Environmental Seismology

Earth's Surface and Subsurface Hazards, Dynamics and Resources

14–18 October 2025 • Denver, CO

Welcome to SSA's 2025 Fall Meeting

We look forward to learning more about your research and the unique perspectives that you bring to the study of seismic and acoustical phenomena in environmental contexts.

We've prepared a program that emphasizes community interaction and encourage you to take advantage of the many opportunities to expand your network of colleagues throughout the meeting. To further enrich this week's scientific discussions, we strongly encourage your engagement during the question periods at the end of each session.

In addition to responding to SSA's post-meeting survey, feel free to share any thoughts about the meeting directly with us. Your feedback helps the Society continue to plan meetings that will best serve your professional needs.

We are grateful to each of you for joining us and offer special thanks to our sponsors for their generous support of this meeting.

Rick Aster and Siobhan Niklasson
SSA 2025 Topical Meeting Co-Chairs

Important Meeting Details

- WiFi Info:
  SSID: Embassy-Meeting
  Password: SSATopical25
- The conference will take place on the 3rd floor.
- Breakfasts will take place from 7 to 8 AM in the dining area on the 4th floor.
- Lunches will take place in the 3rd floor conference space.
- Poster Sessions begin on Tuesday evening.
- **Please note that audio and video recording of any kind is only allowed in public meeting spaces.**

SSA Code of Conduct

SSA is committed to providing a safe, productive and welcoming environment for all meeting participants. Please do your part by following the SSA Code of Conduct (seismosoc.org/meetings/code-of-conduct) throughout the meeting.

Congratulations to Grant Recipients

Thanks to generous donations to SSA's General Fund, **Taylor Kenyon** (*University of Waterloo, U.S. National Park Service*) and **Samara Omar** (*Colorado School of Mines*) received complimentary meeting registration and a stipend for their travel expenses.

Thank You to Our Sponsors!

GEOSCIENCES
COLORADO STATE UNIVERSITY

güralp

nanometrics

Technical Program

The following schedule of events and abstracts are valid as of 11 September 2025. See "Program Changes" handout at the Registration Desk for changes to the program.

Tuesday, 14 October

- Registration Open, 3:30–7:30 PM
- Know Your Noise Workshop, 4–6 PM
- Opening Reception & Posters, 5:30–6:30 PM
- Opening Session & Keynote Presentation, 6:30–7:30 PM

Wednesday, 15 October

- Breakfast, 7–8 AM
- Session: Cryoseismology, 8–9:30 AM
- Coffee Break & Posters, 9:30–10:30 AM
- Session: Cryoseismology, continued 10:30–11:30 AM
- Lunch & Posters, 11:30 AM–1:30 PM
- Session: Geophysical and Biogenic Signals from the Oceans, Surface Water and Atmosphere, 1:30–3 PM
- Posters, 3–4 PM
- Session: Geophysical and Biogenic Signals from the Oceans, Surface Water and Atmosphere, continued 4–5 PM
- Reception, Posters & Sponsor Table Time, 5–6:30 PM

Thursday, 16 October

- Breakfast, 7–8 AM
- Session: Anthropogenic and Urban Seismology, 8–10:15 AM
- Coffee Break & Posters, 10:15–11:15 AM
- Session: Novel Approaches for Environmental Seismology, 11:15 AM–12:15 PM
- Lunch & Posters, 12:15–2:15 PM
- Session: Novel Approaches for Environmental Seismology, continued 2:15–3:30 PM
- Break: 3:30–4 PM
- Panel Discussion: Seismic and Environmental Data Access and Management, 4–5 PM
- Reception, Posters & Sponsor Table Time, 5–6:30 PM

Friday, 17 October

- Breakfast, 7–8 AM
- Session: Subsurface Monitoring and Imaging, 8–9:30 AM
- Coffee Break & Posters, 9:30–10:30 AM
- Session: Subsurface Monitoring and Imaging, continued 10:30–11:30 AM
- Lunch & Posters, 11:30 AM–1:30 PM
- Session: Seismic Investigation of Mass Movements, 1:30–3 PM
- Posters, 3–4 PM
- Session: Seismic Investigation of Mass Movements, continued 4–5 PM
- Reception, Posters & Sponsor Table Time, 5–6 PM

Technical Sessions

Tuesday, 14 October, 6:30–7:30 PM

Opening Session Introduction

Rick Aster, Colorado State University; Siobhan Niklasson, New Mexico Tech & Los Alamos National Laboratory

Keynote Presentation

Environmental Forcing of Faults and Slow-moving Landslides.
Roland Bürgmann, University of California, Berkeley

Cryoseismology

Wednesday, 15 October, 8–9:30 AM & 10:30–11:30 AM

The Earth's cryosphere encompasses all frozen occurrences of water on our planet. It hosts a wealth of seismic sources, like snow avalanches, iceberg calving, glacier slip events and frost cracking. At the same time, seismic waves can also probe the structure and integrity of ice bodies. Consequently, seismic monitoring has become an important tool to document changes within the cryosphere, especially as we prepare for a warmer world.

Many recent advances in cryosphere research were only made possible with the introduction of seismological techniques originally developed for solid earth applications. This includes a wide range of approaches ranging from seismic source models to interferometry and noise monitoring. The advantage is that seismic techniques can hone in on subglacial systems, ice-ocean boundaries and other difficult-to-access environments. Whereas some methods are now standard in cryosphere research, we expect that much of the seismological toolbox has yet to be leveraged for fundamental new discoveries advancing our process understanding in glaciology, permafrost and snow physics research.

In this session, we invite contributions within this diverse field of cryoseismology where the seismic wavefield is used to understand different properties and processes of frozen environments. This includes field and laboratory studies, methodological and instrumental advancements as well as theoretical considerations on seismic sources and wave propagation specifically aimed at the cryospheric domain. We look forward to a lively discussion on the key challenges in cryospheric research and how recent advancements in seismology can help address them.

