NSF Public Outcomes Report

Project Title: The Southern California Earthquake Center, Phase 4 (SCEC4): Tracking Earth-quake Cascades
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The Southern California Earthquake Center (SCEC) is one of the world's largest geoscience collaborations, involving over 1000 scientists at more than 70 universities and research organizations in the study of earthquakes and their hazards. During Phase 4 of its research program (2012-2017), SCEC coordinated fundamental research on earthquake processes using Southern California as its main natural laboratory; it built earthquake system science across the disciplines of seismology, tectonic geodesy, and earthquake geology, and it engaged earthquake engineers and computer scientists in the development of new tools for assessing and reducing earthquake risks.

- Special Fault Study Areas were established in the Ventura and San Gorgonio Pass regions, where multi-disciplinary research teams investigated the interplay of earthquake dynamics with fault complexity. They discovered that very large earthquakes can occur on the Ventura fault system, revising the estimates of seismic and tsunami hazards for this part of California, and they found that the "knotted" fault structure of the San Gorgonio Pass typically arrest ruptures, although occasional ruptures propagate through the knot as very large earthquakes.

- SCEC developed and sustained a set of interconnected community models to support the development of physics-based hazard models. Hundreds of studies of California faults and crustal structure were integrated into a Unified Structural Representation comprising a Community Fault Model and a Community Velocity Model. The latter was improved using the new technique of full three-dimensional waveform tomography, developed by SCEC researchers. SCEC initiated a Community Geodetic Model and a Community Stress Model to support research in fault-system modeling.

- The Working Group on California Earthquake Probabilities developed the Third Uniform California Earthquake Rupture Forecast, UCERF3, through a USGS-SCEC partnership with major support from the California Earthquake Authority. The time-independent component of the model was incorporated into the 2014 update of the USGS's National Seismic Hazard Model. The long-term time-dependent component, released in 2015, now serves as the standard California time-dependent forecast. The short-term component was published in 2017 and is currently under testing in SCEC's Collaboratory for the Study of Earthquake Predictability.

- SCEC developed the high-performance computational platform, CyberShake, that produces seismic hazard models from hundreds of millions of earthquake simulations. CyberShake models of ground shaking are now being used by earthquake engineers in the seismic safety design of tall buildings.

- SCEC's Communication Education and Outreach (CEO) program expanded the Earthquake Country Alliance to include more than 400 associates and partner organizations and grew participation in the Great California ShakeOut to 10.5 million. SCEC expanded ShakeOut nationally to include all U.S. states and territories and internationally into Canada, Japan, New

Zealand, and a growing number of other countries. In 2017, more than 58 million people worldwide were registered in ShakeOut drills.

Intellectual Merit of SCEC4 Research. Earthquakes emerge from complex, multiscale interactions within active fault systems that are opaque, and are thus difficult to observe. They cascade as chaotic chain reactions through the natural and built environments, and are thus difficult to predict. SCEC has developed a system-science approach and requisite cyberinfrastructure to address these problems. Its goal has been earthquake forecasting models that are comprehensive, integrated, verified, predictive, and validated against observations.

SCEC4 advanced earthquake system science through three basic activities: gathering information from seismic and geodetic sensors, geologic field observations, and laboratory experiments; synthesizing knowledge of earthquake phenomena through physics-based modeling, including system-level hazard modeling; and communicating the understanding of seismic hazards to reduce earthquake risk and promote community resilience. It sponsored highly integrated collaborations that were coordinated across scientific disciplines and research institutions and enabled by high-performance computing.

Broader Impacts of SCEC4 Research. Probabilistic forecasting of fault ruptures and earthquake shaking informs all major decisions aimed at reducing seismic risk and improving earthquake resilience. SCEC has developed a new generation of physics-based seismic hazard models, including the Uniform California Earthquake Rupture Forecast, earthquake rupture simulators, and the CyberShake simulation-based hazard model. These projects contribute to key elements of the USGS National Hazards, Risk, and Resilience Assessment Program.

SCEC's CEO program has developed effective new mechanisms to promote community preparedness and resilience, including the many publications branching from Putting Down Roots in Earthquake Country, installation of "Quake Catcher Network" sensors in schools and museums, and development of curricular materials. Through ShakeOut, the Seven Steps to Earthquake Safety has become a global messaging framework, and SCEC leads efforts worldwide for standardized earthquake safety messaging. SCEC now also coordinates consistent national and global tsunami messaging via its TsunamiZone.org website.

About two-thirds of the SCEC science budget was used to support students and early-career scientists engaged in investigator-initiated research. Some of SCEC's broadest and deepest impacts are through its highly successful Summer Undergraduate Research Experience and Undergraduate Studies in Earthquake Information Technology intern programs, which have involved more than 560 undergraduates of widely varying backgrounds since 1994.

Southern California Earthquake Center

SCEC4: Tracking Earthquake Cascades

Final Report

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1. Introduction

The Southern California Earthquake Center (SCEC) was created as a Science & Technology Center (STC) on February 1, 1991, with joint funding by the National Science Foundation (NSF) and the U. S. Geological Survey (USGS). SCEC graduated from the STC Program in 2002, and was funded as a stand-alone center under cooperative agreements with both agencies in three consecutive phases, SCEC2 (1 Feb 2002 to 31 Jan 2007), SCEC3 (1 Feb 2007 to 31 Jan 2012), and SCEC4 (1 Feb 2012 to 31 Jan 2017). SCEC coordinates fundamental research on earthquake processes using Southern California as its main natural laboratory. Currently, over 1000 earthquake professionals are participating in SCEC projects. This research program is investigator-driven and supports core research and education in seismology, tectonic geodesy, earthquake geology, and computational science. The SCEC community advances earthquake system science by gathering information from seismic and geodetic sensors, geologic field observations, and laboratory experiments; synthesizing knowledge of earthquake phenomena through system-level, physics-based modeling; and communicating understanding of seismic hazards to reduce earthquake risk and promote community resilience.

SCEC requested and was granted a no-cost extension by NSF, which extended the award end date to January 31, 2018. This report outlines the SCEC4 accomplishments from November 16, 2016 - January 31, 2018.

Intellectual Merit of SCEC4 Research

Earthquakes emerge from complex, multiscale interactions within active fault systems that are opaque, and are thus difficult to observe. They cascade as chaotic chain reactions through the natural and built environments, and are thus difficult to predict. The SCEC4 research program pioneers time-dependent seismic hazard analysis—the geoscience required to track earthquake cascades. This science seeks to understand the unusual physics of how matter and energy interact during the extreme conditions of rock failure. No theory adequately describes the basic features of dynamic rupture, nor is one available that fully explains the dynamical interactions within networks of faults. Progress towards a comprehensive theory will improve the predictive capabilities of earthquake system science.

Through highly integrated collaborations that are coordinated across scientific disciplines and research institutions and enabled by high-performance computing and advanced information technology, SCEC4 science focuses on six fundamental problems of earthquake physics:

1. Stress transfer from plate motion to crustal faults: long-term fault slip rates.
2. Stress-mediated fault interactions and earthquake clustering: evaluation of mechanisms.
3. Evolution of fault resistance during seismic slip: scale-appropriate laws for rupture modeling.
4. Structure and evolution of fault zones and systems: relation to earthquake physics.
5. Causes and effects of transient deformations: slow slip events and tectonic tremor.
6. Seismic wave generation and scattering: prediction of strong ground motions.

SCEC4 Broader Impacts

The Center translates basic research into practical products for reducing risk and improving community resilience in Southern California and elsewhere. The SCEC4 program helps to:

- transform long-term seismic hazard analysis, the most important geotechnology for characterizing seismic hazards and reducing earthquake risk, into a physics-based science;
- develop operational earthquake forecasting into a capability that can provide authoritative information about the time dependence of seismic hazards to help communities prepare for potentially destructive earthquakes;
- enable earthquake early warning—advanced notification that an earthquake is underway and predictions of when strong shaking will arrive at more distant sites—and

- improve the delivery of post-event information about strong ground motions and secondary hazards.

The Center creates, prototypes, and refines these operational capabilities in partnership with the USGS and other responsible government agencies. In addition to better earthquake forecasting and ground motion prediction models, important SCEC4 contributions include the Collaboratory for the Study of Earthquake Predictability (CSEP) cyberinfrastructure needed to evaluate prospectively and continually the performance of the operational models and their components by comparing the forecast ground motions with those actually recorded. SCEC's international leadership in system science and sustained efforts to educate a diverse scientific workforce also contribute to its broader impacts.

SCEC4 Project Plan

Seismic hazards change dynamically in time, because earthquakes release energy on very short time scales and thereby alter the conditions within the fault system that will cause future earthquakes. The project's long-term goal is to understand how seismic hazards change across all time scales of scientific and societal interest, from millennia to seconds.

The six fundamental problems listed above constitute the basic-research focus of the project. They are interrelated and require an interdisciplinary, multi-institutional approach. Each is described by a short problem statement, a set of SCEC4 objectives, and a listing of priorities and requirements. Interdisciplinary research initiatives focused on special fault study areas, the development of a community geodetic model for Southern California (which will combine GPS and InSAR data), and a community stress model. The latter is a new platform where the various constraints on earthquake-producing stresses can begin to be integrated. Improvements were made to SCEC's unified structural representation and its statewide extensions.

The SCEC4 research program addresses four major challenges of earthquake system science:
(1) discover the physics of fault failure; (2) improve earthquake forecasts by understanding fault-system evolution and the physical basis for earthquake predictability; (3) predict ground motions and their effects on the built environment by simulating earthquakes with realistic source characteristics and three-dimensional representations of geologic structures; and (4) improve the technologies that can reduce long-term earthquake risk, provide short-term earthquake forecasts and earthquake early warning, and enhance emergency response.

The SCEC4 organizational structure comprises disciplinary working groups, interdisciplinary focus groups, special projects, and technical activity groups. The Southern San Andreas Fault Evaluation (SoSAFE) project, which was been funded by the USGS Multi-Hazards Demonstration Project for the last four years, transitioned into a standing interdisciplinary focus group to coordinate research on the San Andreas and the San Jacinto master faults. Research in seismic hazard and risk analysis was bolstered through an Earthquake Engineering Implementation Interface that includes educational as well as research partnerships with practicing engineers, geotechnical consultants, building officials, emergency managers, financial institutions, and insurers. A set of special projects funded separately by the NSF, USGS, and other agencies leverages core research support.

The theme of the CEO program during SCEC4 was creating an earthquake and tsunami resilient California. It aims to prepare individuals and organizations for making decisions (split-second and long-term) in response to changing seismic hazards and introduce them to the new technologies of operational earthquake forecasting and earthquake early warning. A public education and preparedness thrust area educates people of all ages—in California, across the country, and internationally—about earthquakes, and motivate them to become prepared. A K-14 earthquake education initiative seeks to improve earth science education and school earthquake safety, and SCEC's experiential learning and career advancement program provide students and early-career scientists with research opportunities and networking to encourage and sustain careers in science and engineering.

2. Organization and Management

SCEC has developed an effective management structure for coordinating earthquake research and education activities. The Center's ability to facilitate collaborative, investigator-driven research has been repeatedly proven in its diverse accomplishments. Participation in SCEC is rising despite flat funding and its national and international partnerships are flourishing. In its annual reports, the SCEC External Advisory Council has repeatedly documented the enthusiasm among SCEC participants and endorsed their high levels of satisfaction with the Center's leadership and management.

Core and Participating Institutions

SCEC continues as an institution-based center, governed by a Board of Directors, who represent its members. The Center currently involves more than 1000 scientists and other experts in active SCEC projects, making it one of the largest formal collaborations in geoscience. It continues to operate as an open consortium, available to all qualified individuals and institutions seeking to collaborate on earthquake science in Southern California, and its membership continues to evolve. The institutional membership currently stands at 75, comprising 18 core institutions and 57 participating institutions (not limited to universities, nor to U.S. organizations). The three USGS offices in Menlo Park, Pasadena, and Golden and the California Geological Survey are core institutions. Thirteen foreign institutions are currently recognized as partners with SCEC through a set of international cooperative agreements.

Board of Directors

Each core institution has appointed one member to the SCEC Board of Directors, which is chaired by the Center Director. The Board is the primary decision-making body of SCEC; it meets three times per year (typically in February, June, and September) to approve the Annual Collaboration Plan and budget and deal with major business items. The SCEC board comprises 18 voting members. Jean-Philippe Avouac (Caltech), Tim Dawson (CGS), John Shaw (Harvard), Patrick Fulton (Texas A&M), Toshiro Tanimoto (UCSB), and Graham Kent (UNR) are new members to the Board. John Shaw serves as Vice-Chair of the Board. The USGS members serve in non-voting liaison capacity. Nico Luco (USGS, Golden) joined the Board as a non-voting liaison member. Ex officio members include the Co-Director; the PC Vice-Chair; the Executive Science Director for Special Projects; and the Associate Directors for CEO, IT, Science Operations, and Administration. The Board is empowered to elect two nominees from the participating institutions to serve two-year terms as At-Large Members. The At-Large Members of the SCEC Board of Directors were not elected until Spring, 2018.

Director Transition

The SCEC Director acts as Principal Investigator (PI) on most proposals submitted by the Center, retaining final authority to make and implement decisions on Center programs, budgets, and financial obligations. (The modified SCEC By-Laws allow the Co-Director to act as PI on special project proposals.) The Director oversees all Center activities and is the Center's official liaison to the rest of the world, and specifically, to the funding agencies. The Director chairs the SCEC Board of Directors, and may appoint committees as needed to carry out Center business.

In 2016, Thomas Jordan (SCEC4 and SCEC5 proposal PI) announced plans to retire as SCEC Director as soon as a replacement was found. USC and SCEC began a nationwide search in Fall 2016 for an outstanding scientist to lead SCEC as a Professor in Earth Sciences at USC. The search identified John Vidale from the University of Washington as the top candidate. The USC Department of Earth Sciences, SCEC Board of Directors, and program officers for the SCEC cooperative agreements unanimously supported Vidale's appointment as SCEC Director. John Vidale is a member of the National Academy of Sciences with extensive experience leading a large organization and projects, including serving as Director of the Pacific Northwest Seismic Network and helping lead U.S. efforts in Earthquake Early Warning. He has long been engaged with SCEC, most recently as a member and then Chair of the SCEC Advisory Council. Vidale was appointed Dean's Professor of Earth Sciences at USC in August 2017. The SCEC Director transition took place in September 2017 at the SCEC Annual Meeting. Jordan had served more than 15 years as Center Director.

Executive Committee

The changes in the SCEC leadership structure and formation of an Executive Committee of the Center (ExCom), as written in the modified SCEC By-Laws (effective February 2017), were intended to redistribute some of the Director's responsibilities and workload. The ExCom handles daily decision-making responsibilities for the Center. It comprises of the Center Director and Board Chair (John Vidale), the Co-Director and PC Chair (Greg Beroza), the Board Vice-Chair (John Shaw), the PC Vice-Chair (Judi Chester), the Executive Director for Special Projects (Christine Goulet), the Associate Directors for Information Technology (Philip Maechling), Science Operations (Tran Huynh), CEO (Mark Benthien), and Administration (John McRaney). The Board Chair and Vice-Chair coordinate program activities with the SCEC Board of Directors. The Co-Director may serve as the Principal Investigator of SCEC special projects. The PC Chair serves as a liaison to SCEC science partners, chairs of the annual meeting, and oversees the annual science planning process. The PC Vice-Chair and the Executive Director of Special Projects (ED-SP) provide added science leadership when formulating and implementing the annual science program. The ED-SP manages the science activities of projects funded outside the core cooperative agreements and coordinating these activities with the PC and Associate Director for IT. The Associate Director for Science Operations manages all operational and financial aspects of the science planning process. The Associate Director for CEO is responsible for Center communication, education, and outreach activities. The Associate Director for Administration manages the Center budget as approved the Board and liaises with the funding agencies.

External Advisory Council

The external Advisory Council (AC) serves as an experienced advisory body to the Center, charged with developing an overview of SCEC operations, identifying strengths, opportunities, and vulnerabilities, and advising the Director and the Board. Since the inception of SCEC in 1991, the AC has provided perspective to maintain the vitality of the SCEC and help its leadership chart new directions. The Center has always provided its sponsoring agencies and participants, with a complete copy of the yearly AC report.

The AC was reconstituted as part of the SCEC4 to SCEC5 transition in 2017. Meghan Miller, the president of UNAVCO, accepted the position as AC Chair, effective September 2017. She has served on the AC since 2012 and is well known for her organizational skills and scientific leadership. The new AC members are Rick Aster (Colorado State U.), Susan Beck (U. Arizona), Yann Klinger (IPGP), Tom O'Rourke (Cornell), Susan Owen (JPL), and Heidi Tremayne (EERI). Continuing members are Roger Bilham (U. Colorado), Donna Eberhart-Phillips (UC Davis), Warner Marzocchi (INGV, Rome), and Tim Sellnow (U. Central Florida).

Science Planning Committee

The Planning Committee (PC) is responsible for formulating the Center's science plan, conducting proposal reviews, and recommending projects to the Board for SCEC support. The chair of the PC is the SCEC Co-Director, Greg Beroza of Stanford, and its Vice-Chair is Judi Chester of Texas A&M. The PC comprises the leaders of the SCEC science working groups—disciplinary committees, focus groups, and special project groups—who, together with the working group co-leaders, guide SCEC's research program. Its members play key roles in implementing the SCEC science plan. In late 2016, the PC membership and working groups were restructured to prepare for the transition between SCEC4 (**Figure 2.1**) and SCEC5 (**Figure 2.2**).

Science Working Groups

The SCEC organization comprises a number of disciplinary committees, focus groups, special project teams, and technical activity groups (TAGs). These working groups have been our engines of success, and many of the discussions at this meeting will feed into their plans.

The Center supports disciplinary science through standing **disciplinary committees** in Seismology, Tectonic Geodesy, Earthquake Geology, and Computational Science. These groups are responsible for disciplinary activities relevant to the SCEC Science Plan, and they make recommendations to the Planning Committee from the perspective of disciplinary research and infrastructure. The leaders of the disciplinary committees are Seismology: Yehuda Ben-Zion and Jamie Steidl; Tectonic Geodesy: David Sandwell and Gareth Funning; Earthquake Geology: Mike Oskin and Whitney Behr; Computational Science: Eric Dunham and Ricardo Taborda.

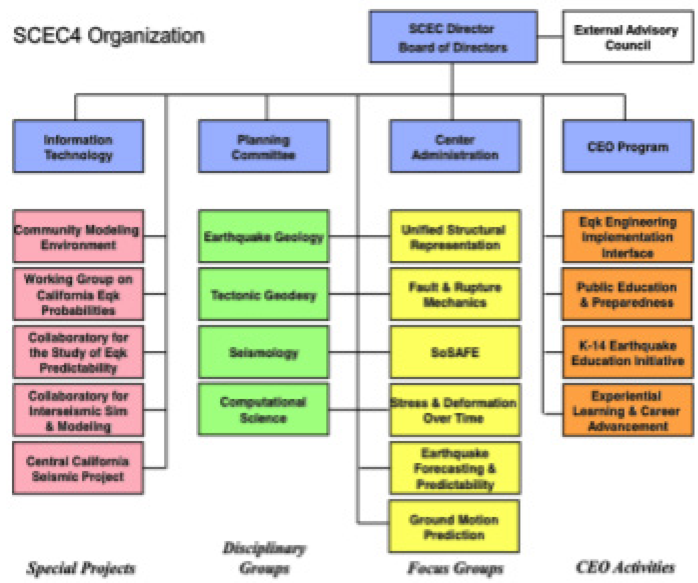


Figure 2.1. The SCEC4 organization chart, showing the disciplinary committees (green), focus groups (yellow), special projects (pink), CEO activities (orange), management offices (blue), and the external advisory council (white).

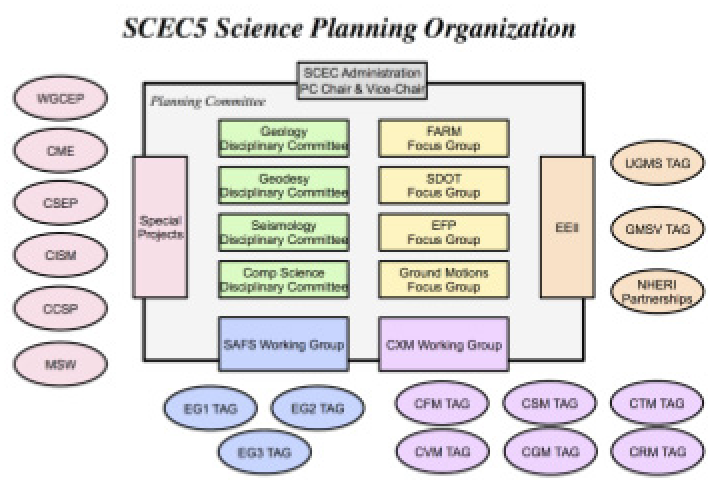


Figure 2.2. SCEC science planning organization chart, consisting of Disciplinary Committees (green boxes), Interdisciplinary Focus Groups (yellow boxes), and Technical Activity Groups (ellipses) coordinated by Working Group leaders in Special Projects, San Andreas Fault System, SCEC Community Models, and the Earthquake Engineering Implementation Interface.

SCEC coordinates earthquake system science through a number of **interdisciplinary focus groups**. Most of the SCEC4 interdisciplinary focus groups remain unchanged, with the exception of "Ground Motion Prediction" becoming "Ground Motions" (GM). The SoSAFE working group evolved into the San Andreas Fault System (SAFS) group, with a greater emphasis on modeling the fault systems. The Unified Structural Representation (USR) group from SCEC4 broadened into the SCEC Community Models (CXM) group in SCEC5. The leadership for the current interdisciplinary focus groups are FARM: Nadia Lapusta and Nick Beeler; EFP: Max Werner and Ned Field; SDOT: Kaj Johnson and Bridget Smith-Konter; EEII: Jack Baker and Jon Stewart; GM: Domniki Asimaki, Annemarie Baltay-Sundstrom; SAFS: Kate Scharer and Michele Cooke; CXM: Liz Hearn and Scott Marshall.

SCEC **special projects** are research partnerships in targeted earthquake research that heavily leverage the core program. Synergy between the special projects and the core program is ensured by a central SCEC policy, instituted by the Board of Directors in 2005: the science objectives of all SCEC special projects must be aligned with those of the SCEC core program and explicitly included as objectives in the SCEC Annual Science Plan. Current SCEC special projects include UCERF, CSEP, SEISM2, CISM, MSW, and CCSP. Special Projects are currently funded by NSF, USGS, the California Earthquake Authority, the W. M. Keck Foundation, and Pacific Gas & Electric Company. The ED-SP (Christine Goulet) manages the science activities of special projects in coordination with the Associate Director for IT (Phil Maechling), who oversees the SCEC's CME, a high-performance collaboratory for large-scale earthquake simulations. The CME infrastructure and software developers currently support five major SCEC computational platforms: High-F, CyberShake, Broadband, F3DT, and UCVM. The importance and scale of effort involved with CSEP, CXM, and data management led us to request additional funding for software developers focused on these activities in the SCEC5 proposal.

SCEC researchers are encouraged to self-organize into **technical activity groups** (TAGs) to develop and test critical methodologies for solving specific problems. TAGs have formed to verify the complex computer calculations needed for wave propagation and dynamic rupture problems, to assess the accuracy and resolving power of source inversions, and to develop geodetic transient detectors and earthquake simulators. TAGs share a modus operandi: the posing of well-defined "standard problems", solution of these problems by different researchers using alternative algorithms or codes, a common cyberspace for comparing solutions, and meetings to discuss discrepancies and potential improvements. TAGs are initiated through successful proposals submitted through the science collaboration process. TAG proposals typically involve a workshop and include a research coordination plan that sets a timetable for successful completion of TAG activities no later than the end of SCEC5.

Science Planning Process

The annual budget cycle begins with a SCEC Leadership Meeting in early June, when the Board, Planning Committee, Executive Committee of the Center, and agency representatives discuss SCEC research priorities. Based on these discussions, the PC drafts an annual SCEC Science Plan (www.scec.org/scienceplan), which is presented to the SCEC community at the Annual Meeting in early September. The PC uses the feedback received at the meeting to finalize the Annual Science Plan, and a project solicitation released in October. SCEC participants submit proposals in response to this solicitation in November. All proposals are independently reviewed by the Director, the Co-Director, Vice-Chair of the PC, and the leaders of at least three relevant science working groups. Reviews are assigned to avoid conflicts of interest.

The PC meets in January to review all proposals and construct an Annual Collaboration Plan. The plan's objective is a coherent science program, consistent with SCEC's basic mission, institutional composition, and budget that achieves the Center's short-term objectives and long-term goals, as expressed in the Annual Science Plan. The PC Chair submits the recommended Annual Collaboration Plan to the Board of Directors for approval. The annual budget approved by the Board and the Center Director is submitted to the sponsoring agencies for final approval and funding. Upon approval by the agencies, notifications are sent out to the investigators.

To construct the annual SCEC Collaboration Plan, proposals submitted in response to the annual solicitation are evaluated based on: (a) scientific merit of the proposed research; (b) competence, diversity, career level, and performance of the investigators; (c) priority of the proposed project for short-term SCEC objectives; (d) promise of the proposed project for contributing to long-term SCEC goals; (e) commitment of the principal investigator and institution to the SCEC mission; (f) value of the proposed research relative to its cost; and (g) the need to achieve a balanced budget while maintaining a reasonable level of scientific continuity given funding limitations. With respect to criterion (b), improving the diversity of the SCEC community and supporting early-career scientists is a major goal of the Center. It is important to note that a proposal that receives a low rating or no funding does not necessarily imply it is scientifically inferior. Rather, these proposals may be downgraded because they may not meet other criteria noted above.

SCEC maintains close alignment with the USGS Earthquake Hazards Program during the science planning process through three mechanisms: (1) reporting and accountability required by USGS funding of SCEC, (2) liaison memberships on the Board of Directors by the three USGS offices now enrolled as SCEC core institutions, and (3) a Joint SCEC/USGS Planning Committee (JPC). The JPC augments the SCEC Planning Committee with a group of program leaders designated by the USGS who participate in the construction of the Annual Collaboration Plan. If requested, the PC chair will continue to sit on the Southern California Proposal Review Panel for the USGS External Research Program.

Communication, Education and Outreach

The Associate Director for CEO (Mark Benthien) manages SCEC's Communication, Education, and Outreach program, with activities focused on four areas: Knowledge Implementation, Public Education and Preparedness, K-14 Earthquake Education, and Experiential Learning and Career Advancement. The Earthquake Engineering Implementation Interface, led by Jack Baker (Stanford) and Jon Stewart (UCLA), provides the organizational structure for connecting SCEC scientists and research results with practicing engineers, government officials, business risk managers, and other professionals in order to improve application of earthquake science. Through coordination with the Earthquake Country Alliance (ECA) and other outreach partners, SCEC educates people of all ages about earthquakes, tsunamis, and other hazards, and motivate them to become prepared. SCEC's education programs are managed by Gabriela Noriega of USC through the Office of Experiential Learning and Career Advancement.

A Communication, Education, and Outreach Planning Committee (CEO PC) provides guidance for CEO programs and activities, reviews reports and evaluations, and identifies synergies with other parts of SCEC and external organizations. Its members include stakeholders representing CEO program focus areas: public education and preparedness (Kate Long); K-14 education initiative (Danielle Sumy); experiential learning and career advancement (Sally McGill); and knowledge implementation (Ricardo Taborda, Tim Dawson). The CEO PC is chaired Tim Sellnow of the University of Central Florida, who also serves as the liaison to the SCEC Advisory Council.

SCEC Participants

SCEC is a large consortium of institutions with a national, and increasingly worldwide, distribution that coordinates earthquake science within Southern California and with research elsewhere. The SCEC community now comprises one of the largest formal research collaborations in geoscience. Among the most useful measures of SCEC size are the number of people on the Center's email list (2,291 as of June 2017) and the registrants at the SCEC Annual Meeting (596 in 2017). Annual Meeting registrations for SCEC's entire history and other demographic information are shown in **Figure 2.3**.

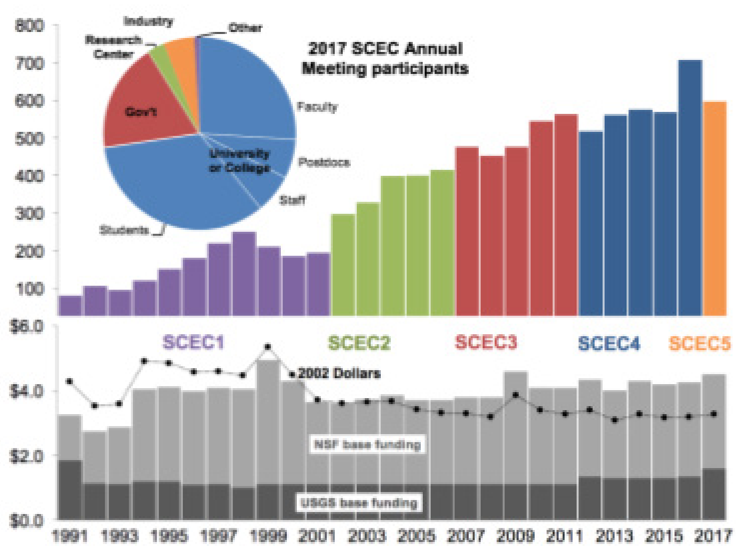


Figure 2.3. Upper bar chart shows registrants of SCEC Annual Meetings (1991-2017). Pie chart shows the demographic for 2017 pre-registrants (596 total). The lower bar chart is the history of SCEC base funding in as-spent millions of dollars; the connect dots are the base-funding totals in 2002 dollars.

