Clara E. Yoon

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EDUCATION

- 2012 – 2018   **Stanford University, Stanford, CA**
  Ph.D. Geophysics
  Thesis title: A FAST Data Mining Approach for Similar Earthquake Detection
  Thesis URL: https://purl.stanford.edu/nc875km0099
  Advisor: Prof. Gregory Beroza

- 2012 – 2015   **Stanford University, Stanford, CA**
  M.S. Geophysics

- 2002 – 2006   **University of California Los Angeles, Los Angeles, CA**
  B.S. Physics, with minor in Mathematics

PROFESSIONAL EXPERIENCE

- 2018 – present   **Supervisory Geophysicist**
  Earthquake Science Center, Pasadena Field Office
  United States Geological Survey (USGS), Pasadena, CA

- Assumed USGS advisory/leadership role for development, maintenance, and operation of real-time earthquake monitoring software in the Southern California Seismic Network (SCSN), in collaboration with Caltech Seismological Laboratory
- Responded to magnitude 6.4 and 7.1 Ridgecrest, California, earthquakes in July 2019 as duty seismologist: reviewed automatic earthquake solutions for accuracy, coordinated with external partner agencies, and conducted interviews with local media
- Led product planning and requirements development for the next-generation Earthquake Notification Service (ENS), a flagship USGS IT product that sends customized real-time email and text earthquake notifications to over 400,000 users
- Tested, maintained, documented, and supported users of a Java software application (Jiggle) used by seismic networks nationwide to refine earthquake phase picks, locations, and magnitudes
- Supported, planned, and coordinated operations of real-time ground shaking intensity (ShakeMap) products for southern California earthquakes
- Introduced and promoted software development best practices: version control, git workflow, coding standards, unit tests, integration tests, issue tracking, code review, documentation

- Managed local USGS IT team: supervised two direct reports, led new hiring effort, and interviewed multiple job candidates
- Collaborated with stakeholders in geographically distributed locations including other USGS offices, academic institutions, and external organizations

- 2012 – 2018   **Graduate Student Researcher with Prof. Gregory Beroza**
  Observational Earthquake Seismology
  Department of Geophysics, Stanford University, CA

Performed a diverse range of scientific investigations and fundamental research in observational earthquake seismology and geophysics (see below):

Data mining algorithms for earthquake detection
- Developed a novel technique to detect earthquakes with similar waveforms in continuous seismic data, based on music recognition technology
- Detected low-magnitude, uncataloged earthquakes on the Calaveras Fault in central California 140 times faster than a reference autocorrelation algorithm
- Presented complex technical information in conference posters, oral presentations, software documentation, and peer-reviewed publications

Big seismic data analytics: unsupervised large-scale search for similar earthquakes
- Developed, tested, and documented a parallel Python/C++ software application on Linux clusters to detect earthquakes with similar waveforms in decade-long continuous data sets, in collaboration with Stanford Computer Science researchers
- Key contributor to open-source software application for similar earthquake detection: https://github.com/stanford-futuredata/FAST
- Identified and located uncataloged small earthquakes in coastal central California from 2007-2017
- Tested utility of software on additional seismic data sets, with varying network configurations and durations, from Saudi Arabia, Italy, New Zealand, Netherlands, and Tanzania

Induced seismicity
- Detected, located, and characterized thousands of microearthquakes in first 3 months of the Guy-Greenbrier, Arkansas, earthquake swarm, to understand its initiation process
- Analyzed well data from public Arkansas Oil and Gas Database; identified earthquakes induced by hydraulic fracturing stimulation and deep wastewater injection

Foreshocks and mainshock nucleation
- Detected, located, and computed source parameters for foreshocks of the 1999 Mw 7.1 Hector Mine, California earthquake to gain insight into the physics of earthquake nucleation
- Interpreted that foreshocks and mainshock were triggered by a cascade of stress transfer

Repeating earthquake and aftershock detection
- Detected repeating earthquakes and aftershocks of the 2012 Mw 7.4 Ometepec, Mexico earthquake to assess changes in deep aseismic slip, in collaboration with Prof. Luis Dominguez (UNAM ENES Morelia, Mexico)

