

# UNIVERSITY OF UTAH SEISMOGRAPH STATIONS ANNUAL REPORT 2020





Cover photo: Structural damage to a historic brick house in Salt Lake City caused by the 2020 M5.7 Magna Earthquake. The home was subsequently demolished due to the extensive damage. Photo courtesy of Utah Geological Survey.

Inside photo: Temporary seismometer station COY installed by Wesley O'Keefe.



UNIVERSITY OF UTAH  
SEISMOGRAPH STATIONS

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Salt Lake City, UT 84112-0102  
quake.utah.edu

University of Utah  
Seismograph Stations  
2020 Annual Report  
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Left to right: Mark Hale, Maria Mesimeri, Avery Conner, Jonathan Voyles, and Nicholas Forbes volunteer at the College of Mines and Earth Sciences open house on Jan. 30, 2020.



UUSS Director Keith Koper is interviewed live by KUTV in response to the M5.7 Magna, Utah, earthquake on March 18, 2020.

## DIRECTOR'S MESSAGE

2020 was an unprecedented year in many ways. University of Utah Seismograph Stations was thrown into the thick of things by not only dealing with the COVID-19 pandemic but also responding to the largest Utah earthquake to occur since 1992.

The pandemic impacted our operations by causing us to work-from-home among other things. There were also complications in working out how to safely conduct field work and research. Overall, UUSS was able to rise to the challenge and quickly adjust to all the changes.

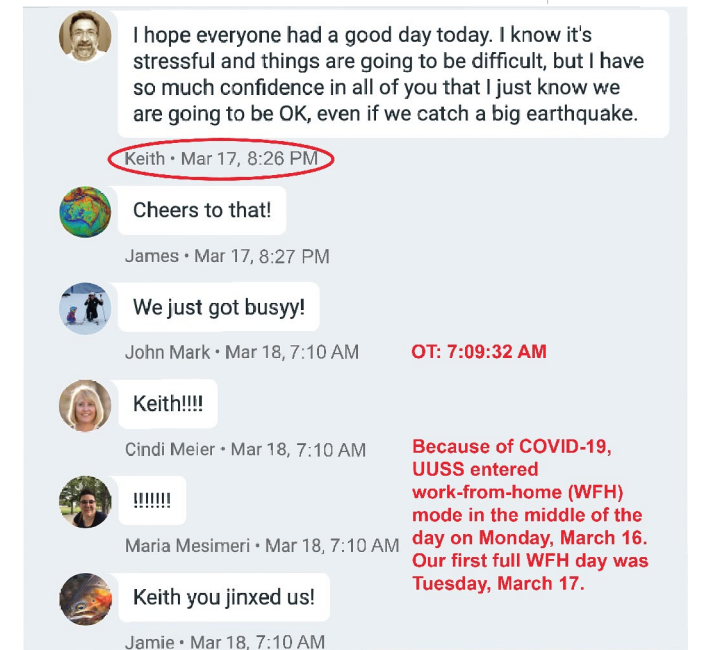
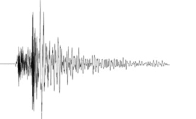
After our first-full day of working-from-home, Utah experienced its largest earthquake since 1992. The March 18, 2020 moderate M5.7 earthquake shook the Wasatch Front and brought a lot of attention to UUSS and our operations, especially as felt aftershocks continued to shake the public for months. We remained busy throughout the year because of the sequence. In a way, the Magna earthquake was a validation of the importance of the work we accomplish and a reminder that Utah is earthquake country.

The Magna, Utah, earthquake sequence provided substantial opportunities for research. Our staff and students worked on several different projects regarding the sequence. Research included documenting how we responded to the earthquake during a pandemic, evidence for a listric Wasatch Fault, and monitoring the sequence with nodal seismometers and machine learning.

Several of the Magna specific projects will be featured in a special issue of Seismological Research Letters that will focus on 2020 Intermountain West earthquakes. The special issue will be published in March 2021.

We're grateful to call 2020 a successful year even through all the challenges it provided. Our staff and students worked hard and accomplished incredible things. We expect even greater accomplishments in 2021.

Best Wishes,  
Keith D. Koper, UUSS Director



Screenshot from Google Hangouts immediately after the Magna earthquake on March 18, 2020.



## COVID-19 IMPACT ON UUSS

2020 brought a world-wide pandemic that impacted millions of lives. Constantly evolving information and directives caused a need for adaptability. University of Utah Seismograph Stations (UUSS) had the support and resources necessary to find success through the difficult year.

The beginning of the year brought whispers of COVID-19 and its potential to spread. In March, Utah received its first cases of the disease. By March 16, the state government announced a soft-closure for public schools. The University of Utah announced a move to online learning and a transition to working-from-home for faculty and staff as part of the government's directive.

March 17 was the first full work-from-home day for UUSS. A complicated situation was compounded when, on March 18, Utah experienced the largest instrumentally recorded earthquake in the Salt Lake Valley. UUSS showed amazing adaptability in responding to the earthquake while adhering to pandemic restrictions.

## OUTREACH

Outreach was severely limited due to COVID-19 and the work-from-home directive. Virtual capabilities increased the number of presentations and talks towards the end of the year. However, the beginning of the year's restrictions greatly reduced outreach efforts.

Before March, some notable events were:

- Exhibit at Silver Mesa Elementary School – Jan. 14
- University of Utah College of Mines and Earth Sciences Open House – Jan. 30
- Utah: Life of Elevated Earthquake Risk panel – Feb. 4
- Preparedness Day on the Hill – Feb. 27

The most notable outreach in 2020 was the more than 45 media interviews that took place in relation to the Magna, Utah, earthquake sequence.

*Becca Sumsion (left) and Mo Holt (right) participate in Preparedness Day on the Hill on Feb. 27, 2020.*

What was thought to be temporary work assignments soon became more permanent as restrictions increased through the rest of March and April. The work-from-home situation remained in place through the end of the year.

The M5.7 Magna, Utah earthquake on March 18 and the following sequence kept UUSS extremely busy. UUSS was forced to quickly find effective means of communication, deploy field equipment in a safe manner, and continue routine network operations in addition to the increased work from Magna. Methods that were put into place for earthquake response were able to improve and help operations throughout the rest of the year.

As the pandemic took the world by storm, UUSS produced quality work through good planning and diligence. UUSS published valuable research, attended conferences and meetings virtually, safely conducted equipment deployment, supported student research and education, and continued public service efforts.



## PERSONNEL

### Faculty

- Dr. Keith D. Koper  
Director  
Professor of Geology and Geophysics
- Dr. Kristine L. Pankow  
Associate Director  
Research Professor of Geology and Geophysics
- Dr. James C. Pechmann  
Research Associate Professor of Geology and Geophysics
- Dr. Jamie M. Farrell  
Research Assistant Professor of Geology and Geophysics
- Dr. Walter J. Arabasz  
Research Professor Emeritus of Geology and Geophysics  
[Past UUSS Director, 1985–2010]

### Full-Time Staff

- |                    |                                   |
|--------------------|-----------------------------------|
| Dr. Ben Baker      | Research Scientist                |
| Bill Blycker       | Systems Administrator             |
| Relu Burlacu       | Network Manager                   |
| Mark Hale          | Earthquake Information Specialist |
| Corey Hatch        | Seismic Network Engineer          |
| Dr. James Holt     | Postdoctoral Research Associate   |
| Cindi Meier        | Administrative Officer            |
| Dr. Maria Mesimeri | Postdoctoral Research Associate   |
| Wesley O'Keefe     | Seismograph Technician            |
| Arvind Parapuzha   | Seismograph Technician            |
| Paul Roberson      | Earthquake Information Specialist |
| Jon Rusho          | Seismic Network Engineer          |
| Becca Sumsion      | Communications Specialist         |
| Dr. Sin-Mei Wu     | Postdoctoral Research Associate   |

*\*graduated*

*+moved from undergraduate student to graduate student*

### Part-Time Staff

- |                   |                    |
|-------------------|--------------------|
| Amir Allam        | Research Scientist |
| Barry Morse       | Station Attendant  |
| Sheryl Peterson   | Communications     |
| Katherine Whidden | Research Scientist |

