SEISMOLOGICAL SOCIETY of AMERICA

2019 Annual Meeting

Technical Sessions

The 2018 Eruption of Kīlauea Volcano, Hawaiʻi

The 2018 volcano-seismic activity on Kīlauea, Hawaiʻi manifested in three distinct phases: (1) a magma intrusion along the Lower East Rift Zone, beginning 30 April, resulting in eruptive fissures that eventually produced the highest flow rates ever recorded at Kīlauea; (2) a M6.9 earthquake on 4 May located under the south flank of Kīlauea; the second largest event in Hawaii instrumented history; and (3) the episodic collapse of Halemaʻumaʻu crater at the Kīlauea summit from mid-May to early-August. Advances in techniques to assess the temporal evolution of seismicity, seismic parameters and structure and to link changes to dynamic shifts in eruption behavior, are exciting advances in monitoring, particularly techniques that do so in a largely automated fashion. This session will focus on improving our scientific understanding of seismicity with respect to volcanic and tectonic activity at Kīlauea, the 2018 M6.9 event, caldera collapse processes and advances in techniques that address the temporal evolution of seismic parameters that may accompany these eruptive phases. We invite contributions that include new observations, modeling and other pertinent studies. Topics include, but are not limited to: automated or semi-automated location methods, source rupture processes, foreshock and aftershock studies, early warning systems and geophysical imaging. We seek contributions from diverse fields to facilitate a multi-disciplinary discussion.

Conveners: Jefferson C. Chang, U.S. Geological Survey (jchang@usgs.gov); Charlotte A. Rowe, Los Alamos National Laboratory (char@lanl.gov); Ellen M. Syracuse, Los Alamos National Laboratory (syracuse@lanl.gov)

Advances in Intraplate Earthquake Geology

Paleoseismic studies of intraplate faulting in regions such as the Basin and Range Province, Walker Lane and crustal Pacific Northwest are often challenged by slow (<5 mm/yr) slip rates, long (> 1 k/yr) earthquake recurrence times, distributed faulting and limited event preservation because of episodic sedimentary and pedogenic processes. To address open questions about earthquake timing and rupture length in these regions, extract new information on potential seismic sources and better characterize intraplate faulting for seismic-hazard models, new techniques and dense and high-quality data are required.

This session will include invited and contributed presentations focused on how new data and methods in earthquake geology advance our understanding of intraplate faulting. In particular, we welcome presentations on (1) high-resolution and/or long-term earthquake timing, recurrence and slip rate constraints; (2) the application of Bayesian modeling to geochronological data; (3) methods of evaluating and propagating paleoseismic uncertainties; (4) spatial and temporal trends in rupture length and displacement from high-resolution surface topography (e.g., from lidar and unmanned aircraft systems); and (5) techniques for synthesizing earthquake histories and developing fault-rupture scenarios.

Conveners: Christopher DuRoss, U.S. Geological Survey (cduross@usgs.gov); Mark Zellman, BGC Engineers (mzellman@bgcengineering.ca); Stephen Angster, U.S. Geological Survey (sangster@usgs.gov)

Advances in Ocean Floor Seismology

Marine seismology has enjoyed a rapid growth in recent years, as significant advances have been realized in sensors, deployment and data recovery methods. Continued development of these technologies have led to greater capability to pose, and answer, more questions regarding the tectonics, seismicity and geodynamics associated with the ocean floors. We invite contributions detailing not only recent and ongoing seismological research on the ocean floors, but also focusing on hardware, software and deployment innovations that can facilitate new revelations for ocean bottom seismological research.

Conveners: Charlotte A. Rowe, Los Alamos National Laboratory (char@lanl.gov); Susan M. Bilek, New Mexico Institute of Mining and Technology (sbilek@nmt.edu); Michael L. Begnaud, Los Alamos National Laboratory (mbegnaud@lanl.gov)

Advances in Tectonic Geodesy

Geodetic datasets such as GPS, InSAR and measurements of strain and tilt are critical to observing many tectonic processes. Geodetic data is often complementary to seismic data, with the ability to record aseismic transients such as slow slip events. Geodetic data record the active accumulation of tectonic strain across seismogenic faults, which are often used to create locking models used in seismic hazard mapping. These data are also critical to monitoring volcanic processes, such as inflation and deflation, which are useful in forecasting and monitoring eruptions. Significant recent advances have been made in the field of seafloor geodetic observations, which require novel instrumentation and techniques. Seafloor observations are key to constraining locking in shallow subduction environments and studying offshore volcanic processes. In addition, a wealth of land based geodetic data in many areas has enabled rapid progress in the study of various tectonic processes. In this session, we welcome contributions from any topic related to geodetic observations, modeling and interpretation of geodetic data and development of geodetic techniques as they relate to tectonics. Contributions may describe analyses of seismic or other complementary data in addition to geodetic data. We especially encourage contributions which focus on any of the following topics:

- Advances in geodetic measurement techniques, including seafloor geodesy
- Novel modeling, inversion or data processing approaches applicable to geodetic data
- Studies which rigorously explore the role of geodetic data in constraining hazards, including those that analyze GPS noise
- Geodetic studies of recent geophysical events, including the 2018 eruptive activity at Kilauea volcano
- Studies focusing on aseismic phenomena, including slow slip, post-seismic processes and viscoelastic mantle flow

Conveners: Noel Bartlow, University of California, Berkeley (nbartlow@berkeley.edu); Kang Wang, University of California, Berkeley (kwang@seismo.berkeley.edu)

Advances, Developments and Future Research into Seismicity in Natural and Anthropogenic Fluid-driven Environments

Induced seismicity has been associated with many fluid-related anthropogenic activities, such as hydraulic fracturing, geothermal exploitation, waste-water injection and reservoir impoundment. However, fluid-induced seismicity can also be observed in natural environments, such as volcanic systems. Through recent advances in seismic monitoring, a closer examination of such seismicity can be achieved, particularly with regards to understanding the role of highly-pressurized fluids at depth and the consequences this may have at the surface. However, several fundamental questions remain, including: What factors control fluid-induced seismicity? What can be inferred from the seismicity in terms of ongoing processes? Can this information be used to inform hazard assessment, e.g., forecast volcanic eruptions or large induced earthquakes? Can comparisons between fluid-induced seismicity from different environments improve our understanding of the source processes involved?

This session aims to bring together a variety of topics related to fluid-induced seismicity to further our understanding of the physics behind earthquakes that are both natural and anthropogenic. We welcome contributions relating to seismicity in any fluid-driven environment. We are looking for abstracts related to lab experiments, statistical analysis, field observations and novel techniques in data processing/interpretation that characterize the physical conditions and mechanisms of fluid-related seismicity.

Conveners: Rebecca O. Salvage, University of Calgary (rebecca.salvage1@ucalgary.ca); Megan Zecevic, University of Calgary (megan.zecevic@ucalgary.ca); Ruijia Wang, University of Western Ontario (ruijia.wang@uwo.ca)

Better Earthquake Forecasts

Earthquake forecasts have a wide range of applications from short-term guidance during earthquake sequences and swarms to being an ingredient in long-term Probabilistic Seismic Hazards Assessments (PSHA). In this session, we will discuss what makes an earthquake forecast useful and how to improve them. For short-term forecasts of swarms and earthquake sequences, most current, official forecasts are based on statistical models of earthquake clustering such as the Reasenberg & Jones model or the ETAS (Epidemic Type Aftershock Sequences) model. Can we improve these by including physics-based models of stress transfer or results from numerical simulators of earthquake occurrence on fault networks? For long-term forecasts, PSHA often relies on seismicity rates obtained by smoothing declustered earthquake catalogs. Would other declustering methods improve the forecasts or should we abandon declustering altogether and include aftershocks in hazards assessments and building codes? Some PSHA now also includes deformation information from plate motions or geodetic monitoring. How do we best combine that information with the seismicity rates? For all forecasts, how do we include fault-based information and do we need better ways to address earthquake catalog incompleteness and uncertainty? A critical step is testing these forecasting methods and the forecasts themselves, for example using approaches from the Collaboratory for the Study of Earthquake Predictability (CSEP). As we develop tests we need to consider the role of local versus global tests, prospective versus retrospective tests and tests of forecast ingredients versus complete forecasts. Questions about testing are particularly timely as CSEP develops its second phase of operations. Finally, we need to communicate these forecasts with different users to help inform a variety of decisions. These communications methods range from hazard curves for engineers to simplified text or graphics for the people impacted by the earthquake, broadcast media, emergency managers and first responders. Working alongside our social science colleagues is an important step to understanding more about our users, the channels they prefer and what information they need most to inform their decisions. We seek contributions that address any of the questions posed above or other ideas on how to improve earthquake forecasts.

