S22D-03 1420h

Kirchhoff Reconstruction for Real-Time Fault Rupture Determination

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We present a method for locating earthquake ruptures in real time using Kirchhoff reconstruction. The method determines not the hypocenter, but the actual shape and dimensions of the earthquake fault rupture. The real time capability to generate a detailed rupture map will provide emergency response teams with information about the region of damage and thereby allow them to optimize the distribution of resources and personnel. In addition, it will allow for rapid deployment of instruments focused on collecting observations of post-seismic activity. Computational time does not scale with event magnitude, so the Kirchhoff reconstruction method can accurately handle earthquakes of any magnitude. The Kirchhoff method uses measurements of ground motion from an array of sensors. A grid is generated covering the area of interest. The ground motion at each grid coordinate is summed based on the measurements at contributing sensor locations and the wave propagation time and distance from these locations. Correlation of the measurements occurs at the grid points that correspond to the trace of the event. Our implementation handles arbitrary grid densities and configurations, allowing high resolution over areas of interest. The method is furthermore independent of any particular sensor geometry. The software is capable of integrating the most detailed rheology or wave velocity model available, in order to achieve greater accuracy. Preliminary results are presented for tests of the method on both simulated and historic data. We demonstrate the robustness of the method with respect to signal noise, and show the level of detail and precision available for example historic events. We intend for the software to be integrated into the TriNet earthquake information system. This will enhance the service TriNet provides to emergency response teams and scientists and researchers assessing the status of seismic activity. The Kirchhoff method can contribute to development of a computerized alert network. The continuous sequence of ground motion images generated by the method provide a rich source of data for further types of science analysis, including the application of various pattern recognition and data mining techniques.

S22D-04 1435h

Locating and Modeling Regional Earthquakes with Broadband Waveform Data

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Retrieving source parameters of small earthquakes (Mw < 4.5), including mechanism, depth, location and origin time, relies on local and regional seismic data. Although source characterization for such small events achieves a satisfactory stage in some places with a dense seismic network, such as TriNet, Southern California, a worthy revisit to the historical events in these places or an effective, real-time investigation of small events in many other places, where normally only a few local waveforms plus some short-period recordings are available, is still a problem. To address this issue, we introduce a new type of approach that estimates location, depth, origin time and fault parameters based on 3-component waveform matching in terms of separated Pnl, Rayleigh and Love waves. We show that most local waveforms can be well modeled by a regionalized 1-D model plus different timing corrections for Pnl, Rayleigh and Love waves at relatively long periods, i.e., 4-100 sec for Pnl, and 8-100 sec for surface waves, except for few anomalous paths involving greater structural complexity, meanwhile, these timing corrections reveal similar azimuthal patterns for well-located cluster events, despite their different focal mechanisms. Thus, we can calibrate the paths separately for Pnl, Rayleigh and Love waves with the timing corrections from well-determined events widely recorded by a dense modern seismic network or a temporary PASSCAL experiment. In return, we can locate events and extract their fault parameters by waveform matching for available waveform data, which could be as less as from two stations, assuming timing corrections from the calibration. The accuracy of the obtained source parameters is subject to the error carried by the events used for the calibration. The detailed method requires a Green's function library constructed from a regionalized 1-D model together with necessary calibration information, and adopts a grid search strategy for both hypercenter and focal mechanism. We show that the whole process can be easily automated and routinely provide reliable source parameter estimates with a couple of broadband stations. Two applications in the Tibet Plateau and Southern California will be presented along with comparisons of results against other methods.

