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**Title:** **Tsunami Source Standardization for Hazards Mitigation in the United States**

*Short title:* Tsunami Source Synthesis

*Principal investigator:*

Stephanie L. Ross, U.S.G.S.

[sross@usgs.gov](mailto:sross@usgs.gov), Office: 650-329-5326; cell: 650-533-0114,  
345 Middlefield Road, MS-999, Menlo Park, CA 94025

Marie Eble, National Oceanic and Atmospheric Administration (NOAA)

[marie.c.eble@noaa.gov](mailto:marie.c.eble@noaa.gov)

Office: 206.526.6805

7600 Sand Point Way NE, Seattle, WA 98115

Dmitry J. Nicolovsky, Univ. of Alaska, Fairbanks

[djnicolovsky@alaska.edu](mailto:djnicolovsky@alaska.edu)

Office: 907-474-7397

903 Koyukuk Dr., Geophysical Institute, Univ. of Alaska, Fairbanks, AK, 99709

Rick Wilson, California Geological Survey (CGS)

[Rick.wilson@conservation.ca.gov](mailto:Rick.wilson@conservation.ca.gov)

Office: 916-327-0981; cell: 916-261-8143

801 K Street, MS 12-31, Sacramento, CA 95814

*Project summary:* This Powell Center Working Group will produce a collection of vetted and standardized earthquake and landslide tsunami sources, a high priority request from our partners in the U.S. coastal states and territories, all of which are vulnerable to tsunamis. This work transfers decades of USGS research on subduction zone earthquakes and coastal landslides, along with expertise on tsunami modeling to the mitigation community. The workshops will start by addressing the scientific question of how increasing sophistication in tsunami source models impacts products such as evacuation plans, mitigation of damage, and land-use planning. We will then synthesize existing geological and geophysical knowledge of submarine earthquake faults and coastal landslide sources to produce a database of source models for use in creating hazards assessments for risk reduction. Tsunamis cross oceans, so providing our sources to the developing Global Tsunami Model means that our work will have a global impact.

*Proposed start and end dates:* October 1, 2017 to September 30, 2019

*Number and duration (4 day minimum) of Working Group:* 5 workshops of 4 days each.

*Proposed data release date:* September 30, 2019

*Total requested budget:* total \$212,535; year 1 \$42,050; year 2 \$170,485

*Is this a resubmission?:* No

*Conflicts of interest with reviewers:* None

*Keyword(s):* natural hazards

## Statement of Problem

Both earthquakes and landslides cause tsunamis; tsunami hazard assessment therefore relies on having good information about potential earthquake and landslide sources. The goal of this Powell Center Working Group is to produce a collection of vetted and standardized earthquake and landslide tsunami sources that can be used to produce the meaningful hazard assessment products required for effective tsunami hazard mitigation and risk reduction. The process of analyzing these vetted sources would include: 1) determination of various tsunami hazard planning efforts (evacuation, mitigation, land-use, etc.) and U.S. regions in need of standardized sources; 2) evaluation of existing tsunami sources used in tsunami hazard products; and 3) characterization of the sources in both a deterministic and probabilistic sense which meets the needs of tsunami hazard planning efforts. Within the U.S., the states, territories, and National Oceanographic and Atmospheric Administration (NOAA) look to the USGS for authoritative judgments on tsunami sources because we have expertise on geology, tectonics, and earthquake and landslide source processes that many of these groups lack.

Tsunamis are rare but extreme events that have caused devastation worldwide over the past several decades. The tsunami from the 2004 Indonesian earthquake killed over 230,000 people in 14 different countries. Over 18,000 people were either killed or remain missing after the tsunami caused by the 2011 Tohoku-Oki earthquake. The 2011 tsunami is also considered the costliest natural disaster by the World Bank at \$235 billion, and led to the nuclear disaster at the Fukushima Power Plant.

Likewise, all U.S. coastal states and territories are vulnerable to tsunamis. For example, the area from northern California to British Columbia is under the threat of a massive (M9) local earthquake and tsunami from the Cascadia subduction zone, which has ruptured 19 times in the last 10,000 years with the most recent rupture in 1700. More recently, 165 people in Hawaii, Alaska and California lost their lives in the 1946 tsunami generated by an earthquake near the Aleutian Islands. An earthquake in 1918 off the coast of Puerto Rico caused a tsunami that took 40 lives there. In 1958, a magnitude 7.7 earthquake in southeast Alaska caused a rockfall in Lituya Bay that generated a wave with a maximum height of 1720 feet, the world's largest recorded tsunami. The fourth largest recorded tsunami happened very recently, and without a large earthquake. In October, 2015, a mountainside collapsed into a fjord of Icy Bay, Alaska, creating a wave that sheared trees more than 500 feet up the hillside; if this had occurred at a different time of year, when boats fish that area, there would have been loss of life. Even without notable inundation of dry land in California, the 2010 Chilean and 2011 Tohoku tsunamis caused damages totaling nearly \$100 million to dozens of harbors (Wilson and others, 2012).

The assessment of tsunami hazards is an important part of the USGS Natural Hazards Science Strategy (Holmes and others, 2013). This Working Group will address the following USGS priorities:

- To identify and characterize tsunami sources, such as earthquake faults, volcanoes, and landslides;
- To assess tsunami sources and hazards and model tsunami generation; and,

- To improve understanding of how tsunamis are generated and determine probabilities of tsunami hazards in different regions of the U.S.

Tsunami work at the USGS spans five different Programs and six Science Centers. However, without a primary Program or Science Center overseeing this work, there is not support staff or funding for a comprehensive project to synthesize key results. Thus, the proposed Powell Center support will provide the necessary catalyst for this synthesis to take place. Furthermore, it will allow the USGS to leverage decades of research on subduction zone earthquakes and coastal landslides, along with expertise on tsunami modeling. This will ensure that we fulfill the practical goals of the USGS Natural Hazards Mission.

As previously mentioned, great tsunamis are rare but very destructive events. Because destructive tsunamis occur infrequently, our historical tsunami records are relatively short, and in most locations do not reveal the level of hazard we need to prepare for. In this way, tsunamis are qualitatively different than, for example, floods or cyclones, for which destructive events are more likely to be well represented in regional historical records and provide a useful reference for understanding the hazard. This ‘low frequency / high impact’ property introduces considerable uncertainty into assessments of tsunami hazard in most locations, which should be carefully accounted for in tsunami risk assessments. Recent history highlights that it is all too easy to underestimate these uncertainties, as the most intense tsunami impacts of both the 2004 Indian Ocean tsunami and the 2011 Tohoku tsunami were not widely anticipated or integrated into disaster management plans. We must try to do better.

For example, the USGS’ Science Applications for Risk Reduction (SAFRR) Tsunami Scenario (Ross et al., 2013a,b) showed that a hypothetical but plausible tsunami generated by an earthquake offshore of the Alaska Peninsula could cause ten billion dollars of damage in California and require evacuating three-quarters of a million people. The Scenario was a collaborative effort between the USGS, NOAA, the California Governor’s Office of Emergency Services, the California Geological Survey, and many other organizations (the 13-chapter report included 60 authors and 170 other contributors from 72 from organizations). It presents a comprehensive view of the impact of this one source including the modeled inundation areas, current velocities in key ports and harbors, physical damage and repair costs, environmental and environmental health impacts, impacts to ecosystems, economic consequences, social vulnerability, emergency management, and policy implications for California associated with the scenario tsunami.

The intended Tsunami Scenario users are those who need to make mitigation decisions before future tsunamis, and those who will need to make rapid decisions during tsunami events. Among others, these include emergency managers, maritime authorities, first responders, elected officials and staffers, the business sector, state agencies, local media, scientific partners, and special districts such as utilities. The scenario provided the basis for many exercises involving, among others, NOAA, the National Institutes of Health, the Bank of America, several counties in California, and the State of Washington. The SAFRR Tsunami Scenario has already yielded positive outcomes. In areas where the scenario inundation exceeds the State’s maximum inundation zone, emergency managers have been notified and evacuation plans have been updated appropriately. And, based on issues identified in the scenario, the State of California has

