2022 Basin and Range Earthquake Summit

Utah Geological Survey

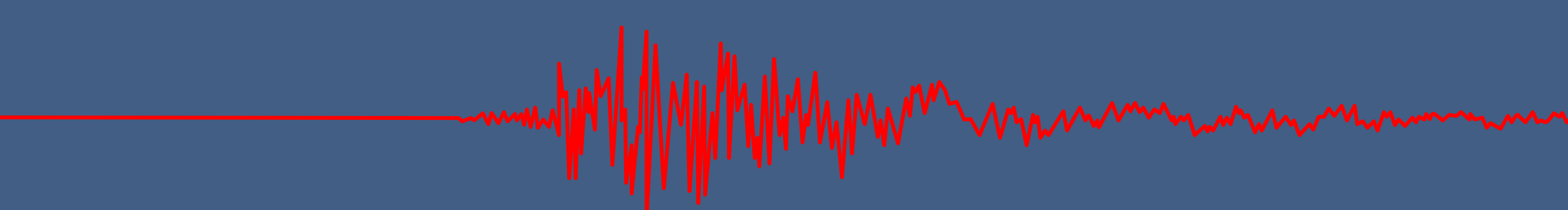
Seismology – Day 2

Technical Session 1 - The 2020–2021 Basin and Range Province Earthquakes

Conveners: Kris Pankow (University of Utah Seismograph Stations), and Jim Pechmann (University of Utah)

Technical Session 2 - Short- and Long-Term Seismic Hazard Analysis in the Basin and Range Province

Conveners: Jim Pechmann (University of Utah) and Kris Pankow (University of Utah Seismograph Stations)



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SEISMOLOGY – DAY 2

Technical Session 1 - The 2020–2021 Basin and Range Province Earthquakes

Conveners:
Kris Pankow (University of Utah Seismograph Stations)
Jim Pechmann (University of Utah)

Bringing Recent Basin and Range Earthquakes and the Seismic Cycle into Focus with Geodetic Networks; *William Hammond, University of Nevada, Reno*

Kinematic Slip Models of Four Moderate Intermountain West Earthquakes of 2020 and 2021; *Fred Pollitz, U.S. Geological Survey*

BRINGING RECENT BASIN AND RANGE EARTHQUAKES AND THE SEISMIC CYCLE INTO FOCUS WITH GEODETIC NETWORKS

William C. Hammond, University of Nevada Reno, whammond@unr.edu

ABSTRACT

The past two and a half years have seen a cluster of notable earthquakes that have highlighted the seismic hazard driven by active tectonics of the Basin and Range Province. These events not only remind us of the hazard but also supply crucial data that illuminate the connections between the various seismic, geologic, hydrologic and geodetic datasets that pertain to the physical processes at play before, during, and after the events.

In this presentation, I will focus on the lessons learned from the May 15, 2020, M 6.5 Monte Cristo Range earthquake (MCR), but also touch on other recent events such as the March 31, 2020, M 6.5 Stanley, Idaho earthquake, and the July 8, 2021, M 6.0 Antelope Valley earthquake. While these events were widely separated from one another, they share a role in the accommodation of active plate boundary tectonic deformation of the Intermountain Western United States. The presentation will highlight their locations within the active background tectonic strain rate field measured by GPS stations from multiple networks currently in operation and past GPS campaigns. The geodetic data are particularly useful for directly assessing the relationship between various aspects of the earthquake cycle, such as interseismic strain accumulation, coseismic strain release, and postseismic deformation. One example is that for each of these events, the coseismic strain was in a style consistent with the interseismic tensor strain rate style.

The MCR event is a particularly good example of observations made through multiple stages of the seismic cycle. Following the event, data were collected in the dense semi-continuous MAGNET GPS Network in a rapidly mobilized field deployment, supplementing prior data obtained in regular surveying for over 16 years. These data were integrated with those from other GPS networks in the western Great Basin and InSAR data from the ESA Sentinel 1 satellite mission. They were used to create slip models of the event which showed the consistency between pre-event strain accumulation, long-term slip rate on the Candelaria fault, and post-event after-slip which proceed for at least several months following the origin time.