S22D-05 1450h

Constraining hypocentral position by focal mechanism and 3D velocity model

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The quality of earthquake hypocentral position relies on distribution of stations, precision of traveltime picks, and quality of the velocity model. In light of recent advance in improved station coverage, cross-correlation time picking, and more detailed 3D velocity models, I will discuss two approaches to further improve the hypocentral determination. The first is a joint determination of hypocenters with first-motion focal mechanisms. While the hypocentral determination suffers from the tradeoff between focal depth and origin time, focal mechanism solution depends on the hypocentral position but not the origin time. Hence a joint determination of both hypocenter and focal mechanism could improve both solutions. Since the first-motion polarity data is now available at many stations, the joint process is very effective, as shown by tests on over 40,000 earthquakes in southern California. The second approach is a thorough evaluation of the impact of 3D velocity model on the hypocentral determination, particularly in some general scenarios where hypocentral position can be systematically biased by the model error. One such scenario is near the edge of a basin, where the wedge-shaped low velocity basin is difficult to be constrained accurately by most tomographic methods. In this case the location of the basement boundary will greatly impact both lateral and depth positions of the earthquakes. I will present a new deformable-layered tomography method that is effective in constraining the basin boundaries. In general, the 3D velocity model shall be determined together with hypocenters and focal mechanisms of most earthquakes.

S22D-06 1505h

Probabilistic earthquake location and 3-D velocity models in routine earthquake location

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Earthquake monitoring agencies, such as local networks or CTBTO, are faced with the dilemma of providing routine earthquake locations in near real-time with high precision and meaningful uncertainty information. Traditionally, routine earthquake locations are obtained from linearized inversion using layered seismic velocity models. This approach is fast and simple. However, uncertainties derived from a linear approximation to a set of non-linear equations can be imprecise, unreliable, or even misleading. In addition, 1-D velocity models are a poor approximation to real Earth structure in tectonically complex regions. In this paper, we discuss the routine location of earthquakes in near real-time with high precision using non-linear, probabilistic location methods and 3-D velocity models. The combination of non-linear, global search algorithms with probabilistic earthquake location provides a fast and reliable tool for earthquake location that can be used with any kind of velocity model. The probabilistic solution to the earthquake location includes a complete description of location uncertainties, which may be irregular and multimodal. We present applications of this approach to determine seismicity in Switzerland and in Yellowstone National Park, WY. Comparing our earthquake locations to earthquake locations obtained using linearized inversion and 1-D velocity models clearly demonstrates the advantages of probabilistic earthquake location and 3-D velocity models. For example, the more complete and reliable uncertainty information of non-linear, probabilistic earthquake location greatly facilitates the identification of poorly constrained hypocenters. Such events are often not identified in linearized earthquake location, since the location uncertainties are determined with a simplified, localized and approximate Gaussian statistic.

S22D-07 1520h INVITED

Bayesian Location of Seismic Sequences in 3D Media

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We have developed a method for the Bayesian location of seismic sequences in three dimensional heterogeneous velocity models. The method is based on a Bayesian algorithm for single earthquake location. Joint location of seismic sequences is performed by adding together the probability density functions for individual earthquake locations. One of the main features of the method is the possibility to accumulate travel times in the heterogeneous model, as a function of both the seismic stations and of the grid points simulating the seismogenic volume. The possibility to separate the travel time computation, performed just once, from the location process, is an attractive feature for implementing fast location procedures in 3D models, for instance for surveillance purposes. Probabilistic location of seismic sequences, visualised in terms of contours of earthquake density, moment and energy release etc., can be obtained to give much more seismotectonic insight than classical location algorithms displayed with dots on maps. The continuous character of the output quantities is particularly indicated for seismic network testing purposes. It is in fact possible to compute the response of the location procedure, given the seismic network geometry, to various input earthquake distributions. Some applications of the method are also shown in this work, both to the location of synthetic earthquakes end of real sequences, in volcanic and tectonic areas.

S22E MCC: 3009 Tuesday 1600h

Mechanical Strength of the Continental Lithosphere II *(joint with T, V)*

Presiding: **F J Simons,** Princeton University**; M R Drury,** Utrecht University

S22E-01 1600h INVITED

Rheological Stratification of the Continental Lithosphere: Constraints from Space Geodesy

