its users with occurrence of an earthquake prior to arrival of strong ground motion for a decade. Earthquake Research Institute, the University of Tokyo, is preparing a demonstrative experiment in collaboration with JMA, for a better utilization of Nowcast Earthquake Information to apply actual measures to reduce earthquake disasters caused by strong ground motion.

### S21B-04 0900h

### Progress on Earthquake Rapid Reporting and Early Warning Systems in Taiwan

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We report the recent progress on real-time seismic monitoring in Taiwan. Particularly on the earthquake rapid reporting (RRS) and earthquake early warning (EWS) systems developed by us at the Central Weather Bureau (CWB), using the telemetered signals from strong-motion instruments in the free-field. For the RRS, CWB has provided intensity map, hypocenter, and magnitude within one minute of the occurrence of large (M> 4) earthquakes since 1995. The reliability, as documented by electronic messages to government agencies and scientists, has a nearly perfect record, especially for large damaging earthquakes. Using a set of empirical relationships from a study of the 1999 Chi-Chi earthquake, CWB has been able to release through RRS the estimated distributions of PGA, PGV and potential damage within a few minutes after a big earthquake. This near real-time damage assessment is useful for rapid post-disaster emergency response and rescue missions. The concept of a virtual sub-network (VSN) has been implemented at CWB. The VSN-approach reduces the earthquake rapid reporting time to about 30 seconds or less. This represents a significant step towards a more realistic earthquake early warning capability, and has been in operation at CWB since December 2000. A 6-month result shows successful locations of 54 earthquakes with equivalent estimates of moment magnitude. The RRS and EWS have been in operation for several years essentially without false reports. For EWS since 2002, comprehensive earthquake reports have been issued mostly in less than 30 seconds, with an average of about 22 seconds from the origin time. At 3 km/sec for a typical shear wave velocity, the present operation is not useful if an earthquake occurs less than 66 km from a city, but the lead time will increase to more than 10 seconds for cities at distances greater than 100 km from the source. In the latter case, a lead time of several seconds will allows pre-programmed emergency response to take place prior to the arrival of strong shaking. The CWB's RRS and EWS reports are open to scientists (by e-mail) if a request is sent to ym.wu@socmail.cwb.gov.tw. Besides the earthquake-related information, these reports also document the processing time.

### S21B-05 0920h INVITED

### Can Seismic Early-Warning Information Help Engineers?: The Benefits to, and the Information Requirements for Structural Control and Monitoring Applications

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The potential benefits of advance-warning information of an earthquake event, on the order of seconds prior to seismic wave arrival, is explored in the context of structural engineering loss reduction. Structural control technologies have been developed, principally over the last two decades, to reduce the vibration response of structural systems during transient dynamic loading such as earthquake ground motions. A brief overview of the state-of-the-art in structural control is presented. Although not typically considered, there are possible control algorithm-level benefits to having *a priori* information on the magnitude, spectral content and duration of the transient loading. In addition, there are potential benefits of advance knowledge for the actuator and sensor hardware that implement the control. In addition to structural control applications, the modeling and damage detection of structural systems is of particular interest to engineers for whom an earthquake event presents a rare high-level loading and response dataset from which structural health can potentially be inferred. Increasingly, large arrays of wireless sensor are proposed for this monitoring purpose. Early-warning information could potentially be used to wake-up sensors from a low-power mode to a full-power mode at which they can record and wirelessly communicate a large volume of data. While the potential of incorporating early-warning information for structural engineering loss-reduction measures may be attractive, it is important to note that one can of course not predict the location of future events relative to a structure of interest, and therefore one should not design systems which exclusively depend on early-warning information for basic life safety or other performance criteria. Rather, the goal should be to design measures whose performance can be *enhanced* with early-warning information.

