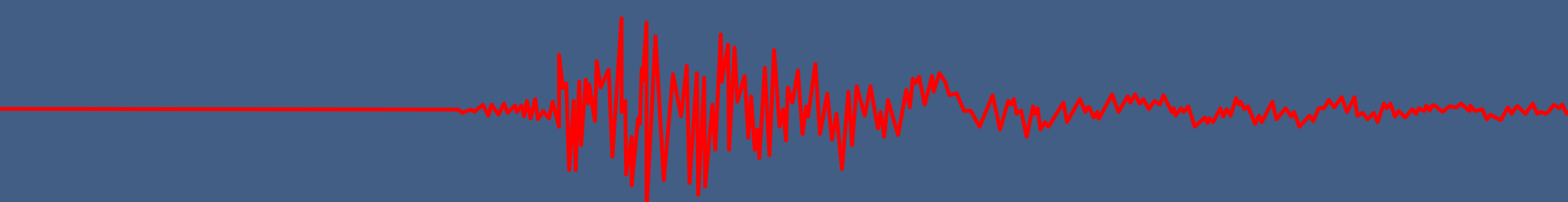
2022 Basin and Range Earthquake Summit

Utah Geological Survey

Earthquake Early Warning – Day 3

Technical Session 1 - Earthquake Early Warning

Conveners: Keith Koper (University of Utah Seismograph Stations)



Blank pages are intentional for printing purposes.

EARTHQUAKE EARLY WARNING – DAY 3

Technical Session 1 - Earthquake Early Warning

Convener:
Keith Koper (University of Utah Seismograph Stations)

Real-Time Performance of the Propagation of Locally Undamped Motion (PLUM) Earthquake Early Warning Algorithm for the West Coast, U.S.A.; *Debi Kilb, University of California, San Diego*

Future Expansion of the EEW Platform into Nevada Using an Internet of Things (IOT) Approach; *Graham Kent, Emily Morton, Daniel Trugman, Seth Saltiel, and Jayne Bormann, University of Nevada Reno*

Towards Earthquake Early Warning in Alaska; *Natalia Ruppert, Alaska Earthquake Center, University of Alaska*

Fixed Network Smartphone-Based Earthquake Early Warning; *Ben Brooks, U.S. Geological Survey*

Social Science and ShakeAlert; *Sara McBride, U.S. Geological Survey*

Earthquake Early Warning Panel Discussion: Keith Koper, University of Utah Seismograph Stations, Graham Kent, University of Nevada Reno; Natalia Ruppert, Alaska Earthquake Center, University of Alaska; Sara McBride, U.S. Geological Survey. A video of the Panel Discussion is available at the following link: https://geodata.geology.utah.gov/pages/view.php?ref=77188

REAL-TIME PERFORMANCE OF THE PROPAGATION OF LOCALLY UNDAMPED MOTION (PLUM) EARTHQUAKE EARLY WARNING ALGORITHM FOR THE WEST COAST, U.S.A.

Debi Kilb, University of California San Diego, dkilb@ucsd.edu

Elizabeth S. Cochran, U.S. Geological Survey, ecochran@usgs.gov

Julian Bunn, California Institute of Technology, Julian.Bunn@caltech.edu

Jessie K. Saunders, California Institute of Technology, jsaunder@caltech.edu

Sarah E. Minson, U.S. Geological Survey, sminson@usgs.gov

Annemarie Baltay, U.S. Geological Survey, abaltay@usgs.gov

Colin O'Rourke, U.S. Geological Survey, corourke@usgs.gov

Tim Clements, U.S. Geological Survey, tclements@usgs.gov

Clara Yoon, U.S. Geological Survey, cyoon@usgs.gov

ABSTRACT

"Earthquake detected! Drop, Cover, and Hold On. Protect yourself now." This is one example of the messages provided by the Earthquake Early Warning (EEW) ShakeAlert partners to warn those on the U.S. West Coast (California, Oregon, Washington) about potential large shaking from earthquakes. Here, we use lessons learned from the ShakeAlert system to aid in assessing the feasibility of an EEW system for the state of Utah. Currently, ShakeAlert system partners deliver alerts based on the ShakeAlert system thresholds, which vary according to the system provider (e.g., wireless emergency alert (WEA) magnitude 5+; cell phone apps magnitude 4.5+). The ShakeAlert earthquake early warning (EEW) system currently uses two algorithms (EPIC and FinDer) that are both source-based methods, meaning they initially derive estimates of the earthquake magnitude and location. Subsequently, from these source-based estimates, ground-motion-prediction-equations are used to forward predict ground motions across the ShakeAlert operational region (spanning California, Oregon, and Washington). Project partners use these ground motion estimates to decide when and where to issue alerts.