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Postseismic transient deformation, isostatic rebound from removal of pluvial lake loads, and lithospheric deflection due to reservoir impoundment are each converging on consistent rheological models for the crust and upper mantle of actively deforming continental regions. These results imply a strong elastic crust 25-40 km thick overlain by a viscoelastic substrate with an effective viscosity of 10**18 to 10**19 Pa-s. The most surprising result of these studies is that the upper mantle is weaker than the lower crust. However, the lower crust in these regions may deform by ductile flow on longer time scales, and the data provide a lower bound of 10**20 Pa-s for its effective viscosity. This bound on lower crustal viscosity is consistent with spectral admittance studies of the gravity field and its relation to topography in the western U. S. (Lowry et al., 2000). These results indicate effective elastic lithospheric thickness is 5-15 km in the same regions where the post-loading results indicate the entire crust is strong over about 10 to 10,000 years. Recent (and not so recent) relevant results include: (1) Deformation imaged by InSAR and GPS following the 1992 Landers and 1999 Hector Mine, California earthquakes; (2) Leveling surveys following the 1959 M=7.3 Hegben Lake, Montana earthquake; (3) Isostatic rebound of Lake Bonneville, Utah; (4) Leveling surveys following filling of Lake Mead, Arizona in 1935. Postseismic transient deformation observed following several other recent large earthquakes provides potential constraints on bulk rheology of the lithosphere. However, deformation following events at major plate boundaries, including the 1993 Hokkaido-oki (M=7.8), 1999 Taiwan

(M=7.6) and 1999 Izmet (M=7.5) earthquakes is dominated by the effects of buried aseismic afterslip, making it difficult to extract any signals that may be due to bulk relaxation of the lower crust and upper mantle. This suggests that large intraplate earthquakes on faults adjacent to major plate boundaries may be the best sources for probing the rheology of actively deforming continental lithosphere.

S22E-02 1615h

Lithosperic strength and current tectonics of the Northern Canadian Cordillera

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Western Canada exhibits large variations in continental lithosphere from very old rocks in the Canadian Shield across the younger Cordillera to the current accretion of the Yakutat Terrane in the Gulf of Alaska. The Northern Canadian Cordillera is remarkably tectonically and seismically active, extending from this terrane collision zone to the fold and thrust belt at the eastern mountain front. The geodynamics are driven by the Pacific-North America relative plate motion resulting in deformation, seismicity, and mountain building across the whole Northern Canadian Cordillera. Important constraints on the tectonic regime are provide by topography and gravity, estimates of lithosphere thickness and strength, the thermal regime, seismicity, and deformation rates from precision GPS data. The way the lithosphere reacts to deformation or loading depends on its thickness and strength. The effective elastic thickness of the lithosphere, Te, has been estimated over the region using a coherence analysis of Bouguer gravity and topography. There is very thick and strong lithosphere in the old Canadian Shield (T_e = 100 km) and thin and weak lithosphere in the Cordillera (T_e = 20-30 km). Lithospheric temperatures are the most important control on the strength of the lithosphere, and the depths to the thermally controlled brittle-ductile transition are in general agreement with the T_e estimates. The high temperatures in the lower crust and upper mantle of the Cordillera reduce the density by thermal expansion. This thermal isostasy explains the surprising observation of high elevations over thin crust in the Cordillera. In the Canadian Cordillera high temperatures result in a weak zone in the lower crust facilitating detachment of the upper crust. Analysis of GPS continuous and campaign data show that the Northern Cordillera is moving at 5-10 mm/y in a northward direction driven by the collision of the Yakutat Block in the Gulf of Alaska and is overthrusting the strong lithosphere of the Canadian Shield. This is supported by the distribution and rate of seismicity. A 2D finite element mechanical model has been used to model the horizontal strain transfer over a distance of 600-800 km, the development of a lower crust detachment zone, and thrusting at the eastern mountain front.

S22E-03 1630h

Water Weakening of Clinopyroxene in the Dislocation Creep Regime

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In our experimental studies, we investigated water weakening in the dislocation creep regime of natural Sleaford Bay clinopyroxenite containing diopside of compostion $Ca_{1.0}Mg_{0.8}Fe_{0.2}Si_2O_6$. Samples were deformed in a gas-medium apparatus at confining pressures of 300 to 400 MPa and temperatures of 1373 to 1498 K with the oxygen fugacity buffered by the solid state reaction between Ni and NiO. A small amount of free water was added to each sample to obtain water-saturated conditions. Based on results from compressive creep experiments on seven samples deformed under hydrous condition, coarse-grained natural clinopyroxene yielded a stress exponent of $n = 3.6 \pm 0.6$ and an activation energy of $Q = 520 \pm 63$KJ/mol. Compared to published data for dislocation creep of dry clinopyroxene, the wet aggregate flows up to 150 times faster at a given stress and temperature. Together with creep data for olivine, which show that olivine flows less than 10 times faster under hydrous condition than under anhydrous condition, the water weakening effect is much more significant in clinopyroxene than in olivine.

