral Stochastic BEM (Estimation of the Effect of Geometrical Uncertainty of Boundary)

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With many factors for estimation of strong ground motion being unknown, it is essential to quantitatively evaluate how uncertainty affects the results calculated using those uncertain parameters.

We develop Spectral Stochastic Boundary Element Method (SSBEM) based on the idea of Spectral Stochastic FEM [1,2]. SSBEM is applied to wave propagation analysis in the media which has uncertainty in geometric condition.

SSBEM expands the uncertain field (geometric condition of the boundary) $s(t)$ using Karhunen Loeve (KL) expansion as

$$s(x, \xi_i) = \bar{s}(x) + \sum_{i=1}^{\infty} \xi_i \sqrt{\lambda_i} f_i(x) \qquad (1)$$

where $\bar{s}$ is expectation of s; $f_i(x)$ is the basis of KL expansion; ξ_i are normalized Gaussian probability variable.

Solution of BEM (displacement etc.), $u(\xi_i)$, is approximated in the form as

$$u(\xi_i) = \sum_{i=0}^{\infty} u_i \Psi_i[\{\xi_\ell\}] \qquad (2)$$

where $\Psi_i[\{\xi_\ell\}]$ are basis of Polynomial Chaos (PC) expansion.

In BEM, displacement u^i is obtained by integrating the Green's function along the boundary as

$$u^i = \int_\Gamma q\bar{u}d\Gamma - \int_\Gamma \bar{q}ud\Gamma \quad (3)$$

If we introduce the parameter τ to represent the uncertainty of geometrical condition of boundary, variation of displacement u^i can be estimated by using Talyor expansion as

$$u^i_\tau = \int_\Gamma \left\{1 + \tau\frac{D}{D\tau} + \cdots\right\} q\bar{u}d\Gamma' - \int_\Gamma \left\{1 + \tau\frac{D}{D\tau} + \cdots\right\} \bar{q}ud\Gamma \quad (4)$$

where $\frac{D}{D\tau}$ denotes Lagrange derivative. This can be evaluated using the expression of uncertain boundary, Eq (1). By using Eq (4) instead of Eq (3) in BEM formulation, we can estimate the solution in the form as Eq (2).

Efficiency of the proposed scheme is verified by numerical examples, in which computation results of SSBEM are compared with those of MCS in terms of expectation, standard deviation and probability density function. Their results are close to each other and efficiency of SSBEM is verified.

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S12B-1212 1330h POSTER

Numerical Simulation of Strong Ground Motion at Mexico City:A Hybrid Approach for Efficient Evaluation of Site Amplification and Path Effects for Different Types of Earthquakes

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The estimation of scenarios of the strong ground motions caused by future great earthquakes is an important problem in strong motion seismology. This was pointed out by the great 1985 Michoacan earthquake, which caused a great damage in Mexico City, 300 km away from the epicenter. Since the seismic wavefield is characterized by the source, path and site effects, the pattern of strong motion damage from different types of earthquakes should differ significantly. In this study, the scenarios for intermediate-depth normal-faulting, shallow-interplate thrust faulting, and crustal earthquakes have been estimated using a hybrid simulation technique. The character of the seismic wavefield propagating from the source to Mexico City for each earthquake was first calculated using the pseudospectral method for 2D SH waves. The site amplifications in the shallow structure of Mexico City are then calculated using the multiple SH wave reverberation theory. The scenarios of maximum ground motion for both inslab and interplate earthquakes obtained by the simulation show a good agreement with the observations. This indicates the effectiveness of the hybrid simulation approach to investigate the strong motion damage for future earthquakes.