### S21B-06 0940h INVITED

### Earthquake Early Warning and Public Policy: Opportunities and Challenges

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Development of an earthquake early warning capability and pilot project were objectives of TriNet, a 5-year (1997-2001) FEMA-funded project to develop a state-of-the-art digital seismic network in southern California. In parallel with research to assemble a protocol for rapid analysis of earthquake data and transmission of a signal by TriNet scientists and engineers, the public policy, communication and educational issues inherent in implementation of an earthquake early warning system were addressed by TriNet's outreach component. These studies included: 1) a survey that identified potential users of an earthquake early warning system and how an earthquake early warning might be used in responding to an event, 2) a review of warning systems and communication issues associated with other natural hazards and how lessons learned might be applied to an alerting system for earthquakes, 3) an analysis of organization, management and public policy issues that must be addressed if a broad-based warning system is to be developed and 4) a plan to provide earthquake early warnings to a small number of organizations in southern California as an experimental prototype. These studies provided needed insights into the social and cultural environment in which this new technology will be introduced, an environment with opportunities to enhance our response capabilities but also an environment with significant barriers to overcome to achieve a system that can be sustained and supported. In this presentation we will address the main public policy issues that were subjects of analysis in these studies. They include a discussion of the possible division of functions among organizations likely to be the principle partners in the management of an earthquake early warning system. Drawing on lessons learned from warning systems for other hazards, we will review the potential impacts of false alarms and missed events on warning system credibility, the acceptability of fully automated warning systems and equity issues associated with possible differential access to warnings. Finally, we will review the status of legal authorities and liabilities faced by organizations that assume various warning system roles and possible approaches to setting up a pilot project to introduce early warning. Our presentation will suggest that introducing an early warning system requires multi-disciplinary and multi-agency cooperation and thoughtful discussion among organizations likely to be providers and participants in an early warning system. Recalling our experience with earthquake prediction, we will look at early warning as a promising but unproven technology and recommend moving forward with caution and patience.

## S21C MCC: 3009 Tuesday 0800h

### Crustal Structure

*Presiding:* **A Rodgers,** Lawrence Livermore National Laboratory**; D Eberhart-Phillips,** U.S. Geological Survey

### S21C-01 0800h

### Imaging the Transition From Aleutian Subduction to Yakutat Collision in Central Alaska, With Local Earthquakes and Active Source Data

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In central Alaska, the rapid subduction and active volcanism of the Aleutian subduction zone gives way to a broad plate boundary zone with mountain building and strike-slip faulting, where the Yakutat terrane joins the subducting Pacific plate. We are imaging the 3-D velocity structure using the abundant local earthquakes, which occur to 200-km depth, supplemented by active source data. Both permanent AEIC (Alaska Earthquake Information Center) stations and temporary BEAAR (Broadband Experiment Across Alaska Range) stations are included. Low velocity in the upper crust correlates with the Cook Inlet and Copper River basins. The relatively high-velocity slab and low-velocity mantle wedge are readily observed. Lower velocity mantle underlies the active volcanism in contrast to higher velocity mantle of the relatively undeformed southwestern Alaska area further inboard of the arc. In the region north of Cook Inlet, a low-velocity zone overlies the shallow slab to about 80-km depth and may represent the underthrust Yakutat terrane, consistent with BEAAR receiver function and attenuation results. The subduction of thick crust in central Alaska at the end of a subduction zone is similar to the northern South Island of New Zealand.

### S21C-02 0815h

### The 2003 Western Anatolia Seismic Experiment: an Integrated Study of Crust/Upper Mantle Structure and Anisotropy in Western Turkey

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Western Turkey is one of the most seismically active continental regions in the world and much of it is undergoing extensive north-south extensional deformation. In a cooperative study, seismologists from Saint Louis University and Dokuz Eylul University in Izmir, Turkey, deployed 5 broadband and 24 short-period seismic stations in western Anatolia in November 2002. The high-frequency instruments were located along a NS 100 km long profile with 2 to 3 km station spacing in the central portion of the zone of extension. The remaining instruments were deployed as a regional array distributed throughout the region. All stations record contineously with a sampling rate of 40 samples per second. The recording experiment will last for one year. We plan to use both the linear array and regional array recordings to perform a combined inversion for precise local earthquake location and a tomographic velocity model of the region. We will also determine crustal thicknesses and crust/upper mantle anisotropy using telesesimic earthquakes. Preliminary analysis of the first eight months of teleseismic data has resulted in a 2-D crustal image beneath the linear array which shows that Moho depth varies from 28 km to 32 km.