Geophysical and Biogenic Signals from the Oceans, Surface Water and Atmosphere

Wednesday, 15 October, 1:30–3 PM & 4–5 PM
Seismoacoustic signals from oceans, rivers, and the atmosphere provide valuable insights into a wide range of environmental phenomena, including storms, ocean waves, water flow, sediment transport, marine mammal behavior, and fish choruses, as well as dynamic processes related to seafloor earthquakes, volcanic activity, and anthropogenic sources. These signals result from complex interactions across Earth's spheres and serve as a powerful tool for understanding the Earth system. Seismoacoustic signals propagating through the hydrosphere and atmosphere can also provide important constraints on understanding long-term climate change. We invite contributions exploring geophysical and biogenic seismic signals from these environments, such as ocean-generated seismic noise, river and lake hydrodynamics, atmospheric coupling with the solid Earth, and biogenic signals from marine life and ecosystem processes. Studies focusing on the propagation of signals through these environments to understand change are also encouraged. The session aims to encourage discussion on integrating seismic and acoustic data from the hydrosphere and atmosphere with other observations to investigate their characteristics, sources, propagation, and climatology in the environment, as well as to advance our understanding of how hydrodynamic processes influence the environment and their interconnections across spheres in the Earth system.

Anthropogenic and Urban Seismology

Thursday, 16 October, 8–10:15 AM
The cities of the future must efficiently support thriving human communities and also be resilient to natural and anthropogenic hazards. Seismic data can provide invaluable information to achieve these goals by cost-effective continuous monitoring of the subsurface under cities, the built environment, and the impact of human activities on urban life. New data acquisition technologies (e.g. autonomous nodes and fiber sensing) coupled with emergent approaches to harness human-generated seismic noise for subsurface imaging and monitoring open unprecedented opportunities for seismology to contribute to the quality and safety of urban life.

Recent developments in AI/ML methods tailored to the processing and analysis of seismic data enable the extraction of valuable information from huge amounts of data.

Contributions are encouraged on the following topics, among others: characterization and mitigation of geologic hazards in urban areas, monitoring of urban infrastructure, urban hydrogeophysics, and any other application contributing to advancing urban resilience and sustainable development. We welcome presentations of novel observational studies, theoretical and numerical modeling methods, instrumental advances, data-driven analyses, and geophysical-inversion techniques.

Novel Approaches for Environmental Seismology

Thursday, 16 October, 11:15 AM–12:15 PM & 2:15–3:30 PM
As the scope of environmental seismology expands, driven by a global need to take the pulse of our changing planet, novel approaches are required to make seismographic measurements in extreme environments, mine ever-growing data archives, and develop theoretical understanding of the ambient seismic wavefield. This session explores advances in environmental seismology through innovative instruments and methods. We invite contributions highlighting new instrumental developments (e.g., low-cost dense arrays, fiber-optic sensors, or low-noise seismometers), new computational tools (e.g., machine learning, data assimilation, or wavefield simulation algorithms), new geophysical theory (e.g., seismic source or rock physics models describing the seismic fingerprint of environmental processes), and new environmental applications or analytical approaches not covered by other sessions. Contributions which integrate seismology with interdisciplinary methods and datasets, such as electromagnetics or remote sensing, are particularly welcome.

Subsurface Monitoring and Imaging

Friday, 17 October, 8–9:30 AM & 10:30–11:30 AM
Seismology provides unique perspectives in illuminating the Earth's subsurface across multiple spatial and temporal scales, which is crucial for understanding important environmental processes such as groundwater flow, vadose zone hydrology, geothermal activity, carbon sequestration, hydrogen exploration, and wastewater disposal. This session highlights recent advances in seismic imaging and monitoring that enhance our understanding of subsurface structure and dynamics. We welcome observational and methodological contributions utilizing seismic sources such as micro-earthquakes, ambient fields, active-source experiments, traffic, and other human activities. Applications of interest include, but are not limited to, near-surface and critical-zone processes, soil moisture and groundwater dynamics, sustainable energy and mineral production, geothermal and hydrothermal systems, and interactions between the solid Earth, hydrosphere and/or atmosphere.

Seismic Investigation of Mass Movements

Friday, 17 October, 1:30–3 PM & 4–5 PM

Evolving landscapes, coupled with improved monitoring capabilities, are contributing to a notable increase in seismic and infrasound detections of surficial mass movements. These events — landslides, rock/ice/snow avalanches, debris flows, lahars, pyroclastic density currents, etc. — modify the landscape and can pose significant hazards, so there is a pressing need to better understand, characterize, and mitigate them. While these sources are not routinely monitored in real-time like earthquakes, ever-expanding seismic, infrasound and hydroacoustic networks offer opportunities for rapid early warning and post-event detection and analysis. Improved data sources and techniques can also help search for reliable precursors to catastrophic failure and can be used to characterize existing slope instabilities.

This session explores innovative methods that improve our comprehension of these non-earthquake seismic and acoustic sources and enhance our ability to characterize and monitor them and mitigate their associated hazards. We invite presentations that investigate various types of surficial mass movements by leveraging seismic and/or infrasound techniques, including the application of machine learning or inclusion of ancillary constraints through ground-based, airborne, and satellite imagery or other geophysical data streams. Topics of interest encompass — but are not limited to — source detection, location, characterization, modeling, and classification; precursory signal analysis; monitoring; innovative instrumentation (e.g., distributed acoustic sensing, nodal sensors, large-N arrays/networks); and hazard mitigation.

Schedule

Tuesday, 14 October 2025

3:30–7:30 PM	Registration Open
4–6 PM	Know Your Noise Workshop
5:30–6:30 PM	Opening Reception & Posters
6:30–7:30 PM	Opening Session and Keynote Presentation: Environmental Forcing of Faults and Slow-moving Landslides. **Roland Bürgmann**.

