

# Towards a Global School Seismic Network

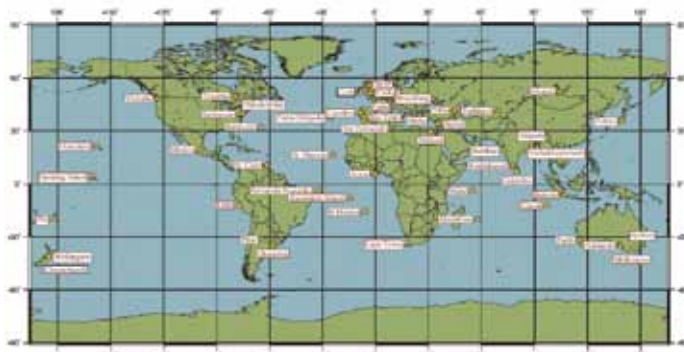
Paul Denton (*British Geological Survey*)

Scientists often work in a virtual global laboratory, collaborating with partners in countries overseas who they might never meet. Seismologists have been doing this for over a century ever since John Milne set up the first global seismic network from his garden shed in Shide on the Isle of Wight in 1910. He used the irregular mail-ships of the day to exchange seismograms with far flung outposts. Today school students and teachers in high schools across the world can experience what it is like to do science on a global scale and use the internet to exchange data in near real time with colleagues on any continent. Schools are using very simple mechanical seismometers in their own classrooms coupled to simple digitisers and PC's used for datalogging to detect and analyse seismic signals from across the world.

In 2009 the school seismology projects of the UK, Ireland and the USA merged their online databases to create a seamless and integrated environment where teachers from any country can automatically view and download data files submitted by teachers in any other country. UK and Ireland schools are using a simple horizontal pendulum seismometer which shows up S and surface waves well. US schools use a vertical sensor with a Lacoste type suspension which gives a stronger P wave signal.

The devastating earthquakes in Haiti and Chile during early 2010 highlighted the effectiveness of global monitoring in schools, and within days of the M8.8 event in Chile 45 schools had posted their seismograms online for all to see. In 2010 and beyond we are working hard to try and widen the reach of the global school seismology network and support seismologists in Africa and elsewhere to set up their own local school seismology networks.

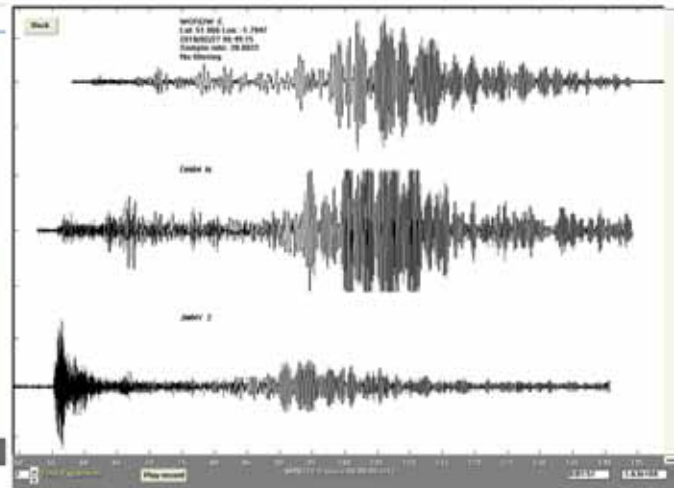
*Acknowledgements:* I would like to thank Matt Toigo from IRIS and Tom Blake from DIAS for their assistance with linking our projects together. See project websites at [www.bgs.ac.uk/ssp](http://www.bgs.ac.uk/ssp), [www.iris.edu/hq/sis](http://www.iris.edu/hq/sis), and [www.dias.ie/sis](http://www.dias.ie/sis)



Milne network 1910



Schools network 2010



Data from the M8.8 Chile earthquake was recorded by schools right across the world. Seismograms recorded by schools in the UK (top), Ireland (middle) and the US (bottom).

# The Quake-Catcher Network: Bringing Seismology to Homes and Schools

**Elizabeth S. Cochran** (*University of California, Riverside*), **Jesse F. Lawrence** (*Stanford University*), **Jennifer Saltzman** (*Stanford University*), **Carl M. Christensen** (*Stanford University*), **Michael Hubenthal** (*Incorporated Research Institutions for Seismology*), **John Taber** (*Incorporated Research Institutions for Seismology*)

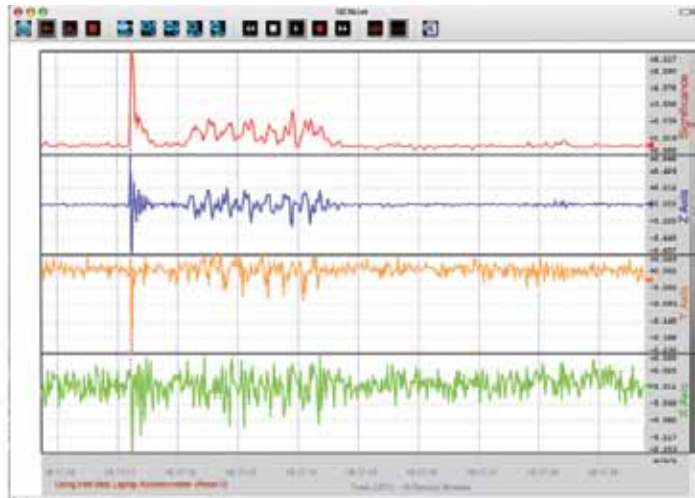
The Quake-Catcher Network (QCN) is a collaborative initiative for developing the world's largest, low-cost strong-motion seismic network by utilizing sensors in and attached to volunteer internet-connected computers [Cochran *et al.*, 2009a,b]. QCN is not only a research tool, but provides an educational tool for teaching earthquake science in formal and informal environments. A central mission of the Quake-Catcher Network is to provide software and hardware so that K-12 teachers, students, and the general public can better understand earthquakes while participating in the collection and analysis of seismic data. The primary educational outreach goals are 1) to present earthquake science and earthquake hazards in a modern and exciting way, and 2) to provide teachers and educators with seismic sensors, interactive software, and educational modules to assist in earthquake education. QCNLive (our interactive educational computer software) displays recent and historic earthquake locations and 3-axis real-time acceleration measurements. This tool is useful for demonstrations and active engagement for all ages, from K-college. QCN provides subsidized sensors at \$49 for the general public and \$5 for K-12 teachers. Teachers and academics are taking QCN into classrooms across the United States and around the world. With greater understanding, teachers and interested individuals can share their new knowledge, resulting in continued participation in the project, and better preparation for earthquakes in their homes, businesses, and communities.

## References

Cochran, E.S., J.F. Lawrence, C. Christensen, and R. Jakka, The Quake-Catcher Network: Citizen science expanding seismic horizons, *Seismol. Res. Lett.*, 80, 26-30, 2009.

Cochran E., Lawrence J., Christensen C., Chung A., A novel strong-motion seismic network for community participation in earthquake monitoring, *IEEE Inst & Meas*, 12, 6, 8-15, 2009.

*Acknowledgements:* This work was performed with support from NSF-GEO0753435, NSF-GEO0753290, NSF-EAR0952376 and an IRIS sub-award. We thank the thousands of volunteer participants who make the Quake-Catcher Network possible.



Left: Student using the QCNLive software to explore earthquakes around the world. Right: Display of the real-time output from a MEMS sensor in the QCNLive software.

# On-Line Seismology Curriculum for Use with Educational Seismographs

**Alan Kafka** (*Weston Observatory, Department of Geology and Geophysics, Boston College*), **Anastasia Macherides Moulis** (*Weston Observatory, Department of Geology and Geophysics, Boston College*), **Leslie Campbell** (*Weston Observatory, Department of Geology and Geophysics, Boston College*), **Michael Barnett** (*Weston Observatory, Department of Geology and Geophysics, Boston College*), **Camelia Rosca** (*Weston Observatory, Department of Geology and Geophysics, Boston College*), **John Ebel** (*Weston Observatory, Department of Geology and Geophysics, Boston College*)

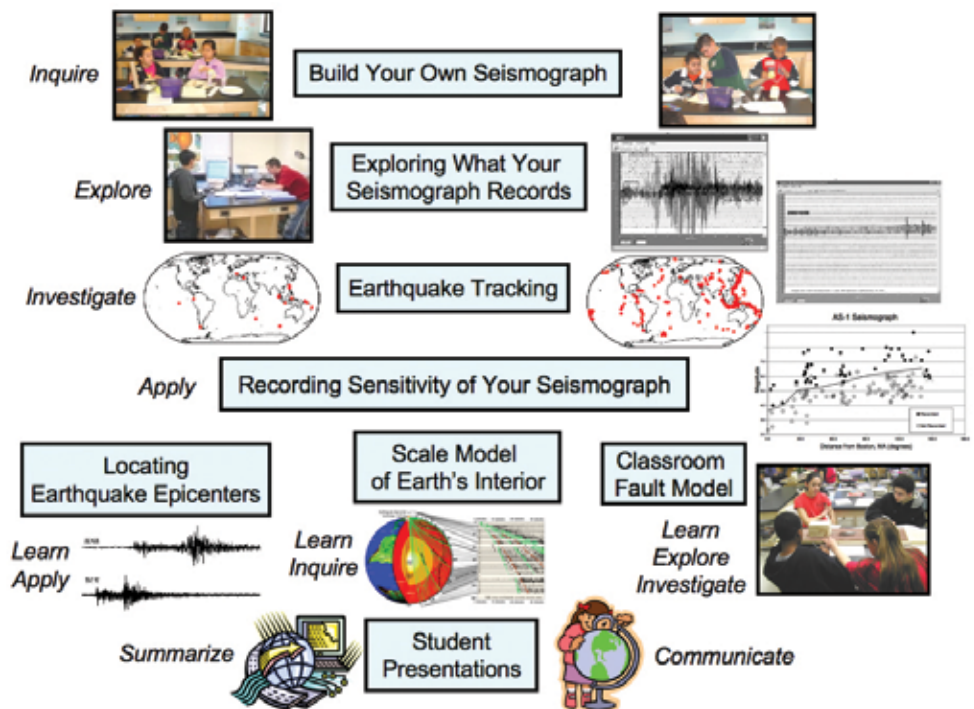
We developed a user-friendly, on-line seismology curriculum for teachers, students, and anyone else who operates an educational seismograph. The goal of this endeavor is to provide a resource on the web for people who are looking for some guidance regarding what they can do with their AS1 (or EQ1) seismograph once they have successfully installed it and have it up and running. The curriculum exercises are linked together with a unifying theme that helps guide students to engage in their own inquiry regarding what is recorded by their seismograph. A very common question that we hear from students and teachers, is: “The news reported that there was a \_\_\_\_\_ magnitude earthquake in \_\_\_\_\_. Did we record it on our seismograph?” Using this question as a “hook”, we encourage scientific inquiry by designing our curriculum around asking students to look at their own seismograms and figure out the answer to this question by themselves. The philosophy behind this approach is that, in the process of learning how to go about answering this specific question, students will become more comfortable with scientific inquiry in general. The figure shows the structure of the on-line curriculum, which can be found at <http://bcespcurriculum.wordpress.com>.

The blue boxes in the figure represent exercises that are part of the curriculum, and the words in italics, such as Inquire, Explore, Investigate, Learn, etc. depict the aspect of the scientific method that is highlighted in a particular exercise. During any exercise, many of these aspects of scientific investigation will, of course, be expected to be happening, but the words in italics indicate what part of the process is highlighted in that exercise.

This curriculum was assessed by way of a pre-post test administered to classes using this curriculum as part of the Boston College Educational Seismology Project (BC-ESP). We investigated how well the test assesses content and comprehension of the topics we cover, as well as readability and appropriate grade level of the test questions. Based on an analysis of how the pre-test results compare with the post-test results, we found that: (1) the test is suitable for the population it was used for, and (2) the students made significant gains between the pre-test and the post-pest, providing evidence that the curriculum is effective.

Acknowledgements: This work was performed with support from an IRIS subaward to Weston Observatory, Department of Geology and Geophysics, Boston College.

Structure of the BC-ESP on-line curriculum. Blue boxes represent specific exercises that are part of the curriculum. Words in italics, such as Inquire, Explore, Investigate, Learn, etc. depict the aspects of the scientific process that are highlighted in a particular exercise.