S

S21C-03 0830h

## Seismic Refraction Experiments In The Eastern Marmara Region, Western Part Of The North Anatolian Fault Zone

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The velocity-depth model of the eastern Marmara region is determined using controlled source data. In order to obtain a reliable velocity structure, seismic modeling was performed in two stages; first, forward modeling was applied to controlled source data by means of basically two-dimensional ray tracing technique. Then, traveltime inversion was applied to the data obtained from seismic refraction experiments in the eastern Marmara region. A two-dimensional P wave velocity structure was aimed to obtain from the refraction profiles. Two quarry blasts and one controlled source data were collected. In addition to those recordings, a survey conducted by Turkish-German Group and three previous quarry blast experiments were reanalyzed. Velocity model for the Marmara region shows a four-layered structure of 20 km thick. Results of the calculated velocity structure and known geological information from the region might probably listed as: The first layer corresponds to quaternary sediments, second layer consist of a sequence of thick sediments including Eocene aged volcano-sediments, Mesozoic aged sedimentary rocks and Paleozoic aged thick sedimentary rocks including carbonates. Below this second layer there are two more layers. Third layer might consist of granitic rocks and fourth layer shows high seismic velocities, which indicate that this layer represents more basic rocks. The seismic refraction surveys provided a good estimation of seismic velocity model for the region. The overall pictures of the all controlled source experiments indicate that Pg velocities are ranging between 5.4 - 5.7 km/s and Pn wave velocity is about 8.0 km/s for the eastern Marmara region. This high Pn velocity is consistent with the earthquake data interpretation results. Evidence from quarry blast, explosion data and previous studies strongly suggest that along the western end of the North Anatolian Fault has a complexity in the local velocity structure. This issue is addressed here in conjunction with the determination of models for two-dimensional structure of the upper crust in the eastern Marmara region

S21C-04 0845h

## A New Generation of Large Seismic Refraction Experiments in Central Europe (1997-2003)

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Beginning in 1997, Central Europe has been covered by an unprecedented network of seismic refraction experiments. These experiments (POLONAISE'97, CELEBRATION 2000, ALP 2002, SUDETES 2003) have only been possible due a massive international cooperative effort. The total length of all profiles is about 19,000 km, and over 300 explosive sources were employed. The result is a network of seismic refraction profiles that extends along the Trans-European Suture Zone region of Poland and the Bohemian massif, Pannonian basin, trough the Carpathians and Alps to the Adriatic Sea and the Dinarides. As reflected in structures within these areas, Central Europe has experienced a complex tectonic history that includes the Caledonian, Variscan, and Alpine orogenies. The related TESZ region is a broad zone of deformation that extends across Europe from British Isles to the Black Sea region that formed as Europe was assembled from a complex collage of terranes during the late Palaeozoic. For example, the Bohemian massif is mostly located in the Czech Republic and is a large, complex terrane whose origin can be traced to northern Gondwana (Africa). These terranes were accreted along the margin of Baltica that was formed during the breakup of Rodinia. The tectonic evolution of this region shares many attributes with the Appalachian/Ouachita origin and is certainly of global important to studies in terrane tectonics and continental evolution. In southern Poland, several structural blocks are located adjacent to Baltica and were probably transported laterally along it similar to the Cenozoic movement of terranes along the western margin of North America. The younger Carpathian arc and Pannonian back-arc basin were also targeted by these experiments. Thickness of the crust in the area of investigations changes from 22-25 km in the Pannonian basin to about 55 km in the Trans-European Suture Zone in SE Poland. Together, these experiments are providing an unprecedented 3-D image of the evolution and assembly of a continent. Experiment Working Group Members: K. Aric, S. Azevedo, I. Asudeh, M. Behm, A.A. Belinsky, T. Bodoky, R. Brinkmann, M. Broz, E. Brueckl, W. Chwatal, R. Clowes, W. Czuba, T. Fancsik, B. Forkmann, M. Fort, E. Gaczynski, H. Gebrande, H. Geissler, A. Gosar, M. Grad, H. Grassi, R. Greschke, A. Guterch, Z. Hajnal, S. Harder,E. Hegedus, A. Hemmann, S. Hock, V. Hoeck, P. Hrubcova, T. Janik, G. Jentzsch, P. Joergensen, G. Kaip, G.R. Keller, F. Kohlbeck, K. Komminaho, M. Korn, O. Korousova, S.L. Kostiuchenko, D. Kracke, C.-E. Lund, U. Luosto, M. Majdazski, M. Malinowski, K.C. Miller, A.F. Morozov, G. Motuza, V. Nasedkin, E.-M. Rumpfhuber, Ch. Schmid, A. Schulze, K. Schuster, O. Selvi, C. Snelson, A. Spicak, P. Sroda, F. Sumanovac, E. Tacasc, H. Thybo, T. Tiira, C. Tomek, J. Vozar, F. Weber, M. Wilde-Piórko, J. Yliniemi, A. Zelazniewicz

