



## 2020 Technical Sessions

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## **Advances in Real-Time GNSS Data Analysis and Network Operations for Hazards Monitoring**

Real-time GNSS data are being incorporated into earthquake and tsunami early warning systems, space weather monitoring and near real-time meteorological forecasting. The upgrading of decades-old GNSS networks to real-time systems combined with the ability of NTRIP casters to distribute data streams from multiple networks is creating hemispherical-scale GNSS networks. For real-time GNSS to become an integral part of monitoring systems the networks must have redundant data flow paths, reliable power and latencies on the order of tenths of a second. This, and the interest in integrating existing GNSS, seismic and meteorological networks combined with the push of data processing to the network edge points has created a new set of challenges in network operations, data management and real-time data analysis.

This session provides an opportunity for network operators and researchers to discuss these challenges. We encourage presentations that discuss the merging of geophysical networks, the use of cloud technology to manage data flow and data processing and the development of real-time analytics and machine-learning algorithms to monitor the state of health of the networks and detect transients in the incoming data.

### **Conveners**

Kathleen M. Hodgkinson, UNAVCO (hodgkinson@unavco.org); David J. Mencin, UNAVCO (dmencin@unavco.org)

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## **Advances in Seismic Imaging of Earth's Mantle and Core and Implications for Convective Processes**

Global, regional and local scale seismic array data and improved imaging methods are providing increasingly detailed constraints on the heterogeneous structure of Earth's mantle and core. Heterogeneity is documented by seismic properties such as isotropic wave speeds, anisotropy, attenuation, scattering and the topography, polarity and sharpness of reflective interfaces. These seismic results have implications for how the convection systems in the two largest layers of the Earth operate and potentially interact. We seek contributions that advance knowledge of the internal properties and boundaries of distinctive sub-layers ranging from the lithosphere to the inner core.

Studies that use new seismic imaging results to test hypotheses related to thermal and compositional boundary layers, phase transitions, compositional mixing, the role of fluids and active deformation are especially encouraged.

### **Conveners**

Alan Levander, Rice University (alan@rice.edu); Fenglin Niu, Rice University (niu@rice.edu); Peter Shearer, University of California, San Diego (pshearer@ucsd.edu); Brandon Schmandt, University of New Mexico (bschmandt@unm.edu)

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### **Advances in Seismic Interferometry: Theory, Computation and Applications**

Seismic interferometry extracts information from the ambient seismic field and enables imaging in the absence of earthquakes or artificial sources. Recent developments in seismic interferometry have benefited from the increasing availability of continuous records of ambient seismic noise from traditional broadband instruments and emerging new acquisition technologies, such as large-N nodal arrays and distributed acoustic sensing systems. This has opened up the possibility of performing high-resolution tomographic imaging anywhere dense networks are available. In addition to applications in seismic tomography, the potential temporal resolution in continuous seismic records provides the possibility of monitoring the transient changes of subsurface properties for various geological targets such as glaciers, volcanoes, groundwater, reservoirs, active faults, infrastructure and even other planetary bodies. The utilization of continuous seismic records meanwhile demands the development of computer programs capable of handling massive data sets (terabytes to petabytes). We welcome contributions of recent advances in seismic interferometry on a broad range of topics, including (but not limited to) theoretical developments in amplitude measurements and structural inversion, utilization of higher-order cross-correlations, new analyzing techniques and computer programs, and novel applications across disciplines.

### **Conveners**

Doyeon Kim, University of Maryland, College Park (dk696@umd.edu); Xiaotao Yang, Harvard University (xiaotaoyang@fas.harvard.edu); Tim Clements, Harvard University (thclements@g.harvard.edu); Ross Maguire, University of New Mexico (rmaguire@unm.edu); Tieyuan Zhu, Penn State University (tuz47@psu.edu); Nori Nakata, Massachusetts Institute of Technology (nnakata@mit.edu); Ved Lekic,

University of Maryland (ved@umd.edu); Marine Denolle, Harvard University  
(mdenolle@g.harvard.edu)

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### **Advances in Upper Crustal Geophysical Characterization**

The upper crust plays a critical societal role, from access to clean water to the production of energy to the impact of geologic hazards. It is also our window into the layers below; geophysical variability in the near surface can map into deeper structure if not properly considered. With respect to seismic hazards and earthquake ground motions, variability in near surface geophysical properties can lead to an overall amplification or deamplification of strong ground motions, large lateral variability in site response, as well as resonance at specific ground shaking frequencies. With respect to groundwater, characterizing soil porosity, regolith development and fracture permeability all lead to better estimates of storage potential and groundwater flow rates. Geophysical characterization of the near surface is therefore critical to being able to address these issues. A vast number of methods exists with which to characterize the subsurface from direct methods that measure rock density and seismic velocity in-situ to indirect methods where seismic wave travel times, gravity, resistivity and other parameters are measured at the Earth's surface, and subsurface properties are inferred. We seek contributions that include direct and indirect field observations, laboratory experiments and geophysical theory that link observation and expectation to studies that explore the impact of competing assumptions.

#### **Conveners**

Oliver S. Boyd, U.S. Geological Survey (olboyd@usgs.gov); Bill Stephenson, U.S. Geological Survey (wstephens@usgs.gov); Lee Liberty, Boise State University (lliberty@boisestate.edu)

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### **Alpine-Himalayan Alpide Shallow Earthquakes and the Current and the Future Hazard Assessments**

Historically, the Alpine-Himalayan seismic belt has been frequently witnessed some of the most destructive earthquakes. This vast area, more than 15,000 km along from the southern margin of Eurasia, extends from Java and Sumatra to the Indochinese

Peninsula, the Himalayas, the mountains of Iran, the Caucasus, Anatolia, the Mediterranean, terminating at the Atlantic Ocean.

The seismotectonic and occurrence sequences of earthquakes in each region on the Alpide belt are significant (Jackson and McKenzie, 1984; Gupta, 1993) and, due to the unique character of these active regions, deserves further attention from the scientific community. Earthquake-prone countries located along the Alpide major deformation belt include Nepal, Pakistan, Afghanistan, Iran, Turkey, Greece, Italy, etc. In last decades, there have been many large earthquake occurrences with magnitude 6 and larger events in the area such as the 2010 Kerman, Iran M6.3; 2012 East Azarbaijan M6.4; 2013 Sistan and Baluchistan, Iran M7.7; 2017 Kermanshah, Iran M7.3; 2011 Van, Turkey M7.2; 2015 Katmandu, Nepal M7.8; and 2015 Badakhshan, Pakistan M7.5 are examples of earthquakes within the Alp-Himalayan region.

The number of disastrous earthquakes in the Alpine areas is high, leading to hundreds of deaths and billions of dollars per year in comparison with similar scale earthquakes in other regions (e.g. the more developed countries). For example, in 2017, a M7.3 earthquake struck northern Iraq, causing more than 200 deaths and 1,900 injuries (Aon Benfield, 2017f). In 2018, an Indonesian earthquake of M6.9, killed 460 and displaced 350,000 people; in 2012, a northwest Iran earthquake caused 250 deaths and injured 2,000; and in 2011 in south-eastern Turkey, an earthquake killed 200 and injured 1,000. Events within the Alp-Himalayan seismic belt show a broad range of human, social, financial, economic and environmental damage, with a potentially long-lasting, multi-generational effects (OECD, 2018).