Conveners: Andrew J. Michael, U.S. Geological Survey (ajmichael@usgs.gov); Camilla Cattania, Stanford University (camcat@stanford.edu); David D. Jackson, University of California, Los Angeles (djackson@g.ucla.edu); Sara K. McBride, U.S. Geological Survey (skmcbride@usgs.gov); Warner Marzocchi, Istituto Nazionale di Geofisica e Vulcanologia (warner.marzocchi@ingv.it); Maximilian J. Werner, University of Bristol (max.werner@bristol.ac.uk)

Building, Using and Validating 3D Geophysical Models

Geophysical models, such as 3D geologic and seismic velocity models, are needed in three and sometimes four dimensions for a host of applications from predicting earthquake ground motions to locating natural resources to planning subsurface infrastructure. Many types of observations can be used to inform geophysical models including geologic mapping, borehole data, active and passive seismic imaging, potential field observations and observations from other direct and indirect methods. Geophysical theory or empirical models may also be used to solve for missing geophysical attributes given other related observations, for example, solving for S-wave velocity and density given the P-wave velocity. Further, some observations sample distinct locations while others average over volumes of varying size and different methods of informed interpolation and extrapolation may be used to reconcile observations, theory and empirical relationships into a single geophysical model. We seek contributions in which researchers have developed and/or applied methods for reconciling multiple datasets into a unified geophysical model. Discussion should address the advantages and disadvantages of various types of datasets and methods in an effort to improve and validate the next generation of geophysical models. Applications of geophysical models to improve assessment of hazard and risk, particularly in novel ways or for novel applications, are also encouraged.

Conveners: Oliver Boyd, U.S. Geological Survey (olboyd@usgs.gov); Bill Stephenson, U.S. Geological Survey (wstephens@usgs.gov); Brad Aagaard, U.S. Geological Survey (baagaard@usgs.gov)

Causes and Consequences of the Columbia River Flood Basalts

Flood basalt eruptions represent the largest volcanic events on Earth and the most recent one occurred 16 million years ago. It covered most of eastern Oregon and parts of western Idaho and southern Washington. In many cases, flood basalts are associated with the presence of hotspots, such as in Yellowstone. While processes driving the flood basalt event originate in the asthenosphere, the connection between these processes and the subsequent modification of the lithospheric plate is still poorly understood.

This session welcomes studies focused on the origin, evolution and dynamics of the Columbia River flood basalts and the Yellowstone system. We welcome contributions from geology, geochemistry, geochronology and geophysics that explore the architecture and dynamics of the crust-mantle system in the Columbia River flood basalts region.

Conveners: A. Christian Stanciu, University of Oregon (cstanciu@uoregon.edu); YoungHee Kim, Seoul National University (younghkim@snu.ac.kr); Eugene D. Humphreys, University of Oregon (genehumphreys@gmail.com); Robert W. Clayton, Caltech (clay@gps.caltech.edu)

Central and Eastern North America and Intraplate Regions Worldwide

This session aims to be a home for a wide variety of presentations tied together by a shared intraplate setting. Submissions treating crustal to lithospheric imaging in cratonic regions such as new results from EarthScope data, paleoseismology of intraplate faults, geodynamic models of continental seismicity, geodetic observations in low strain-rate regions, ground-motion and attenuation models and any other studies focused away from active plate boundaries are warmly encouraged.

Conveners: Will Levandowski, TetraTech (will.levandowski@tetratech.com); Weisen Shen, Stony Brook University (weisen.shen@stonybrook.edu); Christine Powell, University of Memphis (capowell@memphis.edu)

Characterizing Faults, Folds, Earthquakes and Related Hazards in the Pacific Northwest

This session will showcase recent advances in quantifying the activity and impacts of active faults and folds that accommodate oblique plate convergence along the Cascadia margin. We invite studies that characterize recent deformation related to the Juan de Fuca-North America plate boundary, including offshore structures, the plate interface and slab and upper plate structures from the forearc to the backarc. We welcome contributions from the fields of tectonic geomorphology, paleoseismology, geophysics and others that exploit lidar, bathymetry, seismic, potential field, GPS, InSAR and other high-resolution data to map active Cascadia structures and characterize their hazards.

Conveners: Scott E. K. Bennett, U.S. Geological Survey (sekbennett@usgs.gov); Ashley R. Streig, Portland State University (streig@pdx.edu); Colin B. Amos, Western Washington University (colin.amos@wwu.edu); Megan L. Anderson, Washington Geological Survey (megan.anderson@dnr.wa.gov)

Coseismic Ground Failure and Impacts on the Built and Natural Environment

In this session, we invite presentations on coseismic landslides and liquefaction, and their impacts on the built environment. We encourage submissions on empirical and analytical models, sensitivity analyses, data collection and analyses and scenario exercises. We welcome submissions focusing on both local and regional-scales, especially those addressing data or methods that bridge the gap between detailed local studies and generalized regional or global models. Submissions addressing the effect of frequency content, duration, or improved ground motion intensity measures on ground failure triggering are encouraged, as well as considerations of regional differences. Additionally, we encourage submissions on the collection and analysis of ground failure impacts and development of proxies for predicting the likelihood and the spatial distribution of earthquake ground failure impacts.

Conveners: Alex Grant, U.S. Geological Survey (agrant@usgs.gov); Kate Allstadt, U.S. Geological Survey (kallstadt@usgs.gov); Eric Thompson, U.S. Geological Survey (emthompson@usgs.gov); Keith Knudsen, U.S. Geological Survey (kknudsen@usgs.gov)

Current and Future Challenges in Engineering Seismology

The impressive ongoing densification of modern high-quality earthquake monitoring networks in most earthquake prone countries means that near-field strong ground motions—which dominate earthquake hazard—are increasingly recorded worldwide. Earthquake records are then made available to the seismological and engineering communities through open access databases and associated, state-of-the art web services. These high-quality earthquake waveforms are typically acquired at a variety of recording sites, ranging from rocklike ground to very soft sediments, with well characterized geotechnical and geophysical properties. This allows novel, physically sound representations of site terms in empirical ground-motion models and for reliably constraining reference rock ground motions. At the same time, tremendous advances in computational seismology allow physics-based numerical simulations of strong ground motions to reliably complement and further constrain ground-motion prediction efforts and hazard studies, by providing opportunities to model and test the impacts of complex source characteristics on expected ground motions. Ground-motion models are one of the key ingredients of seismic hazard assessments for tectonic and induced earthquakes, increasingly implemented also in real-time or rapid fashion to promptly identify potential associated impacts and losses and to optimize emergency response. Earthquake impact mitigation, that chiefly relies on modern earthquake resistant construction practice, requires effective translation of scientific investigation into building codes and requires continuous dialogue between the seismological and engineering communities. With this background, this session welcomes novel and multi-disciplinary contributions focusing on the current "grand challenges" in engineering seismology like: (a) prediction of near-field strong ground motions; (b) prediction of reference rock ground motions; (c) new approaches to empirical and computational ground motion modelling (including novel functional forms and predictors and attempts to reduce prediction uncertainties); (d) advanced site characterization (beyond the use of Vs,30 and site classes); (e) real-time/rapid earthquake hazard and impact assessment; and (f) translation of seismological science into building codes. We aim at a rich discussion that brings together experiences and ideas from the operational and research communities, and from empirical and numerical modelers. Students and early career seismologists are encouraged to present their ongoing and recent works.

Conveners: Carlo Cauzzi, Swiss Seismological Service at ETH Zurich & ORFEUS (carlo.cauzzi@sed.ethz.ch); Ralph Archuleta, University of California, Santa Barbara (ralph.archuleta@ucsb.edu); Fabrice Cotton, GFZ Research Center for Geosciences (fcotton@gfz-potsdam.de); Nicolas Luco, U.S. Geological Survey (nluco@usgs.gov); Alberto Michelini, Istituto Nazionale di Geofisica e Vulcanologia (alberto.michelini@ingv.it); Stefano Parolai, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (sparolai@inogs.it); Ellen Rathje, University of Texas at Austin (e.rathje@mail.utexas.edu); David Wald, U.S. Geological Survey (wald@usgs.gov)

Earthquake Ground Motions and Structural Response in Subduction Zones: A Focus on Cascadia

Accurate estimates of earthquake ground motions and structural response in subduction zone settings are critical to improving seismic hazard assessment and community resilience. This is especially true in the Cascadia subduction zone, with its susceptibility to multiple types of earthquake sources (e.g., megathrust, crustal and intraslab), the presence of deep sedimentary basins and proximity to major cities such as Portland, Oregon; Seattle, Washington and Vancouver, British Columbia.