S12B-1213 1330h POSTER

Strong Motion Prediction Within a Basin Located Above the Teton Fault in Wyoming

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Strong motion estimates were developed for a site near the center of a basin located above the Teton fault near Jackson, Wyoming for scenario M 6.9 to 7.1 normal-faulting earthquakes. A 3D velocity-hypocenter inversion using 1150 earthquakes recorded by the Jackson Lake Seismic Network delineates a $\sim$ 4-km-deep low-velocity basin located above the east-dipping Teton fault, but fails to resolve details of the velocity structure within the basin. Basin velocity structure was derived from reinterpretation of existing seismic refraction data, and 2D finite-difference waveform modeling of three microearthquakes (MEQ) located near the perimeter of the basin and recorded on broadband stations near the middle of the basin. The refraction data and MEQ waveform modeling indicate nearly linear vertical velocity gradients within the basin. Published interpretations of the refraction data used constant velocity layers with strong velocity discontinuities within the basin which fail to reproduce strong broadband arrivals that follow direct S-waves by $\sim$ 4-6 s; these arrivals are composed of S-waves and surface waves produced at the basin margins. Reciprocity 3D finite-difference viscoelastic Green's functions were used to synthesize motions for frequencies $<$1 Hz and eight empirical Green's functions (EGF) were used to synthesize $>$ 1 Hz motions. Kinematic finite-fault rupture models were generated with self-similar slip distributions and variable rupture and rise times. A 3D eikonal equation solver was used to calculate first S-wave arrival times for point-source summations of EGF's. The dip of the Teton fault is not well constrained; dips of 35, 45, and 60 degrees where used to synthesize ground motions. For a 35-degree fault dip, directivity produces factor of two stronger peak responses on the fault perpendicular component than the fault parallel component for all periods. For periods $>$ 0.7 s and a 60 degree fault dip, peak motions were stronger on the fault parallel component than the fault perpendicular component; the strongest arrivals on the fault parallel component are associated with basin-edge waves. The top 5 km of the Teton fault is within 2-3 km of the western edge of the basin. The western edge of the basin acts as a strong secondary seismic source for sites within the basin; basin-edge S-waves close to the fault are nearly critically reflected for sites near the center of the basin and produce large acceleration and velocity responses that extend the duration of strong shaking by $>$ 10 s within the central portion of the basin.

S12B-1214 1330h POSTER

Prediction of broad-band strong ground motions from large subduction earthquakes using a characterized source model

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In Japan, long-term probabilities of several large subduction earthquakes have been evaluated by the Headquaters for Earthquake Research Promotion. In order to mitigate the disaster caused by such earthquakes, it is very important to predict broad-band strong ground motions of engineering interest before events. A methodology has been proposed for estimating strong ground motions from scenario earthquakes caused by active faults by Irikura et al. (2002). They characterized source model with heterogeneity of slip on the fault based on the self-similar scaling relations of asperities with respect to seismic moments derived statistically from the source inversion results. In this study, we apply much the same approach for the source characterization to future subduction earthquakes, and attempt to estimate broad-band strong ground motions using some simulation techniques. Our objective earthquakes are two large ones , occurred on the Nankai trough (larger than M8) and in the sea off Miyagi Prefecture (M7.4) in Japan. The former earthquakes have been repeatedly occurring with an interval of approximately 100 years. The recent one occurred fifty-six years ago. The average interval of the latter ones is about 37 years. 24 years have already passed since the previous one. The validity and applicability of strong ground motion predictions are examined in comparisons with the observed records and the measured seismic intensity and so on during the old earthquakes occurred the corresponding subduction zones.

S12B-1215 1330h POSTER

Broadband Strong Ground Motion Simulation Of The 17 August And 12 November 1999, Turkey Earthquakes

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The main objective of this study is to determine the source characteristics of the Duzce and Kocaeli Earthquakes such as source size, asperity location and asperity size and also compare these findings with empirical scaling relations obtained from worldwide earthquakes. The possibility of supershear rupture propagation during the Duzce earthquake proposed by Bouchon et.al.(2001) is also examined by performing numerous inversions changing the first time-window propagation velocities at each time. Besides these, results may contribute to the relation between coseismic slip distribution at the fault plane and the distribution of surface ruptures.

The waveform inversion of the 12 November 1999 Duzce, Turkey Earthquake was performed for the frequency range of 0.1-0.5 Hz. using the multiple time-window linear waveform inversion methodology. For the inversion, strong motion records of the Duzce Earthquake from 8 stations within 50 km epicentral distance were used. An approximate 41 x 13 km size fault plane was assumed and subdivided into 52 subfaults. Hypocenter is at a depth of 10km, located in the bottom left hand-side of the plane, approximately 7 km away from the center of the fault plane. In order to calculate the theoretical Green's function between each subfault and each station in 1D velocity structure, the discrete wave number method of Bouchon (1981) together with the reflection-transmission matrix method (Kennett and Kerry, 1979) were used.