# Seismology in Schools (seismeolaíocht sa Scoil) Pilot Programme, Dublin Ireland

Thomas Blake (*Dublin Institute for Advanced Studies*)

An Outreach pilot programme called Seismology in Schools (Seismeolaíocht sa Scoil) was introduced by the Dublin Institute for Advanced studies to 50 primary and secondary schools throughout Ireland. This programme has been enthusiastically received by both teachers, students and parents alike. Using the seismometer and associated software distributed in this programme, students are able to record earthquakes from the other side of the world in real-time. The implementation of the pilot programme has been very a successful joint venture between DIAS, (Dublin Institute for Advanced Studies), ATECI, (Association of Teachers Educations Centers in Ireland), BGS (British Geological Survey) and IRIS (Incorporated Research Institutions for Seismology). A major contribution to the success of the programme is the teaching materials available to the teachers and students from the E&O Section of IRIS. Teacher training days organized by DIAS ensured that the teachers went back into the classroom fully conversant with the hardware, software and animated teaching software necessary to teach the programme. Significant success has been achieved in the pilot already as students from Scoil Chonglais, Co Wicklow, won 1st Prize in the Senior Chemical, Physical and Mathematical Sciences Category at the BT 2009 Young Scientist Competition for their research into seismic waves using the school's seismometer. The next phase of the programme for 2010 is to consolidate the learning and data collection techniques in the participating schools outlined in the training days and practiced by the students for the last year. Ultimately students will be in a position to share their earthquake data with other schools initially in Ireland, the UK, and USA. The international makeup of our partners reflects the fact that seismology is an international subject that transcends national boundaries. Recognising this internationality, the next phase of the programme starts to explore the possibilities of the twining schools of a similar educational level with a view to students exchanging earthquake data, firstly with another Irish school and in subsequent years with schools in the UK, USA and Africa via the internet. The experience of the seismology in schools pilot programme for students reinforces the idea that when science is relevant, learners become more engaged and see how science is reflected in the reality of their own lives and what they read in the newspaper.

*Acknowledgements:* DIAS would like to acknowledge the contribution in time, expertise, funding and material by ATECI, (Association of Teachers Educations Centers in Ireland), BGS (British Geological Survey) Edinburgh, Scotland and IRIS (Incorporated Research Institutions for Seismology) in the USA.



Presentation by Mr Matt Toigo, IRIS at the 1st Teachers Workshop for Seismology in Schools (Seismeolaíocht sa Scoil) Programme, held in Dublin in April, 2009

Programme presenters and teachers at the 1st Teachers Workshop for Seismology in Schools (Seismeolaíocht sa Scoil) Programme, held in Dublin in April, 2009

# Teachers on the Leading Edge: Earth Science Teacher Professional Development Featuring Pacific Northwest Earthquake and Tsunami Hazards

**Bob Butler** (*University of Portland*)

Teachers on the Leading Edge (TOTLE) is a professional development program for K-12 Earth Science teachers in the Pacific Northwest. TOTLE offered five-day summer workshops in 2008 – 2010 for Earth Science teachers from Oregon and Washington states. Through a problem-solving approach to active continental margin geology, teachers learn how geoscientists developed our understanding of Pacific Northwest plate tectonics, earthquakes, and volcanoes and how EarthScope research is advancing frontiers of knowledge. This cutting-edge science content learning is blended with pedagogical sessions led by award-winning TOTLE Master Teachers. Three days of classroom and computer-based studies of active continental margin geology and EarthScope science are reinforced by two field days investigating Cascadia great earthquakes and tsunamis and Cascade volcanic hazards. Participants in TOTLE workshops receive maps, posters, and experimental apparatus that greatly facilitate transfer of workshop learning to Earth Science classroom teaching.

Educational software, video lectures, animations, and K-12 Earth Science lesson plans are prominently featured in TOTLE teacher workshops. Robert Butler worked extensively with Jenda Johnson (IRIS E&O) and John Lahr (USGS Emeritus Seismologist, now deceased) on compilation and organization of educational seismology resources currently published by IRIS and EarthScope as the DVD Middle School Teachers' Guide to Earthquakes and Seismology. Michael Hubenthal (IRIS E & O) and Shelley Olds (UNAVCO E&O) attended the 2008 TOTLE – EarthScope workshop and provided insightful feedback on workshop design that led to program improvements between 2008 and 2009. Butler currently works with Tammy Bravo, Jenda Johnson, and John Taber to produce teaching resources for all magnitude 7 or larger earthquakes worldwide and for smaller earthquakes of regional interest in the Pacific Northwest. All of these teaching resources are tailored for middle-school Earth Science and are posted on the IRIS Recent Earthquakes Teachable Moments web site (<http://www.iris.edu/hq/retm>) within four to 16 hours after a notable earthquake. These teaching resources have received high acclaim from and wide use by K-12 Earth Science teachers across the US. Teachers on the Leading Edge personnel look forward to many years of fruitful collaborations with IRIS Education and Outreach.

*Acknowledgements:* Teachers on the Leading Edge is supported by a grant from the NSF EarthScope Program. Collaborations with IRIS Education and Outreach, the US Geological Survey, and the Oregon Department of Geology and Mineral Industries have been essential to the development of TOTLE.



Exploring Mt Hood volcanic history and hazards.



Examining the ghost forest produced by the 1700 great Cascadia earthquake.



Brian Atwater (USGS Seattle) explaining Cascadia tsunami geology along the banks of the Copalis River near the central Washington coast.

# The Earth Science Literacy Initiative

Michael Wyession (*Washington University*), John Taber (*IRIS*)

In 2009, the Earth Science Literacy Initiative (ESLI), which was led by Michael Wyession (Chair, IRIS E&O Committee) and John Taber (Manager, IRIS E&O Program), created a document entitled the Earth Science Literacy Principles (ESLPs) that contains a framework of the essential information that all citizens should know about Earth Science. The program was run by an outstanding Organizing Committee that also included David A. Budd (University of Colorado), Karen Campbell (University of Minnesota), Martha Conklin (UC Merced), Ellen Kappel (Geo Prose), Nicole LaDue (Michigan State), Gary Lewis (GSA), Robert Reynolds (Denver Museum of Science and Nature), Robert W. Ridky (USGS), Robert M. Ross (Paleontological Research Institute), Barbara Tewksbury (Hamilton College), and Peter Tuddenham (College of Exploration).

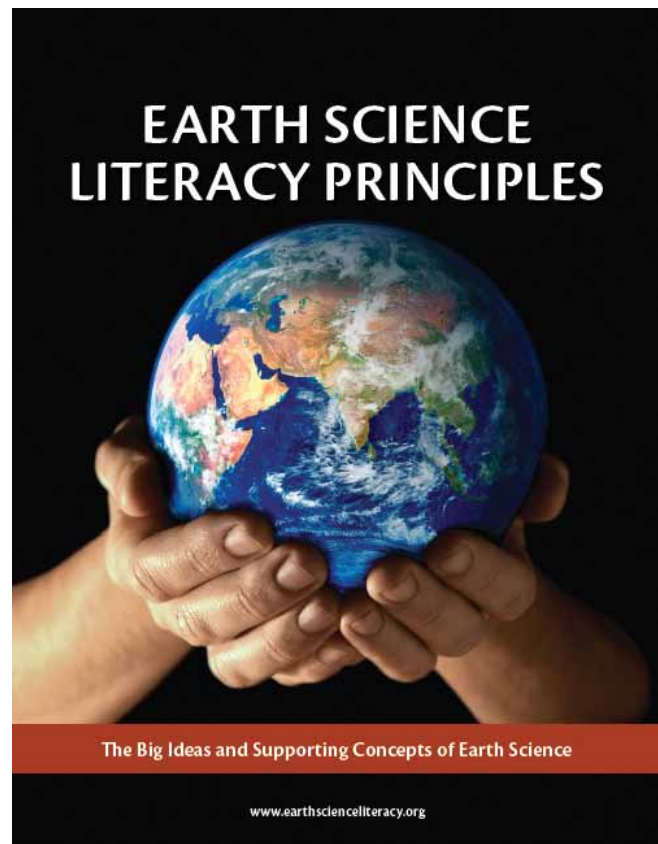
Understanding Earth science concepts is critical for humanity to successfully respond to these challenges and thrive in the decades to come. The twenty-first century will be defined by challenges such as understanding and preparing for climate change and ensuring the availability of resources such as water and energy, issues that are deeply rooted in the Earth sciences. To address this need, ESLI was formed in 2008 with the task to create a succinct document outlining what all citizens should know about Earth science. This document followed vigorous discussions at several workshops and multiple reviews. The resulting (ESLPs) consisted of 9 “Big Ideas” and 75 “Supporting Concepts” that highlighted the fundamental understandings of Earth science. Combined with similar efforts from the Ocean, Atmosphere, and Climate communities, it forms a foundation of essential information in the geosciences that has had a tremendous impact in many ways.

The ESLPs have already had broad-reaching applications in both public and private arenas. It is helping to guide future decisions involving governmental legislation and educational science standards. For example, the ESLPs were used to guide the formation of a new K–8 national science program developed in 2009 by Pearson. The ESLPs were also the basis for the Earth science part of the “Conceptual Framework for Science Education Standards” by the National Research Council, which will be used as the foundation for future national science education standards within the US. For more information, see [www.earthscieliteracy.org](http://www.earthscieliteracy.org)

## References

Wyession, M., *et al.*, The Earth Science Literacy Principles, NSF, 2009.

*Acknowledgements:* Funding was provided by NSF: EAR-0832415 (Wyession) and NSF: EAR-0832418 (Taber).



The Earth Science Literacy Principles, presented as a published brochure and available on line at [www.earthscieliteracy.org](http://www.earthscieliteracy.org), contains 9 “big ideas” and 75 supporting Concepts that outline the essential understandings that all citizens should know about Earth science. Its creating was led by members of the IRIS E&O program.

# USArray Education and Outreach in Southwest Indian Country

Steven Semken (*Arizona State University, School of Earth and Space Exploration*)

The EarthScope project has benefited greatly from permission to deploy USArray and Plate Boundary Observatory geophysical instruments on American Indian lands. Some instruments were sited near K-14 schools with expectations that (1) in the short term, students and teachers would be able to monitor “their” station online, and (2) long after deployment, the school would benefit from a continuing outreach association with the EarthScope project and the greater geoscience research community.

A cross-cultural workshop (NAPP-ES) held at ASU in 2005 yielded a number of specific recommendations for follow-up education and outreach activities [Semken *et al.*, 2007]. As USArray moves out of tribal lands in the intermountain West and traverses Indian country in the Rockies and Great Plains, it is important to remain constructively engaged with Native schools and communities.

A follow-up E&O workshop, Exploring Southwest Geology and Geophysics through the EarthScope program, was held in Flagstaff, Arizona on 26-27 September 2009 and served 20 K-12 and college teachers from schools located on or near Native American nations across Arizona, many of which hosted seismic stations during the USArray deployment in Arizona in 2007-2009. The workshop was co-led by geoscience educators from ASU, UNAVCO, and IRIS, with visiting speakers from NAU, USGS, and the National Park Service. Educational materials produced for and used at the workshop can be accessed at <http://cws.unavco.org:8080/cws/learn/2009/earthscopeArizona/>.

Further education and outreach activities among Southwest Native nations are planned.

## References

Semken, S., Fouch, M., Garnero, E., Zah, P., & Lippert, D. (2007). Meshing American Indian concerns with goals of EarthScope's USArray. *Eos, Transactions, American Geophysical Union*, 88(31), 309-310.

*Acknowledgements:* The NAPP-ES workshop and follow-up meetings were supported by award EAR-0454502 from the EarthScope Science Program of the National Science Foundation. Siting-related outreach work was supported by a grant from the USArray Siting Outreach Program. The Flagstaff E&O workshop was supported by IRIS, UNAVCO, and ASU.



Teachers participating in the September 2009 workshop in Flagstaff.

# Implementing Inquiry-Based Approaches in Geoscience Education and Research

Michael Brudzinski (*Miami University of Ohio*)

One of the most important issues in geoscience is the growing disparity between workforce needs and our ability to produce well trained students. This project is examining whether inquiry-based approaches to education and research can aid in this challenge by partnering with the successful IRIS Undergraduate Internship Program and building on a university-wide course revision project converting introductory courses from lecture-based to inquiry-based. The inquiry-based approach is also a natural one to investigate an exciting new observation that plate boundary faults produce episodic tremor and slip (ETS). This project has 3 integrated research and teaching initiatives:

1. Expand the inquiry-based approach to other courses by i) developing a workshop to train high school instructors how to use this approach in an AP environmental science class and by ii) constructing a new second-course at the college level that focuses on how physical processes associated with plate tectonics relate to geologic hazards. These efforts ensure that students are practicing the scientific method not just memorizing the outcomes;
2. Expand the investigations of ETS behavior by i) searching for ETS in a global context using newly developed detection algorithms and by ii) investigating the spatial and temporal relationships between tremor, slow slip, earthquakes, and geologic structures. These efforts cultivate physical understanding of how faults move and generate hazards;
3. Expand the student research experience by i) offering undergraduate research to a larger set of students including an investigation into what makes a successful research project and by ii) experimenting with online research discussion both in classes and with collaborating research groups. These efforts identify key areas for improvement in the integration of teaching and research.

Collectively, the integrated teaching and research plan targets 3 broader impact outcomes that address the key issue of preparing a scientifically trained workforce:

1. Encourage students to consider a career in geoscience through earlier exposure to experiences with intrinsic motivation (i.e., AP credit or personal interest in hazards);
2. Retain majors and graduate students through work on newly developed areas of research (i.e., ETS) that address problems of high societal importance (i.e., what causes earthquakes);
3. Improve students' scientific training through more regular use of the scientific method.