SCEC is an open community of trust that nurtures early-career scientists and shares information and ideas about earthquake system science. The Center's working groups, workshops, field activities, and annual meeting enable scientists to collaborate over sustained periods, building strong interpersonal networks that promote intellectual exchange and mutual support. In particular, SCEC encourages colleagues with creative physics-based ideas about earthquakes to formulate them as hypotheses that can be tested collectively. An advantage is that researchers with new hypotheses are quickly brought together with others who have observational insights, modeling skills, and knowledge of statistical testing methods. Participation in SCEC is open, and the participants are constantly changing.

The SCEC leadership is committed to the growth of a diverse scientific community and actively pursues this goal by (1) encouraging core institutions to consider diversity in their appointments of Board members and electing the Board's members-at-large; (2) making diversity a major criterion in appointments to the Planning Committee, a crucible for developing leadership because it has significant responsibilities in managing SCEC activities; (3) including diversity as a criterion used to evaluate proposals and construct the Annual Collaboration Plan; and (4) promoting diversity among our students and early-career scientists through recruitment for the SCEC internship and diversity programs.

Recognizing that diversity is a long-term issue requiring continuing assessments and constant attention, SCEC continues to track the demographics in order understand the composition and evolution of the SCEC community. For example, people who participate in the SCEC Annual Meeting and/or Annual Collaboration Plan must register in the SCEC Community Information System, which includes providing demographic information. The table below shows a snapshot of the diversity of the SCEC Community as a whole. The SCEC community generally follows historical trends in the geosciences, with much greater diversity among students than senior faculty. Participation of underrepresented minorities is very low, again reflecting the Earth Sciences at large.

We recognize that the current situation is not unique to SCEC and reflects historical trends in the geoscience and physical science communities. We believe SCEC can be most effective in changing these trends by promoting diversity among its students and early-career scientists; i.e., by focusing on the "pipeline problem". The SCEC internship programs have been an effective mechanism for this purpose and we will redouble our efforts to encourage a diverse population of students to pursue careers in earthquake science through the launch of the Transitions Program in 2017. This program will provide junior members of the SCEC community with resources and mentoring across key career transitions, directing efforts to encourage and sustain careers in the geosciences and other STEM fields.

Center database of SCEC participants in 2017

	Race						**Ethnicity**		
	Native	Asian	Black	Pacific	White	NA	Latino	Not	NA
Faculty (Tenure-Track)	0	22	0	0	127	65	12	142	60
Faculty (Non-Tenure-Track)	0	2	0	0	4	2	0	6	2
Research Faculty (Tenure-Track)	0	4	0	0	9	8	0	11	10
Research Faculty (Non-Tenure-Track)	0	5	0	0	17	6	3	18	7
Postdoctoral Scholar or Fellow	0	17	0	0	28	28	0	40	33
Teacher (K-12)	0	0	0	0	1	0	0	1	0
Student (Graduate)	0	48	2	2	99	65	14	130	72
Student (Undergraduate)	0	5	4	1	15	19	11	20	13
Student (High School)	0	0	0	0	0	0	0	0	0
Staff (Management and Administration)	0	3	0	0	23	5	0	22	9
Staff Scientist (Doctoral Level)	0	17	1	0	58	18	3	68	23
Staff (Research)	0	7	0	0	21	10	1	24	13

Staff (Comm, Outreach, Public Relations)	0	0	1	0	5	1	1	6	0
Technician	0	0	0	0	2	1	0	2	1
Professional Engineer (Civil and Environ)	0	3	0	0	8	2	1	8	4
Professional Engineer (Other)	0	1	0	0	3	1	0	2	3
Professional Geologist	0	1	0	0	15	18	3	12	19
Consultant (Engineering)	0	1	0	0	3	2	0	4	2
Consultant (Information Technology)	0	2	0	0	1	1	0	2	2
Consultant (Other)	0	0	0	0	3	1	0	2	2
Building Official	0	0	1	0	0	0	0	0	1
Emergency Manager	0	0	0	0	3	2	1	2	2
Self-Employed	0	0	0	0	2	0	0	2	0
Unemployed	0	0	0	0	0	0	0	0	0
Retired	0	0	0	0	3	1	0	3	1
Other	0	1	0	0	6	3	1	3	6
Unspecified	0	5	0	0	14	60	1	14	64

	Gender			Citizenship		
	Male	Female	NA	US	Other	NA
Faculty (Tenure-Track)	146	45	23	130	59	25
Faculty (Non-Tenure-Track)	7	1	0	3	5	0
Research Faculty (Tenure-Track)	14	5	2	9	10	2
Research Faculty (Non-Tenure-Track)	19	6	3	16	10	2
Postdoctoral Scholar or Fellow	37	25	11	21	43	9
Teacher (K-12)	1	0	0	1	0	0
Student (Graduate)	112	81	23	116	93	7
Student (Undergraduate)	15	24	5	28	9	7
Student (High School)	0	0	0	0	0	0
Staff (Management and Administration)	15	13	3	25	5	1
Staff Scientist (Doctoral Level)	69	22	3	65	23	6
Staff (Research)	23	13	2	23	12	3
Staff (Comm, Outreach, Public Relations)	3	4	0	7	0	0
Technician	1	1	1	2	0	1
Professional Engineer (Civil and Environ)	10	3	0	10	3	0
Professional Engineer (Other)	4	1	0	3	2	0
Professional Geologist	23	6	5	25	5	4
Consultant (Engineering)	6	0	0	3	3	0
Consultant (Information Technology)	3	1	0	3	1	0
Consultant (Other)	2	2	0	3	1	0
Building Official	1	0	0	0	1	0
Emergency Manager	2	3	0	4	1	0
Self-Employed	2	0	0	2	0	0
Unemployed	0	0	0	0	0	0
Retired	4	0	0	3	1	0
Other	4	5	1	6	4	0
Unspecified	22	11	46	11	59	9

International Collaborations

- **SCEC Advisory Council.** We have two international members, Yann Klinger of Institute for Physics of the Globe in Paris and Warner Marzocchi of INGV in Rome.

- **CEO/ShakeOut.** SCEC collaborates with 60 countries on ShakeOut activities, including partnerships with Afghanistan, Canada, Colombia, Greece, Iran, Mexico, New Zealand, India, Japan, Italy, Afghanistan, Pakistan, CNMI, and the Philippines on holding ShakeOut drills. SCEC hosts the websites for all ShakeOut drills worldwide. In 2017, there were > 58 million partiicpants worldwide, with ~20 million participating in the U.S. See www.shakeout.org.

- **ERI/Tokyo and DPRI/Kyoto.** SCEC has long term MOU's with the Earthquake Research Institute in Tokyo and the Disaster Prevention Research Institute in Kyoto. A partnership between SCEC and these two institutions was initiated in 2012 with funding from NSF under its Science Across Virtual Institutes (SAVI) initiative. This program established a Virtual Institute for the Study of Earthquake Systems (VISES), which will coordinate SCEC/ERI/DPRI collaborations in earthquake system science.

- **CSEP (Collaboratory for the Study of Earthquake Predictability).** SCEC founded CSEP in 2006. CSEP testing centers are now located at USC, ERI/Tokyo, GNS/New Zealand, ETH/Zurich, and CEA/China.

- **ACES (APEC Cooperative for Earthquake Simulation).** SCEC and JPL are the U.S. organizations participating in ACES. Information on ACES can be found http://www.quakes.uq.edu.au/ACES/. Andrea Donnellan of SCEC/JPL is the U.S. delegate the ACES International Science Board and John McRaney of SCEC is the secretary general. Eiichi Fukuyama of the National Research Institute for Earth Science and Disaster Prevention (NIED) in Japan is the current Executive Director of ACES. The next international workshop is planned for September25-28, 2018 on Awaji Island near Osaka, Japan. Awaji Island was the epicenter of the 1995 Kobe Earthquake.

- **ETH Zurich/Switzerland.** Stefan Wiemer participates in the SCEC/CSEP projects. Luis Dalguer participates in the rupture validation project.

- **Korea Institute of Geosciences.** Seok Goo Song participates in the rupture validation project.

- **KAUST/Saudi Arabia.** Martin Mai participates in the Source Inversion Validation TAG.

- **IGNS/New Zealand.** David Rhoades and Matt Gerstenberger of the Institute for Geological and Nuclear Sciences of New Zealand are involved in the CSEP program. Charles Williams, Caroline Holden, and Susan Ellis participate in the ground motion modeling program.

- **University of Otago/New Zealand.** Mark Stirling of Otago participates in the ground motion modeling program.

- **Canterbury University/New Zealand.** Brendon Bradley of QuakeCore participates in the SCEC ground motion simulation program.

- **GFZ Potsdam/Germany.** Danijel Schorlemmer participates in the CSEP special project. Olaf Zielke participates in the simulators project.

- **University of Bristol/UK.** Max Werner is the co-leader of the Earthquake Forecasting and Prediction Interdisciplinary Focus Group of the SCEC PC.

- **UNAM/Mexico.** Victor Cruz-Atienza works in the rupture validation project.

- **INGV Rome/Italy.** Warner Marzocchi is a member of the Scientific Review Panel (SRP) for the UCERF3 project.

- **University of Naples/Italy.** Iunio Iervolino participates in the Ground Motion Simulation Validation TAG under support from the European REAKT Project.

- **GSJ/Japan.** Yuko Kase works in the rupture validation program.

- **CICESE/Mexico.** John Fletcher and Jose Gonzalez-Garcia are collaborating with SCEC scientists in post earthquake studies of the El Mayor-Cucupah earthquake and its aftershocks, on modeling for the CGM, and development of slip-rate data for faults in northern Baja California..

- **Imperial College London/UK.** Dylan Rood collaborates on dating tsunami projects.

- **SCEC Annual Meeting.** The SCEC annual meeting continues to attract international participants each year. There were participants in the 2017 annual meeting from Australia, China, Japan, India, Mexico, Canada, France, Switzerland, Germany, Russia, Italy, Taiwan, Turkey, and New Zealand.

- **International Participating Institutions.** ETH/Zurich, CICESE/Mexico, Western University/Canada, University of Bristol/UK, University of Canterbury/New Zealand, and Institute for Geological and Nuclear Sciences/New Zealand; and 4 institutions from Taiwan (Academia Sinica; National Central University; National Chung Cheng University; National Taiwan University) are participating institutions in SCEC.

- **China Earthquake Administration/Beijing.** Director Jordan, Co-Director Beroza, and Associate Director McRaney gave invited presentations on SCEC research and the SCEC organization at several venues in Beijing in December 2016. Talks were given at the CEA Institutes for Earthquake Science, Institute for Geology, and Institute for Geophysics. Talks were also given at the China Earthquake Networks Center and the Chinese Academy of Sciences. An MOU was signed at the end of the meetings to work for closer collaboration between the China Earthquake Administration and SCEC in the future. The first workshop, International Conference for the Decade Memory of the Wenchuan Earthquake, resulting from this MOU will be held in Chengdu, China in May 2018. John Vidale, Bruce Shaw, and Gareth Funning will represent SCEC at the workshop.

- **10th World Congress on Earthquake Engineering, Santiago, Chile, January 2017.** SCEC participating scientists include Mark Petersen, Nico Luco, Ricardo Taborda, Norm Abrahamson, Andrew Whittaker, David Jackson, Jack Baker, Jonathan Stewart, John Anderson, Greg Deierlein, Jorge Crempien, Ralph Archuleta, Kevin Milner, Jamie Steidl, Matt Gerstenberger, Farzin Zareian. Monica Kohler, Max Werner, David Wald, Luis Dalguer, Mark Stirling, Keith Porter, Hong-Kie Thio, Ting Lin, and Heidi Tremayne.

- **StatSeis 10, Wellington, New Zealand, February 2017.** SCEC participating scientists include David Jackson, Tom Jordan, David Rhoades, Annemarie Christopherson, Ned Field, Jeanne Hardebeck, Bill Ellsworth, Xiaowei Chen, Bruce Shaw, Morgan Page, Zhigang Peng, Xiaofeng Meng, Martin Mai, Mark Stirling, Warner Marzocchi, Matt Gerstenberger, Yan Kagan, Danijel Schorlemmer, Ruth Harris, and Margaret Boettcher.

- **GADRI Summit, Kyoto, Japan, March 2017.** Mark Benthien and Michelle Wood of CSU-F represented SCEC at the 3rd Global Summit of Research Institutes for Disaster Risk Reduction.
PSHA Meeting, Lenzburg, Switzerland, September 2017. Tom Jordan, Norm Abrahamson, Luis Dalguer, Ned Field, Matt Gerstenberger, David Jackson, Martin Mai, Warner Marzocchi, Danijel Schorlemmer, and Stefan Wiemer represented SCEC at this meeting.

- **Korea Institute of Geosciences, October 2017.** Christine Goulet visited the KIG to discuss SCEC research in ground motions.

- **Probabilities of Earthquake Under Wellington, New Zealand, November 2017.** John Vidale, Heidi Houston, and Bruce Shaw were on the review panel for this meeting.

- **Child-Centered Disaster Risk Reduction and Comprehensive School Safety, Chengdu, China, November 2017.** Mark Benthien represented SCEC at this meeting at the invitation of Save the Children International. He gave a presentation on the SCEC CEOP program.

- **International Travel by PI and SCEC Scientists.** The PI and other SCEC scientists participated in many international meetings and workshops during the report year. The former PI presented SCEC research at INGV in Rome in May 2017 and November 2017

3. Research Accomplishments

Aftershocks, stress triggering, and induced seismicity all highlight ways in which seismic hazard varies with time. This time-dependence motivated the SCEC4 research program of, “tracking earthquake cascades – understanding how seismic hazards change across all time scales of scientific and societal interest” (Figure 3.1). The SCEC4 science plan resolved the challenges of tracking earthquake cascades into six fundamental problems of earthquake physics (Box 3.1). We use this interdisciplinary framework to present the SCEC4 research accomplishments.

Box 3.1 Fundamental Problems of Earthquake Science

1. Stress transfer from plate motion to crustal faults: long-term fault slip rates
2. Stress-modulated fault interactions and earthquake clustering: evaluation of mechanisms
3. Evolution of fault resistance during seismic slip: scale-appropriate laws for rupture modeling
4. Structure and evolution of fault zones and systems: relation to earthquake physics
5. Causes and effects of transient deformations: slow slip events and tectonic tremor
6. Seismic wave generation and scattering: prediction of strong ground motion

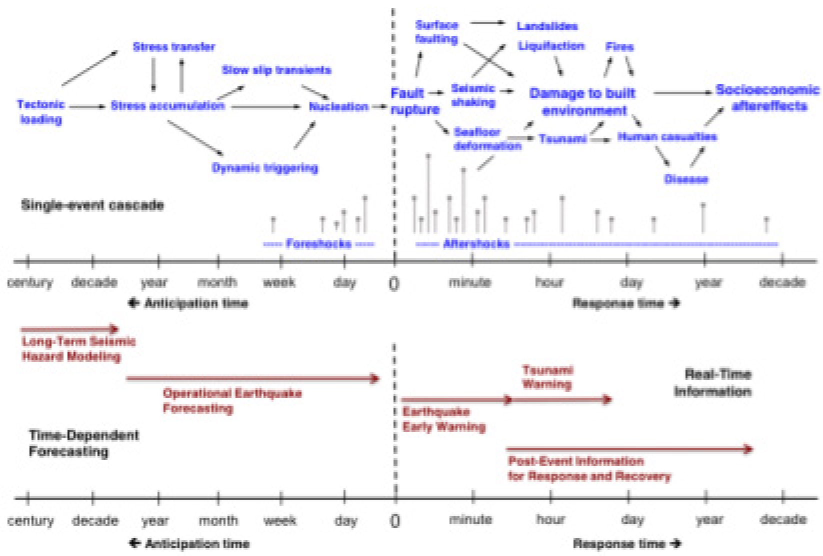


Figure 3.1. Earthquake processes (in blue) cascade through the natural and built environments, depicted here for a damaging event on a nonlinear timeline. Red arrows indicate the time scales for long-term seismic hazard modeling, operational earthquake forecasting, earthquake early warning, tsunami warning and post-event response and recovery. SCEC has advanced the basic science that underlies these technologies, which is helping to reduce seismic risk and improve resilience. From the SCEC4 proposal.

1. Stress transfer from plate motion to crustal faults

The potential strain energy released in earthquakes accumulates steadily because faults are frictionally locked between earthquakes while plate motion continues. This energy is released as kinetic energy expressed in earthquake activity that is spatially complex and temporally variable. SCEC4 merged previous efforts that focused separately on crustal deformation modeling of geodetic data and lithospheric architecture and dynamics into the single interdisciplinary focus group, Stress and Deformation Over Time (SDOT), which develops and applies system-wide lithospheric deformation models to develop a better understanding of crustal deformation, the forces loading the lithosphere, rheology, structural heterogeneity, and the distribution of stress.

Stress and Deformation Over Time (SDOT)

As a part of the UCERF3 effort, SCEC researchers developed a suite of kinematic deformation models for California from GPS measurements of horizontal velocities and geologic estimates of fault slip rates [Field et al., 2014; Field et al., 2015]. These models refine our understanding of the distribution of fault slip rates and are the culmination of decades of research into using geodetic data to constrain earthquake potential. This effort led to the surprising result that as much as 20-30% of the total permanent deformation in southern California may be distributed through the crust, rather than localized on mapped active faults.

UCERF3 deformation models provide the highest-resolution representation of California crustal deformation to date. The challenge for SCEC is how we move beyond kinematic models towards internally consistent physics-based models of the plate boundary. These include finite-element models of a lithosphere cut by faults, allowing plastic deformation, and driven from the sides by far-field plate motion [Bird, 2014; Hearn, 2015]. Lithospheric deformation and stress are controlled by friction and elasticity at low temperature and by viscous creep at high temperature. Their predicted stress field agrees well with the inferred principal stress directions from focal mechanism inversions in the SCEC Community Stress Model (CSM).

Understanding deformation over time and how plate-boundary faults are loaded requires an improved understanding of the rheology of the lithosphere and the transfer of stress between the elastic upper crust and the flowing lower crust and mantle. Numerical models of earthquake cycles on a strike-slip fault that incorporate laboratory-derived power-law rheologies with Arrhenius temperature dependence, viscous dissipation, conductive heat transfer, and far-field loading predict that deformation in the lower crust localizes in ~5 km-wide shear zones that broaden to ~15-20 km in the upper mantle [Takeuchi and Fialko, 2012]. The surface velocity field is relatively steady for much of the earthquake cycle, but has rapid postseismic deformation for 10-20 years following large earthquakes. The models are broadly consistent with geodetic data and heat flow constraints across the central San Andreas. Future refinement will require better constraints on the depth distribution and temporal evolution of grain-size and rock fabric during shear zone evolution. Developing a comprehensive stress evolution model that takes into account known earthquake history both historical and from the geologic record, is an important target of SCEC research (Figure 3.2).

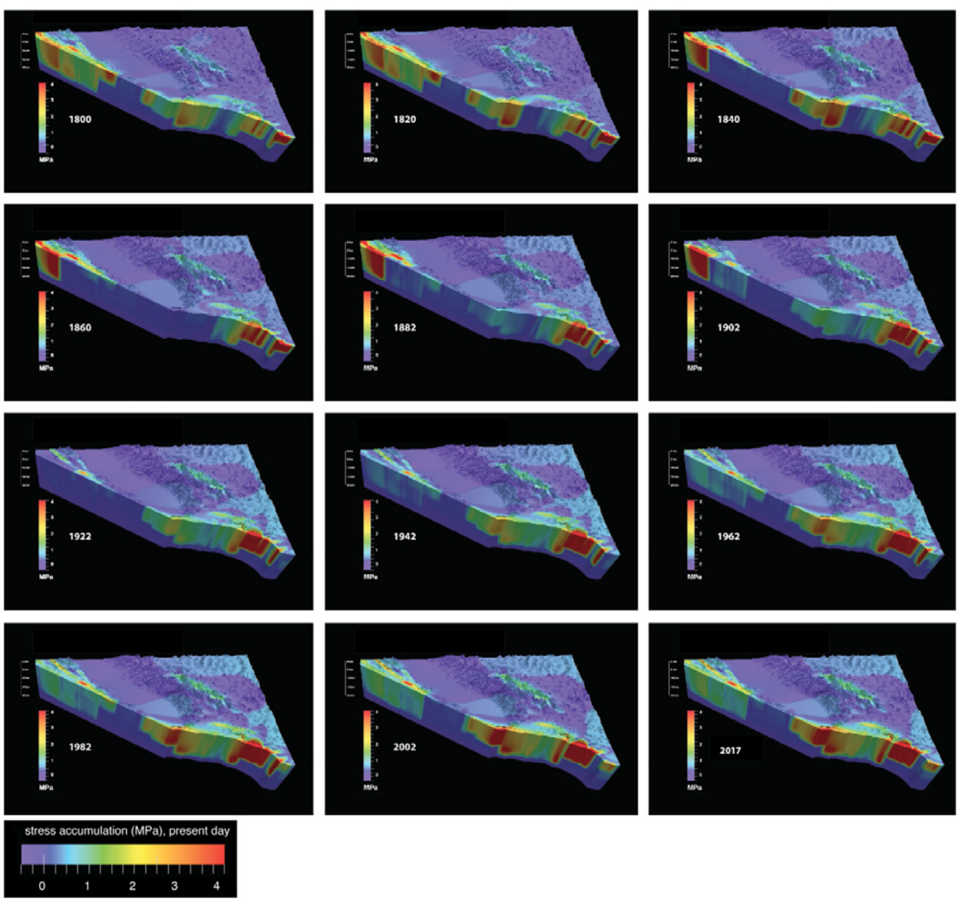


Figure 3.2. From Smith-Konter et al. (2017), sliced view of present-day (2017) Coulomb stress accumulation model of the San Andreas Fault System based on interseismic stress accumulation rates and stress changes from 112 historical and pre-historical earthquake ruptures. Stress variations with depth are due to transitions in along-strike locking depth.

Community Geodetic Model

The need for improved spatial and temporal resolution of crustal deformation motivated development of a SCEC Community Geodetic Model (CGM) that combines data from continuous and campaign GPS data (Figure 3.3) with Interferometric Synthetic Aperture Radar (InSAR) for Southern California. The CGM has been designed to be time-dependent, and it incorporates InSAR data to constrain the vertical deformation field and resolve small-scale regional deformations. It supports SCEC studies of earthquake physics and new methods for detecting time-dependent deformations [Amos et al., 2014; Borsa et al., 2014]. The CGM uses GPS, InSAR, and combined time series to estimate secular deformation rates and to identify time-dependent processes, such as those from recent earthquakes. To develop the CGM, SCEC compiled and reprocessed campaign GPS data into a self-consistent position time series (Figure 3.3). This required identifying discrepancies among continuous GPS solutions provided by different processing centers, assessing time-dependent noise, and developing a strategy for merging solutions. A parallel effort reduced errors (Figure 3.4) and reconciled InSAR time series analyses developed using different processing methods [Liu and Shen, 2015; Marinkovic and Larsen, 2013]. Version 1.0 of the CGM was released in Fall, 2016 and is available at (http://topex.ucsd.edu/CGM/CGM_html/). Ongoing development will include additional campaign GPS results, increasing InSAR line of site measurements, and be hosted at SCEC (http://topex.ucsd.edu/CGM/CGM_html/). We achieved the milestone of developing consensus GPS time series from multiple research groups [Herring and Floyd, 2017].

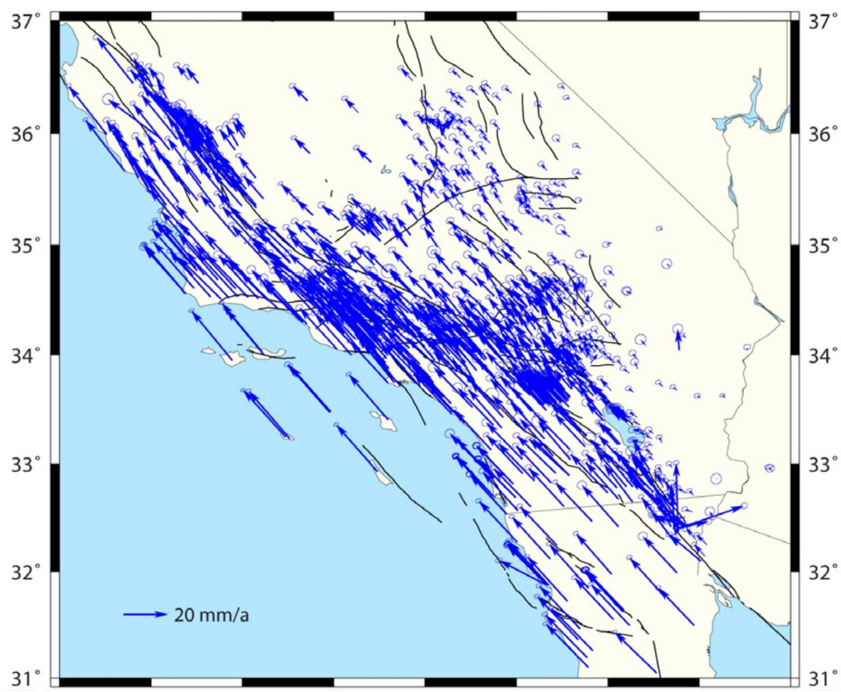


Figure 3.3. From Shen et al. (2016) showing velocities, determined from campaign GPS sites, with respect to stable North America. Error ellipses represent 95% confidence.

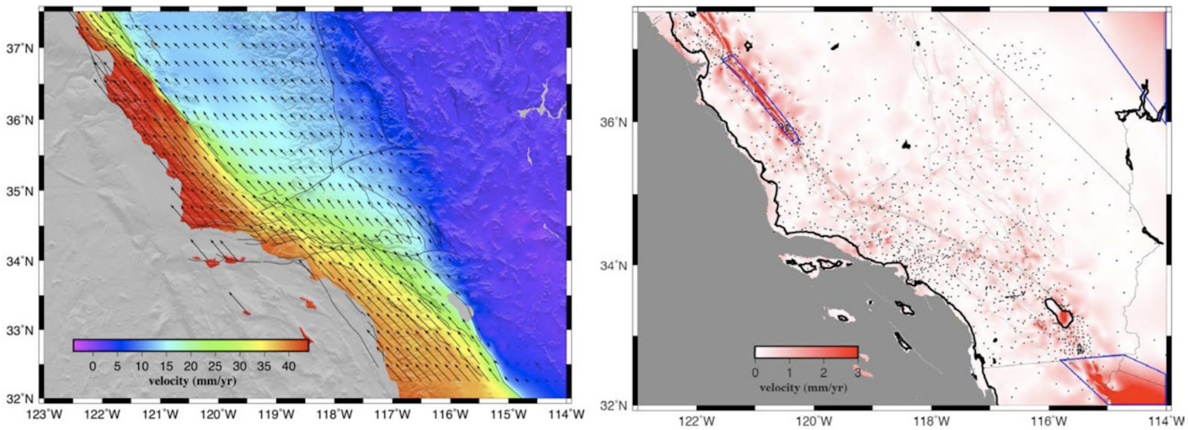


Figure 3.4 (left) Mean velocity is the average of 10 models. Colors show velocity magnitude and arrows show direction. (right) Standard deviation of the CGM velocity. Note the deviations are small in the locations of the GPS constraints, especially in areas where the velocity model is smooth. The blue lines outline areas of higher standard deviation.

The boundary between geodesy and precision topography is blurring. LiDAR has revolutionized the measurement of fine-scale faulting and earthquake deformation features as expressed by topography. Extracting new information from such measurements has been an active research area in SCEC4 [Nissen et al., 2012; Glennie et al., 2014; Donnellan et al., 2015; Zielke et al., 2015] and has led directly to important new insights into fault system behavior. It is also an important part of response planning for future earthquakes. Topographic differencing for the El Mayor-Cucapah earthquake (Figure 3.5) [Oskin et al., 2012] and for crustal earthquakes in Japan [Nissen et al., 2014] documented strong variations in the continuity and expression of slip along faults in the uppermost crust. These results are complementary to InSAR, and have the potential to inform geodetic deformation models. SCEC hosted a series of workshops with tutorials to support wider application of the various approaches to image processing.

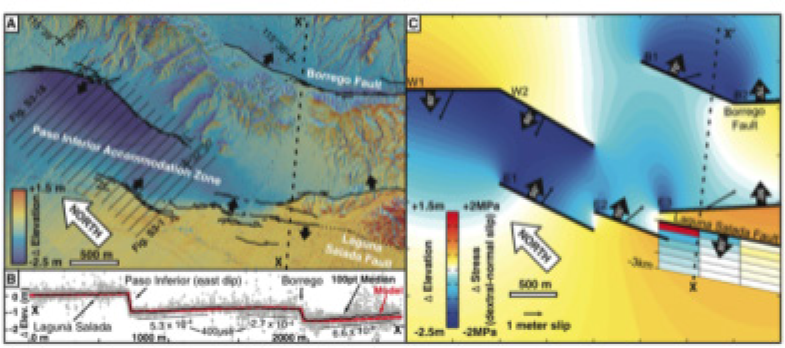


Figure 3.5. Differential LiDAR and elastic model for part of El Mayor-Cucapah rupture. (A) Elevation difference showing distributed deformation as slip steps from the NW Borrego Fault into the PIAZ. Arrows show dip direction. (B) Profile of elevation difference along line X-X' in (A). (C) Elastic model, using rectangular dislocations, showing vertical surface deformation due to imposed slip along the PIAZ fault array. Slip vectors point in the direction of hanging wall motion. Modeled slip vectors match field observations, except for faults E1 to E3, where slip is 30% above the observed values. Coulomb stress change for oblique slip along the Laguna Salada Fault is shown from the surface to 3-km depth. From Oskin et al. (2012).