Thus, these data provide a holistic view of the earthquake cycle in space and time and allow us to make comparisons between various other datasets that pertain to the event such as surface rupture, aftershock seismicity, and impacts on nearby geothermal well chemistry and physical parameters. We can also compare the coseismic parameters inferred from several of the various techniques to identify which are most sensitive to total moment, and what they imply for the tectonic regime of the east-central Walker Lane and Mina Deflection. The presentation will also discuss similar insights gained from the Antelope Valley and Stanley, Idaho, events via coverage by regional GPS networks and InSAR data.

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

https://geodata.geology.utah.gov/pages/view.php?ref=77155

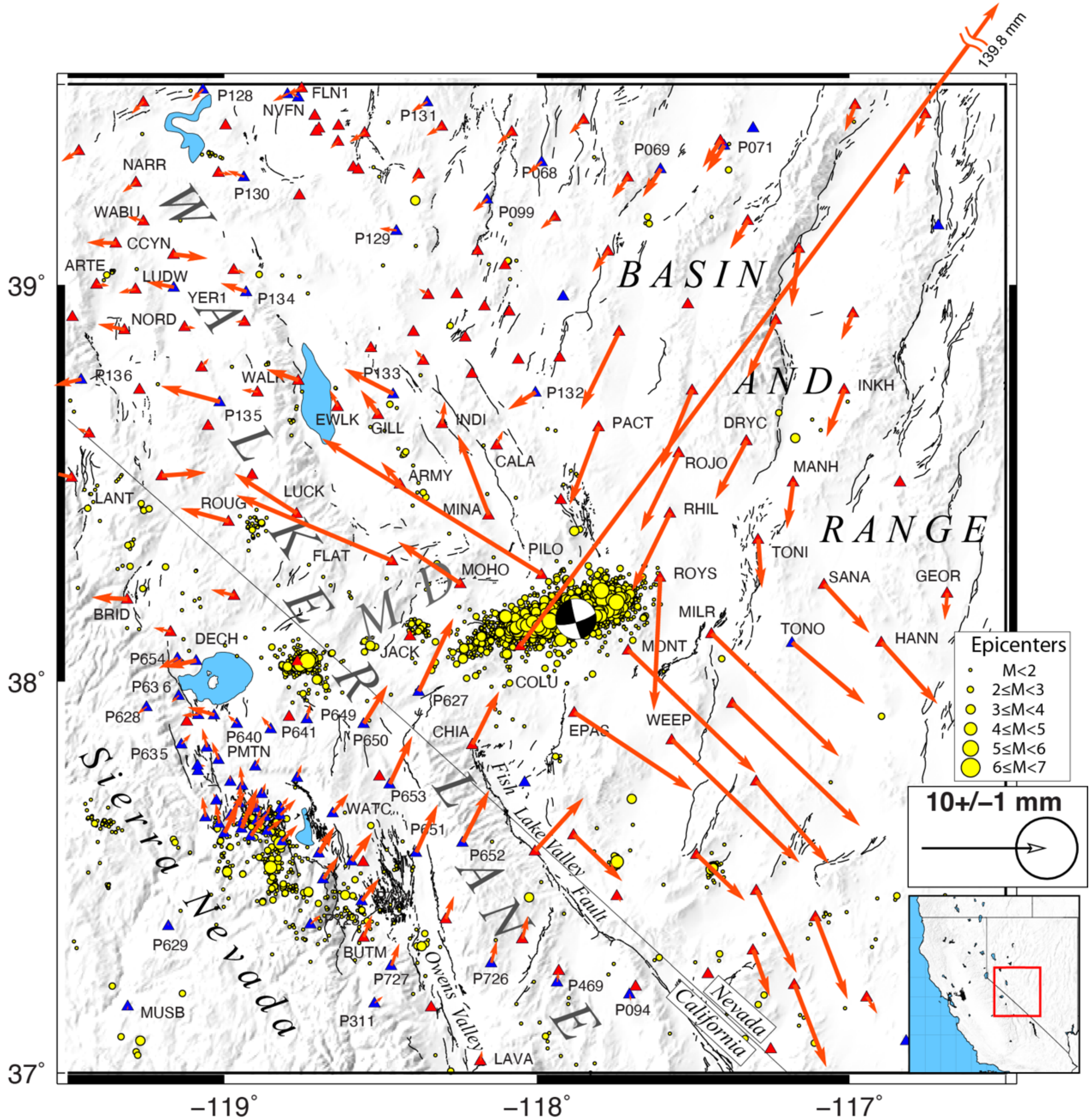

Figure 1. Red vectors are coseismic displacements from May 15, 2020, M6.5 Monte Cristo Range earthquake measured with the regional GPS networks. Using this vector scale emphasizes the extent and pattern of the coseismic displacement in the medium- to far-field but makes the displacement of the station nearest to the epicenter (139.8 mm at COLU) extend beyond the figure bounds. Regional seismicity in the year 2020 is shown with yellow circles. Figure from Hammond and others, 2020 (SRL). Moment tensor and seismicity locations are from the Nevada Seismological Laboratory.

KINEMATIC SLIP MODELS OF FOUR MODERATE INTERMOUNTAIN WEST EARTHQUAKES OF 2020 AND 2021

Fred F. Pollitz, U.S. Geological Survey, fpollitz@usgs.gov

Charles W. Wicks, U.S. Geological Survey, cwicks@usgs.gov

Jerry Svarc, U.S. Geological Survey, jsvarc@usgs.gov

William C. Hammond, Nevada Geodetic Laboratory, Nevada Bureau of Mines and Geology, University of Nevada Reno, whammond@unr.edu

Thorne Lay, University of California Santa Cruz, tlay@ucsc.edu