Wednesday, 15 October 2025

7–8 AM	Breakfast
Session: Cryoseismology	
8–8:30 AM	KEYNOTE: News From the Dark: Portable and Distributed Seismic Sensors Shed Light on Subglacial Processes. **Fabian Walter**.
8:30–8:45 AM	The Seismic Signature of Transient Water Flow Underneath the Greenland Ice-sheet. **Florent Gimbert**.
8:45–9 AM	INVITED: Quantifying the Cryoseismic Background of Mount Baker Volcano, Washington, USA. **Nathan T. Stevens**.
9–9:15 AM	INVITED: Assessing the Mechanisms Behind Ice Fracture Using Surface and Downhole Seismic Observations on the Brunt Ice Shelf, Antarctica. **Emma Pearce**.
9:15–9:30 AM	How Surface Melt Drives Dynamic Fjord-ice Interactions in Greenland. **Dominik Gräff**.
9:30–10:30 AM	Coffee Break & Posters
10:30–10:45 AM	Time-lapse Active Source Seismic Measurements Through Seasonal Snow: Mechanical Property Changes Within and Beneath the Snowpack. **Lee M. Liberty**.
10:45–11 AM	STUDENT: Creating a Comprehensive Cryoseismic Catalog at Rhonegletscher: A Scalable Approach Using Distributed Acoustic Sensing and Machine Learning. **Rachel M. Willis**.
11–11:30 AM	Discussion Period
11:30 AM–1:30 PM	Lunch & Posters

Session: Geophysical and Biogenic Signals from the Oceans, Surface Water and Atmosphere	
1:30–2 PM	KEYNOTE: Using Seismology for Non-earthquake Signals. **Victor C. Tsai**.
2–2:15 PM	STUDENT: Decadal Analysis of Nonlinear Internal Waves in the South China Sea Using Satellite and Ocean Bottom Pressure Data. **Amanda Syamsul**.
2:15–2:30 PM	Effect of Wide Excitation and Multipath Propagation of T-wave for Ocean Tomography. **Shane Zhang**.
2:30–2:45 PM	Monitoring Alongshore Coastal Processes in South Island, New Zealand Using Distributed Acoustic Sensing. **Voon Hui Lai**.
2:45–3 PM	STUDENT: Behind the Curtain: Characterizing the Nisqually Watershed of MORA as a Means to Explore the Use of Non-contact Data Sources in Mountain Hydrology. **Taylor R. Kenyon**.
3–4 PM	Posters
4–4:15 PM	STUDENT: Turbulent Seismoacoustic Imprints of a Hurricane Landfall. **Qing Ji**.
4:15–4:30 PM	High-latitude IMS Infrasound Station Noise and Seasonal Sea-ice Extent. **Loring P. Schaible**.
4:30–5 PM	Discussion Period
5–6:30 PM	Reception, Posters & Sponsor Table Time

Tuesday, 14 October, and Wednesday, 15 October—Posters

Cryoseismology

1. Development and Testing of a Very Broadband Seismometer Package for Deployment at 2.4 km Depth Within the Icecap at South Pole, Antarctica as Part of the IceCube Neutrino Observatory. **Robert E. Anthony**.
2. Tracking Seasonal Growth of Sea Ice Thickness Using Seafloor Distributed Acoustic Sensing and Flexural-gravity Wave Dispersion. **Michael G. Baker**.
4. Towards Automatic Detection of Snow Avalanche Activity with Distributed Acoustic Sensing. **Charlotte Bruland**.
5. The Detectability of Explosively Formed Craters Russian Arctic Permafrost. **Joshua Carmichael**.
6. Seismic Properties of Mélange in an Ice Shelf-penetrating Rift from the ARROW Deployment at the Ross Ice Shelf. **Kat Dapré**.

7. Student: Using Icequakes to Pin Point the Crack Tip Locations of Water-filled Crevasses on Helheim Glacier, Greenland. **Kniya N. Duncan**.
8. Characterizing Ambient Seismic Noise in the Labrador Sea. **Jianhua Gong**.
9. Interrogating Crevasse Source Physics and Subsurface Fracture Extent using Distributed Acoustic Sensing. **Thomas S. Hudson**.
10. Student: Glacier Quakes and Calving Dynamics: A 20-year Analysis of Columbia Glacier. **Sebin John**.
11. Student: When River Ice Breaks Faster Than Expected: One Week of Distributed Acoustic Sensing Monitoring on the Sävar River. **Jiahui Kang**.
12. Student: Seismic Constraints on Glacier Density. **Ariane Lanteri**.
13. Disentangling the Contribution of Surface and Bed Hydrology for Single-station Seismic Data. **Nathan Maier**.
14. Glacial Earthquakes in Thwaites Glacier Detected by Short Period Surface Waves. **Thanh-Son Pham**.
15. Student: Seismic Signatures of Ice-wedge Cracking from DAS in Arctic Permafrost. **Gabriel Fernando Rocha dos Santos**.
16. Student: Seismic Signatures of Pack Ice Collisions with Landfast Ice Near Utqiaġvik, Alaska. **Gabriel Fernando Rocha dos Santos**.
17. Ice-bed Healing Between Subglacial Seismic Slip Events: Connecting Lab Results to Observations from Whillans Ice Plain. **Seth Saltiel**.
18. Near Surface Shear Velocity Structure Showing Ice, Sub-ice, Ground, and Seasonal Hydrological Characteristics from Teleseismic Single Sensor Recordings. **Vera Schulte-Pelkum**.
19. Seismic Investigation to the Pensacola-pole Basin of Antarctica. **Weisen Shen**.
20. Rock Falls, Glacier Failure and Ensuing Avalanche: The 28 May 2025 Catastrophe at Blatten, Switzerland. **Fabian Walter**.
21. Tracking Seasonal Shear-wave Velocity Variations of Permafrost Freeze–thaw Using Distributed Acoustic Sensing. **Zhinong Wang**.
22. Location and Source Studies of Recurrent Antarctic Icequakes. **Douglas A. Wiens**.
23. Mapping Subglacial Sediments Beneath the Greenland Ice Sheet with Seismic Receiver Functions. **Yan Yang**.
24. Student: Seasonal Fluctuations in Subsurface Seismic Velocity Cross Permafrost of the Tibetan Plateau. **Lulu Zhao**.
50. Seismic Site Response in Discontinuous Permafrost Environments: Examples from Dakwakada (Haines Junction), Yukon, Canada. **Jeremy Gosselin.**