Aftershock detection and phase picking
- Automatically detected and picked phases on aftershock waveforms of the 2008 Wenchuan earthquake for the SeismOlympics data science competition, as part of a 4-student team

- 2013 – 2016   **Graduate Student Researcher with Prof. Howard Zebker**
  Radar Interferometry Applied to Induced Seismicity
  Department of Geophysics, Stanford University, CA

- Performed comprehensive search for crustal deformation signals in interferometric synthetic aperture radar (InSAR) data associated with potentially induced seismicity in the United States
- Conducted multi-year InSAR time series analysis with Python/MATLAB/shell scripts to estimate surface deformation from deep wastewater injection near Oklahoma City during 2011-2014
- Reported research findings in oral presentations to oil and gas industry professionals

- 2006 – 2012 **Staff Scientist**
  Areté Associates, Northridge, CA
  - Lead scientific programmer on research and development projects for remote sensing systems; performed simulation and modeling, data analysis, algorithm development, and software implementation in C++ and Fortran 90
  - Implemented and tested a C++ computational geometry optimization software package
  - Extensively debugged deliverable software; developed unit and regression tests
  - Generated algorithm documents with conceptual and mathematical descriptions
  - Wrote three technical papers summarizing data analysis procedures and results
  - Presented technical briefings to customers at review meetings
  - Designed, developed and implemented an interpolation algorithm to map high-resolution synthetic aperture radar data, which improved image resolution, added processing flexibility, and reduced computational cost
  - Debugged, refined, and analyzed physics-based algorithms used to process optical image data: enhanced feature detection performance, reduced run-time
  - Developed and implemented noise reduction algorithms, then analyzed their performance on large data sets
  - Experienced with image processing, signal processing, digital filtering, numerical analysis and iterative algorithms, probability and statistics

TEACHING EXPERIENCE

- 2016 **Teaching Assistant: Imaging Radar and Applications**
  Department of Electrical Engineering/Geophysics, Stanford University
  - Presented lectures on advanced synthetic aperture radar imaging methods
  - Prepared solutions for and graded homework and exams
  - Maintained course website and online message board for student questions
  - Held office hours and exam review session

- 2014 **Teaching Assistant: Introduction to Seismology**
  Department of Geophysics, Stanford University
  - Presented lecture on signal processing techniques in seismology
  - Held office hours, graded homework, and responded to student questions

PUBLICATIONS

- Hauksson, E., **C. Yoon,** E. Yu, J. R. Andrews, M. Alvarez, R. Bhadha, and V. Thomas (2020). Caltech/USGS Southern California Seismic Network (SCSN) and Southern California Earthquake Data

Center (SCEDC): Data Availability for the 2019 Ridgecrest Sequence, *Seismological Research Letters*, https://doi.org/10.1785/0220190290.

- **Yoon, C. E.**, K. J. Bergen, K. Rong, H. Elezabi, W. L. Ellsworth, G. C. Beroza, P. Bailis, P. Levis (2019). Unsupervised Large-Scale Search for Similar Earthquake Signals, *Bulletin of the Seismological Society of America*, 109, 4, 1451-1468, https://doi.org/10.1785/0120190006.
- **Yoon, C. E.**, N. Yoshimitsu, W. L. Ellsworth, and G. C. Beroza (2019). Foreshocks and Mainshock Nucleation of the 1999 M_w 7.1 Hector Mine, California, Earthquake, *Journal of Geophysical Research – Solid Earth*, 124, 1569-1582, https://doi.org/10.1029/2018JB016383.
- Rong, K., **C. E. Yoon,** K. J. Bergen, H. Elezabi, P. Bailis, P. Levis, and G. C. Beroza (2018). Locality-Sensitive Hashing for Earthquake Detection: A Case Study Scaling Data-Driven Science, *Proceedings of the VLDB Endowment,* 11, 1674-1687, https://doi.org/10.14778/3236187.3236214.
- **Yoon, C. E.**, Y. Huang, W. L. Ellsworth, and G. C. Beroza (2017). Seismicity During the Initial Stages of the Guy-Greenbrier, Arkansas, Earthquake Sequence, *Journal of Geophysical Research – Solid Earth*, 122, https://doi.org/10.1002/2017JB014946.
- Bergen, K., **C. Yoon**, and G. C. Beroza (2016). Scalable Similarity Search in Seismology: A New Approach to Large-Scale Earthquake Detection, *Proceedings of the 9ᵗʰ International Conference on Similarity Search and Applications,* 301-308, https://doi.org/10.1007/978-3-319-46759-7_23.
- **Yoon, C. E.**, O. O'Reilly, K. J. Bergen, and G. C. Beroza (2015). Earthquake detection through computationally efficient similarity search, *Science Advances*, 1, e1501057, https://doi.org/10.1126/sciadv.1501057.