Chengli Liu, Institute of Geophysics and Geomatics, China University of Geosciences, liuchengli@cug.edu.cn

ABSTRACT

Four large earthquakes struck the Intermountain West and the Basin and Range Province in 2020 and 2021: the M 5.7 March 18, 2020, Magna, Utah; the M 6.5 March 31, 2020, Stanley, Idaho; the M 6.5 May 15, 2020, Monte Cristo Range, Nevada; and the M 6.0 July 8, 2021, Antelope Valley, California, earthquakes. As noted by Wesnousky (2020 SRL), each of the first three occurred in areas of relatively high background seismicity and geodetic strain rate; the same is true for the Antelope Valley earthquake. The events sample different tectonic environments with distinct fault geometries, leading to unique rupture characteristics of each event. We explore kinematic slip models of these earthquakes based on observations of geodetic static offsets and seismic waveforms. The Magna and Antelope Valley earthquakes are both normal faulting events that did not approach Earth's surface (centroid depths ~8–10 km). However, their fault dips differ substantially, 30 deg. and 50 deg., respectively, reflecting likely differing tectonic stress fields. The Monte Cristo Range event involves predominantly left-lateral strike slip on steeply dipping faults and normal slip on a small near-surface gently dipping fault. The Stanley event is the deepest of the four, with significant slip concentrated at a depth of ~8 to 16 km. It involves both strike slip and normal slip, with a gradual transition between the two in the along-strike direction, reflecting a spatially variable tectonic stress field. The Stanley and Antelope Valley events involve unilateral rupture propagation, but the Magna and Monte Cristo Range events have bilateral rupture propagation. Geodetic data (GNSS and InSAR) complement seismic waveform data and play important roles in constraining the fault geometry and spatial distribution of slip.