S21C-05 0900h

## Central European Lithospheric Experiment - CELEBRATION 2000: Summary of the Results

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A large consortium of European and North American institutions - 28 in all - recently completed a huge active source seismic experiment focused on Central Europe. This experiment is called the Central European Lithospheric Experiment Based on Refraction or CELEBRATION 2000. It targeted the structure and evolution of the complex collage of major tectonic features in the Trans-European suture zone (TESZ) region, as well as the southwestern portion of the East European craton, the Carpathian Mountains, the Pannonian basin, and the Bohemian massif. The layout of the CELEBRATION 2000 experiment was a network of interlocking recording profiles whose total length was about 9000 km an for which the station spacing along the profiles was 2.8 or 5.6 km. Shots (147) were fired along most of the recording profiles, so that in addition to forming an array, about 5400 km of traditional profile data were obtained. The sources ranged in size from 15 metric tons to 90 kg, with the average being 500 kg. Thanks to Canadian, European, and IRIS/PASSCAL resources, the total number of instruments deployed was 1230. CELEBRATION 2000 also targeted the lithospheric mantle, and our goal is to provide new information about structure below the Moho discontinuity. One particularly long profile extends from Russia across Belarus, Poland, Slovakia to Hungary (1430 km). The massive data set produced by this experiment is providing a 3-D picture of the crust and upper mantle that will help answer many of the key questions that remain about the structure and tectonic evolution of this very interesting region of the European continent. For example, the depth of the consolidated basement with velocity Vp> 6.0 km/s changes from 1-3 km on the East European Craton to about 5-8 km beneath Pannonian basin, reaching up to 10-18 km in TESZ and Carpathians. The East European Craton has a typical thick, three-layer structure for the crystalline crust (with velocities of 6.1, 6.4, 6.5-6.6 and 6.8-6.9 km/s, respectively), while in the Carpathian-Pannonian area, thin crust is characterized by relatively low Vp velocities (6.1-6.4 km/s in the upper crust and 6.4-6.6 km/s in the lower crust). The velocity in the uppermost mantle is 8.1-8.25 km/s beneath East European Craton and 7.8-8.0 km/s beneath Carpathian-Pannonian area. CELEBRATION Working Group: K. Aric, S. Azevedo, I. Asudeh, A.A. Belinsky, T. Bodoky, E. Brueckl, W. Chwatal, R. Clowes, W. Czuba, T. Fancsik, E. Gaczynski, M. Grad, A. Guterch, Z. Hajnal, S. Harder, E. Hegedus, P. Hrubcova, T. Janik, G. Jentzsch, P. Joergensen, G. Kaip, G.R. Keller, F. Kohlbeck, K. Komminaho, S.L. Kostiuchenko, D. Kracke, K.C. Miller, A.F. Morozov, K. Posgay, O. Selvi, C. Snelson, A. Spicak, P. Sroda, E. Tacasc, H. Thybo, T. Tiira, J. Vozar, M. Wilde-Piórko, J. Yliniemi