### Graduate Students

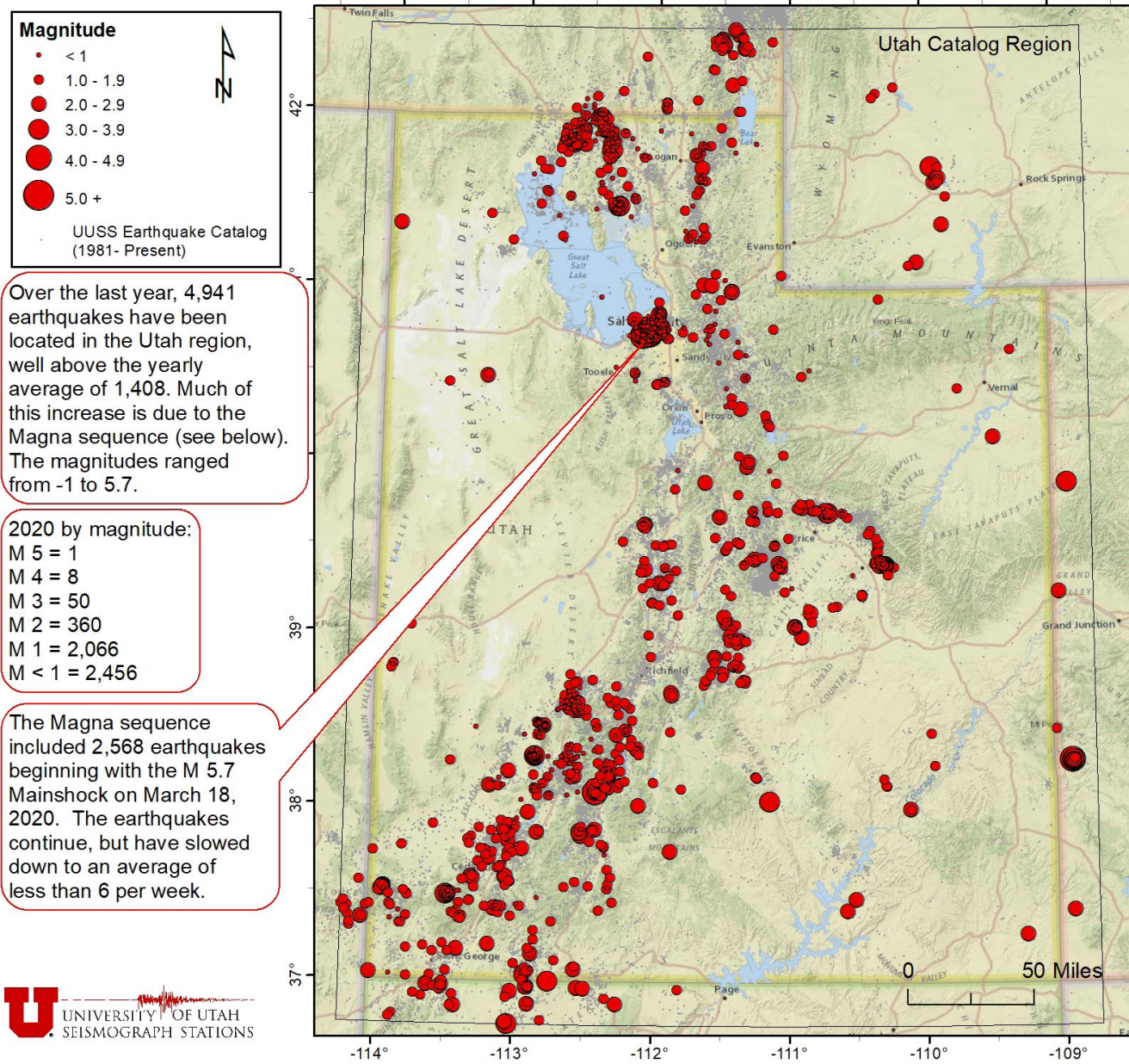
- |                    |                 |
|--------------------|-----------------|
| Monique Holt       | Ph.D. Candidate |
| Guanning Pang      | Ph.D. Candidate |
| Daniel Wells       | Ph.D. Candidate |
| Alysha Armstrong** | MS Geophysics   |
| Nicholas Forbes**  | MS Geophysics   |
| Amy Record*        | MS Geophysics   |

### Undergraduate Students

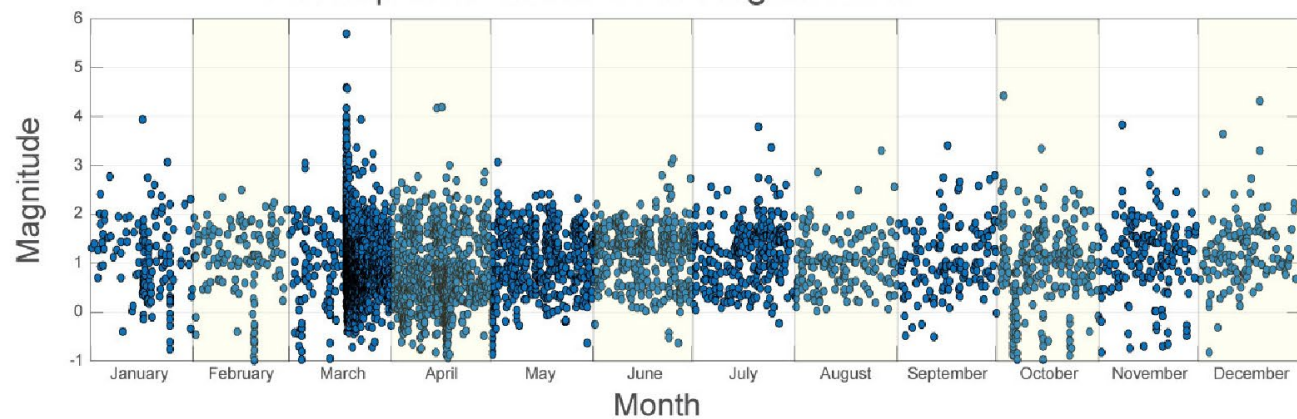
- |                   |
|-------------------|
| Zachary Claerhout |
| Avery Conner*     |
| Boe Ericksen      |
| Miles Haynes      |
| Barrett Johnson*  |
| Jonathan Voyles*  |