### **Conveners**

Zoya Farajpour, The University of Memphis (zfrjpour@memphis.edu); Shahram Pezeshk, The University of Memphis (spezeshk@memphis.edu); Sinan Akkar, Bogazici University (sinan.akkarak@boun.edu.tr); Hadi Ghasemi, Geoscience Australia (hghasemi@gmail.com)

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### **Amphibious Seismic Studies of Plate Boundary Structure and Processes**

Recent years have seen a rapid increase in the number of shore-crossing seismic experiments aimed at characterizing seismicity, deformation and structure at continental margins. Many studies use controlled source imaging in conjunction with continuous recordings of natural seismic sources. Examples of data integration include using ocean-bottom seismometer data in both disciplines and combining results from

shallower, high-resolution imaging with deeper, lithospheric-scale studies to understand structures that influence seismicity and plate boundary processes. We invite contributions from the community of seismologists studying plate boundary processes at the transition from onshore to offshore (ocean or lake) environments, including subduction zones, active or relict rifted margins and transform faults.

### **Conveners**

Jenny Nakai, University of New Mexico (jenakai@unm.edu); Lindsay Lowe-Worthington, University of New Mexico (lworthington@unm.edu); Anne Trehu, Oregon State University (anne.trehu@oregonstate.edu)

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### **Applications and Technologies in Large-Scale Seismic Analysis**

The growth and maturation of technologies that make it easier to analyze large volumes of data has enabled new areas of research in seismology. Computational frameworks like Apache Spark and Dask augment existing tools like MPI. New programming languages like Julia and the emergence of new scalable analysis capabilities in languages like Java and Python supplement traditional languages like C and Fortran. Finally, new platforms like the commercial cloud offer alternatives to existing high performance computing platforms. Technologies like these increase accessibility to a new scale of inquiry, making large-scale research in seismology more tractable than ever before. In this session, we invite researchers and data providers to share work in data-hungry applications, approaches to large data collection, storage and access and experiences with processing platforms and architectures.

### **Conveners**

Jonathan K. MacCarthy, Los Alamos National Laboratory (jkmacc@lanl.gov); Chad Trabant, Incorporated Research Institutions for Seismology (chad@iris.washington.edu)

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### **Back to the Future: Innovative New Research with Legacy Seismic Data**

There has been much discussion in recent years about Big Data and within the seismological community, how to cope with its ever-expanding volume of digital data. But there exists a source of yet Bigger Data: historical seismic records. With more than a century of seismic waveform data, there is opportunity to resolve intimate details of, and potentially revolutionize, our understanding of Earth dynamics, including

phenomena associated with tectonic and geologic processes, seismic sources, climate change and seismic hazard. The challenge: much of the waveform data is tucked away on analog media such as paper, tape, film or archaic and arcane digital media in holdings that are at risk of being lost forever. These data sets are not only more difficult to physically access and read than their digital counterparts, but often demand innovative approaches to perform any type of modern seismic analysis.

We invite presentations that highlight the discovery, preservation and/or use of seismic datasets spanning multiple decades. Such presentations would include those that address the problems of restoration, digitization and storage of the vast archives of legacy data. We encourage contributions that illustrate the on-going value of legacy data in the general fields of study for which seismographic data have been used and the value of legacy seismographic data in other geophysical disciplines. A few examples include studies of regional or local seismicity, earthquake recurrence and prediction, seismic hazard, climate signatures, inner core rotation and growth and 4D seismic tomography. We also seek contributions that feature efforts in standardizing metadata and image data formats, improving accessibility through rapid scanning, advances in vectorization software and tuned data compression algorithms, efforts in compiling calibrations of seismometers and application of machine learning techniques to directly extract geophysical information from the legacy data.

### **Conveners**

Garrett Euler, Los Alamos National Laboratory (ggeuler@lanl.gov); Brian Young, Sandia National Laboratories (byoung@sandia.gov); Ana Aguiar, Livermore National Laboratory (aguiarmoya1@lnl.gov); Thomas Lee, Harvard University (thomasandrewlee@g.harvard.edu); James Dewey, U. S. Geological Survey (jdewey@usgs.gov)

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### **Crustal Stress and Strain and Implications for Fault Interaction and Slip**

During earthquake cycles, crustal deformation includes multiple components such as inelastic strain increments associated with earthquakes, elastic strain accumulated in the interseismic period, aseismic slip on some fault sections and viscoelastic strain near and below the brittle-ductile transition depth. Resolving stress and strain distributions in the crust, specifically near fault zones, is essential for a better understanding of deformation processes, fault interactions and providing constraints on fault zone geometry and rheology.



This session focuses on (1) the estimation of the state of stress/strain in different phases of earthquake cycle and (2) the analysis of stress/strain distributions at different spatial and temporal scales by soliciting works based on theory, observations, modeling and laboratory experiments. Contributions are encouraged but not limited to address the following questions:

- 1) What can we extract from geodetic, geologic, borehole and seismic data regarding the state of stress and strain at regional and local scales?
- 2) How are stress and strain distributed in laboratory experiments and nature and how can we bridge the two?
- 3) What are the insights from numerical simulations on the state of stress and to what extent can models help in interpreting observations such as earthquakes or slow slip events?
- 4) How will spatial stress/strain variations from long-term data compilations improve our knowledge of the motion partitioning across complex fault zone areas, aseismic slip, fault zone structure and earthquake cycles?
- 5) How can information on the state of stress/strain be used to improve long-term earthquake forecasting and seismic hazard assessments?

### **Conveners**

Niloufar Abolfathian, University of Southern California (niloufar.abolfathian@gmail.com); Thomas H. W. Goebel, University of Memphis (thgoebel@memphis.edu); Mong-Han Huang, University of Maryland (mhhuang@umd.edu)

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### **Cryptic Faults: Assessing Seismic Hazard on Slow Slipping, Blind or Distributed Fault Systems**

Characterization of active faults for seismic hazard often relies on the analysis of geomorphic records preserved within the landscape that indicate fault movement. In certain environments, particularly those that are slow (<5 mm/yr) slip rate, blind and distributed fault systems, the tectonic activity leaves subtle tectonic signals within the landscape, challenging the conventional methods of identification and characterization of these fault systems. In recent years, advances in remote sensing, including high-resolution topographic data from lidar and unmanned aerial vehicles, have revolutionized the identification of fault-related features at the Earth's surface and led

to increasing confidence in the characterization (fault length, slip rate, recurrence interval) of faults. Recent numerical and experimental models further provide analogues for surficial fault rupture patterns and fault-related features to locate potential faults. In addition, advances in Quaternary geochronology and Bayesian modeling have refined ages of geomorphic and stratigraphic surfaces, resulting in better constraints on the activity of faults. Thus, the recognition of active and potentially active fault traces is expanding, ultimately leading to improved seismic hazard models.

This session will include studies that focus on new data and how methods have been applied to the characterization of cryptic faults. In particular, we welcome presentations on the application of remote sensing, geophysical, modeling and field work techniques, as well as geomorphic or paleoseismic case studies on slow slip rate, blind or distributed fault systems in any tectonic setting.