S22E-04 1645h

Deformation Mechanism Maps for Feldspar Rocks

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Feldspar is the most abundant mineral in the Earth's crust. The deformation behavior of feldspar-rich rocks like granitoids and gneisses largely controls the strength of the continental crust. Deformation mechanisms maps for feldspar rocks were constructed based on recently published constitutive laws for dislocation and grain boundary diffusion creep of wet and dry plagioclase aggregates. The maps display constant temperature contours in stress-grain size space for strain rates ranging from 10^{-16} s^{-1} - 10^{-12} s^{-1}. Two fields of dominance of grain boundary diffusion-controlled creep and dislocation creep are separated by a strongly grain size-sensitive transition zone. For wet rocks diffusion-controlled creep dominates below a grain size of about 0.1-1 mm, depending on temperature, stress, strain rate, and feldspar composition. The strength of feldspar rocks is moderately dependent on composition and water fugacity, but is strongly affected by water trace content. Dry feldspar rocks are stronger than water-bearing aggregates by more than two orders of magnitude in stress. For a grain size range of about 10-50 μm commonly observed in rocks from natural shear zones the deformation maps predict that diffusion-controlled creep is dominant at pressure and temperature conditions typical for the lower crust. Low-viscosity estimates of 10^{18}-10^{19} Pa.s from modelling postseismic stress relaxation and channel flow of the continental lower crust can only be reconciled with laboratory experiments assuming dislocation creep at high temperatures $> 900 deg$ C or, at lower temperatures, diffusion creep of fine-grained rocks possibly localized in abundant high-strain shear zones. Viscosity of the lower crust is predicted to be less than one order of magnitude smaller than that of the upper mantle.

S22E-05 1700h

On the Strength Contrast Between Naturally Deformed Crust and Mantle Rocks.

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Field studies on upper mantle peridotite bodies provide information on deformation processes and mechanical strength of continental upper mantle rocks. Microstructures and lattice preferred orientations (LPO) in many continental peridotites indicate that dislocation creep is often the dominant deformation process in medium to coarse-grained rocks. Such coarse, dry, mantle rocks are expected to be much stronger than continental crust. In this contribution an example is described where, grain-size sensitive creep was the dominant deformation mechanism resulting in a low strength contrast between crust and mantle rocks. The example is from hydrated ultra-high-pressure peridotites from W. Norway. The geometry of folded compositional layers and the foliation refraction across layers implies that fine-grained olivine and pyroxene rocks are weaker than coarse-grained rocks. The structures are consistent with a granular flow process, like diffusion creep, with a limited viscosity contrast between the compositional layers. Some of the fold generations in the mantle rocks were formed after the mantle peridotites were emplaced into the continental crust. The intense post-emplacement deformation in the mantle rocks is consistent with a limited strength contrast between the hydrated mantle rocks and the surrounding quartzo-feldspathic crustal rocks.

