S32D-06 1455h

The Prediction of Spatial Aftershock Probabilities (PRESAP)

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It is now widely accepted that the goal of deterministic earthquake prediction is unattainable in the short term and may even be forbidden by nonlinearity in the generating dynamics. This nonlinearity does not, however, preclude the estimation of earthquake probability and, in particular, how this probability might change in space and time; earthquake hazard estimation might be possible in the absence of earthquake prediction. Recently, there has been a major development in the understanding of stress triggering of earthquakes which allows accurate calculation of the spatial variation of aftershock probability following any large earthquake. Over the past few years this Coulomb stress technique (CST) has been the subject of intensive study in the geophysics literature and has been extremely successful in explaining the spatial distribution of aftershocks following several major earthquakes. The power of current micro-computers, the great number of local, telemeter seismic networks, the rapid acquisition of data from satellites coupled with the speed of modern telecommunications and data transfer all mean that it may be possible that these new techniques could be applied in a forward sense. In other words, it is theoretically possible today to make predictions of the likely spatial distribution of aftershocks in near-real-time following a large earthquake. Approximate versions of such predictions could be available within, say, 0.1 days after the mainshock and might be continually refined and updated over the next 100 days. The European Commission has recently provided funding for a project to assess the extent to which it is currently possible to move CST predictions into a practically useful time frame so that low-confidence estimates of aftershock probability might be made within a few hours of an event and improved in near-real-time, as data of better quality become available over the following day to tens of days. Specifically, the project aim is to assess the extent to which this is scientifically feasible in terms of our understanding of the physical phenomena which control the variation of seismicity following a large event due to stress redistribution and practically possible given present limitations on data availability, data quality and computational or data transfer speeds. The project is divided into a number of elements designed to reflect the temporal sequence of tasks that must be undertaken for the prediction of aftershock hazard. These tasks include determining a time-indexed sequence of slip distributions for both real and synthetic events, calculating a suite of time-indexed stress perturbations and quantitatively comprising predicted and observed aftershock distributions, and developing techniques for predicting likely strong ground motion from the predicted spatial distribution of aftershocks.

S32D-07 1510h

A Possible Triggering Mechanism for the Earthquake Swarms in Vogtland/NW-Bohemia: Data Analysis and Numerical Modeling

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Vogtland/NW-Bohemia (VB) at the German/Czech border region, central Europe, is characterized by recurring intraplate earthquake swarms, Quaternary volcanism, carbon-dioxide-rich mineral springs, a complex tectonic environment of intersecting fault systems, and an established connection between ascending magmatic fluids and seismicity. As the triggering mechanism of seismicity in VB is still unknown, this study aims to contribute by investigating the possible role of fluids in VB, based on the theory of linear poroelasticity. We assume that ascending fluids, of magmatic origin, trigger earthquakes by the mechanism of pore-pressure diffusion (i.e. relaxation). Two physical fields, the hydraulic diffusivity and the criticality (i.e. critical pore-pressure value leading to failure), both heterogeneously distributed in rocks, mainly control this triggering process. The results of the analysis of the year 2000 earthquake swarm data allowed the identification of diffusive characteristics, thus supporting this concept. It is further strengthened by a numerical model, with correlated high-diffusivity and high-criticality patches (corresponding to highly fractured and permeable compartments of the fault zone region in VB), which successfully simulates the general seismicity pattern of the earthquake swarms 2000, including the spatio-temporal clustering of the events, and the seismic activity migration.

S32D-08 1525h

Plate-Tectonic Analysis of Shallow Seismicity: Apparent Boundary Width, beta-Value, Corner Magnitude, Coupled Lithosphere Thickness, and Coupling in 7 Tectonic Settings