### **Conveners**

Jessica A. T. Jobe, U.S. Bureau of Reclamation (jjobe@usbr.gov); Stephen J. Angster, U.S. Geological Survey (sangster@usgs.gov)

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### **Data Fusion and Uncertainty Quantification in Near-Surface Site Characterization**

Non-invasive methods for site characterization have clear advantages of cost and effort over their invasive counterparts. The inverse problem ill-posedness, however, the inherent complexity of the shallow crust and associated measurement and modeling uncertainties of active and passive surface wave techniques can lead to poor estimations of site properties, which would affect in turn the assessment of earthquake hazard at the site of interest. Recent studies have shown that joint inversion of multiple data-sets recording sub-surface heterogeneities (e.g. active and passive data, ground motion recordings) and statistical inference techniques can improve the estimated properties and better quantify associated uncertainties of non-invasive methods. We here invite contributions on the development and/or implementation of state-of-the-art methods in inverse problems, data assimilation and uncertainty quantification, to improve the characterization of near-surface site conditions.

### **Conveners**

Elnaz Esmailzadeh Seylabi, University of Nevada, Reno (elnaze@unr.edu); Domniki Asimaki, California Institute of Technology (domniki@caltech.edu); Nori Nakata,

Massachusetts Institute of Technology (nnakata@mit.edu); Alan Yong, U.S. Geological Survey (yong@usgs.gov.)

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### **Early Results from the 2020 M6.4 Indios, Puerto Rico Earthquake Sequence**

On January 7, 2020 a magnitude 6.4 earthquake occurred 8 km south of Indios, Puerto Rico. This earthquake is part of an ongoing sequence that started on Dec 28, 2019. The sequence includes 11 foreshocks M 4.0 and larger and numerous M 4-5 aftershocks. In the days following the mainshock, seismologists, geologists and engineers mobilized to gather data on the rapidly evolving earthquake sequence. In this session, we hope to bring together experts to discuss early results from the field. We especially encourage presentation of new results that contribute to improved understanding of the hazard posed by the poorly known and potentially tsunamigenic Muertos Trough subduction zone. Potential topics include: 1) high-quality earthquake catalogs, 2) region specific ground motion models, 3) local site amplification, 4) ground failure observations, 5) structural damage observations, 6) fault slip rates and 7) novel and creative methods and parameters that contribute to advancing probabilistic seismic hazard models for Puerto Rico.

#### **Conveners**

Daniel McNamara, U.S. Geological Survey (mcnamara@usgs.gov); Elizabeth Vanacore, University of Puerto Rico (elizabeth.vanacore@upr.edu); Alberto Lopez, University of Puerto Rico (lberto.lopez3@upr.edu); Emily Wolin, U.S. Geological Survey (ewolin@usgs.gov)

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### **Earthquake Early Warning: Current Status and Latest Innovations**

The field of earthquake early warning (EEW) is expanding, incorporating research from a wide range of other domains including computer science, civil engineering and social science. The number of examples of earthquakes recorded by operational EEW systems continues to grow. The 2019 Ridgecrest sequence, for example, included both the largest main shock and the most energetic aftershock sequence encountered by the US ShakeAlert EEW system. This sequence, along with other large earthquakes e.g. in Japan, Mexico and China, provide operational experience and insight into the

potential and the limitations of EEW systems. Many challenges remain to maximize the potential of these systems. Unanswered questions range from the scientific (e.g., real-time magnitude estimates of large earthquakes and rupture predictability) to the practical (e.g., how to distribute alerts to the public most efficiently, minimizing data transmission delays).

In this session we welcome abstracts related to all aspects of EEW including, but not limited to, algorithm development, system performance, improved trigger detection/discrimination techniques, network build-out, alerting methods and technology and EEW education and outreach.

### **Conveners**

Angela I. Chung, University of California, Berkeley (angiechung07@gmail.com);  
Men-Andrin Meier, Caltech (mmeier@caltech.edu)

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### **Earthquake Source Parameters: Theory, Observations and Interpretations**

Understanding origin and spatio-temporal evolution of seismicity needs a careful quantitative analysis of earthquake source parameters for large sets of earthquakes in studied seismic sequences. Determining focal mechanisms, seismic moment tensors, static stress drop, apparent stress and other earthquake source parameters provides an insight into tectonic stress and crustal strength in the area under study, material properties and prevailing fracturing mode (shear/tensile) in the focal zone, and allows investigating earthquake source processes in greater detail. In addition, studying relations between static and dynamic source parameters and earthquake size is essential for understanding the self-similarity of rupture processes and scaling laws and for improving our knowledge on ground motion prediction equations.

This session focuses on methodological as well as observational aspects of earthquake source parameters of natural or induced earthquakes in broad range of magnitudes from large to small earthquakes, including acoustic emissions in laboratory experiments. Presentations of new approaches to determination of focal mechanisms, seismic moment tensors and other source parameters as well as case studies related to analysis of earthquake source parameters are welcome. We also invite contributions related to scaling of static and dynamic source parameters, to self-similarity of earthquakes and inversions for stress and other physical parameters in the focal zone.

## Conveners

Vaclav Vavrycuk, Institute of Geophysics of the Czech Academy of Sciences (vv@ig.cas.cz); Grzegorz Kwiatek, GFZ Potsdam (kwiatek@gfz-potsdam.de)

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## Environmental and Near Surface Seismology: From Glaciers and Rivers to Engineered Structures and Beyond

Environmental seismology is the study of seismic signals generated at and near the surface created by environmental forces in the atmosphere, hydrosphere or solid Earth. Contributions to this session are welcome on a wide variety of topics including --but not limited to-- the seismic signals associated with the microseism, landslides, rock falls, debris flows, lahars, snow avalanches, cliff or pinnacle resonance, river bedload transport, flood events, fluid flow in open and confined channels, water gravity waves or infragravity waves, tides, sea ice variability, glacier stick-slip, iceberg calving, glacier crevassing, subglacial hydrology, hurricanes, tornadoes or anthropogenic sources. Studies focusing on engineering applications are additionally welcome and may include studies of groundwater and remediation, site characterization for geologic and seismic hazard applications, monitoring of critical infrastructure and geotechnical applications. In addition, other processes monitored by seismic waves such as permafrost, groundwater in confined or karst aquifers, glacier mass, using seismometers or DAS (distributed acoustic sensing; fiber-optic seismology) data are welcome. Contributions that seek to conduct monitoring, create physical or statistical models of source processes or systems, detect events, characterize a wave propagation environment or interact with other branches of the Earth or social sciences are additionally encouraged. Submissions running the gamut from site-specific case studies to ongoing methodological advances are warmly welcomed.

## Conveners

Bradley P. Lipovsky, Harvard University (brad\_lipovsky@fas.harvard.edu); Richard C. Aster, Colorado State University (rick.aster@colostate.edu); Will Levandowski, Tetra Tech, Inc. (will.levandowski@tetratech.com); Jamey Turner, Tetra Tech, Inc. (jamey.turner@tetratech.com)

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## **Exploring Rupture Dynamics and Seismic Wave Propagation Along Complex Fault Systems**

Investigations related to how complexities in fault parameters and geometry could potentially impact the behavior of earthquake rupture and affect seismic hazard are areas of active and challenging research. This session will highlight recent advances in rupture dynamics on complex fault systems. We are open to a wide range of studies related to numerical, experimental and observational fault rupture dynamic studies with heterogeneities such as fault geometry, fault roughness, frictional parameters, topography, creeping mechanisms, stress asperities, off-fault material properties, bi-material interfaces and wedge structures along subduction zones. We also encourage contributions on research that explores links between earthquake source physics, tsunami generation/propagation and ground motion variability.