We invite studies focusing on ground motion estimates using a variety of seismological approaches (e.g., observational, theoretical, numerical modeling), as well as those that assess the response of man-made structures and the underlying local site due to earthquake ground motions. We welcome results from all subduction zone systems, with a particular focus on those that may improve our understanding of seismic hazard in Cascadia.

Conveners: Erin Wirth, U.S. Geological Survey (ewirth@usgs.gov); Marine A. Denolle, Harvard University (mdenolle@fas.harvard.edu); Nasser Marafi, University of Washington (marafi@uw.edu); Valerie Sahakian, University of Oregon (vjs@uoregon.edu)

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 of ground motion prediction equations.

This session focuses on methodological as well as observational aspects of earthquake source parameters of natural or induced earthquakes in a 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, Prague (vv@ig.cas.cz); Douglas Dreger, University of California, Berkeley (dreger@seismo.berkeley.edu); Grzegorz Kwiatek, GFZ Potsdam (kwiatek@gfz-potsdam.de)

Emerging Science from the EarthScope Transportable Array in Alaska and Western Canada

The USArray Transportable Array deployment in Alaska and Western Canada was completed in the fall of 2017 with 194 telemetered broadband seismic and infrasound expected to collect data though the summer of 2020. This unprecedented systematic broadband coverage of the entirety of continental Alaska and far northwestern Canada provides the seismological community with a dataset intended to help illuminate long-standing questions and aid in new discoveries. The diverse tectonic environment of Alaska and northwest Canada provides a world-class setting for investigating seismicity, plate boundaries, distributed intraplate deformation, subduction, active volcanism, infrasound phenomena and a myriad of other Earth processes. This session welcomes emerging studies using all or part of this new community asset to investigate structures ranging from the crust to core, active tectonics, local, regional and teleseismic earthquakes or other elastic wave sources and seismic wave propagation.

Conveners: Natalia A. Ruppert, University of Alaska Fairbanks (naruppert@alaska.edu); Kevin M. Ward, South Dakota School of Mines & Technology (kevin.ward@sdsmt.edu); Meghan S. Miller, The Australian National University (meghan.miller@anu.edu.au)

Environmental Seismology: Glaciers, Rivers, Landslides 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 landslides, rock falls, debris flows, lahars, snow avalanches, cliff or pinnacle resonance, bedload transport, fluid flow in open and confined channels, open water waves, tides, glacial stick-slip, iceberg calving, crevassing, extreme weather, other anthropogenic sources. In addition, other processes monitored by seismic waves such as permafrost, groundwater, soil moisture using seismometers or DAS 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.

Conveners: Bradley Paul Lipovsky, Harvard University (brad_lipovsky@fas.harvard.edu); Marine A. Denolle, Harvard University (mdenolle@fas.harvard.edu); Richard C. Aster, Colorado State University (rick.aster@colostate.edu)

Evolving Best Practices for Station Buildout in EEW and New Permanent Networks

On the US West Coast, the U.S. Geological Survey and its partner institutions, University of California, Berkeley, Caltech, the University of Oregon and the University of Washington are focusing on completing the build-out of the infrastructure for initial implementation of ShakeAlert Earthquake Early Warning (EEW) in the United States. Over the next few years, the number of EEW-capable seismic stations must at least double from today's ~850 contributing stations. This effort requires planning regarding station density and type as well as complex logistics including siting, legal and environmental permitting, equipment specification and delivery. Other important topics include data quality and latency, continuous monitoring systems, delivery of alerts and other technical topics. This session invites contributions from any EEW system operator on all these topics related to EEW build, including case studies for current and planned seismic networks as well as new ideas for developing EEW deployments and collaborations with contributing networks that are novel for their design or approach in handling these issues.

Conveners: Fabia Terra, Berkeley Seismological Laboratory (terra@seismo.berkeley.edu); Mouse Marie Reusch, Pacific Northwest Seismic Network (topo@uw.edu); Tim Parker, Nanometrics Incorporated (timparker@nanometrics.ca); Geoffrey Bainbridge, Nanometrics Incorporated (geoffreybainbridge@nanometrics.ca)

Explore the Fault2SHA Paradigms Across the Ponds

After the formalization of a Fault2SHA working group inside the European Seismological Commission (2016), some initiatives for presenting new data sets and the latest integration of fault sources in SHA models in Latin Americas were organized by the Executive Committee in the “Old Word” (http://fault2sha.net/what/) and at a fruitful session at SSA2018. This session aims at exploring differences and similarities in treating fault data in seismic hazard assessment across the Ponds (the Oceans). Descriptions of earthquake sources coming from field observations and from modelling, discussions on how to handle uncertainties in source representation for Seismic Hazard Assessment (i.e. probability of multi-fault ruptures) and contributions to the identification of 3D, geometrically complex fault systems and their incorporation in either physics-based or probabilistic seismic hazard results are welcome.

This session is jointly organized by the European Seismological Commission and SSA.

Conveners: Laura Peruzza, Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (lperuzza@inogs.it); Ned Field, U.S. Geological Survey (field@usgs.gov); Richard Styron, Global Earthquake Model Foundation (richard.styron@globalquakemodel.org); Alessandro Valentini, Università degli Studi "G. d'Annunzio" Chieti – Pescara (alessandro.valentini@unich.it)

Explosion Seismology Applications

Explosion sources are an important component of seismology and are used in everything from characterization of geologic environments to nuclear test identification. 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, multi-physics data fusion and advanced processing techniques applied to explosion sources.

Conveners: William R. Walter, Lawrence Livermore National Laboratory (walter5@llnl.gov); Robert E. Abbott, Sandia National Laboratories (reabbot@sandia.gov); Jesse Bonner, Nevada National Security Site (bonnerjl@nv.doe.gov); Catherine M. Snelson, Los Alamos National Laboratory (snelson@lanl.gov)

Facebook and Twitter and Snapchat, Oh My! The Challenges and Successes of Using Social Media to Communicate Science to the Public

Social media is becoming a more important component of communicating science and local hazard information to the public. With the rise of this new media and the internet of things, scientists now have a more direct connection to communicate not only science information but also near real-time information about seismic hazards (e.g. tsunami alerts, earthquake information). However, this new communication avenue is a double-edged sword, as the same social media can be used to spread misinformation or create unrealistic expectations from the public regarding how and when local hazard information is disseminated. Here we invite presentations that relate to the use of social media as an education and outreach tool or as a method to disseminate hazard information including but not limited to: case studies of using social media to disseminate emergency information, applications of social media as an education and outreach tool, challenges and successes in using social media to communicate with the public and new methods or techniques that aim to improve interactions on social media.

Conveners: Elizabeth A. Vanacore, University of Puerto Rico, Puerto Rico Seismic Network (elizabeth.vanacore@upr.edu); Sara K. McBride, U.S. Geological Survey (skmcbride@usgs.gov)

From Drifting to Anchored: Advances in Improving Absolute Hypocenter Location Accuracy for Natural, Induced and Explosion Seismic Events

Accurate, absolute geographic location of seismic event hypocenters is important for characterizing seismic activity and estimating seismic hazard. The increasing societal demands for robust and actionable hazard estimation of natural and induced earthquakes, the requirements for nuclear explosion monitoring and other social and economic needs require improved hypocenter accuracy and robust error estimation. But, in general, seismic event locations are not well anchored to the geographic Earth because they depend on poorly distributed and distant seismogram measurements, simplified and erroneous Earth models and approximated physical processes. While many common hypocenter relocation methods can precisely constrain relative locations, hypocenters remain poorly constrained in absolute geographic coordinates. Only in rare cases is there relatively direct and accurate “ground truth” (GT) information on location that can be derived from static source displacement or from the known source of a human caused event or explosion.