Geophysical and Biogenic Signals from the Oceans, Surface Water and Atmosphere

25. Student: Primary Microseism Weekly Maps for Monitoring Near Coastal Oceanic Swell Activity. **Giacomo Aloisi**.
26. Global Annual Variations in Primary and Secondary Microseism Intensity. **Richard C. Aster**.
27. Using Seismic and DAS Observations to Characterize Rock Impact and Motion in Controlled Flume Experiments. **Susan L. Bilek**.
28. Student: Evaluation of Geophysical and Anthropogenic Sources of Hydroacoustic Noise in the Alaskan Arctic. **Siobhan Niklasson**.
29. Relationship Between the 2024–2025 Los Cabos Earthquakes and Geohydrological Potential: A Multidisciplinary Opportunity for Hydraulic Conductivity Calibration Models. **Roberto Ortega**.
30. Seasonal Variability in Microseismic Energy Associated with Waves, Wind and Surface Conditions in the Saint Lawrence River, Canada. **H. K. Claire Perry**.
31. Science Monitoring And Reliable Telecommunications (SMART) Cables: Advances in Global Seismic Modeling, Earthquake and Tsunami Early Warning and Ocean Observing. **Charlotte A. Rowe**.
32. Characteristics of Seismic Noise Recorded by a Dense Seismometer Array During the September 2024 Heavy Rainfall Event in the Noto Peninsula, Japan. **Kaoru Sawazaki**.
33. Student: Identifying Tornado Seismic Signals (TSS) from the December 10th-11th, 2021, Central U.S. Tornado Outbreak. **N. Seth Carpenter**.
34. Mechanical Modeling of Long-term Earthquake Clustering in the Dead Sea Basin in Response to Climate-induced Lake Level Variations. **Mita Uthaman**.
35. Seasonally Varying Seismicity in Sikkim Himalaya. **Mita Uthaman**.
36. Various Comments on the Excitation of Earth's Hum Motivated by DAS Observations of Infragravity Waves. **Ethan F. Williams**.
37. Deep Ocean Thermometry Using Scholte and T-waves. **Wenbo Wu**.
38. Probing Underwater Turbulence Using Distributed Acoustic Sensing. **Chu-Fang Yang**.

Novel Approaches for Environmental Seismology

40. Multidisciplinary Geophysical Stations: A Next Generation Tool Kit for Environmental Seismology. **Geoffrey Bainbridge**.
41. Desert Seismology: Multi-modality Datasets for Ultra High Frequency Ambient Seismic Wavefields in Particle Rich Environments. **Julien Chaput**.
42. Artius: A Revolutionary Broadband Node to Further Enable Passive Seismology. **James C. Lindsey**.

43. Güralp Stratis—a Commercial 6 Degree of Freedom Seismometer for Academic and Research Applications. **James C. Lindsey**.
44. Unveiling Volcanic Eruptions with Geometric Phase Sensing of Seismic Waves. **Bingxu Luo**.
46. Student: Transdimensional Bayesian Inversion of Multi-component Rayleigh-wave Dispersion. **Samara M. Omar**.
47. Recent Advances in Seismic Detections of Rock Exfoliation Events at Arabia Mountain, Georgia. **Zhigang Peng**.
49. Leaking Mode Dispersion from Distributed Acoustic Sensing. **Zhinong Wang**.

Thursday, 16 October 2025

7–8 AM	Breakfast
Session: Anthropogenic and Urban Seismology	
8–8:30 AM	Keynote: Machine-learning Ground Motions for Infrastructure Risk Reduction. **Domniki Asimaki**.
8:30–8:45 AM	Invited: Scalable Urban Sensing and Monitoring via Telecom Fiber Networks with DAS. **Haeyoung Noh**.
8:45–9 AM	Investigating Subsurface Changes in a Quick Clay Risk Area with Urban Seismic Noise and Low-cost Seismic Sensors. **Charlotte Bruland**.
9–9:15 AM	Invited: Investigating Geothermal Energy Potential in Singapore and Central Java, Indonesia. **Ping Tong**.
9:15–9:30 AM	Student: Monitoring Wind Turbine Vibrations with Ground-based Seismic Sensors for Subsurface and Structural Insight. **Sayan Mukherjee**.
9:30–9:45 AM	Student: Daily Groundwater Monitoring Using Vehicle-DAS Elastic Full-waveform Inversion. **Haipeng Li**.
9:45–10:15 AM	Discussion Period
10:15–11:15 AM	Coffee Break & Posters
Session: Novel Approaches for Environmental Seismology	
11:15–11:45 AM	Keynote: Integrated Fiber-optic Sensing—Technological Developments and Potentials for Environmental Applications. **Andreas Fichtner**.
11:45 AM–Noon	Invited: Exploring the Use of Soft Matter Physics Frameworks for Environmental Seismology. **Vashan Wright**.
Noon–12:15 PM	Student: Nature-informed Seismology: Biomimetic Method Improves Detection and Location Accuracy of Geomorphic Events. **Stefania Ursica**.
12:15–2:15 PM	Lunch & Posters
2:15–2:30 PM	Monitoring Rain and Temperature-driven Stress Changes in a Limestone Cliff with Ultrasonic Testing and Resonance Frequency. **Juliane Starke**.
2:30–2:45 PM	An Unprecedented View of Lake Waves in Motion Using Video InSAR. **Robert E. Abbott**.
2:45–3 PM	Existing and Envisioned Environmental Seismic Models to Leverage our Understanding of Landscape Dynamics. **Michael Dietze**.
3–3:30 PM	Discussion Period
3:30–4 PM	Break
4–5 PM	Panel Discussion: Seismic and Environmental Data Access and Management consisting of the following panelists: Pat Hogan, (National Oceanic and Atmospheric Administration), Walt Meier, (National Snow and Ice Data Center), Chad Trabant, (EarthScope Consortium)
5–6:30 PM	Reception, Posters & Sponsor Table Time

Friday, 17 October 2025

7–8 AM	Breakfast
Session: Subsurface Monitoring and Imaging	
8–8:30 AM	Keynote: Recent Advances in the Understanding and Forecasting of Induced Seismicity. **Jean-Philippe Avouac**.
8:30–8:45 AM	Monitoring Groundwater Dynamics Using Seismic Attenuation Variations from Train Signals. **Laura Pinzon Rincon**.
8:45–9 AM	Student: Soil Slope Monitoring with Distributed Acoustic Sensing Under Cyclic Drying and Wetting Cycles. **Jiahui Kang**.
9–9:15 AM	A Novel Near-surface Geophysics Approach to Constrain Material Porosity and Moisture Within Critical Zone Structure in Central Puerto Rico. **Mong-Han Huang**.