INVITED TALKS

- **Yoon, C. E.**, G. C. Beroza, K. J. Bergen, K. Rong, H. Elezabi, P. Bailis, and P. Levis. A FAST Data-Mining Approach for Similar Earthquake Detection, 2018 SSA Meeting, Miami, Florida.
- Big data analytics for finding small earthquakes, UC Santa Cruz IGPP Seminar, January 2018.
- **Yoon, C.**, K. Bergen, K. Rong, H. Elezabi, P. Bailis, P. Levis, and G. Beroza. Efficient blind search for similar-waveform earthquakes in years of continuous seismic data, 2017 AGU Meeting, New Orleans, Louisiana, Abstract S21E-01.
- Earthquake Detection Through Computationally Efficient Similarity Search (with K. Bergen), U.S. Geological Survey Earthquake Science Center Seminar, Menlo Park, CA, August 2015, https://earthquake.usgs.gov/contactus/menlo/seminars/999.

ORAL PRESENTATIONS

- Dominguez, L. A., T. Taira, W. Frank, **C. Yoon**, M. A. Santoyo, D. Legrand, and A. Iglesias, Detection of missing foreshocks and afterslip estimates of the 2012 M_w 7.4 Ometepec earthquake, Hazard Assessment of Large Earthquakes and Tsunamis in the Mexican Pacific Coast, SATREPS workshop, July 2017.
- Dominguez, L. A., T. Taira, W. Frank, **C. Yoon**, M. A. Santoyo, D. Legrand, and A. Iglesias, Investigation of the foreshock and aftershock sequence of the 2012 M_w 7.4 Ometepec earthquake using fingerprint and matched filter techniques, JpGU-AGU Joint Meeting, May 2017.
- **Yoon, C.**, Y. Huang, W. Ellsworth, and G. Beroza, Microearthquakes Induced by Hydraulic Fracturing and Wastewater Injection in Guy-Greenbrier, Arkansas, Stanford Center for Induced and Triggered Seismicity Affiliates Meeting, May 2017.
- **Yoon, C.**, N. Yoshimitsu, W. Ellsworth, and G. Beroza, Another Look at the Foreshocks of the 1999 M_w 7.1 Hector Mine, California, Earthquake, SSA Annual Meeting, April 2017.

- **Yoon, C.**, Y. Huang, W. Ellsworth, and G. Beroza, New Evidence for Earthquakes Induced by Hydraulic Fracturing and Wastewater Injection in Guy-Greenbrier, Arkansas, Stanford Center for Induced and Triggered Seismicity Affiliates Meeting, October 2016.
- **Yoon, C.**, and H. Zebker, InSAR Time Series Analysis Reveals the Absence of Injection-Induced Surface Deformation in Central Oklahoma, Stanford Center for Induced and Triggered Seismicity Affiliates Meeting, October 2016.
- **Yoon, C.**, Y. Huang, W. Ellsworth, and G. Beroza, The initial stages of the Guy-Greenbrier sequence using FAST earthquake detection, Stanford Center for Induced and Triggered Seismicity Affiliates Meeting, May 2016.
- **Yoon, C.**, and H. Zebker, InSAR Observations of Injection-Related Deformation, Stanford Center for Induced and Triggered Seismicity Affiliates Meeting, February 2015.
- **Yoon, C. E.**, O. J. O'Reilly, K. Bergen, and G. C. Beroza, Computationally Efficient Search for Similar Seismic Signals in Continuous Waveform Data over a Seismic Network, 2014 AGU Meeting, Abstract S52A-04.
- **Yoon, C.**, and H. Zebker, InSAR Observations of Deformation at Oil and Gas Production Sites, Stanford Center for Induced and Triggered Seismicity Affiliates Meeting, October 2014.
- **Yoon, C. E.**, O. J. O'Reilly, and G. C. Beroza, Waveform Fingerprinting for Efficient Seismic Signal Detection, 2013 AGU Meeting, Abstract S21D-02.