ShakeAlert is considering enhancing the system by including the Propagation of Local Undamped Motion (PLUM) EEW algorithm. PLUM differs from the source-based methods as it predicts ground motions directly, without the extra step of computing earthquake location and magnitude. When neighboring stations observe ground motions above trigger thresholds (configurable) PLUM issues a detection. Based on spatial extrapolation of these ground motion detections, a PLUM alert map is constructed for each 0.2° x 0.2° grid cell spanning the west coast and offshore regions. These final PLUM ground motion maps are used to establish alert regions. PLUM has been running on a ShakeAlert development server in real-time for the last ~3 years. Here, we report lessons learned throughout the PLUM real-time test span and offer things to consider when exploring the feasibility of an EEW system in the state of Utah. These can be broken down into the following three categories: (1) Leveraging co-located acceleration and velocity sensors; (2) Incorporation of site terms in regions of prolific shallow seismicity; and (3) Configurable alerting strategies that do not require methodology changes.

A video of this talk is available at the following link:

https://geodata.geology.utah.gov/pages/view.php?ref=77159

A PDF version of the author's slide presentation is available at the following link:

https://ugspub.nr.utah.gov/publications/misc_pubs/mp-177/mp-177-d3t1.pdf

FUTURE EXPANSION OF THE EEW PLATFORM INTO NEVADA USING AN INTERNET OF THINGS (IOT) APPROACH

Graham Kent, University of Nevada Reno, gkent@unr.edu

Emily Morton, University of Nevada Reno, emilymorton@unr.edu

Daniel Trugman, University of Nevada Reno, dtrugman@unr.edu

Seth Saltiel, University of Nevada Reno, ssaltiel@unr.edu

Jayne Bormann, University of Nevada Reno, jaynebormann@gmail.com

ABSTRACT

With the potential for ShakeAlert to expand its geographic footprint eastward, transitioning to greater network resiliency and incorporation of low-cost sensors may provide the necessary combination to ensure reliable and timely warnings across the entire platform. This strategy may also provide an economically efficient framework for expanding earthquake early warning (EEW) deployments to less populated regions, where seismic hazard is nonetheless high. An Internet of Things (IOT) approach that leverages existing "points-of presence" (Figure 1) helps drive costs downward as several hazard applications (e.g., weather, fire, and seismic) help support individual nodes and network backbone communications. The foundation of a reliable and resilient communication network for ShakeAlert is through a diversified set of data transmission paths to each instrumented site, such as a combination of point-to-point (PtP) microwave links, fiber optic cable drops, and cellular backhaul. To achieve some reasonable service level agreement (SLA) target (e.g., 99.9 % uptime) upgrades to the current network topology are needed. The cost-performance of microwave links along with improvements in cellular reliability such as AT&T's FirstNet provide an opportunity to harden the ShakeAlert network without too much financial burden to the project. In remote locations, Starlink internet connectivity from a low-orbit constellation of satellites may be yet another opportunity to provide resiliency to outages resulting from weather events, wildfires, fiber-cuts, and earthquakes. An expanded ShakeAlert system could leverage other microwave networks from existing commercial Wireless Internet Service Providers (WISPs), state-wide and county networks to provide alternative routes out for seismometers/accelerometers as demonstrated by the ALERTWildfire project in the western U.S. Together, these technologies can help build affordable mesh network topologies that can provide reliable failover through Open Shortest Path First (OSPF) routing strategies. Embracing the concepts of "points-of-presence," or more simply put, adopting the Internet of Things (IOT) approach, may be the best strategy for an expanded ShakeAlert system to achieve reasonable SLAs for data delivery, while bringing down costs for a truly resilient and hardened network. The Nevada Seismological Laboratory is piloting a low-cost sensor deployment across NSL's wireless IOT network in the greater Tahoe-Truckee ShakeAlert footprint to explore this approach. Some 20 low-cost sensors are going to be added to existing "points of presence" over the next two years to explore the cost-benefit of densifying the current eastern California EEW network in this manner, potentially further benefiting EEW in this seismically active border region.