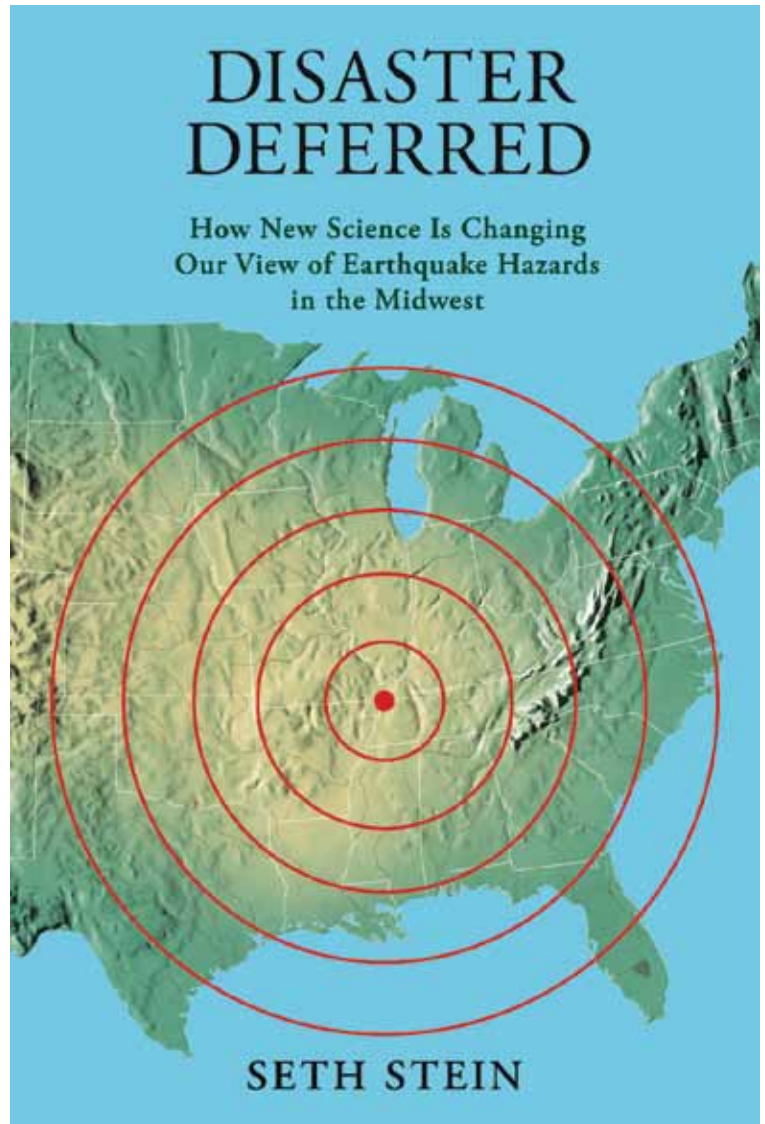
*Acknowledgements:* NSF EAR-0847688



# From an IRIS Lecture Tour to a General Audience Book About Midwest Earthquakes

Seth Stein (*Northwestern University*)

Following earthquakes of public interest, seismologists are effective at explaining to the media about the earthquake's location, magnitude, and tectonic setting. However, the underlying research questions are typically not discussed, in part owing to the challenge of explaining ongoing and unresolved scientific questions. As a result, we often do not show the public the challenges and complexities of earthquake research. An exception is IRIS/SSA Distinguished Lectures, which give the speaker the motivation and time to explain earthquake research in some depth. In 2006 I gave IRIS/SSA lectures on "Giant earthquakes: Why, Where, When, and What We Can Do" at a number of science museums. Although the focus was on the largest earthquakes, the lecture also explained general concepts of plate tectonics, earthquakes, seismology, and earthquake hazards. Giving the lectures was interesting and satisfying, and indicated that the material could be presented using an approach that focused on the key ideas and unresolved issues. Based on this experience, I have incorporated much of this material in a new book written for a non-technical audience: "Disaster Deferred: How new science is changing our view of earthquake hazards in the Midwest" that will be published in fall 2010 by Columbia University Press.



"Disaster Deferred: How new science is changing our view of earthquake hazards in the Midwest" will be published in fall 2010 by Columbia University Press.

# Active Earth Display Kiosk Education and Outreach Missouri Department of Natural Resources

**Hylan Beydler** (*Missouri Department of Natural Resources, Division of Geology and Land Survey*), **Ed Clark** (*Museum of Missouri Geology – Rolla*)

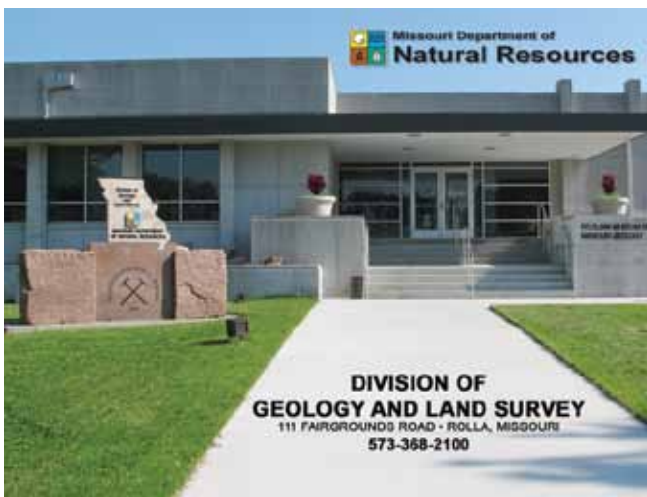
The Active Earth Display kiosk provides an exciting educational opportunity for teaching earthquake science in the informal environment of the Ed Clark Museum of Missouri Geology. The museum is located at the Division of Geology of Land Survey, Missouri Department of Natural Resources, 111 Fairgrounds Road, Rolla, Mo. The virtual tools, animations and interactive, real-time presentation of seismic data and the science behind it has drawn visitors from all walks of life and all age groups including students, scouts, geology and other nature club members, families, scientists, community and state leaders, and those traveling along Interstate 44 and historic U.S. Route 66.

Visitors are welcome to tour the museum at their own pace, while others request a tour led by a staff geologist who enhances the experience by sharing additional geologic information. EarthScope literature provided by IRIS is also available.

Especially exciting is that the AED has afforded greater information dissemination about earthquake potential in the New Madrid Seismic Zone; the most seismically active area east of the Rockies, which lies in southeastern Missouri and neighboring states. A series of webpages about the NMSZ developed by MoDNR staff are integrated in the AED. Visitors also learn about the large earthquakes that occurred in the NMSZ in the winter of 1811-12, and about the fast approaching 200th anniversary of the historic events. Staff members also educate visitors about the department's responsibility for activating the Post-Technical Earthquake Clearinghouse, which is a clearinghouse for scientists wishing to enter the affected area in the event of a large, damaging earthquake in the NMSZ.

In August 2010 and 2011, the AED will relocate to Sedalia, where more than 25,000 people are expected to visit it at the Historic Womans Building during the Missouri State Fair. Sedalia is 90 miles east of Kansas City. EarthScope Transportable Array Stations have arrived in that region, and continue to be placed in Missouri throughout 2010, with full state coverage in 2011. The AED also debuts on the state Capitol grounds in Jefferson City where more than 2,000 fifth graders and others will have an opportunity to learn about earthquakes during MoDNR's Earth Day celebration April 22, 2011.

The AED has greatly enhanced the learning experience for young people and life-long learners interested in earthquakes.



The Ed Clark Museum of Missouri Geology is located at the Missouri Department of Natural Resources' Division of Geology and Land Survey, 111 Fairgrounds Road in Rolla, Missouri. The museum provides a background for staff to share the importance of the state's natural resources and highlights rocks, minerals and fossils found in our state. The museum also identifies the role the division plays in the management and protection of these resources.



The Active Earth Display kiosk is popular stop for visitors to the Ed Clark Museum of Missouri Geology.

The Active Earth Display kiosk will debut at the Missouri State Fair, in Sedalia, August 12-22 and will return in 2011.



## Explorer Series

**Robert Bartolotta** (*Cleveland Museum of Natural History*)

The Cleveland Museum of Natural History has offered a public lecture series nearly since the museum was founded in 1920. In 1997 the museum developed a seismology program with leftover parts from the defunct John Carroll University Seismic Observatory. Mostly a monitoring program initially eventually developed into a Seismic Observatory of our own and participation in the The Ohio Seismic Network OhioSeis under the direction of Dr. Michael C. Hansen within the Ohio Department of Natural Resources, Division of Geological Survey. Thanks to IRIS, SSA and the Distinguished Lecture Series, the museum has hosted six speakers since 2003. It has been an honor for the museum to host Dr. Susan Hough, Dr. Anne Sheehan, Dr. David Wald, Dr. Uri ten Brink, Dr. Seth Stein and Dr. Roger Bilham. All of these IRIS/SSA sponsored speakers have brought a world of knowledge to our Explorer Series. The tradition of hosting an IRIS speaker in conjunction with Earth Science Week will continue in 2010 with a program by Dr. Brian Stump speaking about forensic seismology.

## The IRIS Workshop as Outreach

Wayne D Pennington (*Michigan Technological University*)

The IRIS Workshop is not usually considered to be an element of outreach, but it is. And here is why:

No seismologist is an expert in all aspects of the field. Some, such as myself, were experts in some areas years ago, but my own career has drifted into a few niche specialties, only peripherally related to mainstream solid-earth seismology as currently practiced. Yet, I need to teach classes and advise graduate students, and serve on student committees. I can do that from a position of ignorance, or I can do it from a position of knowledge, and IRIS Workshops help me obtain that knowledge.

I have long appreciated the IRIS Workshop for two major reasons: (1) it is always attractive to attend, being inexpensive for IRIS member representatives and in a nice location; and (2) it provides, in a couple of relatively painless days, an in-depth introduction to some of the most advanced and current topics of research. In one half-day session, I can learn about a topic of which I had been vaguely aware, and learn from the masters: speakers who had been invited based on their expertise and on their ability to present the topic well. In the course of one Workshop, I can learn enough about three or so different topics to go back to my home institution and teach the topic at the undergraduate or beginning-graduate level; I can speak intelligently with people on these topics; and I can point graduate students whose research may benefit, to the experts and/or top papers on the topic, and help those students understand it all.

True, the main reason for the Workshop is (probably) for the researchers to communicate with each other. But, to me, the main advantage of the Workshop is that it provides an opportunity to master subjects that would have taken tedious days of hard mental labor with published papers otherwise (assuming I would know where to start). It is outreach to people like me.



Image of Plenary Session in 2010. (From IRIS website.)

# Workshop "Earth System Science for Educators" at North Carolina A&T State University

Solomon Bililign (North Carolina A&T State University)

Over the past five years, AfricaArray (AA) program has established a multifaceted geosciences education and research program in Africa with a US component to enhance diversity in the geosciences. The Incorporated Research Institutions for Seismology (IRIS) has played a pivotal role in AA by providing refurbished data loggers for the seismic network, by archiving and distributing seismic data, and by supporting a summer workshop for high school science teachers at NCAT.

A workshop "Earth System Science for Educators" has been run for 5 years with assistance from the IRIS Education and Outreach Program. The workshop was run fully by IRIS in the first year, and since 2007, with the establishment of the National Oceanic and Atmospheric Administration (NOAA) Interdisciplinary Scientific Environmental Technology Cooperative Science Center (ISETCSC) Center at North Carolina A&T State University the workshop has expanded the content to include atmospheric sciences with instructors from NOAA. The goals of ISETCSC are consistent with the goals of Africa Array: to increase the number of educated, trained, and graduated students from underrepresented communities. The workshop has become so successful that in the summer of 2008 there were 150 applications for the 25 available slots. The participants are eligible to receive up to 4 continuing education units (CEU) credits. With additional support from NSF the number of participants was increased to 50 in 2009. The workshop was filled to capacity with 50 teachers with a lot more on the waiting list.

Earth science has become a required course in North Carolina School systems, and most teachers lacked the necessary training and background to be effective teachers. The AA workshops have been instrumental in increasing the skills and knowledge of a number of teachers in North Carolina, and teachers were able to develop curriculum material and teaching aid for their classes as a result of their participation in the workshops.

Earth science has become a required course in North Carolina School systems, and most teachers lacked the necessary training and background to be effective teachers. The AA workshops have been instrumental in increasing the skills and knowledge of a number of teachers in North Carolina, and teachers were able to develop curriculum material and teaching aid for their classes as a result of their participation in the workshops.

*Acknowledgements:* The workshops were made possible by support from NSF-PIRE program and NOAA Cooperative Agreement No: NA06OAR4810187



The participants of the 2009 teachers workshop at North Carolina. Workshop instructors included John Taber (E&O Program Manager, IRIS Consortium), Lev Horodyski (Pennsylvania State University), Angela Reusch (Pennsylvania State University), Michael Hubenthal (Education Specialist, IRIS).