Geochronology Infrastructure

Quantification of fault slip rates, and the date of past events through paleoseismology, depends on effective geochronology, for which SCEC has developed a coordinated approach. The geochronology infrastructure provides a community resource for SCEC researchers to draw from for dating using carbon-14, in-situ cosmogenic nuclides, and luminescence techniques. By pooling resources, the geochronology infrastructure program saves resources, increases flexibility, and allows investigators to adjust quickly to pursue new research opportunities. SCEC supports basic research on laboratory techniques, sample collection protocols, and comparison of multiple dating methods at field sites (Figure

3.6). The geochronology infrastructure has helped SCEC scientists lead the way in building well-constrained, long paleoseismic event chronologies to test earthquake models [Onderdonk et al., 2013; Rockwell et al., 2015; Scharer et al., 2014], has developed the pIR-IRSL technique for luminescence dating of feldspar to meet dating needs in arid regions [Roder et al., 2011; Rhodes, 2015], and advanced the application of multi-chronometer techniques to expand capabilities and reduce epistemic uncertainty in the timing of events and slip rates [Blisniuk et al., 2012; Blisniuk et al., 2013; Balco, 2014; DeVechio, 2013]. The geochronology program facilitates sharing of expertise among researchers/labs through interactions at the annual meeting and workshops, and provides opportunities for students to use world-class analytical facilities at participating labs. All SCEC geochronology infrastructure data is archived and openly available.

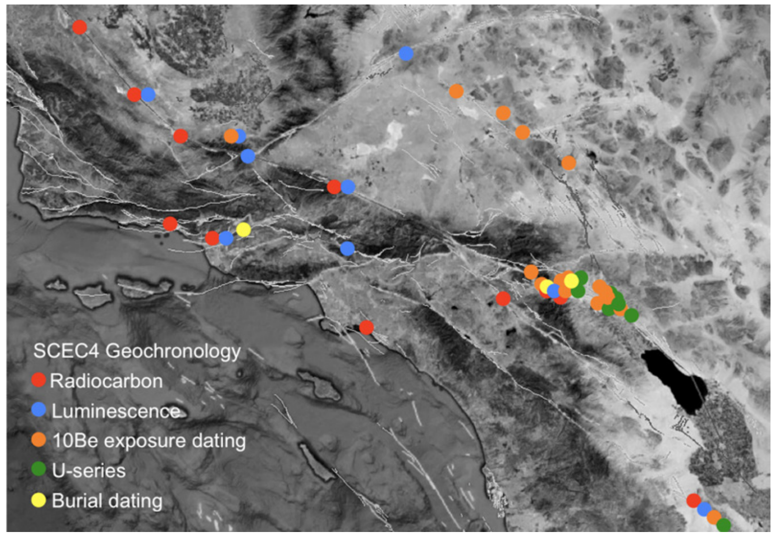


Figure 3.6. Map view of distribution of different geochronology approaches by study area under during SCEC4.

2. Stress-mediated fault interactions and earthquake clustering

Key to understanding earthquake cascades is understanding stress – both absolute stress levels, and the magnitude of stress changes – that influences the southern California fault system. Stress is a tensor quantity, and most measurements of it are only sensitive to some aspects of the total field. As a result, even the magnitude of stress in the Earth is poorly understood; however, the importance of stress in driving earthquake behavior and the need for better constraints on how faults are loaded motivated a SCEC collaboration to develop a community stress model (CSM). This effort is embedded in, and has proceeded collaboratively with, other SCEC initiatives such as SDOT and the CGM.

CSM products include a suite of models of the 4D stress and stressing-rate tensor in the California lithosphere. Community discussions and a series of four dedicated workshops led to a common CSM analysis framework and workflow. The CSM web site [SCEC Community Stress Model, 2015] hosts all of the models contributed by the community. These include four stress and five stressing-rate models that are available in a standardized, comprehensive format, and all models can be visualized and validated against available constraints in a consistent way. The CSM web page also provides plotting and validation scripts for user-driven reanalysis. Among the insights that arose from initial comparison efforts were that the stress state inferred from focal mechanisms shows a remarkable agreement among models, whereas other parameters, such as the absolute value of stress vary significantly and remain a research problem. The community advanced several candidate CSM models; a focal-mechanism based model (YHSM-2013) [SCEC Community Stress Model, 2015] was the first to be released. Future challenges for the CSM include the expansion of the range of data available, in particular expansion of the borehole database (in collaboration with industry), and the examination of absolute crustal stress levels within the context of a rheologically realistic lithosphere and asthenosphere model.

Improved earthquake catalogs – new detections [Meng et al., 2012], precise locations [Hauksson et al., 2012; Hauksson, 2017], and improved source parameters [Chen and Shearer, 2011; McGuire, 2017; Crempien and Archuleta, 2017] – are foundational to many SCEC activities. New techniques allow detection of far more earthquakes than in standard catalogs. This increased sensitivity reveals earthquake behaviors, such as the combined effects of dynamic triggering and static stress shadowing [Meng and Peng, 2014; Brodsky, 2017], that might otherwise not be apparent (Figure 3.7). In this case, the triggered earthquakes were all small, but in the 2010-2012 Canterbury NZ sequence, a M 6.3 aftershock directly beneath Christchurch destroyed the city center, killing 185 people. Subsequent aftershocks compounded the damage and hampered recovery efforts. SCEC partnered with the REAKT project and New Zealand's GNS Science to conduct within CSEP a retrospective evaluation of forecasting models. The Canterbury experiment showed for the first time, that the short-term performance of the physics-based models, which update forecasts with Coulomb stress changes, match and can even outperform models updated only with the conventional seismicity statistics [Werner et al., 2015; Williams et al., 2015; Cattania et al., 2017]. Induced seismicity is a form of triggered seismicity, and a growing concern. The stressing rate from geothermal energy development locally exceeds the tectonic stressing rate [Trugman et al., 2014], and hence has the potential to play an important role in earthquake triggering. Earthquake rates in the Salton Sea Geothermal Field, when interpreted in the context of an ETAS model, are correlated with the net extraction of fluid from the field [Brodsky and Lajoie, 2013].

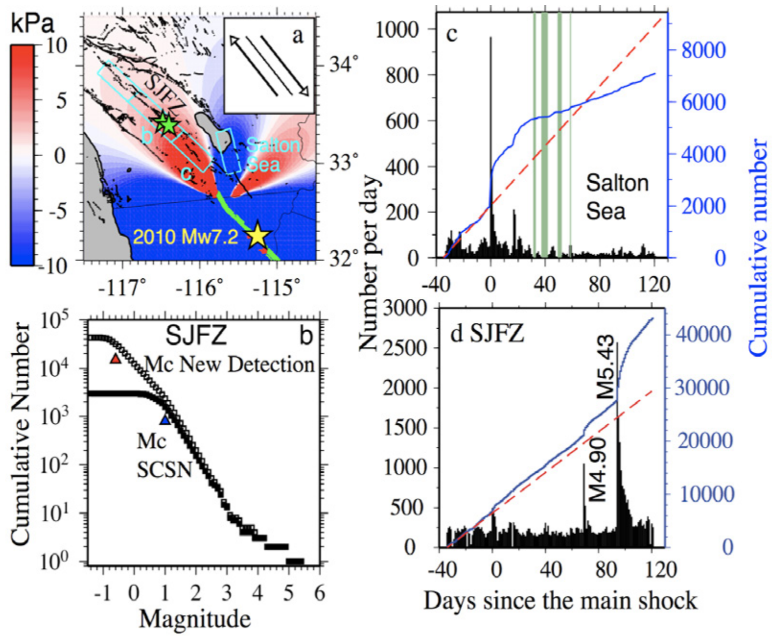


Figure 3.7. (After Meng and Peng [2014]) (a) Coulomb stress change following the 2010 Mw7.2 El Mayor Cucapah earthquake. (b) Frequency-magnitude statistics in the SJFZ. Open and black squares denote newly detected events and those in the original catalog. Triangles show magnitude of completeness Mc. There are over an order of magnitude more newly detected earthquakes. Seismicity rate changes show responses that depend on Coulomb stress change: (c) a short-time increase followed by long-term decrease for the Salton Trough (d) both short-term and long-term increase for the San Jacinto Fault.

UCERF3, developed during SCEC4, is the first complete earthquake forecast to include fault-based information when simulating the evolution of cascading earthquake sequences, and to include the possibility that large earthquakes may involve multiple faults. Several recent earthquakes have demonstrated both these phenomena. The UCERF3 model also addresses long-standing debates regarding the influence of stress relaxation and the relative frequency of small versus large earthquakes. UCERF3 is now under evaluation by the USGS as a prototype component of an operational earthquake forecasting system.

Development of long-term earthquake chronologies is an explicit SCEC4 goal. Outstanding examples are the Mystic Lake and Hog Lake sites on the San Jacinto Fault. These two 2000+ year records of earthquakes [Onderdonk et al., 2013; Onderdonk et al, 2015; Rockwell et al., 2015a; Rockwell et al., 2015b] lend support for the role of segmentation in earthquake rupture forecasting by showing that most events did not cross the Hemet step-over. Comparison with work on the San Andreas suggests that these faults could rupture in a single earthquake, raising complex scenarios where an earthquake starts on one fault then propagates onto the other [Lozos, 2016], although not in all events [Rockwell et al., 2015b].

Despite progress in constraining slip rates and earthquake chronologies, important inconsistencies remain, even for the San Andreas Fault. UCERF3 event rates on the southern SAF average about 25% less than the most reliable paleoseismic estimates [Field et al., 2014]. Similarly, prehistoric paleoseismic data do not resolve large variability seen in the recurrence during the 200 year historic period [Biasi et al., 2016]. Such discrepancies, and also those between geologic vs. geodetic slip rates on individual faults, point to possible inconsistencies in assumptions that we should strive to understand and resolve. Among the most prominent is that between geologic and geodetic slip-rate estimates for the Garlock Fault. High-resolution LiDAR, coupled with advances in OSL dating of feldspar, reveal strong temporal earthquake clustering on the Garlock Fault [Dolan et al., 2015; Dolan et al., 2016], which could explain the discrepancy. Similar clustering is found for the faults of the eastern California shear zone (ECSZ), although results from the Panamint Valley Fault [McAuliffe et al., 2013] suggest more complex behavior than simply alternation with the activity of the Garlock. Distributed off-fault deformation surrounding active faults is another potential contributor to this discrepancy [Dolan and Haravitch, 2014]. Modeling of the ECSZ [Herbert et al., 2014] suggests that substantial slip occurs as distributed deformation around fault tips within the Mojave block.

The Earthquake Simulator TAG focused on the comparison, validation, and verification of results from earthquake simulators that characterize interaction among earthquakes in a complex fault system through physics-based simulations. Because they have the potential to extend the ~100-year instrumental, several 100-year historical, and scant 1000-year paleoseismological records to 10,000-year and longer durations, simulators represent a promising pathway for physics-based earthquake forecasting. Results of this activity are documented in seven papers published in a special issue of SRL [Tullis et al., 2012]. These efforts indicate that it is not uncommon for 200-year periods of seismic activity to vary by a factor of 3 in seismic moment, which could help to explain differences in historical vs. geologically documented seismic activity.

3. Evolution of fault resistance during seismic slip

Processes that determine frictional resistance and its evolution during co-seismic slip are critical to understanding earthquake behavior because they determine how, when, and where ruptures initiate, propagate, and stop. The lack of heat-flow anomalies, principal stress directions and their rotations due to earthquake stress drops, the geometry of thrust-belt wedges, as well as recent measurements from rapid response drilling [Fulton et al., 2013] all point to effective friction during slip on mature, well-developed faults of less than 0.2, while quasi-static friction coefficients for most rock materials are 0.6-0.8. Understanding the origin of this difference is critical to understanding earthquake cascades.

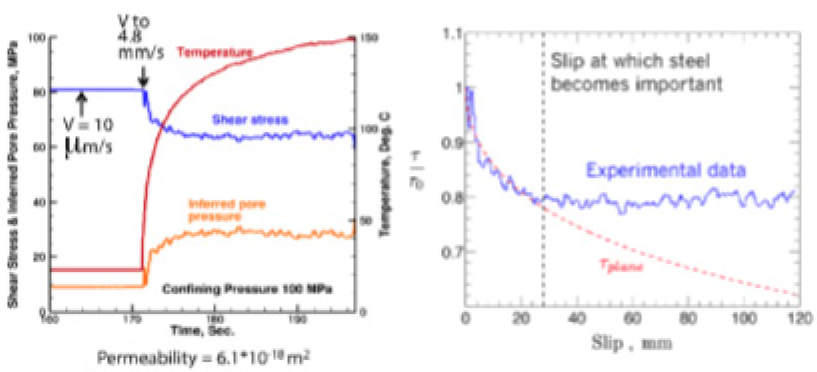


Figure 3.8. Reductions in strength and increase in pore pressure for experiment with a velocity step change, assuming changes of shear stress are due to changes in fluid pressure. Right panel shows experimentally measured stress decays as predicted, demonstrating thermal pressurization in the lab for the first time. Deviation from theory after ~28 mm is attributed to steel sample grip conducting heat and preventing temperature from rising as it would for a half-space. From Tullis & Goldsby (2013)

Dynamic weakening remains a focus. Platt et al. [Platt et al., 2014a; Platt et al., 2014b] found that thermal pressurization and decomposition provide multiple rupture modes. Slip pulses dominated by thermal decomposition have a distinctive slip rate profile, with peak slip rates near the trailing edge of the rupture. Simulations of the influence of flash heating and thermal pressurization on earthquake nucleation and rupture for faults with low background stress suggest that thermal pressurization is required to explain the observed relationship between fracture energy and slip [Schmitt et al., 2015]. New experiments have characterized the processes responsible for flash weakening in gouge [Proctor et al., 2014] and thermal pressurization (Figure 3.8) [Tullis and Goldsby, 2013] – the latter being documented in the lab for the first time. SCEC activities provided synergy between analysis of these data and the physical models for dynamic weakening, new insights into the physical processes responsible for dynamic weakening, and a rationale for their inclusion into earthquake cycle and rupture models. Further constraints on stress levels on natural faults may be enabled by newly developed fault slip thermometers that evaluate thermally induced changes in organic compounds within gouge [Savage et al., 2014] and reduction of iron (Fe^{3+} to Fe^{2+}) and associated conversion of hematite to magnetite on fault surfaces [Evans et al., 2014].

A strong theme that emerged in SCEC4 is how heterogeneous fault stress and fault geometry influence rupture propagation. SCEC scientists have done pioneering research on fault roughness [Sagy et al., 2007]. Studies of the effect of fault roughness on the frictional resistance of faults undergoing dynamic weakening, found that rough, immature faults operate at higher stress levels, while mature, smoother faults operate at lower stress levels [Fang and Dunham, 2013], as expected. New calculations indicate that supershear ruptures are more likely on rough faults [Bruhat et al., 2015], an effect contrary to expectations (Figure 3.9). Fault roughness was also found to influence the distribution of seismicity in laboratory experiments where the power-law exponent that describes the decay of acoustic emission with

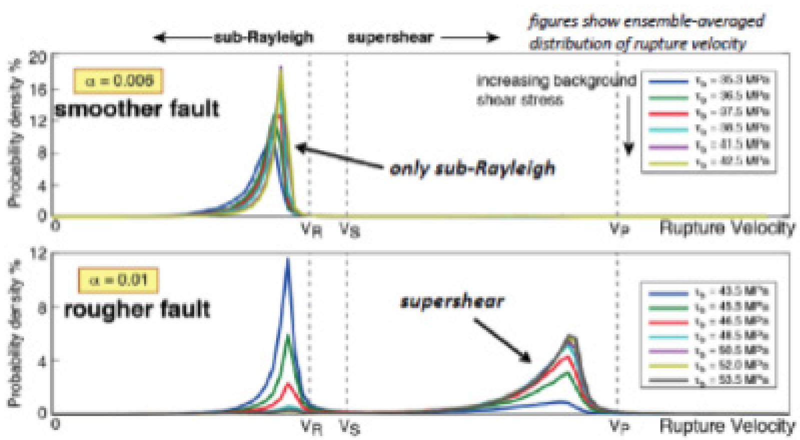


Figure 3.9. Rupture velocities from 1000 rupture simulations of smoother faults (upper) and rougher faults (lower) are shown as probability density functions. Supershear rupture is favored on rougher faults. From Bruhat et al. (2015).

distance from the slip surface depends on roughness as well as normal stress [Goebel et al., 2014]. New models also show the limitations of modeling multi-strand fault surfaces with a single fault surface [Shaw, 2015]. Introduction of complex fault geometry led to an increased appreciation for the importance of inelastic, “off-fault” deformation, which was studied in idealized scenarios [Kang and Duan, 2014] and in the field [Qiu et al, 2015]. Off-fault plasticity was found to be important not only to rupture dynamics, but also to crustal deformation modeling [Bird, 2014] and ground-motion prediction [Roten et al., 2014].

Understanding the base of the seismogenic zone is critical for evaluating the potential for large events. These properties have been studied by incorporating thermally activated power-law creep rheologies into earthquake cycle models [Takeuchi and Fialko, 2013]. The history of such ruptures may be identified by lack of microseismicity at the base of the seismogenic zone [Lapusta and Jiang, 2014; Jiang and Lapusta, 2014]. Recent developments in source inversion and imaging including advances in uncertainty quantification in finite source inversion, accounting for uncertainties in the crustal velocity model, and high-frequency back-projection rupture imaging allow us to rapidly extract robust information about large strike-slip earthquakes worldwide [Meng et al., 2014].

Computational Science

SCEC4 established a new disciplinary group in Computational Science to develop and apply state of the art computation to earthquake science problems. The Computational Science Disciplinary Group promotes the use of advanced numerical modeling techniques and high performance computing (HPC) to address the emerging needs of SCEC users and application community on HPC platforms.

Key advances in HPC during SCEC4 enabled new capabilities in modeling source physics – particularly geometric fault complexity as the origin of rupture variability that generates high-frequency radiation in earthquakes [Dunham et al., 2011; Shi and Day, 2013]. Dynamic rupture simulations, involving thousands of realizations of the stochastic fault geometry, helped quantify the range of stress levels at which earthquakes occur, with contributions to resistance coming from both friction and geometric complexity [Fang and Dunham, 2013]. Correlations between slip and rupture velocity fluctuations were linked to the fault geometry, offering new approaches to pseudo-dynamic rupture modeling [Trugman and Dunham, 2014]. The short spatial and temporal scales over which fault strength and slip rate vary near the rupture front motivated introduction of a refined mesh to track the rupture front and other sharp features like wavefronts. Both static and adaptive mesh refinement (AMR) were first applied to rupture dynamics problems during SCEC4 [Kozdon and Wilcox, 2015; Pelties et al., 2014; Kozdon and Dunham 2015], and show great promise for future modeling studies.

Additional advances enabled by HPC include the ability to model high-frequency ground motions and inelastic material response (Figure 3.10). Both scattering and intrinsic attenuation reduce seismic wave amplitudes. Fine-scale material heterogeneities, as spatially correlated random perturbations to existing velocity models, significantly alter simulated ground motions, particularly at high frequencies (>2 Hz) [Withers et al., 2015]. With scattering directly modeled, it became necessary to alter intrinsic attenuation used in simulations by making the quality factor Q dependent on both frequency and depth [Wang and Jordan, 2014; Withers et al., 2015]. User-driven validation studies [Taborda and Bielak, 2014; Scheitlin et al., 2013] are bringing predicted ground motions into closer agreement with observations. A major breakthrough in SCEC4 was the demonstration that inelastic material response, in both the near-fault and near-surface regions, can substantially decrease ground motions. Predicted ground motions from the 2008 M 7.8 ShakeOut earthquake scenario were reduced by up to 70% compared to the linear case [Roten et al., 2014].

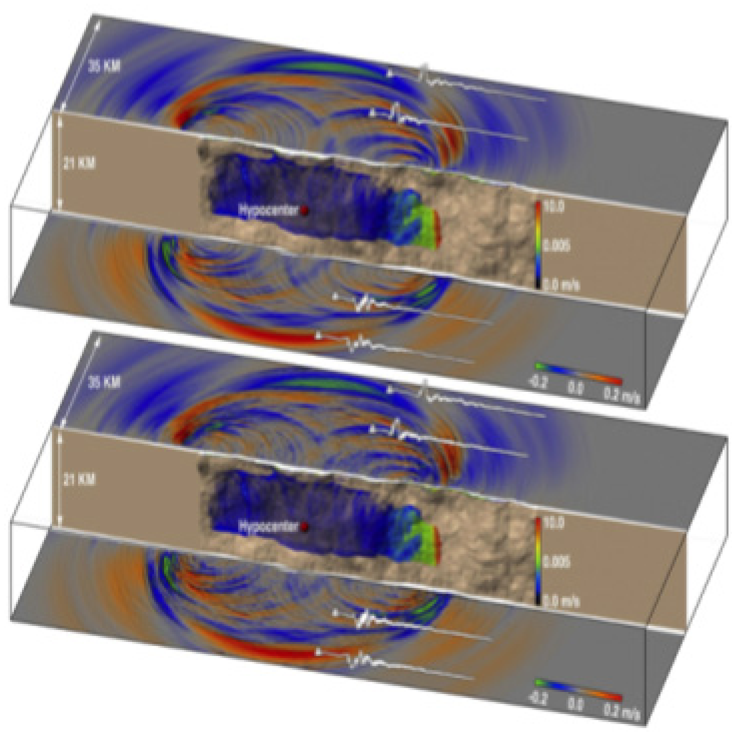


Figure 3.10. Snapshots of propagation of 10 Hz wavefield for a crustal model without (top) and with (bottom) small-scale heterogeneity. Fault complexities were included in the simulation. Strike-parallel seismograms are superimposed as white traces at selected sites. The parts of the crustal model located in front of the fault is lowered for a better view. Note strongly scattered wavefield in bottom snapshot due to small-scale heterogeneity. Simulation run by Cui et al. (2014) on Cray XK7 GPUs on Titan at ORNL and Blue Waters at NCSA. Visualization by A. Chourasia.

SCEC has integrated its CyberShake, Broadband, High-F, and

F3DT computational platforms into a software ecosystem for physics-based seismic hazard analysis [Lee et al., 2013; Isbiliroglu et al., 2015; Taborda and Bielak, 2013; Callaghan et al., 2013]. It has developed highly efficient codes that run efficiently on the largest GPU-enabled supercomputers [Cui et al., 2013; Zhou et al., 2013; Mu et al., 2013b; Mu et al., 2013a, Small et al., 2014; Cui et al., 2013]. Combined with workflow efficiencies gained through our collaborations with the National Center for Software Applications and the Oak Ridge Leadership Computing Facility, these HPC capabilities have made it possible to run CyberShake at seismic frequencies up to 1 Hz. This milestone takes CyberShake from the low-frequency simulations relevant to the design of tall buildings, dams, and bridges up to the edge of the 1-10 Hz frequency band of primary interest for most smaller structures. CyberShake site and path effects unexplained by the Next Generation Attenuation (NGA) models [Power et al., 2008] account for 40%–50% of total residual variance, suggesting that improvements to simulation-based hazard models could reduce the unexplained variability in current GMPEs by up to 25% [Wang and Jordan, 2014].

SCEC computational science involved collaborations with HPC stakeholders. Through a collaboration with Intel, we have developed new software with the potential of increasing the throughput of extreme scale seismic ensemble simulations by orders of 1.8x to 4.6x. In particular, we have diversified SCEC's simulation tools by supporting the development of a new code called EDGE, based on a discontinuous Galerkin approach. We optimized existing SCEC code based on the finite difference method to work on Intel Xeon Phi Knights Landing microarchitecture gaining speedups of the order of 1.6x - achieving levels of performance efficiency comparable to other versions of SCEC simulation codes for forward wave propagation simulation running on NVIDIA GPU systems.

4. Structure and evolution of fault zones and systems

Plate-boundary fault systems are geometrically complex, even though they may be organized around a master fault that takes up most of the plate motion. A major problem in earthquake physics is how rupture is influenced by geometrical complexity. The ability of ruptures to navigate geometrically complex fault systems is documented for some large earthquakes [Tchalenko and Berberian, 1975; Wesnousky, 2006; Biasi et al., 2013], and increasingly realistic numerical simulations are illuminating the conditions under which this can occur [Lozos et al., 2011; Lozos et al., 2012; Lozos et al., 2014; O'Reilly et al., 2015; [Duru and Dunham, 2015]. Simulations over multiple cycles result in stress buildup at geometrical heterogeneities, which will impact the rupture. To develop a better understanding of the interplay of earthquake physics with fault complexity, the SCEC4 collaboration established two Special Fault Study Areas (SFSAs), which are both scientifically rich targets that are the focus of integrated multi-disciplinary research teams that carry out a coordinated research agenda.

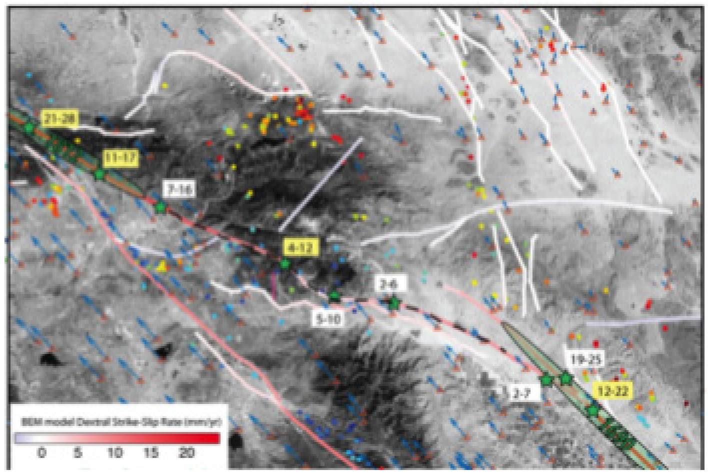


Figure 3.11. Boxes show dextral slip rates from geologic studies (stars) along the San Andreas through the San Gorgonio Pass (SGP) Special Fault Study Area. White boxes are data obtained in SCEC4. Green ellipses with year show extent of known surface rupture during most recent, large San Andreas Fault events. Extent of most recent earthquake in SGP likely involved the entire southern San Andreas. Blue/red lines show dextral slip rates from crustal deformation BEM. Dashed segments were used in dynamic simulations. Triangles show GPS stations CMM4 velocity arrows in blue. Circles show seismicity M>3 since 2000 with cooler colors indicating greater depth.

San Gorgonio Pass Special Fault Study Area

The largest discontinuity along the San Andreas Fault occurs in the San Gorgonio Pass (SGP) where active strands form a distributed zone of faulting [Yule, 2009], in contrast to regions outside of the SGP, where deformation is restricted to a single active strand (Figure 3.11). Forecasting earthquake hazards in this complex region requires addressing three fundamental questions: 1) What is the subsurface geometry of active faulting through the SGP? 2) What is the earthquake potential in the SGP region? 3) What is the probability of a through-going San Andreas rupture? The SGP SFSA took a multi-disciplinary approach to address these questions. The emerging view is that the complex structure of SGP typically arrests ruptures, yet occasional events rupture all the way through as very large earthquakes.

Through an array of field studies [Gold et al., 2015; Blisniuk et al., 2013; Morelan et al., 2014; Kendrick et al., 2015; Scharer et al., 2014], microseismicity [Nicholson, 2014], geodetic inversions for slip rate [McGill et al., 2015] and crustal deformation models [Cooke, 2014], we improved our understanding of slip partitioning through the SGP fault system. Field studies added key strike-slip rates, that filled gaps within previous coverage (Figure 3.11) [Gold et al., 2015; Blisniuk et al., 2013; Scharer et al, 2014]. Dynamic rupture models in realistic fault geometry [Shi and Day, 2014] demonstrated that the rupture through the SGP is sensitive to initial stress levels as well as fault geometry, and microseismicity shows a systematic change in stress drop north and south of the SGP thrust [Goebel et al., 2014]. The question of through-going rupture potential has also been addressed through deep trenches that show that the last event to rupture through the SGP may have been ~1400 AD [Yule et al., 2014]. This is consistent with strain accumulation [McGill et al., 2015], measured strike-slip rates [McGill et al., 2013] and modeled strike-slip rates [Herbert and Cooke, 2012] within the SGP.

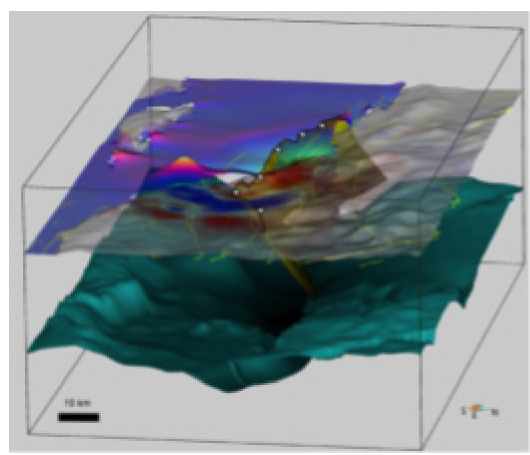


Figure 3.12. Perspective view of the Ventura-Pitas Point-Southern San Cayetano Fault system, showing ground motion and tsunami simulations for M7.8 scenario. Vertical component of velocity (red to blue) at time step 27s is shown onshore; vertically exaggerated water elevation at time step 200 min shown offshore. Qfault traces are yellow. Lower image includes perspective view of the top basement horizon from the SCEC USR, highlighting co-location of the Ventura basin and the source fault. Graphic by A. Plesch.