### **Conveners**

Roby Douilly, University of California, Riverside (roby.douilly@ucr.edu); Christos Kyriakopoulos, University of Memphis (ckyrkpls@memphis.edu); Kenny Ryan, Air Force Research Laboratory (0k.ryan0@gmail.com); Eric Geist, U.S. Geological Survey (egeist@usgs.gov); Ruth Harris, U.S. Geological Survey (harris@usgs.gov); David Oglesby, University of California, Riverside (david.oglesby@ucr.edu)

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## **Explosion Seismology Advances**

Explosion sources are an important component of seismology used as a tool to characterize the sub-surface for a variety of applications. For example, in regions of low natural background seismicity, mine blasting can dominate monitoring catalogs and finding and separating these sources from tectonic earthquakes is important for hazard estimation. Recent work using template matching, waveform modeling for moment tensors and combining seismic and acoustic data has shown great success in discriminating explosions from earthquakes and other sources. With the advent of inexpensive and easy to deploy arrays and networks of sensors, the wavefield produced by explosions is being studied with unprecedented detail. We welcome abstracts on explosion source physics, wave propagation, Large-N network design, distributed acoustic sensing (DAS), new sensor technologies, multi-physics data fusion and advanced processing techniques applied to explosion sources.

## Conveners

Catherine M. Snelson, Los Alamos National Laboratory (snelsonc@lanl.gov); Robert E. Abbott, Sandia National Laboratories (reabbot@sandia.gov); William R. Walter, Livermore National Laboratory (walter5@lnl.gov); Cleat P. Zeiler, Mission Support & Test Services (zeilercp@nv.doe.gov)

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## Forthcoming Updates of the USGS NSHMs: Hawaii, Conterminous U.S. and Alaska

The U.S. Geological Survey (USGS) National Seismic Hazard Models (NSHMs) are the bridge between best-available earthquake science and public policy. In the next few years, the National Seismic Hazard Model Project (NSHMP) will complete three model updates: Hawaii (2020), the conterminous U.S. (COUS, 2023) and Alaska (2024?). The Hawaii seismic hazard model was last updated in 1998. The NSHMP is currently in the process of updating this model and held a public workshop in September 2019 to present early findings and solicit feedback from the scientific community. The current status of the model will be presented in this session, as well as preliminary hazard results. The COUS model was last updated in 2018 and includes NGA-East ground motion models (GMMs) in the central and eastern U.S. and basin amplifications in the western U.S. (WUS). The next model update for the COUS will be in 2023 with a focus on updating the WUS source model and subduction zone GMMs. The deadline for publications that the USGS may consider for this update is December 2020. We have also begun to plan for the Alaska NSHM, last updated in 2007.

For this session, we invite contributions relevant to the 2023 COUS and Alaska NSHM updates including, but not limited to: Atlantic and Gulf Coast and other alternative site amplification models, new fault models (WUS and Alaska), UCERF3 update/simplification, NGA-Subduction GMMs, physics-based (3D simulation) ground motion model validation and implementation, non-ergodic aleatory uncertainty, basin models, new geodetic data and inversions, M-area scaling relations and the Alaska megathrust geometry and recurrence.

## Conveners

Allison M. Shumway, U.S. Geological Survey (ashumway@usgs.gov); Mark D. Petersen, U.S. Geological Survey (mpetersen@usgs.gov); Peter M. Powers, U.S. Geological

Survey (pmpowers@usgs.gov); Sanaz Rezaeian, U.S. Geological Survey (srezaeian@usgs.gov)

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## **From Aseismic Deformation to Seismic Transient Detection, Location and Characterization**

The fundamental role that slow earthquake phenomena are playing in our understanding of the physical mechanisms that lead to the preparation and generation of large earthquakes is, by this time, well-defined. Nevertheless, our knowledge about the nature of slow earthquakes and their complex behavior is far from being complete.

The main goal of this session is to provide an overview of the phenomenon in its entirety, from the aseismic to seismic event-components. Specifically, we welcome innovative studies based on the analysis of large data-sets of continuous seismic ground motions and/or geodetic (GPS) recordings.

We aim to focus on the most recent advances in the methodological developments of the detection and location techniques, together with the characterization and interpretation of the related events source characteristics.

We are particularly encouraging contributions that shine a light on the connection between slow and fast earthquakes.

### **Conveners**

Florent Aden-Antoniow, University of Southern California (adenanto@usc.edu); Mariano Supino, Institut de Physique du Globe de Paris (supino@ipgp.fr); Sushil Kumar, Wadia Institute of Himalayan Geology (sushil\_rohella@yahoo.co.in)

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## **Full-Waveform Inversion: Recent Advances and Applications**

With ever increasing computational resources, full-waveform inversion (FWI) is becoming a more feasible method to study the Earth's interior. There are, however, still many challenges that the method faces. Uncertainty quantification is an open debate, the scaling of cost with the number of modeled sources makes the usage of large datasets expensive, and probabilistic solutions are still in their infancy. The progress of FWI as an imaging method has largely been driven by increased computational resources, development of numerical wave propagation solvers and workflow software



developments. FWI has the potential to greatly improve our understanding of the Earth's subsurface, but in order to make further progress, methodological innovations are essential as they can make the progress less dependent on the available computational resources.

In this session we encourage contributions related to technological, algorithmic or other advances of FWI, as well as recent applications of the method.

### **Conveners**

Solvi Thrastarson, ETH Zurich (soelvi.thrastarson@erdw.ethz.ch); Dirk-Philip van Herwaarden, ETH Zurich (dirkphilip.vanherwaarden@erdw.ethz.ch); Carl Tape, University of Alaska Fairbanks (ctape@alaska.edu)

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### **Innovative Seismo-Acoustic Applications to Forensics and Novel Monitoring Problems**

Seismic and acoustic sensors are capable of recording ground motion and acoustic waves originating from many phenomena and activities. Besides traditional monitoring of natural environmental phenomena and military activities, seismo-acoustic measurements can also be used to detect, identify, locate, characterize and monitor animal, domestic and industrial processes that generate recordable acoustic, infrasonic and/or seismic waves. Both established and more innovative data analyses can extract useful information from these wavefields. As our homes, factories and communities get smarter, more data is needed, if not required, for safe operation. The information extracted from seismo-acoustic measurements of both persistent and transient activity will improve our state-of-health assessments of these environments. For example, seismo-acoustic signals related to machinery operations can be used to monitor status and specifics of the machinery independently.

We welcome submissions on collection and analysis of seismo-acoustic data and techniques including but not limited to (1) seismo-acoustic monitoring of animal, domestic and industry activities; (2) acoustic and seismic analyses of chemical, ammunition or vapor explosions; (3) multi-signature fusion of seismo-acoustic data with other geophysical signatures; (4) methods to quantify uncertainties of parameter estimates that are derived from observing surficial, transient sources in noisy and cluttered signal environments; (5) special geophysical considerations of human-made environments that can bias source parameter estimates; (6) leveraging unconventional

data streams for association and source location that include social media posts; and (7) machine learning applications to acoustic and seismic signals.