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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-d2t2.pdf

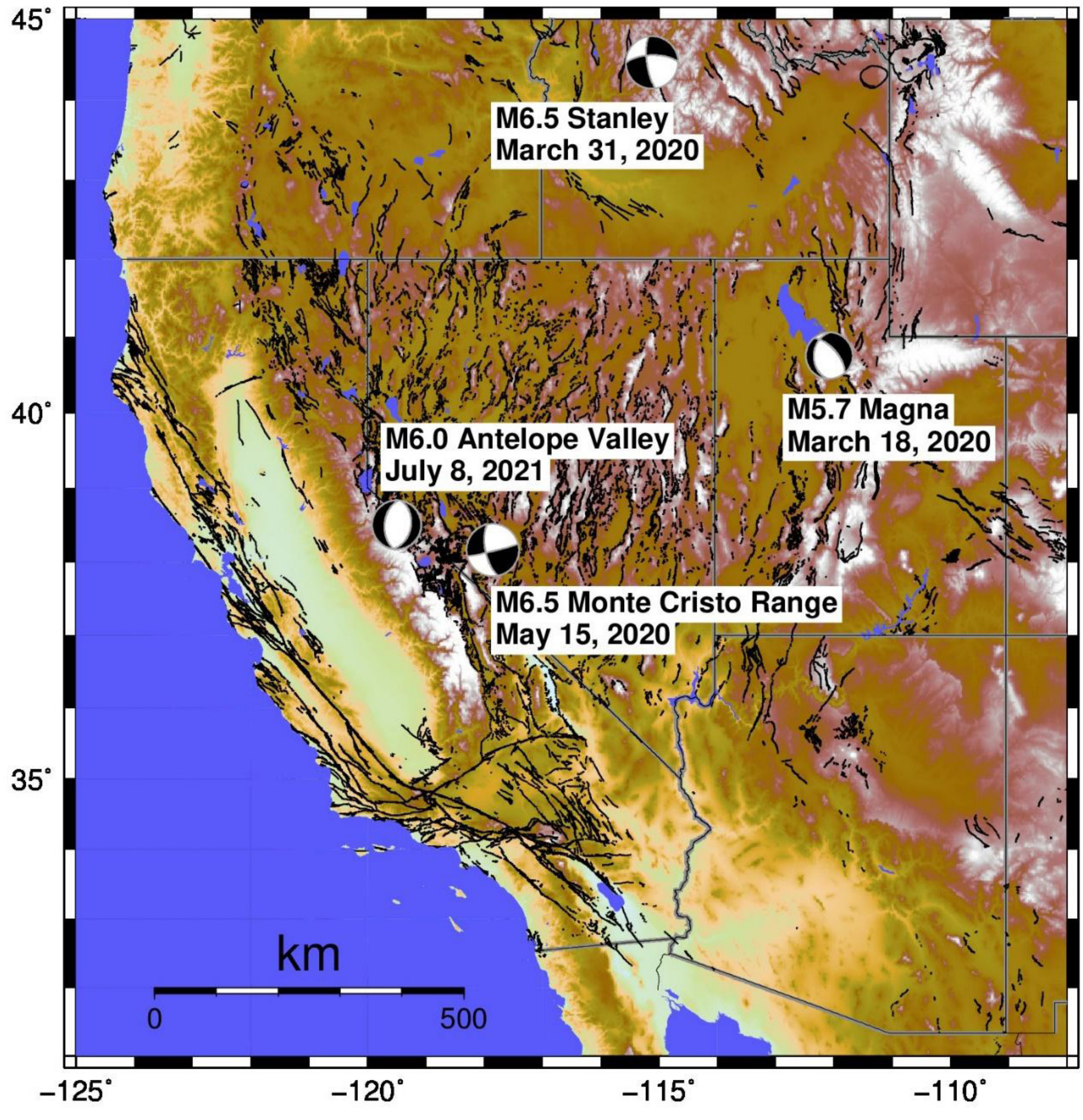

Figure 1. *Locations and focal mechanisms of the notable Intermountain West earthquakes. Superimposed are fault traces from the USGS Quaternary Fault and Fold Database.*