9:15–9:30 AM	Advancing Critical Zone Science with Nodal Seismic Arrays. **Steve Holbrook**.
9:30–10:30 AM	Coffee Break & Posters
10:30–10:45 AM	INVITED: Unraveling Arctic Cryosphere Processes with Distributed Acoustic Sensing: Signals from Sea Ice and Permafrost. **Tieyuan Zhu**.
10:45–11 AM	STUDENT: Diffusion in the Field: A Real-world Application for Velocity Change Localisation. **Tjaart de Wit**.
11–11:30 AM	Discussion Period
11:30 AM–1:30 PM	Lunch & Posters
Session: Seismic Investigation of Mass Movements	
1:30–2 PM	KEYNOTE: The Societal Relevance of Landslide Seismology. **Kate Allstadt**.
2–2:15 PM	Seismic Precursors Reveal the Role of Internal Processes in Driving Slow-to-fast Transition of the 15th June 2023 Brienz/Brinzauls Rockslide Collapse. **Sibashish Dash**.
2:15–2:30 PM	STUDENT: Illuminating Debris Flow Dynamics at Illgraben, Switzerland with Distributed Seismic Measurements. **Christoph Wetter**.
2:30–2:45 PM	STUDENT: Characterizing Surges from a Debris Flow Induced by a Glacial Outburst Flood at Mount Rainier, USA. **Avery E. Conner**.
2:45–3 PM	Seismological Monitoring of Sandstorms and Sand Dune Migration via High-frequency Seismic Signals in the Taklamakan Desert. **Xiaofeng Liang**.
3–4 PM	Posters
4–4:15 PM	Locating Pyroclastic Flows Using Seismic Amplitudes: Rebuilding a Lost Monitoring Tool from Soufrière Hills Volcano. **Glenn Thompson**.
4:15–4:30 PM	INVITED: From Seismic Waves to Landslide and Tsunami Processes. **Anne Mangeney**.
4:30–5 PM	Discussion Period
5–6 PM	Reception, Posters & Sponsor Table Time

Thursday, 16 October, and Friday, 17 October—Posters

Anthropogenic and Urban Seismology

1. STUDENT: Structural Health Monitoring of Native American Masonry Architecture. **Joseph Borg**.
2. Quantifying Environmental Influence on Building Seismic Response with Dense MyShake Smartphone-based Monitoring. **Utpal Kumar**.
3. Seismic Investigations of Singapore's Subsurface Using Large-N Arrays. **Karen Lythgoe**.
5. STUDENT: Towards Real-time Near-surface Characterization Using Passive Distributed Acoustic Sensing Data. **Nikhil Punithan**.
6. Characterizing the Urban Shallow Subsurface using Fiber-optic Sensing and Ambient Seismic Noise for Improved Hazard Assessment. **Verónica Rodríguez Tribaldos**.
7. Monitoring Urban Geohazards and Subsurface Water Flow Using Distributed Acoustic Sensing in Pittsburgh, PA. **Tieyuan Zhu**.

Seismic Investigation of Mass Movements

8. Seismic Characteristics of the Transition from Debris Flow to Hyperconcentrated Flow, Tahoma Creek, Washington. **Katie Biegel**.
9. Toward a Seismic Model of a Debris Flow: Applying and Adapting a Granular Flow Model to the U.S. Geological Survey Experimental Debris-flow Flume. **Katie Biegel**.
10. Understanding Spitze Stei Rockslide Dynamics: A Passive Seismic Approach to Mass Movement Detection, Characterization, and Trigger Identification. **Małgorzata Chmiel**.
11. Using Horizontal-to-vertical Spectral Ratio to Characterize Landslides in Complex Terrain. **Elaine A. Collins**.
12. STUDENT: Ground Motions, Infrasound Signals, and Seismic Velocity Perturbations: Environmental Impacts of the Rock Avalanche Induced by the 2025 Mw 6.5 Jan Mayen Strike-slip Earthquake. **Guilherme W S de Melo**.
13. STUDENT: Heterogeneous Spatial and Temporal Distribution of Small Seismic Signals Associated with the Oak Ridge Earthflow in California. **Yuriko Iwasaki**.
14. Rock Slope Instability Zonation from Ambient Vibration Array Measurements in Skagway, Alaska, USA. **Erin K. Jensen**.
15. Advancing Seismic Monitoring of Landslides in Alaska. **Ezgi Karasozen**.
16. STUDENT: Developing a Framework for Time Varying Inversion of Distributed Point Forces for Landslides. **Justin Krier**.
17. Passive Seismic Monitoring of the Åknes Unstable Rockslope: Unveiling the Potential of Borehole Sensors. **Nadège Langet**.

18. Student: The Impact of Grain Size on Bedload-generated Seismic Signals: Field and Flume Observations. **John M. McLaughlin**.
19. Avalanche Localization with Distributed Acoustic Sensing Near Milford Sound/Piopiotahi, New Zealand. **Konstantinos Michailos**.
20. Student: Environmental Seismology Applied to Unstable Rock Slopes in Kaafjord, Norway. **Amandine F. J. M. Missana**.
21. Preliminary Results from a Deployment of Seismic, Infrasound, and Auxiliary Sensors at the Chalk Cliffs, Colorado Debris Flow Site. **Liam Toney**.
22. Source Type Classification of Non-earthquake Signals Commonly Recorded on Regional Seismic Networks: Implementation and Pipeline Development. **Liam Toney**.
23. The Disenchanting Effect of Petrichor—The First Rain After a Dry Spell, on a Landslide. **Anne Voigtländer**.
24. Use Small Aperture Nodal Arrays to Capture the Debris Flow in the Bailey Canyon. **Auden Reid-McLaughlin**.
25. Seismic Characterization of Debris-flow Erosion Dynamics and Channel-bed Elevation Changes in Alpine Environments. **Zhen Zhang**.