### **Conveners**

Chengping Chai, Oak Ridge National Laboratory (chaic@ornl.gov); Joshua D. Carmichael, Los Alamos National Laboratory (josh.carmichael@gmail.com); Monica Maceira, Oak Ridge National Laboratory (maceiram@ornl.gov); Omar Marcillo, Los Alamos National Laboratory (omarcillo@lanl.gov)

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### **Insight Seismology on Mars: Results From the First (Earth) Year of Data and Prospects for the Future**

The InSight mission landed on Mars on November 26, 2018 and was the first to place an ultra-sensitive broadband seismometer on the surface of another planet. It will provide key information on the composition and structure of an Earth-like planet that has gone through most of the evolutionary stages of the Earth up to, but not including, plate tectonics. Using seismology, geodesy and heat flow measurement, InSight aims to determine the thickness and structure of the Martian crust and mantle, the size and state of the core, the planet's thermal state and the level of tectonic activity and rate of meteorite impacts.

The two-year (one Mars year) InSight mission ushers in a new era in planetary seismology. In the coming years and decades NASA may launch missions to explore the interiors of our Moon, Venus and the "Ocean Worlds" of the Solar System (e.g., Europa, Enceladus and Titan). Other Space agencies might also launch additional missions with seismometers. While the focus of these mission concepts vary from fundamental geophysics to detection of life and conditions for life, seismological exploration of planetary bodies' interiors is likely to play a key role in understanding planetary state and evolution by helping to determine their thermal and chemical make-up.

We invite contributions that take advantage of the seismic data from the first year on Mars, as well as modeling that looks forward to upcoming data from Mars or other planetary bodies. With data being made available through the IRIS Data Management Center, results from both within and outside the mission science team are welcome.

### **Conveners**

Mark P. Panning, Jet Propulsion Laboratory, Caltech (mark.p.panning@jpl.nasa.gov); Sharon Kedar, Jet Propulsion Laboratory, Caltech (sharon.kedar@jpl.nasa.gov); Bruce Banerdt, Jet Propulsion Laboratory, Caltech (william.b.banerdt@jpl.nasa.gov)

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### **Leveraging Advanced Detection, Association and Source Characterization in Network Seismology**

In a classic seismic monitoring framework, automatic pickers detect earthquakes, individual detections are associated into events and events are further characterized using routine methods (e.g., single-event locators, magnitude estimators). While this processing structure underlies the operations of the majority of seismic networks, researchers continue to develop novel ways to extract additional earthquake data from continuous waveforms. Template matching is routinely applied to lower detection thresholds. Machine learning algorithms detect earthquake signals and further classify key seismic characteristics (e.g., phase-type). Multiple-event relocation algorithms retrospectively enhance earthquake hypocenter estimates. While many such techniques have vastly improved our understanding of cataloged seismicity, hurdles remain when applying these techniques to real-time systems and therefore they have not been routinely adopted. In this session, we invite submissions that investigate novel earthquake detection and characterization techniques, particularly with a focus on how these could be applied in a real-time environment to regional and global seismic networks.

#### **Conveners**

William L. Yeck, U.S. Geological Survey (wyeck@usgs.gov); Kris Pankow, University of Utah (pankowseis2@gmail.com); Gavin Hayes, U.S. Geological Survey (ghayes@usgs.gov); Paul Earle, U.S. Geological Survey (pearle@usgs.gov); Harley Benz, U.S. Geological Survey (benz@usgs.gov)

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### **Mechanisms of Induced Seismicity: Pressure Diffusion, Elastic Stressing and Aseismic Slip**

The rise of man-made earthquakes has generated interest from a broad range of scientists and stakeholders. The interest stems from both practical and scientific standpoints, whereby induced seismicity poses a hazard that can potentially be mitigated and also presents an opportunity to learn about earthquakes in an

environment where driving mechanisms may be better constrained. Recent advances in seismic and geodetic monitoring has allowed for more detailed observations of anthropogenically induced and triggered seismicity. These observations have revealed more complex interactions beyond effective stress reduction, including aseismic processes and elastic stress effects. A better understanding of the contributions from these processes (as a function of distance and time, as well as flow and elastic parameters) has significant implications for the expected seismic hazard. In addition, seismic hazard assessment is tied to improved characterizations of the primary controlling factors on induced earthquakes (e.g. injection volumes and rates, change in reservoir pressure, induced stressing rates).

We solicit studies on any types of induced seismicity around the world, including geothermal, hydrocarbon production, waste-water disposal, CO<sub>2</sub> sequestration and gas storage. Case studies from the laboratory to large-N array deployments to field-scales are welcomed. We also seek studies from a wide variety of disciplines that aim to monitor, observe and model injection-induced seismicity. The aim of this session is to bring together numerical, observational and experimental studies on both aseismic and seismic processes associated with induced earthquakes.

### **Conveners**

Matthew Weingarten, San Diego State University (mweingarten@sdsu.edu); Ruijia Wang, University of New Mexico (ruijia@unm.edu); Thomas Göbel, University of Memphis (thgoebel@memphis.edu); Heather R. DeShon, Southern Methodist University (hdeshon@mail.smu.edu); Kyung-Won Chang, Sandia National Laboratories (kchang@sandia.gov)

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### **Modeling and Understanding of Ground Motion for the Island of Hawaii**

The island of Hawaii has been the site of numerous large earthquakes with a growing database of strong ground motion observations. The crustal earthquakes in the island of Hawaii originate from volcanic activity and include both swarms of small-magnitude volcanic events and larger tectonic events. Ground motion modeling in the island of Hawaii is challenging due to the depth distribution of events and different anelastic attenuation characteristics. The historical devastating earthquakes have raised significant awareness of vulnerability in the highly populated cities with the fragile infrastructures and numerous major national transportation infrastructure, power plants and pipelines in the island of Hawaii. Undoubtedly, this demands the skills of seismic

hazard specialists at the highest level based on the technical resources to be expanded and improved.

This session aims at collecting contributions as to how to understand and model ground motion in the island of Hawaii. Considerable scientific effort is required focusing on understanding and modeling strong ground motions for the island of Hawaii, which is the most isolated populated group of islands on earth - 2,390 miles from California and 3,850 miles from Japan - with an estimated population of 1.4 million. We welcome studies that may shed light on different aspects of ground motion modeling. Topics of interest include deriving seismological parameters such as attenuation studies, kappa value, fmax, spectral analysis, Quality factor (Q), stress drop, kappa and source potential trade-offs, as well as quantification and interpretation of scattering and intrinsic attenuation. We believe that the outcome of this session will provide the most up-to-date science-based seismic hazard information on ground motion modeling for the island of Hawaii that can be used in research, provisions of building codes, risk assessments for insurance and disaster management planning and local governmental policy decisions.

### **Conveners**

Alireza Haji-Soltani, Mueser Rutledge Consulting Engineers (ahaji-soltani@mrce.com);  
Shahram Pezeshk, University of Memphis (spezeshk@memphis.com)

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### **Near-Surface Effects: Advances in Site Response Estimation and Its Applications**

The effects of shallow geological layers and interfaces (within the upper 1-2 km) on the seismic-induced ground motion recorded at the surface have been the focus of numerous studies over the past few decades. However, while the methods for simulating ground shaking have rapidly evolved, making robust 3D calculations feasible for broadband seismograms, the approaches for determining their input parameters at the necessary level of detail still suffer from a range of limitations and uncertainties. Furthermore, it is today recognized that the ground shaking recorded at the surface is also affected by the energy released back to the ground by building structures that might contribute to locally increase or decrease ground motion.