SEISMOLOGY – DAY 2

Technical Session 2 - Short- and Long-Term Seismic Hazard Analysis in the Basin and Range Province

Conveners:
Jim Pechmann (University of Utah)
Kris Pankow (University of Utah Seismograph Stations)

Move to Non-Ergodic Ground-Motion Models for PSHA in Utah; *Norman Abrahamson, University of California, Berkeley*

Aftershock Forecasting in the Basin and Range; *Jeanne Hardebeck, U.S. Geological Survey*

U.S. National Seismic Hazard 50-State Model: Science Objectives and Products; *Mark Petersen, U.S. Geological Survey*

MOVE TO NON-ERGODIC GROUND-MOTION MODELS FOR PSHA IN UTAH

Norman Abrahamson, University of California, Berkeley, abrahamson@berkeley.edu

Chih-Hsuan Sung, University of California, Berkeley, karensung@berkeley.edu

ABSTRACT

With the large increase in the number of recorded ground motions, it has become clear that there are large systematic differences in ground-motion scaling within the western U.S. and even within relatively small regions such as the Wasatch Front, Utah. The results from 3-D simulations also show large effects of the 3-D crustal structure on the ground motion at a specific site from a specific source location that cause significant deviations from the average scaling for the region. These observations have led to the move from ergodic to non-ergodic ground-motion models (GMMs). While ergodic GMMs provide a stable estimate of the average ground-motion scaling for a region, they are poor predictors of the ground motion at a specific site from a specific source, and they overestimate the aleatory variability at a single site. Non-ergodic GMMs mimic the source/site-specific effects seen in 3-D simulations by allowing the coefficients of the GMM to depend on the source and site location.

Sung and others (2021) developed a non-ergodic GMM using the observed ground motions from about 1500 recordings from 60 small to moderate earthquakes in Utah. The standard deviation of the non-ergodic GMM is about 25% smaller than the ergodic standard deviation. The median values vary by up to a factor of 2 from the average model depending on the site/source pair. In addition, the 3-D simulations for Utah developed by Moschetti and others (2017) are used to develop a non-ergodic site term for long-period basin effects from large-magnitude earthquakes on the Wasatch fault. The non-ergodic basin terms lead to a range of a factor of 1.5 increase or decrease relative to average scaling based on basin depth terms.

The application of non-ergodic GMMs in PSHA requires three modifications to the ergodic GMMs: (1) reduce the aleatory standard deviation of the ergodic GMM; (2) estimate the source/site-specific adjustment to the median from the ergodic GMM, and (3) estimate the epistemic uncertainty source/site-specific adjustment term. The hazard is computed using the adjusted median and reduced standard deviation with the epistemic uncertainty in the adjustment included in a logic tree. We show examples of hazard for T=0.2 and T=3 sec computed for the Salt Lake region using ergodic and non-ergodic GMMs from both empirical data and 3-D simulations. The mean hazard decreases for 70% of the sites and increases for 30% of the sites due to the skewed distribution of ground motions.

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AFTERSHOCK FORECASTING IN THE BASIN AND RANGE

Jeanne L. Hardebeck, U.S. Geological Survey, jhardebeck@usgs.gov
Michael Barall, U.S. Geological Survey, mbarall@usgs.gov
Sara K. McBride, U.S. Geological Survey, skmcbride@usgs.gov
Andrew J. Michael, U.S. Geological Survey, ajmichael@usgs.gov
Morgan T. Page, U.S. Geological Survey, mpage@usgs.gov
Gabrielle M. Paris, U.S. Geological Survey and Portland State University, gparis@usgs.gov
Nicholas J. van der Elst, U.S. Geological Survey, nvanderelst@usgs.gov