Subsurface Monitoring and Imaging

26. Seismic Interferometry-based Monitoring of the Spitze Stei Rockslide. **Gabriela Arias**.
27. Low-cost, High-impact: Deploying Nodal Seismometers to Study Upper Mississippi Embayment Aquifers. **N. Seth Carpenter**.
28. Integration of Seismic Velocity and Azimuthal Anisotropy from Ambient Noise Tomography for Groundwater Aquifer Characterization. **Li-Wei Chen**.
29. Probing the Full Potential Spectrum of Landslide Thickness. **Li-Wei Chen**.
30. Student: Ambient Noise Imaging of Offshore Faults Using Distributed Acoustic Sensing in Monterey Bay, California. **Yuancong Gou**.
31. Monitoring Water in the Shallow Soil Using Ambient Noise Seismology. **James Hammond**.
32. Student: Using Ambient Noise to Monitor Groundwater and Industrial Activities in the Delaware Basin of Texas. **Chongpeng Huang**.
33. Mapping Hydrologic Dynamics in the Critical Zone using Ambient Seismic Noise at a Legacy Mine in the Colorado Front Range. **Stephanie R. James**.
34. Student: Discovering Spatial Variability of Critical Zone Processes at Mount Rainier using DAS. **Manuela Koepfli**.
35. Time-domain Seismic Response Retrieval from Seismic Records of Dams Based on Interferometric Processing. **Seiichiro Kuroda**.
36. Alpine Fault Zone Structure Revealed Using Distributed Acoustic Sensing (DAS). **Voon Hui Lai**.
37. Student: Bayesian Time-lapse Full-waveform Inversion for Geological CO2 Storage Monitoring Using Hamiltonian Monte Carlo. **Haipeng Li**.
39. Optimizing 3D Distributed Acoustic Sensing Arrays and Detection Algorithms to Detect Low-signal-to-noise Subsurface Sources. **Nathan Maier**.
40. Probing Soil Moisture Groundwater Drainage Dynamics in High-relief Environments Using Seismic Velocity Variations. **Peter Makus**.
42. Student: 4-Dimensional Characterization of Groundwater, Oil, and Gas Production at the Eagle Ford Basin, TX. **Hongrui Peng**.
43. Student: Imaging Earth's Subsurface with Thunderstorm-generated Seismic Waves. **Nolan Roth**.
44. Seismology in Abandoned Mine Reclamation—Active- and Passive-source Case Studies from Seven Projects. **Lincoln Steele**.
46. Student: Time-dependent Variations of F_0 and $\Delta V/V$ in 1D and 2D Sedimentary Structures. **Beatrice Tiboni**.
47. Tracking Spatiotemporal Transportation of Magma Reservoirs Beneath Piton de la Fournaise by Using Ambient Noise Cross-correlation Functions. **Shuo Zhang**.
48. Using Coda Wave Interferometry to Monitor Changes of Groundwater, Glacier and Rivers. **Hejun Zhu**.
49. Using Water Level Responses to Atmospheric Pressure Variations to Measure and Monitor Vertical Leakage Through Confining Units, With Application to the Jurassic Shaximiao Crust, China. **Yan Zhang.**
50. Monitoring Groundwater Fluctuations in Norway and Sweden Using Ambient Seismic Noise. **Karina Loviknes.**

Oral Presentation Abstracts

Presenting author is in bold.

Opening Session and Keynote Presentation

Oral Session • Tuesday, 14 October • 6:30 PM Pacific

Environmental Forcing of Faults and Slow-moving Landslides

BÜRGMANN, R., University of California, Berkeley, California, USA, burgmann@berkeley.edu

There has been long-standing interest in the effects of climatic processes and the tides on deformation and seismicity in the Earth's crust. The external loading processes and Earth's response to them span a wide range of temporal and spatial scales. Space- and ground-based geodetic and seismological observations allow us to characterize these interactions and provide new insights into the underlying mechanics of fault and landslide movements. Periodic climatic and tidal forcings induce stress changes on faults that in some cases can be shown to significantly encourage or retard the occurrence of earthquakes. We find that the frequency-dependent nature of the fault response to tidal and climatic forcing provides important insights into the physical processes and variable constitutive properties of frictional faulting in the earth. Similarly, slow-moving landslides are sensitive to climatic forcing and detailed examination of their deformation helps us better understand their dynamics, stability and hazard.

Cryoseismology

Oral Session • Wednesday, 15 October • 8 AM Pacific

Convener: Małgorzata Chmiel, Géoazur Laboratory (malgorzata.chmiel@geoazur.unice.fr); Nathan Maier, Los Alamos National Laboratory (nmaier@lanl.gov)

News From the Dark: Portable and Distributed Seismic Sensors Shed Light on Subglacial Processes

WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, fabian.walter@wsl.ch; CHMIEL, M., Côte d'Azur Observatory, Valbonne, France, malgorzata.chmiel@geoazur.unice.fr; FICHTNER, A., ETH Zürich, Zürich, Switzerland, andreas.fichtner@eaps.ethz.ch; GRIEDER, S., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, simon.grieder@wsl.ch; NAP, A., University of Zürich, Zürich, Switzerland, ana.nap@wsl.ch; LÜTHI, M., University of Zürich, Zürich, Switzerland, martin.luethi@geo.uzh.ch

Basal motion is a major ingredient to glacier dynamics. It often dominates internal deformation to facilitate fast ice stream flow and thus plays an important role in ice sheet stability. Meltwater runoff can drastically change hydraulic conditions at the bed, which in turn control basal motion and thus modulate large-scale ice flow.

Despite its key role for ice sheet dynamics, basal motion is still incompletely understood. Previous studies have shown that deformable till beds, deformation and regelation of the ice sole and frictional sliding may all contribute to basal motion, but it is not clear to what extent which of the mechanisms is dominant. However, frictional sliding has now been confirmed in many polar and non-polar environments. It is still debated if the resulting seismogenic patches at the bed support a significant amount of the driving stress or whether they only occur as by-products of another, more important sliding mechanism. At the same time, their seismic signals allow detection of basal stick-slip "icequakes" at the glacier surface, rendering them an ideal means to probe variations in basal motion.