The best source model was determined by an asperity near the hypocenter and a second asperity closer to the surface in the eastern part of the fault plane. First time-window propagation velocity was found as 4.3km/s in the eastern propagation, where it is 2.9km/s in the western propagation. A simplified version of this source model was used for getting higher frequency simulation through Empirical Green's Function (EGF) Method. The distribution of the coseismic slip in the fault plane is consistent with the surface dislocation. However the displacement values measured at surface show larger values than the final slip values found at the shallower portion of the fault plane.

In order to get the broadband simulation of the 17 August 1999 Kocaeli earthquake, the EGF simulation has been performed using the available aftershock records as Green's function. The source process results of the Kocaeli Earthquake obtained by Sekiguchi et.al. (2002) was used to set up an initial source model for the forward simulation of this earthquake.

S12B-1216 1330h POSTER

Seismic Measurements of the Site Effect in the Mugello Basin (Italy)

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Shallow sediments can affect dramatically the seismic motion at the surface leading to an increase in the seismic vulnerability and resulting critical for seismic risk assessment. Site effects have been worldwide observed, associated both with destructive large earthquakes and with moderate magnitude earthquakes. The Mugello is a recent fluvio-lacustrine basin located 30 km north from Firenze (Italy) and is interested by strong historical earthquakes, which have produced severe damage in a large area including Firenze. Site effects were analyzed in 85 locations measuring seismic noise for 24 hours. We used three components Lennartz seismometers (LE 3D/5sec), with 5 seconds of eigenperiod, and 16 bits A/D converters. One seismic station was permanently deployed on bedrock assuming no seismic amplification. This station was used as reference both for earthquakes and for noise records. Magnitude of the site effects has been estimated from seismic noise and earthquakes. The amplification factor (Fa) was calculated as the integral of the horizontal-to-vertical spectral ratio (HVRS) of the ground acceleration in the frequency range between 2 and 10 Hz, of engineering interest. Amplitude of the regional earthquakes recorded in the basin varies in agreement with the estimated amplitude of the site effects calculated by the HVRS of the noise, showing the strong relation with the shallow geology. In addition, the HVRS calculated for earthquakes and for noise is consistent, giving a strong reliability to the method used. The site effects of the Mugello basin are represented in maps of the amplification and peak frequency distribution. These maps

provide interesting information and appear consistent with the local geomorphology and geology. The estimated amplification factor results quite high near the border of the basin, where shallow sediments cover the bedrock while decreases towards the center in relation with thicker sediments. In the same way, the resonant frequency decreases from the border to the center of the basin, where the bedrock has a depth of ∼ 600 meters. In general the amplification distribution seems to be in good agreement with geological and morphological local constraints.

S12B-1217 1330h POSTER

Surface faulting and liquefaction related to the Changureh (Avaj) earthquake, Iran, June 22, 2002

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The Changureh (Avaj) earthquake occurred in western Iran, about 225 km west of Tehran at 7:28 local time, June 22, 2002. The moderate moment magnitude of 6.4(ERI, University of Tokyo) - 6.5 (USGS) was calculated for this earthquake and the depth of epicenter was about 7 km (ERI) - 10 km (USGS). The fault plane solution indicates that the main shock was occurred on a reverse fault with NW-SE trending.

Epicenter and damaged area are located in a fold and thrust belt in the north of Zagros tectonic boundary. This belt trends NW-SE direction. Several large earthquakes with reverse faulting, such as 1962 Ipak (Buin-Zahra) earthquake, was occurred near the area.

Surface faulting and liquefaction related to this earthquake appeared near the epicenter area of main shock. The surface fault appeared at the east of Abdareh continuously. The length of the surface fault is at least 700 m and it is possible that the surface fault could elongate to rather east. The rupture runs across the slope of ridges with compressional displacement. Amount of displacement is as much as 10 cm and south side was thrown up through whole of the trace. Trend of this trace is N70W. Liquefaction could be seen near the river. Sand (partly gravel) boiling were on the ground along the surface ruptures.