Error estimates for seismic location fall into at least three main classes: (1) True, absolute geographic error (hypocenter - GT); (2) Nominal absolute error (nominal hypocenter uncertainties output by location algorithms or other analyses without GT); and (3) Nominal relative location errors. Here we welcome observational, theoretical and methodological contributions addressing determination of absolute geographic location of seismic events. We specifically ask - is it possible to achieve true absolute hypocenter estimates with representative uncertainties? If yes, what methods and data are needed to achieve this goal? We also welcome contributions on absolute and relative location procedures and their nominal error estimates that relate to improving absolute geographic location accuracy.

Conveners: Alexandros Savvaidis, Texas Seismological Network, Bureau of Economic Geology, University of Texas at Austin (alexandros.savvaidis@beg.utexas.edu); Anthony Lomax, ALomax Scientific (alomax@free.fr); William L. Yeck, National Earthquake Information Center, U.S. Geological Survey (wyeck@usgs.gov); Stephen C. Myers, Atmospheric, Earth, and Energy Division, Lawrence Livermore National Laboratory (myers30@llnl.gov)

Frontiers in Earthquake Geology: Bright Futures and Brick Walls

Since its infancy in the mid-1960s, the study of earthquake geology and paleoseismology has grown into a multi-disciplinary field. In concert, we have seen an increase in the precision and detail of coseismic earthquake observations and of complex fault behavior, including multi-fault rupture, earthquake triggering and fault interaction. In addition to the challenges of combining various geochronologic techniques, event stratigraphy and geomorphic surface reconstruction, paleoseismologic studies must also reconcile evidence from the upper several meters of the Earth with processes that initiate at several kilometers depth and with various models of rupture scenarios and earthquake recurrence. Despite these challenges, scientists are using new and improved methods and concepts to characterize both regional and local fault behavior, compare short term deformation rates with longer-term geologic slip rates, add critical constraints to dynamic rupture models and improve estimates of fault rupture length, earthquake magnitude and fault slip rates.

This session covers recent advancements, ongoing challenges and the future of earthquake geology. We welcome submissions focused on incorporating new concepts and methods that improve our understanding of short- and long-term fault behavior, place controls and insight on rupture modeling and provide new constraints on seismic hazard analyses.

Conveners: Lydia Staisch, U.S. Geological Survey (lstaisch@usgs.gov); Brian Sherrod, U.S. Geological Survey (bsherrod@usgs.gov); Stuart Nishenko, Pacific Gas and Electric Company (spn3@pge.com); Daniel Brothers, U.S. Geological Survey (dbrothers@usgs.gov); Gary Greene, Moss Landing Marine Labs (greene@mlml.calstate.edu)

Imaging Subduction Zones

Subduction zones host most of the deep earthquakes on Earth. The dynamic processes within subduction zones create volcanic arcs, control the global volatile cycle that impacts the climate and lead to orogeny that is responsible for the rise of mountains, e.g., the Andes mountains along the Andean subduction zone. Although there have been tremendous advances in imaging subduction zones (especially in Japan and Cascadia) with increasing seismic data coverage and improved imaging theory and methods, it is still very challenging to obtain consistent 3D high-resolution seismic images of these systems. Such high-resolution images are critical in definitively answering questions such as how volatiles are recycled, what are the pathways of melt migration and whether or not serpentine exists in the “cold nose” of the mantle wedge or the cold core of the slab mantle. The goal of this session is to motivate discussion on the current state of subduction zone imaging with a special focus placed on new seismic array deployments (e.g., OBS) and advanced seismic imaging methods (e.g., ambient noise tomography, migration imaging and full waveform inversion) that can explore and fully utilize big seismic data sets to better image subduction zones. We welcome and encourage research topics on robust imaging method development and applications and image interpretations of global subduction zones.

Conveners: Min Chen, Michigan State University (chenmi22@msu.edu); Eric D. Kiser, University of Arizona (ekiser@email.arizona.edu); Zhongwen Zhan, Caltech (zwzhan@caltech.edu)

Injection-induced Seismicity

Induced seismicity related to oil and gas production has been a growing concern in the last few years. Although the majority of wastewater disposal and hydraulic fracturing operations do not generate seismicity or large magnitude events, there have been few reports of damaging earthquakes in North America, resulting in some damages to infrastructure and other properties. This led to an increased demand for appropriate risk assessment and management of induced seismicity and the development of effective risk mitigation strategies. Injection-induced seismicity and associated risk and hazard have been the subject of many studies and research. However, there are still many questions to answer. In this session, we welcome contributions on geomechanics, numerical modelings, case studies, induced seismicity forecasting and risk assessment techniques, estimating ground motions, assessing liquefaction, lateral spreading, site amplification and infrastructure damage.

Conveners: Sepideh Karimi, Nanometrics Inc. (sepidehkarimi@nanometrics.ca); Zia Zafir, Kleifelder (zzafir@kleinfelder.com); Dario Baturan, Nanometrics Inc., (dariobaturan@nanometrics.ca); David Shorey, Nanometrics Inc. (davidshorey@nanometrics.ca)

The InSight Mission – Seismology on Mars and Beyond

The InSight mission landed on Mars on November 26, 2018 and was the first to place an ultra-sensitive broad band 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 provide overviews of the InSight mission, including description of its experiments, instruments, models, data access and services, as well as observations made in the first few months of operation. We also invite contributions that describe past and future seismological exploration of the Solar System.

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

Large Data Set Seismology: Strategies in Managing, Processing and Sharing Large Geophysical Data Sets

As seismology grows increasingly data rich, studies are being designed that use ever larger volumes of available data. The strategies for collecting, processing and sharing these data are evolving accordingly. In cases when the traditional research pattern of downloading, managing and processing data locally becomes untenably slow, new approaches are required. These strategies may include employing a compute cluster, either operated by a research group, an institutional HPC resource or a cloud computing provider. Researchers may use new technologies and frameworks to orchestrate more advanced processing workflows aimed at large scale computation, e.g. Hadoop. Furthermore, they may employ stream processing, where data are processed as it is collected from a center, thus mitigating the local storage issues. Ultimately, working with large data sets challenges researchers to be more informed and deliberate about computation, data transmission, compression and storage. This shift in data processing scale has a number of implications for both data providers and research processing pipelines and a variety of approaches are being used to address these changes. We invite researchers and data providers to describe their experiences in collecting, managing and processing large data sets.

Conveners: Chad Trabant, IRIS Data Services (chad@iris.washington.edu); Jonathan K. MacCarthy, Los Alamos National Laboratory (jkmacc@lanl.gov)

Large Intraslab Earthquakes

The physical processes associated with intermediate-depth and deep-focus earthquakes are not well understood. However, understanding these events can provide insights into earthquake mechanics, subduction dynamics, mineral physics and mantle thermal structures. In addition, some intermediate-depth earthquakes can pose significant hazards to local communities. Therefore, investigating rupture processes of these earthquakes has both significant intellectual and societal relevance. Recently large intermediate-depth and deep-focus earthquakes have occurred at multiple subduction zones with distinct characteristics, including the 2013 M8.3 Sea of Okhotsk earthquake, the 2015 M7.5 Hindu Kush earthquake, the 2015 M7.8 Bonin Islands earthquake, the 2017 M8.2 Mexico earthquake and the 2018 M8.2 and M7.9 Fiji doublet. The high-quality seismic records of these events provide excellent opportunities to probe kinematic and dynamic processes of these earthquakes, to differentiate their associated physical mechanisms, to investigate geodynamics of different subduction zones and to understand the related seismic hazards. We welcome contributions on all aspects of intra-slab earthquakes, including but not limited to rupture process, foreshocks and aftershocks, dynamic triggering, geodynamic modeling, mineral laboratory experiments and seismic imaging of slabs.

Conveners: Zhongwen Zhan, California Institute of Technology (zwzhan@caltech.edu); Wenyuan Fan, Woods Hole Oceanographic Institution (wfan@whoi.edu); Linda Warren, Saint Louis University (linda.warren@slu.edu)

The M7 Anchorage Earthquake: Testing the Resiliency of South-Central Alaska

The M7 Anchorage Earthquake of November 30, 2018 struck under Alaska's most densely populated urban area, and generated the strongest ground motions in south-central Alaska since the Great 1964 Alaska Earthquake. The Anchorage earthquake is the third $M_w \geq 7$ earthquake in the subducting Pacific Plate to impact south-central Alaska in the past three years. The rupture appears to have occurred inside the Pacific Plate and generally propagated upward and northward toward the plate interface. Strong ground motions across the Anchorage and Mat-Su Valley regions caused major impacts to the built environment and local economy, estimated in the hundreds of millions of dollars. Yet, despite the shaking severity most buildings, critical facilities and lifelines performed remarkably well. Damage was generally minor to moderate though spread across a large geographic area. In this session, we invite contributions from all fields addressing an array of topics including, but not limited to, the earthquake source, propagation and ground motion observations, geodetic observations, geotechnical impacts to the built environment and ground failures placed in the context of the local geology. We also seek perspectives that address community preparedness, mitigation measures, resiliency to seismic hazards and lessons learned.