Here, we report on recent observations of stick-slip icequakes beneath polar ice streams and non-polar, Alpine glaciers. We focus on new observations from densely spaced sensors, including installations in poorly accessible environments. These data acquisitions were made possible with technical advances like fiber-optic technology using Distributed Acoustic Sensing and compact, portable seismic stations. We find evidence for hydraulic modulations in stick-slip activity as sudden pressurization of subglacial water channels promotes seismogenic sliding. On fast flowing ice streams in Greenland, stick-slip icequakes seem to be related to tidal phases at the calving front and/or may occur throughout the ice column. Our observations highlight the potential of seismic monitoring in ice flow studies and capture phenomena that have yet to be included in theoretical and modeling efforts.

The Seismic Signature of Transient Water Flow Underneath the Greenland Ice-sheet

GIMBERT, F., French National Centre for Scientific Research, Institute of Environmental Geosciences, Grenoble, France, flo.gimbert1754@gmail.com; LE BOT, J., French National Centre for Scientific Research, Institute of Environmental Geosciences, Grenoble, France, jules.le-bot@univ-grenoble-alpes.fr; ROUSSEAU, H., French National Centre for Scientific Research, Institute of Environmental Geosciences, Grenoble, France, hugo.rousseau1@univ-grenoble-alpes.fr; DOKHT DOLATABADI ESFAHANI, R., French National Centre for Scientific Research, Institute of Earth Sciences, Grenoble, France, reza.dokhtdolatabadiesfahani@univ-grenoble-alpes.fr; CAMPILLO, M., French National Centre for Scientific Research, Institute of Earth Sciences, Grenoble, France, michel.campillo@univ-grenoble-alpes.fr; LE BRIS, T., French National Centre for Scientific Research, Institute of Environmental Geosciences, Grenoble, France, tifenn.le-bris@univ-grenoble-alpes.fr; MICHEL, A., French National Centre for Scientific Research, Institute of Environmental Geosciences, Grenoble, France, alexandre.michel@univ-grenoble-alpes.fr; PARIS, N., French National Centre for Scientific Research, Institute of Environmental Geosciences, Grenoble, France, nicolas.paris3@univ-grenoble-alpes.fr; DOYLE, S., Sheffield University, Sheffield, United Kingdom, s.h.doyle@sheffield.ac.uk; SOLE, A., Sheffield University, Sheffield, United Kingdom, a.sole@sheffield.ac.uk; LIVINGSTONE, S., Sheffield University, Sheffield, United Kingdom, s.j.livingstone@sheffield.ac.uk

Subglacial hydrology strongly modulates glacier basal friction through lubricating the ice-bed interface. However, the physics that controls subglacial water storage through weakly-connected water pockets (commonly referred to as cavities) remains particularly poorly documented. Here we report new seismic signals observed from a dense seismic array on Isunguata Sermia (Western Greenland). These sgnals exhibit characteristics similar to those of low frequency earthquakes previously observed on volcanoes and subduction zones: they are low frequency (1-5 Hz) and long duration (tens of seconds) and they do not follow the magnitude-frequency scalings of regular earthquakes. Using a clustering analysis we demonstrate these events operate in cascade and exhibit distinct families with similar waveform signatures. Systematic location of these events from matched field processing indicates they occur in places of significant glacier surface lowering observed from GPS. We suggest these events are associated with pressure transients from unsteady fluid motion as weakly-connected cavities transiently connect with each other. Using a pressure diffusion model we infer water flow permeability from these observations, yielding key constraints for the representation of weakly-connected cavities in subglacial hydrology models.

Quantifying the Cryoseismic Background of Mount Baker Volcano, Washington, USA

STEVENS, N. T., Pacific Northwest Seismic Network, Washington, USA, ntsteven@uw.edu; HARTOG, R., Pacific Northwest Seismic Network, Washington, USA, jrhartog@uw.edu; MALONE, S., Pacific Northwest Seismic Network, Washington, USA, smalone@uw.edu; THELEN, W. A., U.S. Geological Survey, Washington, USA, wthelen@usgs.gov; CAPLAN-AUERBACH, J., Western Washington University, Washington, USA, caplanj@wwu.edu; WRIGHT, A., Pacific Northwest Seismic Network, Washington, USA, akwright@uw.edu

Mount Baker has a very high volcanic threat potential, but compared to other Cascade volcanoes, it hosts relatively few volcano-tectonic earthquakes. In contrast, Mount Baker has a disproportionate number of deep low-frequency earthquakes (DLFs). DLFs may be indicative of magmatic processes, however, they share characteristics with the abundant, energetic seismicity generated by the glaciers cladding the volcano. Accurate characterization of seismicity at Mount Baker has been challenging due to limited network coverage, strong path effects, and limitations of classic methodologies, leading to event misclassifications. Growing interest from the Pacific Northwest Seismic Network and the Cascades Volcano Observatory in discriminating DLFs from glacier seismicity motivated our recent reconciliation of the authoritative catalog using template matching, which provides a launching point for this study.

Here we apply a combination of machine learning and matched filter detectors to the 23-year continuous waveform archive to develop an augmented catalog of low frequency seismic events near Mount Baker, both glacial and volcanic. We then use data from three on-edifice seismic deployments to better localize and constrain seismic sources detected during summer/autumn 2007–2009 and associate them with the entire augmented catalog using template matching and relative magnitude calculations. Finally, we use this catalog and contextual data to investigate the processes relevant to glacier seismicity at Mount Baker and their modulation over the decades. By developing our understanding of the cryoseismic background at Mount Baker we can improve our ability to accurately identify seismic signals of future volcanic unrest.

Assessing the Mechanisms Behind Ice Fracture Using Surface and Downhole Seismic Observations on the Brunt Ice Shelf, Antarctica

PEARCE, E., British Antarctic Survey, Cambridge, United Kingdom, emmear@bas.ac.uk; MARSH, O., British Antarctic Survey, Cambridge, United Kingdom, olrs@bas.ac.uk; BRISBOURNE, A., British Antarctic Survey, Cambridge, United Kingdom, aleisb@bas.ac.uk

Fracture propagation on Antarctic ice shelves is a key control on their long-term stability and, by extension, future sea level rise. Yet the processes governing the initiation and growth of ice fractures remain poorly resolved, especially at depth. To address this, we conducted a five-week geophysical deployment focused on Halloween Crack, a large active rift on the Brunt Ice Shelf. A dense surface array of 64 seismometers was installed across the rift zone to capture ice-quake activity associated with ongoing fracture processes, along with two borehole fibre-optic cables.