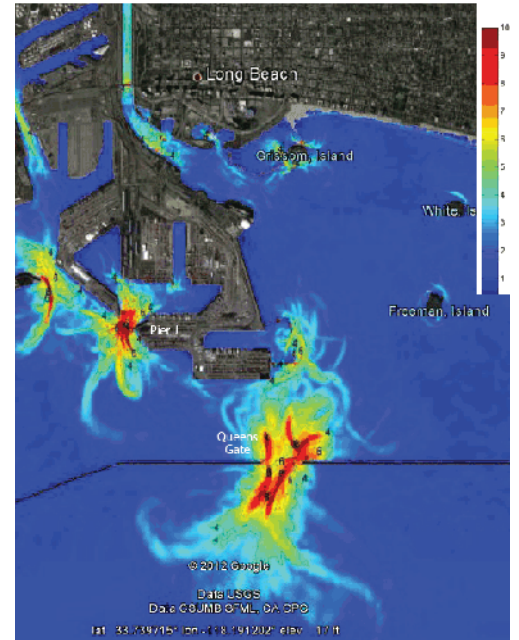
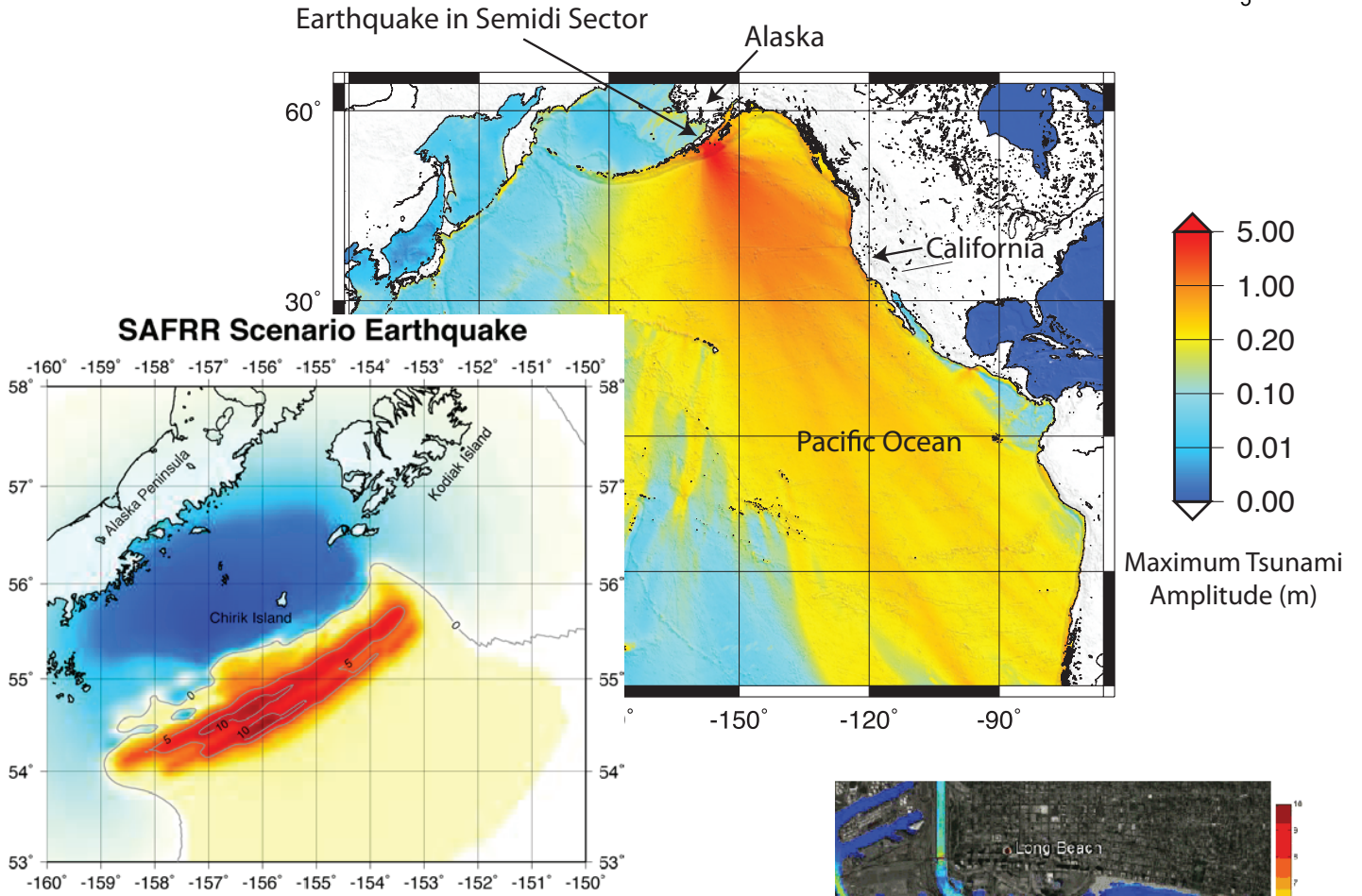
worked with NOAA's National Tsunami Warning Center to modify message protocols to facilitate effective evacuations in California.

Hazard scenarios provide emergency managers and others with information to help them prepare for future disasters. One complicated and important aspect of any hazard scenario is defining the source event. The source earthquake for the SAFRR Tsunami Scenario had to be geologically plausible and have the potential to create a damaging tsunami along the California coast and especially at the economically critical ports of Los Angeles and Long Beach. The Semidi sector (Figure 1), along the Alaska Peninsula segment of the Aleutian-Alaska subduction zone was selected because it is the source of great earthquakes that are best oriented to send tsunami waves toward southern California. Having selected the Semidi sector, the next step was to create the spatial pattern of slip in the earthquake. Because of geometric and geological similarities between the Semidi sector and the Tohoku margin in northeastern Japan, we chose a slip pattern that mimicked the 2011 Tohoku earthquake, which produced a devastating tsunami. Using the slip pattern from that earthquake also made sense because it is the best-characterized giant earthquake and tsunami source in history.

The entire process of choosing the source, and translating it into a form that could be used by the tsunami modeling programs, involved input from 35 people over a period of about 2 years (Kirby et al., 2013). This intensive effort was reasonable for a scenario that covered a broad range of tsunami impacts in great detail.

The states and territories vulnerable to tsunamis need to make accurate plans to mitigate the hazard. They do this by developing products such as tsunami inundation (e.g. Nicolsky et al., 2011, 2013; Walsh et al., 2005) and evacuation maps (e.g. Puerto Rico Seismic Network Tsunami Program, 2017), tsunami "playbooks" (evacuation and maritime guidance plans for dealing with tsunamis of various sizes and source locations) (e.g. Wilson and Miller, 2014; Wilson et al., 2016; Wood et al., 2016), and probabilistic tsunami hazards assessments (e.g. Thio et al, 2010) that require evaluating the tsunami waves, inundation, and currents from many sources. The need to model the many sources that affect the entire coastline of the United States precludes the sort of intensive effort used to define the single tsunami source for the SAFRR tsunami scenario. The goal of this Powell Center Working Group is to create an efficient process for defining hypothetical tsunami sources and then carry it out for earthquake and landslide source zones that can create tsunamis that will impact the U.S.

The beginning of this effort was a tsunami source and hazard mapping workshop in January 2016, partly funded by the USGS National Hazards Mission Area, between USGS scientists and the National Tsunami Hazards Mitigation Program (NTHMP). The NTHMP is a consortium of a scientist and an emergency manager from each of the U.S. States and Territories that have tsunami risk, and is managed by NOAA. During the 2016 workshop, we identified a number of possible collaborations between the USGS and NTHMP members, with the highest priority being placed on defining a set of realistic and consistent tsunami sources.



Currents in the Port of Long Beach (knots)



Inundation Map of Huntington Beach, California

Figure 1. This Powell Center Group will focus on producing a collection of vetted tsunami sources to enable modeling to produce useful mitigation products such as inundation maps and current velocities in ports and harbors. Examples from the SAFRR Tsunami Scenario include the earthquake source shown as vertical deformation of the seafloor, models of transoceanic tsunami propagation, resulting in currents in the Port of Long Beach, and an inundation map of Huntington, Beach, California.

## Proposed Activities

One of the first steps for the proposed Powell Center Working Group is to define what we need to know about each earthquake source in order to produce meaningful mitigation products. An earthquake source is defined by the orientation and endpoints of the fault along which slip takes place, the point at which slip initiates (the earthquake hypocenter), the spatial pattern of slip on that fault, the time over which slip propagates from the hypocenter, and the duration of slip at each point on the fault. Slip patterns can range from very simple (constant slip over the fault plane), to complex but pre-defined patterns, to stochastic models that are random but produce realistic looking slip patterns, to complex dynamic rupture models that start with a fault's frictional/material properties and the forces imposed on it and then compute the slip pattern using the physics of fault rupture. Part of the SAFRR Scenario involved investigating different frictional and force parameters along the fault, with each parameterization ultimately resulting in significant differences in local tsunami amplitude and wave patterns (Ryan et al., 2013). Such analysis is still in its infancy, and therefore more work is needed to assess the impact of such modeling on tsunami hazards.

The more complex methods are more realistic but are also increasingly computationally intensive. A first step for this process is to determine how much increasing complexity improves tsunami hazards mitigation. A key team member for that step is Kenny Ryan, currently a USGS Mendenhall Postdoctoral Fellow in the Pacific Coastal and Marine Science Center working on dynamic rupture models for tsunami modeling, work he began for his thesis as part of the SAFRR Tsunami Scenario and models of other tsunami sources (Ryan et al., 2015). The use of dynamic rupture models for tsunami modeling is rare and thus he is uniquely capable of calculating and comparing these complex models with simpler sources. For the Working Group, Kenny would be a Powell Center Fellow, extending his time at the USGS to work on these problems.

Along with earthquakes, the working group will also consider landslide sources (e.g. Chaytor et al., 2009; Geist et al., 2009; Grilli et al., 2009, ten Brink et al., 2009). Tsunamis can be caused by both subaerial landslides that fall into the water and by submarine landslides that occur below the water surface. Identifying possible landslide source regions is done by using topography, bathymetry, and geologic mapping to locate past landslide sources and evaluate steep areas of materials prone to failure in the future. David George at the USGS Cascades Volcano Observatory is an expert on modeling landslide driven tsunamis and will advise the group on the information required to represent a landslide source for accurate modeling.

The first workshop will focus on the question of how to best create, represent, and store the standardized earthquake and landslide sources of tsunamis. The ensuing workshops will focus on implementing these processes for different regions, including: 1) Alaska-Aleutian Islands; 2) the rest of the Pacific Ocean including the Pacific Northwest; 3) the Caribbean; and 4) the East Coast of the U.S. and the Gulf of Mexico. The experts on each region will provide the data needed to define tsunami sources, including the USGS Slab1.0/2.0 models (Hayes et al., 2012), which give the geometry of subduction zone faults that produce the large earthquakes that cause most tsunamis. We can start with standard subduction zone fault models, including those used

by the National Seismic Hazard Maps, but may need to modify them, especially in the shallow parts of the source zones that are critical to tsunami generation.

### Participants:

We have a large group of participants broken into a core group of 9 people that will attend every workshop and a larger group of people with topical or regional expertise that will generally attend only one or two workshops. Some members of the Working Group will provide input without attending any of the workshops. This approach allows us to have small, effective workshops, while benefitting from the input of a wide range of experts.

For workshops that slightly exceed 15 people, we will use travel funding from the USGS Earthquake Science Center's Tsunami Source Working Group (TSWG) and possibly from NOAA. Note: the Tsunami Source Working Group is a small task within the Earthquake Science Center's Earthquake Processes and Probabilities Project and does not have the resources for this sort of broad synthesis effort.