Ventura Special Fault Study Area

The Ventura SFSA (Figure 3.12) was established to promote interdisciplinary investigations of the prospects for large, multi-segment thrust fault ruptures in southern California, and to address the hazards posed by these potentially devastating events. Several recent earthquakes (1999 M7.6 Chi-Chi, Taiwan; 2005 M7.6 Kashmir, Pakistan; and 2008 M7.8 Wenchuan, China) demonstrate the potential for thrust fault ruptures to breach segment boundaries and involve multiple, stacked fault splays. Prior to UCERF3, these large, multi-segment events were generally not considered in seismic hazard assessments. Larger events may pose great risks due to the intensity, duration, and potential for offshore thrust faulting to trigger tsunamis. Results from the Ventura SFSA support the notion of infrequent, but extremely large earthquakes on this fault system.

The Ventura Fault and overlying Ventura Avenue anticline [Rockwell et al., 1988] occupy a unique position at the juncture of several of the largest and fastest slipping faults in the Transverse Ranges (e.g., San Cayetano and Red Mountain Faults). Holocene terraces on the anticline suggest that it deforms in discrete 5-10 m uplift events, with the latest occurring ~900 years ago [Rockwell, 2011; McAuliffe et al., 2015]. The magnitude of these uplifts implies rupture of adjacent faults, yielding large (M 7.5 to 8), multi-segment earthquakes. The SFSA effort integrated geology, paleoseismology, exploration geophysics, seismology, geodesy, rupture dynamics, strong ground-motion simulations, and tsunami studies [Thio et al., 2014; Ryan et al., 2014].

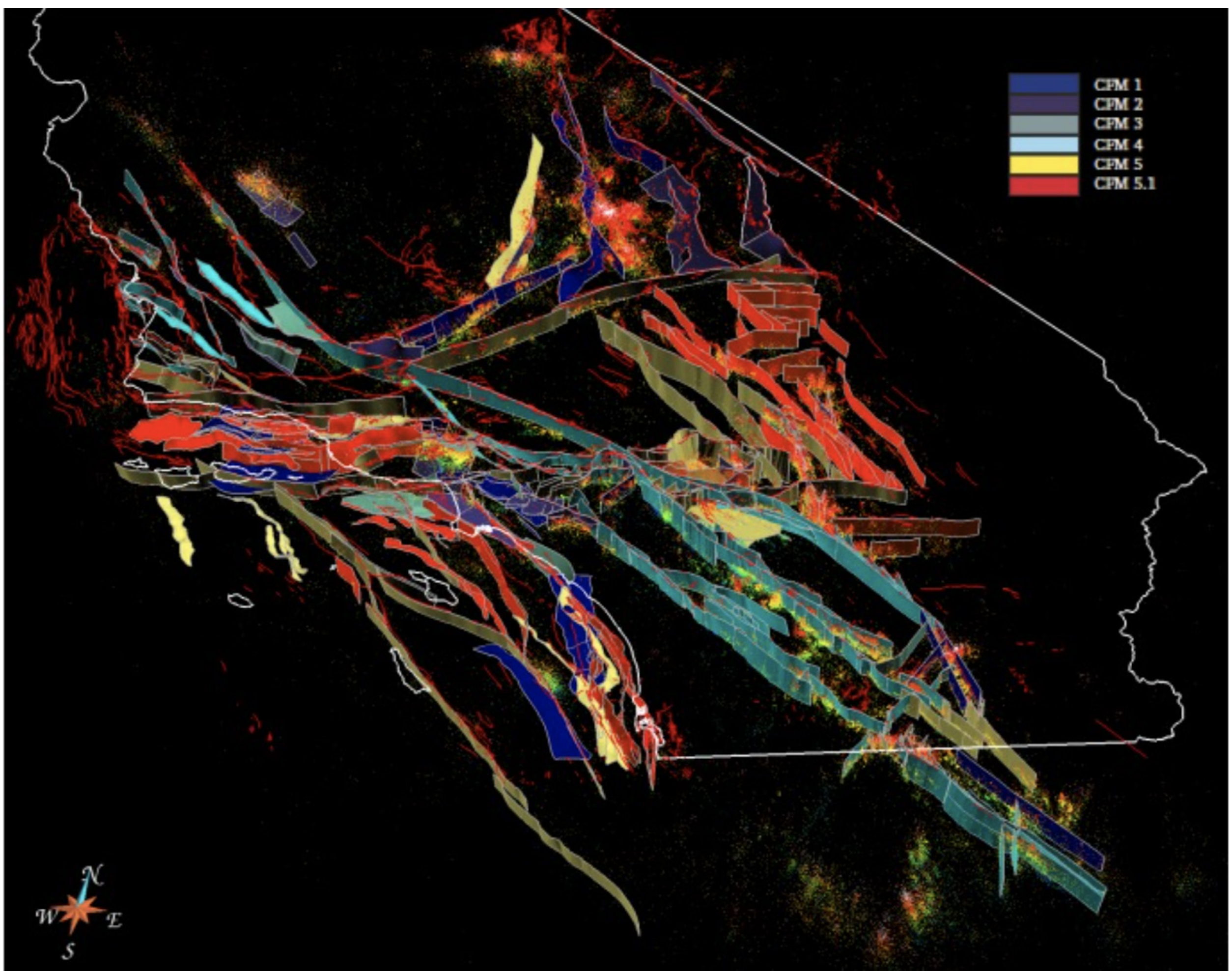


Figure 3.13. Perspective view showing development history of the CFM. Color depicts when the current fault presentation was added or improved during development of the CFM. All phases of development from CFM1 to CFM5.1 can be identified in the current model. 1981-2011 hypocenter locations by Egill Hauksson.

An initial focus of the SFSA was to understand the structures in this system using seismic reflection data and well control [Hubbard et al., 2014]. The Ventura, Pitas Point, San Cayetano, and Red Mountain Faults are likely connected along strike at seismogenic depths, despite >10-km offsets of their surface traces [Sarna-Wojcicki et al., 1976; Sarna-Wojcicki and Yerkes, 1982; [Yerkes and Lee, 1987; Yerkes et al., 1987; Huftile and Yeats, 1995; Kamerling and Sorlien, 1999; Kamerling et al., 2003]. Excavations across the fold scarp above the blind Ventura Fault, reveal at least two large (4.5 to 6 m uplift), Holocene earthquakes [McAuliffe et al., 2013; McAuliffe et al., 2015]. These events correlate with marine terrace uplift at the coast [Rockwell, 2011]. Studies of the offshore extent of the fault system document Holocene seafloor folding [Ucarkus et al., 2013]. Geodetic observations and fault system modeling constrain the rapid shortening (2.7 to 8 mm/year) and uplift (> 2 mm/yr) rates across the structure [Marshall et al., 2014; Johnson et al., 2014; Hammond et al., 2014]. Together, these observations all support the occurrence of very large multi-segment thrust fault earthquakes on this fault system, as illustrated in the M7.8 scenario of Figure 3.12.

Community Fault Model

The SCEC Community Fault Model (CFM 5.0) includes several major improvements (Figure 3.13). Among these are refinement of fault geometries using the USGS Qfault traces and relocated seismicity [Hauksson et al., 2012]. CFM 5.0 provides improved representations in the Santa Maria and Ventura Basins, Santa Barbara Channel, Inner Borderlands, E Transverse Ranges, Peninsular Ranges, San Gorgonio Pass, and the Mojave Desert. Fault representations are precise, and often more segmented than in previous models, and there are now simplified, meshed representations intended to aid modeling studies.

5. Causes and effects of transient deformations

The 21st century has seen the discovery of a new mode of fault motion: episodic tremor and slow slip. Although primarily observed in subduction zones, it has also been reported in continental settings, including the San Andreas Fault. Triggered tremor driven by dynamic stresses in the long period wavetrain of large earthquakes has been observed widely in California [Gomberg et al., 2008]. A continuing goal of SCEC has been to document the occurrence of tectonic tremor in Southern California, and to search systematically for possibly related aseismic deformation transients.

Between 2001 and 2011, only the M_w 7.8 Denali earthquake triggered tremor on the San Jacinto Fault, even though closer earthquakes, such as the 2009 Gulf of California event, resulted in larger dynamic

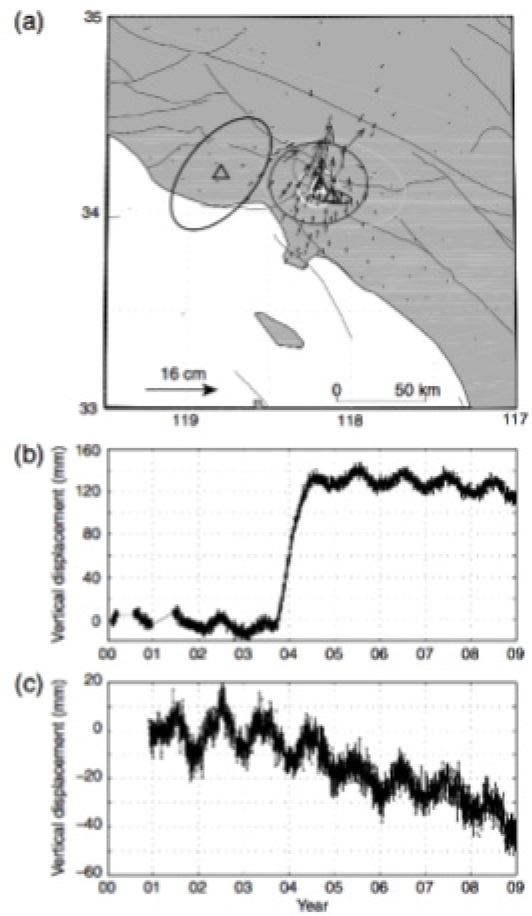


Figure 3.14. Phase IIA of the transient detection exercise showing (a) Predicted horizontal deformation during the simulated transient (vectors). Triangles and ellipses indicate location and deforming region found by the detectors. (b) Vertical displacement history at station with maximum displacement, showing the large signal (detectable by eye). (c) Vertical displacement for a more subtle case that resulted in no detections. From Lohman and Murray (2013).

stresses [Wang et al., 2013]. No tremor has been discerned on the San Andreas south of Cholame. The continuing effort to find tremor has driven development of new, computationally efficient approaches to detect isolated low frequency earthquakes [Yoon et al., 2015] that is sensing wider application to improving catalogs. Another new approach to detect precursors applied to 10,000 southern California earthquakes yielded only a handful of newly recognized foreshocks [Hawthorne and Ampuero, 2014]. A search for transients by combining ETAS and rate-state models of seismicity, on the other hand, detected a large transient in the Salton Trough – also seen with geodetic data – and an anomaly associated with the 2009 Bombay Beach swarm, suggesting it may have been accompanied by aseismic deformation [Llenos and McGuire, 2011]. Systematic analysis of foreshock sequences suggest a role for aseismic forcing [Chen and Shearer, 2013], and perhaps fluid diffusion [Chen et al., 2012]. The Aseismic Transient Detection TAG developed systematic searches for aseismic transients. The effort began with a community blind-test exercise to detect transient signals in synthetic data (Figure 3.14) [Lohman and Murray, 2013]. A subset of the detection algorithms are now systematically mining GPS data in Southern California for deformation transients.

6. Seismic wave generation and scattering

SCEC continues to champion the use of numerical simulations in seismic hazard analysis. Simulations incorporate the best available geoscientific understanding of faulting and wave propagation – including the effects of directivity, basin response, small-scale structure, topography, and nonlinearity. There has been a strong trend in SCEC4 to validate simulations against data. Much of this effort has been led by engineering seismologists and engineers, who recognize the potential of SCEC's efforts in physics-based ground-motion prediction [Crouse, 2012].

Community Velocity Models and Unified Structural Representation

SCEC has pursued the systematic integration of seismological and geological information into a unified structural representation [Shaw et al., 2015]. A new USR was recently released for the San Joaquin Basin, which incorporates tens of thousands of well-log measurements, seismic reflection, and geologic constraints. This model will be embedded into future versions of the CVMs.

During SCEC4, the CVMs were improved using the techniques of full three-dimensional waveform tomography (F3DT) [Tape et al., 2010; Lee et al., 2013, Shaw et al., 2015]. This required improving computational capabilities and workflows [Small et al., 2015; Cui et al., 2013a,b] and incorporating ambient-field data, which provide strong sensitivity to the shallow Earth structure that governs strong ground motion [Lee et al., 2013] The basin structures in Figure 3.15 come from CVM-S4.26, which assimilated more than a half-million misfit measurements from 38,000 earthquake seismograms and

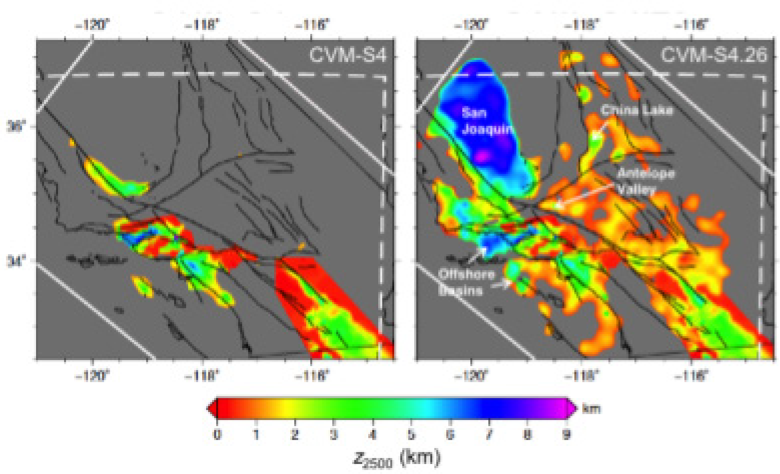


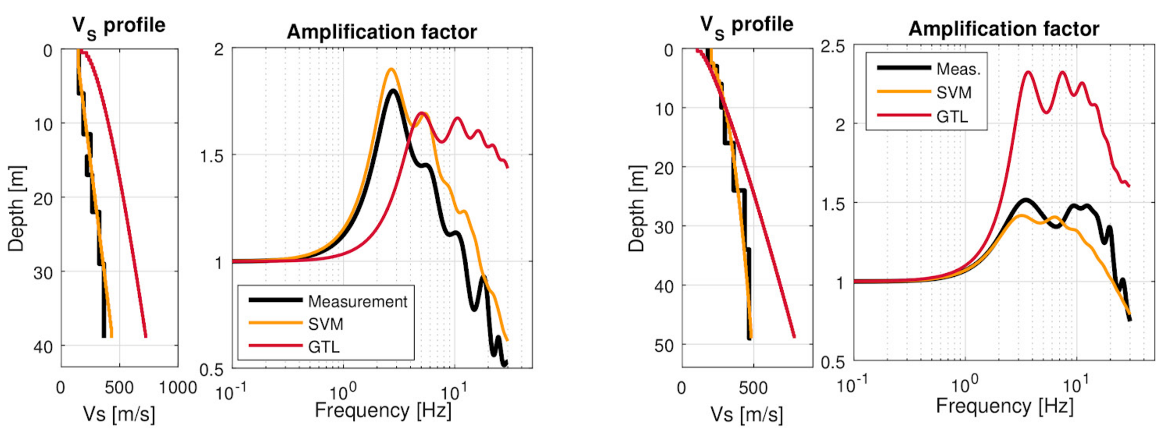
Figure 3.15. Maps of Southern California showing improvements in basin structure obtained by full-3D tomography (F3DT). Colors represent z_{2500} (iso-velocity surface at v_s = 2.5 km/s), a common measure of basin depth. Left panel is z_{2500} for the SCEC Velocity Model, CVM-S4, which was used as the starting model. Right panel is z_{2500} for CVM-S4.26, the 26th iteration of a dataset comprising over half a million waveform measurements from earthquake seismograms and ambient-field correlagrams. Basin structures from the CVM-S4.26 are consistent with seismic reflection and refraction data. From Lee et al. (2014)

12,000 ambient-noise correlograms [Lee and Chen, 2013]. This high-resolution tomography provides insight into the crustal structure and has improved earthquake ground motion simulations, including the latest CyberShake model (Figure 3.20). SCEC is working to quantify the predictive value of the new CVMs.

Additional innovations include incorporating anisotropy, attenuation, and small-scale heterogeneity [Olsen, 2014], which are needed to push simulations to higher frequencies. Moreover, we developed a velocity model for the Los Angeles basin sediments (Sediment Velocity Model, or SVM), intended to replace the CVM-S4.26 velocity structure at depths less than z_{1000} to account for shallow basin amplification and nonlinear effects on high frequencies. SVM is designed to translate Vs30, the only proxy available to describe soil stiffness in CVM, into a 3D stochastic velocity structure at resolution suitable for high-frequency physics-based ground motion simulations. SVM is based on the statistics of nearly a thousand measured velocity profiles in Southern California, aggregated from a variety of open and proprietary sources. Pending validation by comparison of 3D wave propagation simulations with recordings of historic events, we are working to integrate SVM (Figure 3.16) in UCVM as well as in the BBP, to account for site amplification in the time domain [Shi and Asimaki, 2017].

High-Frequency Simulations

SCEC is pushing ground motion predictions to higher frequencies (f > 1 Hz). Accurate simulations require new levels of knowledge about fault complexity and crustal structure, and the computational demands are substantial. Characterizing the source at high resolution and modeling wave propagation at short wavelengths is a dual challenge. High-frequency ground motion simulations are currently done using kinematic source models with stochastic variability (Figure 3.10), crustal velocity models with short-wavelength components constrained by limited observations (Figure 3.15), and scattering operators to represent unmodeled structure.



(a) Site No.937 (b) CE.12108

Figure 3.16. Predicted versus measured VS profiles; predicted versus true amplification functions. SVM offers a better prediction than GTL for both sites (from Asimaki, 2017).

The kinematic/stochastic source can be tuned to agree with empirical ground motion metrics but this leads to high-variance predictions (because we lack a physical basis to constrain parameters and correlations) and provides an inadequate basis for scaling to large earthquakes. Scattering formulations depend on assumptions about the scattering process, e.g., whether coda is due to trapping within layers or scattering from heterogeneities; whether Q is frequency dependent; whether scattering is anisotropic and/or concentrated near the surface, and where single- vs. multiple-scattering dominates. Small-scale heterogeneity from analysis of sonic logs and Vs30 measurements in the Los Angeles Basin indicate a von Kármán heterogeneity spectrum. When these heterogeneities are added to the SCEC CVM-S ground motion intensities for 0-2.5 Hz waves are amplified/de-amplified by up to a factor of two. The results also suggest a trade-off between Q and the strength of heterogeneity. SCEC4 implemented new research initiatives at the engineering interface, which broadened the impact of SCEC's work and provided an important feedback loop for focused refinement of scientific models. Three examples of these activities are: i) the development and validation of the Broadband Platform for ground motion simulation, ii) the Ground Motion Simulation Validation Technical Activity Group, and iii) the Committee for Utilization of Ground Motion Simulations.

Broadband Platform and Collaboration with PEER

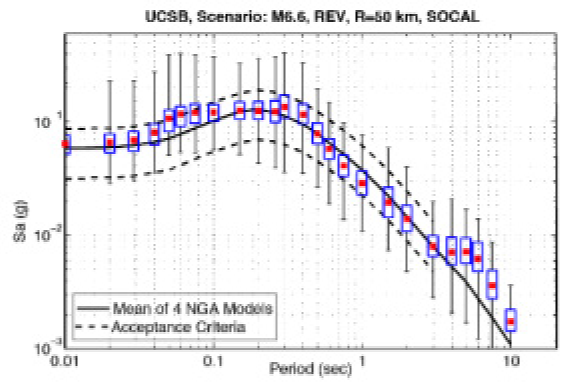


Figure 3.17. Broadband Platform validation results. Prediction of UCSB method for mean acceleration response spectrum derived from four GMPE's for NGA West. The mean is based on the ground motion at 30 stations and 50 scenario MV 6.6 earthquakes on a reverse fault. All stations were within 50 km of the fault. From Dreger et al. (2015)

SCEC4 developed the Broadband Platform (BBP) to simulate ground motion from finite faults for frequencies up to 100 Hz using different methods. An issue of Seismological Research Letters [Dreger and Jordan, 2015] includes nine papers describing the motivation for the BBP, validation, computational aspects and basic science underlying the different methods [Goulet et al., 2015]. A critical element of the BBP is that different methods are validated against ground motion prediction equations [Abrahamson et al., 2008; Gregor et al., 2014] (Figure 3.17) and against data for particular earthquakes [Goulet et al., 2015]. The BBP has been used to examine ground motions for the Nuclear Regulatory Commission requirement that all nuclear plants in the US be evaluated for seismic safety. For the central and eastern US, where there are no data from large earthquakes, simulation provides guidance on scaling ground motions to large magnitudes. SCEC keeps pace with the ongoing evolution of the methods as they are subjected to validation against new data and new metrics through formal releases of the BBP on a regular basis.

Collaboration between SCEC and the Pacific Earthquake Engineering Research Center (PEER) grew substantially during SCEC4. We undertook collaborations that included: 1) development of additional BBP computational capabilities, 2) validation for Central and Eastern North America (CENA) ground motions, and 3) forward simulation for CENA ground motions. The compilation of a final version of the BBP including the latest features and the simulation data were needed by NGA-East due to the lack of recorded ground motions for magnitudes larger than 6. A strong collaboration between teams from SCEC and PEER made this project successful.

Ambient-Field Studies

SCEC scientists pioneered a new approach for predicting the strength of shaking using the ambient seismic field [Denolle et al., 2013]. This approach is possible because the waves that comprise the ambient field and those from large earthquakes propagate through the same complex geologic structure. While this "virtual earthquake" method does not account for nonlinear, high-amplitude effects, it provides a new way to predict complex wave-propagation effects that influence strong earthquake shaking. We have used it to validate predictions of a strong waveguide-to-basin amplification (Figure 3.18) predicted by simulations of a large San Andreas earthquake for Los Angeles. Scientists in France [Viens et al., 2014] and Japan [Viens et al., 2015] have applied this approach, and similar efforts are underway in Mexico, South Korea, New Zealand, Switzerland, and the Netherlands in settings ranging from subduction zones to gas reservoirs. Ground motion nonlinearity is an important research topic. During the SCEC4 project period SCEC scientists carried out ambitious simulations that included nonlinear response - not just at the site, but also near the source and along the path [Roten et al., 2014]. The simulations were carried out with a range of plasticity parameters, which are poorly constrained, but Roten et al., concluded that nonlinearity was important along the entire path and could diminish long-period ground motion by over a factor of two (Figure 3.19).

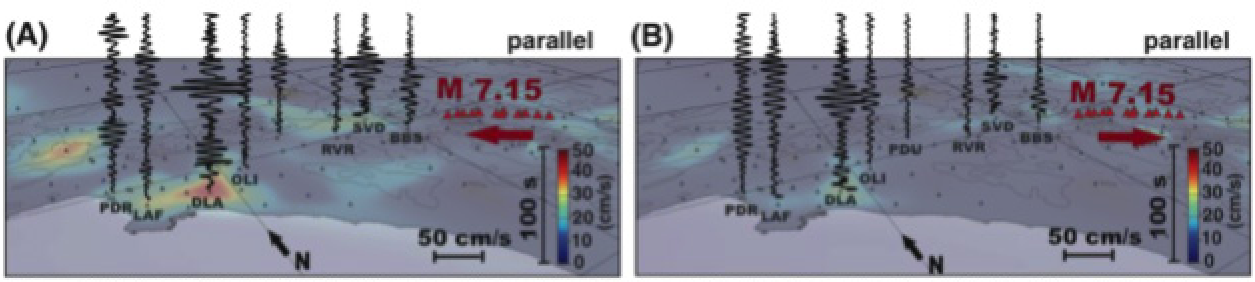


Figure 3.18. Predicted PGV in Los Angeles using ambient-field ground motions to synthesize "virtual earthquakes." Left panel is for M 7.1 San Andreas rupture towards downtown Los Angeles (SE > NW); right panel is for the same event with the opposite directivity (NW > SE). These observation-based seismograms will be used in SCEC5 to validate 3D ground-motion simulations. From Denolle et al. (2015).

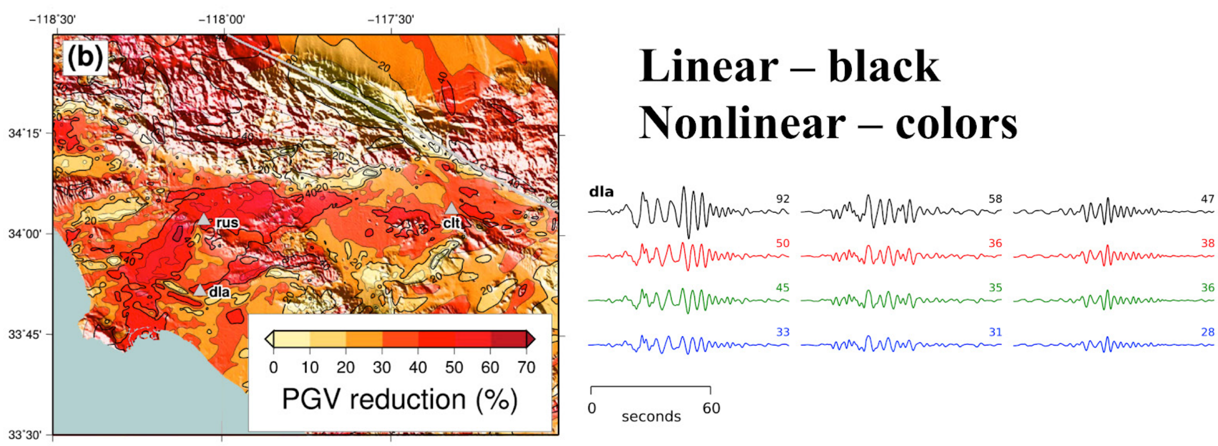


Figure 3.19. (after Roten et al., 2014) Showing the reduction in peak ground velocity (PGV) due to distributed nonlinear response of the shallow crust for a large earthquake on the San Andreas Fault. Seismograms at right show amplitudes in downtown Los Angeles may be reduced by up to a factor of 3 by these effects.

Ground Motion Simulation and Validation (GMSV)

GMSV is a TAG within SCEC to develop and implement validation methods for simulations. The GMSV focused on how simulations, such as those produced by the BBP, could be used in probabilistic seismic hazard analysis, structural nonlinear response history analysis, and site response analysis. Validating simulations is daunting, as they are of greatest interest for conditions that are not well observed (e.g., close to large earthquakes). The TAG developed "validation gauntlets" that simulated motions should pass to be deemed suitable for application. Gauntlets have been developed for single- and multi-degree-of-freedom oscillators and for geotechnical systems, and they are being extended to complex problems; e.g., the validation for applications that are frequency and duration sensitive, such as nonlinear structural response analysis of slope displacements and liquefaction. The TAG held an international workshop during the 2016 annual meeting to summarize international GMSV efforts and initiate future collaborations.

Committee for Utilization of Ground Motion Simulations

This committee, chaired by C. B. Crouse, is working within the framework of the Building Seismic Safety Council's Project 17 to develop long-period, simulation-based response spectral acceleration maps for LA region for future inclusion in the NEHRP and ASCE 7-10 Seismic Provisions and the Los Angeles City Building Code [Building Seismic Safety Council, Project 17]. The goal is to use CyberShake simulations to quantify the effects of sedimentary basins and other 3D structures on the seismic hazard. By averaging over thousands of simulated earthquakes, we have constructed prototype CyberShake hazard maps for Los Angeles (Figure 3.20). Prototype risk-targeted maximum considered earthquake (MCE_R) response spectra have also been mapped using the CyberShake model. The Committee has regularly held twice-annual open workshops to move towards these goals.

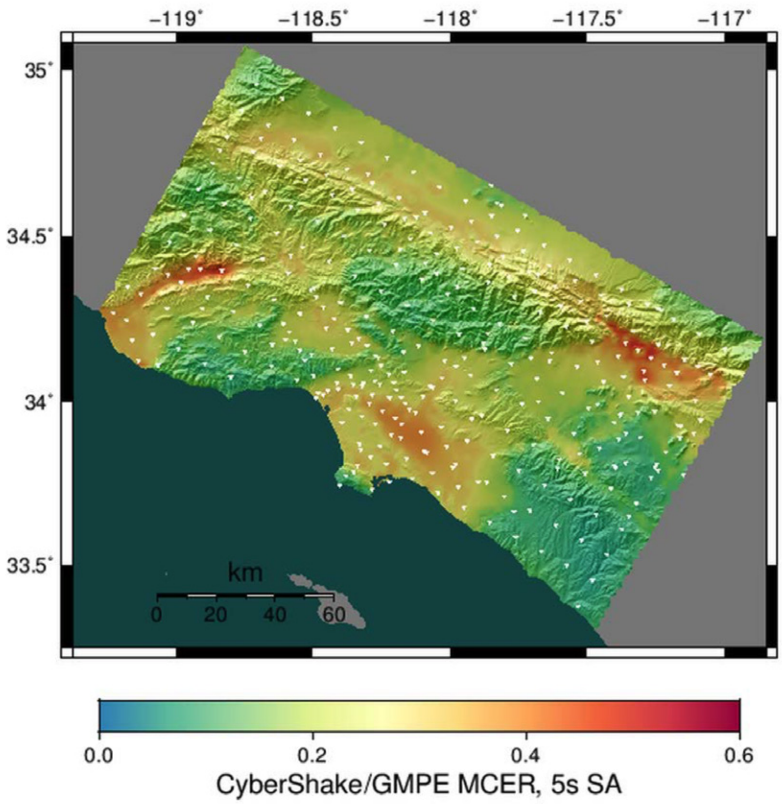


Figure 3.20. Regional MCER spectral acceleration map for 5-sec period. The 336 CyberShake sites are solid inverted white triangles. Acceleration scale in g.