URL: http://paces.geo.utep.edu/research/celebration.shtml

S21C-06 0915h

## Earthquakes and Seismic Structure of the United Arab Emirates

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Tectonic structure of the United Arab Emirates (UAE) is dominated by the obduction of ocean crust and mantle onto the continental shelf of the Arabian Plate in the context of continental collision of the Arabian Plate with the southern Eurasian margin. On March 11, 2002 a moderate-sized earthquake, M 5.1, struck the northern United Arab Emirates. The event and aftershocks were widely felt in the northern Emirates, however damage was greatest near the town of Masafi. The mainshock was large enough to be located by global catalogs from teleseismic data (e.g. USGS-PDE, CMT, REB). Earthquakes are rare in this region and this event provides an opportunity to understand the active tectonics of the region. Two faults are known from structural mapping: the Dibba-Masafi (Wadi Al-Fay) Fault north of Masafi and the Wadi Ham Fault between Masafi and Fujairah south of Masafi. A focal mechanism, estimated from regional waveform modeling, suggests that the event occurred by normal faulting probably along the north-striking Dibba-Masafi Fault, however right-lateral strike-slip is not entirely ruled out. We compare this mechanism with the Harvard CMT, which reported a normal mechanism. In May 2003 we deployed two broadband seismic stations to record local and distant earthquakes. We will report results on this earthquake, as well as local earthquakes and crustal structure from a recent deployment of broadband instruments.

S21C-07 0930h

## High-resolution Seismic Reflection Imaging of Thin, Diamondiferous Kimberlite Dykes and Sills

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A unique seismic reflection experiment has successfully imaged a thin, diamondiferous kimberlite dyke intruded into granitic host rock. Although the typical dyke thickness is only 1-3 m, it is mapped from the near-surface to 1500 m depth. Such an application of seismic techniques to the diamond exploration and mining industry is unusual because the primary exploration targets are near-vertical kimberlite pipes that often are detected using magnetic and electromagnetic techniques. Subhorizontal dykes and sills do exist but they are poor potential field targets and have not been discovered by these techniques. However, one subhorizontal structure, the Snap Lake dyke, was discovered in 1997 in the Archean Slave geological province of the Northwest Territories, Canada by tracking indicator minerals in the glacial till overburden. The Snap Lake dyke is a thin, dipping sheet that extends over at least 25 square km and plunges at approximately 15 degrees. The intrusion is richly diamondiferous and currently in the permitting stage for development of an underground mine. Its discovery heightened industry interest in dykes and sills, both in terms of their potential economic value and the information they yield regarding kimberlite emplacement. Since seismic reflection methods are especially well suited for mapping subhorizontal structures, dykes and sills have the potential to be excellent seismic targets. As a result, the Snap Lake seismic program was carried out to evaluate the seismic reflection method as a tool for exploration and deposit characterization of subhorizontal kimberlite intrusions. Snap Lake provides a superb test site for such

a study because the dyke's gross geometry and composition have been determined through a substantial drilling program. Prior to the seismic field experiment, drill-core samples from the kimberlite and host rocks were used to measure P velocities and densities. These data were used to generate finite-difference and reflectivity synthetic seismograms in order to explore thinbed resolution limitations, tuning effects and acquisition parameters. The seismic survey included two 2-d lines designed to obtain comparative datasets between different sources (explosives and vibroseis) and ground types (land and lake-ice). The explosive-source, land data yield a superb image of the thin dyke with high-amplitude reflections mapping the dyke topography to 1300 m depth. Weaker reflections indicate the dyke can be imaged to depths in excess of 1500 m. The vibroseis data detect the dyke only when sources and geophones are on land; they provide an image with nearly equivalent resolution. The dyke is not imaged beneath the ice by either source, due to reverberation and attenuation effects. The thickness of the thin intrusive layer is not directly resolved and 3-d structure makes the interpretation of fine-scale variations in reflectivity and continuity difficult. However, apparent correlations between variations in reflection characteristics and dyke properties (thickness, feathering, structure, and physical properties) suggest that seismic reflection data may be valuable for guiding drilling programs. The results demonstrate that, in the appropriate situation, seismic reflection methods have great potential for use in kimberlite exploration, subsurface mapping, and detailed imaging for mine development purposes.

### S21C-08 0945h

### Relating Pore Fabric Geometry to Acoustic Wave Velocity, Anisotropy and Fluid Flow in Porous Sandstone: A Laboratory Study Using Magnetic Ferrofluid.