The aim of this session is to present studies dealing with innovative approaches for the investigation of shallow geological layers and interfaces; site response assessment, in particular, considering the spatial variability of seismic ground motion at small

wavelengths and uncertainties in site response models and their inputs; and building/city-soil interaction. Studies dealing with the assessment of the attenuation of wave propagation and those focusing on non-linear behavior by making use of arrays of sensors, both in boreholes and in buildings, are particularly welcome. Studies involving innovative applications of horizontal to vertical spectral ratio (HVSr) methods for investigations of shallow geological interfaces, seismic microzonation studies and site response assessment are also encouraged. Furthermore, case studies dealing with local secondary effects due to earthquake shaking, such as liquefaction and landslides, in non-standard situations are also invited.

### **Conveners**

James Kaklamanos, Merrimack College (kaklamanosj@merrimack.edu); Dhananjay A. Sant, The Maharaja Sayajirao University of Baroda (sant.dhananjay-geology@msubaroda.ac.in); Stefano Parolai, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (sparolai@inogs.it); Philippe Guéguen, ISTERre, Université Grenoble Alpes / Université Savoie Mont-Blanc/CNRS/IRD/IFSTTAR (philippe.gueguen@univ-grenoble-alpes.fr); Imtiyaz Parvez, CSIR Fourth Paradigm Institute (parvez@csir4pi.in); Hiroshi Kawase, Disaster Prevention Research Institute, Kyoto University (kawase@zeisei.dpri.kyoto-u.ac.jp); Ashly Cabas, North Carolina State University (amcabasm@ncsu.edu)

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### **Numerical Modeling of Rupture Dynamics, Earthquake Ground Motion and Seismic Noise**

Faithfully modeling rupture propagation, seismic wave propagation and earthquake ground motion in increasingly complex models of the Earth's interior requires algorithmically advanced and computationally efficient numerical-modeling methods. These methods are often developed in response to challenges imposed by new data but sometimes due to progress in mathematical and numerical methodology itself. Evolution of the HPC infrastructure further facilitates and influences numerical modeling in seismology.

We invite contributions focused on development, verification and validation of numerical-modeling methods as well as important applications of the methods especially to rupture dynamics, seismic wave propagation, earthquake ground motion including non-linear behavior, seismic noise and earthquake hazard.

Applications to compelling observational issues in seismology are especially welcome.

We also encourage contributions on the analysis of methods, fast algorithms, high-performance implementations and large-scale simulations.

### **Conveners**

Peter Moczo, Comenius University Bratislava (moczo@fmph.uniba.sk); Steven M. Day, San Diego State University (sday@sdsu.edu); Jozef Kristek, Comenius University Bratislava (kristek@fmph.uniba.sk); Martin Galis, Comenius University Bratislava (martin.galis@uniba.sk)

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### **Observations From the 2019 Ridgecrest Earthquake Sequence**

The  $M_w$  7.1 July 5 mainshock of the 2019 Ridgecrest Earthquake Sequence was the largest earthquake in California in the 20 years since the 1999  $M_w$  7.1 Hector Mine event and the first major earthquake in southern California since the regional seismic monitoring was expanded to pave the way for earthquake early warning. Over the past 20 years, our community has developed many advances in methods and technology used to observe pre-, co- and post-seismic deformation due to earthquakes. Such advances include the use of aerial and terrestrial lidar, image correlation methods, low-altitude aerial photography, interferometric synthetic-aperture radar (InSAR) and dense deployments of geophysical and geodetic sensors in both permanent and campaign arrays. In addition to augmenting the methods in our collective toolbox, we have learned from other continental strike-slip earthquakes in these intervening 20 years, allowing us to target fundamental questions and high-resolution datasets to characterize earthquake processes and fault behavior. These investigations include, as an example, coupling field and remote-sensing approaches to determine fine-scale slip distributions along and across fault strike to quantify strain partitioning and off-fault deformation. We welcome contributions with direct observations of the 2019 Ridgecrest Earthquake Sequence, including the July 4  $M_w$  6.4 foreshock event, that elucidate processes specific to this sequence that will help us better understand the behavior of earthquake and fault processes, as well as the characteristics of ground motions from large crustal earthquakes, globally.

### **Conveners**

Alexandra E. Hatem, U.S. Geological Survey (ahatem@usgs.gov); Susan Hough, U.S. Geological Survey (hough@usgs.gov); Christopher W. D. Milliner, Jet Propulsion

Laboratory, Caltech (christopher.milliner@jpl.nasa.gov); Sinan Akciz, California State University, Fullerton (sakciz@fullerton.edu); Alana Williams, Arizona State University (amwill25@asu.edu); Timothy Dawson, California Geological Survey (timothy.dawson@conservation.ca.gov)

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### **Ocean Bottom Seismology – New Data, New Sensors, New Methods**

The accelerating number of OBS deployments and research incorporating emerging technology such as distributed sensing has propelled marine seismology into a leading role in our field. New developments have opened doors for improving sensors, deployment methods, analysis techniques and calibration and understanding of propagation and noise characterization for the marine environment. We welcome contributions outlining new seafloor seismic deployments, new data sets, new methods and new insights within this growing branch of seismic monitoring and exploration. Whether you're imaging the lithosphere, modeling global or seafloor propagation or focused on offshore seismicity or earthquake early warning, we hope you will contribute to a lively session on expanded marine efforts.

#### **Conveners**

Charlotte A. Rowe, Los Alamos National Laboratory (char@lanl.gov); Susan L. Bilek, New Mexico Institute of Mining and Technology (sbilek@nmt.edu); Nathaniel J. Lindsey, University of California, Berkeley (natelindsey@berkeley.edu)

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### **Photonic Seismology**

Emerging measurement tools have the potential to expand how we apply seismology to study and monitor Earth systems. Recent advancement in the field of photonics has led to novel sensing methods based on optical interferometry, including Distributed Acoustic Sensing (DAS), which is rapidly becoming a popular tool among seismological research groups worldwide. DAS enables Large-N array seismology in novel and unique spaces such as in boreholes, mines, underneath streets in urban areas and offshore. The main advantages of DAS for seismology include, but are not limited to, high-resolution, long spatial and temporal deployment of sensors, time-lapse repeatability and the unique opportunity to leverage existing fiber infrastructure such as



telecommunication cables for geophysics. Because data acquired with DAS instruments contain information on the displacement gradient of a seismic wavefield (i.e., strain), there is a need to develop a fundamental theoretical framework to cope with this new data type. The high spatial resolution and broadband nature of DAS furthermore allows for new data analysis methods or the adaptation of existing Large-N methods to this new data type. This session will span a wide range of topics related to fiber-optic sensing methods in seismology and geophysics, including but not limited to: advancements in optical engineering; developments in theoretical and methodological aspects of fiber-optic sensing; case studies from ongoing fiber-optic sensing experiments worldwide; comparisons between non-inertial and inertial instruments; and insights gained from fiber-optic sensing measurements in the context of other types of seismological/geophysical datasets.

We invite contributions from research related to all aspects of photon-based sensing.

### **Conveners**

Nathaniel J. Lindsey, University of California, Berkeley (natelindsey@berkeley.edu); Patrick Paitz, ETH Zurich (patrick.paitz@erdw.ethz.ch); Verónica Rodríguez Tribaldos, Lawrence Berkeley National Laboratory (vrodrigueztribaldos@lbl.gov)

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### **Recent Advances in Very Broadband Seismology**

Observational seismology is fundamentally limited by our ability to record seismic signals across a very large bandwidth. The sensitivity of modern seismic instrumentation to non-seismic noise sources as well as other undesirable signals can limit our ability to record seismic events with high fidelity. The purpose of this session is to communicate recent advances in seismic instrumentation and deployment methods, as well as observations that highlight the heavy demands on instrumentation of very broadband seismology. Abstracts that highlight recent advances, techniques or methods for seismic instrumentation, seismic network advances or advances in earthquake early warning instrumentation are encouraged. We also encourage abstracts that focus on long-period or high-frequency seismology that could show limitations in our ability to record such signals.