A video of this talk is available at the following link:

https://geodata.geology.utah.gov/pages/view.php?ref=77160

A PDF version of the author's slide presentation is available at the following link:

https://ugspub.nr.utah.gov/publications/misc_pubs/mp-177/mp-177-d3t2.pdf

Figure 1. *IOT EEW and ALERTWildfire site at Dollar Point, California.*

TOWARDS EARTHQUAKE EARLY WARNING IN ALASKA

Natalia Ruppert, Alaska Earthquake Center, University of Alaska Fairbanks, narruppert@alaska.edu

ABSTRACT

Alaska is the most seismically active state in the United States. Seventy-five percent of all earthquakes in the United States with magnitudes larger than five happen in Alaska. Over the course of the past 5 years, there were 5 earthquakes with magnitudes over 7. All Alaskans live with earthquake hazards. Earthquake Early Warning (EEW) is a system for warning the public and automated alert systems that a significant earthquake has begun and that shaking will soon occur at their location. An EEW system for the Pacific Coast, known as the U.S. Geological Survey's (USGS) ShakeAlert, is currently operational in California, Washington, and Oregon. Other systems have long been in place in Japan, Taiwan, and in parts of Mexico, China, and Korea. Developing such a system for Alaska faces many unique challenges: huge size of the region, wide range of earthquake sources, lack of communications and other robust infrastructure, and harsh climate. In 2022, the USGS Earthquake Hazards Program began working in partnership with the State of Alaska to fulfill the recent Congressional directive to deliver a written implementation plan describing what is needed to expand the USGS ShakeAlert System to Alaska. EEW in Alaska would need to be leveraged off of existing federal and state supported monitoring networks. The Alaska Earthquake Center is a participating regional seismic network for the USGS Advanced National Seismic System and is dedicated to strengthening Alaska's resilience to earthquakes and tsunamis through monitoring, research, and public engagement. Preliminary research conducted at the Earthquake Center indicates that warning times are possible for significant shaking intensities caused by the earthquakes along the subduction zone margin. These are the very 1st efforts towards advancing EEW possibility in Alaska.

A video of this talk is available at the following link:

https://geodata.geology.utah.gov/pages/view.php?ref=77161

A PDF version of the author's slide presentation is available at the following link:

https://ugspub.nr.utah.gov/publications/misc_pubs/mp-177/mp-177-d3t3.pdf

FIXED NETWORK SMARTPHONE-BASED EARTHQUAKE EARLY WARNING

Benjamin A. Brooks, U.S. Geological Survey, bbrooks@usgs.gov

Marino Protti, Observatorio Vulcanologico y Sismologico de Costa Rica Campus Omar Dengo, Costa Rica, marino.protti@gmail.com

Elizabeth S. Cochran, U.S. Geological Survey, ecochran@usgs.gov

Julian Bunn, California Institute of Technology, Julian.Bunn@caltech.edu

Todd Ericksen, U.S. Geological Survey, tericksen@usgs.gov

Floribeth Vega, Observatorio Vulcanologico y Sismologico de Costa Rica Campus Omar Dengo, Costa Rica, fvega@una.ac.cr

Chris Duncan, GISmatters, duncan@gismatters.com

Jon Avery, University of Hawai`i

Sarah E. Minson, U.S. Geological Survey, sminson@usgs.gov

Esteban Chavez, Observatorio Vulcanologico y Sismologico de Costa Rica Campus Omar Dengo, Costa Rica, esteban.j.chaves@una.cr

Juan Carlos Baez, Centro Sismologico Nacional de Chile

James Foster, University of Hawai`i, jamesfos@hawaii.edu

Craig L. Glennie, University of Houston, clglennie@uh.edu

ABSTRACT

We discuss an example of how off-the-shelf, low-cost sensor technology could be employed for earthquake early warning (EEW) purposes. We show that a fixed smartphone network could provide robust earthquake early warning for at least 2 orders of magnitude less cost than scientific-grade networks and could be stood-up in a matter of days. For Costa Rica, we evaluated a non-parametric ground-motion detection and alerting strategy with a threshold of 0.55%–0.65 % at four neighboring stations. During a six-month evaluation period we detected and alerted on 5 of 13 earthquakes with M_w 4.8–5.3 that caused felt Modified Mercalli Intensity shaking levels of 4.3–6. The system did not produce any false alerts and the undetected events did not produce wide-spread or significant felt shaking. Alerts for all 5 detected events would have reached the capital city, San Jose, before strong S-wave shaking, affording time for drop, cover, and hold on actions by most residents. An important result is that two of the five alerts were triggered by P-waves. This suggests that, with future improvement in sensors and/or algorithms, smartphone-based networks could approach the fastest theoretical EEW performance. We also show new results using the PLUM algorithm from a hybrid network of smartphones and the preexisting Costa Rican traditional seismic network. We show examples of how the increased density of smartphones permits faster alerts for the hybrid network in comparison to the traditional network alone. This suggests a simple and effective role for these low-cost sensors in future EEW build-outs.