\* = *confirmed*

+ = *core group who will attend all workshops, other people will come to specific workshops based on their regional expertise.*

\*\* = *confirmed to provide input. Might not attend workshops.*

<b>Participant</b>	<b>Expertise and/or Role</b>
*+Stephanie Ross, USGS, Menlo Park, CA	<b>PI</b> ; Geophysicist; Tsunami Scenarios Coordinator, Science Application for Risk Reduction (SAFRR)
*+Marie Eble, NOAA, Pacific Marine Environmental Laboratory (PMEL), Seattle, WA	<b>PI</b> ; Oceanographer, Co-chair of NTHMP Mapping and Modeling Subcommittee
*+Dmitry Nicolsky, University of Alaska, Fairbanks	<b>PI</b> ; Tsunami Modeler; Alaska NTHMP Science Representative, Co-chair of NTHMP Mapping and Modeling Subcommittee
*+Rick Wilson, California Geological Survey	<b>PI</b> ; Engineering Geologist; CGS Tsunami Program Lead, California NTHMP Science Representative,
*+Kenny Ryan, USGS, Menlo Park, CA	<b>Powell Center Fellow</b> ; Geophysicist, Dynamic modeling of earthquakes and tsunamis
*+Hong Kie Thio, AECOM (consulting company)	Seismologist, tsunami modeler; Global Tsunami Model representative
*+Paula Dunbar, NOAA, National Centers for Environmental Information (NCEI)	Manages distribution and archive of historical tsunami events, significant earthquake, and significant volcanic eruptions databases.
*+Walter Mooney, USGS, Menlo Park, CA	Geophysicist; Coordinator, USGS Tsunami Source Working Group
+Florence Wong, USGS, Menlo Park, CA	GIS expert
**Eric Geist, USGS, Menlo Park, CA	Tsunami modeling
*Paul Whitmore, NOAA, NTWC, Palmer, AK	Director, National Tsunami Warning Center
*Chip McCreary, NOAA, PTWC, Ewa Beach, HI	Director, Pacific Tsunami Warning Center

*Ruth Harris, USGS, Menlo Park, CA	Earthquake source rupture modeling
*Gavin Hayes, USGS, Golden, CO	Global earthquake seismology and seismic monitoring, leader of Slab1.0/2.0 model
*Guy Gelfenbaum, USGS, Santa Cruz, CA	Geological Oceanography; Tsunami sediment deposits; Director, Pacific Coastal and Marine Science Center
Diego Arcas, NOAA PMEL, Seattle, WA	Tsunami Scientist; Director, Pacific Marine Environmental Laboratory (PMEL)
*Kara Gately, NOAA, National Tsunami Warning Center, Palmer, AK	Expertise in operational tsunami forecasting improvements, tsunami early warning
Art Frankel, USGS, Seattle, WA	Seismologist, earthquake hazards expert, Pacific Northwest/Cascadia
Brian Sherrod, USGS, Seattle, WA	Geologist, seismic hazard analysis, Pacific Northwest/Cascadia
Bruce Jaffe, USGS, Santa Cruz, CA	Oceanographer, modern and paleotsunami deposits
Bruce Richmond, USGS, Santa Cruz, CA	Geologist, modern and paleotsunami deposits
Patricia McCrory, USGS, Menlo Park, CA	Marine geology and geophysics, expert on Cascadia Subduction Zone
Richard Briggs, USGS, Golden, CO	Geologist, characterizing active faults for seismic hazard analysis
Rob Witter, USGS, Anchorage, AK	Geologist, megathrust paleoseismology
*Kwok Fai Cheung, University of Hawai'i, Manoa	Tsunami modeling, Hawai'i NTHMP Science Representative
*Jonathon Allen, Oregon Department of Geology and Mineral Industries	Coastal geomorphologist, Oregon NTHMP Science Representative
*Corina Forson, Washington Department of Natural Resources	Geothermal geoscientist, Washington NTHMP Science Representative
Alan Nelson (Pacific sources, Alaska sources)	Geologist, tsunami recurrence in Alaska
*Chip Guard, NOAA NWS Forecast Office, Guam	Warning Coordination Meteorologist, Guam and Commonwealth of Northern Mariana Islands NTHMP Science Representative
David Scholl, USGS, Menlo Park, CA	Marine geologist, expert on subduction zones
Peter Haeussler, USGS, Anchorage, AK	Geologist, Alaska Coordinator for USGS Earthquake Hazards Program
*Elinor Lutu-McMoore, NOAA NWS Weather Services Office, American Samoa	Meteorologist, American Samoa NTHMP Science Representative
*David George, USGS, Vancouver, WA	Mathematician, landslide modeler
Uri ten Brink, USGS, Woods Hole, MA	Marine geophysicist, expert on Caribbean, East Coast and Gulf of Mexico
Jason Chaytor, USGS, Woods Hole, MA	Geological oceanography, expertise on earthquakes, landslides and tsunamis, Caribbean, East Coast and Gulf of Mexico
Danny Brothers, USGS, Santa Cruz, CA	Geophysical approaches to offshore earthquake, landslide and tsunami hazard assessments
Janet Watt, USGS, Santa Cruz, CA	Expert on 3D characterization of faults and fault interactions.
*Juan Horillo, Texas A&M University, Galveston	Tsunami modeling, Gulf Coast NTHMP Science Representative

*Stephan Grilli, University of Rhode Island	Coastal engineering, East Coast NTHMP Science Alternate
*Jim Kirby, University of Delaware	Tsunami modeling, East Coast NTHMP Science Representative
*Victor Huerfano, University of Puerto Rico, Mayaguez	Director of Puerto Rico Seismic Network, Puerto Rico NTHMP Science Representative
*Christa von Hillebrandt-Andrade, NOAA National Weather Service, Puerto Rico	Seismologist; Director, NOAA Caribbean Tsunami Warning Program; Chair, UNESCO IOS CARIBE early warning system
Roy Watlington, Scientist Emeritus	Tsunami scientist, U.S. Virgin Islands NTHMP Science Representative
Aurelio Mercado, University of Puerto Rico, Mayaguez	Physical oceanography, Puerto Rico NTHMP Science Alternate
Patrick Lynett, University of Southern California	Coastal engineering; tsunami current and landslide modeling specialist

Stephanie Ross will be the technical liaison who will work with Powell Center computing staff and will be the participant responsible for ensuring the data reporting requirements are met.

Many of the unconfirmed participants have previously expressed interest in attending workshops on tsunami sources.

*Research Statement from Proposed Powell Fellow Kenny Ryan*

I am interested in the combined physics of earthquake/tsunami events. My primary research involves dynamic models of both earthquakes and their corresponding tsunamis. We generally use numerical methods such as the finite difference or finite element method to elucidate the physics of earthquakes and tsunamis. We also utilize real-world data such as topographic data, bathymetric data, geologic datasets that describe structure and material properties, as well as data from previous earthquakes and tsunamis that are crucial to our understanding of the physics of such processes. Such source data can provide valuable constraints on numerical modeling efforts.

Typical tsunami generation modeling methods rely on static or kinematic models of the earthquake source, in which the seismic moment, slip distribution, and rupture path are assumed *a priori*. These properties are typically based on models of prior earthquakes and/or a probabilistic slip model. However, such models are not guaranteed to be consistent with any physically plausible faulting scenario: they may span a range of parameter space far outside what is physically realistic. In addition, the historical record is incomplete for very large (magnitude 9 or larger) earthquakes, and may not encompass all the physically possible earthquake scenarios, with the recent 2011 magnitude 9.0 Tohoku earthquake being a tragic example. One way to ensure that tsunami models are grounded in realistic physics and span a realistic range of earthquake sizes and slip patterns is to use spontaneous dynamic earthquake rupture models to simulate the earthquake source. These models start with the fault geometry available for rupture, the material properties, the loading stress on the system, and the frictional behavior on the fault; based on these input parameters and physical laws the earthquake rupture and slip process (including the final size of the earthquake, the spatiotemporal slip distribution, and the rupture path) are calculated results of the models.

Dynamic earthquake models do not just produce a rupture pattern on a fault; they also produce the full wave field and surface/seafloor deformation, which can then be used directly as a time-dependent boundary condition in tsunami models.

*Describe how proposal meets gender, ethnicity, and age diversity goals*

We are a diverse group. Of the 45 possible participants, 18 are women and/or ethnic minorities. In the core group of nine, who will attend all workshops, five are women and/or ethnic minorities and two are early career. (One of the four women in the core group is not yet confirmed, but her primary backups are also women). We were somewhat constrained on the percentage of women because it is important to include each State or Territory's science representative to the NTHMP when we hold the regional workshops, and only one of these thirteen representatives is a woman. We are confident that at least one third of each workshop will be women. Several of the participants are early career.

## Powell Center Data Management Plan

Note: Defining the complexity of the source models and how to best store them for use in a variety of tsunami modeling programs is the first step in our working group process. The collaborative nature of our process means that our data management plan is uncertain at this point.

<b>Data Inputs</b> (list of datasets used to produce the synthesized data product(s))				
<b>Title</b>	<b>Format (csv, ascii)</b>	<b>Data Volume Estimate (MB, GB, TB)</b>	<b>Source/URL</b>	<b>Use Restrictions</b>
Slab 1.0	KML or NetCDF	1.4MB (KML) 35.3 MB (NetCDF)	USGS, <a href="https://earthquake.usgs.gov/data/slab/">https://earthquake.usgs.gov/data/slab/</a>	None
Geologic Maps and Studies	GIS, papers	50 GB	Varied	none

<b>Data Processing</b> (will occur during the course of Working Group activities)	
Access and Sharing	Data will be downloaded from Slab 1.0 and provided by working group members. We will use the Powell Center Resources ScienceBase and a private wiki to share information.
Data Storage	During development we intend to use the USGS ScienceBase through Powell Center.
Transformation and processing workflow	The process for creating the source models will depend on the outcome of the first workshop which will focus on what information will be included for these standardized sources.
Technology needs	We will require the use of GIS to create the sources and then will design a storage system based on user needs identified during the workshops. We will appreciate GIS and database support from the Powell Center.