Conveners: Michael West, University of Alaska (mewest@alaska.edu); Rob Witter, U.S. Geological Survey (rwitter@usgs.gov)

Machine Learning in Seismology

Recent advances in computer science and data analytics have brought machine-learning (ML) techniques, including deep learning, to the forefront of seismological research. While ML methods continue to produce impressive successes in conventional artificial intelligence (AI) tasks, they also start to show powerful applicability in augmenting big data analysis in seismology by improving accuracy and efficiency compared to the traditional methods. Successful ML applications in seismology include seismic event detection, seismic signal classification, earthquake parameter estimation, signal denoising, ground motion prediction, subsurface tomography, aftershock pattern recognition and efficient visualization. However, challenges remain in terms of discovering new ML methods that can be applied to seismic and other geophysical data to learn about Earth's subsurface structure and the underlying processes of Earth such as earthquakes. Furthermore, instead of considering ML models as "black boxes", developing human-interpretable ML models and learning about their decision-making process also remain as grand challenges in ML field. The goal of this session is to highlight some of most recent ML results in our seismology community to motivate discussions of new ML research directions in seismology and beyond.

This session is jointly organized by the Seismological Society of Japan and SSA.

Conveners: Youzuo Lin, Los Alamos National Laboratory (ylin@lanl.gov); Sepideh Karimi, Nanometrics Incorporated (sepidehkarimi@nanometrics.ca); Takahiko Uchide, Geological Survey of Japan, AIST (t.uchide@aist.go.jp); Qingkai Kong, University of California, Berkeley (kongqk@berkeley.edu); Dario Baturan, Nanometrics Incorporated (dariobaturan@nanometrics.ca); Zhigang Peng, Georgia Institute of Technology (zpeng@gatech.edu); Ting Chen, Los Alamos National Laboratory (tchen@lanl.gov); Andrew Delorey, Los Alamos National Laboratory (andrew.delorey@lanl.gov); Min Chen, Michigan State University (chenmi22@msu.edu); Chengping Chai, Oak Ridge National Laboratory (chaic@ornl.gov); Paul Johnson, Los Alamos National Laboratory (paj@lanl.gov)

Metamaterials, Resonances and Seismic Wave Mitigation, an Emerging Trend in Seismology

The study of the interaction between waves propagating in a medium and its structure continues to be one of the most active research areas of wave physics and notably seismology. After the introduction of a new class of artificially engineered media called "metamaterials" in electromagnetism and acoustics, the idea that full control on wave propagation can be achieved through an appropriate design of the medium's microstructure is now widely accepted. In elasticity for instance, several laboratory experiments have shown how waves can be stopped, converted or amplified using resonant inclusions or periodic arrangement of heterogeneities. This evokes the compelling question whether metamaterial concepts can be scaled up and work for seismic waves at earthquakes frequencies.

Major research directions are emerging in this area including the development of barriers for seismic waves, the design of periodic frames for buildings and, at a larger scale, the study of city layouts that exploit building resonances and site-city interaction (SCI) to mitigate the propagating seismic field.

We invite theoretical, numerical and experimental contributions dealing with metamaterials, site-city interaction and wave control applications, including ground borne vibrations, to the field of geophysics and seismic engineering.

Conveners: Andrea Colombi, ETH Zürich (andree.colombi@gmail.com); Philippe Gueguen, UGA, ISTerre (philippe.gueguen@univ-grenoble-alpes.fr); Antonio Palermo, Caltech (palerman@caltech.edu)

Methods for Site Response Estimation

Assessing the influence of soil and rock properties on the strength of earthquake ground shaking is an area of active research because of the importance of such "site effects" to realistically quantify potential seismic risk to infrastructure. The hazards community is moving beyond simple measurements of Vs30 (average shear-wave velocity in the upper 30 m) to measuring, modeling and predicting more accurate site response. These approaches include inverting various datasets for shear wave velocities at a range of depths, identifying hard boundaries that influence site response and also developing methods for direct measurement of site response through, such as spectral ratios using earthquake or ambient noise signals. In this session we invite abstracts on innovative methods for site response characterization, data collection approaches needed for such characterizations, as well as case studies showing the application of these methods.

Conveners: Thomas Pratt, U.S. Geological Survey (tpratt@usgs.gov); Lisa Schleicher, Defense Nuclear Facilities Safety Board (lisasschleicher@gmail.com); Lee Liberty, Boise State University (lliberty@boisestate.edu)

Modeling and Understanding of High-frequency Ground Motion

Seismic wave attenuation is an important topic for both seismology and engineering, as it enters in the prediction of ground motions, site response analyses and the assessment of seismic hazards. In this session, we would like to bring in studies focusing on high-frequency ground motion and its attenuation, as this may have significant impact on the site response and engineering design. As physics-based broadband simulations can reach unprecedented high frequencies, such studies can be of help in understanding ground motion at high frequencies crucial to the seismic response of certain structures, especially for critical facilities.

This session aims at collecting contributions as to how physics-based and empirical modeling handle high-frequency ground motion. We welcome simulation studies that may shed light on the nature of high-frequency attenuation of ground motion, in particular considering also a proper statistical treatment of the uncertainties associated with data collected in the field, the laboratory and through analysis of ground motion records. Topics of interest include crustal attenuation studies, fmax, kappa, spectral analysis studies (stress drop and Q), potential trade-offs between kappa and source, path and site effects, rock and site characterization studies, as well as contributions on the quantification and interpretation of scattering and intrinsic attenuation. Further contributions that help quantify uncertainties in high-frequency attenuation and corresponding ground motion models are also particularly welcome.

Conveners: Marco Pilz, GFZ Potsdam (pilz@gfz-potsdam.de); Ashly Cabas, Virginia Polytechnic Institute and State University (amcabasm@ncsu.edu); Olga Ktenidou, National Observatory of Athens (olga.ktenidou@noa.gr)

New Approaches to Geophysical Research Using Dense Mixed Sensor and Broadband Seismology Arrays

Researchers are deploying complementary geophysical instruments such as high and low gain seismic velocity sensors, accelerometers, infrasound, GNSS, MT in dense and sparse arrays along with broadband seismic sensors. Some of these techniques require longer-term deployments than others and contributors are encourage to discuss these constraints and tradeoffs when considering these types of combined instrument observations.

We would encourage session contributors to present their research, motivation and innovative approaches to geophysical studies using mixed sensor deployment techniques for Earth and climate sciences observations including: broadband and geophone velocity sensors, accelerometers, GNSS, tilt, pressure and infrasound, magnetotelluric instruments. Presentations may describe the results, challenges and discoveries of the multidisciplinary approach to geophysical studies.

Conveners: Tim Parker, Nanometrics Incorporated (timparker@nanometrics.ca); Ninfa Bennington, University of Wisconsin–Madison (ninfa@geology.wisc.edu); Bruce Townsend, Nanometrics Incorporated (brucetownsend@nanometrics.ca)

New Frontiers in Global Seismic Monitoring and Earthquake Research

Driven by the societal expectation for timely, accurate information, the past decade has seen dramatic improvements as a result of increased computational efficiency, seismic data coverage and improved communication technology. While aspects of earthquake research have taken advantage of this evolution, the adoption of improvements in earthquake monitoring has not been fully leveraged. In real-time monitoring, earthquakes are characterized in a vacuum, without leveraging knowledge of past events. New data types may help characterize earthquakes more quickly and accurately. New opportunities exist for rapidly communicating information. With these advances, global seismic monitoring can improve the quality and timeliness of information shared with the public.