SOCIAL SCIENCE AND SHAKEALERT

Sara K. McBride, U.S. Geological Survey, skmcbride@usgs.gov
Robert M. de Groot, U.S. Geological Survey, rdegroot@usgs.gov

ABSTRACT

As of May 2021, rollout of public alerting of the ShakeAlert Earthquake Early Warning (EEW) System, has been completed in Washington, Oregon, and California. Critical questions remain about what people understand and expect from ShakeAlert, including if they know what to do when they receive an alert. To evaluate whether the ShakeAlert system has been successful in answering these key research questions, the U.S. Geological Survey (USGS) collaborates with partners from the National Science Foundation, universities, emergency management and other state agencies, and USGS licensed alert distribution partners to implement a social science initiative focusing on three goals:

1. Understand earthquake risk perception, protective action knowledge, and basic earthquake preparedness across Washington, Oregon, and California populations.
2. The application of social science research to inform the ShakeAlert communication, education, outreach, and technical engagement (CEO&TE) programs.
3. Develop a monitoring and evaluation plan for CEO&TE programs for ShakeAlert.

The ShakeAlert social science initiative focuses on research that is currently underway and plans future directions to reach our goals. This extended abstract outlines the various publications that have been published or are in draft, future projects, and how social science research has been integrated into the ShakeAlert System.

Key words:
Warnings, protective actions, earthquake early warning, preparedness, alerting

INTRODUCTION

Earthquake early warning (EEW) has had several iterations in the United States, emerging from testing in the late 1960s to an operational system today in Washington, Oregon, and California. ShakeAlert is the EEW system for the U.S. West Coast; however, other EEW systems are active globally, as outlined in McBride and others (2022). The first concerted efforts for developing an EEW system for the United States began in the late 1990s with the Tri-Net studies; this project included surveying members of the public about EEW awareness in southern California, as outlined in Goltz (2003). Awareness at that time was generally very low, largely because the system was not yet active, and the seismic network was not even close to the full build out required for alerting. Nor had algorithms been developed or tested to quickly detect and determine which areas required alerting. The potential of the system was outlined in Allen and Kanamori (2003) with state and federal funding beginning in a coordinated way starting in 2006 (Allen and Melgar, 2019).

The need for the U.S. Geological Survey (USGS) to coordinate communication, education, outreach, and technical engagement (CEO&TE) efforts with its partner organizations about ShakeAlert was noted in Given and others (2014, 2018). The importance of social science to be included in the research projects for development of the ShakeAlert system was suggested in Cochran and others (2018). Several social science research projects and initiatives were undertaken prior to the creation of the Social Science Working Group (SSWG), specific to the ShakeAlert project. These projects included developing sounds for alerting (Burkett and Given, 2015) as well as a white paper that outlined warning messaging composition. The group had senior risk communication scholars including Dennis Mileti, Michele Wood, Deanna Sellow, Tim Sellnow, among others. However, it was noted that more research was required to better understand issues regarding protective actions, post alert delivery messaging, human behavior in earthquakes, risk perception and evaluation of CEO&TE efforts. In October 2018, a ShakeAlert social science research coordinator was hired to support these efforts including managing an international multi-institution SSWG.

ABOUT THE SOCIAL SCIENCE WORKING GROUP (SSWG)

Acknowledging the people who interact with EEW is essential (Given and others, 2018). A significant factor in the adoption and ultimate success of the ShakeAlert EEW System is effective communication, education, outreach, and technical engagement. The USGS's 2018 Revised Technical Implementation Plan for the ShakeAlert System – An Earthquake Early Warning System for the West Coast of the United States (2018 Technical Implementation Plan) notes that "EEW alerts are useless if people do not know how to respond to them" and "Extensive communication, education, and outreach (CEO) for both public and institutional users is needed for ShakeAlert to have maximum beneficial impact."