ABSTRACT

Aftershock forecasts can help a wide range of users—including the public, emergency responders, and lifeline engineers—prepare for, respond to, and recover from earthquake disasters. The U.S. Geological Survey (USGS) delivers public forecasts of the probability and expected number of aftershocks following domestic earthquakes M≥5. We have updated the Reasenberg and Jones (Science, 1989) methodology to improve the uncertainty estimates, the handling of early catalog incompleteness, and the Bayesian parameter adaptation as aftershock sequences progress (Page et al., BSSA 2016). The aftershock forecasts are generated automatically, integrated with other earthquake products on the USGS event webpages, and communicated with a template that provides basic aftershock information as well as detailed numerical forecasts. We are working to operationalize ETAS forecasting (Ogata, JASA 1988), which works better for sequences with large aftershocks, and more accurately estimates the forecast uncertainty. We have developed new generic aftershock parameters based on tectonic regionalization (Page and others, 2016). For much of the Basin and Range, we use globally derived parameters for active shallow continental regions, while locally derived parameters are used in California (Hardebeck et al., SRL 2019) and soon in Utah (Mesimeri and Pankow, AGU 2020). The USGS has released forecasts for numerous Basin and Range earthquakes, including: 2019 M 6.4 and M 7.1 Ridgecrest, CA; 2020 M 5.7 Magna, UT; 2020 M 5.2 Bodie, CA; 2020 M 6.5 Monte Cristo, NV; 2020 M 5.8 Lone Pine, CA; and 2021 M 6.0 Antelope Valley, CA. The forecasts were successful in that the observed number of aftershocks of various magnitudes generally fell within the ranges given in the forecasts. A few of the longer forecasts (1 month or 1 year) were less accurate, and these were usually made early in the sequence before a sequence-specific decay rate could be determined. The Lone Pine, Ridgecrest, Monte Cristo, and Bodie aftershock sequences, in particular, decayed faster than the generic model. The late M4 Magna aftershocks are consistent with the generic decay. The Ridgecrest forecast suggests that the Lone Pine earthquake was more likely an independent event than an aftershock. The aftershock forecasts have been used to inform the resumption of operations at the China Lake Naval Air Weapons Station following the Ridgecrest earthquakes, and by the State of Utah to determine the duration of the disaster declaration following the Magna earthquake.

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U. S. NATIONAL SEISMIC HAZARD 50-STATE MODEL: SCIENCE OBJECTIVES AND PRODUCTS

Mark D. Petersen, U.S. Geological Survey, mpetersen@usgs.gov

ABSTRACT

The U.S. National Seismic Hazard Model (NSHM) is developed periodically by the U.S. Geological Survey to account for new and improved data, models, and methods that have been developed since the previous model release. This probabilistic model is applied in building design criteria, risk assessments, and other public policy documents requiring that the best available and defensible science be considered. This 2023 NSHM will consider seismic hazard in all 50 states taking into account inherent differences in geological setting, tectonic strain rates, and earthquake rupture mechanics while allowing for more uniform methodologies and more consistent representation of epistemic uncertainties. Public workshops during 2020–2021 allowed for critical discussions on important elements of the NSHMs. The 2023 NSHM will be developed over the next two years and will include updates to both the source and ground motion inputs. For the statistical seismicity elements of the source model, we plan to update and decluster earthquake catalogs based on new algorithms, assess gridded seismicity rates using alternative statistical assessments, possibly evaluate application of time-dependent hazard branches, and calculate hazard. For applying new geologic and geodetic data in the source models, we are developing a database of geologic fault rupture rates and geodetic slip rates that will be used to construct multi-fault rupture models. For improving the ground motion models (GMM), we plan to update the CEUS-WUS boundary, implement several new GMM including new NGA-Subduction models, consider how to better implement GMM uncertainty and variability by evaluating new nonergodic methods, and improve the assessment of ground shaking in basins using basin depth information and simulations. Several important implementation issues will also consider better non-linear ground shaking estimates for the CEUS, assessment of hazard near basin edges, and implementation of uncertainty analysis.