S22E-06 1715h

Melt Segregation & LPO in Anorthite-Basalt Deformed in Torsion

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Deformation in the middle and lower crust is in large part controlled by the rheology of feldspar. Seismic studies have shown that the middle crust of orogenic belts is partially molten. Structural studies of mylonites and migmatites from these terrains record large strain deformation. Therefore, we performed torsional shear deformation experiments on fine grained (10 μm) samples of Beaver Bay anorthite (An_{70}) $\pm$ 10 vol% basalt to shear strains γ = 2-6 to investigate the development of lattice preferred orientation (LPO) and melt segregation at large shear strains. We performed experiments in a gas medium apparatus equipped with an internal torque cell at T = 1450 K, P = 300 MPa, and constant twist rate. Melt segregated in the An_{70} + basalt samples into melt-rich bands oriented at $\sim 20^\circ$ to the shear plane and antithetic to the shear direction. The spacing between bands is $\sim$0.5 mm. Distortion of the iron jacket demonstrates that strain localized in the melt-rich bands. We determined the LPO of An_{70} with scanning electron microscopy using electron back scatter diffraction (SEM-EBSD). In patterns from an An_{70}+ basalt sample deformed to $\gamma \approx 2.5$, (001) planes are aligned subparallel to the shear plane and [100] axes are concentrated close to the shear direction. Both the (001) and the [100] are rotated counter clockwise from the shear direction by 20-25°. The formation of melt-rich bands is consistent with results from simple shear experiments on olivine + chromite + basalt and olivine + FeS $\pm$ basalt, as well as An_{70} + basalt and indicates that deformation can drive melt segregation. Deformation drives the self organization of melt-rich bands and decreases the effective viscosity of the rock. The LPO is consistent with results from experiments on albite in shear and anorthite in compression and compatible with slip dominantly on (001) with [100] as the slip direction. A similar back rotation, attributed to partitioning of the strain between melt-rich and melt-depleted regions, occurred in partially molten olivine rich samples deformed in simple shear. The formation of melt-rich bands and the development of LPO in plagioclase during high strain shear experiments will lead to significant shear wave splitting and seismic anisotropy in the continental lithosphere.

S22E-07 1730h

Strength, strain, and structure of the Australian continental lithosphere

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The diverse geologic makeup of Australia makes the continent an ideal candidate to investigate the relation of lithospheric strength to the age of the overlying crust. Australia is made up from Archean cratons, Proterozoic orogens and Phanerozoic formations in a west-to-east age decrease. Surrounded by active earthquake belts, Australia is ideally suited for regional seismic tomographic studies. High-quality seismic data sets from portable SKIPPY instruments have been inverted to yield detailed models of the three-dimensional wave speed structure, including its anisotropy. Australia's topography is subdued, which makes strength measurements using traditional admittance/coherence techniques between gravity and topography rather difficult. However, the development of advanced spectral techniques has made measurements of the relative strength of the lithosphere possible. In particular, the application of multitaper techniques for cross-spectral analysis has enabled us to study elastic thickness variations with location (and thus age) as well as azimuth (measuring strength anisotropy). Using our seismic wave speed model we have estimated the thickness of the high-velocity lid underlying the Australian continent and compared it to coherence estimates of its elastic thickness. The variations in seismic thickness within broad age divisions of the Australian continent are larger than the differences between the means over the age groups. This is especially surprising for the Australian Archean, whose high-velocity lid is far less pronounced than traditional evolution models would have suggested. Following a similar pattern, the mechanical strength of the lithosphere increases with age to first order only, and substantial strength differences exist within domains of equal crustal age. Seismically thicker continental keels are not necessarily mechanically stronger, and shallow mechanical strength does not appear to control the preservation of such keels. The seismic data set and the two-dimensional coherence measurements can respectively be analyzed for anisotropy in the wave speed deviations or mechanical strength variations. Surface-wave tomography and gravity-topography analysis can thus provide independent measures of elastic anisotropy (one instantaneous, the second long-term) and, by implication, strain in the lithospheric upper mantle. The depth variation of their relation resolves a change both in the character of seismic anisotropy and in its relation to strain near $\sim$200 km depth in the Australian subcontinental lithospheric mantle. In our interpretation, the top 200 km of the Australian lithosphere primarily records the coherent signature of past deformation episodes, whereas below 200 km, active processes related to current plate motion provide the dominant explanation for the observed seismic anisotropy. The alignment of the fast axes in the flow direction is consistent with the deformation of a dry olivine mantle by simple shear. The correspondence between seismic fast axes and plate motion of Australia is best when the latter is expressed in a hot-spot reference frame. Thus, seismic anisotropy can add information on plate motion with respect to the underlying mantle that is independent from geodetic and plate-circuit constraints. Finally, the comparison of our results with mantle convection simulations suggests how seismic and mechanical models of the lithosphere are approaching resolutions at which they can be treated as "data" to refine forward models, thereby strengthening the crucial links between seismology, tectonics, and geodynamics.

S22E-08 1745h

Did Flow of Weak Middle or Lower Crust Accommodate Extension in the Gulf of California and Salton Trough?