We made the trench excavation surveys at 3 sites on 27-29 July. 2 sites were excavated on the surface fault and another was on the liquefaction site. Trench survey on the surface fault showed the slip occurred on the bedding plane of Miocene siltstone which dipping to south of 20-30 degrees. At the liquefaction trench we could see the sand (and gravel) had come up from 2 m below.

S12B-1218 1330h POSTER

Regional Characterization of Metropolitan Areas in Japan for Strong Ground Motion Evaluation

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Introduction

After the 1995 Kobe earthquake, the Japanese government increased its focus and funding of earthquake hazards evaluation, studies of man-made structures integrity, and emergency response planning in the major urban centers. A new agency, the Headquarters for Earthquake Research Promotion, was formed to oversee appropriate research in the earth sciences and civil engineering. This agency distributes research funds of $130 million per year. Projects include these topics: 1) Densification of seismic and GPS networks, 2) Paleoseismological investigation of major active faults, 3) Research on the geometry and physical properties of basins under the cities, 4) Probablistic strong ground motion estimation, and 5) Regional characterization of faults and physical parameters.

Regional Characterization Study

A long-term goal is to produce map of reliable estimations of strong ground motion. This requires accurate determination of: Source, Propagation path, Near surface and Ground motion response.A new five year project starts this year to characterize the "source" and "propagation path" in the Kanto (Tokyo) region and Kinki (Osaka) region. The proximity of the Pacific and Philippine Sea subducting plates requires study of the relationship between earthquakes and regional tectonics. This projects focuses on identification and geometry of: 1) Source faults, 2) Subducting plates and mega-thrust faults, 3)Crustal structure, 4) Seismogenic zone, 5) Sedimentary basins, 6) 3D velocity properties Reconstruction of source fault and velocity models allow for more realistic 3D EQ wave simulations. All of these information will be synthesized and provided to communities involved in probablistic hazards analysis, risk assessment and societal response.

In 2002, we have started to deploy seismic profiling lines in the Boso Peninsula (112 km) and the Sagami bay area(75 km) to image the subducting Philippine Sea plate

URL: http://www.eri.u-tokyo.ac.jp/daidai/index.html

S12B-1219 1330h POSTER

An Approximate Expression of Slip Velocity Time Function for Simulation of Near-field Strong Ground Motion

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Nakamura and Miyatake (2000) proposed an approximate expression of slip velocity time function for simulation of near-field strong ground motion on the basis of the numerical solution of 2D and 3D crack simulations including a slip-weakening friction law. The approximate slip rate time functions are applied to near-source seismic waves from various fault models, (a) rectangular crack in which rupture propagate unilaterally, (b) asperity model (c) square shaped crack in which rupture start around bottom corner and propagate circularly, and then compared with those from dynamic rupture model. The approximate slip rate time functions are implemented as a double couple force systems in 3D finite difference calculation (Graves, 1998). Dynamic rupture calculation is also carried out in same staggered grid 3D FD model with stress or frictional condition imposed on the fault-ruptured area. The waveform from approximate expressed slip rate function fits well to that from dynamic crack models but there exists discrepancy between them near the starting point or first asperity. In the present paper, we also discuss an approximate expression of non-uniform slip rate time function for a propagating crack. The near-fault ground motion with slip weakening friction above mentioned (a), (b), and (c). The revised expression improves the fitting.

S12B-1220 1330h POSTER

Macro-Micro Analysis Method for Computation of Strong Motion Distribution with High Resolution and High Accuracy

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In order to obtain trustful strong motion information, it is necessary to simulate the fault mechanism, the wave propagation through the heterogeneous crust, and amplification near the surface with high resolution. This simulation, however, has two difficulties, the requirement of huge computation and the uncertainty of the ground and geological structures information.

For resolving these two difficulties, we propose a new analysis method, macro-micro analysis method, which takes advantage of the singular perturbation expansion and the bounding media theory, such that required numerical computation is reduced due to the efficient multi-scale analysis and the uncertainty of the ground and geological structures information are accounted for.