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A new plate model [*Bird*, 2003, G^3, 10.1029/2001GC000252] is used to analyze the mean seismicities of 7 types of plate boundary (CRB continental rift boundary, CTF continental transform fault, CCB continental convergent boundary, OSR oceanic spreading ridge, OTF oceanic transform fault, OCB oceanic convergent boundary, SUB subduction zone). We compare the plate-like (non-orogen) regions of model PB2002 with the CMT catalog to select apparent boundary half-widths, and then assign 95% of shallow earthquakes to one of these settings. A tapered Gutenberg-Richter model of the frequency/moment relation is fit to the subcatalog for each setting by maximum-likelihood. Best-fitting β values range from 0.53 to 0.92, but all 95%-confidence ranges are consistent with a common value of 0.61-0.66. To better determine some corner magnitudes we expand the subcatalogs by: (1) inclusion of orogens; and (2) inclusion of years 1900-1975 from the catalog of *Pacheco and Sykes* [1992]. Combining both earthquake statistics and the plate-tectonic constraint on moment rate, corner magnitudes include: CRB $7.64_{-.26}{}^{+.76}$, CTF $8.01_{-.21}{}^{+.45}$, CCB $8.46_{-.39}{}^{+.21}$, OCB $8.04_{-.22}{}^{+.52}$, and SUB $9.58_{-.46}{}^{+.48}$. Coupled lithosphere thicknesses are found to be: CRB $3.0_{-1.4}{}^{+7.0}$ km; CTF $8.6_{-4.1}{}^{+11}$ km; CCB $18_{-11}{}^{+?}$ km; OSR $0.13_{-0.09}{}^{+.13}$ km for normal-faulting and $0.40_{-.21}{}^{+?}$ km for strike-slip; OTF $12_{-7.1}{}^{+?}$, $1.6_{-0.5}{}^{+1.4}$, and $1.5_{-0.6}{}^{+1.2}$ km at low, medium, and high velocities; OCB $3.8_{-2.3}{}^{+13.7}$ km, and SUB $18.0_{-10.8}{}^{+?}$ km. Generally high coupling of subduction and continental plate boundaries suggests that here all seismic gaps are dangerous unless proven to be creeping. Generally low coupling within oceanic lithosphere suggests a different model of isolated seismic asperities surrounded by large seismic gaps which may be permanent.

URL: http://moho.ess.ucla.edu/~kagan/kagan.html

S32E MCC: 3011 Wednesday 1600h

Global and Regional Tomography II
(joint with DI)

***Presiding:* D W Vasco,** Berkeley Laboratory, University of California, Berkeley**; R D van der Hilst,** Massachusetts Institute of Technology

S32E-01 1600h

Resolution Limit of Traveltime Tomography

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We derive an explicit formula relating a recovered 3-D seismic slowness image to the actual seismic slowness, under the assumption that a tomographically complete collection of finite-frequency traveltime shifts is inverted using linearized ray theory. The tomographically recovered image is blunted, or diminished in amplitude, and blurred, or spread laterally, as a result of wavefront healing and other finite-frequency diffraction effects. The 1-D spreading $\sim$ (amplitude reduction)$^{-1/3}$, so that total volume-integrated slowness is conserved.

S32E-02 1615h

3D mantle P-velocity model based on uniform tetrahedronization of the Earth and the natural-neighbour interpolation method

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Traditional parameterization of three dimensional (3D) Earth models consists of radial and horizontal basis functions with a constant lateral grid size, independent of depth. As a result, the horizontal basis functions become more densely distributed with increasing depth. The nominal resolution thus becomes finer. For example, in the lower mantle and D" region, current whole-mantle models appear to be characterized by particularly short-wavelength structures and high gradients, which might not be real features. In this study, we use instead a 3D parameterization generated by an "advancing front method" (NETGEN), given an initial triangulation on the surface of the Earth. The result is a number of tetrahedrons of optimal and roughly similar size making up of the Earth's volume. We then utilize the natural neighbour interpolation technique to set up the whole mantle 3D inverse problem. The functional value (in our case, perturbation to the P-velocity) at any point within the Earth can be found through interpolation of the values of its natural neighbours (on the order of 10). The number of nodes decreases with depth as the volume decreases. The basis function at each node is smooth, and dependent on the distances of other nodes around it. No separation of radial and horizontal basis functions is needed. Synthetic tests with 3D S-model S362 show that most of significant structures of S362 are recovered. Two major differences exist: (1) at 2,500 km and 2,800 km depth, the recovered model is smoother and has less short-wavelength signal than S362; (2) at the surface and CMB, the recovered S-velocity perturbation tends to be larger than S362. Currently we are deriving a whole mantle P-model. The preliminary result is promising. Compared to the traditional approach which employs both radial and horizontal basis functions, this parameterization allows a true 3D representation of the Earth's seismic velocity perturbations. It is also straightforward to build norm and roughness damping matrices and apply them to the target model. Because of the ease of the grid generation and the grid-dependent basis functions, it is also possible to introduce multigrid (finer resolution in a particular region) into the 3D seismic tomography to achieve multi-scale resolution.

S32E-03 1630h

Long-period mantle structure from Earth's free oscillation spectra

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Models of the Earth's long period three dimensional structure are obtained from the study of the splitting of Earth's free oscillation spectra. These data place important constraints on the aspherical compressional and shear wave velocity structure, and in addition has the capability to provide information on aspherical density structure. In general, *splitting functions* are measured from the normal mode spectra using a least squares inversion. These splitting functions are linearly dependent upon the aspherical velocity and density structure and are then used in a second least squares inversion to obtain tomographic velocity models. Many recent tomographic models, including S20RTS, have used splitting functions in addition to body wave and surface wave data. In principle, normal mode spectra could also be inverted directly to get tomographic models. In order to use splitting functions, it has been assumed that modes are isolated and therefore can be studied in the self-coupling approximation or that only small groups of modes need to be coupled. We will show that for many modes, this represents a poor approximation compared to full coupling, where large groups of modes are coupled. This implies that it is actually not accurate enough to use splitting functions. In order to access the influence of the splitting function approximation on the long period structure in tomographic models, we have performed tests for a data set of normal mode spectra of recent large earthquakes, including the Bolivia and Kuril Island events of 1994. We will show the different tomographic models obtained from a two-step inversions using splitting functions compared with a one-step direct inversion of the normal mode spectra. We will also show the difference between a direct inversion of normal spectra using the self coupling approximation versus the group coupling approximation.