# IRIS Undergraduate Intern Research: Colorado Seismicity

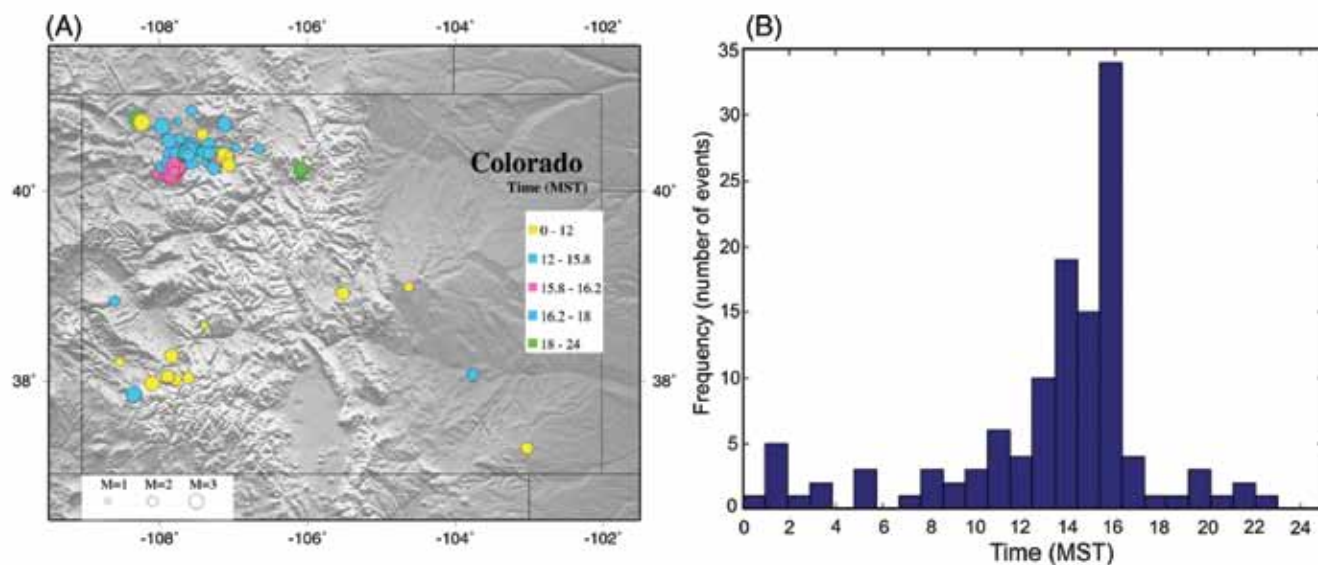
Christina Viviano (University of Colorado at Boulder), Gaspar Monsalve (University of Colorado at Boulder), Anne Sheehan (University of Colorado at Boulder)

The IRIS undergraduate intern program pairs promising undergraduate students with research mentors from IRIS member institutions for a summer of seismological research. The student research culminates in a technical presentation at the national AGU meeting, and often leads to published research or contributions to publications. Undergraduate intern Christina Viviano participated in the project described here as part of the IRIS Undergraduate Internship Program, and the work resulted in a paper published in *Seismological Research Letters*. Viviano's project involved analysis of data from the Rocky Mountain Front IRIS PASSCAL seismic experiment (RMF). The RMF experiment consisted of the installation of 33 broadband seismic stations spread throughout Colorado with a few additional stations in Kansas and Utah. The use of this relatively dense seismic network, with an average seismometer separation of 75 km, allowed for the detection and location of Colorado earthquakes on a regional scale. The Rocky Mountain Front experiment was one of the first PASSCAL experiments, occurring in 1992. The data are archived at the IRIS DMC and analysis such as this many years after the original experiment is still possible. The analysis resulted in a six-month catalog of regional seismicity, which combined with additional temporary deployments contributes to improved understanding of Colorado seismicity. Though the majority of the events detected during the six-month deployment were classified as mining blasts (about 80%), the remaining remaining events reveal a six-month snapshot of seismicity in the state. Twenty-four events characterized as earthquakes were recorded during the six-month deployment. Extrapolation of our small sample of seismicity to higher magnitudes indicates that, at the most, two earthquakes of magnitude 6 are expected to occur every 1,000 years. However, the validity of the extrapolation of results based on a small data set is tenuous. A long-term uniform seismic network would give a better representation of the seismicity of Colorado, and further analysis will be advanced through the EarthScope USArray deployment.

## References

Monsalve, G., C. Viviano, and A. Sheehan, An assessment of Colorado seismicity from a statewide temporary seismic station network, *Seismol. Res. Lett.*, v. 79, n. 5, p. 645-652, 2008.

*Acknowledgements:* We thank Frederick Blume and Gregory Bensen for their hard work in archiving the continuous RMF seismic data at the IRIS DMC many years after the original experiment, Art Lerner-Lam for running the RMF experiment, and IRIS for providing seismometers and assistance. Christina Viviano participated in this project as part of the IRIS Undergraduate Internship Program, funded by the National Science Foundation (NSF- EAR-0453427). The archiving of the continuous RMF data at the IRIS DMC 10 years after the original experiment and the seismicity analysis presented here were supported by NEHRP Grant No. 03HQGR0091.



Seismic events (including suspected mine blasts) recorded by the RMF network between May and December 1992. (A) Seismicity map with symbol size scaled by event magnitude and colored by event origin time of day. Note the predominance of afternoon events (hours 12–18 MST). (B) Time-of-day histogram of events. Note the peaks at afternoon hours (hours 12–18 MST).

# The IRIS Internship Cycle: From Intern to Graduate Student to Intern Mentor

Andy Frassetto (*University of Copenhagen*)

Serving as an overture to seismological theory and application, computing methods, and fieldwork; IRIS internships have introduced undergraduate students to the rigors of graduate school and eventual careers in geophysics. During my internship in 2003 the program resembled a summer job away from home, where students worked on a research project at their host institute and then convened at AGU to meet and present their results. Now the program has become an institution unto itself, starting with a week-long orientation that creates a peer group which can engage and support itself throughout the summer when spread across the U.S. [Hubenthal *et al.*, 2009]. The satisfaction of participating in the development of this program and witnessing its impact firsthand is trumped by hosting an intern. In many respects this experience is a natural sequel to doing an internship. When supervising an intern, the formative experiences during the internship program and graduate school helped me to recognize what enables a successful summer project.

Like many IRIS interns, I matriculated to the school of my internship for graduate study in seismology. When an appropriate summer project arose, my advisor and I proposed to host a student during the summer of 2008. That intern, Jamie Ryan, participated in the last orientation that I helped oversee and worked on a study of earthquake focal mechanisms using data from the Sierra Nevada EarthScope Project [Ryan *et al.*, 2008]. Working with Jamie was a pleasure, and his work will be featured prominently in a future publication on the fundamentally important seismicity occurring beneath the Sierra Nevada. Jamie will be starting graduate study in seismology at Arizona in the fall of 2010.

There are many skills involved in research that become engrained and thus may be hard to articulate when steering an intern's summer project. These include developing set goals and timetables, focusing literature searches, resolving code and program errors, recognizing data issues, integrating an interpretation with other constraints, *et al.* Experiencing this process via a previous internship allows a host greater finesse as a mentor. The transition of former interns to intern hosts has been unfolding over the last few years within the classes of IRIS alumni. This lineage of researchers with a specific familiarity and appreciation for the scope and goals of the internship program should continue to fortify a new generation of seismologists.

## References

- Ryan, J.C., A. Frassetto, O. Hurd, G. Zandt, H. Gilbert, T. Owens, C. Jones (2008), Focal Mechanisms for Deep Crustal Earthquakes in the Central Foothills and Near Yosemite National Park in the Sierra Nevada, California, *Eos Trans. AGU*, 89(53), Fall Meet. Suppl., Abstract S33B-1957.
- Hubenthal, M., Wysession, M., Aster, R. (2009), Virtual cohorts and face-to-face recruitment: Strategies for cultivating the next generation of the IRIS Community, *Eos Trans. AGU*, 90(52), Fall Meet. Suppl., Abstract ED23B-02.
- Acknowledgements:* Thanks to Jamie Ryan for his dedicated work during the summer internship and while finishing his undergraduate degree and to George Zandt and Susan Beck for introducing me to the IRIS program.

# IRIS Membership and E&O Program Team up for Intern Orientation Week

**Richard Aster** (*New Mexico Tech*), **Michael Hubenthal** (*IRIS Consortium*)

“Technology alone is not enough to create a strong social cohesion and sense of community among online members... It is essential to apply some techniques that help members in online communities enthusiastically and willingly work together” [*Ubon and Kimble, 2003*]. Students accepted into the IRIS Internship Program, prior to heading to their sponsoring institutions, attend a 5-day orientation to develop a strong sense of community among the interns and to provide an introduction to some of the most exciting aspects of modern seismology. Extensive experience with Earth science “field camps” shows that, for example, discussing earthquakes and faulting at the base of a dramatic fault scarp, provides a vastly richer learning experience than the normal classroom setting. Because of its excellent location for field experiences along Rio Grande Rift, a wide-ranging Earth Science department, its teaching, research, and computational facilities, and state-of-the-art field equipment and expertise at the IRIS PASSCAL



IRIS Interns installing a broadband seismic station in 2010. Students installed three stations and analyzed teleseismic seismograms recorded over a three-day period.

Instrument Center, New Mexico Tech (NMT) has successfully hosted the orientation since 2006. Instructors lead a variety of field excursions to collect and analyze active and passive seismic data and explore the relationship to regional and local scale geologic structures, and cutting-edge science questions [*e.g., Hubenthal et al., 2007*]. Orientation Week also highlights in-depth laboratory exercises and special lectures/discussion sessions by faculty and staff. Formative observations of instruction by the internship facilitator, who is trained in instructional supervision, help tailor instruction to the group and ensure quality delivery. Classroom sessions introduce interns to a variety of topics including: history and theory of seismology, earthquakes and earth structure, geophysical inverse theory, general reflection and refraction theory, and seismological data collection and seismic processing. Lab sessions introduce interns to the basics of UNIX and to computer programs that students are likely to encounter (*e.g., Matlab, GMT and ProMax*), and research-grade field equipment used by NSF and other researchers. Participants during 2010 included: Seth Stein (Northwestern University), M. Beatrice Magnani (University of Memphis), Catherine Snelson, Gary Axen, William McIntosh, Pnina Miller, Rick Aster, and Hunter Knox (NMT), Darren Hart (Sandia National Laboratories), Michael Hubenthal and John Taber (IRIS), and Robert Porritt (U.C. Berkeley).

## References

- Hubenthal, M., Taber, J., Aster, R., IRIS Undergraduate Internship Program and Orientation Enters its Second Year, Proc. EarthScope National Meeting, Monterey, CA, 2007.
- Ubon, A., Kimble, C., Supporting the creation of social presence in online learning communities using asynchronous text-based CMC, Proceedings of the The 3rd International Conference on Technology in Teaching and Learning in Higher Education, 295-300, 2003.