<b>Proposed Data Publishing<sup>1</sup></b> (repeat if there will be multiple derived data products)	
Title	Collection of Standardized Tsunami Sources
Description	Fault geometry and spatiotemporal slip patterns for a large suite of tsunami sources as input to simulations for hazards mitigation.
Format	To be determined as part of the working group process.
Data Volume Estimate	Several to many gigabytes depending on the complexity of the source models which will be defined early in the working group process.
Data Storage	We will use the USGS ScienceBase, another USGS data center, or the NOAA National Centers for Environmental Information, as determined early in the working group process.
Metadata Point of Contact	Stephanie Ross
Restrictions	None

<sup>1</sup> USGS has outlined a new, formal data publishing process, applicable to all projects started in FY17+, as part of its Fundamental Science Practices. More details on this can be found here: <https://www.usgs.gov/fsp/policies.asp>

### *Timetable of activities*

**October to December, 2017:** exchange ideas via email and conference calls to identify and carry out the work required before the first workshop, which will cover how to create and store tsunami sources.

**January, 2018:** hold the first workshop to decide what types of models, discussed earlier, are required to define an earthquake or landslide tsunami source in order to provide sufficient accuracy for mitigation products, while considering the impact of additional computational expense on being able to create a large number of sources and tsunami models. We will also discuss the process for vetting sources at the regional workshops. The attendees will be the core group plus experts on tsunami sources, modeling, and mitigation requirements.

**February to April, 2018:** follow-up work to finalize the processes defined at the first workshop and create the tsunami source storage system.

**May, 2018:** hold the workshop on Alaska tsunami sources. Each regional workshop will consider the available geological and geophysical data to define likely earthquake and landslide tsunami sources as designed during the first workshop. The workshop attendees will be the core group plus regional experts.

**June to September, 2018:** finalize the Alaska tsunami sources through remote collaboration and enter them in the tsunami source storage system. It is important to give this step a significant period of time as the first regional work may well identify modifications to make to our initial plan.

**October, 2018:** hold the workshop on Pacific tsunami sources other than Alaska.

**November, 2018 to January, 2019:** finalize the Pacific tsunami sources through remote collaboration and enter them in the tsunami source storage system.

**February, 2019:** hold the workshop on Caribbean tsunami sources

**March to May, 2019:** finalize the Caribbean tsunami sources through remote collaboration and enter them in the tsunami source storage system.

**June, 2019:** hold the workshop on East and Gulf coast tsunami sources. This workshop will have a greater than usual focus on landslide tsunami sources and will also include experts on landslide processes.

**July to September, 2019:** finalize the East and Gulf coast tsunami sources through remote collaboration and enter them in the tsunami source storage system.

### *Anticipated results and benefits*

The standardized tsunami sources, stored in an open database, will be used to model impacts in each U.S. State and Territory with tsunami risk. The standardized sources, based on USGS science in collaboration with our partners, will form the basis for authoritative hazards mitigation products including inundation zones, evacuation plans, tsunami playbooks, and land-use and construction planning. The States and Territories will also be able to create tsunami scenarios to estimate the physical damages, economic, and societal impacts of these potential disasters. This information can

then be used to create public policy to mitigate these hazards and reduce future risks. Without this effort, the States and Territories are left to create sources on their own, making it difficult for them to utilize USGS expertise, thus slowing and decreasing the quality of these mitigation efforts and producing inconsistent products across state lines.

In addition to improving hazards mitigation within the U.S., we will share information with the Global Tsunami Model (GTM, [www.globaltsunamimodel.org](http://www.globaltsunamimodel.org)), a new organization aimed at providing coordinated action for tsunami hazard and risk assessment (Løvholt et al., 2016). Working Group members who are involved in GTM include PI Stephanie Ross, Eric Geist, Hong-Kie Thio, and Christa von Hillebrandt-Andrade. By providing our tsunami sources to the GTM, we will help with tsunami hazards assessment globally. This is particularly important for tsunamis because the waves cross oceans, making them a hazard that requires international cooperation.

This is the perfect time to address these issues because outside users have made it clear that they need this help from the USGS, the GTM effort is just beginning, and, most importantly, proposed Powell Center Fellow, Kenny Ryan, is in the first year of his two-year Mendenhall Postdoctoral Fellowship. This timing will allow him to participate in the Working Group during the second year of that Fellowship and then continue with the Working Group as a Powell Center Fellow. If we delay a year then he would only be with the Working Group for part of its first year, significantly reducing the benefit we will get from his participation.

At least two papers will be published. The first will cover the results of the first workshop in order to inform the broader community about this effort and to stimulate their interest and input. It will also describe the research on the relationship between source model complexity and mitigation products. The second paper will come at the end of the entire process to announce the availability of the tsunami sources for mitigation applications and to summarize lessons learned about this process. Potentially, additional papers will be written about the sources for each region. A database of tsunami source characteristics will also be available as an outcome.

### Literature cited

Chaytor, J.D., ten Brink, U.S., Solow, A.R., Andrews, B.D., 2009. Size distribution of submarine landslides along the U.S. Atlantic margin. *Mar. Geol.* 264, 16–27.

Geist, E.L., Lynett, P.J., Chaytor, J.D., 2009. Hydrodynamic modeling of tsunamis from the Currituck landslide. *Mar. Geol.* 264, 41–52).

Grilli, S.T., Taylor, O.-D.S., Baxter, C.D., Marezki, S., 2009. A Probabilistic Approach for Determining Submarine Landslide Tsunami Hazard along the Upper East Coast of the United States. *Mar. Geol.* 264, 74–97.

Hayes, G. P., D. J. Wald, and R. L. Johnson (2012), Slab1.0: A three-dimensional model of global subduction zone geometries, *J. Geophys. Res.*, 117, B01302, doi:10.1029/2011JB008524.

Holmes, R.R., Jr., Jones, L.M., Eidenshink, J.C., Godt, J.W., Kirby, S.H., Love, J.J., Neal, C.A., Plant, N.G., Plunkett, M.L., Weaver, C.S., Wein, Anne, and Perry, S.C., 2013, U.S. Geological Survey natural hazards science strategy—Promoting the safety, security, and economic well-being of the Nation: U.S. Geological Survey Circular 1383–F, 79 p. <http://pubs.usgs.gov/circ/1383f/>.

- Kirby, S., Scholl, D., von Huene, R., and Wells, R., 2013, Alaska earthquake source for the SAFRR tsunami scenario, chap. B in Ross, S.L., and Jones, L.M., eds., The SAFRR (Science Application for Risk Reduction) Tsunami Scenario: U.S. Geological Survey Open-File Report 2013–1170, 40 p., <http://pubs.usgs.gov/of/2013/1170/b/>.
- Løvholt, F., H.K. Thio, C.B. Harbitz, Jascha Polet, S. Lorito, R. Basili, M. Volpe, F. Romano, J. Selva & A. Piatanesi, G. Davies, J. Griffin, M.A. Baptista, R. Omira, A. Babeyko, W.L. Power, M. Salgado Gálvez, J. Behrens, AC Yalciner, U. Kanoglu, O. Pekcan, S. Ross, T. Parsons, R.J. LeVeque, F.I. Gonzalez, R. Paris, A. Schäfer, M. Canals, S.A. Fraser, Y. Wei & C. von Hillebrandt-Andrade, R. Weiss, F. Zaniboni, G.A. Papadopoulos, I. Didenkulova, O. Necmioglu, C. Ozer, A. Suppasri, P.J. Lynett, M. Mokhtari, M. Sørensen, I. Aguirre Ayerbe & Í. Aniel-Quiroga, S. Guillas, J. Macias, 2016, The Global Tsunami Model (GTM), Abstract NH52A-04, presented at 2016 Fall Meeting, AGU, San Francisco, Calif., 12-16 Dec.
- Nicolosky, D.J., Suleimani, E.N., Combellick, R.A., and Hansen, R.A., 2011, Tsunami inundation maps of Whittier and western Passage Canal, Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2011-7, 65 p. <http://doi.org/10.14509/23244>.
- Nicolosky, D.J., E.N. Suleimani, P.J. Haeussler, H.F. Ryan, R.D. Koehler, R.A. Combellick, and R.A. Hansen (2013), Tsunami Inundation Maps of Port Valdez, Alaska, Alaska Division of Geological & Geophysical Surveys Report of Investigation 2013-1, 77 p., <http://doi.org/10.14509/25055>
- Puerto Rico Seismic Network Tsunami Program, Flood and Evacuation Maps, <http://redsismica.uprm.edu/English/tsunami/maps.php>, last accessed January 29, 2017.
- Ross, S.L., Jones, L.M., Miller, Kevin, P., K.A., Wein, A., Wilson, Ri.I., Bahng, B., Barberopoulou, A., Borrero, J.C., Brosnan, D.M., Bwarie, J.T., Geist, E.L., Johnson, L.A., Kirby, S.H., Knight, W.R., Long, K., Lynett, P., Mortensen, C.E., Nicolosky, D.J., Perry, S.C., Plumlee, G.S., Real, C.R., Ryan, K., Suleimani, E., Thio, H., Titov, V.V., Whitmore, P.M. and Wood, N.J., 2013a, SAFRR (Science Application for Risk Reduction) Tsunami Scenario—Executive Summary and Introduction: U.S. Geological Survey Open-File Report 2013–1170–A, in Ross, S.L., and Jones, L.M., eds., The SAFRR (Science Application for Risk Reduction) Tsunami Scenario: U.S. Geological Survey Open-File Report 2013–1170, 17 p., <http://pubs.usgs.gov/of/2013/1170/a/>.
- Ross, S.L., Jones, L.M., Miller, K., Porter, K.A., Wein, A., Wilson, R.I., Bahng, B., Barberopoulou, A., Borrero, J.C., Brosnan, D.M., Bwarie, J.T., Geist, E.L., Johnson, L.A., Kirby, S.H., Knight, W.R., Long, K., Lynett, P., Mortensen, C.E., Nicolosky, D.J., Perry, S.C., Plumlee, G.S., Real, C.R., Ryan, K., Suleimani, E., Thio, H., Titov, V.V., Whitmore, P.M., and Wood, N.J., 2013b, The SAFRR tsunami scenario—Improving resilience for California: U.S. Geological Survey Fact Sheet 2013–3081, 4 p., <https://pubs.usgs.gov/fs/2013/3081/>.
- Ryan, K. J., E. L. Geist, M. Barall, and D. D. Oglesby (2015), Dynamic models of an earthquake and tsunami offshore Ventura, California, *Geophys. Res. Lett.*, 42, 6599–6606, doi:[10.1002/2015GL064507](https://doi.org/10.1002/2015GL064507).
- Ryan, K. J., Oglesby, D. D., and E. L. Geist (2013). *Modeling Sea-Floor Deformation and Tsunami Generation using Dynamic Finite Element Analysis*, in Geist, E.L., ed., Modeling for the SAFRR Tsunami Scenario—generation, propagation, inundation, and currents in ports and harbors: U.S. Geological Survey Open-File Report 2013–1170–D, p 6-35.