4. Communication, Education & Outreach Accomplishments

Overview

SCEC's Communication, Education, and Outreach (CEO) program facilitates learning, teaching, and application of earthquake research. In addition, SCEC/CEO has a global public safety role in line with the third element of SCEC's mission: "Communicate understanding of earthquake phenomena to end-users and society at large as useful knowledge for reducing earthquake risk and improving community resilience." The theme of the CEO program during SCEC4 was Creating an Earthquake and Tsunami Resilient California. However, our geographic reach expanded far beyond the Golden State via partnerships across the country and worldwide, to prepare people for making decisions about how to respond appropriately to changing seismic hazards, including tsunami warnings and new technologies such as earthquake early warning.

SCEC/CEO has been very successful in leveraging its base funding with additional support. For example, since 2010, FEMA has provided SCEC nearly $3 million to coordinate the Earthquake Country Alliance in California (at the request of the California Governor's Office of Emergency Services, CalOES) and for national ShakeOut coordination. ShakeOut regions in the U.S. and internationally have also provided funding, and the California Earthquake Authority (CEA) has spent more than $15 million dollars on advertising that features ShakeOut promotions each year. SCEC's intern programs have been supported with more than $2.5 million in additional funding from several NSF programs and a private donor, and for several years NASA supported SCEC's "Vital Signs of the Planet" teacher development program (via JPL) as part of the NASA InSight mission. NOAA (via CalOES) now provides funding to SCEC for developing the TsunamiZone.org website.

Evaluation of the CEO program is conducted each year by SCEC's external Advisory Council, via annual reporting to funding agencies, as part of individual activities (post-ShakeOut surveys, teacher workshop evaluations, post-internship discussions, etc.), and as part of proposal reviews. In Spring 2015 a new "CEO Planning Committee" comprising members of the SCEC Advisory Council as well as SCEC community stakeholders was established to help guide and support SCEC/CEO activities and partnerships, which have significantly expanded during SCEC4. In addition, an experienced program evaluator has reviewed the CEO program overall including its evaluation structures [Wood, 2015]. Analyses for each CEO area were provided along with recommendations for how to expand and improve evaluation, including a new comprehensive logic model to tie all CEO activities to a set of long term intended outcomes. The results indicate that the SCEC/CEO program plays an important role in earthquake education and preparedness (**Box 4.1**), and the evaluation's recommendations have influenced the CEO program plan for SCEC5.

Box 4.1. Summary of 2015 CEO Evaluation

1. SCEC CEO programs embody the advancement of discovery and understanding while promoting teaching, training, and learning.
2. The SCEC Internship Programs are a key way in which SCEC CEO has successfully broadened participation of under-represented groups.
3. SCEC CEO program activities are integrated in that [ShakeOut] drill efforts coordinate with K-14 education programs.
4. SCEC programs are uniformly high quality, science-based, and effective.
5. SCEC has been successful in teaching safety skills and motivating earthquake preparedness.
6. As a trusted "honest broker", SCEC continues to provide essential leadership by bringing together and supporting key audiences to improve earthquake safety.
7. Since its inception, SCEC CEO has grown and expanded its programs in strategic ways.
8. SCEC has been successful in leveraging funds and partnerships to maximize program impact.

Major Activities and Results

a. Global network of Great ShakeOut Earthquake Drills, and related campaigns

Great ShakeOut Earthquake Drills. The first ShakeOut was held in southern California in 2008, based on the USGS-led "ShakeOut Scenario" for a large (M7.8) San Andreas earthquake. Working with a committee of Earthquake Country Alliance (ECA) leaders, SCEC created an online registration system and website (ShakeOut.org) where more than 5.4 million southern Californians were registered in 2008, building to 10.5 million people statewide in 2017. While K-12 and college students and staff comprise the largest number of participants, ShakeOut has involves businesses, nonprofits, government agencies, community groups, and households.

ShakeOut communicates scientific and preparedness information with the mission to motivate everyone, everywhere to practice earthquake safety ("Drop, Cover, and Hold On"), and to promote resiliency through preparedness and mitigation. Thus in addition to leading the California ShakeOut, SCEC manages a network of ShakeOut Regions worldwide, and hosts the website for each of their drills (except Japan). As of 2017, 27 Official ShakeOut Regions span all states and U.S. territories, three Canadian provinces, New Zealand, Southern Italy, and Japan (**Box 4.2**).. People and organizations in any other state or country can also register to be counted in the overall global total. More than 57 million people worldwide were registered in 2017.

ShakeOut has become a global infrastructure for providing earthquake information to the public and involving them in community resilience. New countries continue to join the ShakeOut movement, which serves to coordinate earthquake messaging internationally. Participants receive monthly ShakeOut newsletters and more frequent content via social media. Millions more learn about ShakeOut via broad news media coverage that encourages dialogue about earthquake preparedness. Surveys of ShakeOut participants show increased levels of mitigation and planning, and encouragement of peers to participate and get better prepared [Wood, 2015]. In 2017, ShakeOut coordinated with the USGS and its state/university partners in the West Coast ShakeAlert system to create a special ShakeAlert versi0n of the "ShakeOut Drill Broadcast" for beta-users of the system to play during their ShakeOut drills. In the future ShakeOut day will be an annual test of the system for all west coast states.

Box 4.2: Growth of ShakeOut Drills

2008: 5.4 million
Southern California
2009: 6.9 million
California, New Zealand West Coast
2010: 7.9 million
California, Nevada, Guam
2011: 12.5+ million
CA, NV, GU, OR, ID, BC, and Central US (AL, AR, GA, IN, IL, KY, MI, MO, OK, SC, TN)
2012: 19.4 million
All above plus:
AK, AZ, Southeast (DC, GA, MD, NC, SC, VA), UT, WA, Puerto Rico, Japan (central Tokyo), New Zealand, Southern Italy (US naval bases and surrounding areas), and a new "Global" site for all other areas.
2013: 24.9 million
All above except New Zealand, plus:
Rocky Mountain region (CO, WY, MT), HI, OH (now in the Central U.S.), WV & DE (now in the Southeast region), Northeast region (CT, PA, MA, ME, NH, NJ, NY, PA, RI), American Samoa, U.S. Virgin Islands, Commonwealth of Northern Marianas Islands. Charlevoix region of Quebec, and expansion across Japan.
2014: 26.6+ million
All above plus New Mexico, Yukon, all Quebec, and participation in 59+ countries via coordination of Aga Khan Development Network
2015: 43+ million
All above plus inclusion of annual nationwide school drills in Iran (held since 2005), and 70+ total countries.
2016: 55+ million
Continued growth in the U.S. and recognition of regional drills in Mexico City and Manila.
2017: 57+ million
Increased international participation, including Taiwan, expansion in Japan, and other areas

TsunamiZone. As a result of its leadership of ShakeOut, SCEC now also receives NOAA funding provided through CalOES to create and manage TsunamiZone.org. This international site adapts the ShakeOut registration system to assess participation in Tsunami activities, whether as part of their ShakeOut activities or during local tsunami preparedness weeks or months. Participation in 2017 exceeded 820,000 people in California, Oregon, Washington, Hawaii, and also more than 40 countries in the Caribbean and surrounding areas that participated in the "Caribe Wave" regional exercise. Jason Ballmann has become a leader within the National Tsunami Hazard Mapping Program community, and redeveloped tsunami educational graphics (TsunamiZone.org/graphics) that are now being used worldwide.

b. Extensive public education and preparedness activities and resources

Science and Crisis Communication. This program led by SCEC's Communications Manager Jason Ballmann focuses on communicating SCEC research findings as well as about the SCEC Community, as well as coordinating activities that improve risk communication both internally and externally of SCEC. This includes the distribution of press releases, management of interviews and media events, developing articles for the SCEC website, oversight of SCEC's social media presence (Twitter.com/scec, Facebook.com/scec, Youtube/com/scecmovies, and Instagram.com/SCECinsta, and coordination via all these aspects for post-event messaging and media requests.

Figure 4.1. EarthquakeCountry.org, one of several websites managed by SCEC/CEO for the Earthquake Country Alliance.

SCEC partners with several organizations to offer programs that train (1) the media on how to report earthquake science and (2) the SCEC community on how to communicate diverse and highly technical research to the public and media. For the latter, communications workshops are now held at each SCEC Annual meeting. The GeoHazards Messaging Collaboratory (GMC), led by Ballmann with partners at IRIS (Wendy Bohon) and UNAVCO (Beth Bartel) is a multi-organization messaging group, which now includes representatives of USGS (Lisa Wald) and NOAA (Cindi Preller). The GMC offers webinars for media and scientists, special outreach campaigns, and conference workshops, all focused on the value of messaging consistency and resource leveraging. Post-earthquake messaging coordination has been an active aspect of the GMC, allowing each organization to share or amplify key findings or messaging in order to reach more people with the information they need.

Earthquake Country Alliance (ECA). This public-private-grassroots partnership was created in southern California by SCEC with many partners in 2003 and is now a statewide coalition with similar groups in the Bay Area and North Coast. ECA's sector-based committees develop consistent messaging and resources distributed via activities led by each regional alliance. SCEC manages annual budgets for each regional alliance, coordinates 6-8 workshops each year, manages more than 40 conference call meetings annually across all ECA groups, creates messaging documents and graphics with input from these groups, distributes ECA materials, maintains ECA's EarthquakeCountry.org (English) and Terremotos.org (Spanish) websites (**Figure 4.1**), and manages ECA social media channels (twitter.com/eca and facebook.com/earthquakecountryalliance). SCEC Associate Director for CEO Mark Benthien is ECA's Executive Director.Financial support for ECA is provided to SCEC by the California Governor's Office of Emergency Services (CalOES) and FEMA.

Each year, ECA SoCal and Bay Area each hold 3-4 regional workshops, award 6-8 "mini awards" ($500 purchases on behalf of ECA partners for their earthquake preparedness and outreach), and coordinate primary media events on ShakeOut day with an earthquake simulator and displays for news media beginning at 4 a.m. at a Shakeout drill location. In 2017 the SoCal event was at the Los Angeles County Natural History Museum, and the Bay Area event was at Google Headquarters. In 2017, the Bay Area alliance was greatly expanded, including the completion of a Coordinating Committee (with support from SCEC's Sharon Sandow) and since April 2017 was involved in the coordination for the release of the HayWired Scenario for a M7 earthquake on the Hayward fault (in April 2018).

ECA's sector-based committees develop resources and organize activities for many audiences. SCEC's Sandow de Groot took over coordination of the committees in 2017 and is increasing participation, frequency of meetings, and development of products. Committee membership includes leaders from each sector, primarily within California but because the committees develop resources promoted via ShakeOut across the country (and beyond), some participants are from other regions. Sectors served include Businesses, the Public Sector, Non-Profits & Faith-Based Organizations, Healthcare, K-12 Schools, and Higher Education. ECA's EPIcenter Network of Museums, Parks, and Libraries is being reorganized with the same structures of other sector-based committees.

Preparedness Resources. SCEC's Putting Down Roots in Earthquake Country handbook (**Figure 4.2**) has provided earthquake science and preparedness information to southern Californians since 1995. The 2004 update coordinated by ECA introduced the Seven Steps to Earthquake Safety (**FIgure 4.2**), which has continued to be the main organizing structure for preparedness messaging of SCEC, ECA, CEA, and (as a result of ShakeOut) a growing number of other partners, states, and national organizations (including FEMA). In 2014 the California Earthquake Authority, California Office of Emergency Services, and ECA created a simpler booklet, Staying Safe Where the Earth Shakes, with customized versions for 10 regions of the state and multiple language editions (Spanish and Chinese to start). SCEC has distributed more than 50,000 printed copies of these booklets.

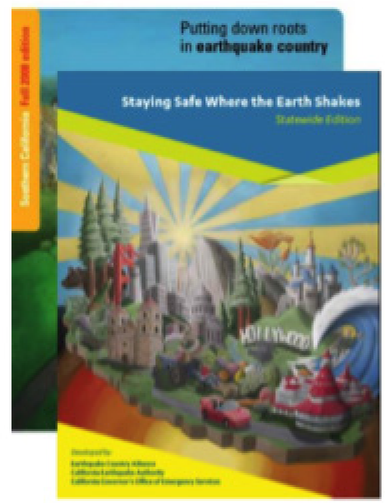


Figure 4.2. Public education booklets distributed by the Earthquake Country Alliance and SCEC.

Additional resources developed by SCEC and ECA Associates include earthquake safety materials and ShakeOut guidelines for seniors and people with disabilities, higher education, government agencies, businesses, and healthcare facilities. Each year new materials are developed by ECA Sector-based Committees and made available through ECA's websites, social media channels, and ShakeOut websites, emails, and social media messaging worldwide. SCEC also has developed as series of short videos in its "Earthquake Safety Video Series" which can be viewed at Youtube.com/greatshakeout.

Quake Heroes Documentary. This 50-minute documentary based on interviews of people who experienced the Northridge earthquake, has been in development for several years by SCEC and Blue Tavern Productions (established by Mark Romano, a former SCEC intern), and in 2017 began a year of feedback screenings which have helped refine the messaging and identify needed elements. Primary funding was provided by FEMA; additional sponsors include Simpson Strong Tie, State Farm, the Structural Engineers Association of Southern California, the Hero in You Foundation, Safe-T-Proof, and More Prepared.

The film portrays stories of people who took action to help their neighbors, along with a description of the science of the earthquake by SCEC and USGS scientists, engineering aspects by a structural engineer, and several others. Recent interview footage is shown with archival news footage, as well as live-action reenactments filmed with actors portraying our main characters at the time of the earthquake and realistic sets built for the filming. The Seven Steps to Earthquake Safety and ShakeOut are featured with the goal of prompting viewers to take action.

The film will be made available via a variety of settings and approaches. A classroom toolkit with science and engineering lesson plans is described in the next section. Quake Heroes Special Events will be organized to screen the film with partners and vendors present so that attendees can buy furniture straps, disaster supplies, learn about earthquake insurance, register for CERT and other trainings, and much more (all these activities will provide assessment of our success of motivating preparedness behaviors). The Quake Heroes website will let viewers share their own earthquake stories, expanding on the personal stories showcased in the film. The film is also expected be of interest to cable television or streaming services.

C. Broad range of K-14 educator partnerships, programs, and resources

EarthConnections San Bernardino Alliance: SCEC is a founding national partner (along with InTeGrate, UNAVCO, and IRIS) of EarthConnections, an NSF INCLUDES project linking three regional projects (one of which is centered in San Bernardino with CSU San Bernardino Prof. Sally McGill) to increase diversity in the geosciences, managed by SCEC/CEO's Gabriela Noriega. The program develops pathways for high school, community college, and university students to explore and achieve career opportunities, including geology club joint activities, field trips, and meetings with geotechnical professionals and research scientists. Educator workshops have also been offered. The program builds on SCEC's long-term partnership with Prof. McGill in support of summer GPS data collection by teachers and students as part of the NASA-funded InSight Vital Signs of the Planet (VSP) Professional Development Program which involved more than 30 teachers and students in real-world research along with lesson plan development and presentation of posters at the SCEC Annual Meeting.

Workshop Partnerships. SCEC is an active participant in the science education community including local and national organizations such as the California Science Teachers Association (CSTA). Since 2009, SCEC has hosted earthquake-oriented field trips and workshops for more than 150 teachers. In addition, SCEC and the California Geological Survey co-host a booth at CSTA meetings that draw ~2000 attendees each year. SCEC also hosted a booth at the 2016 National Science Teachers Association (NSTA) conference held in Los Angeles, where it distributed educational resources, highlighted internship opportunities (for future undergraduates), and encouraged ShakeOut participation

Quake Catcher Network (QCN). SCEC has expanded QCN with installations of low cost seismometers at over 26 EPIcenter museum locations in California and Oregon, and at more than 100 schools in each west coast state including Alaska. The goal is to establish several K-12 sensor stations around a local museum hub as a means to build long-term educational partnerships around the ShakeOut, citizen science, and enrich K-12 STEM curriculum. In 2015 a new partnership was established between SCEC, IRIS, and USGS to continue the expansion and development of QCN to schools, beginning with installations in summer 2015 by SCEC in 14 schools and museums in the Central U.S, and in several Coachella Valley school districts (along the San Andreas fault) in 2016.

Rocket Rules. In 2017 SCEC worked with the local Hero in You Foundation non-profit to create earthquake science and preparedness materials for grades K-3 (Figure 4.3). An earthquake safety video was created along with the "Rocket's Earthquake Safety Adventure" booklet (in English and Spanish). These resources are promoted via ShakeOut emails and the ShakeOut.org/schools website.

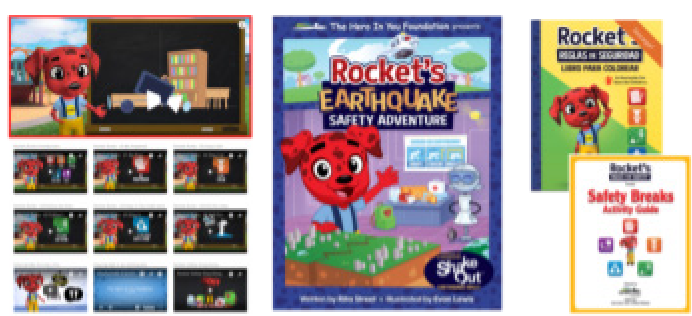


Figure 4.3. New resources for grades K-3 developed with guidance from SCEC (RocketRules.org)

Plate Tectonics PuzzleMap. This teaching tool created and distributed by SCEC was developed to make plate tectonics activities more accessible for science educators and their students. SCEC developed a user-friendly version of the This Dynamic Planet puzzle map, which is used to teach about plate tectonics. Educators often suggested that lines showing the location of plate boundary on the back of the maps would make it easier for them to correctly cut the map, so SCEC designed a new, two-sided map. More than 1000 PuzzleMaps have been distributed.

Quake Heroes Toolkit. To improve the ability for the Quake Heroes documentary to be shown in high-school classes, a toolkit has been developed that features several simple earthquake science and engineering lessons and activities that correlate with each act of the film (allowing the film to be shown over several days, with a lesson delivered each day). The toolkit will also include household and community preparedness guidance, and encourage schools to organize a Teen CERT (Community Emergency Response Teams) club at their school. State Farm has provided sponsorship support of this program for bringing the toolkits to Los Angeles Unified School District high schools, which will be among the first to receive the toolkits. We hope to expand such sponsorships to deliver more free kits to schools, however they also will be available for sale.

d. Well-established undergraduate research and career advancement experiences

Internship Programs. The SCEC Experiential Learning and Career Advancement (ELCA) program, led by Education Manager Dr. Gabriela Noriega, enhances the competency and diversity of the STEM workforce by engaging students in research experiences at each stage of their academic careers and by providing leadership opportunities to students and early career scientists that engage them in the SCEC Community. ELCA manages two undergraduate internship programs that involve over 30 students each summer:

- The Summer Undergraduate Research Experience (SURE) program places undergraduate students with SCEC scientists around the country. More than 270 interns have participated since 1994. Projects have spanned all areas of earthquake science, engineering, and education. In 2017, the delayed start of the SCEC5 NSF award resulted in insufficient time to pair funded SCEC researchers with students for summer projects.

- The Undergraduate Studies in Earthquake Information Technology (USEIT) program brings together students from across the country to an NSF Research Experience for Undergraduates Site at USC. The eight-week program develops computer science skills while teaching the critical importance of collaboration for successful learning, scientific research and product development. Since 2002, 261 students have participated, with significant numbers of women, underrepresented minority, and first-generation college students. USEIT interns tackle a scientific “Grand Challenge” each year that entails developing software and resources for use by earthquake scientists or outreach professionals. The program was successfully funded for another three years (2017-2019) at $120k/year, providing support for 12 interns that is matched by USC (5 interns/year) and several community colleges in Southern California 6-8 interns/year). 22 students participated in 2017. The Grand Challenge was to develop a computational system for probabilistic forecasting of earthquake sequences in Southern California, apply the system to initial-event scenarios, compare the simulator-based probabilities against official data of large aftershocks from Uniform California Earthquake Rupture Forecast version 3 (UCERF3), and illustrate the hazards and risks of multi-event scenarios that could threaten the Los Angeles with sequence-specific maps of expected ground motions, economic losses, and human casualties. This continues the expanded focus on applications of high performance computing, made possible by an allocation of 25,000 hours on the Blue Waters supercomputer. The involvement of nearly all SCEC staff each summer is essential to the success of UseIT.

Since 2002, over 1600 applications have been submitted to the SCEC internship programs (at www.scec.org/internships). In the past three years, 44% of the UseIT have been women, 48% have been under-represented minorities (as defined by NSF), and 38% are first-generation college attendees (**Figure 4.4**). Much of the success in increasing diversity has come from increased efforts to recruit students from other states and also from community colleges, making the internship programs an opportunity that is available to a broader range of students.

Past interns report that their internship made lasting impacts on their education and career, often influencing students to pursue or continue to pursue earthquake science degrees and careers. By observing and participating in the daily activities of earth science research, interns reported having an increased knowledge about working in research and education, which coupled with networking at the SCEC annual meeting, gave them the confidence to pursue earth science and other career options.

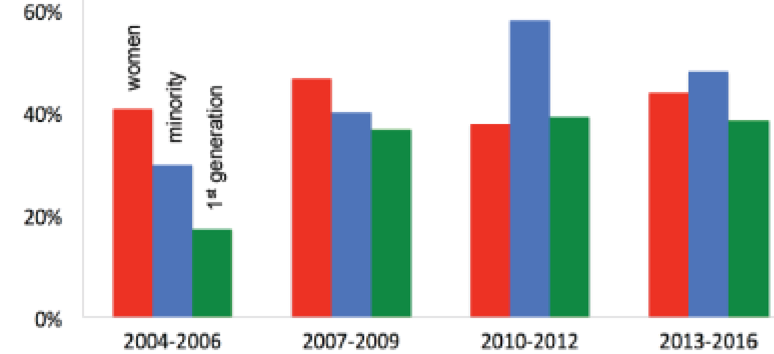


Fig. 4.4 Percentages of UseIT undergraduated interns who are women (red bar), under-represented minorities (blue bar), and first-generation college attendees (green bar). Data are grouped into successive phases of the REU-site program. Growing these percentages has been a major objective of UseIT recruitment efforts.

Transitions Program. In 2017 this new effort to provide junior members of the SCEC community with resources and mentoring across key career transitions, directing efforts to encourage and sustain careers in the geosciences and other STEM fields. At the 2017 SCEC Annual Meeting, ELCA hosted two breakfasts to connect early career attendees with peers and mentors to share experiences and develop strategies for navigating the transition from undergraduate to graduate school and from graduate school to professional career (within and outside of academia). Through the 2018 SCEC Science Plan, the Transitions Program solicited proposals from researchers to expand awareness of professional advancement opportunities and pathways, as well as improve competency in earthquake research tools and techniques for students of the SCEC community. No proposals were submitted, so in 2018 new approaches will be developed.

e. Coordinated activities to facilitate the application of SCEC science

SCEC produces a large body of knowledge about the seismic hazard in California that enhances seismic hazard maps, datasets, and models used in building codes and engineering risk assessments. The SCEC Earthquake Engineering Implementation Interface provides the organizational structure for creating and maintaining collaborations with research engineers to ensure SCEC's research activities are aligned with their needs. The Implementation Interface also develops mechanisms for interacting with technical audiences that make decisions based on an understanding of earthquake hazards and risk, including practicing engineers, geotechnical consultants, building officials, emergency managers, financial institutions, and insurers. SCEC CEO has partnered for many years with city, county, and state agencies who need earthquake information, organizes workshops and other trainings (including those provided by the Earthquake Country Alliance and GeoHazards Messaging Collaboratory), and held activities with the EERI Southern California Chapter and the Structural Engineers Association of Southern California (SEAOSC). An example is the annual SEAOSC Buildings at Risk Summits, which SCEC has co-organized since 2011 in both Los Angeles and San Francisco (with SEAONC). In 2017 SCEC partnered with the Earthquake Engineering Research Institute (EERI) as a technical co-sponsor for the 11th National Conference on Earthquake Engineering in Los Angeles on June 25-29, 2018. Regular committee meetings to plan the conference began early in 2017. SCEC's Christine Goulet helped develop the conference technical program with the theme of "Integrating Earthquake Science, Engineering, and Policy" and Mark Benthien co-led the publicity committee.

SCEC is increasing its involvement with professional associations and regional government groups such as the Building Owners and Managers Association (BOMA), Association of Contingency Planners (ACP), California Emergency Services Association (CESA), Southern California Association of Governments (SCAG) and Association of Bay Area Governments (ABAG), and the International Association of Emergency Managers (IAEM). SCEC/ECA also helped create the "Earthquake 2014 Business Preparedness Summit" with FLASH, Safe-T-Proof, Simpson Strong Tie, and several other partners, which launched the FEMA QuakeSmart recognition program for businesses that demonstrate mitigation they have implemented; this program is now offered in many locations nationwide each year.

5. Report of the Advisory Council

Introduction

The SCEC Advisory Committee (AC) convened at the SCEC Annual meeting in Palm Springs from September 10 to 13, 2017, reviewing SCEC activities in order to offer advice to the SCEC leadership. The SCEC AC comprises the following members, all of whom were present at the meeting, except where noted:

- M. Meghan Miller, Chair, UNAVCO
- Rick Aster, Colorado State U.
- Susan Beck, U. Arizona
- Roger Bilham, U. Colorado
- Donna Eberhart-Phillips, U. California, Davis
- Yann Klinger, IPGP/Paris
- Warner Marzocchi, INGV, Rome
- Tom O'Rourke, Cornell U. (not present)
- Susan Owen, JPL
- Tim Sellnow, U. Central Florida (not present)
- Heidi Tremayne, EERI

Advisory Committee members were given a 140-page briefing book on September 6. The AC met initially on September 9 and was briefed by SCEC leadership and by USGS and NSF representatives. Director Tom Jordan and incoming Director John Vidale provided the AC with a summary of the state of SCEC and provided a list of issues on which they sought AC feedback. Following the leadership briefing, the AC attended scientific sessions and solicited feedback from attendees. The AC also met three additional times during the meeting to discuss observations and findings. AC Chair Miller presented a summary of AC observations on Wednesday morning of the meeting, and this written report is intended to provide more detail. All committee members reviewed this report.

This report addresses the various questions and topics posed by the SCEC leadership, and offers additional observations.

Overview

At this critical transition to SCEC5 and a new SCEC Director, the Advisory Committee commends the exceptional achievements of SCEC and its globally significant contributions to earthquake and Earth system science. In spite of funding limitations and other external challenges, the AC sees a healthy organization with excellent future prospects and a coherent and ambitious 5-year plan.

AC Membership

<u>0. Are new AC members needed?</u>

An Engineering Seismologist or Geotechnical Engineer would be an appropriate addition to the AC to expand the committee expertise at the interface between engineering and seismology. Heidi Tremayne can help to identify possible candidates, if desired.

SCEC5 Science and Applications

<u>1. Are the SCEC5 milestones appropriate?</u>

The milestones are appropriate with enough detail to assure a structure to evaluate progress. The workshop provides useful points to engage current and new researchers in SCEC5 components and milestones that include a useful mixture of developmental research, quantitative products and consensus building aspects.

2. The Earthquake Gates Area Initiative represents a sustained commitment. How should they evolve, and should more be seeded?

The Earthquake Gates initiative looks very promising with some exciting early results. Understanding the controls on the probability of an earthquake rupturing multiple segments is key because it may control the ultimate size of the earthquake rupture. Hence, we view the Earthquake Gates initiative as an important activity for SCEC. We agree with the SCEC plan to use community input to identify one or more focus sites. Some issues, however, might not be possible to tackle at the chosen EG site and SCEC should stay open to investigation outside EG site proper, elsewhere in the US or abroad, as long as the study area remains clearly relevant to SCEC EG activities. Starting with a small number of focus sites and then expanding as resources allow may be the best approach. It will be important to identify criteria to define the success of the Earthquake Gates initiative.

3. SCEC Community Models are in various stages of completion and improving at various rates. Are the levels of effort and accomplishment appropriate?

The SCEC community models, with their wide and integrated application, are a highlight achievement. The articulated goals going forward are appropriate (and appropriately ambitious). The goal of going to higher frequency and more accurately reflecting near-surface structure and effects, as well as fault geometries, will require even more massive data collection, assimilation, and validation.

The levels of effort and accomplishment are appropriate. The development of unified ways to represent detail will make the results more useful and facilitate addressing research questions that flow from integrating the various CXM. The systematic study of velocity and rheology of basin sediment will provide necessary parameters for inferring near-surface effects on ground motion. At the meeting, it has been good to see the work done so far on the rheology component, including even some implementation. It appears that the CRM will also eventually improve the CVM, and the groups will develop new understanding, as the rheology users may define deeper crustal features for determining viscoelastic response.