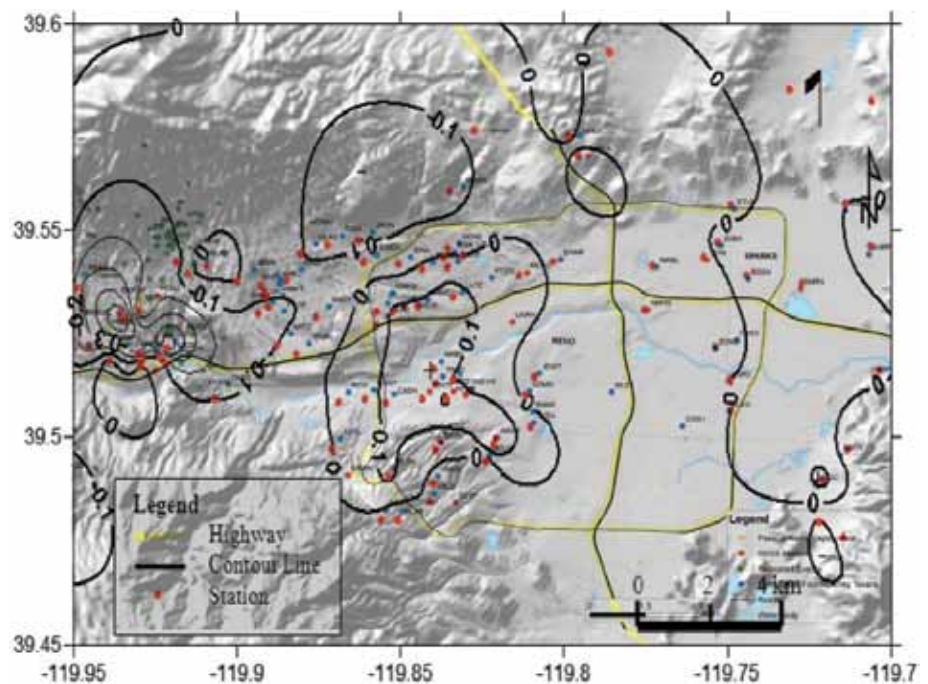
# Community-Outreach Efforts in Data Collection and Analysis for the 2008 Mogul Earthquake Sequence

**Annie Kell-Hills** (University of Nevada, Reno), **Mahesh S. Dhar** (University of Nevada, Reno), **Mayo Thompson** (University of Nevada, Reno), **John N. Louie** (University of Nevada, Reno), **Kenneth D. Smith** (University of Nevada, Reno)

Beginning February 28, 2008 the residents of west Reno and Sparks, Nevada experienced continuous earthquakes ranging in magnitude from M1.0 to M5.0, centered in the west Reno neighborhoods of Mogul and Somerset. The occurrence of these earthquakes within residential areas stimulated the attention of the public and the media, providing an opportunity for the Nevada Seismological Laboratory (NSL) to involve the public in earthquake research. The NSL invited the public to host single-channel USArray Flexible Array RefTek RT-125A (Texan) recorders in their homes during May and June of 2008. Reno and Sparks residents volunteered to attend training sessions on installing and hosting recorders at their residences, filling the many gaps in NSL's permanent and RAMP station arrays. The use of instruments from the IRIS PASSCAL center allowed us to accommodate the unprecedented volume of public interest in local aftershock response. During the deployments, the 90 instruments covered a dense area of the Reno area with 106 different deployed locations (see figure). Evaluation of recorded seismograms for a M3.1 event display atypical responses for areas of bedrock and basin fill, in that bedrock seismograms in the north of Reno displayed higher than expected amplitudes and long durations, and that some regions of basin fill showed lower than expected amplitudes. Comparing these seismograms allows us to better interpret basin depths and bedrock locations for the Reno basin, and allows us to develop better models for local earthquake hazards. Analyses of the recorded data include time delay calculations and straight-ray tomography. A back-projection of pick delays indicates positive delays in the volcanic hills north of Reno, atypical of bedrock settings. Curve fitting on a time-distance plot for the M3.1 event estimated a hypocentral depth greater than the depth derived from NSL's permanent stations, motivating a study relocating the event depths. Data were then used to relocate the 97 recorded events by integrating event arrival times recorded with the PASSCAL instruments with the NSL network database for the permanent, strong-motion, and RAMP stations. Results from simple hypoinverse runs show that the dense station dataset drastically improves event locations, providing a better understanding of this swarm under urbanized Reno.

*Acknowledgements:* Research partially supported by the U.S. Geological Survey (USGS), Department of the Interior, under USGS award number 08HQGR0046. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government. Instruments used in the field program were provided by the PASSCAL facility of the Incorporated Research Institutions for Seismology (IRIS) through the PASSCAL Instrument Center at New Mexico Tech. Data collected during this experiment are available through the IRIS Data Management Center. The facilities of the IRIS Consortium are supported by the National Science Foundation under Cooperative Agreement EAR-0552316 and by the Department of Energy National Nuclear Security Administration.

Location of deployed USArray Flexible Array Texan seismographs (red and blue) along with station time-delay contours calculated using both the permanent and portable stations.



# USArray Student Siting Program Has a Big Impact in Oklahoma

Randy Keller (*University of Oklahoma*)

The Student Siting Program had a number of positive outcomes for the students from the University of Oklahoma who were involved. These impacts began with our trip to the training workshop where they had a chance to meet fellow students from around the southwest and visit another university. The summer support provided them a positive professional experience and saved 3 out of the 4 from menial summer jobs. They all enjoyed seeing parts of our state they had never seen before and meeting landowners who were mostly very helpful. However, they did come back with some interesting stories about some of their encounters. Catherine Cox was a new MS student and had a particularly positive experience that led toward her being very effective in helping layout and plan logistics for a large NSF project, the High Lava Plains project, after her siting work was finished. She is currently finishing her MS and is continuing her education in our PhD program. She was also asked to help with a subsequent Student Siting Program training workshop. Jonathan Green, Julianna Gay, and Matt Hamilton all went on to finish their BS degrees with excellent academic records and are now pursuing their MS degrees. They all remember their siting experience fondly. Their interest in EarthScope certainly spread across our student body and made them more aware of the project. An example of how good relations with landowners were in most cases is an event that occurred when a large group of students, faculty and media attended the equipment installation at a site near our university this spring. The landowner was very helpful and even cooked hamburgers for the crowd. We had two young visiting scientists from China attend this event and also became very interested in EarthScope. Pictures of this event are included in this report.

*Acknowledgements:* This research was supported by a sub-award from IRIS.



Figure 1: Catherine Cox at a TA station installation.



Figure 2: Seismologist Austin Holland speaking to the media during a TA station installation.

# Site Reconnaissance for Earthscope USArray: A Vehicle for Integrating Geophysics and GIS Education with Outreach to the Community While Saving Money

Anne Trehu (*Oregon State University*), Perle Dorr (*IRIS*)

Identification and permitting of sites for seismic stations of EarthScope's USArray Transportable Array is a very ambitious undertaking. Initial site reconnaissance requires integration of information from a variety of geographic databases as well as an understanding of the regional geology and tectonics, the objectives of the EarthScope and USArray programs, and the technical requirements for a seismically quiet site. It thus provides rich opportunities for students in Earth sciences and geography to apply and enhance their knowledge. During summer 2005, Oregon State University (OSU) and IRIS initiated the USArray student-driven site reconnaissance program that continues today with participation by universities in the regions where stations will be installed in the following year or two.

The program began with a 3-day workshop for 11 students (8 from OSU; 3 from Arizona State University) organized by Anne Trehu (OSU geophysics), Mark Myers (OSU geography) and Bob Busby (USArray). The workshop included lectures about the scientific objectives of EarthScope, training on procedures to identify sites that meet the requirements of USArray, and a field trip to find a few local sites. Prior to going into the field, GIS tools using databases assembled by OSU, IRIS, and the Institute for the Application of Geospatial Technology were used to identify locations that met as many requirements as possible: 1) appropriate topography and geology; 2) adequate distance from cultural noise sources; 3) private ownership; and 4) digital cell phone coverage.

GIS lab work was followed by field visits to make contact with landowners and identify specific sites. In rural areas, University extension agents provided a valuable introduction to the local community. The "products" of this project were formal "Reconnaissance Reports" that included contact information, special site considerations and detailed instructions for finding the sites. Site locations were finalized by professional USArray staff.

Since this initial pilot program, the Transportable Array has conducted six additional siting workshops that have trained nearly 100 students who have identified locations for about 900 seismic stations. Based on feedback from the participants, the program has evolved, and continues to incorporate new techniques and technologies. The more recent workshops have placed more emphasis on determining and assessing site communications and the application of customized GIS products for initial site reconnaissance. But one thing that has not changed is the fact that the Transportable Array site reconnaissance program is popular among students and PIs alike. It has also proven to be an efficient and cost-effective way to locate a large number of sites while simultaneously providing an exciting practical training opportunity for students and transmitting the excitement of USArray to the public.



Students and instructors who participated in the 2005 Transportable Array Site Reconnaissance Program.

# Educational and Outreach Experience from EarthScope/USArray 2010 Summer Siting Program

Jer-Ming Chiu (CERI, The University of Memphis)

The IRIS siting program has provided a very exciting educational and learning opportunity for two summer interns, William Jackson and Brian Young, as well to many landowners who we deal with in northern Mississippi, western Tennessee, western Kentucky, and southern Illinois. Summary of comments from the two interns are included below.

*Will Jackson:* During my internship with Earthscope and USArray, through the University of Memphis, I feel that I have gained valuable experiences and learned numerous lessons that will help me in my future career as a graduate student and professional. Several of the most significant things learned this summer include: 1) Communication Skills - whether it be face to face, on the phone, or in a professional setting, I gained a new found confidence that allowed me to communicate my idea

to the person that I was engaging. 2) Successful Planning – creating and implementing a plan that included many different facets that had to be organized and carried out from start to finish. 3) Teamwork – whether it be with the professionals from Earthscope or with my team leader and partner, this internship gave me an opportunity to experience teamwork with professionals from the Earth Sciences that allowed me to gain knowledge of many other aspects beyond just the USArray project. I feel that the skills that I have obtained over the summer interning with Earthscope will help me throughout the rest of my graduate studies along with my professional career. In summary this summer internship has been an invaluable experience that I will never forget and always be indebted to the people who allowed me the opportunity.

*Brian Young:* Being a Physics undergraduate, prior to my participation in the Earthscope project I had never had any field experience outside of a laboratory, at all. Through my siting endeavors with my partner, we explored rural areas and farmland from northern Mississippi to western Kentucky, all the way up to St. Louis, Missouri. Not only did we drive around for days looking for suitable places for next year's seismic stations to be installed, experiencing the local landscapes and culture, but by speaking with landowners about the project and asking for their permission to install a seismic station on their land, we learned effective methods for presenting scientific projects to people who may not even know what a "seismic station" is. During the first few weeks of our siting experience, we could only find about one suitable site a day, and many landowners declined to host a seismic station on their land, having no interest in the project. Though frustrating, we eventually gained experience in explaining this exciting and ground-breaking project to local landowners, and many became enthusiastic to hosting a site for Earthscope and USArray – scientific endeavors of unprecedented scale. Into July and nearing the completion of our siting job, we were able to find two, or even three landowners in as many as three different states to agree to host a seismic station, all in a single day of siting.

*Acknowledgements:* This project is sponsored by the IRIS siting program at ISIS 1310 BP10. Landowners in the northern Mississippi, western Tennessee, western Kentucky, and southern Illinois help to make this siting project possible.



Brian Young (left) and William Jackson (right) are listening to a brief instruction of regional geology and oil field operation status in southern Illinois by Michael D. Podolsky (second from the right), a petroleum geologist, before heading to field to find a nearby site (R45A) near Fairfield, Illinois.

# jAmaseis: Seismology Software Meeting the Needs of Educators

Ben Coleman (*Moravian College*)

jAmaseis is a piece of educational software that replaces and updates Amaseis, the current standard program IRIS supports through "Seismographs in Schools." jAmaseis allows users to send and receive seismic data in realtime, filter data, fit a seismogram to travel time curves, triangulate event epicenters on a globe, estimate event magnitudes, and generate images showing seismograms and corresponding calculations. Users accomplish these tasks through an interface specifically designed to enhance education.

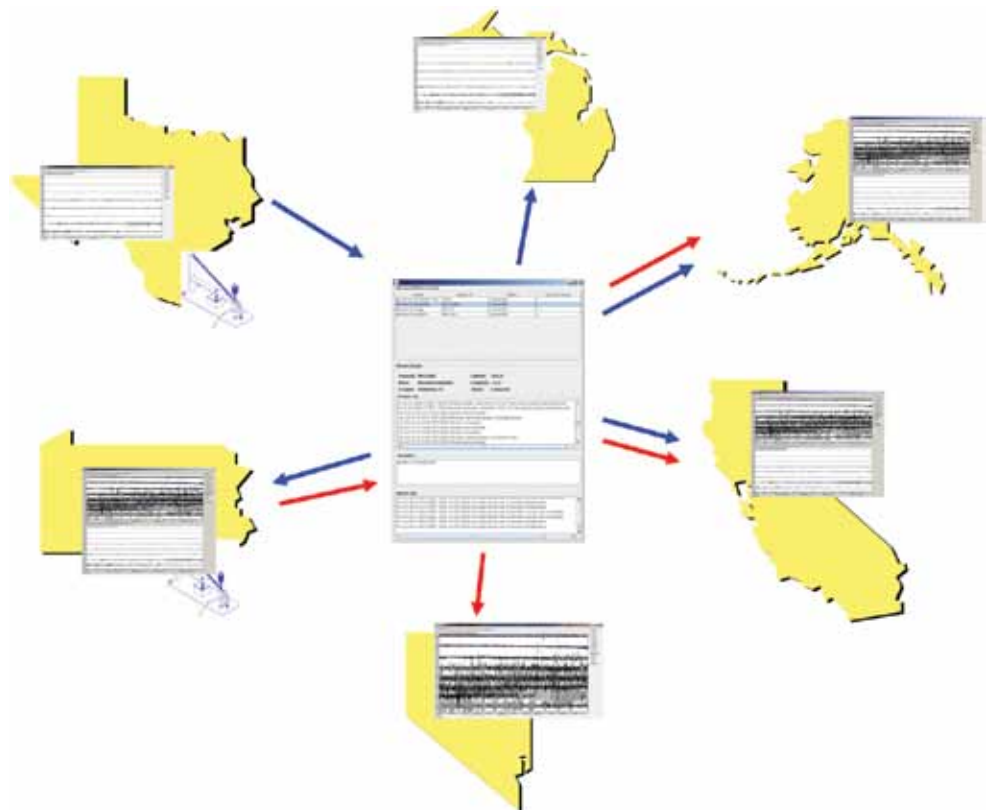
Beyond providing educators with an improved version of AmaSeis with new features, jAmaseis offers a number of benefits. Most importantly, the scope of the educational seismology program is significantly larger because jAmaseis allows an educator to use the wealth of resources already developed for AmaSeis without actually possessing a seismometer. In addition, new classroom pedagogies are possible. With jAmaseis, a user can view and manipulate multiple streams of data simultaneously and produce visual representations of the results. Using these capabilities, an educator can instruct students to compare or combine the analysis of various seismic records, providing a deeper learning experience. Finally, because jAmaseis untethers the seismometer from the viewing computer, new applications are possible. For example, jAmaseis can be used to create engaging displays in public spaces simply by mounting a computer monitor.