- ten Brink, U.S., Lee, H.J., Geist, E.L., Twichell, D.C., 2009. Assessment of tsunami hazard to the U.S. East Coast using relationships between submarine landslides and earthquakes. *Mar. Geol.* 264, 65–73.
- Thio, H.K., Somerville, P., and Polet, J., 2010, Probabilistic Tsunami Hazard in California: Berkeley, Calif., Pacific Earthquake Engineering Research Center Report 2010/108, 331 p., [http://peer.berkeley.edu/publications/peer\\_reports/reports\\_2010/web/PEER2010\\_108\\_THIOetal.pdf/](http://peer.berkeley.edu/publications/peer_reports/reports_2010/web/PEER2010_108_THIOetal.pdf/).
- Walsh, T.J., V.V. Titov, A.J. Venturato, H.O. Mofjeld, F.I. Gonzalez, 2005, Tsunami hazard map of the Anacortes–Whidbey Island area, Washington: modeled tsunami inundation from a Cascadia subduction zone earthquake , Washington Division of Geology and Earth Resources Open File Report 2005-1, 1 sheet, scale 1:62,500.
- Wilson, R.I., Admire, A.R., Borrero, J.C., Dengler, L.A., Legg, M.R., Lynett, P., Miller, K.M., Ritchie, A., Sterling, K., McCrink, T.P., and Whitmore, P.M., 2012, Observations and impacts from the 2010 Chilean and 2011 Japanese tsunami in California (USA): *Pure and Applied Geophysics*, accessed August 23, 2013, at <http://dx.doi.org/10.1007/s00024-012-0527-z>.
- Wilson, R.I., and K.M. Miller, 2014, Tsunami emergency response playbooks and faster tsunami height calculation: background information and guidance for use, California Geological Survey Special Report 236, 42 p.
- Wilson, R., P. Lynett, K. Miller, A. Admire, A. Ayca, E. Curtis, L. Dengler, M. Hornick, T. Nicolini, and D. Peterson, 2016, Maritime tsunami response playbooks: background information and guidance for response and hazard mitigation use, California Geological Survey Special Report 241, 48 p.
- Wood, N., Wilson, R., Jones, J., Peters, J., MacMullan, E., Krebs, T., Shoaf, K., and Miller, K., 2016, Community disruptions and business costs for distant-tsunami evacuations using maximum versus scenario-based zones. *Nat Hazards*, 25pp, . doi:10.1007/s11069-016-2709-y

## STEPHANIE LOUISE ROSS

United States Geological Survey  
 MS 999, 345 Middlefield Road, Menlo Park, CA 94025  
 ph#: 650-329-5326 cell#:650-533-0114 email: sross@usgs.gov

### Education:

Stanford University, M.S., Department of Geophysics, Advisor: Allan Cox, 1986  
 University of Miami, B.S. (Honors), Department of Geology, minors in math and chemistry, 1982

### Professional Appointments:

Tsunami Scenarios Project Manager, USGS Science Application for Risk Reduction, 10/2010 - present  
 Staff Scientist, Office of the USGS Western Regional Geologist, 2002-2003  
 Geophysicist, Pacific Coastal and Marine Science Center, 1983-present

### Professional Interests:

My primary focus is connecting USGS tsunami science with those who need it in order to help mitigate tsunami hazards. To that end, I represent the USGS on the National Tsunami Hazards Mitigation Program (NTHMP), on the Global Tsunami Model (GTM), and led the USGS Science Application for Risk Reduction (SAFRR) project's Tsunami Scenario which described in detail the impacts of a tsunami generated by a hypothetical, but realistic, M9 earthquake near the Alaska Peninsula. As the coordinator, I led a 29-person coordinating committee (from 13 agencies and universities) that oversaw the work of about 60 authors and 170 other contributors (representing 72 organizations including the California Geological Survey, the California Emergency Management Agency, the National Oceanic and Atmospheric Administration) and I was the lead editor for a 13-chapter report of over 1000 pages that received over a million page views during the first year. In February, 2016, I ran a 2-day NTHMP-USGS workshop on tsunami sources and I am currently working on tsunami mitigation issues with the States of Alaska and Hawaii.

I have also led interdisciplinary geological hazards assessments to proposed liquid natural gas facilities offshore of southern California and during my career I have mapped the ocean floor from mid-ocean ridge spreading centers to coastal faults by diving in submersibles such as ALVIN and by using remote operated vehicles, camera sleds, side-scan sonar, seismic reflection, and earthquake relocations.

### Products from Leadership of Collaborative Tsunami and Coastal Marine Hazards Projects

Ross, S.L., Jones, L.M., Miller, Kevin, P., K.A., Wein, A., Wilson, R.I., Bahng, B., Barberopoulou, A., Borrero, J.C., Brosnan, D.M., Bwarie, J.T., Geist, E.L., Johnson, L.A., Kirby, S.H., Knight, W.R., Long, K., Lynett, P., Mortensen, C.E., Nicolsky, D.J., Perry, S.C., Plumlee, G.S., Real, C.R., Ryan, K., Suleimani, E., Thio, H., Titov, V.V., Whitmore, P.M. and Wood, N.J., 2013, SAFRR (Science Application for Risk Reduction) Tsunami Scenario—Executive Summary and Introduction: U.S. Geological Survey Open-File Report 2013–1170–A, *in* Ross, S.L., and Jones, L.M., eds., The SAFRR (Science Application for Risk Reduction) Tsunami Scenario: U.S. Geological Survey Open-File Report 2013–1170, 17 p., <http://pubs.usgs.gov/of/2013/1170/a/>.

Ross, S.L., Jones, L.M., Miller, K., Porter, K.A., Wein, A., Wilson, R.I., Bahng, B., Barberopoulou, A., Borrero, J.C., Brosnan, D.M., Bwarie, J.T., Geist, E.L., Johnson, L.A., Kirby, S.H., Knight, W.R., Long, K., Lynett, P., Mortensen, C.E., Nicolsky, D.J., Perry, S.C., Plumlee, G.S., Real, C.R., Ryan, K., Suleimani, E., Thio, H., Titov, V.V., Whitmore, P.M., and Wood, N.J., 2013, The SAFRR tsunami scenario—Improving resilience for California: U.S. Geological Survey Fact Sheet 2013–3081, 4 p., <https://pubs.usgs.gov/fs/2013/3081/>.

Porter, K.A., L. Jones, S. Ross, J. Borrero, J. Bwarie, D. Dykstra, E.L. Geist, L. Johnston, S. Kirby, K. Long, P. Lynett, K. Miller, C. Mortensen, S. Perry, G. Plumlee, C. Real, L. Ritchie, C. Scawthorn, H.K. Thio, A. Wein, P. Whitmore, R. Wilson, N. Wood, 2013, USGS Science Application for Risk

Reduction's Next Wave Tsunami Scenario, Paper 79 in ASCE COPRI *Proceedings of PORTS '13*, Seattle, WA, 10 pp.

- Real, C.R., Johnson, L., Jones, L.M., Ross, S., 2014, Improving Tsunami Resiliency: California's Tsunami Policy Working Group: In: Kontar, Y.A., Santiago-Fandiño, V., Takahashi, T. (Eds.). *Tsunami Events and Lessons Learned 35*, Springer Netherlands, Dordrecht, pp. 377–386, URL: [http://link.springer.com/10.1007/978-94-007-7269-4\\_21](http://link.springer.com/10.1007/978-94-007-7269-4_21).
- Ross, Stephanie L., Lee, Homa J., Parsons, Tom E., Beyer, Larry A., Boore, David M., Conrad, James E., Edwards, Brian D., Fisher, Michael A., Frankel, Arthur D., Geist, Eric L., Hudnut, Kenneth W., Hough, Susan E., Kayen, Robert E., Lorensen, Thomas D., Luco, Nicolas, McCrory, Patricia A., McGann, Mary L., Nathenson, Manuel, Nolan, Michael, Petersen, Mark D., Ponti, Daniel J., Powell, Charles L., Ryan, Holly F., Tinsley, John C., Wills, Chris J., Wong, Florence L., and, Jingping Xu, **2008**, Comments on potential geologic and seismic hazards affecting proposed liquefied natural gas site in Santa Monica Bay, California: *U.S. Geological Survey Open-File Report 2008-1344*, 60 p., <http://pubs.usgs.gov/of/2008/1344/>.
- Ross, S.L., D.M. Boore, M.A. Fisher, A.D. Frankel, E.L. Geist, K.W. Hudnut, R.E. Kayen, H.J. Lee, W.R. Normark, and F.L. Wong, **2004**, Comments on Potential Geologic and Seismic Hazards Affecting Coastal Ventura County, California: U.S. Geological Survey Open-File Report 2004-1286, 20pp. <http://pubs.usgs.gov/of/2004/1286/>