To assist understanding how people interact with the ShakeAlert system, the Social Science Working Group emerged from the 2018 CEO&TE strategy, which was updated in June 2022. The vision and mission of the strategy are in Figure 1.

Figure 1: Vision and Mission of the CEO&TE Strategy for 2021–2026.

The five core priorities from the strategy focus on all aspects of the system and are dedicated to real-world applications of ShakeAlert in sectors such as transportation, utilities, and health care. These five core priorities are:

1. Public Safety, Preparedness, and Resilience,
2. Technical Implementation and Engagement,
3. Consistent Messaging and Communication,
4. Integration with Other Federal and State Earthquake Hazards Products, and
5. Educational Resources Development and Dissemination.

Integral to the ShakeAlert CEO&TE program is a team of social scientists who conduct research with the primary goal of improving the ShakeAlert EEW System's ability to enhance public safety. Meeting for the first time in October 2019, the working group originally was small, involving only eight researchers. The original intent of the group was to assist in determining research priorities and provide feedback for survey and semi-structured and structured interview instruments.

From these five priority areas, SSWG developed three goals:

1. Understand where populations are currently in terms of risk perception, protective action knowledge, and basic preparedness across Washington, Oregon, and California.
2. Use social science research to inform the ShakeAlert CEO&TE program.
3. Develop a monitoring and evaluation plan for ShakeAlert CEO&TE.

SSWG has grown from 8 to currently over 30 researchers working on 20 research projects. There was a delay due to work loads and COVID-19, as disaster researchers became increasingly busy assisting with responses to the global pandemic.

PUBLISHED WORKS

Published work includes the first project funded partially by USGS, which was research regarding people's understanding of public education and messaging (Sutton, Fischer, James, and Sheff, 2020). The second published article, developed a typology and nomenclature for the system, to ensure consistent messaging and information (McBride and others, 2020). Protective actions for ShakeAlert, which included an analysis of global earthquake injury data from 1960 to present day, was explored in McBride and others (2021). Jenkins and others (2022), which explores how to create more inclusive communication campaigns about ShakeAlert. Another article explores types of museum and free choice learning environment exhibits and displays and how to develop specific materials for different kinds of educational environments (Sumy and others, 2022).

Adams and others (2022), explores generational gaps, educational environments, and protective actions for the 2018 M 7.1 Anchorage and the 2019 M 6.4 and M 7.1 Ridgecrest earthquakes. Another study analyzes Twitter and Reddit user's responses to the 2019 Ridgecrest earthquakes and ShakeAlert performance (Ruan and others, 2022). Minson and others (2022) explores how to develop a more tailored approach to the needs of individual public users, including the communication and educational programs regarding ShakeAlert. Goltz and others (2022) posits additional questions about earthquake early warning to Did You Feel It? Citizen science questionnaire. Wireless Emergency Alert latency testing was also conducted in 2018; the results of these tests are in McBride and others (2022). A baseline survey was conducted in February 2021, before the ShakeAlert system rollouts in Washington and Oregon, to determine attitudes and perceptions of earthquake early warning and earthquakes (Bostrom and others, 2022). Further, ShakeAlert researchers at the USGS have assisted researchers in New Zealand, to understand how previous earthquake experiences (Becker, 2022) and attitudes about earthquake early warning for New Zealand (Becker, 2020).

Finally, three short papers relating to ShakeAlert were submitted to the National Earthquake Engineering Conference for June–July 2022 in Salt Lake City, Utah. These papers include collection of video footage of people responding to earthquake shaking using Virtual Emergency Response Teams (VERTs) (McBride and others, 2022), developing a conceptual model for protective actions for earthquake early warning systems (Wood and others, 2022), and how the JCCEO&TE developed (de Groot and others, 2022).

INTEGRATING RESEARCH INTO PRACTICE

The first goal of the SSWG is to understand where populations are currently in terms of risk perception, protective action knowledge, and basic preparedness across Washington, Oregon, and California. This is currently in process, as Professor Ann Bostrom at University of Washington manages a project, funded by the National Science Foundation and with collaboration with the USGS, to develop a survey to monitor perceptions, attitudes, and knowledge of the ShakeAlert System, earthquakes, and protective actions. This research informed, in part, the rollout of ShakeAlert in Washington, shifting their campaign to focus more on protective actions as well as basic knowledge of the system. The post-alert delivery messaging research outlined in McBride and others (2020) has informed a suite of responses, with examples provided in Hauksson and others (2021). Development of drills for the ShakeAlert System is in process, partially informed by Adams and others (2022), particularly to address the generational knowledge-behavior gap. Research on protective actions, human behavior, and communication informed a report on Pacific Northwest earthquakes and modeled warning times (McGuire and others, 2021). Latency testing for the Integrated Public Alert and Warning System and geofence, as explored by McBride and others (2022), has assisted decision making on messaging and information.