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Pore fabric geometry is a key feature of sedimentary rocks. Anisotropy arising from pore fabric has been commonly studied in terms of acoustic-wave (seismic) anisotropy, fluid flow (permeability) anisotropy and magnetic anisotropy (Anisotropy of Magnetic Susceptibility - AMS). However, combined approaches are relatively few, and often concentrate on grain fabric AMS. Here, we present results from an experimental study in which the AMS technique is used to determine the average 3D void space geometry in porous rock saturated with a high susceptibility magnetic ferrofluid. Using this approach, we independently show that the acoustic wave anisotropy and permeability anisotropy are well described by knowledge of the pore fabric anisotropy. We also demonstrate that pressure produces marked changes in both permeability and acoustic wave velocity, and that pore fabric is a useful tool with which to explain such changes. Measurements were made on Crab Orchard sandstone (COS) and Bentheim sandstone (BHS), chosen specifically for their contrasting strong (COS) and weak (BHS) anisotropy. COS is fine-grained and exhibits layering on a mm scale. It has a high cement content, resulting in a porosity of 4.5%. By contrast, BHS comprises 95% quartz grains in an open structure, resulting in a porosity of 22%. AMS was determined by measuring the susceptibility of ferrofluid saturated samples in 15 different orientations. A least squares ellipsoidal fit was then applied to this data to calculate the principal directions. Comparative elastic wave velocity measurements were then made in 10 degree increments around the circumferences of sets of three orthogonal cores. An equivalent 3D velocity ellipsoid was then determined, allowing for direct comparison of the velocity and AMS data. The error in using an ellipsoidal fit, rather than a fourth rank tensor, is estimated as less than 1.5%; approximately equal to the error in velocity measurement. Finally, measurements of permeability anisotropy, together with simultaneous ultrasonic velocity measurements, were made in a servo-controlled permeameter at effective pressures from 5 to 90MPa. In general, the permeability of COS parallel to bedding is some 3 times higher than that normal to bedding; whereas the permeability of BHS exhibits no discernible anisotropy. We find a strong positive correlation between the principal directions given by pore space AMS, velocity anisotropy, and permeability anisotropy. P-wave velocity anisotropy on dry samples was 19% and 5% for COS and BHS, respectively. This compares with a pore fabric anisotropy of 3.8% (COS) and 1.4% (BHS). The permeability of COS decreases from 75 to 8 mDarcy as effective pressure is increased from 5 to 90 MPa, a corresponding increase in acoustic wave velocity is also observed. BHS has a considerably higher permeability (830 mDarcy), but this changes little as pressure is increased. Our results clearly demonstrate that the overall anisotropy in these sedimentary rocks is dominated by the average pore fabric shape and orientation. Hence, the analysis of this fabric provides a good indicator of the anisotropy of other related physical properties, such as mechanical strength.

## S21D MCC: Level 1 Tuesday 0830h

## Earthquake Location: Applications and Developments of New Techniques I Posters *(joint with NG)*

***Presiding:*** **S Husen,** Swiss Seismological Service**; A O Konca,** California Institute of Technology

### S21D-0319 0830h POSTER

### The Rupture Characteristic of 1999 Izmit Sequence Using IRIS Data

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The standard source studies use teleseismic data (30° to 90°) to analyze earthquakes. Therefore, only a limited portion of the focal sphere is involved in source determinations. Furthermore, the locations and origin times of events remain incompatible with local determinations. Here, we attempt to resolve such issues by using IRIS data at all distances, leading to more accurate and detailed rupture properties and accurate relative locations. The 1999 Izmit earthquake sequence is chosen to test our method. The challenge of using data outside the conventional teleseismic distance range is that the arrival times and waveforms are affected more by the Earth structure. We overcome this difficulty by calibrating the path effects for the mainshock using the simpler aftershocks. Therefore, it is crucial to determine the source parameters of the aftershock. We constructed a Green's function library from a regionalized 1-D model and performed a grid search to establish the depth and fault parameters based on waveform matching for the Pnl waves between the synthetics and data, allowing the synthetics in each station to shift separately to account for the path effect. Our results show that the earthquake depth was around 7 km, rather than 19 km from local observatory (Kandilli) and 15 km from the Harvard's CMT solution. The best focal mechanism has a strike of 263°, a dip of 65°, and a rake of 180°, which is very close to the Harvard's CMT solution. The waveform fits of this aftershock is then used as a criterion to select useful source-station paths. A path with a cross-correlation value above 90% between data and synthetics is defined as a "good path" and can be used for studying the Izmit and Duzce earthquakes. We find that the stations in Central Europe and some of the Greek Islands are "good paths", while the stations in Northeast Africa and Italy cannot be used. The time shifts that give the best cross-correlation values are used to calibrate the picks of the Izmit and Duzce events. We realize that this is a very objective way to pick arrival times. However, our preliminary inversions using teleseismic data for Duzce and Izmit events show that handpicked P and S arrival times of the same station from two very close events are not always well correlated. Obviously, how we pick the arrival time governs the rupture pattern and rupture velocity. Therefore, our methodology brings a more objective approach to pick the travel times. To the end, we will invert for the source history of the Duzce and Izmit earthquakes with the regional data and compare with the inversion result using teleseismic data. Moreover, predictions of the teleseismic data, using the solution from the inversion using regional phases will be presented.