#### **Other Selected Products**

- Ross, Stephanie L., and Zierenberg, Robert A., **2009**, Sidescan Sonar Imagery of the Escanaba Trough, Southern Gorda Ridge, Offshore Northern California: *USGS Scientific Investigations Map 2907*, scale 1:25,000, <http://pubs.usgs.gov/sim/2907/>
- Michael, A.J., S.L. Ross, F.W. Simpson, M.L. Zoback, D.P. Schwartz, M.L. Blanpied, **2003**, Understanding earthquake hazards in the San Francisco Bay Region: Is a powerful quake likely to strike in the next 30 years?, *USGS Fact Sheet 039-03*, 4pp. <http://pubs.usgs.gov/fs/2003/fs039-03/>
- Michael, A.J., S.L. Ross, H.D. Stenner, 2002, Displaced rocks, strong motion and the mechanics of shallow faulting associated with the Hector Mine, California, earthquake, *Bull. Seis. Soc. of Am.*, 92, 1561-1569, doi:10.1785/0120000927. <http://bssa.geoscienceworld.org/content/92/4/1561>
- Ryan, H.F., Ross, S.L., and Graymer, R. W., 2001, Earthquakes, Faults and Tectonics, in *Beyond the Golden Gate-Oceanography, Geology, Biology, and Environmental Issues in the Gulf of the Farallones*, U.S. Geological Survey Circular 1198, edited by H. Karl, J. Chin, E. Ueber, P.H. Stauffer, and J.W. Hendley, II, p. 16-19. <http://pubs.usgs.gov/circ/c1198/>
- Ross, S.L., Paleomagnetic constraints on rotation within Mount Abbot quadrangle, central Sierra Nevada, California, **1988**, *Journ. of Geophys. Res.*, v. 93, 11,711-11720. <http://onlinelibrary.wiley.com/doi/10.1029/JB093iB10p11711/full>

**Selected Collaborators (last 5 years):** B. Bahng, NOAA; A. Barberopoulou, GNS New Zealand; J. C. Borrero, Univ. Of Southern California; D. M. Brosnan, UC Davis; J. T. Bwarie, USGS; K.F. Cheung, Univ. of Hawaii; G. & Chock Inc.; D. Clague, Monterey Bay Aquarium Research Inst.; E. L. Geist, USGS; E. Hemphill-Haley, Humboldt State; L. A. Johnson, Laurie Johnson Consulting; L. M. Jones, USGS; S. H. Kirby, USGS; E. Knight, California Ocean Science Trust; W. R. Knight, NOAA; K. Long, California Emergency Management Agency; P. Lynett, Univ. Of Southern California; K. Miller, California Emergency Management Agency; C. E. Mortensen, USGS; D. J. Nicolsky, Univ. of Alaska, Fairbanks; D. D. Oglesby, UC Riverside; S. C. Perry, USGS; K. A. Porter, Univ. Of Colorado, Boulder; C. R. Real, California Geological Survey; K. Richards, Hawaii Emergency Management Agency; K. Ryan, UC Riverside; E. Suleimani, Univ. Of Alaska, Fairbanks; H. K. Thio, URS Corporation, A. Wein, USGS; J.E. Waddell, NOAA; P. M. Whitmore, NOAA; R. I. Wilson, California Geological Survey; N. J. Wood, USGS; R. Zierenberg, UC Davis.

**MARIE C EBLÉ**

7600 Sand Point Way NE  
 Seattle, WA 98115  
 206.526.6805 marie.c.eble@noaa.gov

**Education:**

M.S. 1984 Oceanography (Physical)	Department of Oceanography Texas A&M University, College Station, Texas
B.S. 1979 Marine Science	School of Natural Sciences and Mathematics The Richard Stockton College of New Jersey, Pomona, NJ
A.A.S 1974 Accounting (with honors)	Accounting Burlington County Community College, Pemberton, NJ

**Employment**

2008 - present	Deputy, NOAA Center for Tsunami Research NOAA Pacific Marine Environmental Laboratory, Seattle, WA <i>Responsible for acquisition and quality assurance of sea level data, serve as liaison between NOAA Center for Tsunami Research and Tsunami Warning Centers as well as NOAA and NOS archival and operational agencies, track budgets, present scientific findings at national and international scientific venues, and provide technical oversight and supervision of staff. Serve as co-chair of National Tsunami Hazard Mitigation Program (NTHMP), Mapping &amp; Modeling Sub-committee. Serve as NTHMP state partner grant process reviewer, including formal review of new proposals as well as progress reports during existing grant cycles.</i>
2000 - 2008	Research Oceanographer NOAA Pacific Marine Environmental Laboratory, Seattle, WA <i>Responsible for acquisition and processing of sea level data, track budgets, and present scientific findings at national and international scientific venues.</i>
1999 - 2000	Project Manager: Deep-ocean Assessment & Reporting of Tsunamis (DART) NOAA Pacific Marine Environmental Laboratory, Seattle, WA <i>Managed DART budget, scheduled ship time, coordinated design efforts of Engineering Development Division, supervised project personnel, developed processes and software for the quality control of data, coordinated web display and distribution of real-time data, point of contact for NOAA's Alaska and Pacific Tsunami Warning Centers, and represented project at conferences.</i> <i>Coordinated the transition of DART array operations and maintenance to NOAA's operational National Data Buoy Center.</i>
1986 - 1999	Research Oceanographer NOAA Pacific Marine Environmental Laboratory <i>Collected, processed, analyzed, and interpreted bottom pressure and sea level time series data using numerical time-series analysis techniques. Prepared journal articles and reports, conference and seminar representation, and developed processing and analysis software to accomplish goals</i>
1984 - 1986	Oceanographer Northern Technical Services, Inc., Redmond, WA <i>Oceanographic and hydraulic numerical modeling, field surveys and data collection, time series and synoptic data collection, processing and analysis, interpretation and presentation of results in reports and oral presentation formats, and development of computer software.</i>
1980 - 1984	Research Assistant Texas A&M University, College Station, Texas

## SELECTED PUBLICATIONS

1. Eblé, Marie C., George T. Mungov, and Alexander B. Rabinovich. "On the leading negative phase of major 2010–2014 tsunamis." *Pure and Applied Geophysics* 172.12 (2015): 3493-3508.
2. Rabinovich, Alexander B., and Marie C. Eblé. "Deep-ocean measurements of tsunami waves." *Pure and Applied Geophysics* 172.12 (2015): 3281-3312.
3. Uslu, B., M. Eble, D. Arcas, and V. Titov (2013): Tsunami Hazard Assessment for the Commonwealth of the Northern Mariana Islands. Tsunami Hazard Assessment Special Series, Vol. 3, 188 pp.
4. Mungov, G., M. Eblé, and R. Bouchard (2012): DART® tsunameter retrospective and real-time data: A reflection on 10 years of processing in support of tsunami research and operations. *Pure Appl. Geophys.*, doi: 10.1007/s00024-012-0477-5.
5. Uslu, B., W. Power, D. Greenslade, V. Titov, and M. Eble (2011): The July 15, 2009 Fiordland, New Zealand tsunami: Real-time assessment. *Pure Appl. Geophys.*, 168(11), doi: 10.1007/s00024-011-0281-7, 1963–1972
6. Mungov, George, M. Eblé, and R. Bouchard, DART® tsunameter retrospective and real-time data: a reflection on 10 years of processing in support of tsunami research and operations", *Pure and Applied Geophysics*. PAAG-714R2
7. Titov, V.V., F.I. González, E.N. Bernard, M.C. Eble, H.O. Mofjeld, J.C. Newman, and A.J. Venturato (2005): Real-time tsunami forecasting: Challenges and solutions, in: *Developing Tsunami-Resilient Communities, The National Tsunami Hazard Mitigation Program*, E. Bernard (ed), *Nat. Haz.* **35**/1, 40-58,
8. Percival, D.B., D.W. Denbo, M.C. Eble, E. Gica, H.O. Mofjeld, M.C. Spillane, L. Tang, and V.V. Titov (2011): Extraction of tsunami source coefficients via inversion of DART® buoy data. *Nat. Hazards*, 58(1), doi: 10.1007/s11069-010-9688-1, 567–590.
9. Uslu, B., W. Power, D. Greenslade, V. Titov, and M. Eble (2011): The July 15, 2009 Fiordland, New Zealand tsunami: Real-time assessment. *Pure Appl. Geophys.*, 168(11), doi: 10.1007/s00024-011-0281-7, 1963–1972.
10. González, F.I., E.N. Bernard, C. Meinig, M. Eble, H.O. Mofjeld, and S. Stalin (2005): The NTHMP tsunameter network. *Nat. Hazards*, 35(1), Special Issue, U.S. National Tsunami Hazard Mitigation Program, 25–39
11. Mofjeld, H.O., F.I. González, and M.C. Eble (1996): Subtidal bottom pressure observed at Axial Seamount in the northeastern continental margin of the Pacific Ocean. *J. Geophys. Res.*, 101(C7), 16,381–16,390
12. Mofjeld, H.O., F.I. González, M.C. Eble, and J.C. Newman (1995): Ocean tides in the continental margin off the Pacific Northwest Shelf. *J. Geophys. Res.*, 100(C6), 10,789–10,800.
13. Eble, M.C., and F.I. González (1991): Deep-ocean bottom pressure measurements in the northeast Pacific. *J. Atmos. Ocean. Tech.*, 8(2), 221–233.
14. González, F.I., C.L. Mader, M.C. Eble, and E.N. Bernard (1991): The 1987–88 Alaskan Bight Tsunamis: Deep ocean data and model comparisons. Special Issue on Tsunami Hazard (E.N. Bernard, ed.), *Nat. Hazards*, 4(2,3), 119–139.