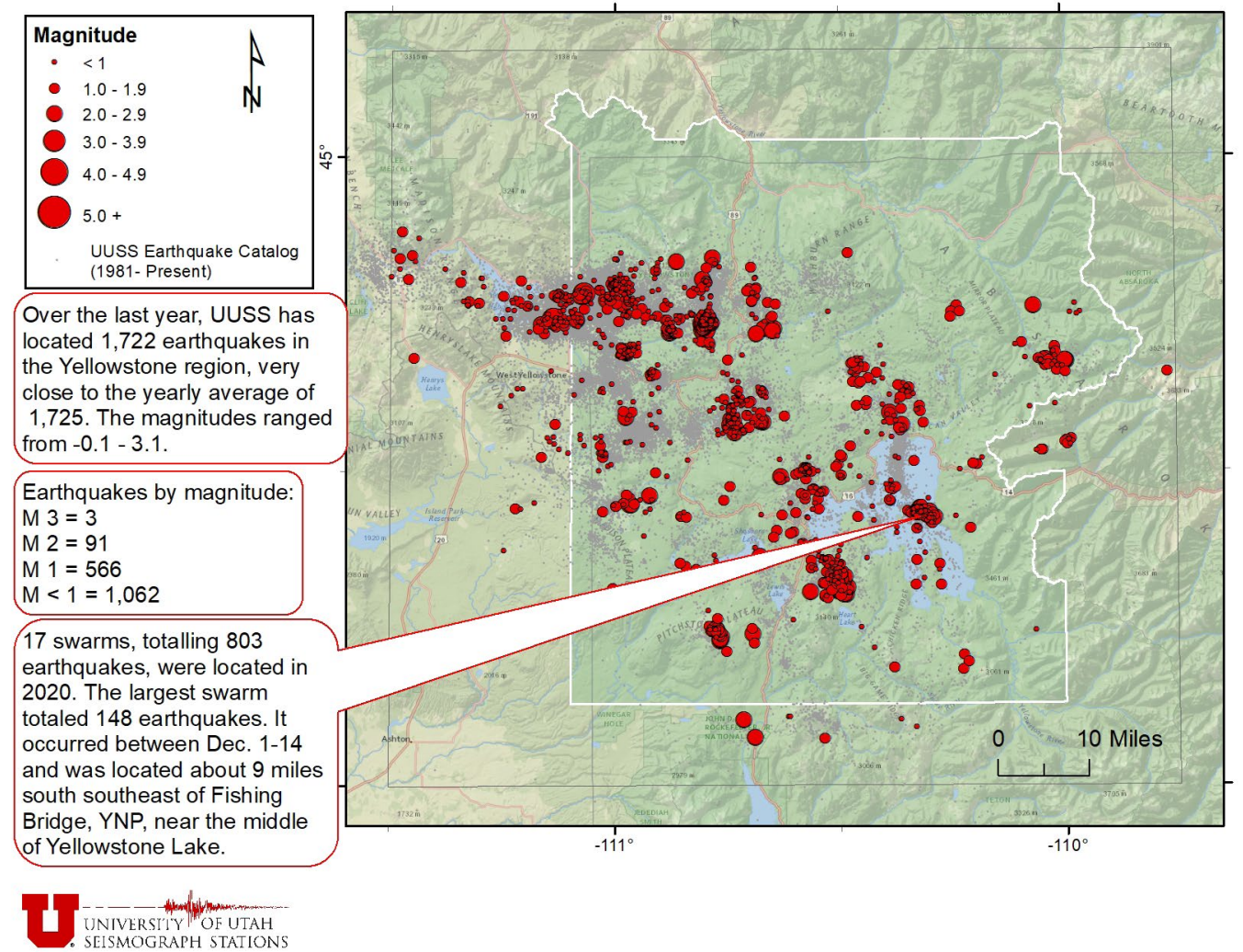
# SEISMICITY IN THE UTAH REGION



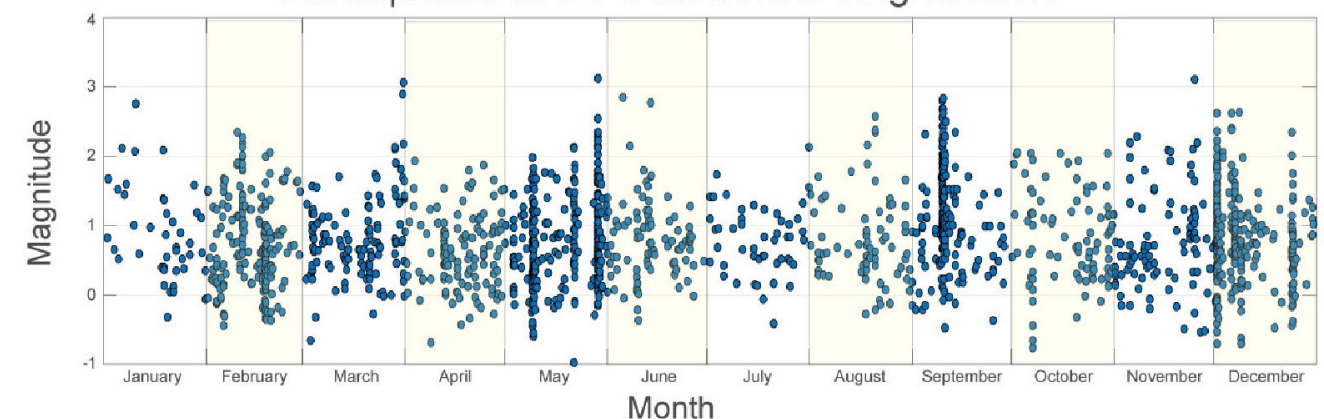
Earthquakes in the Utah Region 2020



# SEISMICITY IN THE YELLOWSTONE REGION

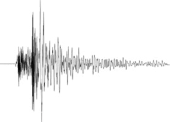


Earthquakes in the Yellowstone Region 2020





# SEISMO TEA



SeismoTea was interrupted early in the spring due to COVID-19 and the shift to working-from-home and online classes. Later in the summer, SeismoTea started again through virtual meetings. The fall semester was extremely successful and allowed a variety of speakers to present from throughout the country and internationally.

Date	Name	Institution	Lecture Title
Jan. 28	Sin-Mei Wu	PhD Candidate, Department of Geology and Geophysics, University of Utah	Spatiotemporal Seismic Structure Variations Associated with the 2018 Kilauea Eruption based on Temporary Dense Geophone Arrays
Feb. 11	James Holt and Surya Pachhai	Postdocs, Department of Geology and Geophysics, University of Utah	Jamaica earthquake and free-oscillation of the Earth observed by global seismic stations
Feb. 25	Michael Thorne	Associate Professor, Department of Geology and Geophysics, University of Utah	Deep mantle oddities
Mar. 3	Kristine Pankow	Research Professor, Assos. Director of Seismograph Stations, University of Utah	Re-evaluating remote dynamic triggering by first establishing background seismicity rates
Virtual			
Jul. 17	Wei Wang	Postdoc at the University of Southern California	Attenuation and scattering structure of southern California
Jul. 31	Elizabeth Cochran	Research Geophysicist, USGS Pasadena	Clustering Behavior of Induced Seismicity Reveals Triggering Processes
Aug. 7	Daniel Trugman	Assistant Professor, University of Texas at Austin	New Insights into Earthquake Rupture Processes from High-Resolution California Datasets
Aug. 14	Amanda Thomas	Associate Professor, University of Oregon	Overlapping regions of coseismic and transient slow slip on the Hawaiian décollement
Aug. 21	Marine Denolle	Assistant Professor, Harvard University	Monitoring the shallow Earth using the ambient seismic field: new theory, new tools, and applications
Aug. 28	Gesa Petersen	PhD student, GFZ Potsdam (Germany)	Lessons learned from regional CMT inversion of small earthquakes using the AlpArray Seismic Network
Sept. 4	Abdullah Mueen	Associate Professor, University of New Mexico	Automated Phase Classification for Next Generation Seismic Processing
Sept. 11	Ariel Lellouch	Postdoctoral Research Fellow, Stanford University	Seismic monitoring using downhole DAS — examples from the FORGE geothermal experiment
Sept. 18	Guanning Pang,	James Holt, Katherine Whidden, Mo Holt; University of Utah Seismograph Stations	Updates on the 2020 Magna, UT earthquake sequence
Sept. 25	Daniel Blatter	Postdoctoral Scholar, Scripps Institution of Oceanography	Constraining melt fraction and volatile concentration at the lithosphere-asthenosphere boundary using Bayesian inversion of electromagnetic data
Oct. 2	Daniel Wells	PhD Student, University of Utah	Source Physics Experiment: Dry Alluvium Geology (DAG) Gradiometric Analysis
Oct. 9	Dino Bindi	Senior Scientist, GFZ	Decomposition of amplitude Fourier spectra into source, propagation and site amplification factors: insights on ground motion variability
Oct. 23	Kevin Kwong	Postdoctoral Scholar, University of Washington	Modernizing Local Tsunami Warning Operations with GNSS-derived Earthquake Source Products
Oct. 30	Zefeng Li	Professor, University of Science and Technology in China	Learning big earthquakes from big data: from source process to emergency response
Nov. 6	Matthew Haney	Research Geophysicist, USGS and Alaska Volcano Observatory	Detecting and characterizing explosive volcanic activity at Mt. Cleveland Volcano, Alaska
Nov. 13	Brandon Schmandt	Associate Professor, University of New Mexico	Wastewater injection-induced seismicity in the Raton Basin from 2016-2020
Nov. 20	Qicheng Zeng	PhD Student, University of Utah	Analysis of Local Seismic Events near a Large-N Array for Moho Reflections



# LARGEST UTAH EARTHQUAKE SINCE 1992 SHAKES WASATCH FRONT

M5.7 Magna, UT, Earthquake March 18, 2020



## RESPONSE

On Wednesday, March 18, 2020, Utah was jolted by a magnitude 5.7 earthquake that occurred 3.1 miles north of Magna, Utah. The shaking from the earthquake was widely felt throughout the Wasatch Front area of north-central Utah.

Panic from the public was high. In addition to the current pandemic and the start of quarantine, this was

the first moderate earthquake many Utah residents experienced.

The minute the earthquake occurred, the University of Utah Seismograph Stations (UUSS) jumped into action. The location was reviewed, the data posted to the internet, and a press release sent out.

With the recent work-at-home directive from the university, only a handful of staff were sent in to the office to handle network operations and media. Most of



Top: Structural damage to a store in downtown Magna caused by the M5.7 Magna earthquake. Strong ground shaking caused part of a brick wall to collapse. Photo courtesy of Utah Geological Survey.

Left: Structural damage to a building in downtown Magna caused by the M5.7 Magna earthquake. The unreinforced masonry, or brick, on the front of the building failed due to strong ground shaking. Photo courtesy of Utah Geological Survey. Right: Non-structural damage on the third floor of the Department of Natural Resources building in Salt Lake City. Utah Geological Survey filing cabinets full of paper maps toppled in a walkway. Photo courtesy of Utah Geological Survey.



the staff remained at home and effectively collaborated through the use of Google hangouts.

UUSS Director Keith Koper took the lead in talking with the media through several press conferences, videos, and phone calls. It soon became apparent the public needed correct and educational information not only about the M5.7 earthquake, but about earthquakes in general. This was especially made apparent as an unfounded rumor claimed there was a magnitude 9.0 earthquake about to happen.

UUSS staff and students were swamped with work. The website was closely monitored and updated, analysts worked endlessly in locating the numerous aftershocks that continued to shake Utah, moment tensor solutions and other findings were calculated to better understand what occurred, and technicians deployed temporary nodals and seismograph stations to increase the accuracy of the earthquake solutions.

The M5.7 was the largest earthquake to occur in Utah since a magnitude 5.9 earthquake in 1992 in southwestern Utah near St. George. The earthquake occurred in a seismically active part of the Salt Lake Valley. Before March 18, the area experienced six magnitude 3.0 or larger earthquakes since 1962, the largest being the magnitude 5.2 on September 5, 1962.

The M5.7 was designated the mainshock of the Magna Earthquake Sequence. There were no foreshocks. At the end of 2020, there were 2,568 earthquakes recorded as part of the Magna sequence. The sequence is ongoing but has slowed to an average of less than six earthquakes per week.

## RESEARCH

In addition to the Magna M5.7 earthquake, there were other notable earthquakes in the Intermountain West in 2020. This led to research to be published in a special edition of Seismological Research Letters focusing on these events.

The Magna Earthquake Sequence was well-recorded due to the number of permanent and temporary seismometers located throughout the Salt Lake Valley. The well-recorded nature of the sequence led to several research opportunities both published and ongoing that have impacted and will continue to impact our

understanding about faults, earthquakes, and seismic hazard in Utah and the Intermountain West.

Prior to the Magna earthquake, the exact location at depth of the Wasatch fault was unknown, but many scientists thought it dipped at a steep angle deep beneath the Salt Lake Valley. Based on data from the Magna sequence, several research papers now suggest the sequence actually occurred on the Salt Lake City segment of the Wasatch fault. Evidence also suggests that the fault curves to a shallower angle and is not as deep beneath the surface as previously thought.

Researchers concluded that because of the likely shallower dip of the fault, which would put it closer to the surface, ground shaking estimates may be higher than previously thought for future earthquakes on the Salt Lake City segment of the Wasatch fault. Based upon these findings, ground-motion scenarios for future Wasatch fault earthquakes should be reevaluated to account for increased shaking.