### S21D-0320 0830h POSTER

### Cross-Correlation-Based Relocation of Intermediate-Depth Subduction Seismicity in Japan

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We present very high precision hypocenter relocations of intermediate-depth subduction earthquakes off the Ibaraki Prefecture of north-central Honshu, Japan and analyze their implications for subduction mechanics and the mechanism of intermediate-depth earthquakes. Our relocations are obtained using cross-correlation-derived differential arrival times and the double-difference algorithm of Waldhauser and Ellsworth (2000). Cross-correlation-based relocation of subduction seismicity substantially increases the location precision over relocations using only catalog phase picks and dramatically improves routine catalog locations. Our previous relocations in neighboring regions using the double difference method on catalog arrival times have shown a substantial increase in organization of seismicity, compared with the catalog locations. In particular, we observed a narrowing of the seismogenic zone at depth and a narrowing of each limb of the double seismic zone when viewed in cross-section. We have also observed unusual events that appear to be within the mantle wedge above the slab and substantial seismicity within the slab between the two planes of the double seismic zone. We chose the Ibaraki region for its high rate of slab seismicity, its relatively simple geometry, and for the presence of an intermediate-depth double seismic zone. We relocate nearly 5000 mostly intermediate-depth events occurring in this region between June 2002 and May 2003 using more than 100,000 waveforms from the JMA unified catalog. Many of these waveforms are from stations in Hinet, a recently installed national borehole network that provides particularly high-quality data.

### S21D-0321 0830h POSTER

### Earthquake Relocation and Error Estimate for Aftershocks of 2003 M 7.0 Northeastern Japan Earthquake

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We investigate the aftershock sequence of a M 7.0 earthquake that occurred on 26 May, 2003 in northeastern Japan, where the characteristic double seismic zone (DSZ) was first identified by Hasegawa in 1978. The preliminary locations(from Tohoku University) show that these aftershocks are distributed between 65km-80km depth, not along the upper plane of the DSZ, but cut cross the slab at a steep angle. Catalog data from 227 aftershocks and waveform data from 69 large aftershocks (M>3.8) are used to refine earthquakes location. After double-difference earthquake location (hypoDD), the aftershocks are found to distribute along plane with dip angle about 53 (degree), but with significant scatter (RMS deviation is about 1.524km).These aftershocks are right along the eastern coast of Japan, in an area with significant velocity heterogeneity. We test the ability of hypoDD to recover the correct locations using synthetic data without and with noise added. The synthetic data are created based on the real data with the same set of event-station observation but with varying geometry. First, all the aftershocks are projected onto a plane (strike angle = -10 (degree), dip angle =53.79 (degree)) to generate the synthetic events, and synthetic travel time are calculated with 3-D velocity model. Several variations are then created to estimate the relocation error, and examine the effects of initial source locations, Gaussian noise and correlated noise on the relocation results.The results show that hypoDD does well in recovering the correct locations (RMS≃224m) and the initial source locations have little effect on relocation if arrival time errors are small. The absolute relocation error mainly comes from model error (true model is 3-D, hypoDD model is 1-D), and Gaussian noise represents the noise well.

### S21D-0322 0830h POSTER

### Relative relocation of seismic events following the June 15, 1991 eruption of Mount Pinatubo

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