## UAF BIOGRAPHICAL SKETCH – Dmitry Nicolsky

### PROFESSIONAL PREPARATION:

St. Petersburg State University, Russia,	Physics,	B.S.,	2000
University of Alaska Fairbanks, USA,	Mathematics,	M.S.,	2003
University of Alaska Fairbanks, USA,	Interdisciplinary,	Ph.D.,	2007

### APPOINTMENTS:

Research Assistant Professor, University of Alaska Fairbanks,	2013-present
Tsunami Modeler, University of Alaska Fairbanks,	2008-2013
Research Assistant, University of Alaska Fairbanks,	2002-2007

### FIVE PRODUCTS MOST CLOSELY RELATED TO THE PROPOSED PROJECT:

Nicolsky, D.J., J.T. Freymueller, R.C. Witter, E.N. Suleimani, and R.D. Koehler (2016), *Evidence for shallow megathrust slip across the Unalaska seismic gap during the great 1957 Andreanof Islands earthquake, eastern Aleutian Islands, Alaska*, Geophysical Research Letters, 43, doi:10.1002/2016GL070704.

Nicolsky, D.J., E.N. Suleimani, and R.A. Hansen (2011), *Validation and verification of a numerical model for tsunami propagation and runup*, Pure and Applied Geophysics, 168, pp. 1199–1222, doi: 10.1007/s00024-010-0231-9.

Nicolsky, D.J., E.N. Suleimani, and R.A. Hansen, *Note on the 1964 Alaska tsunami generation by horizontal displacements of ocean bottom. Numerical modeling of the runup in Chenega Cove, Alaska*, Pure and Applied Geophysics, DOI: 10.1007/s00024-012-0483-7, 170, pp. 1433-1447, 2013.

Nicolsky, D.J. and E.N. Suleimani (2013), *Modeling tsunami dynamics in the port of Los Angeles, California*, in Geist, E.L., ed., *Modeling for the SAFRR Tsunami Scenario generation, propagation, inundation, and currents in ports and harbors: U.S. Geological Survey Open-File Report 20131170C*.

Grilli, S.T., Shelby, M., Kimmoun, O., Dupont, G., Nicolsky, D., Ma, G., Kirby, J. and F. Shi (2016), *Modeling coastal tsunami hazard from submarine mass failures: effect of slide rheology, experimental validation, and case studies off the US East coast*, Natural Hazards, 39 pps., doi:10.1007/s11069-016-2692-3

### FIVE OTHER SIGNIFICANT PRODUCTS:

Nicolsky, D.J., E.N. Suleimani, J.T. Freymueller, and R.D. Koehler (2015), *Tsunami inundation maps of Fox Islands communities, including Dutch Harbor and Akutan, Alaska*, Alaska Division of Geological & Geophysical Surveys, Report of Investigation 2015-5, 67 p., 2 sheets, scale 1:12,500. doi:10.14509/29414.

Nicolsky D.J., E.N. Suleimani, P.J. Haeussler, H.F. Ryan, R.A. Combellick, and R.A. Hansen, *Tsunami Inundation Maps of Port Valdez, Alaska*, Alaska Division of Geological & Geophysical Surveys, 2013-1, 77 p., 1 sheet, scale 1:12,500.

Garayshin, V.V., M.W. Harris, D.J. Nicolsky, E.N. Pelinovsky and A.V. Rybkin, *An analytical and numerical study of long wave run-up in U-shaped and V-shaped bays*, Applied Mathematics and Computation, 279, 187-197, 2016.

Kirby, J.T., F. Shi, D. Nicolsky, and S. Misra (2016), *The 27 April 1975 Kitimat, British Columbia submarine landslide tsunami: A comparison of modeling approaches*, Landslides, in pres. doi:10.1007/s10346-016-0682-x.

Suleimani, E.N., D.J. Nicolsky, and R.D. Koehler (2016), *Tsunami Inundation Maps for Yakutat, Alaska*, Alaska Division of Geological & Geophysical Surveys, Report of Investigation 2016-2, 47 p., 1 sheet, scale 1:10,000. doi:10.14509/29577.

#### **SYNERGISTIC ACTIVITIES:**

- The Alaska State Science Representative on the Coordinating Committee of the National Tsunami Hazard Mitigation Program (NTHMP) since 2013.
- The State Co-Chair of the NTHMP Mapping and Modeling Subcommittee, which helps guide state and federal tsunami hazard mapping efforts to make sure they are done in an accurate and consistent manner since 2015.
- Contribute to the development of tsunami hazard mitigation products under the Alaska Division of Emergency Management
- Develop a web-based interface to facilitate simulation of the tsunami propagation and potential inundation of the Alaska coastline
- Assistance in developing of a response function approach for rapid far-field tsunami forecasting
- Lead an undergraduate student project "Improving Access to High Performance Modeling Resources at the Arctic Region Supercomputing Center Using a Web Interface", 2010.
- Together with the Department of Mathematical Science, UAF, co-lead Summer Research Experience for Undergraduates (REU) Programs "Run-Up of Non-Breaking Long Waves", 2010, 2012-16.



### Notable Recent Tsunami-Related Publications:

- Wood, N., Wilson, R., Jones, J., Peters, J., MacMullan, E., Krebs, T., Shoaf, K., and Miller, K. “Community disruptions and business costs for distant-tsunami evacuations using maximum versus scenario-based zones.” *Natural Hazards*; **2016**.
- Keen, A., Lynett, P., Eskijian, M., Ayca, A., and Wilson, R. “A Monte Carlo based approach to estimate fragility curves of floating docks for small craft marinas.” *Journal of Waterway, Port, Coastal, and Ocean Engineering*; **2016**.
- Wilson, R., Lynett, P., Miller, K., Admire, A., Ayca, A., Curtis, E., Dengler, L., Hornick, M., Nicolini, T., and Peterson, D. “Maritime Tsunami Response Playbooks: Background information and guidance for response and hazard mitigation use.” *California Geological Survey Special Report 241*, 48 p., **2016**.
- Chock, G., Yu, G., Robertson, I., and Wilson, R. “Tsunami Resilient Design of Buildings for California.” *Proceedings of the Structural Engineering Association of California Meeting*, 16 p., **2015**.
- California Probabilistic Tsunami Hazard Analysis (CA-PTHA) Work Group (R.I. Wilson, lead), “Evacuation and application of probabilistic tsunami hazard analysis in California-Phase 1: Source evaluation and the review of Crescent City demonstration projects,” *California Geological Survey Special Report 237*, 30 p., **2015**.
- Wilson, R., Wood, N., Kong, L., Shulters, M., Richards, K., Dunbar, P., Tamura, G., and Young, E. “A protocol for coordinating post-tsunami field reconnaissance efforts in the USA.” *Natural Hazards* 75, p. 2153-2165; doi 10.1007/s11069-014-1418-7, **2015**.
- Wilson, R.I. and Miller, K.M. “Tsunami emergency response playbooks and FASTER tsunami height calculation: Background information and guidance for use.” *California Geological Survey Special Report 236*, 42 p., **2014**.
- Angove, M., Devaris, A., Biasco, T., Gately, K., Kong, L., Lopes, R., McCreery, C., Miller, K., Rizzo, A., Schelling, J., Whitmore, P., and Wilson, R. (Presenter) “Community Resiliency Efforts through the U.S. National Tsunami Hazard Mitigation Program.” *Proceedings of the 3<sup>rd</sup> International Conference on Urban Disaster Reduction*, Earthquake Engineering Research Institute, Boulder, CO, 4 p., **2014**.
- Wilson, R., Hemphill-Haley, E., Jaffe, B., Richmond, B., Peters, R., Graehl, N., Kelsey, H., Leeper, R., Watt, S., McGann, M., Hoirup, D., Chague-Goff, C., Goff, J., Caldwell, D., and Loofbourrow, C. “The search for geologic evidence of distant-source tsunamis using new field data in California.” Chap. C of Ross, S.L., and Jones, L.M., eds., The SAFRR (Science Application for Risk Reduction) tsunami scenario: *U.S. Geological Survey Open-File Report 2013–1170–C*, 122 p., <http://dx.doi.org/10.3133/ofr20131170c>. **2014**.
- Lynett, P., Borrero, J., Son, S., Wilson, R., and Miller, K. “Assessment of the Tsunami-Induced Current Hazard.” *Geophysical Research Letters*; doi: 10.1002/2013GL058680, 8 p., **2014**.
- Wilson, R., Davenport, C., and Jaffe, B. “Sediment scour and deposition within harbors in California (USA), caused by the March 11, 2011 Tohoku-oki Tsunami.” *Sedimentary Geology*. doi:10.1016/j.sedgeo.2012.06.001. **2012**.
- Wilson, R.I., Admire, A.R., Borrero, J.C., Dengler, L.A., Legg, M.R., Lynett, P., Miller, K.M., Ritchie, A., Sterling, K., McCrink, T.P., Whitmore, P.M. “Observations and impacts from the 2010 Chilean and 2011 Japanese tsunami in California (USA).” *Pure and Applied Geophysics*. <http://dx.doi.org/10.1007/s00024-012-0527-z>. **2012**.
- Wilson, R.I., Dengler, L.A., Goltz, J.D., Legg, M.R., Miller, K.M., Ritchie, A., and Whitmore, P.M. “Emergency response and field observation activities of geoscientists in California (USA) during the September 29, 2009, Samoa tsunami.” *Earth-Science Reviews* 107 (2011), p. 193-200. **2011**.