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The strength of middle and/or lower crust (MLC) is key to understanding continental deformation and controls whether or not brittle upper crust and mantle lithosphere are coupled: weak MLC may flow and decouple the adjacent layers. We analyze the extent of MLC flow during rifting in the northern Gulf of California and Salton Trough (NGC/ST; in the NSF MARGINS Rupturing of Continental Lithosphere focus site) using area-balance techniques to compare upper crustal extension and MLC extension. Mid-Tertiary extension in SE CA, W AZ and W mainland Mexico thinned the crust before ∼E-W extension localized in the GC/ST at ∼12 Ma. By ∼6 Ma, NW-SE Pacific-N. American plate separation was concentrated in the NGC/ST, which began to subside below sea level. By ∼3.6 Ma, transform faults connected pull apart basins forming ocean crust (S gulf) and proto-oceanic crust in the NGC/ST. The Peninsular Ranges west of the NGC/ST were not extended at the surface. MLC flow into the NGC/ST is suggested by (1) the fact that the Moho dips W under the unextended Peninsular Ranges (W of the rift) to a maximum depth well W of the range crest (Lewis et. al., 2000, 2001), (2) by an apparent surplus of MLC relative to upper crust within the rift (e.g., Couch et al., 1991), and (3) by the magnitude of extension (∼255 km) between initially adjacent areas on either side of the NGC/ST (Oskin et al., 2001). We constrain the extent of MLC flow two ways: by comparing known upper crustal extension (e.g., Lewis and Stock, 1998; Axen and Fletcher, 1998) to (1) whole-crustal and (2) lower-crustal extension. Whole and lower crustal extension are obtained from cross-sectional areas constrained by depth to Moho and/or to the base of the upper crust (references above), by the extent of new proto-oceanic crust (e.g., Fuis et.al., 1984), and by assuming end-member initial crustal thicknesses (e.g., ∼37-40 km maximum thickness of the Peninsular Ranges or ∼25 km minimum from previously extended crust east of the NGC/ST). In general, the data are much better W of the NGC/ST than to the E, and constrain Moho depth much better than depth to the base of the upper crust (which may not equate to the base of the brittle crust in any case). Therefore we focus on comparisons of whole crust to upper crust in the Peninsular Ranges and western NGC/ST. Preliminary calculations of whole-crustal extension typically exceed known upper crustal extension by up to ∼4 times, strongly favoring MLC flow into the rift. However, for the end-member case of minimum initial crustal thickness, the higher estimates of known upper crustal extension are subequal to the calculated whole crustal extension, requiring no MLC flow. In most cases, area balance requires a present-day deficit of MLC material beneath the unextended Peninsular Ranges. This is key, because MLC deficits cannot be explained by magmatic processes, unlike the surpluses inferred below the rift (e.g addition of basaltic lower crust). These conclusions support much previous work that favors flow of weak MLC in extended terrains. Better constraints should be provided once reflection and wide-angle refraction data from MARGINS seismic profiles across conjugate margins of the gulf are fully processed.

S22F MCC: 3011 Tuesday 1600h

Earthquake Location: Applications and Developments of New Techniques III *(joint with NG)*

Presiding: **C A Rowe,** Los Alamos National Laboratory**; D R Shelly,** Stanford University

S22F-01 1600h

Investigating the use of Three-dimensional Travel-time Tables for Standard Regional Seismic Event Relocation