Additional research published to date included increasing the number of detected earthquakes through machine learning, testing novel methods for magnitude determination, and documenting the challenges of responding to an earthquake during a pandemic

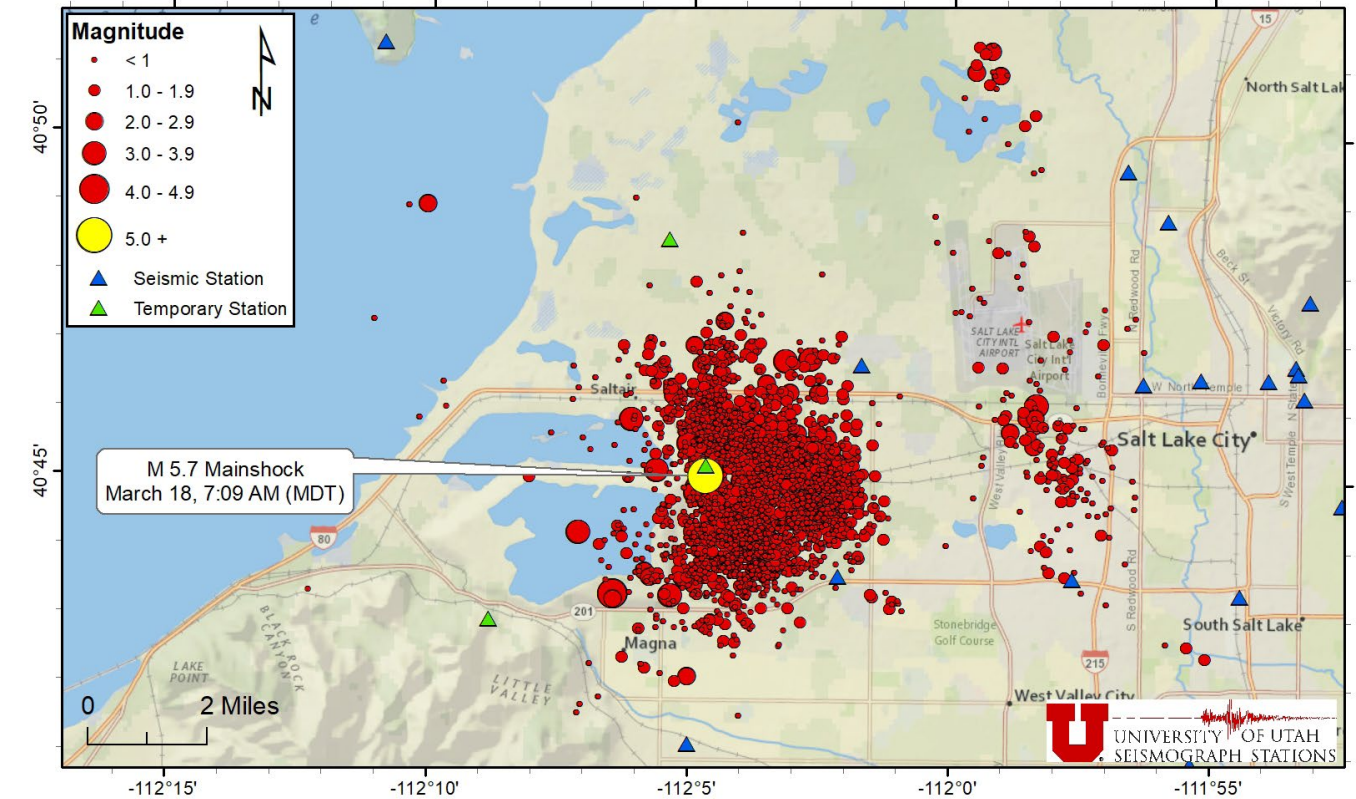
## COMMUNICATION

The Magna sequence impacted the way UUSS communicated internally and externally. The work-from-home situation necessitated the use of an instant messaging system to make quick contact with each other. UUSS heavily relied on Google hangouts. As 2020 progressed, many smaller groups were formed on hangouts to streamline conversations and make efficient decisions.

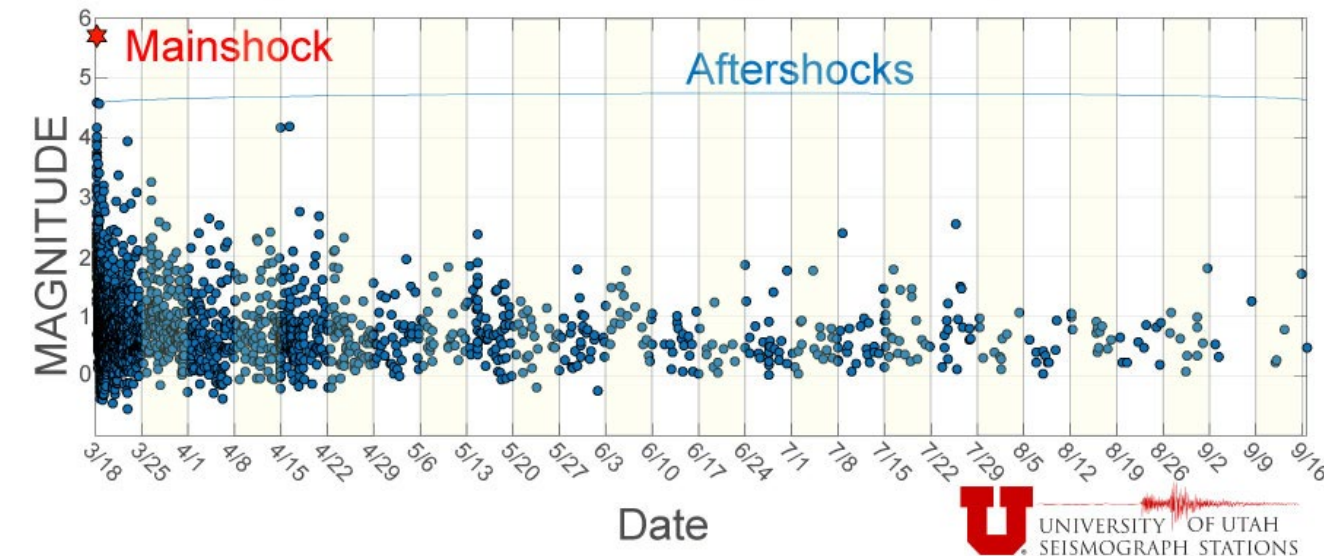
The need to quickly communicate with the public regarding current events also became apparent. In addition to responding to requests from the news media, UUSS established our own methods of communicating through social media to get information out quickly. The number of social media followers increased drastically because of the M5.7 earthquake. The @UUSSQuake Twitter account gained over 10,000 followers.

For the first few months after the M5.7 mainshock, whenever there were felt aftershocks or perceived

## Recent seismicity near Magna, Utah March 18 - September 18 (11AM MDT), 2020



## Magnitude vs Time Magna Earthquakes



Seismicity map and magnitude vs time plot of the Magna, Utah, earthquake sequence. These figures were updated weekly and shared during the first few months following the M5.7 mainshock. As the sequence slowed, updates were shared less frequently for notable moments, like a felt aftershock or the six month anniversary of the mainshock.