CONCLUSIONS

Currently, 20 research projects have either been completed or are currently being conducted to better understand issues regarding the communication, education, and outreach development for ShakeAlert, all with the goal to improve public safety. The SSWG has more than 30 researchers across 12 universities from various stages of career development, universities, and nations, with links to New Zealand, Japan, Switzerland, France, Italy, and Japan. The SSWG studies a broad range of topics, from human behavior to communication campaigns to risk perception, among other topics. SSWG scholars represent a diversity of disciplines, with sociologists, anthropologists, social and development psychologists, geographers, communication and media studies researchers, public policy and administration, computer scientists, and seismologists. Given the multifaceted issues and complexities of ShakeAlert, multiple disciplines and lenses are indispensable to fully appreciating, and responding to these issues. Overall, the SSWG represents a substantial and sustained support for social science research for earthquakes, one of the largest such investments by the USGS in the last 30 years. The SSWG continues to grow annually, adding projects and researchers, becoming a recognized global hub of social science innovation.

ACKNOWLEDGMENTS

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. Funding for ShakeAlert social science projects comes from either the National Science Foundation or the U.S. Geological Survey.

REFERENCES

Adams, R. M., Tobin, J., Peek, L., Breeden, J., McBride, S., and de Groot, R. (2022). The generational gap: Children, adults, and protective actions in response to earthquakes. *Australasian Journal of Disaster and Trauma Studies*, 26(2).

Allen, R. M., and Kanamori, H. (2003). The potential for earthquake early warning in southern California. Science, 300(5620), 786–789.

Allen, R. M., and Melgar, D. (2019). Earthquake early warning: Advances, scientific challenges, and societal needs. Annual Review of Earth and Planetary Sciences, *47*, 361–388.

Becker, J. S., Potter, S. H., Vinnell, L. J., Nakayachi, K., McBride, S. K., & Johnston, D. M. (2020). Earthquake early warning in Aotearoa New Zealand: a survey of public perspectives to guide warning system development. Humanities and Social Sciences Communications, 7(1), 1–12.

Bostrom, A., McBride, S. K., Becker, J. S., DeGroot, R. M., & Goltz, J. D. (2022, in press). Great Expectations for Earthquake Early Warnings on the U.S. West Coast. International Journal of Disaster Risk Reduction.

Burkett, E. R., & Given, D. D. (2015, December). Sounding the Alert: Designing an Effective Voice for Earthquake Early Warning. In AGU Fall Meeting Abstracts (Vol. 2015, pp. S33B–2761).

Cochran, E. S., Aagaard, B. T., Allen, R. M., Andrews, J., Baltay, A. S., Barbour, A. J., . . . Toomey, D. (2018). Research to improve ShakeAlert earthquake early warning products and their utility (2331–1258).

deGroot, R.M., Sumy, D.F., McBride, S.K., Jenkins, M., Lotto, G., Vinci, M., Olds, S. (2022) ShakeAlert: A People-Focused Earthquake Early Warning System. Conference paper presented at the National Conference of Earthquake Engineering in June 27 – July 1, 2022, in Salt Lake City, Utah.

Given, D. D., Cochran, E. S., Heaton, T. H., Hauksson, E., Allen, R. M., Hellweg, P., . . . Bodin, P. (2014). Technical implementation plan for the ShakeAlert production system: An earthquake early warning system for the west coast of the United States: US Department of the Interior, US Geological Survey.

Goltz, J.D., Wald, D.J., McBride, S.K., de Groot, R.M., Breeden, J.K., Bostrom, A. (2022, in press). Development of a Companion Questionnaire for 'Did You Feel It?': Assessing Response in Earthquakes where an Earthquake Early Warning (EEW) may have been eceived. Earthquake Spectra.

Goltz, J. D. (2003). Applications for New Real-time Seismic Information: The TriNet Project in Southern California. Seismological Research Letters, *74*(5), 516–521. doi:10.1785/gssrl.74.5.516.