### **Conveners**

David Wilson, U.S. Geological Survey (dwilson@usgs.gov); Adam Ringler, U.S. Geological Survey (aringler@usgs.gov); Robert Anthony, U.S. Geological Survey (reanthony@usgs.gov)

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### **Recent Development in Ultra-Dense Seismic Arrays With Nodes and Distributed Acoustic Sensing (DAS)**

Recently, ultra-dense seismic deployments, typically consisting of hundreds to thousands of short-period nodal instruments or distributed acoustic sensing (DAS) systems with fiber optic cables, have been widely used in seismological studies. These dense arrays have very close station spacings ranging from several meters to hundreds of meters to record well-sampled and unaliased wavefields in local or regional settings. Data acquired by such dense systems promote the development of new array-based analysis methods to mine seismic wavefields and greatly improve our understanding of fine-scale subsurface properties, microseismic activities and earthquake rupture processes. In this session, we invite contributions from areas that are broadly related to ultra-dense arrays. Example topics include, but are not limited to, novel instrument development, new field experiments with nodal or DAS arrays, high-resolution imaging of subsurface structure, environmental seismology, microseismic detection/relocation, source characterization and related big data processing techniques.

#### **Conveners**

Marianne S. Karplus, University of Texas at El Paso (mkarplus@utep.edu); Nori Nakata, Massachusetts Institute of Technology (nnakata@mit.edu); Xiangfang Zeng, Chinese Academy of Sciences (zengxf@whigg.ac.cn); Xiaobo Tian, Chinese Academy of Sciences (txb@mail.iggcas.ac.cn)

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### **Regional Earthquake Centers: Highlights and Challenges**

This session highlights the unique observations, opportunities and challenges of regional seismic operation centers. Regional seismic operation centers play an important role in monitoring for natural earthquakes and other phenomena, including induced seismicity. They also play an important role in advancing scientific study, especially as it relates to local and regional seismic hazard and the generation of high-quality seismic data and data products, such as earthquake catalogs. Regional seismic operation centers are also important for communicating hazard and risk to a

wide variety of stakeholders, including researchers, emergency management agencies, policy makers, educators, regulators and the general public.

The purpose of the session is to foster collaboration and to communicate advances and challenges of monitoring at a regional scale. We welcome a wide range of contributions spanning science, operations and/or stakeholder engagement. Topics of interest include integrating new technological advances in data acquisition and processing; data policies and data sharing; interactions with stakeholders; and novel education and outreach initiatives. Other topics that highlight current advances and challenges for regional earthquake operation centers are also of interest. We encourage submissions from both large and small regional seismic networks. If you work with real-time data for regional seismic monitoring, we encourage you to submit an abstract.

### **Conveners**

Kristine L. Pankow, University of Utah (pankowseis2@gmail.com); Renate Hartog, University of Washington (jrhartog@uw.edu); Mairi Litherland, New Mexico Bureau of Geology and Mineral Resources (mairi.litherland@nmt.edu); Jeri Ben-Horin, Arizona Geological Survey (jeribenhorin@email.arizona.edu)

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### **Research, Discovery and Education Made Possible by Low-Cost Seismic Equipment**

In the past three years, low-cost seismic devices have become very popular among citizen scientists and academic researchers alike. The amateur seismological network (AM) has expanded to become one of the largest online seismic networks at ~1000 online nodes in ~100 countries and continues to expand at a rate of 1-2 nodes per day. The potential has become increasingly apparent for academic seismologists and network operators to leverage data collected and shared from stations maintained by citizen scientists, educators and students. The network has tracked numerous seismic events, from hyperlocal to teleseismic, and boasts high station density in locations that are typically regarded as lower priority for an expensive broadband installation. Presently, the AM network finds location and magnitude solutions for more than 50,000 earthquakes per year, many of which are too small or local to be identified by other networks. Low-cost seismic devices—and the AM network as a whole—have great value not only to seismological and geophysical research and network densification,

but to education, science communication, structural health monitoring and emergency response applications as well.

This session welcomes contributions from a broad range of subjects including but not limited to: earthquake and aftershock studies, volcano monitoring, cryospheric research, coastal studies, structural monitoring, educational programs, public safety and various other societal benefits made possible by low-cost seismic devices.

### **Conveners**

Ian M. Nesbitt, OSOP Raspberry Shake ([ian.nesbitt@raspberrypi.org](mailto:ian.nesbitt@raspberrypi.org)); Emily Wolin, U.S. Geological Survey ([ewolin@usgs.gov](mailto:ewolin@usgs.gov)); Austin J. Elliott, U.S. Geological Survey ([ajelliott@usgs.gov](mailto:ajelliott@usgs.gov))

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### **Science Gateways and Computational Tools for Improving Earthquake Research**

Science gateways allow research communities to access shared data, software, computing services, instruments, educational materials and other resources. Advances in earthquake science are becoming increasingly tied to the ability to fuse and model multiple data types, requiring advances in computational infrastructure. Earthquake scientists must rely on computational laboratories to integrate disparate data sets and perform simulation experiments, particularly because earthquake processes span multiple spatial and temporal scales, ranging from microscopic, millisecond source physics to long-term, global tectonic scales, earthquakes. This session focuses on identifying best technologies and management strategies of science gateways for facilitating data access and science analysis through user interfaces, middleware and community networking capabilities. Abstracts discussing advances in computational infrastructure and data synthesis for enhancing earthquake science, including software, supercomputing, simulation models, sensor technology, heterogeneous data sets, cloud computing, management of huge data volumes and development of community standards are encouraged. Abstracts identifying management strategies and recommendations for analytics software to provide a feedback loop for making science gateways useful are also encouraged.

### **Conveners**

Andrea Donnellan, Jet Propulsion Laboratory, Caltech ([andrea@jpl.caltech.edu](mailto:andrea@jpl.caltech.edu)); Lisa Grant Ludwig, University of California, Irvine ([lgrant@uci.edu](mailto:lgrant@uci.edu))

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## **Seismic Imaging of Fault Zones**

Material and geometrical properties of the subsurface strongly influence fault-zone dynamics, but are impossible to observe directly. Elastic waves produced by earthquakes, man-made energy sources and environmental disturbances, however, offer diverse signals which can be used to constrain these properties. Imaging fault-zone structures using these signals requires techniques as diverse as the signals themselves and the geometries of observing networks. Robustly interpreting the resulting images challenges seismologists, but also presents information that will help unravel the physics behind hazardous ruptures. In this session, we welcome all contributions pertaining to seismic imaging of fault zones—especially new and improved techniques, case studies and multi-disciplinary surveys.