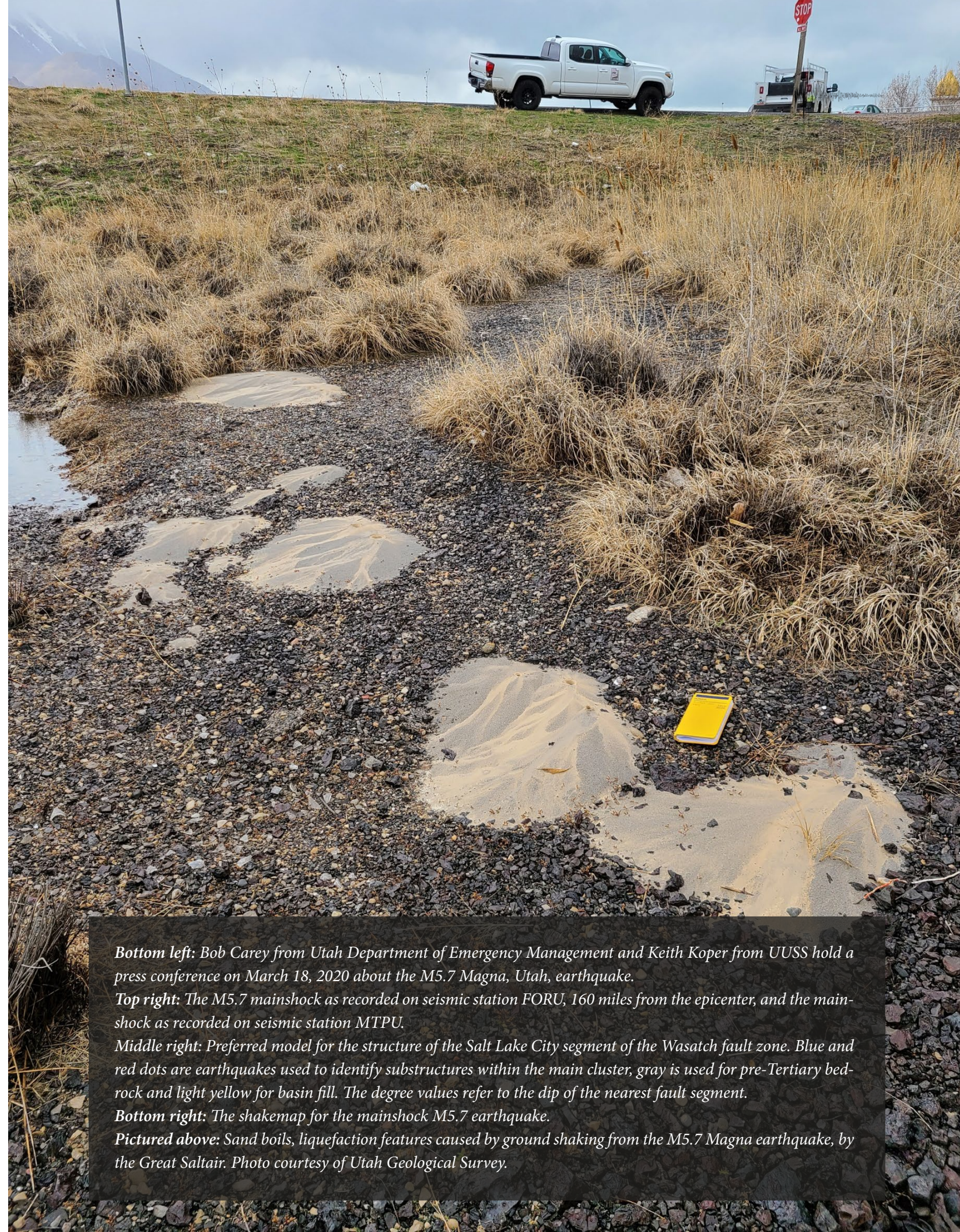
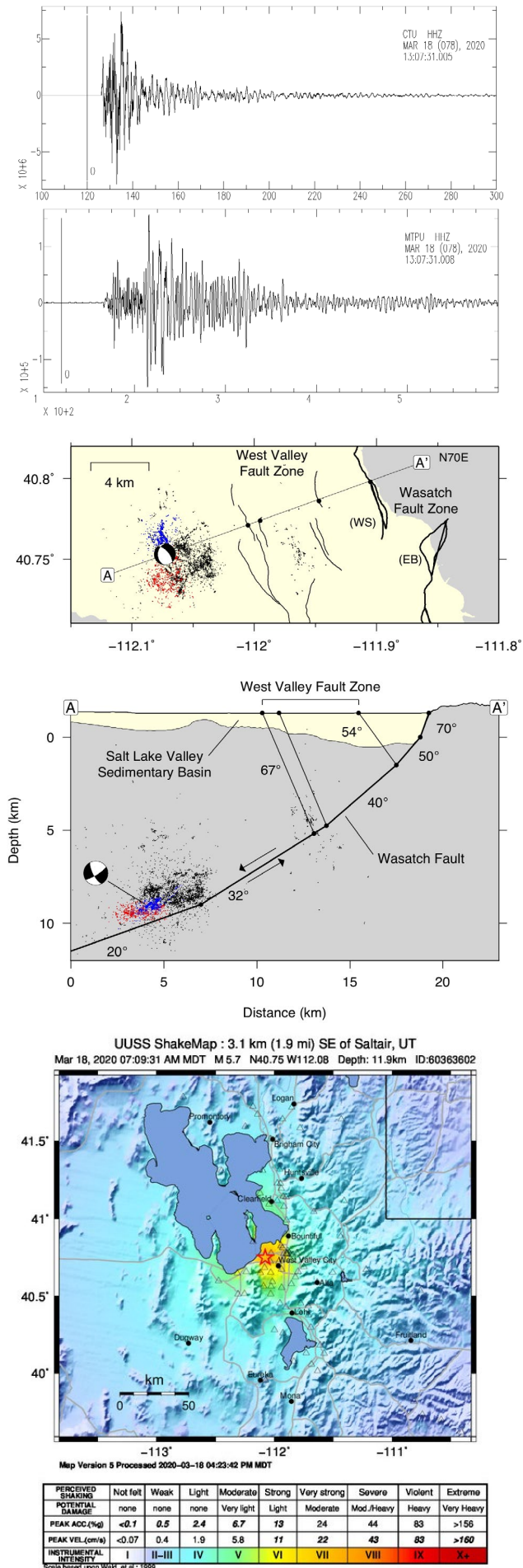


shaking, social media users turned to our social media platforms to find more information. We learned the importance of responding quickly and as accurately as possible to help placate people's fears. Even media outlets turned to our social media for information and many of our tweets were quoted in their articles.

The increased followers on our social media platforms also led to an opportunity to explore new ways to educate and inform the public about seismicity in Utah and Yellowstone. This led to our bi-weekly updates and other scheduled social media posts.

2020 and the Magna sequence were robust reminders that Utah is earthquake country. It confirmed, yet again, that seismic monitoring is important work.

For a more in-depth break down of how UUSS responded to the UUSS earthquake, please view *Pankow, K. L., J. Rusho, J. C. Pechmann, J. M. Hale, K. Whidden, R. Sumsion, J. Holt, M. Mesimeri, D. Wells, and K. D. Koper (2021). Responding to the Magna, Utah, earthquake sequence during the COVID-19 pandemic shutdown, Seism. Res. Lett., 92, 6-16, <https://doi.org/10.1785/0220200265>.*

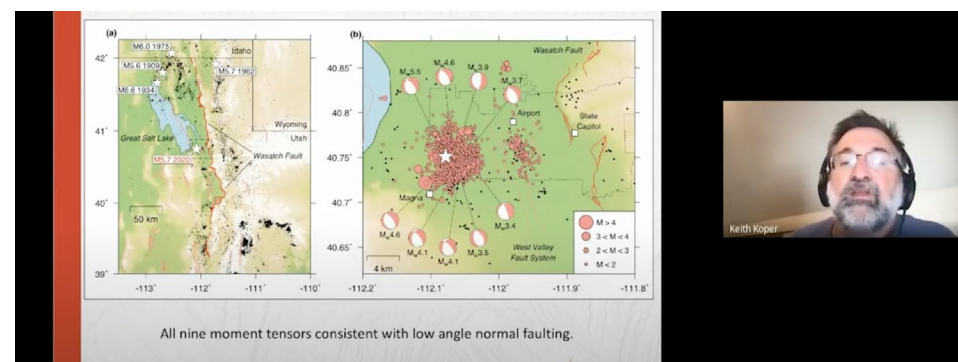


Bottom left: Bob Carey from Utah Department of Emergency Management and Keith Koper from UUSS hold a press conference on March 18, 2020 about the M5.7 Magna, Utah, earthquake.  
 Top right: The M5.7 mainshock as recorded on seismic station FORU, 160 miles from the epicenter, and the mainshock as recorded on seismic station MTPU.  
 Middle right: Preferred model for the structure of the Salt Lake City segment of the Wasatch fault zone. Blue and red dots are earthquakes used to identify substructures within the main cluster, gray is used for pre-Tertiary bedrock and light yellow for basin fill. The degree values refer to the dip of the nearest fault segment.  
 Bottom right: The shakemap for the mainshock M5.7 earthquake.  
 Pictured above: Sand boils, liquefaction features caused by ground shaking from the M5.7 Magna earthquake, by the Great Saltair. Photo courtesy of Utah Geological Survey.



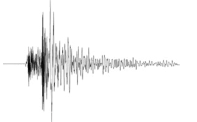
# PRESENTATIONS

Date	Personnel	Location	Topic
May	Kris Pankow	Benz/NEIC Coffee Hour	The 18 March 2020 $M_w$ 5.5 Magna, Utah, Earthquake Sequence
May 7	Keith Koper	Utah Seismic Safety Commission	Responding to the 18 March 2020 $M_w$ 5.7 Magna, Utah, Earthquake Sequence
June 17	Keith Koper	Idaho National Labs	Initial Results for the 18 March 2020 $M_w$ 5.7 Magna, Utah, Earthquake Sequence
July 23	Keith Koper	EERI virtual seminar	Seismic Analysis of the 18 March 2020 $M_w$ 5.7 Magna, Utah, Earthquake Sequence
Aug.	Kris Pankow	Intermountain Center for Disaster Preparedness Lunch & Learn	Earthquakes Don't Stop for Pandemics
Aug. 10	Jamie Farrell	Yellowstone Volcano Observatory seminar series	Using Seismology to Image the Steamboat/Cistern Hydrothermal Plumbing System in the Norris Geyser Basin
Fall	Maria Mesimeri	Seismology I, 2020 Fall Semester, Department of Geology and Geophysics, University of Utah	Backprojection Imaging of the 2020 $M_w$ 5.5 Magna, Utah Earthquake using a Local Dense Strong Motion Network
Sept.	Kris Pankow	Beaver County Commissioners and Milford Public Outreach	Seismic Monitoring at FORGE
Oct.	Kris Pankow	Utah Seismic Safety Commission	Seismic Monitoring at FORGE
Oct. 23	Keith Koper	University of Oregon virtual geophysics seminar	Analysis of the March 2020 Magna, Utah, Earthquake Sequence: Evidence for a Listric Wasatch Fault
Nov. 4	Maria Mesimeri	UU/GFZ Seminar	Detecting the Undetectable: Microearthquake Hunting in South-central Utah
Nov. 13	Mo Holt	University of Oregon	Distinguishing between Earthquakes and Explosions Recorded at Local Distances
Dec. 3	Mo Holt	University of Washington	Low-yield, Local-distance Seismic Discrimination
Dec. 3	James Holt & Katherine Whidden	UU/GFZ Seminar	Towards Robust and Routine Determination of $M_w$ for Small Earthquakes: Application to the 2020 $M_w$ 5.7 Magna, Utah, Seismic Sequence



UUSS Director Keith Koper presents virtually at the Utah Seismic Safety Commission meeting on May 7, 2020.