In order to verify the effectiveness of this new analysis method, the observed earthquakes are simulated, and the reproduction of the strong motion is attempted. The simulation result is compared with the data observed in Yokohama City. It is shown that it succeeded in reproducing the velocity spectrum and the maximum velocity of each place in frequency domain where the calculation accuracy is guaranteed. In addition, the maximum velocity distribution of each every site is also calculated with the spatial resolution of 1[m] order. These results clearly show the effect of soil-structure, crust, and geological structure on the strong motion, and it is confirmed that large-scale numerical simulation is necessary in order to predict the strong motion with high spatial resolution in the sufficient accuracy.

S12B-1221 1330h POSTER

Octree-based finite element method for large-scale earthquake ground motion modeling in heterogeneous basins

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This work reports on the development of a parallel numerical octree-based finite element methodology for simulating large-scale earthquake-induced ground motion in highly heterogeneous basins. We target large sedimentary basins with contrasts in wavelengths of over an order of magnitude. We overcome the problem of multiple physical scales by using finite elements on locally-resolved hexahedra derived from octree-based grids. The extremely large mesh sizes require special mesh generation techniques. We use an out-of-core octree-based mesh generator developed by Tu and OHallaron (2002), which allows us to generate meshes of essentially arbitrary resolution. Despite the method's multi-resolution capability, large problem sizes necessitate the use of distributed memory parallel supercomputers to solve the elastic wave propagation problem. We have developed a system that helps automate the task of writing efficient portable octree-based mesh solvers for distributed memory parallel supercomputers. The numerical methodology and software system have been used to simulate the seismic response of both idealized systems and of the Greater Los Angeles basin to simple pulses and to an aftershock of the 1994 Northridge Earthquake, for frequencies of up to 1 Hz. We report on parallel performance on the Cray T3E and the Terascale Computing System (TCS) at the Pittsburgh Supercomputing Center for several models, ranging in size from 40,000 to 200 million hexahedra. The results indicate that, despite the highly irregular structure of the problem, excellent performance and scalability are achieved.

S12B-1222 1330h POSTER

A Test of Strong Ground Motion "Prediction" for the 26 September 1997, M_w 6.0 Colfiorito Eaethquake (Italy).

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We test a methodology to "predict" ground-motion hazard for a fixed magnitude earthquake along a specific fault or within a specific source volume. In our test, we develope constraints on rupture parameters of the 1997 Colfiorito (Italy) earthquake based on previous studies. Then we develope a suite of 100 rupture scenarios for this fault, and synthesize observed strong motion records for each scenario. We use the program HAZARD (Hutchings, 2002) to randomly select rupture parameters, and the program EMPSYN (Hutchings, 1991) to synthesize strong ground motion with empirical Green's functions. We demonstrate that 100 scenarios is sufficient to statistically span the range of possible ground motion hazard from this fault. We utilize a quantitative comparison between observed and synthesized records to examine the potential for this methodology to develop realistic synthetic strong ground motions for specific sites from specific earthquakes. In the same time we identify our best model of the 26 September 1997, $M_w = 6.0$ Colfiorito earthquake, and we interpret this model to better understand the source process.

S12B-1223 1330h POSTER

Empirical Corrections for Basin Effects in Stochastic Ground-Motion Prediction

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Amplification corrections are presented for the finite-fault stochastic ground-motion simulation model, using the code FINSIM, which represent the total amplification effects for the Los Angeles basin. Spectral amplification ratios were calculated by dividing the observed spectra for the 1994 Northridge and 1987 Whittier Narrows earthquakes by the simulated spectra created assuming an average rock-site condition. Smoothed amplification data were plotted above the three-dimensional images of the basin revealing a general correlation between the estimated basin depth and basin amplification for both earthquakes over three frequency ranges: low (0.2-2 Hz), intermediate (2-8 Hz), and high (8-12.5 Hz) frequencies. The depth-dependent corrections are derived from the regression of the combined data from both earthquakes in order to reduce an uncertainty caused by the azimuth of incoming waves.

Ground-motion duration is defined as the time for 95 percent of the seismic energy to pass after the S-wave arrival. Due to ambiguity in defining a basin parameter controlling duration, it was impossible to develop a generic equation that would relate the duration ratio (observed/synthetic) to some characteristic of the basin. Users are cautioned, though, that the durations within the basin may be as much as four times longer than the simulated ones.

The procedure is outlined for potential users who wish to use the results of this study in synthesizing more accurate earthquake ground motions, taking into account complicated basin and near-surface effects. The results are directly applicable to engineering simulation of strong-ground motions in a sedimentary-basin environment.