POSTER PRESENTATIONS

- **Yoon, C.**, N. Yoshimitsu, W. Ellsworth, and G. Beroza, Foreshocks and Mainshock Nucleation of the 1999 M_w 7.1 Hector Mine, California, Earthquake, 2019 AGU Meeting, Abstract S21F-0580.
- **Yoon, C.**, S. Schwarz, and V. Thomas, Earthquake Notification Service (ENS): Present Capabilities and Next-Generation Product Ideas, 2019 SCEC Meeting, Abstract 304, https://www.scec.org/publication/9826.
- Bergen, K. J., **C. E. Yoon**, K. Rong, P. Bailis, and G. C. Beroza. FAST: a data mining approach to large-scale earthquake detection, 2018 AGU Meeting, Abstract S11E-0416.
- Beroza, G. C., Y. Huang, W. L. Ellsworth, and **C. E. Yoon**, Seismicity During the First Three Months of the Guy-Greenbrier, Arkansas, Earthquake Sequence, SEG/SPE Workshop on Injection-Induced Seismicity, Dallas, Texas, November 2017.
- **Yoon, C.**, N. Yoshimitsu, W. Ellsworth, and G. Beroza, How did the 1999 M_w 7.1 Hector Mine, California, earthquake begin? Insights from foreshocks, 2ⁿᵈ school on earthquakes: nucleation, triggering, rupture, and relationship with aseismic processes, Cargese, Corsica, October 2017.
- **Yoon, C. E.**, K. Bergen, K. Rong, H. Elezabi, P. Bailis, P. Levis, W. L. Ellsworth, and G. C. Beroza, Efficient blind search for small similar-waveform earthquakes in a decade of continuous seismic data (2007-2017) in coastal central California, 2017 SCEC Meeting, Abstract 024, https://www.scec.org/publication/7749.
- **Yoon, C. E.**, Y. Huang, W. L. Ellsworth, and G. C. Beroza. The Initial Stages of the Guy-Greenbrier, Arkansas, Earthquake Sequence: Induced by Both Wastewater Injection and Hydraulic Fracturing Amid Natural Seismicity, 2016 AGU Meeting, Abstract S43C-2883.
- **Yoon, C. E.**, Y. Huang, W. L. Ellsworth, and G. C. Beroza, Earthquakes Induced by Hydraulic Fracturing and Wastewater Injection in Guy-Greenbrier, Arkansas, 2016 SCEC Meeting, Abstract 194.
- **Yoon, C. E.**, O. O'Reilly, K. Bergen, Y. Huang, and G. C. Beroza, Searching for Unknown Earthquakes in the Guy-Greenbrier, Arkansas, Earthquake Sequence using Efficient Waveform Similarity Search, 2015 AGU Meeting, Abstract S13B-2850.
- Bergen, K., **C. E. Yoon**, O. J. O'Reilly, and G. C. Beroza, Unsupervised Approaches for Post-Processing in Computationally Efficient Waveform-Similarity-Based Earthquake Detection, 2015 AGU Meeting, Abstract S53A-2777, https://membership.agu.org/files/2016/02/kbergen_AGU15.pdf.