# COMMITTEE SERVICE



## Dr. Keith D. Koper

- Editor-in-Chief, The Seismic Record, 2020 – present
- Guest Editor, Seismological Research Letters special focus section on 2020 Intermountain West earthquakes
- Chair of SSA Richter Award Subcommittee, 2018 – present
- Vice-Chair & Chair of Utah Seismic Safety Commission, 2010–present
- Member of AGU Aki Award Subcommittee, 2019 – present
- Member of U.S. Air Force Seismic Review Panel, 2011 – present
- Member of EOS editorial advisory board, 2010 – present

## Dr. Kristine L. Pankow

- Guest Editor, Seismological Research Letters: Focus Section on Monitoring During a Crisis, 2020 – present
- Guest Editor, Journal of Seismology Special Issue: Induced seismicity: observations, modeling, monitoring, discrimination, and risk management strategies, 2019 – 2020
- Powell Cntr. Working Group, Future Opportunities in Regional & Global Seismic Monitoring, 2018 – present
- Utah Mine Safety Technical Advisory Council, July 1, 2011 – present
- Advanced National Seismic System (ANSS):
  - NIC representative to ANSS Steering Committee (non-voting), 2019 – present
  - Regional Coordinator, Intermountain West (IMW) region, 2010 – present
  - Member, ANSS National Implementation Committee (NIC), 2010 – present
- ANSS NIC Working Groups: Member, Revisiting Performance Standards Working Group, 2020

## Dr. James C. Pechmann

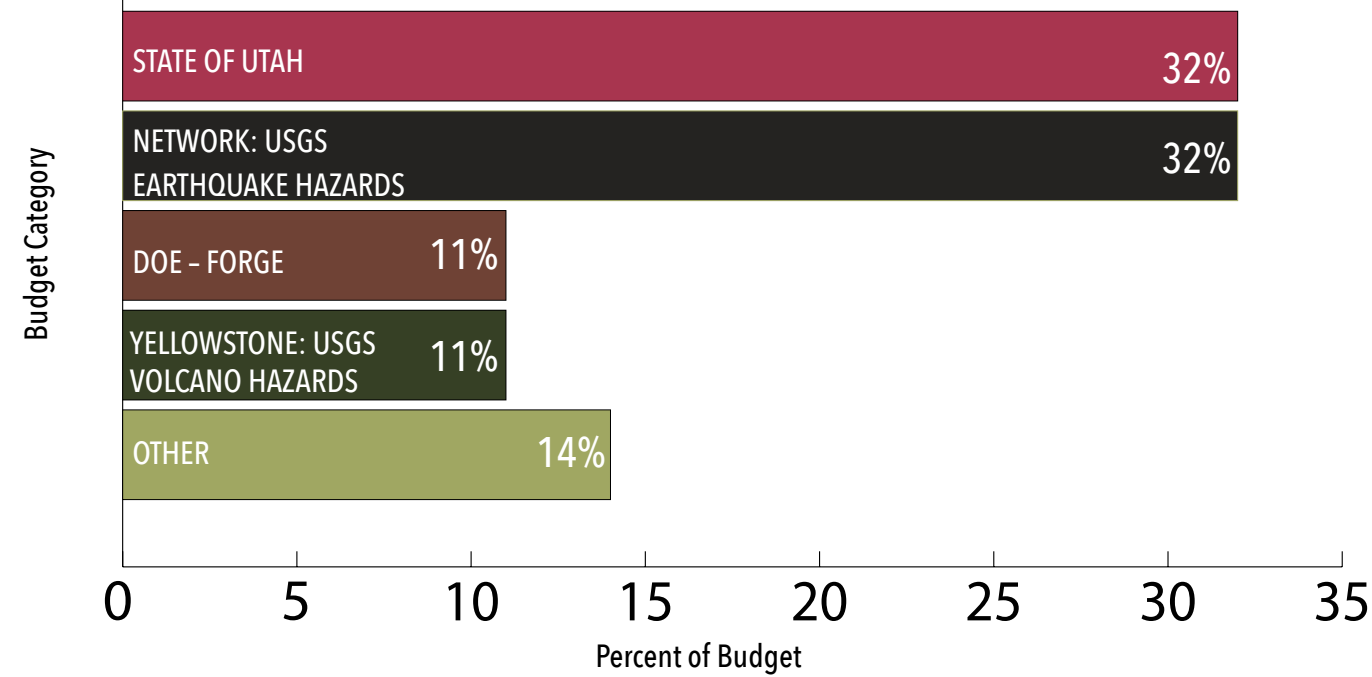
- Member, Western States Seismic Policy Council Program Committee, 2019 – present
- Participant, Utah Geological Survey, Basin and Range Province Earthquake Working Group, 2018 – present
- Member, Utah Quaternary Fault Parameters Working Group, Utah Geological Survey, 2003 – present
- Member, Working Group on Utah Earthquake Probabilities, Utah Geological Survey, 2003 – present
- Reviewer, Seismological Research Letters, 2019, 2020
- Reviewer, National Science Foundation, 2020
- College Council, 2018 – present
- Diversity and Climate Committee, 2020 – present
- Graduate Affairs Committee 2019 – present

## Dr. Jamie M. Farrell

- Chief Seismologist, Yellowstone Volcano Observatory, 2017 – present
- Duty Seismologist, Seismograph Stations
- Reviewer for BSSA, EOS, Frontiers in Earth Science, Geology, GJI, GRL, JGR, JVGR, National Geographic, Nature, National Science Foundation, SRL, and Tectonophysics.
- Member, Graduate Students Committee, Dept. of Geology and Geophysics and University of Texas at El Paso
- Member, University of Utah Dept. of Geology and Geophysics Merit Review committee, 2020
- Member, University of Utah Dept. of Geology and Geophysics Awards committee, 2020
- Member UNAVCO Geodetic Data Services Advisory Committee, 2020 – present
- Co-teacher, GEO 6920-030, MSSST, University of Utah, Spring 2020



## FUNDING



<b>U.S. Geological Survey – Earthquake Hazards Program</b>	<b>32.16%</b>
• Regional and urban seismic monitoring: Wasatch Front and neighboring Intermountain West region	
<b>State of Utah</b>	<b>31.65%</b>
• Earthquake monitoring, research, education and outreach in the Utah region	
<b>U.S. Geological Survey – Volcano Hazards Program</b>	<b>11%</b>
• Operational and maintenance of the Yellowstone regional seismic network and earthquake information system	
<b>U.S. Department of Energy – FORGE</b>	<b>11%</b>
• Enhanced geothermal system concept testing and development at the Milford City, Utah FORGE site	
<b>Other</b>	<b>14%</b>
<b>U.S. Geological Survey</b>	<b>DOI 1.09%</b>
• Temporal characteristics of aftershock sequences in the Intermountain West	
<b>U.S. Department of Energy</b>	<b>.36%</b>
• Structurally controlled geothermal systems in the Eastern Great Basin Extensional Regime, Utah	
<b>Sandia National Laboratory – Department of Energy</b>	<b>4.05%</b>
• Geophysical monitoring and characterization of the Utah Region	
<b>Air Force Research Laboratory</b>	<b>2.74%</b>
• Evaluation of ML-MC as a possible depth discriminant at local distances	1.57%
• Modeling and Observing the Effect of Source Depth on Seismic Waveforms Recorded at Local Distances for Purposes of Source Class	1.16%
<b>National Science Foundation</b>	<b>5.42%</b>
• Capitalizing on earthscope transportable array data to better characterize induced seismic sequences	.09%
• Mapping fine scale structure in earth's inner core with a global array of seismic arrays	1.97%
• The origin and propagation of shallow water microseisms: a multidisciplinary study at Yellowstone Lake	2.22%
• Controlled source seismic investigation of the top of the Yellowstone magmatic system	1.14%

## SPONSORS

University of Utah:

College of Mines and Earth Sciences  
 Department of Geology and Geophysics  
 Department of Mining Engineering  
 Energy and Geoscience Institute