S32E-04 1645h

News from MIDSEA Seismograms on the Upper Mantle of the Eurasia-Africa Plate Boundary Region

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From an extensive study of P to S converted waves, surface waves, and literature data on crustal thickness in this region, we first mapped the depth to the Moho. Our Moho map extends from relatively well-known southern Europe into northern Africa to the south and the Atlantic ocean to the west. We interpret the western Mediterranean to have considerably extended continental crust, the central Mediterranean to have oceanic crust in the north and standard continental crust in the south, the eastern Mediterranean to have continental crust underlying a thick pile of sediments, and the Atlantic Ocean to have an anomalously thick crust and/or a very low sub-Moho S velocity. Mapping this highly heterogeneous crust has helped us to obtain cleaner tomographic images of upper mantle S-velocity structure than possible without our Moho map. In addition to well-known high-velocity subducting lithosphere, these images reveal a widespread shallow low-velocity layer beneath the Mediterranean basin that strongly varies spatially. The images also show widespread high-velocity anomalies in the transition zone beneath the Mediterranean region, which we interpret as fragments of subdcuted lithosphere. One such fragment is beneath NE Spain and possibly related to early Cenozoic subduction there. We also investigated mantle discontinuities below the Mediterranean region and find that P to S converted waves from the 660 km discontinuity are consistent with a sharp discontinuity while those for the 410 km discontinuity indicate that this discontinuity can be 20 to 30 km thick. Our preferred explanation for this anomalously thick 410 km discontinuity is that it was thickened by olivine being hydrated by about 0.05 wt %.

URL: http://www.sg.geophys.ethz.ch/midsea/

S32E-05 1700h

Tomographic modeling of the North American upper mantle

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A large amount of digital seismic data recorded at stations in North America is now available, and the Earthscope project will, over the next decade, increase the amount of data available dramatically. This large amount of high-quality data makes it possible to constrain the three-dimensional velocity structure of the North American upper mantle with a resolving wavelength of several hundred kilometers; improvements in resolution can be expected in the near future. We have collected Love and Rayleigh wave dispersion measurements (T=35–150 s) at stations of the national networks of the U.S. and Canada, as well as at the stations of several temporary networks, using the method of Ekström et al. (1997). These measurements are combined with a similar dataset of global dispersion measurements (T=35–350 s) in an inversion for 3-D, radially anisotropic, S-velocity structure under North America. This modeling follows the approach of Boschi (2002), in which a variable-resolution, global parameterization is used to allow for the simultaneous retrieval of long-wavelength structure globally and shorter-wavelength structure locally. The model we retrieve shows good correspondence with major geological features, with a narrow transition from fast to slow velocities near the edge of the North American craton and a thick (∼275 km) continental root under the Canadian shield. No strong regional variations in radial anisotropy are observed. A second approach to the modeling of seismic velocity structure under the North American continent is to invert for a regional perturbation to a pre-existing global model, with appropriate corrections made for structure encountered by seismic waves along their travel paths outside of North America. Preliminary results suggest that this approach provides an effective and efficient means by which to produce and update a regional or continental-scale model. Such an approach may prove particularly useful as data from USArray begin to arrive during the coming years. In addition to a comparison of results obtained using the two approaches described here, we make a quantitative comparison of our models and previous models of the North American upper mantle (van der Lee, 2002; Godey, 2002) obtained using different datasets and modeling methods.