A U.S. Geological Survey Powell Center Working Group explored these issues at a recent meeting, attempting to prioritize future opportunities in earthquake monitoring and research. Areas of focus identified by the group included improved agency communication during earthquake response; leveraging insights from the nuclear monitoring community in processing array data for earthquake detection and association; use of machine learning techniques to improve the reliability of source characterization; compressing the timeline of rapid source characterization; and improving our use of social media and crowd-sourced data. We solicit contributions that further explore these and related issues. We seek to more clearly identify priorities of future monitoring efforts, what new technologies can improve the speed and accuracy of monitoring and how to improve communication and coordination between groups involved in earthquake response and research.

Conveners: Gavin P. Hayes, U.S. Geological Survey (ghayes@usgs.gov); Paul S. Earle, U.S. Geological Survey (pearle@usgs.gov); Kristine Pankow, University of Utah (pankow@seis.utah.edu); Alberto Michelini, Istituto Nazionale Geofisica e Vulcanologia (alberto.michelini@ingv.it)

Next Generation Earthquake Early Warning Systems: Advances, Innovations and Applications

Recent scientific advances in real-time data processing, source characterization and ground motion prediction shape the future of earthquake early warning (EEW) systems. Machine-learning based techniques take conventional event detection algorithms to the next level by successfully identifying concurrent seismic radiations from multiple sources and reducing the number of false triggers. Integration of real-time seismic and GPS data reduce uncertainties on source characterization by providing additional insights on event magnitude, fault slip and rupture geometry. Ground-motion algorithms that make use of real-time observed amplitudes, regional wave propagation attributes and frequency-dependent site amplification allow for the reliable prediction of shaking intensities. Incorporation of building/facility inventory and associated vulnerabilities allows prediction of where damage potential is high for rapid aftermath response.

This session seeks contributions from the latest advances in the field of earthquake early warning, including (but not limited to):

- real-time earthquake location, rupture and ground motion characterization techniques/algorithms;
- insights gleaned from multi-disciplinary real-time data sets;
- challenges related to complex ruptures and concurrent events;
- characterization of prediction uncertainties and risk-oriented probabilistic early warnings;
- tsunami potential and early warning at local and global scales;
- case studies, testing and performance evaluation of existing systems;
- near real-time of damage predictions for post-disaster management.

This session is jointly organized by the Seismological Society of Japan and SSA.

Conveners: Angela I. Chung, Berkeley Seismology Lab (aichung@berkeley.edu); Emrah Yenier, Nanometrics Incorporated (emrahyenier@nanometrics.ca); Men-Andrin Meier, Caltech (mmeier@caltech.edu); Mark Novakovic, Nanometrics Incorporated (marknovakovic@nanometrics.ca); Mitsuyuki Hoshiba, Japan Meteorological Agency

(mhoshiba@mri-jma.go.jp); Yuki Kodera, Japan Meteorological Agency (y_kodera@mri-jma.go.jp)

Next Generation Seismic Detection

A range of new technologies are revolutionizing how we can detect and characterize seismic events. These include the use of new types of sensors to record motion, as well as new algorithms to process the geophysical data that they generate. Real-time processing of geodetic data is now the norm as the number of GNSS receivers streaming continuous data is steadily increasing. Tens of millions of smartphones equipped with both GNSS and accelerometer sensors have been deployed throughout the western US, while hundreds of millions exist throughout tectonically regions globally, and these are increasingly being harnessed in myriad new ways through crowd-sourcing. Seismic detection by voice- and shaking-activated Internet of Things offer to push sensor density far higher still. Machine learning algorithms are being applied to a wide variety of geophysical data and are improving our capability to detect events of interest. We invite contributions from researchers developing new and innovative ways to detect and characterize seismic events.

Conveners: Timothy Melbourne, Pacific Northwest Geodetic Array/Central Washington University (tim@geology.cwu.edu); Richard Allen, Berkeley Seismological Laboratory (rallen@berkeley.edu); Gavin P. Hayes, National Earthquake Information Center/U.S. Geological Survey (ghayes@usgs.gov); Raymond J. Willemann, Air Force Research Laboratory (raywillemann@gmail.com); G. Eli Baker, Air Force Research Laboratory (glenn.baker.3@us.af.mil)

Non-traditional Application of Seismo-acoustics for Non-traditional Monitoring

Seismo-acoustic measurements have been shown to be sensitive for detecting, locating and characterizing natural environmental phenomena, animal communications and military activities. There are however other phenomena and activities producing seismo-acoustic signals. For example, the operation of industrial facilities generates mechanical energy that potentially propagates into the air as acoustic and infrasonic waves and/or into the solid earth as seismic waves. The types and intensity of vibrational signals recorded at the sensors vary according to the specifics of the machinery and their relative location with respect to the sensors. Innovative analyses techniques can extract useful information from these signals and help us monitor the machinery or related activities. We welcome submissions on collection and application of seismo-acoustic data and techniques that shed light on non-traditional monitoring of facilities and activities.

Conveners: Monica Maceira, Oak Ridge National Laboratory (maceiram@ornl.gov); Chengping Chai, Oak Ridge National Laboratory (chaic@ornl.gov); Omar Marcillo, Los Alamos National Laboratory (omarcillo@lanl.gov)

Numerical Modeling of Earthquake Ground Motion, Seismic Noise, Rupture Dynamics and Seismic Wave Propagation

Continuous development of numerical modeling methodology in seismology is driven by emerging requirements in the observational seismology, advances in the mathematical sciences, evolution of computer architectures and programming models, adaptation of methods originating in other scientific fields, as well as by practical applications including site-specific seismic hazard assessment. This session is a forum for presenting advances in numerical methodology, whether the principal context is observational, mathematical/numerical, computational or application.

We invite contributions focused on development, verification and validation of numerical-modeling methods and methodologically important applications especially to earthquake ground motion, seismic noise and rupture dynamics, including applications from field of induced seismicity with particular focus on multi-physics aspects. Examples may include combining fluid migration and stress transfer in porous media with rupture dynamics and wave propagation in poro-elastic media and full seismic cycle simulations. We encourage contributions on the analysis of methods, fast algorithms, high-performance implementations, large-scale simulations, non-linear behavior, multi-scale problems and confrontation of methods with data.

Conveners: Peter Moczo, Comenius University in Bratislava (moczo@fmph.uniba.sk); Steven M. Day, San Diego State University (sday@sdsu.edu); Jozef Kristek, Comenius University in Bratislava (kristek@fmph.uniba.sk)

Observations of Volcanism in the Three Spheres: Land, Air and Sea

Volcanoes are naturally situated at the intersection of the solid Earth with the air and/or sea. As a result, we can probe the volcanic system using a diverse range of observable waves: seismic, infrasonic and hydroacoustic. While these waves can undergo conversions and move between spheres, information is typically lost in the conversion process and is best analyzed in the sphere where the source originates. Thus, observations in the different spheres may be necessary to fully characterize and understand volcanic activity.

Recent advances have been made using combinations of these observables in complementary ways to improve our understanding of volcanoes in eruption and repose. Monitoring networks are increasingly using infrasound to detect explosions, lahars and other subaerial activity. Underwater cabled networks, such as that at Axial Seamount and other instrumentation are opening new possibilities for monitoring and studying submarine volcanism. Additionally, new seismic technologies, such as large-N arrays, are allowing for more thorough seismic studies. New or improved methods—such as machine learning techniques—for processing, analyzing and combining the variety of data collected from volcanoes are also needed to improve our understanding of volcanism. In this session, we encourage interdisciplinary studies but also welcome new studies that showcase the diversity of advances in volcano seismology within a single sphere. Topics may include scientific studies as well as work focusing on techniques and instrumentation.

Conveners: Alicia J. Hotovec-Ellis, U.S. Geological Survey (ahotovec@gmail.com); Gabrielle Tepp, U.S. Geological Survey (gtepp@usgs.gov); Jackie Caplan-Auerbach, Western Washington University (jackie.caplan-auerbach@wwu.edu); Mel Rodgers, University of South Florida (melrodgers@usf.edu)

Offshore Subduction Zone Structure and Seismicity Along Pacific Northwest: From the Gorda Plate to the Queen Charlotte Fault

The Cascadia subduction zone extends along the Pacific Northwest from Cape Mendocino in the south to northern Vancouver Island in the north. However, convergence continues farther north beneath Haida Gwaii along the Queen Charlotte Fault, where the Pacific and North America plates meet. Across this entire area, several oceanic plates (Explorer, Juan de Fuca, Gorda, Pacific) and one continental plate (North America) interact forming a myriad of structures and a complex stress regime, with most of the important tectonic boundaries and associated seismicity located offshore. In this session we invite contributions that focus on investigating the offshore structure and convergent tectonics along the Cascadia subduction zone and the Queen Charlotte Fault using marine geophysical data, especially those that are centered on or include active and/or passive source seismic studies. We also welcome contributions that use other observational or modeling techniques to characterize stress or deformation along the margin and those that that summarize past, present and future offshore instrument deployments along the Pacific Northwest.