# Kenny J. Ryan

U.S. Geological Survey  
Pacific Coastal and Marine Science Center  
345 Middlefield Rd., Menlo Park, CA 94025

Telephone: 909-938-7581  
Email: kryan@usgs.gov

## EDUCATION

University of California, Riverside, California	2016
<b>Ph.D. Geophysics</b>	
University of California, Riverside, California	2012
<b>M.S. Geophysics</b>	
California State University, San Bernardino, California	2008
<b>B.S. Physics (Honors); B.A. Mathematics (Honors)</b>	

## EXPERIENCE – RESEARCH

U. S. Geological Survey, Menlo Park, California 2016 – present

### **Mendenhall Postdoc Research Geophysicist, Pacific Coastal and Marine Science Center**

- *Implemented dynamic numerical models of earthquakes using random stress distributions. Studying properties of seismic surface waves (i.e., Rayleigh waves) in relation to the 2012 Haida Gwaii Earthquake and Tsunami. Researching a numerical implementation of the Shallow Water Wave Equations using the Finite Element Method. Research conducted at the U. S. Geological Survey. Research in these areas is ongoing.*

University of California, Riverside 2010 – 2016

### **Graduate Researcher, Department of Earth Sciences**

- *Co-completed numerical models of hypothetical earthquakes and tsunamis along the Southern California and Southern Alaska coast. Modeled effects from friction formulations at fault stepovers and dip-slip faults. Studied properties of seismic surface waves (i.e., Rayleigh waves) and how the values of such properties can help constrain local coseismic deformation. Research in these areas is ongoing.*

## PUBLICATIONS

**Ryan, K. J.**, and D. D. Oglesby (2017). Modeling the Effects of a Normal-Stress-Dependent State Variable, Within the Rate- and State-dependent Friction Framework, at Stepovers and Dip-Slip Faults. *Pure and Applied Geophysics*, 1-23.

Neighbors, C., Cochran, E. S., **Ryan, K. J.**, and A. E. Kaiser (2016). Solving for Source Parameters Using Nested Array Data: A Case Study from the Canterbury, New Zealand Earthquake Sequence. *Pure and Applied Geophysics*, 1-19.

**Ryan, K. J.**, Geist, E. L., Barall, M., and D. D. Oglesby (2015). Dynamic models of an earthquake and tsunami offshore Ventura, California. *Geophysical Research Letters*, 42(16), 6599-6606.

Ryan, K. J., and D. D. Oglesby (2014). Dynamically modeling fault step overs using various friction laws. *Journal of Geophysical Research: Solid Earth*, 119(7), 5814-5829. 25

Ryan, K. J., Oglesby, D. D., and E. L. Geist (2013). *Modeling Sea-Floor Deformation and Tsunami Generation using Dynamic Finite Element Analysis*, in Geist, E.L., ed., *Modeling for the SAFRR Tsunami Scenario—generation, propagation, inundation, and currents in ports and harbors*: U.S. Geological Survey Open-File Report 2013–1170–D, p 6-35.

### **SELECTED ORAL PRESENTATIONS**

Ryan, Geist, Barall, and Oglesby (2016). *Dynamic Earthquake and Tsunami Modeling Offshore Ventura, California*. Southern California Earthquake Center Annual Meeting: Ventura Special Fault Study Area Workshop (Invited).

Ryan, Geist, Barall, and Oglesby (2015). *Dynamic Models of Earthquakes and Tsunamis Offshore Ventura, California*. Southern California Earthquake Center Code Validation Workshop (Invited).

Ryan, Oglesby, and Geist (2014). *Modeling Megathrust Rupture through Stable-Sliding Zones, and Implications for an Alaskan-Aleutian Megathrust Earthquake and Tsunami*. United States Geological Survey seminar (Invited).

Ryan, Oglesby, and Geist (2013). *Modeling Dynamic Rupture with Implications for An Alaskan-Aleutian Megathrust Earthquake and Resulting Tsunami*. Society for Industrial and Applied Mathematics bi-annual meeting (Invited).

Ryan and Oglesby (2012). *Friction at Steppers*. Southern California Earthquake Center Code Validation Workshop (Invited).

### **SELECTED POSTER PRESENTATIONS**

Ryan, Geist, Oglesby, and (2016). *Modeling Rupture with Heterogeneous Prestress and through Stable-Sliding Zones: Implications for an Alaskan-Aleutian Megathrust Earthquake and Tsunami*. American Geophysical Union annual conference.

Ryan, Geist, Barall, and Oglesby (2015). *Dynamic Models of Earthquakes and Tsunamis from Rupture on the Pitas Point and Lower Red Mountain Faults Offshore Ventura, California*. Seismological Society of America annual conference.

Ryan and Oglesby (2012). *Modeling Steppers and Dip-Slip Faults: Examining Effects from Normal Stress*. European Center for Geodynamics and Seismology workshop.

Ryan and Oglesby (2011). *Effects of Friction Formulation at Strike-Slip Steppers*. American Geophysical Union annual conference.

### **PROFESSIONAL ACHIEVEMENTS**

- *U.S. Geological Survey Mendenhall Postdoctoral Fellowship 2016-present*
- *University of California, Riverside, Dissertation Year Fellowship Award 2015-2016*
- *Seismological Society of America Student Presentation Award 2015*
- *Seismological Society of America Membership Committee Student Representative 2013-2014*
- *National Science Foundation Graduate Student Fellowship 2011 Honorable Mention*

POWELL CENTER BUDGET SHEET						
Working Group Name: <b>Tsunami Source Synthesis</b>						
A. Travel	Year 1 (2 workshops)			Year 2 (3 workshops)		TOTAL TRANSPORTATION
	Name of Departure City	Roundtrip Economy Airfare	Other transportation expenses	Roundtrip Economy Airfare plus 10%	Other transportation expenses	
1 Stephanie Ross	San Francisco	\$ 616.00	\$ 470.00	\$ 1,016.40	\$ 705.00	\$ 2,807.40
2 Rick Wilson	Sacramento	\$ 564.00	\$ 470.00	\$ 930.60	\$ 705.00	\$ 2,669.60
3 Dmitry Nicolsky	Fairbanks	\$ 2,012.00	\$ 470.00	\$ 3,319.80	\$ 705.00	\$ 6,506.80
4 Marie Eble	Seattle	\$ 636.00	\$ 470.00	\$ 1,049.40	\$ 705.00	\$ 2,860.40
5 Kenny Ryan	San Jose	\$ 1,100.00	\$ 470.00	\$ 1,815.00	\$ 705.00	\$ 4,090.00
6 Hong Kie Thio	Los Angeles	\$ 484.00	\$ 470.00	\$ 798.60	\$ 705.00	\$ 2,457.60
7 Paula Dunbar	Boulder	\$ -	\$ 470.00	\$ -	\$ 705.00	\$ 1,175.00
8 Florence Wong	Oakland	\$ 1,260.00	\$ 470.00	\$ 2,079.00	\$ 705.00	\$ 4,514.00
9 Walter Mooney	San Jose	\$ 1,100.00	\$ 470.00	\$ 1,815.00	\$ 705.00	\$ 4,090.00
10 Varies by Workshop, example cities	San Juan, Puerto Rico	\$ 1,080.00	\$ 470.00	\$ 1,782.00	\$ 705.00	\$ 4,037.00
11 Varies by Workshop, example cities	Boston	\$ 892.00	\$ 470.00	\$ 1,471.80	\$ 705.00	\$ 3,538.80
12 Varies by Workshop, example cities	New York	\$ 1,304.00	\$ 470.00	\$ 2,151.60	\$ 705.00	\$ 4,630.60
13 Varies by Workshop, example cities	San Jose	\$ 1,100.00	\$ 470.00	\$ 1,815.00	\$ 705.00	\$ 4,090.00
14 Varies by Workshop, example cities	Seattle	\$ 636.00	\$ 470.00	\$ 1,049.40	\$ 705.00	\$ 2,860.40
15 Varies by Workshop, example cities	San Francisco	\$ 616.00	\$ 470.00	\$ 1,016.40	\$ 705.00	\$ 2,807.40
	<b>Total Year 1 Transportation expenses=</b>	\$ 20,450.00		<b>Total Y2 transportation=</b>	\$ 32,685.00	\$ 53,135.00
B. Per Diem	Year 1 Per Diem		Y2 Per Diem (with est. cost increase)		TOTAL PER DIEM	
Number of participants * number of days (4 day minimum) * \$180/day	(15 of people) x (4 days) x (2 workshops) x (180) = 21600		(15 of people) x (4 days) x (3 workshops) x (200) = \$36,000		\$ 57,600.00	
C. Fellow Support*	Year 1 Fellow Support*		Year 2 Fellow Support*		TOTAL FELLOW SUPPORT	
Fellow salary and benefits cost:	Fellow Salary&Benefits:	\$ -	Fellow Salary&Benefits:	82500	\$ 82,500.00	
Indirect/Overhead Costs (@17.5%)	Indirect/Overhead Costs (@17.5%)	\$ -	Indirect/Overhead Costs (@17.5%)	17500	\$ 17,500.00	
<b>Total, not to exceed \$100,000</b>	<b>YEAR 1 FELLOW SUPPORT</b>	0	<b>YEAR 2 FELLOW SUPPORT</b>	100000	\$ 100,000.00	
D. Page Charges						\$ 1,800.00
E. Salary support for Water Science Center Participants during Working Group meetings ONLY	Year 1 WSC salary		Year 2 WSC salary		TOTAL WSC SALARY SUPPORT	
WSC participant name					\$ -	
WSC participant name						
	<b>YEAR 1 WSC SALARY</b>	0	<b>YEAR 2 WSC SALARY</b>	0		
F. WORKING GROUP TOTAL EXPENSES	<b>Year 1 Total:</b>	<b>\$ 42,050.00</b>	<b>Year 2 Total:</b>	<b>\$ 168,685.00</b>	<b>WORKING GROUP TOTAL</b>	
<b>Notes</b>					<b>\$ 212,535.00</b>	
Travel Expense Details: The John Wesley Powell Center will reimburse for the following: Fixed transportation expenses per participant: \$235 * Shuttle to and from the Denver International Airport to hotel (~\$80) * Parking at home airport (up to \$70.00) * Taxi (to home airport/back to residence. Up to \$70.00) * Fees: \$15			*Fellow funds only cover Salary plus benefits. It does not include funds to cover travel, computers, tuition, etc. 2nd year travel expences increase by 10% to anticipate higher airfare and per diem costs.			
Per Diem/daily costs \$180 * Hotel (\$109.00 per night plus taxes - \$12 ); Meals (\$59 per day) = \$180 per Working Group participant per day						
All receipts must be submitted for the items listed above. There is no need to submit meal receipts.						