Work on jAmaseis is a productive collaboration between IRIS and Moravian College. At Moravian, a large percentage of the computer science students are involved in the design and implementation of jAmaseis as either a project within a computer science course or as a summer research experience. These students interact with members of the IRIS Education and Outreach group and see the complete development process from design through implementation. This type of hands-on experience is rarely found in undergraduate computer science programs, and consequently the students have the opportunity to publish at peer-reviewed conferences, have stronger resumes upon graduation, and can draw on their experience during interviews for perspective jobs.

jAmaseis is currently under active development, with plans for release to beta testers in August 2010 and release to the general public during the summer of 2011.

*Acknowledgements:* This work is supported by an NSF sub-award from the IRIS E&O program and through the Student Opportunities for Academic Research (SOAR) program at Moravian College.

The scope of educational seismology is expanded because users have access to realtime data over the Internet. The users in Texas and Pennsylvania send data to the data server. Users in Michigan, Alaska, California, and Pennsylvania receive the data from Texas from the server. Similarly, users in Alaska, California, and Nevada receive the data sent from Pennsylvania.



# Visualizing the Ground Motions of Earthquakes: the USArray Ground Motion Visualization (GMV)

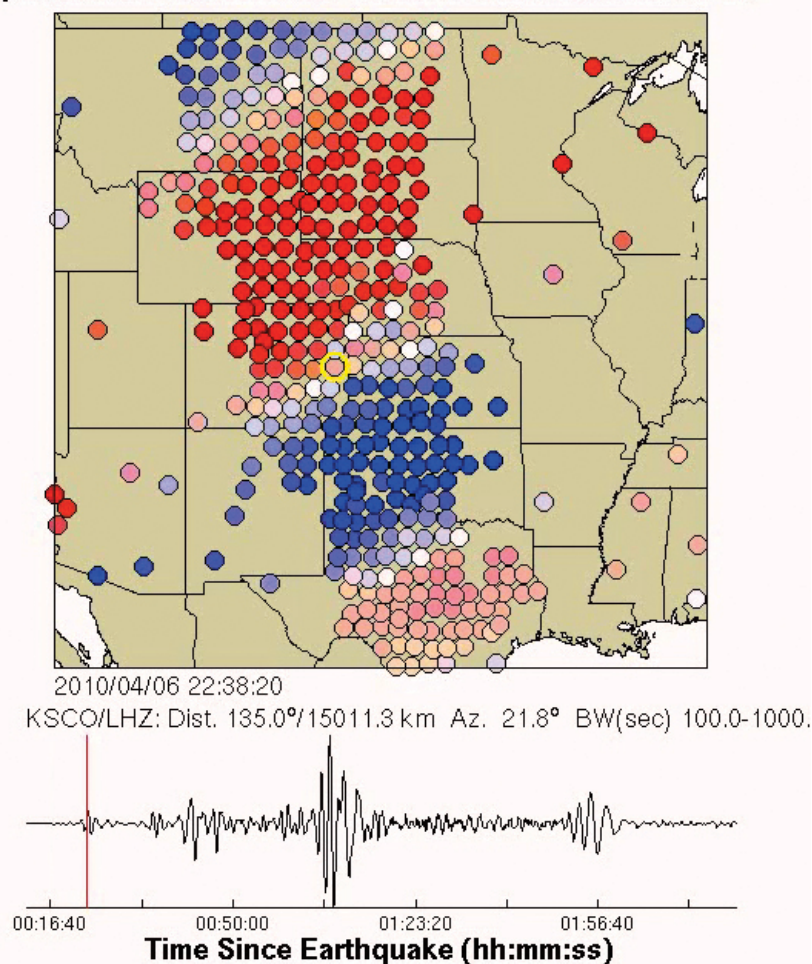
DMC Products Group (IRIS DMC)

When an earthquake occurs, the seismic waves radiate away from the source and travel in different directions and produce ground shakings that last from a few seconds to minutes. Amplitude, duration and nature of shaking at each point on the Earth's surface depend on the size of the earthquake, distance from the source and type of seismic waves. Seismic stations record these ground motions at the station site while seismic arrays that deploy several stations within an area, sample the ground motion over an area. Deployment of dense arrays, in which array sites are closely spaced, provide an opportunity to visualize earthquake ground motions by looking at a series of snapshots that depict ground motion at individual array sites over time.

The Transportable Array component of the USArray/EarthScope project is a rolling array of 400 broadband stations deployed on a uniform 70-km grid. This very large aperture array, along with other stations from USArray, is well suited to visualize seismic waves crossing the contiguous United States. The USArray GMV is an IRIS DMS product that illustrates how seismic waves travel away from an earthquake by depicting the recorded wave amplitudes at each seismometer location using colored circles. The color of each circle represents the amplitude of the ground motion as detected by the station's seismometer and it changes as waves of differing amplitude travel past the seismometer. Blue circles represent downward ground motion while the red circles represent upward ground motions with the darker colors indicating larger amplitudes.

*Acknowledgements:* Product development within the IRIS DMS is supported by the NSF grants #EAR-0552316 and EAR-0733069.

## April 06, 2010, NORTHERN SUMATRA, INDONESIA, M=7.8



Ground Motion Visualization (GMV) of the April 6, 2009 earthquake of Northern Sumatra, Indonesia.

# Near Real-Time Simulations of Global CMT Earthquakes

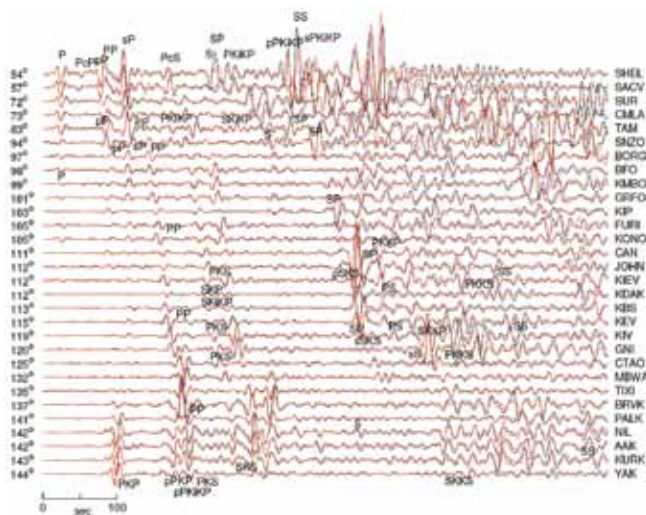
**Jeroen Tromp** (Princeton University), **Dimitri Komatitsch** (University de Pau, CNRS & INRIA), **Vala Hjörleifsdottir** (Lamont-Doherty Earth Observatory), **Qinya Liu** (University of Toronto), **Hejun Zhu** (Princeton University), **Daniel Peter** (Princeton University), **Ebru Bozdog** (Princeton University)

We have developed a near real-time system for the simulation of global earthquakes. Prompted by a trigger from the Global Centroid Moment Tensor (CMT) Project, the system automatically calculates normal-mode synthetic seismograms for the Preliminary Reference Earth Model, and spectral-element synthetic seismograms (Komatitsch & Tromp 2002) for 3D mantle model S362ANI (Kustowski et al. 2008) in combination with crustal model Crust2.0 (Bassin et al. 2000). The 1D and 3D synthetics for more than 1800 seismographic stations operated by members of the international Federation of Digital Seismograph Networks are made available via the internet and the Incorporated Research Institutions for Seismology Data Management Center (IRIS; iris.edu). The record length of the synthetics is 100 minutes for CMT events with magnitudes less than 7.5, capturing R1 and G1 at all epicentral distances, and 200 minutes for CMT events with magnitudes equal to or greater than 7.5, capturing R2 and G2. The mode simulations are accurate at periods of 8 s and longer, whereas the spectral-element simulations are accurate between periods from 17 s to 500 s. The spectral-element software incorporates a number of recent improvements, e.g., the mesh honors the Moho as a first-order discontinuity underneath the oceans and continents, and the performance of the solver is enhanced by reducing processor cache misses and optimizing matrix-matrix multiplication. In addition to synthetic seismograms, the system produces a number of earthquake animations, as well as various record sections comparing simulated and observed seismograms.

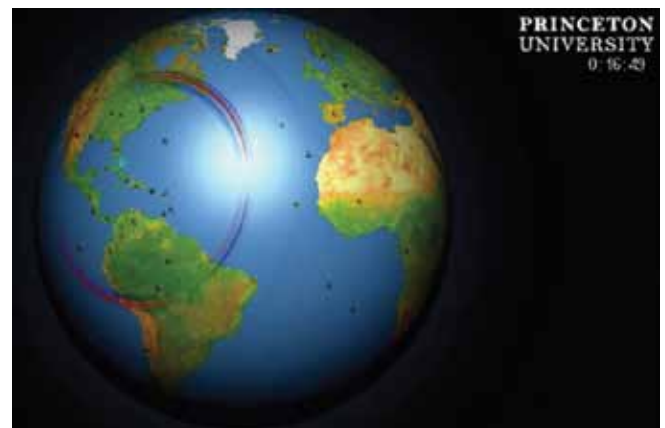
## References

- Bassin, C., Laske, G., and G. Masters, 2000. The current limits of resolution for surface wave tomography in North America, in EOS Trans. Am. Geophys. Union, vol. F897, p. 81.
- Kustowski, B., Ekström, G., and A.M. Dziewonski, 2008. Anisotropic shear-wave velocity structure of the Earth's mantle: A global model, J. Geophys. Res., 113, B06306, doi:10.1029/2007JB005169.
- Komatitsch, D. and J. Tromp, 2002. Spectral-element simulations of global seismic wave propagation—I. Validation, Geophys. J. Int., 149, 390–412.

*Acknowledgements:* This research was supported by the National Science Foundation under grant EAR-0711177.



Vertical component record section comparing data (black) and SEM synthetics (red) for the September 3, 2008, Mw = 6.3 Santiago del Estero, Argentina earthquake, which occurred at a depth of 571 km. The records are aligned on the P wave, plotted as a function of epicentral distance, and bandpass filtered between 17 s and 60 s. Major seismicological body wave arrivals are labeled. Epicentral distance is plotted to the left of each set of traces, and FDSN station identification codes are plotted to the right.



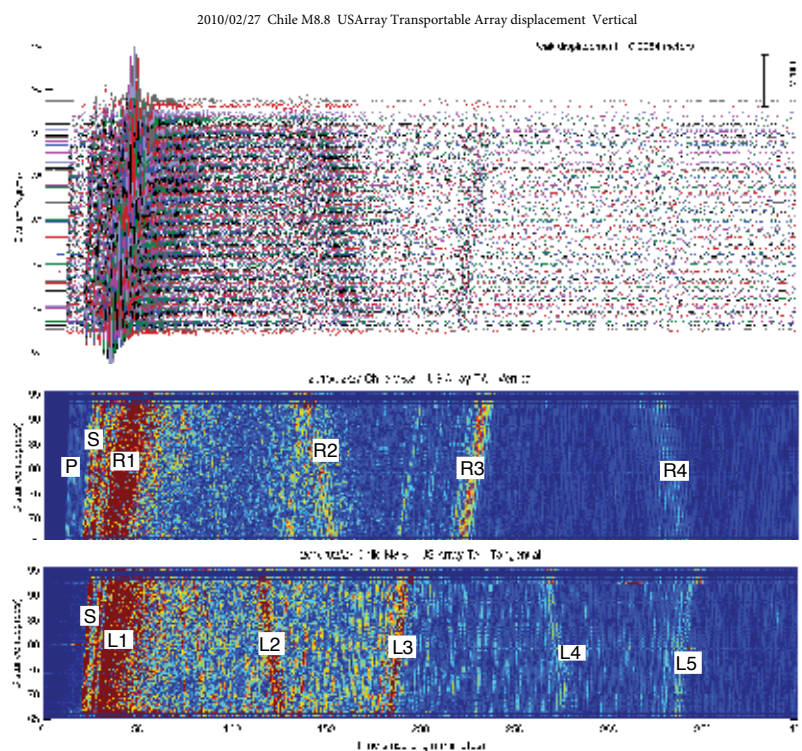
Snapshot of a spectral-element simulation of the January 12, 2010, Mw = 7.1 Haiti earthquake. The near real-time system produces animations of all earthquakes reported by the Global CMT Project. The animations show the velocity wavefield on Earth's surface as a function of time. Red: upward motion; Blue: downward motion. The prominent waves are the Rayleigh surface waves, and one can vaguely see SS waves crossing, e.g., Greenland.