Conveners: Pascal Audet, University of Ottawa (pascal.audet@uottawa.ca); Mladen Nedimovic, Dalhousie University (mladen@dal.ca); Emily C. Roland, University of Washington (eroland@uw.edu); Shuoshuo Han, University of Texas Institute for Geophysics (han@ig.utexas.edu); Suzanne Carbotte, Lamont-Doherty Earth Observatory of Columbia University (carbotte@ldeo.columbia.edu)

Photonic and Non-inertial Seismology

Emerging photonic and non-inertial seismic measurements of ground motion that use laser interferometery or a networked array of stationary receivers (e.g., GNSS) instead of a classical “mass-on-a-spring” are expanding our capacity to observe the structure and dynamics of Earth systems. These photonic and non-inertial tools include fiber-optic and distributed fiber-optic strain sensors (e.g., interferometers, Bragg grating methods, DAS) and ring-laser rotational sensors. There are key theoretical and practical differences (advantages and disadvantages) between inertial and non-inertial sensors, which are the present focus of many seismological and computational science research groups worldwide. These include measurement of strain and rotation, perhaps in addition to particle velocity, and the ability to record terabytes of Large-N seismic data with meter-scale sensor spacing. Also, seismogeodetic techniques such as GNSS precise point positioning increases the dynamic range and accuracy of (particularly large) ground displacements and strain. Because non-inertial data often contain information on displacement gradients of a seismic wavefield (i.e., strain), there is a need to develop a fundamental theoretical framework to cope with this new data type. Moreover, the diverse advantages of non-inertial seismology make way for new data analysis methods, or the adaptation of existing methods to this new data type, with the potential to make novel observations of the planet. This session aims to crosscut the emerging space of photonic and other non-inertial seismological methods with contributions on sensor design, technical instrumentation aspects and current roadblocks, inertial/non-inertial comparisons, case studies involving theoretical and real datasets and applications ranging from basic science to engineering/monitoring.

Conveners: Nathaniel J. Lindsey, University of California, Berkeley (natelindsey@berkeley.edu); Patrick Paitz, ETH Zurich (patrick.paitz@erdw.ethz.ch); Paul Bodin, University of Washington (bodin@uw.edu); Jamie Steidl, University of California, Santa Barbara (steidl@eri.ucsb.edu); Eileen Martin, Virginia Tech (eileenrmartin@vt.edu); Zefeng Li, Caltech (zefengli@gps.caltech.edu)

Problem Unsolved: Knowledge Gaps at the Intersection of Earthquake Engineering Practice and Research

Earthquake engineering is a perpetual balancing act between established methods and innovative techniques. Established best practices and existing code are backed by published research as well as engineering consensus, but for some cases may lead to unrealistic results. The engineer's desire to improve and optimize the design requires adoption of new practices and techniques that are actively being researched. These newer practices may expose deficiencies in scientific understanding of which the research community is unaware. Alternatively, the practitioner may not be aware of the full range of research on these techniques. The intent of this session is to promote a dialogue between the earthquake engineering research and practice communities, and to suggest possible directions for new research to fill in these gaps.

This session invites engineering practitioners and researchers to submit case studies that illustrate difficulties they have encountered in their practice, owing to gaps in scientific knowledge. The session also invites papers on recent research illuminating known gaps in understanding of earthquake engineering practice. Submissions highlighting any earthquake engineering problem are welcome, as are those in the area of risk analysis and mitigation for disaster resilience. Submissions in the areas of seismic risk/hazard analysis, ground response analysis, soil-structure interaction and liquefaction analysis are particularly encouraged.

Conveners: Youssef M. A. Hashash, University of Illinois Urbana-Champaign (hashash@illinois.edu); Shahriar Vahdani, Applied Geodynamics, Inc. (shah.vahdani@gmail.com); Brady Cox, University of Texas at Austin (brcox@utexas.edu); Albert Kottke, Pacific Gas and Electric Company (albert.kottke@gmail.com); Recep Cakir, Senior Scientist, Geophysics and Seismology, Earthquake Hazard and Risk Analysis (cakir.recep@gmail.com); Bahareh Heidarzadeh, ENGEO Incorporated (bheidarzadeh@engeo.com); David P. Teague, ENGEO Incorporated (dteague@engeo.com); Gilead Wurman, ENGEO Incorporated (gwurman@engeo.com)

Recent Developments in High-rate Geodetic Techniques and Network Operations for Earthquake and Tsunami Early Warning and Rapid Post-earthquake Response

Over the past decade, geodetic techniques have become invaluable to rapid evaluation of earthquake hazards, both in real-time and for post-earthquake response. Techniques have included, but are not limited to, high-rate GNSS, strainmeters, ocean bottom pressure sensors, gravimeters and collocated seismic/geodetic instrumentation. These instruments and techniques are particularly useful for extracting moment release and rupture extent for large subduction earthquakes, although they have been shown to provide good source information for moderate sized events as well. Additionally, high-rate geodetic data and associated models can help improve ground motion characterization and prediction. This session seeks proposals that utilize geodetic instrumentation for the rapid modeling of earthquakes and tsunamis, both from the perspective of operational early warning and rapid post-earthquake response. We invite abstracts related to algorithm development, testing and validation of methodologies, machine-learning techniques to analyze GNSS data, analyses in combination with seismic data in real-time and more.

This session will also provide a venue for those involved in operating real-time GNSS networks to discuss current developments both in field operations and at data management centers. Building redundancy into critical data paths, efforts to lower latency and the upgrade of communications to meet the needs of systems being built for public-safety, methods for quantifying solution quality, as well seeking ways to integrate existing GNSS and seismic network infrastructure are topics of interest to this session. We also encourage presentations on the latest advances in the use of cloud architecture to manage the data and, the exploratory use of software such as Kafka and Elasticsearch at data operations centers.

Conveners: Brendan W. Crowell, University of Washington (crowellb@uw.edu); Kathleen M. Hodgkinson, UNAVCO (hodgkinson@unavco.org); Alberto Lopez, University of Puerto Rico at Mayagüez (alberto.lopez3@upr.edu); Benjamin A. Brooks, U.S. Geological Survey (bbrooks@usgs.gov); Joe Henton, Natural Resources Canada (joe.henton@canada.ca); Jeffrey J. McGuire, U.S. Geological Survey (jmcguire@usgs.gov); David J. Mencin, UNAVCO (dmencin@unavco.org)

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. 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, Caltech (andrea@jpl.caltech.edu); Lisa Grant Ludwig, University of California, Irvine (lgrant@uci.edu); Philip J. Maechling, University of Southern California (maechlin@usc.edu)

Science, Hazards and Planning in Subduction Zone Regions

Subduction zones host the Earth's largest faults and many of its active volcanoes. Subduction systems also play a central role in the formation and accretion of continental crust and are responsible for recycling oceanic crust and volatiles into the mantle. This session explores the latest multidisciplinary scientific advances in subduction zones around the world, including their mechanics, structure, evolution and dynamics from the trench to the backarc. We welcome studies that explore such topics as seismicity, tremor and deformation transients, including the slip behavior of faults and tsunami genesis, as well as studies that explore the geologic signatures of these processes. Below the arc, studies may explore volatile and magma migration, mantle wedge dynamics and melt production in the lower crust.

The dynamic processes inherent to subduction zones also challenge society's prosperity given the potential for natural disasters with broad regional impacts. These natural disasters are often compound events, as in the case where large earthquakes can trigger both landslides and tsunamis. The successful mitigation of these natural hazards requires a thorough scientific understanding of the underlying processes. Therefore, we also welcome studies that explore the recurrence, probability, potential impacts and mitigation strategies of these natural hazards.