Hauksson, E., Olson, B., Grant, A., Andrews, J. R., Chung, A. I., Hough, S. E., ... & Valkaniotis, S. (2021). The Normal-Faulting 2020 M w 5.8 Lone Pine, Eastern California, Earthquake Sequence. Seismological Society of America, 92(2A), 679–698.

Jenkins, M. R., McBride, S. K., Morgoch, M., & Smith, H. (2022). Considerations for creating equitable and inclusive communication campaigns associated with ShakeAlert, the earthquake early warning system for the West Coast of the USA. Disaster Prevention and Management: An International Journal.

McBride, S.K., Bellizzi, J., Gin, S., Henry, G., Sumy, D.F., Baldwin, D., Fischer, E. (2022). 2018 M7.1 Anchorage and 2021 M7.2 Nippes, Haiti earthquake case studies for Virtual Earthquake Reconnaissance Team (VERT) activation protocols, policies, and procedures to gather earthquake response footage. Conference paper orally presented at the National Conference of Earthquake Engineering in June 27 – July 1, 2022, in Salt Lake City, Utah.

McBride, S. K., Bostrom, A., Sutton, J., de Groot, R. M., Baltay, A. S., Terbush, B., . . . Vinci, M. (2020). Developing post-alert messaging for ShakeAlert, the earthquake early warning system for the west coast of the United States of America. International Journal of Disaster Risk Reduction, 101713. doi:https://doi.org/10.1016/j.ijdrr.2020.101713.

McBride, S. K., Smith, H., Morgoch, M., Sumy, D., Jenkins, M., Peek, L., . . . de Groot, R. M. (2022). Evidence-based guidelines for protective actions and earthquake early warning systems. *Geophysics*, 87(1), 1–79.

McBride, S.K., Sumy, D., Llenos, A., Parker, G., McGuire, J., Saunders, J., Meier, M.A., Given, D., Schuback, P., DeGroot, R.M. (2022, in press). Latency Testing for Wireless Emergency Alerts intended for the ShakeAlert, the earthquake early warning system for the West Coast of the United States of America. Safety Science.

McGuire, J. J., Smith, D. E., Frankel, A. D., Wirth, E. A., McBride, S. K., & de Groot, R. M. (2021). Expected warning times from the ShakeAlert earthquake early warning system for earthquakes in the Pacific Northwest (No. 2021-1026). US Geological Survey.

Minson, S. E., Baltay, A. S., Cochran, E. S., Hanks, T. C., Page, M. T., McBride, S. K., ... & Meier, M. A. (2019). The limits of earthquake early warning accuracy and best alerting strategy. Scientific reports, 9(1), 1–13.

Minson, S. E., Cochran, E. S., Saunders, J. K., McBride, S. K., Wu, S., Baltay, A. S., & Milner, K. R. (2022). What to expect when you are expecting earthquake early warning. Geophysical Journal International, 231(2), 1386–1403.

Ruan, T., Kong, Q., McBride, S. K., Sethjiwala, A., & Lv, Q. (2022). Cross-platform analysis of public responses to the 2019 Ridgecrest earthquake sequence on Twitter and Reddit. Scientific reports, 12(1), 1–14.

Sumy, D. F., Jenkins, M. R., McBride, S. K., & de Groot, R. M. (2022). Typology development of earthquake displays in free-choice learning environments, to inform earthquake early warning education in the United States. International Journal of Disaster Risk Reduction, 73, 102802.

Sutton, J., Fischer, L., James, L. E., & Sheff, S. E. (2020). Earthquake early warning message testing: Visual attention, behavioral responses, and message perceptions. International Journal of Disaster Risk Reduction, 49, 101664. doi:https://doi.org/10.1016/j.ijdrr.2020.101664.

Wood, M., Zhang, X., Zhao, X., McBride, S.K., Luco, N., Baldwin, D., Cova, T. (2022). Earthquake Early Warning: Toward Modeling Optimal Protective Actions. Conference paper orally presented at the National Conference of Earthquake Engineering in June 27 – July 1, 2022, in Salt Lake City, Utah.

A video of this talk is available at the following link:

https://geodata.geology.utah.gov/pages/view.php?ref=77162

A PDF version of the author's slide presentation is available at the following link:

https://ugspub.nr.utah.gov/publications/misc_pubs/mp-177/mp-177-d3t5.pdf