4. How can we make better progress on the reduction of risk to distributed infrastructure? What would be good ways to interact with the relevant engineering community?

Regional oil and gas pipeline operators have not planned for the possibility of multiple simultaneous lesions during a major earthquake, nor the consequences of unstemmed leaks into State Parks, highways and wildlife preserves. A cost-benefit analysis of cleanup costs following an earthquake that causes multiple or major pipe ruptures (as a counterexample, the averted Alaska Oil Spill after Denali Earthquake) might provide an incentive for future interactions between pipeline operators and SCEC. Although state legislation may ultimately be necessary to ensure implementation, a cost-benefit analysis of a catastrophic multiple failure event may persuade operators of the urgency of pipeline resilience or inform state action.

A useful direction might be to contact and connect with the existing LA lifelines council, National and State Parks, Wildlife organisations, to encourage California legislation to mitigate fault-crossing pipe damage.

In his presentation Jack Baker showed clearly the importance of the spatial correlation of ground shaking in its effects on loss estimation, in particular when the target is a spatially distributed system (e.g. highways). This effect cannot be accounted for through the usual PSHA and GMPEs models, because the models are targeted only on single sites. The procedure described by Jack, although at a preliminary stage, appears very promising and immediately applicable. This motivates higher frequency (temporal and spatial) CyberShake-type ground motion modeling and its use in this type of analysis.

Regarding enhanced partnerships with the engineering community, promoting collaboration on PSHA is an excellent opportunity to shape a common language and to understand what engineers need and what seismologists can provide.

SCEC should also continue knowledge transfer activities to the engineering community that reach engineers in locations where they normally gather. Expanding collaboration with engineering research centers and organizations would facilitate this task. One suggestion is to design more sessions, presentations and workshops at related engineering conferences/events that seek feedback on SCEC products, similar to SCEC's work for the 11th National Conference on Earthquake Engineering in Los Angeles in June 2018 including a partnership with the Earthquake Engineering Research Institute (EERI). Other engineering groups of interest for technical collaboration and feedback include Natural Hazards Engineering Research Infrastructure (NHERI) SimCenter and DesignSafe, Pacific Earthquake Engineering Research (PEER), American Society of Civil Engineers (ASCE) Geo-Institute, and Structural Engineers Association of California (SEAOC).

Communication, Education, and Outreach

<u>5. Does the draft SCEC5 CEO Evaluation Framework and its related logic model, metrics, and milestones provide an appropriate level of assessment?</u>

The scope and scale of CEO activities continues to impress the Advisory Committee. The CEO is successful as a means of educating the public about earthquakes, and as an inspiration for what the public might do to mitigate their effects. Efforts to train and transition students (especially from underrepresented groups) to early career researchers and practitioners is also admirable.

The CEO group has actively responded to the 2015 evaluation recommendations by strategically selecting key indicators and metrics. This work is applauded and should be extended by identifying effective assessment tools or procedures to gather data for metrics that don't have simple quantitative metrics. Because long-term outcomes can be difficult to quantify and the number of outcomes in the logic model are numerous, the CEO group (with limited staff time and funding for assessment) may want to consider focusing more targeted, detailed, or nuanced assessments for some activities or specific outcomes, while more straightforward statistics collection/numerical metrics/reporting for other outcomes may be sufficient to track their progress. Such assessment should be incorporated as the logic model evolves in the first year of application, taking into account how the logic model should influence and inform an evaluation plan.

Some discussion centered on metrics to track ShakeOut success that had been generated in the CEO Planning Meeting, and to work with USGS and social scientists to identify how to add or modify 1-2 questions on the "Did You Feel It" survey to reflect (1) if the citizen reporting providing feedback actually dropped, covered, and held on, or took other protective actions, and (2) if they have participated in ShakeOut drills that influenced this action. This discussion included the caveat that any modification of questions should be carefully reviewed and validated by social scientists.

<u>6. The proposed Transitions Program was favorably reviewed and is a priority for NSF, yet with reduced funding its activities will be limited…. What other cost efficient concepts should we consider to increase retention and diversity into geoscience careers?</u>

We applaud SCEC for the focused breakfast meetings with students and early career scientists at the SCEC meeting. Similar events could be undertaken jointly with UNAVCO and IRIS (or other organizations) at the AGU meeting. A website for early career scientists where they can share information and resources would also be of value. The summer internship programs have been very successful and should be continued. We agree that partnering with SCEC institutions to identify external intern opportunities is important.

One cost efficient concept for increasing diversity and retention in geoscience careers would be to plan for a presentation, workshop, or session at future SCEC annual meetings, one that explores implicit bias and strategies for reducing its influence. AGU (with others) is leading a national and international conversation on implicit bias and its role in limiting diversity. SCEC could consider reaching out to AGU or AWG for speaker suggestions on implicit bias and strategies to avoid it. University programs that succeed in broadening participation in geosciences or other STEM fields (e.g., the Harvey Mudd program to increase female students participation in computer science) could also be a source for inspirational speakers or workshop leaders.

<u>7. The AC has strongly encouraged SCEC to provide risk communication training/discussion at the SCEC Annual Meeting. For the second year CEO has organized a communications workshop on Sunday for interested attendees. Is this sufficient or should there be a plenary session presentation as well?</u>

The Public Communications workshop included an informative talk on how to interact with the public with a hands-on practice; it was commended for engaging participants. The SCEC Distinguished Speaker also did a nice job of elevating the topic of risk communication to all participants in a plenary setting Sunday evening. And the Temblor demonstration provided a useful tool to enable individual conversations between SCEC participants and non-specialists.

The committee further noted the usefulness of skills development for communicating science results to lay-people (as well as communicating risk). Few researchers are likely to participate in a press conference, but many of us have wished we knew how to prepare and perform better in common media situations. SCEC should consider expanding specific training to include the more basic topic of a media interview (live tv, radio, other interviews or written contributions).

<u>8. SCEC annual meeting size challenges SCEC resources and may hinder function — should we strive to limit attendance to ~500, and if so, how?</u>

Optimized meeting size is one broad measure of SCEC's success. The large number of early career attendees, for example, is a positive factor for the community at large and for long-term advancement of SCEC goals; thus their integration is highly desirable. The 2017 meeting hit this right, and corrected for the open floodgates of 2016.

More broadly, limiting strategies should be motivated by clear and prioritized overall meeting goals and letting these goals drive decisions regarding recruitment, with appropriate incentives and disincentives to optimize attendance. The 2017 emphasis on communication, reflected in the Sunday workshop and Distinguished Speaker topic, well served the advancement of SCEC's broader influence and ultimate value to society, while engaging scientists in critical communications, an area where many aspire to do better.

Large plenary sessions can make discussion difficult, and can be intimidating for early career participants. Some organizations are experimenting with ways for attendees to provide questions/comments via tools like Google Docs that moderators and session chairs can use to seed questions and stimulate discussions. Texting could also provide a mechanism that doesn't encourage broad use of laptops in plenaries. That said, the discussions following plenary sessions were much improved over previous years on two counts: colleagues kept each other in check and younger participants were more forthcoming. While they may have been postdocs rather than grad students, this is still good progress. The online strategies could further this progress for 2018, and potentially expand participation.

Recommendations for action - opportunities and threats

9. How can we better recruit excellent high performance computing (HPC) talent and maintain connections to the HPC world?

One strategy to consider for recruiting HPC talent is to reach out to those who have interests in the broader scientific and societal problems to be addressed with the application of their HPC expertise and talent. These individuals can be recruited and retained through broader engagement in the mission, publications, and exposure to Earth science, combined with a concerted focus on mentorship. Emphasizing the scientific mission of SCEC, plus the altruistic appeal and societal impact of careers in earthquake science, could make SCEC positions more desirable to millennials and other early career prospects. SCEC should also expect and plan for the inevitable turnover in its own staff (given national trends for younger professionals) by ensuring overlap in knowledge, tasks, and skills.

10. What additional strategies should we pursue for funding CEO activities?

NSF's Division of Education and Human Resources offers a changing landscape of award opportunities, a landscape that SCEC leadership is aware of. Visit program officers in their new digs in Alexandria, monitor EHR program solicitations for focus areas that align with SCEC goals, and cultivate a spectrum of community-embedded capabilities and expertise (pedagogy, assessment) to draw on for new initiatives. Some of these might be accessed (and are being accessed) in the community geophysics facilities as well; partnerships could provide further synergies.

Mitigation strategies might include: Diversification of the SCEC portfolio and sponsorship, but this can be very time consuming to cultivate and unreliable over time. Choosing what not to do is another mitigation. There is no substitute for sponsorship that has wholesale ownership of the mission and structure of the organization. That said, in the current mix, SCEC should continue to develop projects that cultivate new capabilities and sponsorship including the broader public sector or private interests - power, water, transportation, municipalities.

11. Changes in leadership at PG&E: Norm Abrahamson is leaving, PG&E budget was cut from $1.6M to ~$1M late in the year, and planning the future of PG&E funding is in flux. We proactively discussing with PG&E management on future research priorities.

The committee recognizes the potential impact of losing this key relationship, and encourages the new leadership to commit time to developing new relationships (or strengthening other existing relationships) at PG&E. PG&E's interest is well aligned with SCEC. Find the PG&E new kid in town and cultivate common interests.

12. NSF has postponed announcement of the next solicitation of Geoinformatics and SI2 proposals, two mainstays of SCEC Special Project efforts. How do we plan for continuation of efforts supported by these programs?

Continued engagement with NSF leadership on the importance of specific solicitations to the community, or partnering with other groups affected by the delay in solicitations to communicate en masse, might help shine light on the costs to NSF in lost productivity. NSF programs are expected to evolve, and recipients are expected to evolve as well - so engagement with NSF program managers on future directions could help ensure that NSF is evolving in alignment with SCEC community needs. NSF uses unmet priorities in the investigator community to shape solicitations. The new director would be well served to interact with program officers in a variety of roles and directorates.

Other wisdom from the committee includes guidance (1) to develop a plan that consistently pursues a diverse set of funding sources, to increase stability when programs change and (2) develop a funding ‘succession plan’ by reviewing other information technology programs within NSF (e.g., EarthCube or whatever succeeds it) and outside of NSF (e.g., NASA).

13. A byproduct of the extensive SCEC5 NSF risk assessment has been outlawing the overhead waiver on subcontracts (e.g., subawards). Heroic efforts by John McRaney, Tran Huynh, and Deborah Gormley have adjusted SCEC arrangements so this change does not affect finances, at a cost of increased complication in administration of budgets. Does this somewhat convoluted arrangement require further corrective adjustments?
Heroic efforts are duly noted and highly commended! The subaward rule is long-standing, while NSF’s attention to and application of award rules is increasingly comprehensive and rigid, creating significant new administrative burden. It is not clear if or when the pendulum will swing back. Until a sea change comes, recipient award administrators might benefit from taking a more proactive stance. Participation by the USC award administrator in structured NSF events like the Large Facilities Workshop (or similar professional development) can build understanding on both sides, expose model practices for coming constraints, and help anticipate or even shape change. Such participation develops communication pathways to directly convey the impact of the administrative burden on awardees. This is important to make visible at NSF.

14. The SCEC5 NSF risk assessment and subsequent overhead negotiations have resulted in separate start dates for NSF (May) and USGS (February) cooperative agreements. How do we bring the NSF date back to February, in sync with USGS and internal planning and funding cycles, and obviating the problematic budgetary gyrations necessitated by multiple start and end dates?
Alignment of the dates may simply not be achievable, even at the cost of one quarter of funding. Greg Anderson has demonstrated creativity and effectiveness in finding solutions to odd administrative problems at NSF in cases where a solution could be found. If Maggie and Greg cannot explore and devise a technical fix for this problem, NSF options will likely have been exhausted. At that point, it might be time to seek the serenity to accept the things that cannot change and work to minimize impact on staff and workload, which the committee recognizes will be significant. This might include a reporting schedule based on a defined project year that makes sense for SCEC, but cannot match the various fiscal years of different sponsors, if sponsor agreement can be secured.

15. Future steps for UCERF? We just submitted a 1-year, $370K proposal to CEA for understanding uncertainties in UCERF3 and simplifying calculations (logic tree trimming).
Quantifying uncertainties and simplifying calculations are positive new directions. Ongoing refinement of UCERF is foundational to SCEC’s mission, and for planning and prioritization. The risk information coming out from UCERF3-ETAS may be of interest to reinsurance and insurance companies.

16. There are potential opportunities for SCEC funding through DOE and NASA. Ben Phillips, the lead for NASA’s Earth Surface and Interior Focus Area, has been invited to the past two SCEC meetings, and he has indicated that a SCEC proposal to the NASA Research Opportunities in Space and Earth Sciences (ROSES) program would be appropriate. Funding from DOE is more problematic, because earthquake science is not well represented in the RFP for their Scientific Discovery through Advanced Computing (SciDAC) program. AC advice on how to approach these agencies is welcome.
The AC encourages SCEC leadership to first consider goal alignment between NASA and DOE goals - e.g., does integrating SCEC better with the NASA ESI community make sense and provide benefit to both SCEC and NASA? With NASA launching a SAR mission in 2021, there is potential for significant overlap in research goals related to earthquake science.

As for any sponsor, spend the time to develop new relationships to explore common interests and goals and to explore and understand the agency award mechanisms. Proactive development of the relationship could lead to inclusion of SCEC-aligned NASA priorities in a specific announcement of opportunity, if the groundwork has been done in advance.

There are also institutional structural limitations for researchers at NASA centers to receive funding to participate in research projects and community working groups. SCEC could discuss with Ben Phillips potential avenues for better integration of NASA scientists into the SCEC community through NASA funding of NASA participants in SCEC research projects - effectively enlarging the funding pool for small research awards.

Earthquake Response Planning

<u>17. Post-earthquake response planning is timely and there is growing consensus that we should get more organized: how do we form a southern California response plan and how do we sustain SCEC effort at an operational level?</u>

Revisiting the scope and objectives of SCEC's earthquake response plan and its engagement platform response.scec.org is timely.

Post-Earthquake Response is a cross-cutting topic amongst many areas and many SCEC partnerships. SCEC leadership should define the SCEC vision and strategy in this landscape before working with external partners and finalizing a plan.

After internal alignment of goals and priorities, SCEC should ensure that the leadership successfully engages and strategizes with other partners and agencies who are working in the area of post-earthquake response (e.g., California Earthquake Clearinghouse, GEER, EERI, USGS, CGS, CalOES, IRIS, UNAVCO, universities), and align their plans accordingly. Goals might include filling gaps, avoiding duplication, and capitalizing on SCEC strengths and mission. Several specific recommendations came out of discussions during the meeting that should be explored for feasibility and alignment with other SCEC efforts:

(A) Provide training or resources to support scientists' awareness about mental health impacts when responding to earthquakes, including how to be sensitive to people who have experienced losses. These resources may also be helpful in times of stress unrelated to earthquakes.

(B) Continue to strategize SCEC's involvement and role in the California Earthquake Clearinghouse. One way would be to raise awareness of data sharing and available tools, as an option in addition to SCEC's response.scec.org website.

(C) Conduct an Earthquake Response Workshop at every SCEC Annual Meeting using the California Earthquake Clearinghouse Training module that could be customized for SCEC. This workshop would include a Disaster Service Worker certification.

(D) Explore provision of GIS support (possibly via an ArcGIS Online interface) during the earthquake response phase to collate and visualize data gathered by SCEC researchers, establishing base layers of background data helpful for field studies, or analysis of existing data.

Other comments

<u>18. Notes on the Leadership Transition</u>

The SCEC leadership transition was very well executed. Tom Jordan is commended for his dedication to ensuring the success of the transition, both by continuing his service until a successor was identified and recruited, enabling Greg Beroza's elevated role, and by graciously handing over the reins while remaining available and engaged with SCEC's success.

John Vidale is poised to succeed in this new role and brings breadth, leadership, and a history of work with broader constituencies at PNSN to the leadership position at SCEC. The Committee looks forward to a productive future in working with SCEC Leadership.

The dedication and professionalism of SCEC staff across the organization is also highly commended. Leadership transitions are difficult times, and staff members have clearly engaged in ensuring SCEC's future through staying the course, supporting the transition, and continuing to provide a signature level of extraordinary support for the organization and the SCEC Community. Well done!

19. SCEC5 as a Framework for Augmentation

The committee noted that the scientific, cyber, and observational infrastructure of SCEC could provide leverage and synergies to broader efforts or emerging opportunities:

- Improved understanding of intermediate period fault behavior likely requires greater knowledge of hydrogeology, aqueous geochemistry, fluid pressure effects, and fluid sources. Work in this area may benefit from new and/or smaller-scale simulations of fault-fluid interactions and studies of induced seismicity outside of southern California.
- There may be valuable unrealized opportunities for SCEC programmatic involvement in induced seismicity research and/or possible upcoming in-situ earthquake experiments being considered elsewhere in the seismological community.
- Dense portable seismic arrays have clear benefits for high-resolution modeling of near-surface structures, fault structures, and response, as well as for post-earthquake studies. Such studies could benefit site characterization.
- Coordinate with existing facilities and institutions that support instrumentation and data acquisition to ensure SCEC's unique strengths benefit broader data collection efforts.

20. Annual Meeting Logistics

Additional coffee stations are needed for a meeting of this size. The 15-minute break is simply too short to move 500 people in and out of the large plenary room. The unstructured time to interact with colleagues is very useful in stimulating interaction.

The meeting increasingly relies on posters for expanded participation, and some adjustments are needed to ensure effectiveness. (1) If there is to continue to be no dinner on Tuesday, provide snacks to support poster attendance; this is a key time for interaction between student/early career investigators and senior scientists. (2) There are a number of technical problems with the poster room. A larger room or acoustic absorption props could reduce the decibel level and permit conversations to be undertaken without participants shouting at each other. The illumination cross lighting of the past several years hinders viewing of posters beneath the spotlights. Consider more elevated lighting.

It was further noted that the restrooms really need to be moved to the plenary meeting floor, with little hope that this is within SCEC's span of influence.

21. Improving Clarity and Ease of SCEC and SCEC AC interactions

It would be useful to the AC if SCEC provided a secure discussion list-serve or email list that does not include SCEC staff to freely air, peer-educate, reconcile and integrate disparate perspectives and misconceptions while including off-site committee members, before finalizing the report. We believe that this will provide a more informed report.

Establishing a set of staggered terms for Committee Members is an important step forward. It would be useful for SCEC leadership to communicate the term for each committee member in an appointment letter or email at the time of appointment.

6. SCEC Publications

This section lists the publications recorded in the SCEC community database between November 2016 to January 2018. Each publication is preceded by its SCEC publication number.

A. Journal Articles (150 total)

1964 Burks, L. S., & Baker, J. W. (2016). A predictive model for ground motion fling step based on ground motion recordings and simulations. Soil Dynamics and Earthquake Engineering, 80(1), 119–126.

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6015 Barall, M., & Tullis, T. E. (2016). The Performance of Triangular Fault Elements in Earthquake Simulators. Seismological Research Letters, 87(1), 164-170.

6019 Shi, J., & Asimaki, D. (2017). From stiffness to strength: Formulation and validation of a hybrid hyperbolic nonlinear soil model for site response analyses. Bulletin of the Seismological Society of America, 107(3), 1336-1355.

6043 Erickson, B. A., & Day, S. M. (2016). Bimaterial Effects in an Earthquake Cycle Model using Rate-and-State Friction. Journal of Geophysical Research, 121(4), 2480-2506.

6064 Luttrell, K., & Smith-Konter, B. (2017). Limits on crustal differential stress in southern California from topography and earthquake focal mechanisms. Geophysical Journal International, 211(1), 472-482.

6099 Lui, S. K., & Lapusta, N. (2016). Repeating microearthquake sequences interact predominantly through postseismic slip. Nature Geoscience,.

6117 Howell, S. M., Smith-Konter, B. R., Frazer, N., Tong, X., & Sandwell, D. T. (2016). The vertical fingerprint of earthquake-cycle loading in Southern California. Nature Geosciences, 9, 611-614.

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6265 Zaliapin, I., & Kreemer, C. W. (2017). Systematic fluctuations in the global seismic moment release. Geophysical Research Letters, 44(10), 4820-4828.

6272 Rubino, V., Rosakis, A. J., & Lapusta, N. (2017). Understanding dynamic friction through spontaneously evolving laboratory earthquakes. Nature Communications, 8.

6298 Sleep, N. H., & Nakata, N. (2016). Nonlinear suppression of high-frequency S-waves by strong Rayleigh waves. Bulletin Seismological Society of American, 106(5), 2302–2312.

7056 Biasi, G. P., & Wesnousky, S. G. (2017). Bends and Ends of Surface Ruptures. Bulletin of the Seismological Society of America, 107(6), 2543-2560.
7068 Salisbury, J. B., Rockwell, T. K., & Buga, M. T. (2017). Paleoseismic Evidence for the 21 April 1918 Mw 6.9 Surface Rupture of the Northern Clark Strand of the Central San Jacinto Fault, California. Bulletin of the Seismological Society of America, 107(2), 1027-1032.
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B. Books or Other Non-periodical, One-Time Publications (2 total)

7919 Branum, D., Harmsen, S., Kalkan, E., Petersen, M. D., & Wills, C. J. (2008). Earthquake Shaking Potential for California. Mapsheet 48 (Revised 2008): California Geological Survey.

8136 Li, Y. (2017). Fault-Zone Guided Wave, Ground Motion, Landslide and Earthquake Forecast (pp232). Beijing and Boston, China and USA: China High Education Press with De Gruyter.

C. Conference Papers and Presentations (340 total)

6252 Taborda, R., Khoshnevis, N., Azizzadeh-Roodpish, S., & Huda, M. (2017). Influence Of The Source, Seismic Velocity, And Attenuation Models On The Validation Of Ground Motion Simulations. Poster Presentation at 16 World Conference on Earthquake Engineering.

6266 Anderson, J. G., Brune, R. J., Brune, J. N., & Biasi, G. P. (2017, 01). Wave Propagation and Source Models Compatible with Strong Motion Applications. Oral Presentation at 16 World Conference on Earthquake Engineering.

6571 Farris, A. C., & Onderdonk, N. W. (2017, 03). Quantifying Late Quaternary deformation in the Santa Maria Basin: A OSL, GPS and soil chronosequence based model for determining strath terrace deformation in the Zaca Creek drainage, Santa Barbara County. Poster Presentation at 2016 SCEC Annual Meeting.

6899 Ye, L., Kanamori, H., Lay, T., & Avouac, J. (2017, 05). Strike-slip Faulting Energy Release. Poster Presentation at 2016 SCEC Annual Meeting.

7085 Moser, A. C., Evans, J. P., Ault, A. K., Bradbury, K. K., & Janecke, S. U. (2016). Spatiotemporal evaluation of the San Andreas Fault-related deformation in the Mecca Hills, southern California,

from integrated fault zone characterization and low-temperature thermo-chronology. Oral Presentation at Geological Society of America Annual Meeting.
7086 Janecke, S. U., Markowski, D., Thornock, S. J., Evans, J. P., Steely, A., & Bykerk-Kauffman, A. (2016). The strange geometries of strike slip faults: insights from southern California's active faults. Poster Presentation at 2016 Geological Society of America Annual Meeting.
7113 Bowden, D. C., Tsai, V. C., & Lin, F. (2016). Interpreting site amplification from surface wave tomography. Poster Presentation at Seismological Society of America Annual Meeting.
7140 DeBock, D. J., Wade, K. F., Cook, D. T., & Haselton, C. (2016). FEMA P-58: New Developments in the Analysis Process for Wood Light-Frame Buildings. Oral Presentation at SEAOC Convention.
7150 Hardy, S., Gonzalez-Huizar, H., & Smith-Konter, B. R. (2016). Integrated Static and Dynamic Stress Modeling for Investigating Tremor Source Regions in the San Andreas Fault. Poster Presentation at Integrated Static and Dynamic Stress Modeling for Investigating Tremor Source Regions in the San Andreas Fault.
7151 Bijelic, N., Lin, T., & Deierlein, G. (2017, 01). Seismic response of a tall building to simulated long-period ground motions. Oral Presentation at 16th World Conference on Earthquake Engineering.
7219 Cheng, Y., & Chen, X. (2016, 12). Seismicity and source spectra analysis in Salton Sea Geothermal Field. Poster Presentation at AGU 2016.
7245 Jacobs, J., Howard, S., Forand, D. H., Dor, O., & Evans, J. P. (2006, 09). Field Guide to Exhumed Major Faults in Southern California. Oral Presentation at SCEC 2005 Meeting Field trip. .
7256 Ye, L., Avouac, J., & Lapusta, N. (2016, 12). Dynamic Stress Changes during the 2015 Gorkha, Nepal Earthquake. Oral Presentation at AGU Annual Meeting.
7257 Lay, T., Ye, L., Kanamori, H., & Avouac, J. (2016, 12). The 16 April 2016, Mw 7.8 Ecuador earthquake: a quasi-repeater of the 1942 Ms 7.5 earthquake and partial re-rupture of the 1906 Ms 8.6 Colombia-Ecuador earthquake. Oral Presentation at AGU Annual Meeting.
7268 Abercrombie, R. E., Shearer, P. M., & Trugman, D. T. (2017, 04). A comparison of different methods of calculating source spectra and stress drop in Southern California. Poster Presentation at Annual Meeting of the Seismological Society of America.
7278 Savran, W. H., Olsen, K. B., & Day, S. M. (2017, 04). Kinematic Rupture Generator Based on 3D Rough Fault Dynamic Rupture Simulations. Poster Presentation at Seismological Society of America.
7290 Johnson, C. W., Fu, Y., & Bürgmann, R. (2016, 10). Seasonal stress modulation on active California fault structures. Oral Presentation at State of stress in the Earth.
7298 Crouse, C., & Jordan, T. H. (2016, 10). Development of new ground-motion maps for Los Angeles based on 3-D numerical simulations and NGA West2 equations. Oral Presentation at 2016 California Strong Motion Instrumentation Program Annual Seminar.
7309 Sleep, N. H. (2017, 07). Earthquake cycles with dynamic weakening from flash melting with heterogeneous stress and near-fault anelastic strain. Poster Presentation at 2017 SCEC Annual Meeting.
7311 Hudnut, K. W., Wein, A. M., Cox, D. A., Perry, S. C., Porter, K. A., Johnson, L. A., & Strauss, J. A. (2017, 07). The HayWired Scenario — How can the San Francisco bay region bounce back better?. Oral Presentation at 2017 SCEC Annual Meeting.
7330 Spica, Z., Perton, M., Clayton, R. W., & Beroza, G. C. (2017, 07). Geometry of the Los Angeles Basin Using Full H/V Spectral Ratio Inversion. Poster Presentation at 2017 SCEC Annual Meeting.

7334 Hough, S. E., & Bilham, R. (2017, 07). Rocking the Boat: Poro-elastic Stress Change at Seismogenic Depth Associated with Oil Production in the Los Angeles Basin in the Early 20th Century. Poster Presentation at 2017 SCEC Annual Meeting.

7337 Xu, X., & Sandwell, D. T. (2017, 07). Line-of-Sight Velocity Map along the San Andreas Fault System from GPS and Sentinel-1 InSAR: Contribution to the SCEC Community Geodetic Model. Poster Presentation at 2017 SCEC Annual Meeting.

7345 Hardebeck, J. L. (2017, 07). Are the Stress Drops of Small Earthquakes Good Predictors of the Stress Drops of Larger Earthquakes?. Poster Presentation at 2017 SCEC Annual Meeting.

7346 Foster, K., Bradley, B. A., Wotherspoon, L., & McGann, C. R. (2017, 07). A data-driven V_s,30 model for New Zealand engineering research & practice. Poster Presentation at 2017 SCEC Annual Meeting.

7347 Bowden, D. C., & Tsai, V. C. (2017, 07). The Site Response of Surface Waves. Poster Presentation at 2017 SCEC Annual Meeting.

7350 Marzocchi, W. (2017, 07). Progresses and challenges for Operational Earthquake Forecasting in Italy. Oral Presentation at 2017 SCEC Annual Meeting.

7351 Cochran, E. S., Kroll, K. A., Richards-Dinger, K. B., & Murray, K. D. (2017, 07). Permeability Changes Observed in the Arbuckle Group Coincident with Nearby Earthquake Occurrence. Poster Presentation at 2017 SCEC Annual Meeting.

7355 Evans, E. L. (2017, 07). Strategies for building community-based geodetic models of fault slip rates. Oral Presentation at 2017 SCEC Annual Meeting.

7357 Llenos, A. L., & Michael, A. J. (2017, 07). Space-time earthquake rate models for one-year hazard forecasts in Oklahoma. Poster Presentation at 2017 SCEC Annual Meeting.

7360 Gold, P. O., Behr, W. M., Rockwell, T. K., & Fletcher, J. M. (2017, 07). Quaternary Slip History for the Agua Blanca Fault, northern Baja California, Mexico. Poster Presentation at 2017 SCEC Annual Meeting.

7363 Chen, K., Liu, Z., & Song, T. (2017, 07). Toward a more robust tsunami early warning system: integration of real-time GPS, strong motion and teleseismic data for fast seismic source inversion. Poster Presentation at 2017 SCEC Annual Meeting.

7364 Gerstenberger, M. C., Rhoades, D. A., Christophersen, A., Fry, B., Wallace, L. M., McVerry, G., & Horspool, N. (2017, 07). Earthquake Forecasting in recent large events in New Zealand and the role of CSEP. Oral Presentation at 2017 SCEC Annual Meeting.