# New DMC Data Product: Standardized Event Information Plots Generated in Near Real Time for All $M > 5.5$ Earthquakes

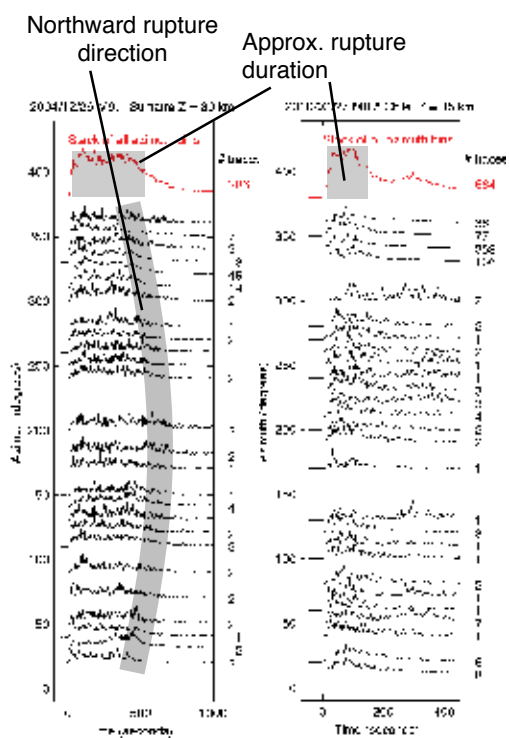
DMC Products Group (IRIS DMC)

As part of the extended product development effort at the IRIS DMC, we have begun to produce a suite of plots automatically generated in near real-time following all  $M > 5.5$  earthquakes. Plots will include record sections, vespagrams, time-distance envelope stacks, time-azimuth envelope stacks, station maps with signal-to-noise ratio and peak amplitudes indicated, phase centered record sections and various source-time function estimates. Depending on the plot type, plots will be generated using various data sets (all IRIS broadband data, USArray, southern California, Pacic Northwest Seismic Network...) in different frequency bands and for vertical, radial and transverse components. The plots will be available by plot type through our searchable product archive as well as on event-based webpages. These standardized plots will allow users to quickly scan data quality for seismic phases of interest or analyze many various features of earthquakes such as rupture duration and direction, coda duration, and complexity (impulsive vs emergent or single event vs doublet).

*Acknowledgements:* Product development within the IRIS DMS is supported by the NSF grants #EAR-0552316 and EAR-0733069.



The long aperture and station density of USArray allow for spectacular record sections such as these from the Feb, 2010 M8.8 Chile earthquake. Long period record sections are routinely generated for all large earthquakes (top) as well as nonlinear versions (bottom), which enhance the coherence of later major and weak arrivals. The bottom panels show clear Rayleigh and Love wave multiples.



Short period envelopes of data between 30-95 degrees distance are stacked in azimuthal bins. Quick looks at these plots can identify source features such as rupture duration, direction and complexity.



# FuncLab: A MATLAB Interactive Toolbox for Handling Receiver Function Datasets

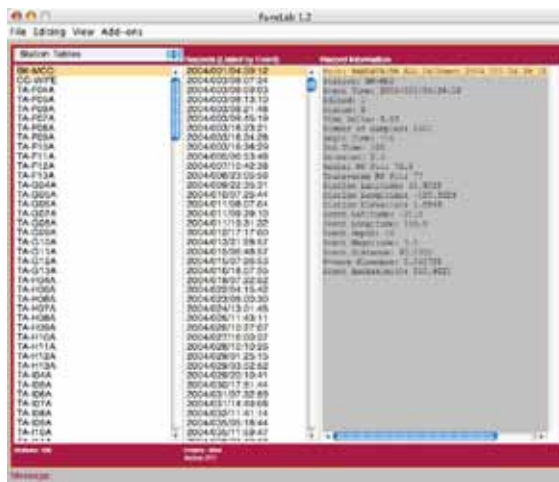
Kevin C. Eagar (School of Earth and Space Exploration, Arizona State University), Matthew J. Fouch (School of Earth and Space Exploration, Arizona State University)

We developed FuncLab, a new MATLAB graphical user interface (GUI) toolbox, for the management and analysis of teleseismic receiver functions. The ability to import and manage potentially large receiver function datasets within the MATLAB environment independent of the method of receiver function computation is the foundation of FuncLab. Additional modules for commonly employed processing and analysis methods, such as common conversion point and Hk stacking, are built around the FuncLab management system. We also provide a framework for the development of future modules that implement alternative analysis methods. Users start by importing data in SAC format and creating an independent project with a formal directory structure, setup by FuncLab. Metadata, such as station and event information, for each record are stored in arrays housed within a MAT-file in the project directory. To handle large datasets and allow faster processing, FuncLab does not store receiver function or seismogram time series data in MAT-files, but rather selectively reads this data only during analysis or visualization processes. Through user-friendly GUIs, information and visualizations of each record are easily accessible. One of the key strengths of FuncLab is its ability to facilitate the always time-consuming pre-processing step of data selection, or trace editing, through visualization of many records at a time. Other processing, preference setting, and data export are also handled by GUIs, providing a combination of customization for experienced researchers and intuitive guidance for beginners. The IRIS Data Management Center is currently developing a conduit to provide receiver functions generated from the EarthScope Automated Receiver Survey (EARS) into a format that can be directly imported into FuncLab. FuncLab will be released to the community in late summer 2010.

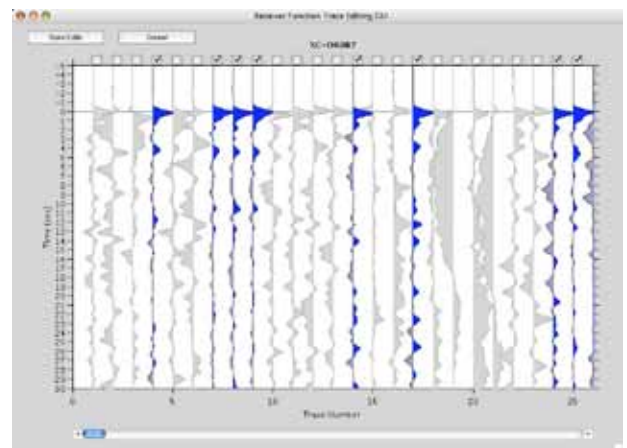
## References

Eagar, K.C. and M.J. Fouch, FuncLab: A MATLAB interactive toolbox for handling receiver function datasets, to be submitted to Computers and Geosciences, August 2010.

*Acknowledgements:* We would like to thank Rick Aster and Gary Pavlis for organizing extremely helpful MATLAB tutorials on receiver functions for the IRIS/Earthscope Imaging Science Workshop at Washington University in 2006 that first inspired KCE to deal with this problem in MATLAB. We would also like to thank Mike Thorne for his original SACLAB codes (<http://web.utah.edu/thorne/software.html>) for importing SAC files into MATLAB, much of which was modified for use with FuncLab. Thanks also to Manoch Bahavar and Chad Trabant of the IRIS Data Management Center and Philip Crotwell for extensive work in providing data products from the EARS project to be directly compatible with the new FuncLab MATLAB toolbox. This research was supported by National Science Foundation award EAR-0548288 (MJF EarthScope CAREER grant).



Screenshot of main FuncLab GUI. Items under the File, Editing, View, and Add-ons menus may be accessed from this screen. Top-left drop-down box lists the types of “tables” used to organize receiver function records. Tables are listed in the left panel. Records in the selected table (highlighted in left panel) are listed in the center panel. Metadata for the selected record (highlighted in center panel) are shown in the right panel. Information about number of tables, records, and active records are listed below the left and center panels, respectively. Text displayed at the bottom is used to convey short messages to the user about ongoing or finished processes.



Screenshot of receiver function Trace Editing GUI. Wiggle traces of records in a selected table are displayed with blue (or red, not shown) fill denoting positive amplitudes and dark gray fill denoting negative amplitudes. Check boxes above waveforms allow the user to change the record status to “on” (checked) or “off” (unchecked). Unchecked records also shaded light gray. Scrollbar at the bottom allows the user to scan through all records listed in the table.

# SEIZMO: a Matlab and GNU Octave Seismology Toolbox

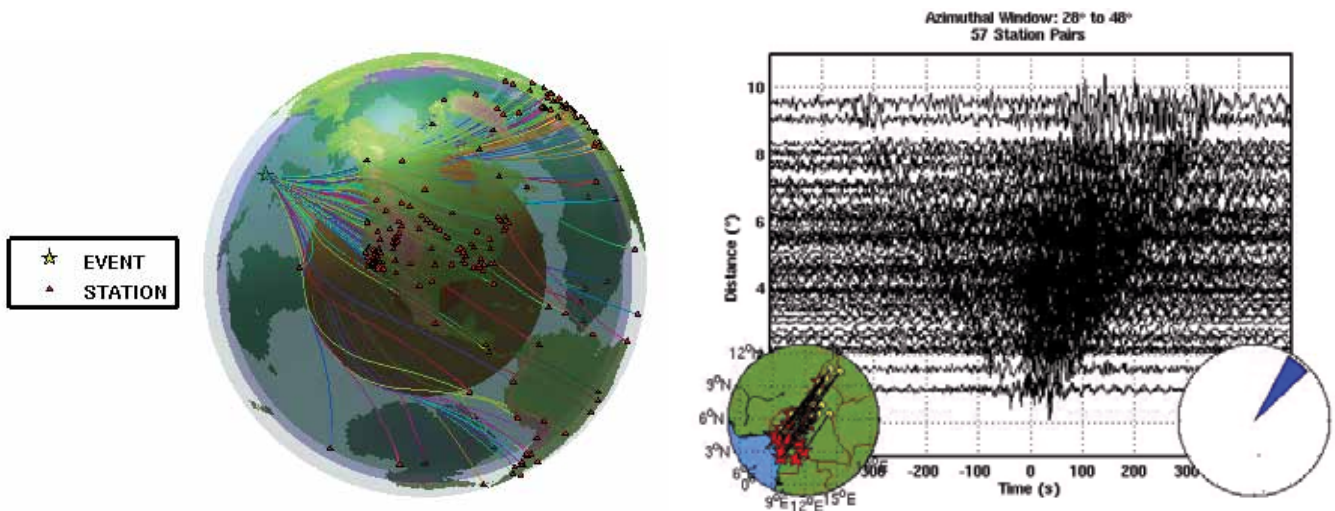
Garrett Euler (Washington University in St. Louis), Michael Wyession (Washington University in St. Louis)

SEIZMO is a Matlab and GNU Octave based toolbox encompassing a collection of nearly 400 seismology related functions that provide a framework for seismic data preparation, quality control, and analysis akin to that of Seismic Analysis Code [Goldstein and Snoke, 2005]. There are numerous functions for reading/writing standard seismic data formats, displaying and editing metadata, plotting seismograms, creating animations, data processing, and interactive analysis. Data processing capabilities include correlation, convolution, deconvolution, detrending, differentiation, integration, interpolation, resampling, filtering, merging, response transferring, rotation, stacking, spectral analysis, tapering, and windowing. The toolbox contains collections of functions for arrival time determination and quality control with cross correlation and cluster analysis, Rayleigh wave two plane-wave analysis, seismic ambient noise processing, and frequency-wavenumber analysis. SEIZMO utilizes direct access to the TauP toolkit [Crotwell et al., 1999] to administer predicted arrival times, raypaths, pierce points, and travel time curves for several widely recognized 1D seismic earth models. Mapping in SEIZMO draws on the numerous projections available in the M\_Map toolbox. The seismology toolbox also incorporates several 3D mantle models, a catalog of moment tensors from the Global CMT project, and a database of instrument responses available through IRIS. There are functions to aid in rapid prototyping and customization for new functions and documentation for every function is accessible through the inline help system.

The project is currently in the development stages with stable releases expected in late 2010. More information and pre-releases can be found at the project's webpage, <http://epsc.wustl.edu/~ggeuler/codes/m/seizmo>

## References

- Goldstein, P., A. Snoke, (2005), SAC Availability for the IRIS Community, IRIS Data Management Center Electronic Newsletter.
- Crotwell, H. P., T. J. Owens, and J. Ritsema (1999). The TauP Toolkit: Flexible seismic travel-time and ray-path utilities, *Seismol. Res. Lett.*, 70, 154
- Acknowledgements:* This research is supported by NSF grant EAR-0544731.



Snapshot of a rotatable and zoomable 3D plot of grazing and core-diffracted P-wave ray paths for numerous stations recording a Mw 7.5 earthquake in the Philippine Islands region on March 5, 2002. The translucent shells correspond to the major discontinuity depths of the Earth.