### **Conveners**

Malcolm C. A. White, University of Southern California ([malcolm.white@usc.edu](mailto:malcolm.white@usc.edu));  
Hongjian Fang, Massachusetts Institute of Technology ([hfang@mit.edu](mailto:hfang@mit.edu))

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## **Seismicity and Tectonics of Stable Continental Interiors**

Perhaps the least understood seismicity and tectonic deformation is that in stable continental interiors far removed from active plate boundaries. Areas of interest include central and eastern North America, northern Europe, Australia, and parts of Asia. New understandings of intraplate tectonic activity and corresponding seismicity have been made through a variety of approaches such as increased completeness of earthquake catalogs from local or national-scale monitoring efforts like USARRAY, from new methods of identifying smaller earthquakes from existing data, through analyses of data sets that image subsurface faults, through studies that constrain historical slip on such faults, from examinations of geodetic, geomorphologic and elevation changes, and through improved measurements of local stresses. Complementing these approaches are studies that show that the lower attenuation of ground motions and strong site responses in continental interior regions result in earthquakes having greater impacts than those at plate boundaries.

This session seeks diverse contributions related to intraplate earthquake hazards with goals of describing seismicity, characterizing active faults and/or deformation in stable continental interiors, learning the long-term earthquake histories, assessing potential ground motion impacts, applying lessons learned from induced earthquakes, and understanding the mechanisms that cause enigmatic intraplate earthquakes.

### **Conveners**

Anjana K. Shah, U.S. Geological Survey (ashah@usgs.gov); Christine Powell, University of Memphis (capowell@memphis.edu); Will Levandowski, TetraTech (will.levandowski@tetratech.com); Martin Chapman, Virginia Tech (mcc@vt.edu); Maurice Lamontagne, Geological Survey of Canada (maurice.lamontagne@canada.ca)

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### **Understanding Non-Traditional Seismic Tsunami Hazards**

Despite its intraplate and strike-slip source mechanism, the 2018 Palu earthquake had a large role in generating a deadly regional-scaled tsunami with run-up field measurements in excess of 4 m. In the Puget Sound and the Georgia Strait near Seattle, Washington, USA and Vancouver, British Columbia, Canada, paleoseismic investigations have begun to unearth shallow crustal faults which may be capable of generating locally damaging tsunami. Splay faults branching from the megathrust, normal faults in the outer rise, thrust faults in the accretionary wedge, strike slip events in plate interiors and seismic ground motion induced landsliding are all capable of generating tsunamis. Historically, however, the majority of tsunami modeling has focused exclusively on the shallow subduction interface. This can largely be attributed to past limits in computational power and our epistemic uncertainty in tsunamigenic processes. Advances in high-performance computing have eased the burden of running detailed and time-sensitive models, allowing for a richer view of seismic and tsunami source processes. Widespread attention, related to recent surprising earthquake and tsunami events, has increased capacity for studying an ever-expanding catalogue of faults and the cascading hazards that can result from their failure. Nevertheless, hazards from off-megathrust faults are currently underrepresented in traditional tsunami hazard assessments.

This session invites papers which aim to improve our limited understanding of the tsunamigenic impact beyond the shallow megathrust interface. Specifically, this session hopes to solicit studies using a broad range of geophysical, geological and oceanographic techniques to characterize non-traditional tsunamigenic processes, as

well as estimate the risks imposed in terms of areal extent of impacts to populations and the built environment.

### **Conveners**

Amy L. Williamson, University of Oregon (awillia5@uoregon.edu); Tiegan Hobbs, Natural Resources Canada (tiegan.hobbs@canada.ca); Valerie Sahakian, University of Oregon (vjs@uoregon.edu)

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### **Waveform Cross-Correlation-Based Methods in Observational Seismology**

Recent developments in observational seismology rely heavily on the mining of increasingly large datasets through waveform cross-correlation-based techniques to improve signal to noise ratios and extract useful information from continuous seismograms. These include obtaining accurate differential arrival times with waveform correlation analysis for accurate earthquake relocation and 3D seismic tomography, detecting low-magnitude events using array-based waveform matching, extracting empirical Green's functions (e.g., surface and body waves) from cross-correlation of continuous ambient noise waveform and creating virtual sources or receivers from cross-correlating earthquake coda waveforms. In this session, we welcome both methodologically and observationally focused contributions that utilize correlation-based methods to detect repeating earthquakes near creeping faults and volcanoes, relocate microearthquakes and low-frequency earthquakes around seismically active regions and image subsurface structures and monitor their temporal changes with ambient noise and earthquake coda correlation techniques. We hope to provide a platform for discussing how to efficiently apply correlation-based methods to ultra-dense arrays and long-duration continuous waveforms to better extract useful seismic events and image subsurface structures.

### **Conveners**

Zhigang Peng, Georgia Institute of Technology (zpeng@gatech.edu); Esteban J. Chaves, Volcanological and Seismological Observatory of Costa Rica, Universidad Nacional (esteban.j.chaves@una.cr); Marine Denolle, Harvard University (mdenolle@g.harvard.edu); William Frank, University of Southern California (wbfrank@usc.edu); Taka'aki Taira, Berkeley Seismology Laboratory, University of California, Berkeley (taira@berkeley.edu); Haijiang Zhang, University of Science and Technology of China (zhang11@ustc.edu.cn)

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## **Weathering the Earthquake Storms: Crisis Communication Following Major Events**

Earthquake scientists face increasing demand to spring into action following significant earthquakes, not only with scientific response, but also as communicators. The demand for information, from media, partners and other stakeholders, can be overwhelming. Opportunities abound, not only to provide critically important information, but also for potential missteps, in particular when a local population is traumatized by the earthquake(s) they have experienced. Earthquake professionals who have weathered local earthquake storms in recent years have learned important lessons about effective crisis communication. For this session, we welcome contributions from individuals with first-hand experience with crisis communication, as well as contributions focusing on evidence-based investigations of crisis communication and contributions about best practices for “peace time” communication that can pave the way for effective “war time” communication. We also welcome contributions that focus on operational aftershock focusing and issues associated with the communication of forecasts and their uncertainties to stakeholders and the public.

### **Conveners**

Susan E. Hough, U.S. Geological Survey ([hough@usgs.gov](mailto:hough@usgs.gov)); Maurice Lamontagne, Geological Survey of Canada ([maurice.lamontagne@canada.ca](mailto:maurice.lamontagne@canada.ca)); Timothy Dawson, California Geological Survey ([timothy.dawson@conservation.ca.gov](mailto:timothy.dawson@conservation.ca.gov))

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## **What Can We Infer About the Earthquake Source Through Analyses of Strong Ground Motion?**

Because the earthquake source cannot be directly observed, we rely on multiple analyses to infer knowledge of the parameters used to describe an earthquake. In this session we would invite presentations that describe methods and results for inferring the properties of the earthquake source, such as, rupture velocity, fracture energy, stress drop (stress parameter), slip-rate functions, critical slip weakening distance, friction, scaling laws, duration, moment rate, spatial heterogeneity, directivity, etc. We



encourage presentations that discuss uncertainties in the inferred parameters. We look forward to presentations that link earthquake simulations, both kinematic and dynamic, to generation of near-source ground motions. In particular, analysis of near-source data sets using inversion, arrays or other novel methods are most welcome.

**Conveners**

Ralph J. Archuleta, University of California, Santa Barbara (ralph.archuleta@ucsb.edu);  
Greg Beroza, Stanford University (beroza@stanford.edu); Massimo Cocco, Istituto  
Nazionale di Geofisica e Vulcanologia (massimo.cocco@ingv.it); Joe Fletcher, U.S.  
Geological Survey (jfletcher@usgs.gov)

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