Advanced National Seismic System

Air Force Research Laboratory

Arizona Geological Survey

Brigham Young University, Idaho

Idaho National Laboratory

International Seismological Centre

Lawrence Livermore National Laboratory

Montana Bureau of Mines and Geology

National Science Foundation

National Strong Motion Project

Northern Arizona University

Plate Boundary Observatory

RioTinto

Sandia National Laboratory

State of Utah

University of Nevada, Reno

U.S. Bureau of Reclamation

U.S. Department of Energy

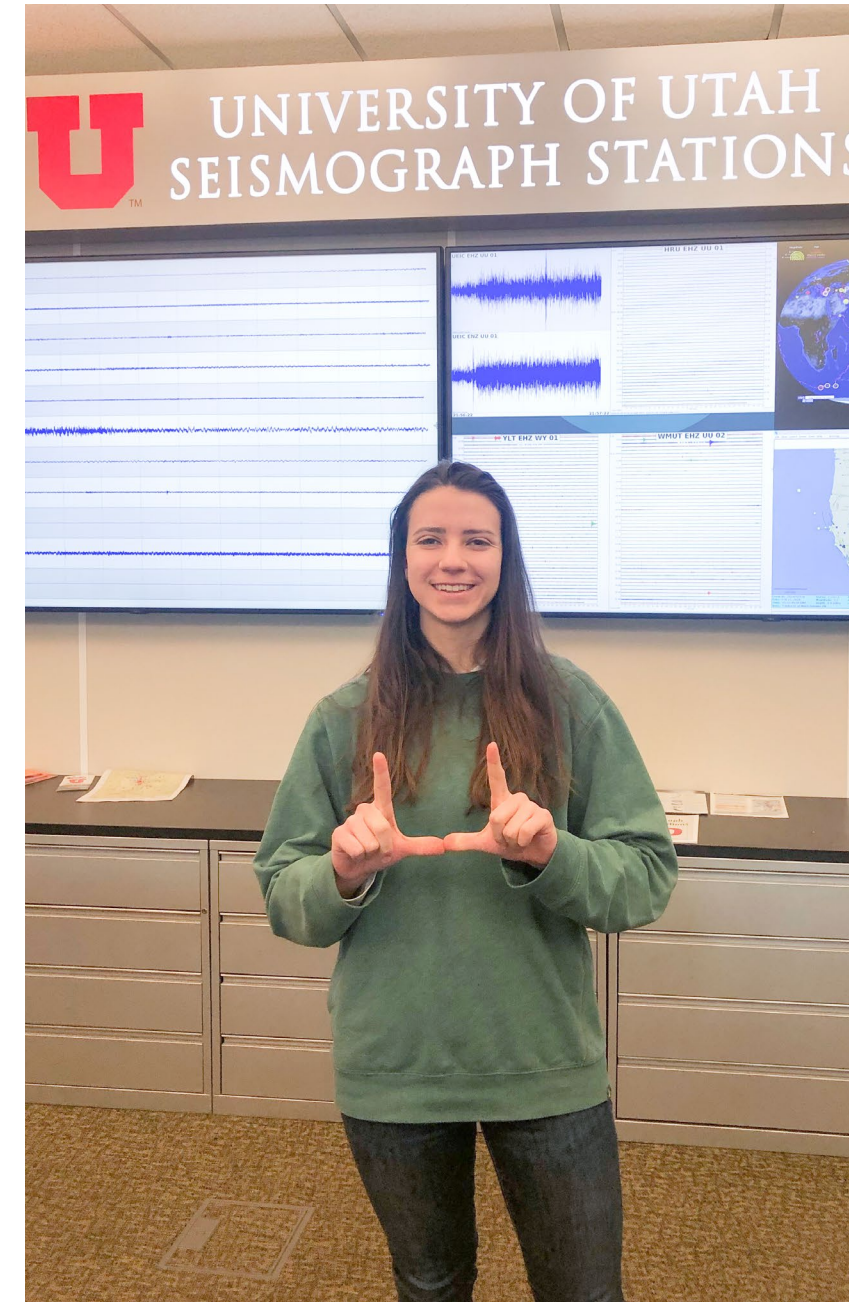
U.S. Geological Survey

Utah Department of Public Safety

Utah FORGE

Utah Geological Survey

Yellowstone National Park



*Student Alysha Armstrong shows support for the University of Utah in the Rio Tinto Earthquake Information Center.*



# STUDENT RESEARCH



**Monique Holt**  
Ph.D. Candidate Geophysics

Monique worked on calculating first-motion focal mechanisms for the Magna earthquake sequence. She also worked on her dissertation research, which deals with using local magnitude and coda magnitude to tell shallow events from deep events. Since the magnitude scales are difficult to develop, she has been working on just using measurements of waveform amplitude and duration as a proxy.



**Guanning Pang**  
Ph.D. Candidate Geophysics

Guanning's research focused on the Magna M5.7 earthquake. He was first author on the paper detailing the discovery of the M5.7 earthquake occurring on the Salt Lake Segment of the Wasatch fault and that the fault is listric, or curved, with a steep dip near the surface that curves to a shallower 30–35° at depth. The paper also suggests that ground shaking in the Salt Lake City region in future Wasatch fault earthquakes may be higher than previously estimated.



**Daniel Wells**  
Ph.D. Candidate Geophysics

Daniel primarily worked on the Utah FORGE project performing ambient noise tomography using four different nodal geophone arrays combined with permanent seismometers. He used a combination of eikonal tomography and ellipticity measurements to generate a 3D velocity model for part of Southern Utah.



**Alysha Armstrong\*\***  
Senior - Geoscience-Geophysics | MS Geophysics

Alysha worked on detecting mining induced seismicity at Sufco mine using template matching. In a project with Los Alamos National Laboratory, she worked on discriminating quarry blasts from earthquakes using spectral variance — a proposed measure of the modulations introduced into the spectra of delay-fired mining blasts. She graduated with her BS in geoscience in May and is now working on her MS in geophysics. Her thesis research is focused on detecting previously uncatalogued earthquakes in the Yellowstone region using machine learning and template matching techniques.



**Nicholas Forbes\*\***  
Senior - Geoscience-Geophysics | MS Geophysics

Nicholas worked on spatial-temporal analysis of the 2008–2009 Yellowstone Lake earthquake swarm. He utilized double difference and hierarchical clustering algorithms to perform relocations of the initial swarm. He applied template matching detection methods to the initial catalog and then used the hierarchical clustering relocation method to relocate the improved earthquake catalog in order to study geodynamical processes associated with the earthquake swarms. He also helped with research in Yellowstone and on the Magna earthquake sequence. Nicholas graduated with his BS in geoscience in May and is now working on his MS in geophysics.



**Amy Record\***  
MS Geophysics

Amy's research focused on defining and characterizing earthquake sequences in south-central Utah using several clustering techniques. The goal was to assess the influence of fluids in the upper crust on earthquake generation in that area. Amy defended her thesis: "Characterizing Seismic Clusters in South-Central Utah" and graduated in December 2020.



**Avery Conner\***  
Senior - Geoscience-Geophysics

Avery researched an earthquake sequence in the San Rafael Swell Region of Utah. She refined event locations in order to establish a potential fault structure, and detected more earthquakes associated with the sequence. Through this research, Avery plans to learn more about tectonic structures present in the San Rafael Swell, as well as determine if the 2019 sequence is linked to a 1988  $M_L$  5.2 earthquake.



**Barrett Johnson\***  
Senior - Geoscience-Geophysics

Barrett researched the Bluffdale, Utah, earthquake sequence. Using waveform cross-correlation methods to calculate differential travel times, Barrett worked to relocate the initial earthquake locations with a cluster-based relative relocation algorithm, GrowClust. The results allowed him to determine if the sequence occurred on the Wasatch fault, illuminate the complex nature of the tectonic setting surrounding the Bluffdale region, and make more precise earthquake hazard assessments moving forward.



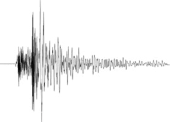
**Jonathan Voyles\***  
Senior - Geoscience-Geophysics and Geological Engineering

Jonathan worked on the  $M_L$ – $M_C$  depth-based discrimination at local distances project for three years. During that time, he tested  $M_L$ – $M_C$  on a new catalog of explosions in Utah, simulated what mechanisms are driving the  $M_C$  depth-dependence using high-performance computing, and tested  $M_L$ – $M_C$  using machine learning methods.

**Zachary Claerhout | Boe Ericksen | Miles Haynes**  
Student Analysts

Utilized various seismic stations located in Utah, Wyoming, and surrounding states to locate earthquakes. Also monitored mining operation blasts in the state of Utah, teleseism events, or background noise.

*\*graduated*  
*+moved from undergraduate student to graduate student*





# ABSTRACTS, PUBLICATIONS, & REPORTS

## ABSTRACTS

### Air Force Research Laboratory Technical Interchange Meeting, Melbourne, FL, January 28–30, 2020

Koper, K. D., M. Holt, J. Voyles, and R. Burlacu (2020).  $M_L$ – $M_C$  as a possible depth discriminant at local distances, Air Force Research Laboratory Technical Interchange Mtg.

### Seismological Society of America Annual Meeting, Albuquerque, New Mexico April 27–30, 2020

Forbes, N., K. Koper, J. Farrell, M. Mesimeri, R. Burlacu (2020). Detection and Location of Small Seismic Events Surrounding Yellowstone Lake, WY.

Holt, J., M. Mesimeri, B. Edwards, P. Suroyo, K. Koper (2020). Monitoring Induced Earthquakes at the Preston New Road Shale Gas Site, Blackpool, UK.

Holt, J., J. C. Pechmann, B. Edwards, and K. D. Koper (2020). Local magnitude (ML) determination for earthquakes in the Yellowstone National Park region, USA, *Seism. Res. Lett.* 91, 1215.

Mesimeri, M., K. Pankow (2020). A frequency-domain-based algorithm for detecting induced seismicity using dense surface N-arrays.

Record, A., M. Mesimeri, K. Pankow (2020). Earthquake clustering in southcentral Utah.

Pankow, K., K. D. Koper, R. Burlacu, B. Baker, J. C. Pechmann, J. Farrell, and J. Holt (2020). The University of Utah Seismograph Stations: A multifaceted regional earthquake center, *Seism. Res. Lett.* 91, 1307.

Rusho, J., W. O’Keefe, J. Farrell, and J. C. Pechmann (2020). Care and feeding of analog-telemetry seismic stations, *Seism. Res. Lett.* 91, 1306–1307.

### European Geosciences Union General Assembly, Vienna, Austria, May 3–8, 2020

Mesimeri, M., K. Pankow, B. Baker, and J. M. Hale (2020). The October 2019 earthquake swarm in the Mineral Mountains, Utah and its relation to the geothermal system, EGU2020–5767.

### American Geophysical Union Fall Meeting, Online, December 1–17, 2020

Lin, F. C., S. M. Wu, J. Farrell, B. Shiro, and L. Karlstrom (2020). High-Resolution Crustal Velocity Response to the 2018 Kilauea Eruption Using Temporary Dense Geophone Arrays (Invited), Abstract V006-02 presented virtually at the 2020 Fall meeting, AGU.

Mesimeri, M. and K. L. Pankow (2020). On earthquake sequences in the Intermountain West (abstract S038-0004).

Pang, G., K. D. Koper, M. Mesimeri, K. L. Pankow, B. Baker, J. Farrell, J. Holt, P. Roberson, R. Burlacu, J. C. Pechmann, K. Whidden, M. M. Holt, A. Allam, and C. DuRoss (2020). Evidence for a listric Wasatch Fault from the 2020 Magna, Utah, earthquake sequence (abstract S041–04).