S12B-1224 1330h POSTER

Ground Motion Response Spectra From Recent Large Earthquakes and Its Dependence on Earthquake Magnitude, Propagation Path and Local Site Effect

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We examined ground motion response spectra from the recent large earthquakes in California, Japan, Turkey and Taiwan. We studied the distance, site, and magnitude effect on the shape of the response spectra and compared these response spectra with the standard response spectra specified by the IEEE 693-1997 for high seismic performance level of electric substation equipment. We found: (1) the shape of the averaged response spectra among different distance groups is similar, especially for the stiff soil or rock sites. (2) Averaged response spectra of soft soil sites show a greater amplification effect at lower frequencies (0.01 Hz to about 2 Hz) than the stiff soil sites or rock sites. (3) By comparing normalized response spectra from events with different magnitudes, we found an increase in low frequency spectra as magnitude increases. (4) Among the earthquakes we have examined, there are stations in every event where some of the acceleration response spectra exceed the IEEE 693-1997 standard. Those stations are generally located at sites that are: a) very close to the fault rupture trace; b) near the edge of the fault that suffer strong directivity effect; c) on the hanging wall adjacent to the primary fault trace; d) at a site with large site amplification. In the low frequency range, the excedance is usually associated with a larger magnitude earthquake at soft soil sites at near source distance (D< 50 km). For larger earthquakes, exceedance at low frequencies may become more common.

S12C MCC: 121 Monday 1330h

Historic Earthquakes II *(joint with HG)*

Presiding: **S Hough,** U.S. Geological Survey**; P Albini,** Istituto Nazionale di Geofisica e Vulcanologia

S12C-01 1330h INVITED

No Great Earthquake in the Central Himalaya Since 1505: a Possible Future M>=8.2 event?

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The re-evaluation of the past several centuries of damaging Himalayan earthquakes has largely decreased their magnitudes and/or rupture areas, with one exception. An earthquake in 1505 that simultaneously destroyed Indian cities near Agra, and Tibetan monasteries between longitudes 78° and 84° appears to be larger than any known hitherto. It occurred exactly one month after a catastrophic earthquake in Kabul, and accounts from the two earthquakes have sometimes been confused. Although the data in Tibetan accounts are sparse the event appears to have had equal violence along the 600 km northern Himalaya and in the northern plains of India. From this we infer a rupture zone possibly twice as long as that associated with recent Himalayan earthquakes, corresponding to the segment that has hitherto been termed the Central Himalayan Gap.

An enigmatic observation is that surface ruptures have been exhumed in trench investigations but have not been reported from the past two centuries of 7.8<M<8.1 earthquakes in the western and central Himalaya. These ruptures are unlikely to have developed aseismically since recent geodetic data indicate that creep processes beneath the Lesser Himalaya are negligible. A possible interpretation of the absence of recent surface ruptures is that they are associated only with the very largest Himalayan earthquakes, such as is inferred to have occurred in 1505.

Geodetic data suggest that present convergence between India and southern Tibet of 16-18 mm/year is developing as elastic strain in the Greater Himalaya. Should this have prevailed since 1505 the so-called Central Himalayan Gap may have accumulated as much as 9 m of potential slip, sufficient to drive a Mw=8.2 earthquake. The infancy of systematic trench investigations, and the absence of a long continuous written history in the Himalaya, prevents conclusions about the timing of this inferred future M=8.2 event. No forecast is currently possible, but since convergence adds roughly 1.8 m/century to the future slip potential, a longer delay will result in a correspondingly larger event.