7367 Sahakian, V. J., Baltay, A. S., Hanks, T. C., Buehler, J., & Vernon, F. L. (2017, 07). Path and site effects in GMPEs: Incorporating crustal physical properties for region-specific ground motion estimation using small magnitude data from Southern California. Poster Presentation at 2017 SCEC Annual Meeting.

7370 Langridge, R. M., Villamor, P., Litchfield, N., Van Dissen, R. J., Clark, K., Ries, W., Kearse, J., Little, T., Gerstenberger, M. C., Goded, T., & Response Team, t. (2017, 07). The 2016 Mw 7.8 Kaikoura Earthquake: Perspectives from Earthquake Geology into Seismic Hazard. Oral Presentation at 2017 SCEC Annual Meeting.

7374 Murray, J. R. (2017, 08). The impact of model prediction error in designing geodetic networks for crustal deformation applications. Poster Presentation at 2017 SCEC Annual Meeting.

7376 Xue, L., Bürgmann, R., & Shelly, D. R. (2017, 08). Frequency-Dependent Tidal Triggering of Low Frequency Earthquakes Near Parkfield, California. Poster Presentation at 2017 SCEC Annual Meeting.

7378 Kroll, K. A., Richards-Dinger, K. B., Dieterich, J. H., & Oglesby, D. D. (2017, 08). 3D Simulations of Earthquakes on Parallel Offset Faults with Homogeneous Stress Conditions. Poster Presentation at 2017 SCEC Annual Meeting.

7379 Douilly, R., Oglesby, D. D., Cooke, M. L., & Beyer, J. L. (2017, 08). Dynamic Models of Earthquake Rupture along branch faults of the Eastern San Gorgonio Pass Region in CA using Complex Fault Structure. Poster Presentation at 2017 SCEC Annual Meeting.

7380 Jones, L. M. (2017, 08). Science in Society: Bridging the Gap. Oral Presentation at 2017 SCEC Annual Meeting.

7383 Wu, B., Oglesby, D. D., Ghosh, A., & LI, B. (2017, 08). Investigating the physics behind VLFEs and LFEs: analysis based on dynamic rupture models with ductile-like friction. Poster Presentation at 2017 SCEC Annual Meeting.

7386 Huang, Y. (2017, 08). The effects of segmented fault zones on earthquake rupture propagation and termination. Poster Presentation at 2017 SCEC Annual Meeting.

7388 Li, Z., & Peng, Z. (2017, 08). Stress- and structure-induced anisotropy in Southern California from two-decades of shear-wave splitting measurements. Poster Presentation at 2017 SCEC Annual Meeting.

7389 Kuo, S., Kitamura, M., & Kitajima, H. (2017, 08). Experimental Investigation on Poro-Elasto-Visco-Plastic Behavior of the Inner Accretionary Wedge Sediments at the Nankai Subduction Zone . Poster Presentation at 2017 SCEC Annual Meeting.

7391 Ma, K., & (TEM) team, T. (2017, 08). Taiwan Earthquake Model: PSHA and Scenario Hazard Map. Poster Presentation at 2017 SCEC Annual Meeting.

7392 Milliner, C. W., Bürgmann, R., Wang, T., Inbal, A., Bekaert, D., Liang, C., & Fielding, E. J. (2017, 08). Capturing Postseismic Processes of the 2016 Mw 7.1 Kumamoto Earthquake, Japan, Using Dense, Continuous GPS and Short-repeat Time ALOS-2 InSAR Data: Implications for the Shallow Slip Deficit Problem . Poster Presentation at 2017 SCEC Annual Meeting.

7393 Skoumal, R., Patlan, E., Dawson, P. B., Kaven, J., & Hickman, S. H. (2017, 08). Microseismic events associated with the Oroville Dam spillway. Poster Presentation at 2017 SCEC Annual Meeting.

7394 Callaghan, S., Graves, R. W., Olsen, K. B., Cui, Y., Milner, K. R., Goulet, C. A., Maechling, P. J., & Jordan, T. H. (2017, 08). 10 years of CyberShake: Where are we now and where are we going with physics-based PSHA?. Oral Presentation at 2017 SCEC Annual Meeting.

7395 Johnson, C. W., Fu, Y., & Bürgmann, R. (2017, 08). Stress models of the annual hydrospheric, atmospheric, thermal, and tidal loading cycles on California faults: Perturbation of background stress and changes in seismicity. Poster Presentation at 2017 SCEC Annual Meeting.

7398 Lohman, R. B., Scott, C. P., & Jordan, T. E. (2017, 08). InSAR coherence time series - soil moisture as a proxy for alluvial fan age?. Poster Presentation at 2017 SCEC Annual Meeting.

7402 Rinkema, S., Oda, A. R., Narvaez-Colon, A. G., Rolón-Domena, K., Tantiwuttipong, P., Kala, E., Yu, J., Milner, K. R., Noriega, G. R., Pearson, J. K., & Jordan, T. H. (2017, 08). 2017 USEIT: SCEC-VDO Enhancement and Release. Poster Presentation at 2017 SCEC Annual Meeting.

7403 Troise, S. A., Bent, M. T., Hernandez, R. A., Cervantes, R. G., Hermosura, J., Martinez, M. D., Callaghan, S., Gilchrist, J. J., Pearson, J. K., Noriega, G. R., & Jordan, T. H. (2017, 08). 2017 UseIT: High Performance Computing Team. Poster Presentation at 2017 SCEC Annual Meeting.

7404 Loh, C. Y., Dorencz, O. J., Escanuela, A., Qualls, K. F., Milner, K. R., Jordan, T. H., Pearson, J. K., & Noriega, G. R. (2017, 08). 2017 UseIT: Probability Team. Poster Presentation at 2017 SCEC Annual Meeting.

7407 Dorencz, O. J., Hernandez, R., Midgley, A., Verna, R., Qualls, K. F., Rolón-Domena, K., Cervantes, R. G., Oda, A. R., Ballmann, J., Jordan, T. H., Pearson, J. K., & Noriega, G. R. (2017, 08). 2017 UseIT: Communications Work Group. Poster Presentation at 2017 SCEC Annual Meeting.

7405 Li, Y., Belvoir, S., Edwards, A., Midgley, A., Uribe, R., Verna, R., Pearson, J. K., Jordan, T. H., Noriega, G. R., Milner, K. R., & Seligson, H. A. (2017, 08). 2017 USEIT: Hazard and Risk Visualization of Earthquake Scenarios . Poster Presentation at 2017 SCEC Annual Meeting.
7409 Wirth, E., Frankel, A., Vidale, J. E., Marafi, N., & Stephenson, W. J. (2017, 08). 3-D Simulations of M9 Earthquakes on the Cascadia Megathrust. Poster Presentation at 2017 SCEC Annual Meeting.
7415 Share, P., Ben-Zion, Y., Thurber, C. H., Zhang, H., & Guo, H. (2017, 08). Seismic imaging of the southern California plate-boundary around the South-Central Transverse Ranges using double-difference tomography. Poster Presentation at 2017 SCEC Annual Meeting.
7416 Wang, K., & Fialko, Y. (2017, 08). Postseismic deformation following the 2013 Mw 7.7 Balochistan (Pakistan) earthquake observed with Sentinel-1 Interferometry. Poster Presentation at 2017 SCEC Annual Meeting.
7420 Lin, J. C., Moon, S., Yong, A., Meng, L., Martin, A., & Davis, P. M. (2017, 08). Linking Subsurface and Surface Processes: Insights on Vs30 Distribution in Southern California. Poster Presentation at 2017 SCEC Annual Meeting.
7425 Baker, J. W., & Chen, Y. (2017, 08). Characterization of spatial correlations in ground motions—insights from physics-based simulations. Oral Presentation at 2017 SCEC Annual Meeting.
7427 Taciroglu, E. (2017, 08). A Vision for Regional Performance-Based Seismic Assessment. Oral Presentation at 2017 SCEC Annual Meeting.
7430 Halkia, G., & Grant Ludwig, L. (2017, 08). Newspaper Media Content Analysis: Community Effects of Induced Seismicity in Oklahoma. Poster Presentation at 2017 SCEC Annual Meeting.
7434 Roh, B., Buyco, K., & Heaton, T. H. (2017, 08). NGA high-pass filters remove important real signals; simple tilt correction is preferable when predicting collapse.. Poster Presentation at 2017 SCEC Annual Meeting.
7436 Retailleau, L., & Beroza, G. C. (2017, 08). Towards Structural Imaging Using Scattering Artifacts Detected in Ambient Field Correlations. Poster Presentation at 2017 SCEC Annual Meeting.
7438 McDermott, R., Ault, A. K., & Evans, J. P. (2017, 08). Examining earthquake processes with microtextural analysis and (U-Th)/He thermochronometry: a case study from hematite fault mirrors in the Wasatch fault zone. Poster Presentation at 2017 SCEC Annual Meeting.
7440 Swiatlowski, J. L., Moore, D., & Lockner, D. A. (2017, 08). Frictional strengths of fault gouge from a creeping segment of the Bartlett Springs Fault, northern California. Poster Presentation at 2017 SCEC Annual Meeting.
7441 Clayton, R. W., Lin, F., Denolle, M. A., Persaud, P., & Polet, J. (2017, 08). Imaging the San Gabriel and San Bernardino Basins with short-term Nodal deployments. Poster Presentation at 2017 SCEC Annual Meeting.
7442 Khoshnevis, N., & Taborda, R. (2017, 09). Towards an Informed Decision Making in Validation Metrics. Oral Presentation at QuakeCoRE Annual Meeting.
7443 Jackson, D. D. (2017, 08). Prospective test of the 1995 WGCEP SoCal earthquake forecast . Poster Presentation at 2017 SCEC Annual Meeting.
7444 Ellsworth, W. L., Boettcher, M. S., & Ogasawara, H. (2017, 08). A Test Case for the Source Inversion Validation: The 2014 ML 5.5 Orkney, South Africa Earthquake. Poster Presentation at 2017 SCEC Annual Meeting.
7445 Xie, Y., & Meng, L. (2017, 08). Application of array-based early warning system to tsunami offshore Ventura, California. Poster Presentation at 2017 SCEC Annual Meeting.
7446 Lee, R. L., Bradley, B. A., Graves, R. W., Rodriguez-Marek, A., & Stafford, P. J. (2017, 08). Investigation of Systematic Ground Motion Effects Through Ground Motion Simulation of

Small-to-Moderate Magnitude Earthquakes in the Canterbury, New Zealand Region. Poster Presentation at 2017 SCEC Annual Meeting.
7449 Bao, X., & Song, X. (2017, 08). Crust azimuthal anisotropy beneath the eastern Tibetan Plateau revealed by ambient noise tomography. Poster Presentation at 2017 SCEC Annual Meeting.
7455 Brune, J. N., Anderson, J. G., & Brune, R. J. (2017, 08). Additional Interpretation of the Orientations of Precariously Balanced Rocks in the Band Between the San Jacinto and Elsinore Faults. Poster Presentation at 2017 SCEC Annual Meeting.
7456 Bruhat, L., & Segall, P. (2017, 08). Can deformation rates across the Carrizo Plain segment of the San Andreas Fault be explained by vertical migration of the locked to-creeping transition? . Poster Presentation at 2017 SCEC Annual Meeting.
7457 Abolfathian, N., Martínez-Garzón, P., & Ben-Zion, Y. (2017, 08). Spatio-temporal variations of stress parameters in the San Jacinto Fault Zone. Poster Presentation at 2017 SCEC Annual Meeting.
7458 Shaw, B. E., Milner, K. R., Field, E. H., Richards-Dinger, K. B., Gilchrist, J. J., Dieterich, J. H., & Jordan, T. H. (2017, 08). Striking agreement of physics-based earthquake simulator and UCERF3 California seismic hazard model. Poster Presentation at 2017 SCEC Annual Meeting.
7460 Wang, K., Ellsworth, W. L., & Beroza, G. C. (2017, 08). Reanalyzing the Rangely earthquake control experiment using machine learning . Poster Presentation at 2017 SCEC Annual Meeting.
7461 Lifton, N. (2017, 08). A new, 170 ka slip rate estimate on the Sierra Madre Fault. Poster Presentation at 2017 SCEC Annual Meeting.
7462 Cheng, Y., Ross, Z. E., & Ben-Zion, Y. (2017, 08). Diverse volumetric seismicity in the Trifurcation area of the San Jacinto fault zone . Poster Presentation at 2017 SCEC Annual Meeting.
7463 Goebel, T. H., Kwiatek, G., Becker, T. W., Brodsky, E. E., & Dresen, G. (2017, 08). What allows seismic events to grow big?: Insights from b-value and fault roughness analysis in laboratory stick-slip experiments. Poster Presentation at 2017 SCEC Annual Meeting.
7465 Kalkan, E., Jones, J., Stephens, C., & Ng, P. (2017, 08). PRISM, Processing and Review Interface for Strong Motion Data Software. Poster Presentation at 2017 SCEC Annual Meeting.
7468 Eymold, W. K., & Jordan, T. H. (2017, 08). Objective Tectonic Regionalization of CVM-S4.26 Using the k-means Clustering Algorithm. Poster Presentation at 2017 SCEC Annual Meeting.
7469 Ogata, Y. (2017, 08). On secular spatial seismicity. Poster Presentation at 2017 SCEC Annual Meeting.
7471 Gong, J., & McGuire, J. J. (2017, 08). Interactions Between Strike-slip Earthquakes and the Subduction Interface near the Mendocino Triple Junction. Poster Presentation at 2017 SCEC Annual Meeting.
7473 Schoenball, M., & Ellsworth, W. L. (2017, 08). A systematic assessment of the spatio-temporal evolution of fault activation through induced seismicity in Oklahoma and southern Kansas. Poster Presentation at 2017 SCEC Annual Meeting.
7477 Page, M. T., van der Elst, N. J., & Shaw, B. E. (2017, 08). Characterizing the Triggering Susceptibility of Characteristic Faults. Poster Presentation at 2017 SCEC Annual Meeting.
7478 Taylor, S. E., & Brodsky, E. E. (2017, 08). Granular Temperature Measured Experimentally in a Shear Flow by Acoustic Energy. Poster Presentation at 2017 SCEC Annual Meeting.
7488 Zhang, Y., Yang, J., & Xie, F. (2017, 08). Stress patterns analysis about the seismic focal zone of the great Tohoku-Oki earthquake (M=9.0) in the Japan Trench subduction zone. Poster Presentation at 2017 SCEC Annual Meeting.
7490 Reynolds, L. C., Simms, A. R., Rockwell, T. K., Yokoyama, Y., Miyairi, Y., & Hangsterfer, A. (2017, 08). Evidence for Holocene coseismic subsidence during a non- plate boundary earthquake. Poster Presentation at 2017 SCEC Annual Meeting.

7493 Wilson, J. M., Rundle, J. B., Ward, S., Donnellan, A., Song, T., Komjathy, A., & Savastano, G. (2017, 08). Tsunami Squares: fast tsunami computation for use in coupled earthquake, tsunami, and ionosphere simulations. Poster Presentation at 2017 SCEC Annual Meeting.

7494 Luginbuhl, M., Turcotte, D. L., & Rundle, J. B. (2017, 08). Natural Time and Nowcasting Induced Seismicity at the Groningen Gas Field in the Netherlands. Poster Presentation at 2017 SCEC Annual Meeting.

7495 Motamed, R., Saxena, S., & Anderson, J. G. (2017, 08). Using Spatial Variation of kappa to Develop Site-Specific Attenuation Model for Improved Broadband Simulations. Poster Presentation at 2017 SCEC Annual Meeting.

7496 Chourasia, A., Nadeau, D. R., & Norman, M. L. (2017, 08). SeedMe: Data Sharing Building Blocks. Poster Presentation at 2017 SCEC Annual Meeting.

7497 Kedar, S., Bock, Y., Moore, A. W., Fang, P., sullivan, A., Argus, D. F., Jiang, S., & Marshall, S. T. (2017, 08). Production and Uses of Multi-Decade Geodetic Earth Science Data Records. Poster Presentation at 2017 SCEC Annual Meeting.

7500 Rubinstein, J. L., & Ellsworth, W. L. (2017, 08). Repeating Earthquakes Trigger Themselves in Parkfield. Poster Presentation at 2017 SCEC Annual Meeting.

7501 Patyniak, M., Landgraf, A., Dzhumabaeva, A., Abdrakhmatov, K., Rosenwinkel, S., Korup, O., Preusser, F., Fohlmeister, J., Arrowsmith, R., & Strecker, M. (2017, 08). Paleoseismic Record of Three Holocene Earthquakes Rupturing the Issyk-Ata Fault near Bishkek, North Kyrgyzstan. Poster Presentation at 2017 SCEC Annual Meeting.

7504 Juarez, A., & Jordan, T. (2017, 08). Automated Waveform Assembling for Full-3D Tomography. Poster Presentation at 2017 SCEC Annual Meeting.

7506 Ross, Z. E., Kanamori, H., & Hauksson, E. (2017, 08). Anomalously large complete stress drop during the 2016 Mw 5.2 Borrego Springs earthquake inferred by waveform modeling and near-source aftershock deficit. Poster Presentation at 2017 SCEC Annual Meeting.

7507 Sandwell, D. T., & Smith-Konter, B. R. (2017, 08). A 4-D Earthquake Cycle Model with Lateral Variations in Shear Modulus. Poster Presentation at 2017 SCEC Annual Meeting.

7510 Morell, K. D., Regalla, C. A., Amos, C. B., Bennett, S. E., Graham, A., Leonard, L., Lynch, E., & Harrichhausen, N. (2017, 08). Lidar data, geologic mapping, and paleoseismic trenching reveal late Quaternary surface ruptures and increased seismic hazard in southwestern British Columbia, Canada. Poster Presentation at 2017 SCEC Annual Meeting.

7513 Gheibi, A., & Hedayat, A. (2017, 08). Laboratory geophysical observation of grain compression and crushing in synthetic fault gouges. Poster Presentation at 2017 SCEC Annual Meeting.

7517 Shinevar, W., Behn, M., Hirth, G., & Jagoutz, O. (2017, 08). Inferring Crustal Viscosity from Seismic Wavespeeds: Applications to the Rheologic Structure of Southern California. Poster Presentation at 2017 SCEC Annual Meeting.

7520 Oskin, M. E., Behr, W. M., Morelan, A. E., Plesch, A., & Shaw, J. H. (2017, 08). Toward a Geologic Framework for the Community Rheology Model, with focus on the Mojave region. Poster Presentation at 2017 SCEC Annual Meeting.

7502 Fuis, G. S., Zhang, E., Catchings, R. D., Scheirer, D. S., Goldman, M. R., & Bauer, K. (2017, 08). A re-examination of the subsurface fault structure in the vicinity of the 1989 Loma Prieta Mw 6.9 earthquake, central California, from analysis of steep reflections, earthquakes, and potential-field data. Poster Presentation at 2017 SCEC Annual Meeting.

7527 Huang, H., & Meng, L. (2017, 08). Large-scale Acceleration of Slow Slip Before the 2015 Mw 8.4 Illapel, Chile Earthquake. Poster Presentation at 2017 SCEC Annual Meeting.

7528 Mousavi, M., & Beroza, G. C. (2017, 08). Towards Testing Probabilistic Seismic Hazard Estimates. Poster Presentation at 2017 SCEC Annual Meeting.

7522 Sheng, Y., Nakata, N., & Beroza, G. C. (2017, 08). On the Properties of Higher-Order Ambient Field Correlation. Poster Presentation at 2017 SCEC Annual Meeting.

7529 White, M. C., Ross, Z. E., Ben-Zion, Y., & Vernon, F. L. (2017, 08). A detailed, automatically-derived, seismicity catalog for the San Jacinto fault zone (1998-2016). Poster Presentation at 2017 SCEC Annual Meeting.

7533 Guns, K. A., Bennett, R. A., & Blisniuk, K. D. (2017, 08). Investigating strain transfer along the Southern San Andreas Fault: A geomorphic and geodetic study of block rotation in the Eastern Transverse Ranges, Joshua Tree National Park, CA. Poster Presentation at 2017 SCEC Annual Meeting.

7534 Beyer, J. L., Cooke, M. L., & Marshall, S. T. (2017, 08). Getting pushy with the San Gorgonio Pass: Investigating active fault geometries with crustal deformation models. Poster Presentation at 2017 SCEC Annual Meeting.

7537 Louie, J. N., Boudjema, M., Dunn, M., & Kent, G. M. (2017, 08). Ground-Motion Variance from Modeling of Multiple Rupture-Directivity Scenarios on the Newport-Inglewood/Rose Canyon Fault System. Poster Presentation at 2017 SCEC Annual Meeting.

7538 Trugman, D. T., & Shearer, P. M. (2017, 08). Examining the relationship between stress drop and peak ground acceleration for small-to-moderate earthquakes in the San Francisco Bay Area. Poster Presentation at 2017 SCEC Annual Meeting.

7539 Yano, T. E., & Matsubara, M. (2017, 08). Seismogenic depth of the crust beneath the Japanese Island using Japan unified hIgh-resolution relocated catalog for earthquakes (JUICE). Poster Presentation at 2017 SCEC Annual Meeting.

7540 Callaghan, S., Juve, G., Vahi, K., Maechling, P. J., Jordan, T. H., & Deelman, E. (2017, 08). rvGAHP - Push-based job submission using reverse SSH connections. Oral Presentation at International Conference for High Performance Computing, Networking, Storage and Analysis (SC 2017).

7543 Wang, W., & Shearer, P. M. (2017, 08). An Improved Method to Determine Coda-Q, Earthquake Magnitude, and Site Amplification: Theory and Application to Southern California. Poster Presentation at 2017 SCEC Annual Meeting.

7544 Kilb, D., Borsa, A. A., & Agnew, D. C. (2017, 08). On the Geodetic Signature from Lake Mead Water Levels Fluctuations (1940-2016). Poster Presentation at 2017 SCEC Annual Meeting.

7545 Zhang, D., & Clayton, R. W. (2017, 08). Near-Surface Shear-Wave Velocities determined using the Community Seismic Network (CSN) . Poster Presentation at 2017 SCEC Annual Meeting.

7546 Elizondo, K. Q., & Polet, J. (2017, 08). Measurements of Tilt from Triangular Bench Mark Arrays Installed Within Long Valley Caldera in the 1980s . Poster Presentation at 2017 SCEC Annual Meeting.

7547 Wesnousky, S. G., & Biasi, G. P. (2017, 08). A predictive model for earthquake rupture extents given an early warning epicenter. Poster Presentation at 2017 SCEC Annual Meeting.

7548 Evans, J. P., Borhara, K., & Webb, S. (2017, 08). Earthquake Petrology: Insights into Fault Slip Localization and Fault Heating via Micro X-Ray Fluorescence Mapping and X-Ray Absorption Near Edge Spectroscopy. Poster Presentation at 2017 SCEC Annual Meeting.

7550 Wang, J., & Tanimoto, T. (2017, 08). Shallow Earth Structure from Wind-Induced Ground Motion. Poster Presentation at 2017 SCEC Annual Meeting.

7551 Todd, E. (2017, 08). Seismicity and tectonic tremor associated with shallow offshore slow slip along the northern Hikurangi Margin, New Zealand. Poster Presentation at 2017 SCEC Annual Meeting.

7553 Teng, G., & Baker, J. W. (2017, 08). Evaluations of CyberShake simulated motions for use in engineering analysis. Poster Presentation at 2017 SCEC Annual Meeting.

7555 Liu, Q., Wen, X., & Shao, Z. (2017, 08). Seismogenic structure and coseismic slip distribution of the 2013 Ms7.0 Lushan earthquake in southwestern China. Poster Presentation at 2017 SCEC Annual Meeting.
7554 Anderson-Merritt, E., Cowgill, E. S., Scharer, K. M., & Keen-Zebert, A. (2017, 08). Preliminary paleoslip results from the Pearblossom site on the Mojave section of the San Andreas Fault. Poster Presentation at 2017 SCEC Annual Meeting.
7557 Böse, M., Smith, D. E., Felizardo, C., Meier, M., Heaton, T. H., & Clinton, J. (2017, 08). Rapid Line-Source and Ground-Motion Estimates for Earthquake Early Warning Using FinDer Version 2. Poster Presentation at 2017 SCEC Annual Meeting.
7561 Bradley, B. A., Savarimuthu, S., Lagrava, D., Huang, J., Motha, J., Polak, V., & Bae, S. (2017, 08). SeisFinder: A web application for extraction of data from computationally-intensive earthquake resilience calculations. Poster Presentation at 2017 SCEC Annual Meeting.
7562 Jeong, S., Mohammadi, K., Asimaki, D., & Bradley, B. A. (2017, 08). Simulation and Validation of Topographic Effects on Mt Pleasant, Christchurch, New Zealand. Poster Presentation at 2017 SCEC Annual Meeting.
7564 McGuire, J. J., & Kaneko, Y. (2017, 08). Directly Estimating Rupture Area to Remove the Uncertainty in Stress Drop. Poster Presentation at 2017 SCEC Annual Meeting.
7565 Nakata, N., & Beroza, G. C. (2017, 08). Towards a High-Resolution Velocity Model with a Very Dense Array at Diablo Canyon, California. Poster Presentation at 2017 SCEC Annual Meeting.
7566 Shearer, P. M., Abercrombie, R. E., & Trugman, D. T. (2017, 08). Testing and Reconciling Stress Drop and Attenuation Models for Southern California. Poster Presentation at 2017 SCEC Annual Meeting.
7570 Inbal, A., Kong, Q., Allen, R. M., & Savran, W. H. (2017, 08). Earthquake Monitoring with the MyShake Global Smartphone Seismic Network. Poster Presentation at 2017 SCEC Annual Meeting.
7569 Glasscoe, M. T., Parker, J. W., & Donnellan, A. (2017, 08). Characterizing fault motion using edge detection in radar images. Poster Presentation at 2017 SCEC Annual Meeting.
7576 Ault, A. K., McDermott, R. G., Moser, A. C., & Evans, J. P. (2017, 08). Hematite nano- to micro-textures and (U-Th)/He thermochronometry inform seismic and aseismic fault damage zone processes. Poster Presentation at 2017 SCEC Annual Meeting.
7579 Khoshnevis, N., & Taborda, R. (2017, 08). An application of machine learning techniques to the evaluation of goodness-of-fit scores used in earthquake ground motion validation. Poster Presentation at 2017 SCEC Annual Meeting.
7580 Withers, K. B., & Moschetti, M. P. (2017, 08). 3D Dynamic Rupture Simulations along Dipping Faults, with a focus on the Wasatch Fault Zone, Utah. Poster Presentation at 2017 SCEC Annual Meeting.
7581 Qin, L., Ben-Zion, Y., & Vernon, F. L. (2017, 08). Ground motion coherence study in multiple distance ranges and frequency bands. Poster Presentation at 2017 SCEC Annual Meeting.
7583 Hirakawa, E. T., & Ma, S. (2017, 08). Effect of Undrained Gouge Plasticity on Rupture Dynamics of Rough Faults. Poster Presentation at 2017 SCEC Annual Meeting.
7578 Field, E. H., & WGCEP Participants, . (2017, 08). An Overview of the 3rd Uniform California Earthquake Rupture Forecast (UCERF3). Poster Presentation at 2017 SCEC Annual Meeting.
7590 Buyco, K., & Heaton, T. (2017, 08). 70%-damped spectral acceleration as a ground motion intensity measure for predicting highly nonlinear response of structures. Poster Presentation at 2017 SCEC Annual Meeting.
7582 Aslam, K., & Daub, E. G. (2017, 08). Modelling the spatio-temporal pattern of heterogeneous stresses and strain accumulation due to earthquake rupture on a geometrically complex fault. Poster Presentation at 2017 SCEC Annual Meeting.