S32E-06 1715h

Global Travel Time Tomography Using ANSS Real Time Data

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As part of the implementation of the Advanced National Seismic System (ANSS) waveform data of a large, growing number of seismic stations from US regional networks is being received in near real time at the National Earthquake Information Center (NEIC) in Golden, CO. A very large number of these stations are only used for regional earthquake monitoring and therefore do not report routinely arrival times from teleseismic events, which could be very useful for imaging in great detail the upper mantle structure beneath the continental US. The availability of this large volume of waveform data in a single data center allows us to carry out the processing (phase picking) in an efficient and consistent manner. For this purpose we have developed a procedure that combines automatic absolute picking, followed by more accurate relative picking using waveform cross-correlation. The algorithm is automated in order to handle the expected large data flow (currently about 40 monitoring networks operate in the US for a total of 3,000 stations) but also allows for interactive quality control. In its testing phase we have processed 125 events occurred in 2002-2003 which provided 18,688 new P-wave arrival times, more than in most teleseismic experiments. We have used these new travel times in combination with a large global dataset of reprocessed ISC data to obtain a global tomographic model of P-wave velocity structure. Although the model is global, the most visible improvements are in the western US, where the data increase and station density is largest. Preliminary results show a more detailed image of the structure in the upper mantle, also due to the incorporation of regional travel times in the new global dataset. A particularly well-imaged feature is the subducted Juan de Fuca slab beneath the Pacific Northwest. The slab is sharply defined between 100 and 410 km depth, extending from the Puget Sound region through Oregon to Northern California, well south of the Mendocino triple junction. We anticipate that with the incorporation of additional networks and the processing of new events the resulting tomographic models will provide significantly improved images of the upper mantle seismic structure beneath the continental US.

S32E-07 1730h

Source and Receiver Effects on Rayleigh Waves

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Recent studies have greatly advanced knowledge of the three-dimensional structure of the upper mantle, but, up to now, the influence of source and receiver effects on the observed seismic waveforms has received little attention. In addition to the path, surface waves are also affected by source and receiver anomalous local structures and by uncertainties in the source mechanism and hypocenter coordinates. Separating each of these contributions to the seismic wavefield is a major challenge in seismic waveform tomography. We use full surface wave ray theory upon 3-D mantle model S20RTS combined with global crust model CRUST 2.0 to investigate these effects on Rayleigh waves. Since full ray theory allows one to express the seismic wavefield in terms of the product of a source term, a term due to propagation and a receiver term, it is a useful tool to study the relative influence of each of these terms. Besides, we use it in an iterative inversion procedure similar to the Harvard-CMT method to determine earthquake source parameters. We estimate that the influence of the local structure at the receiver on the vertical-component waveforms is negligible compared with the other terms. Likewise, the resulting phase perturbation due to local effects, both at the source and at the receiver, is small. However, theoretical amplitude anomalies due to the local structure at the source and to the deviation in takeoff azimuth of the ray leaving the source are more important than previously thought. These two types of anomalies have similar magnitudes and the resulting perturbation is as important as that produced by focusing and defocusing effects along the propagation path. Moreover, we investigate the impact of the ray theoretical forward modelling in characterising the seismic source of large, global events. Including the overall source anomaly into the modelling improves the fits of the theoretical seismograms to the data, and, hence, our ability to extract additional information from the available data. These effects should be taken into account in the next generations of tomography models.

S32E-08 1745h

A Lithospheric Study of Eastern Asia Using Surface Wave Dispersion

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We have continued our study of surface-wave group-velocity dispersion across Eastern Asia in the vicinity of the Korean Peninsula, Yellow Sea, and Sea of Japan. We primarily use seismic data from permanent stations in South Korea, China, Japan, Taiwan and Russia. We also use data from several IRIS PASSCAL deployments in China and North Korea. We measure group-velocity using multiple narrow-band filters on deconvolved displacement data. We use a conjugate gradient method to perform a high-resolution group-velocity tomography over the region. Our current results include Rayleigh wave inversions for periods from 10 to 100 seconds. There is an excellent correspondence between the group velocities and tectonic structure, including large sedimentary features and crustal thickness variations. At long periods (> 50 sec), we find that the inversion has features associated with the subduction of the Pacific and Philippine Plates under the Eurasian continent, including the effects of the subducting slab and magmatic arc. We use the group-velocity results to model the shear-velocity structure of the crust and upper mantle across the region. We employ a grid-search technique to fit the Rayleigh wave group-velocities over the whole period range. This does a very good job at retrieving features in the crust and uppermost mantle. Deeper features in the mantle, however, are harder to model directly using this method. To resolve these features, we will be forwarding modeling the structure by constructing several models of the subduction zone. We will then be testing the various models by comparing the group velocities predicted by the models to the observed group velocities along cross-sections. Preliminary results indicate that the magmatic arc has the largest affect on the long period surface waves, with the subducting slab being a much subtler feature.

S32F MCC: 3009 Wednesday 1600h

S

Stress Transfer, Triggered Earthquakes, and Time-Dependent Seismic Hazard IV *(joint with G, T, NG)*

Presiding: **S A Miller,** Geophysics Institute, ETH-Hoenggerberg**; R Shcherbakov,** University of California, Davis

S32F-01 1600h

A Seismic-Wave-Induced Fluid Pressure Increase: An Alternative Hypothesis for the Strain Transient at Long Valley Caldera Following the 1992 M7.3 Landers, California Earthquake

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