S12C-02 1345h INVITED

Locations and Magnitudes of Historical Earthquakes from Seismic Intensity Data

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Earthquakes before about 1900 are known only through their effects, which are ranked according to intensity scales, such as the Modified Mercalli intensity (MMI) scale commonly used in the US. MMI assignments are an indirect, crude measure of earthquake ground motions, but they are sufficient to provide unbiased estimates of the location and moment magnitude **M** of historical earthquakes, defined here to be those earthquakes with intensity assignments but not recorded on seismographs. Bakun and Wentworth's (1997) technique, for example, provides estimates of location and **M** for historical events by adapting Geiger's (1910) location method and Richter's (1935) M_L prescription to MMI assignments. Such estimates are conditioned on the description of the dependence of MMI on **M** and epicentral distance Δ, MMI = a + f(**M**) + g (Δ). While the dependence of MMI on **M** appears to be consistent from region to region, the rate of decrease of MMI with Δ is very much regionally dependent. For example, MMI decrease rapidly with Δ east of the Rocky Mountains and slowly in California. Estimates of **M** for historical earthquakes depend on the MMI attenuation function applied, just as estimates of M_L depend on the log A_0 function used. Likewise, the well-known limitations of Geiger's method in locating events outside a network of vertical-component seismographs (P-arrival times only) carry over to the location of offshore historical earthquakes. However, if MMI attenuation is known and the available MMI assignments sample all azimuth sectors from the source, then unbiased, objective estimates of source location and **M** and their uncertainties can be estimated, even for events with only a few MMI assignments.

S12C-03 1400h INVITED

In Search of Missing Earthquakes in South-Eastern Alpine Area: Historical Constraints

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Geological investigation has pointed out that some seismogenic sources at the foot-hill of the South-eastern Alpine area may be able to release earthquakes with M equal or greater than 6 and a return period longer than 1000 years. The earthquakes of this size in the current catalogues cannot account for all the seismogenic sources; therefore, a few of them could represent potential seismic gaps. However, before coming to such a conclusion it is necessary to assess the completeness of the available data. This topic has been addressed according to two main issues: a) improving the background of the known earthquakes; b) assessing the completeness of the historical record in the area. Issue a) was mainly devoted to investigate, according to standard procedures, those events which are known through scanty information (few records/intensity datapoints). Issue b) was addressed by expanding to a few localities the investigation of the completeness of the site seismic record which has already been tested in about 15 localities in Italy. The basic idea is to investigate the history of a locality and to find out whether, in the time-windows in which no seismic effects are known yet, the historical records supply reliable constraints, in such a way that it is possible to conclude: i) no destructive earthquake took places; or, on the contrary: ii) nothing more can be said with respect to this. Though conclusions of this kind cannot be exhaustive, preliminary results indicate that most probably no earthquake with M equal or greater than 6, out of those listed in the catalogues, did happen in the investigated area from about 1300 on.

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Detection of Kuril Subduction-zone Earthquakes by Means of Remote Historic Records in Honshu

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Recurrence of large subduction-zone earthquakes around Japan has been estimated from historical records. For the Nankai trough, off southwest Japan, such estimates show that large earthquakes have repeated since 684 AD at average intervals of ~100-200 years. By contrast in northeastern Japan, along the southern Kuril trench, little is known about recurrence because the eastern Hokkaido has little written history earlier than 1800 AD. Here we show that historical seismicity along the Kuril trench can be estimated from remote records in Tohoku and Tokyo. Most modern M≥7 earthquakes along the Kuril trench were felt in Tohoku and all the way to Tokyo, because of low attenuation of seismic waves within the subducting Pacific plate.

During the Edo period (1600-1867 AD), government officials in Tohoku and Tokyo kept daily records that include felt earthquakes. The officials usually noted earthquake time to the nearest 2 hours or less. In Tokyo, nearly 5000 earthquakes were reported, making the average annual number nearly 20. To the north in Tohoku, surviving documents from Hirosaki, Hachinohe and Morioka report about 2500 Edo-period earthquakes starting 1644. Nearly 400 of the earthquakes (about 2 per year) were reported at multiple Tohoku locations; about 100 of these events (about 0.5 per year) were also reportedly felt in Tokyo.

Comparison with modern intensity observations indicates that the above rates are very similar to modern rates, and that the list should contain Kuril earthquakes. Modern Tokyo has an annual average of 15 felt earthquakes with seismic intensity ≥2 on the Japan Meteorological Agency scale (JMA intensity 2 corresponds to Modified Mercalli intensity III). The JMA annual averages also show about 4 earthquakes of intensity ≥2 at Tohoku, of which 0.6 reach that threshold in Tokyo as well. Nearly a quarter of these earthquakes occurred along the Kuril trench. At that rate, about 80 of the Tohoku earthquakes recorded in 1656-1867 likely had a Kuril origin.

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