7595 Hatem, A. E., & Dolan, J. F. (2017, 08). A model for the initiation, evolution and continued activity of the Garlock fault, California. Poster Presentation at 2017 SCEC Annual Meeting.
7596 Pekurovsky, D., Chourasia, A., Richards-Dinger, K. B., Shaw, B. E., Dieterich, J. H., & Cui, Y. (2017, 08). Performance enhancements and visualization for RSQSim earthquake simulator. Poster Presentation at 2017 SCEC Annual Meeting.
7604 Meng, H., Ben-Zion, Y., & McGuire, J. J. (2017, 08). Towards quasi-automated estimates of directivity and related source properties of small to moderate earthquakes with second seismic moments. Poster Presentation at 2017 SCEC Annual Meeting.
7601 Denolle, M. A., Boué, P., Beroza, G. C., & Hirata, N. (2017, 08). Seismic noise based ground motion: strong shaking predicted in Tokyo for the next M7+ earthquake on the Itoigawa-Shizuoka tectonic line.. Poster Presentation at 2017 SCEC Annual Meeting.
7609 Dorsett, J. H., Marshall, S. T., Madden, E. H., & Cooke, M. L. (2017, 08). Mechanical Models of Fault Slip Rates in the Imperial Valley, CA. Poster Presentation at 2017 SCEC Annual Meeting.
7610 da Silva, R. F., Callaghan, S., & Deelman, E. (2017, 08). On the use of burst buffers for accelerating data-intensive scientific workflows. Oral Presentation at International Conference for High Performance Computing, Networking, Storage and Analysis (SC 2017).
7614 Yu, C., Hauksson, E., Zhan, Z., & Cochran, E. S. (2017, 08). Depth Distribution of the 2010 El Mayor-Cucapah Earthquake Sequence (M>=4) Determined from Regional Waveform Modeling. Poster Presentation at 2017 SCEC Annual Meeting.
7611 Silva, F., Maechling, P. J., Goulet, C. A., & Jordan, T. (2017, 08). The SCEC Broadband Platform: Open-Source Software for Strong Ground Motion Simulation and Validation. Poster Presentation at 2017 SCEC Annual Meeting.
7617 Hauksson, E., & Meier, M. (2017, 08). Applying Paleo-earthquake Data to Query for Earthquake Gate Areas. Oral Presentation at 2017 SCEC Annual Meeting.
7615 Quackenbush, P., West, J., Clark, M., Zekkos, D., & Deepak, C. (2017, 08). Tectonic control on landsliding in the nepal himalaya revealed by the 2015 gorkha earthquake. Poster Presentation at 2017 SCEC Annual Meeting.
7597 Evans, W. S., Plesch, A., Lee, W., Pillai, N., Shaw, J. H., Meier, M., & Hauksson, E. (2017, 08). Implementing rapid, probabilistic association of earthquakes with source faults in the CFM for southern California. Poster Presentation at 2017 SCEC Annual Meeting.
7624 Giguere, A. (2017, 08). Natural Time and Earthquake Aftershock Entropy. Poster Presentation at 2017 SCEC Annual Meeting.
7623 Scharer, K. M., Burgette, R. J., Hanson, A., Lifton, N., Rittenour, T. M., & McPhillips, D. (2017, 08). Slip rate variation of the Central Sierra Madre fault, southern California over the past 200 ka. Poster Presentation at 2017 SCEC Annual Meeting.
7625 Rezaeian, S., Sun, X., Clayton, B., & Hartzell, S. (2017, 08). Estimation of Ground Motion Variability in the CEUS. Poster Presentation at 2017 SCEC Annual Meeting.
7607 Minson, S. E., Baltay, A. S., Cochran, E. S., Hanks, T. C., & Meier, M. (2017, 08). The Limits of Earthquake Early Warning. Oral Presentation at 2017 SCEC Annual Meeting.
7628 Gilchrist, J. J., Jordan, T. H., Shaw, B. E., Milner, K. R., Richards-Dinger, K. B., & Dieterich, J. H. (2017, 08). Conditional Probabilities of Large Earthquake Sequences in California from the Physics-based Rupture Simulator RSQSim. Poster Presentation at 2017 SCEC Annual Meeting.
7620 Hauksson, E., Meier, M., & Ross, Z. E. (2017, 08). Can the Depth Distribution of Seismicity be Applied to Probe the Rheology of the Seismogenic Crust in Southern California?. Poster Presentation at 2017 SCEC Annual Meeting.
7631 Levy, Y., Rockwell, T. K., Shaw, J. H., Plesch, A., Driscoll, N. W., & Perea, H. (2017, 08). Structural Architecture of the Western Transverse Ranges and Potential for Large Earthquakes – Trishear Forward Models . Poster Presentation at 2017 SCEC Annual Meeting.

7633 Borhara, K., Bradbury, K. K., & Evans, J. P. (2017, 08). Carbonaceous fault-related rocks in SAFOD Phase III core: Indicators of fluid-rock interaction and structural diagenesis during slip. Poster Presentation at 2017 SCEC Annual Meeting.

7636 Hernandez, A., Persaud, P., Bauer, K., Stock, J. M., Fuis, G. S., Hole, J. A., & Goldman, M. R. (2015, 09). Profile of Shallow Crustal Structure across the San Andreas Fault Zone, Coachella Valley based on Controlled-Source Data from the Salton Seismic Imaging Project (SSIP). Poster Presentation at SCEC Annual Meeting.

7599 Yu, E., Acharya, P., Bhaskaran, A., Chen, S., Andrews, J. R., Thomas, V., Hauksson, E., & Clayton, R. W. (2017, 08). Obspy, Web Services and Big Data – Using the Southern California Earthquake Data Center (SCEDC) and the Southern California Seismic Network (SCSN) Products and Services for Earthquake Research. Poster Presentation at 2017 SCEC Annual Meeting.

7639 Han, J., & Meng, L. (2017, 08). Time Reversal Imaging of the 2014 Iquique Tsunami Source. Poster Presentation at 2017 SCEC Annual Meeting.

7629 Miranda, E., Stewart, C., & Lourcey, K. (2017, 08). Grain boundary sliding triggers coeval pseudotachylyte development in brittle-ductile transition mylonites: an Electron Backscatter Diffraction (EBSD) case study of mid-crustal interseismic and coseismic deformation. Poster Presentation at 2017 SCEC Annual Meeting.

7641 Perea, H., Ucarkus, G., Driscoll, N. W., Kent, G. M., Levy, Y., & Rockwell, T. K. (2017, 08). New high-resolution seismic data reveals the Holocene active structures and deformation events in offshore Ventura basin, CA. Poster Presentation at 2017 SCEC Annual Meeting.

7642 Luttrell, K. M., & Hardebeck, J. L. (2017, 08). Borehole Breakouts Versus Earthquake Focal Mechanisms as Stress Field Orientation Indicators in Southern California: Should We Agree to Disagree?. Poster Presentation at 2017 SCEC Annual Meeting.

7638 Onderdonk, N. W., Farris, A., Tyler, E., Pytlewski, A. M., Garcia, A., & Mahan, S. A. (2017, 08). Strath terraces in the Santa Ynez Valley suggest late Quaternary activity on a detachment fault beneath the Western Transverse Ranges, California. Poster Presentation at 2017 SCEC Annual Meeting.

7644 Breuer, A. N., Heinecke, A., & Cui, Y. (2017, 08). Fused Seismic Simulations with the Discontinuous Galerkin Method at Extreme-Scale. Poster Presentation at 2017 SCEC Annual Meeting.

7646 Ajala, R., Persaud, P., Stock, J. M., Fuis, G. S., Hole, J. A., Goldman, M. R., & Scheirer, D. S. (2017, 08). 3-D Velocity Model of the Coachella Valley Determined Using P-Wave First Arrival Times from the Salton Seismic Imaging Project and Local Earthquakes. Poster Presentation at 2017 SCEC Annual Meeting.

7652 Schulte-Pelkum, V., Mueller, K., Brownlee, S. J., Becker, T. W., & Mahan, K. H. (2017, 08). Constraints on seismic anisotropy in ductile rock fabric and application to imaging fault roots in southern California . Poster Presentation at 2017 SCEC Annual Meeting.

7654 Dougherty, S. L., Cochran, E. S., & Harrington, R. M. (2017, 08). Large-N array observations of injection-induced seismicity in northern Oklahoma: the LASSO experiment. Poster Presentation at 2017 SCEC Annual Meeting.

7653 Shelly, D. R. (2017, 08). A 15-year catalog of more than 1 million low-frequency earthquakes: tracking tremor and slip along the deep San Andreas Fault. Poster Presentation at 2017 SCEC Annual Meeting.

7655 Kraner, M. L., Hammond, W. C., Kreemer, C., & Zaliapin, I. (2017, 08). Seasonal Variation of Strain in Central California and its Correlation with Seismicity. Poster Presentation at 2017 SCEC Annual Meeting.

7656 Gonzalez-Ortega, A., Vidal-Villegas, A., Ramon Morales, E., Valdez, A., & Arregui Ojeda, S. M. (2017, 08). Red Geodesica del Noroeste de Mexico (REGNOM) in northern Baja California.. Poster Presentation at 2017 SCEC Annual Meeting.

7657 Bydlon, S. A., Withers, K. B., & Dunham, E. M. (2017, 08). A Ground Motion Prediction Equation for Earthquakes Mw 4-6 in Oklahoma and Kansas Derived from a Composite Recorded/Simulated Ground Motion Catalog. Poster Presentation at 2017 SCEC Annual Meeting.

7661 Roten, D., Olsen, K. B., & Day, S. M. (2017, 08). Off-fault deformations and shallow slip deficit from dynamic rupture simulations with fault zone plasticity. Poster Presentation at 2017 SCEC Annual Meeting.

7667 Zhuang, J., Guo, Y., Murru, M., Falcone, G., & Tinti, E. (2017, 08). Clustering features of seismicity in Italy during 2005 to 2016. Poster Presentation at 2017 SCEC Annual Meeting.

7668 Lindvall, S. C., Kerwin, S., Evans, J. P., Tyson, J., Chestnut, J., Heron, C., Mass, K., Scharer, K. M., McPhillips, D., Moore, D., Farr, M., Ballard, C., Williams, R. T., Bradbury, K. K., Rowe, C. D., & Savage, H. M. (2017, 08). San Andreas Fault Characterization at the LADWP Elizabeth Tunnel. Poster Presentation at 2017 SCEC Annual Meeting.

7669 Lippoldt, R. C., & Sammis, C. G. (2017, 08). A Simple Spring-Mass-Dashpot Model for Slow Earthquakes on a Viscous Fault . Poster Presentation at 2017 SCEC Annual Meeting.

7671 Khoshmanesh, M., & Shirzaei, M. (2017, 08). Creep avalanches on San Andreas Fault and their underlying mechanism from 19 years of InSAR and seismicity. Poster Presentation at 2017 SCEC Annual Meeting.

7675 Wang, Y., Day, S. M., & Denolle, M. A. (2017, 08). Dynamic Rupture Models of the 2015 Mw7.8 Nepal Earthquake. Poster Presentation at 2017 SCEC Annual Meeting.

7674 Feng, T., & Meng, L. (2017, 08). Detecting small offshore earthquakes with Back-Projection Imaging and Match-filter Method. Poster Presentation at 2017 SCEC Annual Meeting.

7679 Li, G., & West, J. (2017, 08). Distribution of Earthquake-Triggered Landslides across Landscapes: Towards Understanding Erosional Agency and Cascading Hazards. Poster Presentation at 2017 SCEC Annual Meeting.

7681 Tymofyeyeva, E., & Fialko, Y. (2017, 08). Toward the 3-component time-dependent Crustal Motion Model: Integration of Sentinel-1 SAR interferometry and continuous GPS. Poster Presentation at 2017 SCEC Annual Meeting.

7683 Li, Y., Bürgmann, R., Yang, H., & Zhou, S. (2017, 08). Dynamic triggering of earthquakes north of Xiaojiang Fault, Yunnan. Poster Presentation at 2017 SCEC Annual Meeting.

7684 De Cristofaro, J., & Polet, J. (2017, 08). Towards an Understanding of the Geometry of the Hilton Creek Fault System Within the Long Valley Caldera, Using Ground-Based Magnetics and High-Resolution Topographic Profiles. Poster Presentation at 2017 SCEC Annual Meeting.

7689 Rhoades, D. A., Gerstenberger, M. C., Christophersen, A., & Harte, D. S. (2017, 08). Earthquake forecasts and their applications following the M7.8 2016 Kaikoura earthquake. Poster Presentation at 2017 SCEC Annual Meeting.

7692 Wang, N., Roten, D., Olsen, K. B., & Pechmann, J. (2017, 08). Rupture Direction, Basin, Distance and Hanging-wall Effects on Ground Motions from M7 Earthquakes on the Salt Lake City Segment of the Wasatch Fault, Utah. Poster Presentation at 2017 SCEC Annual Meeting.

7693 Liu, X., Beroza, G. C., & Nakata, N. (2017, 08). Separating non-diffuse component from ambient seismic noise cross-correlation in southern California. Poster Presentation at 2017 SCEC Annual Meeting.

7696 Murray, K. D., & Lohman, R. B. (2017, 08). InSAR and GPS time series analysis in areas with large scale hydrological deformation: separating signal from noise at varying length scales in the San Joaquin Valley. Poster Presentation at 2017 SCEC Annual Meeting.

7697 Maeda, T., Fujiwara, H., Hayakawa, T., Shimono, S., & Akagi, S. (2017, 08). Cluster analysis of the long-period ground-motion simulation data – application of the Nankai Trough megathrust earthquakes scenarios. Poster Presentation at 2017 SCEC Annual Meeting.

7698 Ferrarini, F., Lavecchia, G., de Nardis, R., Arrowsmith, R., Brozzetti, F., & Cirillo, D. (2017, 08). Exploring new seismic hazard scenarios in central Italy: hints about a previously unknown active normal fault highlighted by the Norcia 2016 (Mw 6.5) seismic sequence. Poster Presentation at 2017 SCEC Annual Meeting.

7699 Castillo Castellanos, J. A., Kohler, M. D., Massari, A. T., & Clayton, R. W. (2017, 08). Complex Rayleigh Wave Effects on the Seismic Demands of Mid-Rise Buildings. Poster Presentation at 2017 SCEC Annual Meeting.

7701 Burgi, P., & Lohman, R. B. (2017, 08). The effect of InSAR time series generation techniques on signals with small spatial scales. Poster Presentation at 2017 SCEC Annual Meeting.

7702 Chapman, A. D. (2017, 08). The Pelona–Orocopia–Rand and related schists of southern California: a review of the best-known archive of shallow subduction on the planet. Poster Presentation at 2017 SCEC Annual Meeting.

7703 Materna, K., Taira, T., & Bürgmann, R. (2017, 08). Measuring Aseismic Slip through Characteristically Repeating Earthquakes at the Mendocino Triple Junction . Poster Presentation at 2017 SCEC Annual Meeting.

7704 Hutchison, A. A., & Ghosh, A. (2017, 08). Ambient tectonic tremor in the San Jacinto Fault. Poster Presentation at 2017 SCEC Annual Meeting.

7705 Meier, M., Ampuero, J., & Heaton, T. H. (2017, 08). What does an 'average' large subduction earthquake look like?. Poster Presentation at 2017 SCEC Annual Meeting.

7706 Boyd, O. S., Thompson, E. M., Shumway, A., Moschetti, M. P., Stephenson, W. J., & Rezaeian, S. (2017, 08). Basin ZX Maps for use in the USGS National Seismic Hazard Model for the Western United States. Poster Presentation at 2017 SCEC Annual Meeting.

7710 Luo, B., & Duan, B. (2017, 08). Dynamics of Non-planar Thrust Faults Governed by Various Friction Laws. Poster Presentation at 2017 SCEC Annual Meeting.

7709 Vierra, E. J., Webb, H. N., Dennis, K., Peppard, D. W., Girty, G. H., & Rockwell, T. K. (2017, 08). Recognition of a dismembered positive flower structure along the San Jacinto fault: Stratigraphic and structural implications. Poster Presentation at 2017 SCEC Annual Meeting.

7711 Mu, D., Cicotti, P., & Cui, Y. (2017, 08). Manage I/O Task in a Normalized Cross-Correlation Earthquake Detection Code for Large Seismic Datasets. Poster Presentation at 2017 SCEC Annual Meeting.

7713 Alvarez, K., & Polet, J. (2017, 08). Measurements of Ground-Based Magnetics and Vertical Deformation From a Leveling Line Across the San Andreas Fault at Durmid Hill. Poster Presentation at 2017 SCEC Annual Meeting.

7712 Badt, N. Z., Tullis, T. E., & Hirth, G. (2017, 08). Experimental Study of Thermal Pressurization Weakening and the Role of Fault Roughness. Poster Presentation at 2017 SCEC Annual Meeting.

7716 Stein, R. S., Sevilgen, V., Jacobson, D., Kim, A., & Lotto, G. C. (2017, 08). Temblor, an app to transform seismic science into personal risk reduction. Poster Presentation at 2017 SCEC Annual Meeting.

7714 Zhan, Z., Yu, C., Hauksson, E., & Cochran, E. S. (2017, 08). Strong SH-to-Love Wave Scattering off the Southern California Continental Borderland. Poster Presentation at 2017 SCEC Annual Meeting.

7720 Qiu, H., Ben-Zion, Y., & Lin, F. (2017, 08). Eikonal Tomography of the Southern California Plate Boundary Region. Poster Presentation at 2017 SCEC Annual Meeting.

7719 Singleton, D. M., Rockwell, T. K., Murbach, M., Murbach, D., Maloney, J. M., Levy, Y., Marquez, E., & Weidman, L. (2017, 08). Late-Holocene Earthquakes on the Rose Canyon Fault at Old Town, San Diego CA. Poster Presentation at 2017 SCEC Annual Meeting.

7722 Kiuchi, R., Mooney, W. D., Mori, J., Zahran, H. M., AlRaddadi, W., & Youssef, S. (2017, 08). Developing ground motion prediction equations for western Saudi Arabia using an adjustment of a reference model. Poster Presentation at 2017 SCEC Annual Meeting.

7725 Callaghan, S., Maechling, P. J., Goulet, C. A., Milner, K. R., Graves, R. W., Olsen, K. B., & Jordan, T. H. (2017, 08). CyberShake: bringing physics-based PSHA to central California. Poster Presentation at 2017 SCEC Annual Meeting.

7729 Yoshimitsu, N., Ellsworth, W. L., Beroza, G. C., & Schoenball, M. (2017, 08). Two years stress drop estimates for induced earthquakes in Oklahoma. Poster Presentation at 2017 SCEC Annual Meeting.

7732 Savran, W. H., Olsen, K. B., & Day, S. M. (2017, 08). Generating 10 Hz deterministic broadband ground motions using kinematic source descriptions. Poster Presentation at 2017 SCEC Annual Meeting.

7718 Davis, P. M. (2017, 08). How Much Concentrated Earthquake Damage is due to Site Effects Versus Basin Edge Focusing?. Poster Presentation at 2017 SCEC Annual Meeting.

7728 Determan, D. N., Aspiotes, A. G., Guillemot, C., Langbein, J. O., Murray, M., Alvarez, M., & Stark, K. F. (2017, 08). USGS Global Positioning System (GPS) Network in Southern California. Poster Presentation at 2017 SCEC Annual Meeting.

7735 Nicholson, C., Plesch, A., & Shaw, J. H. (2017, 08). Community Fault Model Version 5.2: Updating & expanding the CFM 3D fault set and its associated fault database. Poster Presentation at 2017 SCEC Annual Meeting.

7741 Saunders, J. K., & Haase, J. S. (2017, 08). Improving static slip characterization of near-shore earthquakes with amphibious datasets: A Cascadia example. Poster Presentation at 2017 SCEC Annual Meeting.

7740 Chen, Q., & Elbanna, A. E. (2017, 08). The material-geometry nexus: Understanding topographic effects on wave propagation. Poster Presentation at 2017 SCEC Annual Meeting.

7724 Axen, G., Soundy, K., & Leuth, V. (2017, 08). Comparison of fault rocks formed paleoseismically and by paleocreep(?): Initial results from the West Salton detachment fault, southern California. Poster Presentation at 2017 SCEC Annual Meeting.

7739 Lin, Y., & Jordan, T. H. (2017, 08). Attenuation Tomography at High Frequencies in Southern California. Poster Presentation at 2017 SCEC Annual Meeting.

7730 Wooddell, K. E., & Abrahamson, N. A. (2017, 08). Methodology for Incorporation of 3-D Simulation Results into Non-Ergodic Ground-Motion Models for Central California. Poster Presentation at 2017 SCEC Annual Meeting.

7746 Taborda, R., & Isbiliroglu, Y. D. (2017, 08). Influence of Buildings Spacing in Site-City Interaction Effects. Poster Presentation at 2017 SCEC Annual Meeting.

7745 Pierce, I., Wesnousky, S. G., & Owen, L. A. (2017, 08). Terrestrial cosmogenic surface exposure dating of moraines at Lake Tahoe in the Sierra Nevada, California, and slip rate estimate for the West Tahoe fault.. Poster Presentation at 2017 SCEC Annual Meeting.

7748 Grant Ludwig, L., Donnellan, A., & Parker, J. W. (2017, 08). Using GeoGateway Line-of-Sight (LOS) Tool to Explore Deformation along the San Andreas Fault in the Carrizo Plain, CA. Poster Presentation at 2017 SCEC Annual Meeting.

7749 Yoon, C., Bergen, K., Rong, K., Elezabi, H., Bailis, P., Levis, P., & Beroza, G. C. (2017, 08). Efficient blind search for small similar-waveform earthquakes in a decade of continuous seismic data (2007-2017) in coastal central California . Poster Presentation at 2017 SCEC Annual Meeting.

7753 Schoenberg, F. P., & Molyneux, J. (2017, 08). Nonparametric Hawkes models with strike angle covariates. . Poster Presentation at 2017 SCEC Annual Meeting.

7752 Pritchard, E. H., Persaud, P., & Stock, J. M. (2017, 08). Using Borehole Breakouts in Deviated Offshore Wells to Constrain Stress Regimes Beneath The Santa Barbara Channel, Offshore Southern California. Poster Presentation at 2017 SCEC Annual Meeting.

7742 Walker, R. L., Kumar, A., Hammack, R., Dressel, B., Harbert, W., & Aminzadeh, F. (2017, 08). Identifying Long Period Long Duration Events Spatially Associated With Hydraulic Stimulation Operations. Poster Presentation at 2017 SCEC Annual Meeting.

7686 Ortega-Arroyo, D., Behr, W. M., & Gentry, E. (2017, 08). The rock record of seimic nucleation: a case study from the Whipple Mountains Detachment Fault, eastern California. Poster Presentation at 2017 SCEC Annual Meeting.

7747 Harris, R. A. (2017, 08). Large Earthquakes and Creeping Faults. Poster Presentation at 2017 SCEC Annual Meeting.

7759 Ahamed, S., & Daub, E. G. (2017, 08). A Machine Learning Approach to Earthquake Rupture Dynamics. Poster Presentation at 2017 SCEC Annual Meeting.

7758 Li, B., Ghosh, A., Thurber, C. H., & Lanza, F. (2017, 08). Continuous Tremor in the Alaska-Aleutian Subduction Zone Detected by Aleutian Array of Arrays. Poster Presentation at 2017 SCEC Annual Meeting.

7760 Graves, R. W. (2017, 08). Ground-Motion Simulations on Rough Faults in Complex 3D Media. Poster Presentation at 2017 SCEC Annual Meeting.

7757 Chaudhuri, K., & Ghosh, A. (2017, 08). Tectonic tremor in San Andreas Fault near Cholame captured by a mini seismic array. Poster Presentation at 2017 SCEC Annual Meeting.

7766 Liu, Z., Shen, Z., Liang, C., & Lundgren, P. (2017, 08). Integration of InSAR and GPS data for 3-dimensional crustal deformation mapping. Poster Presentation at 2017 SCEC Annual Meeting.

7761 McNeil, J. C., Yule, D., Scharer, K. M., McGill, S. F., McPhillips, D., Castillo, B. A., & Pace, A. (2017, 08). Assessing stratigraphic correlations and fault zone extent at the 18th Ave trench site, Banning strand of the San Andreas Fault, North Palm Springs, California. Poster Presentation at 2017 SCEC Annual Meeting.

7771 Angster, S. J., Wesnousky, S. G., Owen, L. A., Figueiredo, P. M., & Hammer, S. (2017, 08). Quaternary Rates of Slip for faults of the Central Walker Lane. Poster Presentation at 2017 SCEC Annual Meeting.

7764 Lin, F., Berg, E., Allam, A. A., Qiu, H., Wang, Y., & Ben-Zion, Y. (2017, 08). Shallow crustal imaging in Southern California using ambient noise and fault zone trapped waves. Poster Presentation at 2017 SCEC Annual Meeting.

7774 Crempien, J. G., & Archuleta, R. J. (2017, 08). Seismic source and path parameters in Central California estimated with recorded ground motion. Poster Presentation at 2017 SCEC Annual Meeting.

7777 Donnellan, A., Parker, J. W., Granat, R. A., Heflin, M. B., Rundle, J. B., Grant Ludwig, L., Pierce, M. E., & Wang, J. (2017, 08). Northwest Propagation of Postseismic Deformation in the Yuha Desert from the 2010 M7.2 El Mayor – Cucapah Earthquake. Poster Presentation at 2017 SCEC Annual Meeting.

7775 Kendrick, K. J., & Matti, J. C. (2017, 08). Geomorphic and geologic evidence for slip along the San Bernardino strand of the San Andreas Fault System through the San Gorgonio Pass structural knot, southern California. Poster Presentation at 2017 SCEC Annual Meeting.

7778 Ye, L., Lapusta, N., & Avouac, J. (2017, 08). Dynamic Stress Changes during the 2015 Gorkha, Nepal Earthquake. Poster Presentation at 2017 SCEC Annual Meeting.

7772 Wolfe, F. D., Dolan, J. F., Plesch, A., & Shaw, J. H. (2017, 08). Activity and earthquake potential of the Wilmington blind thrust, Los Angeles, CA: The largest earthquake source not on current southern California hazard maps?. Poster Presentation at 2017 SCEC Annual Meeting.
7767 Chamlagain, D., Wesnousky, S. G., Kumahara, Y., Pierce, I., Reedy, T. J., Angster, S. J., & Giri, B. (2017, 08). Large paleoearthquake timing and displacement near Damak in eastern Nepal on the Himalayan Frontal Thrust. Poster Presentation at 2017 SCEC Annual Meeting.
7781 Scott, C. P., Arrowsmith, R., Lajoie, L. J., Nissen, E., Maruyama, T., & Tatsuro, C. (2017, 08). The M7 2016 Kumamoto, Japan, Earthquake: 3D coseismic deformation from differential topography. Poster Presentation at 2017 SCEC Annual Meeting.
7789 Sudhir, K., & Lapusta, N. (2017, 08). Slip Patterns on Rate-and-State Faults with Heterogeneous Velocity-Weakening and Velocity-Strengthening Friction. Poster Presentation at 2017 SCEC Annual Meeting.
7786 Lin, Y., & Lapusta, N. (2017, 08). Comparison of actual and seismologically inferred stress drops in asperity-type dynamic source models of microseismicity. Poster Presentation at 2017 SCEC Annual Meeting.
7790 Lambert, V. R., & Lapusta, N. (2017, 08). Implications of depth-dependent variations in fault zone properties for the frequency content of seismic radiation. Poster Presentation at 2017 SCEC Annual Meeting.
7782 Best Mckay, M., & Erickson, B. A. (2017, 08). Incorporating anisotropic material properties into simulations of the earthquake cycle . Poster Presentation at 2017 SCEC Annual Meeting.
7792 Hernandez, S. (2017, 08). The seismological aftermath of the 2016 Mw7.8 Pedernales, Ecuador earthquake. Poster Presentation at 2017 SCEC Annual Meeting.
7795 Kyriakopoulos, C., Oglesby, D. D., Meltzner, A. J., Rockwell, T. K., & Barall, M. (2017, 08). Can the Southern San Andreas Fault be Triggered by Cross-Fault Earthquakes?. Poster Presentation at 2017 SCEC Annual Meeting.
7798 Jiang, J., & Fialko, Y. (2017, 08). Earthquake variability, geodetic coupling, and microseismicity on heterogeneous faults: A case study of the Anza seismic gap. Poster Presentation at 2017 SCEC Annual Meeting.
7796 Buehler, J., Kilb, D., Vernon, F. L., Wang, W., & Shearer, P. M. (2017, 08). Focal mechanism effects on S/P amplitude ratios in southern California. Poster Presentation at 2017 SCEC Annual Meeting.
7794 Nie, S., Roten, D., Olsen, K. B., & Day, S. M. (2017, 08). Fourth-Order Staggered-Grid Finite-Difference Seismic Wavefield Estimation Using a Discontinuous Mesh Interface (WEDMI). Poster Presentation at 2017 SCEC Annual Meeting.
7803 Reedy, T. J., & Wesnousky, S. G. (2017, 08). Toward characterizing extension and Quaternary faulting on the Pleasant Valley fault, Central Nevada. Poster Presentation at 2017 SCEC Annual Meeting.
7800 Meng, L., & Feng, T. (2017, 08). Improving Distance Metrics in Ground Motion Prediction Equations Based with Seismic Array Back-Projections. Poster Presentation at 2017 SCEC Annual Meeting.
7801 Weiser, D., Porto, N. B., & Jackson, D. D. (2017, 08). Can maximum magnitude be derived from fault dimensions?. Poster Presentation at 2017 SCEC Annual Meeting.
7797 Baltay, A. S., Ellsworth, W. L., Schoenball, M., & Beroza, G. C. (2017, 08). Proposed Community Stress Drop Validation Experiment. Poster Presentation at 2017 SCEC Annual Meeting.
7804 Gontz, A. M., Rockwell, T. K., Karlsson, K. W., Fletcher, J. M., & Cambron, J. F. (2017, 08). GPR imagery and identification of neotectonic features of the Chupamiertos Fault System, Baja California, Mexico. Poster Presentation at 2017 SCEC Annual Meeting.

7808 Abercrombie, R. E., Ruhl, C. J., & Smith, K. D. (2017, 08). Detailed observations of seismicity, stress drop and directivity on a complex fault structure in Mogul Nevada. Poster Presentation at 2017 SCEC Annual Meeting.
7783 Peshette, P. L., Lozos, J. C., & Yule, D. (2017, 08). Dynamic rupture modeling of thrust faults with parallel surface traces.. Poster Presentation at 2017 SCEC Annual Meeting.
7809 Cui, Y., Mu, D., & Roten, D. (2017, 08). SEISM-IO: A High Level Parallel I/O Library for High-Performance Seismic Applications. Poster Presentation at 2017 SCEC Annual Meeting.
7690 Hu, Z., & Olsen, K. B. (2017, 08). Testing the Density of Seismic Networks with ShakeMap. Poster Presentation at 2017 SCEC Annual Meeting.
7811 Keen-Zebert, A. (2017, 08). Luminescence dating for paleoseismic research: What users need to know. Poster Presentation at 2017 SCEC Annual Meeting.
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