Conveners: David Schmidt, University of Washington (dasc@uw.edu); Lori Dengler, Humboldt State University (lori.dengler@humboldt.edu); Will Levandowski, TetraTech (will.levandowski@tetratech.com); Kathy Davenport, Oregon State University (davenpka@oregonstate.edu); Jamey Turner, TetraTech (jamey.turner@tetratech.com); Rick Wilson, California Geological Survey (rick.wilson@conservation.ca.gov); Brendan W. Crowell, University of Washington (crowellb@uw.edu)

The Science of Slow Earthquakes from Multi-disciplinary Perspectives

Recognition of slow earthquake phenomena originated in Cascadia and Japan. Since the discovery of slow earthquakes, their study has continued to advance rapidly. Discussion in this joint session with Seismological Society of Japan (SSJ) is proposed to advance understanding of the phenomena not only in these two zones, but in many subduction zones around the Pacific Ocean, as well as other tectonic settings. The proximity of slow slip phenomena in subduction zones to great megathrust earthquakes highlights the importance of this topic for seismic hazard.

The goal of the session is to bring together research on slow earthquake phenomena that uses a variety of tools from seismology, geodesy, numerical modeling and laboratory studies, for various tectonic settings and spatial and temporal scales.

This session is jointly organized by the Seismological Society of Japan and SSA.

Conveners: Kazushige Obara, University of Tokyo (obara@eri.u-tokyo.ac.jp); Kenneth C. Creager, University of Washington (kcc@uw.edu); Heidi Houston, University of Southern California (heidi.houston@gmail.com); Takanori Matsuzawa, NIED: National Research Institute for Earth Science and Disaster Resilience (tkmatsu@bosai.go.jp)

Seismology BC(d)E: Seismology Before the Current (digital) Era

We are in the early stages of the seismological digital era, and high-quality digital recordings of earthquakes are plentiful. But there is still much to learn from the early instrumental era with analog recordings on paper, film, or other media; from the pre-instrumental era with earthquake information through reported observations; and from pre-historic times through paleoseismological investigations. The digital era encompasses only a tiny fraction of recorded seismic history. The synthesis of information from the pre-digital eras, combined with modern analyses and modeling, presents new opportunities to learn and discover.

We invite presentations that highlight the finding, preserving and/or using of paleoseismological or historic observational data alone or in conjunction with modern data. Uses may include the exploration of key open questions concerning fault and earthquake processes, seismotectonics and seismic hazard; quantification of uncertainties in using historical and paleoseismological data. Presentations may highlight the use of seismic data to explore other phenomena such as slow slip events, ambient noise, storm surges, tectonic tremors, acoustic phases, induced seismicity, landslides, icequakes and avalanches, and describe recent efforts to develop durable and accessible archives of original sources and datasets. We will conclude the presentations with an open discussion of best practices and identification of actionable tasks to advance reuse of analog data and move preservation efforts forward.

Conveners: Susan E. Hough, U.S. Geological Survey (hough@usgs.gov); Lorraine Hwang, University of California, Davis (ljhwang@ucdavis.edu); Allison Bent, Natural Resources Canada (allison.bent@canada.ca); Maurice Lamontagne, Geological Survey of Canada (maurice.lamontagne@canada.ca); Emile Okal, Northwestern University (e-okal@northwestern.edu); Brian Young, Sandia National Laboratories (byoung@sandia.gov); Graziano Ferrari, Istituto Nazionale di Geofísica e Vulcanologia (graziano.ferrari@ingv.it)

State of Stress and Strain in the Crust and Implications for Fault Slip Based on Observational, Numerical and Experimental Analysis

Understanding the stress and strain distributions in the crust and specifically near fault zones is essential towards refining knowledge on deformation processes, fault mechanics and earthquake source physics. This session focuses on (1) the estimation of the state of stress/strain and (2) the analysis of stress/strain distributions at different spatial and temporal scales by soliciting works based on theory, observational data, modeling and laboratory experiments. Contributions are encouraged but not limited to address the following questions: 1) How are stress and strain distributed in lab experiments and nature and how can we bridge the two environments? 2) What are insights from numerical simulations on stress state and to what extent can models help in interpreting observations such as earthquakes or slow slip events? 3) What can we extract from geodetic, geologic, borehole and seismic data regarding the state of stress at regional and local scales? 4) How can spatial stress/strain variations from long-term data compilations improve our knowledge of fault zone structure, earthquake mechanics, aseismic slip? 5) How can information on the state of stress/strain be used to improve seismic hazard assessments?

Conveners: Niloufar Abolfathian, University of Southern California (nabolfat@usc.edu); Patricia Martínez-Garzón, GFZ Research Center for Geosciences (patricia@gfz-potsdam.de); Thomas Goebel, University of California, Santa Cruz (tgoebel@ucsc.edu)

Structural Seismology: From Crust to Core

Seismic imaging of the Earth’s inaccessible interior, spanning from the lower crust to the deepest inner core, has achieved better resolution and accuracy due to improvements in data coverage, computational power, as well as modelling and inversion algorithms. We invite contributions highlighting results of analyses of new datasets as well as applications of new algorithms for revealing detailed Earth structure across length-scales, from local to global, and throughout the interior, from crust to core.

Conveners: Vedran Lekic, University of Maryland, College Park (ved@umd.edu); Jessica C. Irving, Princeton University (jirving@princeton.edu); Andrew J. Schaeffer, Natural Resources Canada (andrew.schaeffer@canada.ca); Meghan S. Miller, Australian National University (meghan.miller@anu.edu.au)

U.S. Geological Survey National Seismic Hazard Model Components

The U.S. Geological Survey will soon complete the 2018 update to the National Seismic Hazard Model (NSHM) for the coterminous U.S. This update has begun an experiment with a more frequent update process that shortens the time between releases from six to three years on average. More frequent updates permit fewer model changes per update, more opportunities for adoption by a wide array of users and release of the latest models representing best-available science. For instance, the 2018 NSHM update mainly incorporated NGA-East for U.S. Geological Survey (Goulet et al., 2017) in the central and eastern U.S. The NGA-East ground motion model marks a significant change in how we characterize the epistemic uncertainty in ground motions, and it is essential that we be able to evaluate and understand the model without the additional complexity of source model or implementation changes that are necessary to include in longer update cycles. This session focuses on the latest such models and the tools and techniques used to evaluate them. The 2014 update to NSHM for the conterminous U.S. saw the adoption of UCERF3, NGA-West2 and new adaptive smoothing techniques for gridded seismicity sources. The 2018 update brought in NGA-East and considered basin amplification effects in the western U.S. Forthcoming updates will consider NGA-Subduction, the use of the UCERF3 inversion methodology for Alaskan fault systems and further use of simulation-based ground motions. The latest models also commonly present implementation and application challenges. We invite submissions on, but not limited to, the NSHM components listed above. In particular, submissions should focus on sensitivity testing, comparative analysis, implementation techniques, new evaluation tools or metrics, new uses and applications of existing analyses (e.g. deaggregation) or uncertainty analysis.

Conveners: Peter M. Powers, U.S. Geological Survey (pmpowers@usgs.gov); Allison M. Shumway, U.S. Geological Survey (ashumway@usgs.gov); Mark D. Petersen, U.S. Geological Survey (mpetersen@usgs.gov); Sanaz Rezaeian, U.S. Geological Survey (srezaeian@usgs.gov); Richard W. Briggs, U.S. Geological Survey (rbriggs@usgs.gov); Robert C. Witter, U.S.

Geological Survey (rwitter@usgs.gov); Charles S. Mueller, U.S. Geological Survey (cmueller@usgs.gov)

Using Repeating Seismicity to Probe Active Faults

Repeating seismicity provides a novel means of monitoring fault zone processes at depths commonly inaccessible. Various forms of repeating seismicity exist, and we invite studies from the broad suite of repeating seismicity including earthquakes, long-period events and low-frequency earthquakes. Recent studies have shown that repeating seismicity can be used to infer fault slip-rates and physical properties at depths relevant to earthquake nucleation. With growing datasets and computationally efficient routines for detection of repeating seismicity it is now possible to probe faults in great detail and for long durations. Data from catalogs of repeating seismicity can provide the basis for physically realistic models of earthquake cycles and triggering and interaction of seismicity. We invite contributions relating to field and laboratory observations of repeating seismicity, advances in the detection and parameterization of repeating seismicity and the modelling of repeating seismicity.

Conveners: Calum J. Chamberlain, Victoria University of Wellington (calum.chamberlain@vuw.ac.nz); Amanda M. Thomas, University of Oregon (amt.seismo@gmail.com); William B. Frank, University of Southern California (wbfrank@usc.edu)