- Bergen, K., **C. Yoon**, O. O'Reilly, Y. Huang, and G. Beroza, Fingerprint and Similarity Thresholding (FAST) for Computationally Efficient Earthquake Detection, 2015 SCEC Meeting, Abstract 132.
- **Yoon, C.**, O. O'Reilly, K. Bergen, and G. Beroza, Computationally Efficient Earthquake Detection with Continuous Seismic Waveform Data, Stanford-USTC-MIT (SUM) Geoscience Summer Camp, Hefei, China, September 2015.
- **Yoon, C.**, O. O'Reilly, K. Bergen, and G. Beroza, Computationally Efficient Earthquake Detection with Continuous Seismic Waveform Data, 9th International Workshop on Statistical Seismology (Statsei9), Potsdam, Germany, June 2015, https://statsei9.quake.gfz-potsdam.de/lib/exe/fetch.php?media=13_presentations:poster_yoon.pdf.
- **Yoon, C.**, O. O'Reilly, K. Bergen, and G. Beroza, Computationally Efficient Search for Similar Seismic Signals in Continuous Waveform Data over the Northern California Seismic Network, 2014 SCEC Meeting, Abstract 162.
- O'Reilly, O. J., **C. E. Yoon**, and G. C. Beroza, Similarity Search for Continuous Seismic Data, 2013 AGU Meeting, Abstract S11B-2319.
- O'Reilly, O. J., **C. E. Yoon**, and G. C. Beroza, Similarity Search for Continuous Seismic Data, 2013 SCEC Meeting, Abstract 107.

COMPUTER SKILLS

- **Programming Languages (proficient):** C++, Python, MATLAB, bash shell script, Fortran
- **Programming Languages (some experience):** C, Java, Perl, IDL
- **Databases:** MySQL
- **Version Control:** Subversion, git
- **Compilers:** gcc/g++/gfortran, make, Xcode, Microsoft Visual Studio, Eclipse
- **Operating Systems**: Linux (including clusters), Mac OS X, Windows
- **Documentation:** doxygen, Javadoc, Markdown, MkDocs, LaTeX, Microsoft Word
- **Software Tools:** vim, tmux
- **Scientific Visualization:** matplotlib, GMT, Google Earth, Adobe Illustrator, Microsoft PowerPoint
- **Seismology:** ObsPy, SAC, VELEST, HYPOINVERSE, hypoDD

PROFESSIONAL ACTIVITIES

- Reviewer for *Journal of Geophysical Research – Solid Earth* (2019)
- Reviewer for *Seismological Research Letters* (2019)
- Proposal reviewer for National Science Foundation – Earth Sciences (2019)

PROFESSIONAL AFFILIATIONS

- American Geophysical Union (AGU), 2008 – present
- Seismological Society of America (SSA), 2012 – 2018
- Institute of Electrical and Electronics Engineers (IEEE), 2008 – 2012

MEDIA COVERAGE

- "Big One still looms", July 15, 2019, Daily Press, Victorville, CA, https://www.vvdailypress.com/news/20190715/big-one-still-looms
- "The Big One is likely overdue in the Coachella Valley, where major earthquake faults connect", July 8, 2019, The Desert Sun, Palm Springs, CA, https://www.desertsun.com/story/news/2019/07/08/palm-springs-coachella-valley-area-likely-overdue-major-earthquake-san-andreas-fault/1675158001/
- Interviews following the July 4 M6.4 and July 5 M7.1 Ridgecrest, California, earthquakes: TV (Fox 11 Los Angeles), video (Voice of America), radio (100.7 San Diego)

AWARDS AND HONORS

- Exceptional Thesis Award, Stanford Geophysics, 2018
- Joshua L. Soske Memorial Fellowship, Stanford School of Earth Sciences, 2015
- Oral Presentation Award, Stanford School of Earth Sciences Research Review, 2014, 2015
- Chevron Fellow, Stanford Graduate Fellowship, 2013-2016
- E. Lee Kinsey Scholarship, UCLA Physics and Astronomy, 2006
- Rudnick-Abelmann Scholarship, UCLA Physics and Astronomy, 2005
- Regents Scholarship, UCLA, 2002-2006