One frame from an animation produced with SEIZMO that portrays the azimuthal variations in Green's function recovery from the cross correlation of ambient noise recorded by a PASSCAL deployment in Cameroon between 2005 and 2007 (yellow circles). Traces in the main window are sorted by interstation distance for the pairings in the map on the lower-left. The strong asymmetric arrivals in the positive time range are Rayleigh waves from a persistent source of microseismic energy off the station pair great circle paths.

# Five Years of Distributing the Seismic Analysis Code (SAC) Software

Brian Savage (*University of Rhode Island*), Arthur Snoke (*Virginia Tech*), Tim Knight (*IRIS DMC*)

SAC (Seismic Analysis Code) is a general purpose interactive program designed for the study of sequential signals, especially time-series data. SAC was developed by the Lawrence-Livermore National Lab (LLNL) in the mid-80s, and it was maintained and distributed by them until 2005. At that time, in collaboration with LLNL, IRIS began distributing SAC to IRIS members and took over SAC development. [Goldstein & Snoke, 2005]. In late 2006, IRIS enhanced SAC's capabilities and created a "derivative product," thus expanding the licensing agreement and allowing the distribution of SAC software to collaborators including the USGS, members of FDSN and other non-U.S. seismological institutes. The new license agreement led to a large increase in the number of SAC requests each year. Between 2006 and 2007, there was a 237% increase in SAC distributions (see chart and figure below).

Between 2005 and June 2010, there have been four major updates of the SAC package. (See the 2009 newsletter article referenced below that accompanied the release of SAC v101.3b.) Further information about the package, including instructions for requesting the software, can be found at the IRIS SAC software page: .

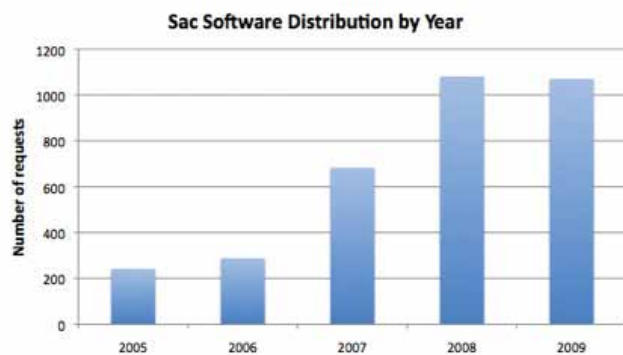
There have been over 4,000 SAC Software requests by scientists and programmers from Feb 2005 to June 2010. (Because the program has been updated four times, many scientists who had downloaded an earlier version, request an updated version.) SAC is available for Linux, Mac, Solaris and Cygwin/Windows computer platforms.

The majority of users request the Linux binary (58%), followed by Mac (29%) and Solaris (13%). In 2008, IRIS began distributing the SAC source code for Cygwin/Windows (429 requests). The SAC source code is requested by 69% of the users. SAC users include students, professors, scientists, engineers and programmers. For further details on the statistics of the SAC distribution by IRIS, see the 2010 newsletter article referenced below.

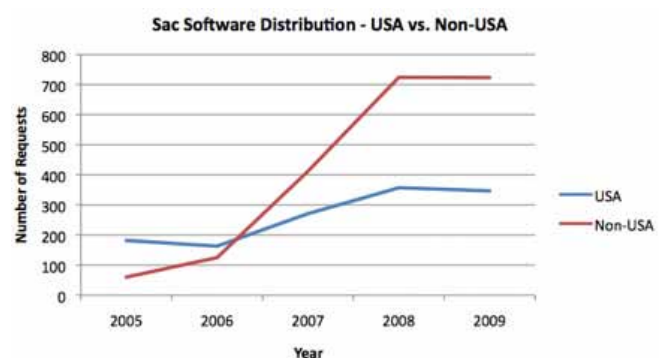
## References

- Goldstein, P. & Snoke, A, SAC Availability for the IRIS Community, RIS DMS Newsletter Vol7 no1 <http://www.iris.edu/news/newsletter/vol7no1/page1.htm>
- Knight, T. (2010), SAC Software Statistics, IRIS DMS Newsletter Vol12 no1 [http://www.iris.edu/news/newsletter/vol12no1/sac\\_stats.htm](http://www.iris.edu/news/newsletter/vol12no1/sac_stats.htm)
- Sac Development Team, Sac v101.3 – New version of SAC Software released in August 2009. IRIS DMS Newsletter Vol11 no2 <http://www.iris.edu/news/newsletter/vol11no2/sac.htm>

*Acknowledgements:* The distribution of SAC software was supported by an NSF grant.



International demand for the SAC software increased following a new license agreement in 2006. The number of SAC requests started to level off in 2009. (Knight, 2010)



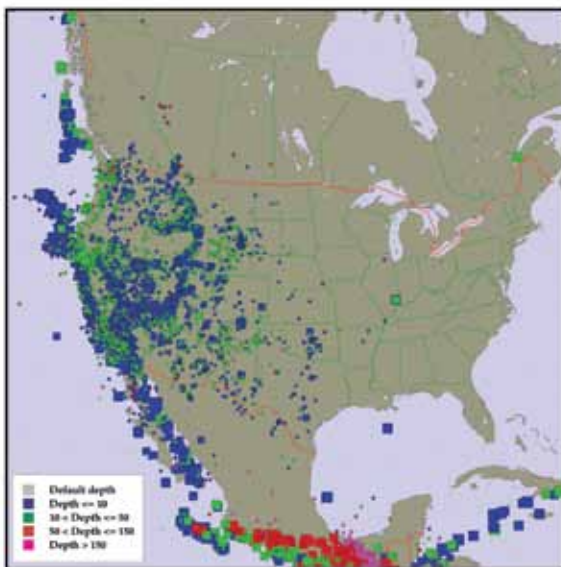
Seismologists worldwide use the SAC software distributed by the IRIS DMC. 38% of SAC requests come from the USA, while 62% of the requests are international. (Knight, 2010)

# The NSF IRIS EarthScope USArray Array Network Facility (ANF): Metadata, Dataflow, Phase Picks, and State of Health Monitoring

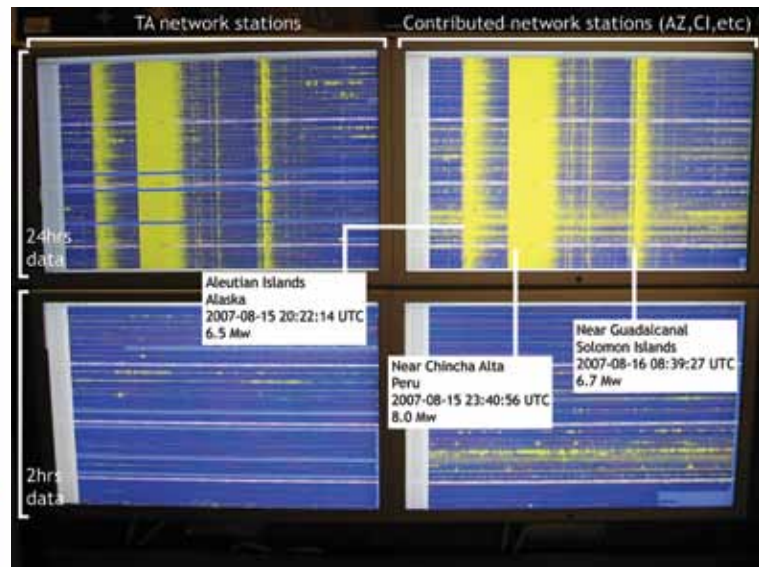
J. A. Eakins (Univ. of California, San Diego), F. L. Vernon (Univ. of California, San Diego), R. L. Newman (Univ. of California, San Diego), L. Astiz (Univ. of California, San Diego), V. Martynov (Univ. of California, San Diego), J. Tytell (Univ. of California, San Diego)

Since 2004, the EarthScope USArray Array Network Facility has been responsible for: metadata distribution; data delivery of all currently operational Transportable Array (TA) stations; data delivery for all post-deployment recovered baler data; station command and control with the goal of improving data quality, data availability, and data completeness; providing useful interfaces for personnel at the Array Operations Facility including access to both current and historic state of health information; distribution of station end-of-life reports; and quality control checks for all data. The Transportable Array is a challenging project due to the dynamic nature of the network. Stations are in place for 18 months to two years, leading to ~18 installations and 18 removals per month. Various tools using the Antelope software package have been developed to deal with the constant influx of data, changes to the metadata, remote retrieval to fill data gaps, and alarm generation and reactionary scripts when state of health parameters exceed given thresholds.

As of June 2010, we maintain data for 893 TA stations (1049 total stations with contributing networks): approximately 400 TA stations are operational at any point in time. Analysts have reviewed over 48,000 events with nearly three million reviewed arrivals available. Phase pick files for reviewed events are available from both the DMC and the ANF website. Round Robin Database (RRD) plots of state-of-health values, maps of the current deployment status, movies of the deployment history, the state of data return, as well as many additional monitoring tools are available from <http://anf.ucsd.edu>.



Seismic events recorded by the NSF supported Earthscope USArray Transportable Array. Analysts review events in near real-time with over 48,000 events reviewed since 2004. All seismic sources are included.



A busy day at the ANF office. Three teleseismic events (6.5Mw+) were recorded within 18 hours. Photo taken: 11:45AM PDT Thursday 16 August 2007. Local media often visit the ANF office when newsworthy events occur.

# IRIS DMS Data Products, Beyond Raw Data at the IRIS DMC

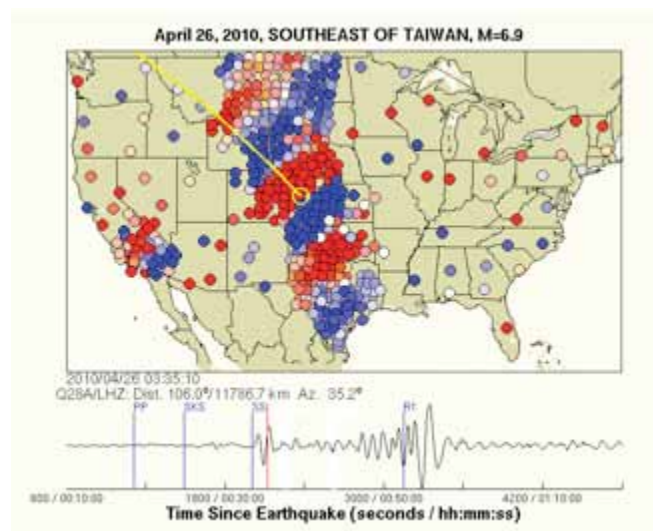
## DMC Products Group (*IRIS DMC*)

The IRIS DMC has begun an increased effort to create, archive and distribute products derived from raw data that serve as the basis for research needs or end-use education and outreach material. These products expand the DMC's offerings beyond the raw data traditionally accessed at the DMC. Data products are being produced both by the scientific community and the IRIS DMC. In most cases these new products, particularly the ones produced at the DMC, will be routinely generated and serve as consistent data sets. To ensure that useful and appropriate products are created and managed at the DMC, a Data Products Working Group (DPWG) representing the research community was formed to evaluate and propose product ideas.

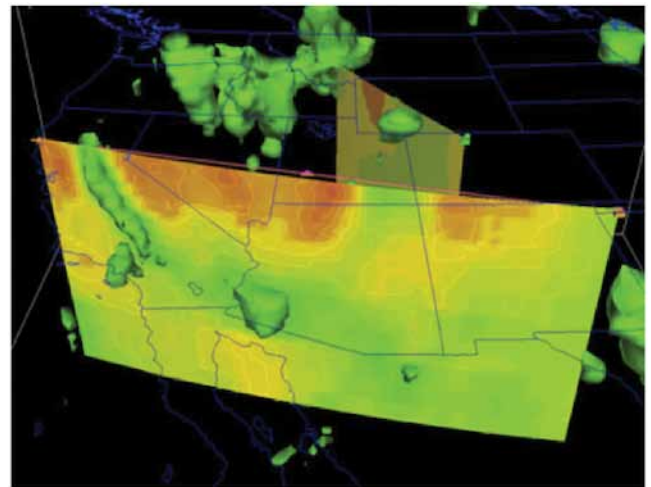
Products released or near release include USArray Ground Motion Visualizations (GMVs), the EarthScope Automated Receiver Survey (EARS) developed at the University of South Carolina, suites of event plots, Princeton 1D & 3D synthetic seismograms and the Earth Model Collaboration (EMC) for exchange, preview and download of tomography models. Many more product ideas are in consideration and will be evaluated and developed in the near future.

See <http://www.iris.edu/dms/products/> for more information.

*Acknowledgements:* Product development within the IRIS DMS is supported by the NSF grants #EAR-0552316 and EAR-0733069.



USArray Ground Motion Visualizations (GMVs): a visualization of seismic waves crossing the contiguous United States, see [www.iris.edu/dms/products/usarraygmv/](http://www.iris.edu/dms/products/usarraygmv/)



Earth Model Collaboration (EMC): a web site dedicated to the preview and distribution of tomography models.