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As computer processor speeds continually increase, we are routinely locating larger earthquake data sets with more complex algorithms. Despite the increase in processing speed and capacity, large global seismic catalogs are still produced primarily using one-dimensional (1-D) velocity models. Results using these models can be significantly improved through application of static or source-specific station corrections – for example, the use of two-dimensional (2-D) correction surfaces developed with kriging methods has greatly improved relocation accuracies for regional events. Three-dimensional (3-D) velocity models, however, are improving in both resolution and reliability. Studies have demonstrated their superiority over 1-D models in terms of improved location and reduction in uncertainty. It therefore seems appropriate that routine seismic event location methods should migrate to the 3-D velocity model standard. We must consider, however, the increased processing time to produce 3-D relocations, even using faster computers. Further, it is important to assess the accuracy of 3-D travel-time (TT) tables and the ray tracing algorithms used to create them, to weigh – in combination with the added computational burden – the merits versus costs of such a transition. The objected-oriented relocation software (LocOO) developed by programmers at Sandia National Laboratories permits the use of 3-D TT tables to relocate events. The code is based on the "libloc" algorithms, accesses Oracle databases, and uses the Parametric Grid Library (PGL) for TT tables and station parameters. We plan to generate TT tables based on an a priori 3-D velocity model of the Central Asia region by selecting stations to maximize azimuthal coverage for the western China area. Using the LocOO software, we will test whether using 3-D TT tables improves the accuracy of regional seismic events that have corresponding ground-truth data for comparison. We will also compare these relocations with those produced using 1-D velocity models coupled with 2-D correction surfaces. Others have used 3-D TT tables for relocation but usually for specific event or event-cluster analyses. Our effort will focus on performing relocation tests on a catalog scale (or at least a large subset), and analyzing computational times to determine if using 3-D TT tables for regional location on a routine basis can be justified in an operational setting.

S22F-02 1615h

MULTIPLE-EVENT LOCATION WITH STATION-CORRELATED PATH CORRECTIONS

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Multiple-event location methods solve jointly for the locations of a set of seismic events and travel-time corrections associated with the paths from the events to the observing stations. Many of these methods assume the path corrections for a given station are the same for all events, which effects an important constraint on the event locations but which restricts the method to event clusters of small aperture. A notable exception is the double-differencing method, which allows for de-correlation of path corrections for well separated pairs of events. However, these methods do not typically incorporate a model of complete or partial correlation of path corrections between seismic stations, and thus omit potentially valuable information for many common network geometries. This paper investigates a new approach to multiple-event location that models the correlation of travel-time corrections for each pair of paths as a function of both event and station separation. The approach generates path corrections from a "universal correction function", which is sampled at the event location and station location to produce the correction for a given path. The universal correction function is estimated from observed travel-time residuals using a geo-statistical interpolation technique (kriging), making use of prior covariance information to impose correlations between paths. We have tested this approach on a data set from the Nevada Test Site (NTS) comprising Pn and Pg arrival times from 64 stations and 74 explosions for which precise location parameters are available. In this data set some stations are separated by less than 10 km while the median nearest-neighbor distance is only 70 km. Our tests compare event locations obtained using station-uncorrelated and station-correlated path corrections, each estimated from the observed travel-time residuals relative to the IASP91 earth model. In our initial tests, the path corrections are derived using the known locations of the events and then used in a single-event location algorithm applied to each event. The resulting event mislocations are consistently smaller when station-correlated corrections are used. More realistic tests entail estimating the path corrections jointly with the event locations in a multiple-event location process. Preliminary tests of this type on the NTS data indicate that multiple-event location methods incorporating station-correlated path corrections yield modestly smaller mislocations than the traditional methods.

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Location Calibration in East Asia: Final Results of a Consortium Project, and Lessons Learned

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We have developed and tested Source Specific Station Corrections (SSSCs) for Pn and Sn travel times at 30 International Monitoring System stations in East Asia, and for 127 other stations used for validation testing. We developed a 3D model of the P–wave velocity for East Asia (using 36 different 1D regions), and used 3D ray tracing in the aggregate model to compute SSSCs. These model–based SSSCs were refined empirically by kriging travel–time residuals for ground–truth (GT) events. Off–line validation tests were performed by relocating GT events, with and without using SSSCs. Nuclear explosions dominated our ground–truth datasets in this project for much of Russia and Central Asia, but it was also necessary to develop GT information on significant numbers of earthquakes, for example to calibrate stations in China. Using the double–difference method and detailed fault maps, we obtained 64 GT5 earthquakes by re-analyzing the Annual Bulletin of Chinese Earthquakes for a 15-year period (1985 to 1999). Other reference events were provided by special studies, and in some cases contributed by colleagues. Using Pn and Sn arrival times for our GT data sets, we relocated 525 events recorded by various combinations of 140 regional stations. Mislocations were reduced for 66% of the events using the model–based SSSCs, and for 85% of the events using model–based SSSCs refined by kriging. Median mislocation improved from 16.9 km to 11.4 km and 6.5 km, respectively. Median error ellipse area was reduced