Tibi, R., R. Hammond, R. Brogan, C. J. Young, and K. D. Koper (2020). Deep learning denoising applied to the University of Utah seismic stations network data, abstract S052–001, presented on Dec. 15.

Wang, R., B. Schmandt, and K. D. Koper (2020). Local distance seismic source classification during the iMUSH project, abstract S049–06, presented Dec. 14.

Wu, S. M., F. C. Lin, J. Farrell, W. Keller, E. White, J. D. G. Hungerford (2020). Interferometric-Based Polarization Analysis: Implications of Geyser Architecture and Dynamics at Steamboat Geyser in Yellowstone National Park, Abstract S017-08 presented virtually at the 2020 Fall meeting, AGU.

## PRESENTATIONS

Holt, M. (2020). A vision for a diverse and equitable environment through the lens of Inclusive Earth, invited talk about diversity, equity, justice and inclusion for the Pardee Symposium at Geological Society of America conference.

Mesimeri, M. (2020). Tectonic and volcanic earthquake swarms: From a multi-disciplinary imaging and tracking of crustal fluids to characterization of transient forcing, Co-convener of EGU 2020 session SM6.1

Pang, G. (2020). Seismic analysis of the 2020 Magna, Utah, earthquake sequence, oral presentation, at the 2020 Fall meeting, AGU, 1–17 Dec.

## PROCEEDINGS

Moore, J., J. McLennan, K. Pankow, R. Podgorney, S. Simmons, P. Wannamaker, C. Jones, W. Rickard, B. Barker, C. Hardewick, and S. Kirby (2020). Overview of Utah FORGE results in 2019: Proceedings, 45th Workshop on Geothermal Reservoir Engineering, Stanford University, CA February 10–12, 10 p.

Pankow, K., M. Mesimeri, J. McLennan, P. Wannamaker, and J. Moore (2020). Seismic monitoring at the Utah Frontier Observatory for Research in Geothermal Energy: Proceedings, 45th Workshop on Geothermal Reservoir Engineering, Stanford University, CA February 10–12, 9 p.

Xing, P., D. Winkler, B. Rickard, B. Barker, A. Finnilla, A. Ghassemi, K. Pankow, R. Podgorney, J. Moore, and J. McLennan (2020). Interpretation of in-situ injection measurements at the FORGE site: Proceedings, 45th Workshop on Geothermal Reservoir Engineering, Stanford University, CA February 10–12, 18 p.

## PUBLICATIONS

Alfaro-Diaz, R., A. A. Velasco, K. L. Pankow, and D. L. Kilb (2020). Optimally oriented remote triggering in the Coso Geothermal Field region, *J. of Geophys. Res.: Solid Earth*, 125, e2019JB019131. <https://doi.org/10.1029/2019JB019131>.

Anthony, R. E., A. T. Ringler, D. C. Wilson, M. Bahavar, and K. D. Koper (2020). How processing methodologies can distort and bias power spectral density estimates of seismic background noise, *Seism. Res. Lett.*, 91, 1694–1706. doi:10.1785/0220190212.

Koper, K. D. (2020), The importance of regional seismic networks in monitoring nuclear test-ban treaties, *Seism. Res. Lett.*, 91, 573–580, doi:10.1785/0220190160.

Mesimeri, M., H. Zhang, and K. L. Pankow (2020). Backprojection imaging of the 2020 Mw 5.5 Magna, Utah earthquake using a local dense strong motion

network, *Seismological Research Letters*, doi:10.1785/0220200326.

Pang, G., K. D. Koper, M. Mesimeri, K. L. Pankow, B. Baker, J. Farrell, J. Holt, P. Roberson, R. Burlacu, J. C. Pechmann, K. Whidden, M. M. Holt, A. Allam, and C. DuRoss (2020). Evidence for a listric Wasatch Fault from the 2020 Magna, Utah, earthquake sequence, *Geophys. Res. Lett.*, 47, e2020GL089798. <https://doi.org/10.1029/2020GL089798>.

Pankow, K. L. and D. Kilb (2020). Going beyond rate changes as the sole indicator for dynamic triggering of earthquakes, *Sci. Rept.* 10, 4120, doi:10.1038/s41598-020-60988-2.

Pankow, K. L., J. Rusho, J. C. Pechmann, J. M. Hale, K. Whidden, R. Sumsion, J. Holt, M. Mesimeri, D. Wells, and K. D. Koper (2020). Responding to the 2020 Magna, Utah, Earthquake Sequence during the COVID-19 Pandemic Shutdown, *Seismological Research Letters*. Doi: 10.1785/0220200265

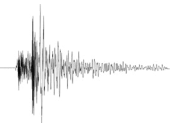
Pankow, K. L., M. Stickney, J. Y. Ben-Horin, M. Litherland, S. Payne, K. D. Koper, S. L. Bilek, and K. Bogolub (2020). Regional seismic network monitoring in the Eastern Intermountain West, *Seism. Res. Lett.*, 91, 631–646, doi:10.1785/0220190209.

Russo, E., A. Tibaldi, G. P. Waite, F. L. Bonali, F. Massin, and J. Farrell (2020). Unraveling the complex deformation pattern at Yellowstone plateau through seismicity and fracture analysis, *Tectonophysics*, 778, doi:10.1016/j.tecto.2020.228352.

Stabile, T. A., A. P. Rinaldi, and K. L. Pankow (2020). Preface to the special issue “Induced seismicity: observations, monitoring, and risk management strategies, *J. of Seis.*, 24, 917–919.

Voyles, J., M. M. Holt, J. M. Hale, K. D. Koper, R. Burlacu, and D. J. A. Chambers (2020). A new catalog of explosion source parameters in the Utah region with application to ML-MC based depth discrimination at local distances, *Seism. Res. Lett.*, 91, 222–236, doi:10.1785/0220190185.

Wu, S.-M., F.-C. Lin, J. Farrell, B. Shiro, L. Karlstrom, P. Okubo, and K. D. Koper (2020). Spatiotemporal seismic structure variations associated with the





2018 Kilauea eruption based on temporary dense geophone arrays, *Geophys. Res. Lett.*, 47(9), doi:10.1029/2019GL086668.

Xu, Y., K. D. Koper, R. Burlacu, R. B. Herrmann, and D.-N. Li (2020). A new uniform moment tensor catalog for Yunnan, China, from January 2000 through December 2014, *Seism. Res. Lett.*, 91, 891–900, doi:10.1785/0220190242.

## REPORTS

Burlacu, R., P. M. Roberson, J. M. Hale, B. Johnson, M. Haynes, K. D. Koper, J. C. Pechmann, and K. L. Pankow (2020), Earthquake Activity in the Utah Region Preliminary Epicenters October 1 – December 31, 2019, quarterly report of Univ. Utah Seismograph Stations, pp. 1–34.

Burlacu, R., P. M. Roberson, J. M. Hale, B. Johnson, N. Forbes, B. Ericksen, K. D. Koper, J. C. Pechmann, and K. L. Pankow (2020), Earthquake Activity in the Utah Region Preliminary Epicenters January 1 – March 31, 2020, quarterly report of Univ. Utah Seismograph Stations, pp. 1–70.

Burlacu, R., P. M. Roberson, J. M. Hale, B. Johnson, N. Forbes, B. Ericksen, K. D. Koper, J. C. Pechmann, and K. L. Pankow (2020), Earthquake Activity in the Utah Region Preliminary Epicenters April 1 – June 30, 2020, quarterly report of Univ. Utah Seismograph Stations, pp. 1–64.

Burlacu, R., P. M. Roberson, J. M. Hale, B. Ericksen, and Z. Claerhout, K. D. Koper, J. C. Pechmann, and K.

L. Pankow (2020), Earthquake Activity in the Utah Region Preliminary Epicenters July 1 – September 30, 2020, quarterly report of Univ. Utah Seismograph Stations, pp. 1–40.

Farrell, J., R. Burlacu, P. M. Roberson, J. M. Hale, N. Forbes, B. Johnson, K. D. Koper, R. B. Smith, J. C. Pechmann, and K. L. Pankow (2020), Earthquake Activity in the Yellowstone Region Preliminary Epicenters October 1 – December 31, 2019, quarterly report of Univ. Utah Seismograph Stations, pp. 1–19.

Farrell, J., R. Burlacu, P. M. Roberson, J. M. Hale, N. Forbes, B. Johnson, B. Ericksen, K. D. Koper, R. B. Smith, J. C. Pechmann, and K. L. Pankow (2020), Earthquake Activity in the Yellowstone Region Preliminary Epicenters January 1 – March 31, 2020, quarterly report of Univ. Utah Seismograph Stations, pp. 1–19.

Farrell, J., R. Burlacu, P. M. Roberson, J. M. Hale, N. Forbes, B. Johnson, B. Ericksen, K. D. Koper, R. B. Smith, J. C. Pechmann, and K. L. Pankow (2020), Earthquake Activity in the Yellowstone Region Preliminary Epicenters April 1 – June 30, 2020, quarterly report of Univ. Utah Seismograph Stations, pp. 1–25.

Farrell, J., R. Burlacu, P. M. Roberson, J. M. Hale, B. Ericksen, and Z. Claerhout, K. D. Koper, R. B. Smith, J. C. Pechmann, and K. L. Pankow (2020), Earthquake Activity in the Yellowstone Region Preliminary Epicenters July 1 – September 30, 2020, quarterly report of Univ. Utah Seismograph Stations, pp. 1–21.