Combined surface and downhole seismic observations offer the potential to investigate the spatial distribution and depth of ice-quake events ahead of Halloween Crack, caused by active propagation and internal deformation, as well as stress-induced structure and anisotropy that potentially preconditions the ice to fracture. Through this approach, we aim to explore how fracture processes may be evolving beneath the ice surface by examining patterns in seismicity and evaluating focal mechanism solutions to understand the tensile and shear deformation driving rift propagation on the Brunt Ice Shelf.

These data will provide new insight into the internal mechanics of rift evolution on ice shelves and represent one of the most detailed seismic investigations of rift propagation on an ice shelf in Antarctic to date. The study demonstrates the value of high-resolution seismic networks and hybrid sensing strategies in resolving the depth structure and dynamics of ice shelf rifting.

How Surface Melt Drives Dynamic Fjord-ice Interactions in Greenland

GRÄFF, D., University of Washington, Washington, USA, graeffd@uw.edu; LIPOVSKY, B. P., University of Washington, Washington, USA, bpl7@uw.edu; DACHAUER, A., University of Zürich, Zürich, Switzerland, armin.dachauer@geo.uzh.ch; VIELI, A., University of Zürich, Zürich, Switzerland, andreas.vieli@geo.uzh.ch; FARINOTTI, D., ETH Zürich, Zurich, Switzerland, daniel.farinotti@ethz.ch; WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, fabian.walter@wsl.ch

The Greenland Ice Sheet (GrIS) is currently undergoing rapid changes due to climate change. Rising air temperatures increase surface melt, which drains to the glacier bed, pressurizes the subglacial drainage system, and temporarily decouples the ice from the glacier bed. This alters the ice flow towards the calving fronts of tidewater outlet glaciers, which channel nearly all the GrIS's discharge into coastal fjords. There, the subglacial discharge plume and iceberg calving activity modulate the fjord stratification by driving an overturning circulation and by perturbing the water column through the excitation of internal gravity waves. Fjord temperatures, in turn, govern submarine melt at the calving fronts—now recognized as the dominant ice loss mechanism for many outlet glaciers. Together, these coupled processes govern the stability of tidewater outlet glaciers, which are responsible for approximately 50% of the GrIS's total ice mass loss and thus critically impact overall ice sheet stability.

Here we present ice front proximal observations demonstrating the effect of variations in glacier surface melt on subglacial discharge, ice flow, fjord stratification, iceberg calving rate, internal wave activity, and finally submarine melt. To investigate this causal chain, we use a multi-sensor approach centered on seismo-acoustic observations from seismometers recording glacio-hydraulic tremor and Distributed Acoustic Sensing (DAS) to detect calving events, monitor internal wave activity, and assess submarine melt from air bubble resonances producing a varying high-frequency noise floor. We complement these with meteo data, glacier surface ablation monitoring, interferometric ice speed measurements, and seafloor Distributed Temperature Sensing (DTS). Our findings underscore the tight coupling of environmental processes and highlight potential feedback mechanisms that may accelerate the destabilization of tidewater glaciers–and ultimately, the Greenland Ice Sheet.

Time-lapse Active Source Seismic Measurements Through Seasonal Snow: Mechanical Property Changes Within and Beneath the Snowpack

LIBERTY, L. M., Boise State University, Idaho, USA, lliberty@boisestate.edu; OTHEIM, L. T., Boise State University, Idaho, USA, larryotheim@boisestate.edu; KANE, C., Boise State University, Idaho, USA, colemankane@boisestate.edu; MARSHALL, H., Boise State University, Idaho, USA, hpmarshall@boisestate.edu

We acquired active source seismic data over a five-month window to capture decimeter-scale mechanical property changes in seasonal snow and underlying soils at the Brundage Mountain, Idaho field site. We used a two Joule push-pull actuator seismic source, placed at the snow/soil interface, to obtain measurements at one-minute intervals through winter and spring months. Prior to snowfall, we installed a 24-channel vertical array of 10-cm spaced 100 Hz geophones (initially air-coupled) and a ground array of 16 50-cm spaced 100 Hz geophones (below the accumulating snowpack). We compare our surface and body wave velocities with independent measurements of snow depth (upwards of 3.5 m), snow water equivalent (up to 1.4 m), snow density, air and snow temperatures, and soil moisture. From the ground-based geophone measurements, we observe upwards of a 20 percent change in wave speeds that reflect soil compaction from snow accumulation and ablation. These velocity changes vary with wavelength, suggesting differing levels of soil compaction with depth. We also explore and model reflections from high impedance snow layers. From our tower-based geophone measurements, we observe arrivals that are consistent with p-wave and s-wave velocities that match empirically-derived bulk density estimates. Seismic amplitudes are controlled by snow densities, with the highest attenuation above the 80% critical porosity of snow. Independent bulk density measurements from a weekly snow pit campaign are consistent with travel-time differences in geophone pair cross-correlations, suggesting that seismic data can provide remotely sensed snow properties. Through changing seismic velocities with time, we estimate the variability of elastic moduli that provide constraints on snow strength, snow water equivalent, and water storage potential within the underlying soils.

Creating a Comprehensive Cryoseismic Catalog at Rhonegletscher: A Scalable Approach Using Distributed Acoustic Sensing and Machine Learning

WILLIS, R. M., Colorado School of Mines, Colorado, USA, rwillis1@mines.edu; GIMM, J., University of Grenoble Alpes, Grenoble, France, julius.grimm@univ-grenoble-alpes.fr; STANEK, F., Silixa, Elstree, United Kingdom, frantisek.stanek@silixa.com; EDME, P., ETH Zürich, Zürich, Switzerland, pascal.edme@erdw.ethz.ch; FICHTNER, A., ETH Zürich, Zürich, Switzerland, andreas.fichtner@erdw.ethz.ch; LIPOVSKY, B. P., University of Washington, Washington, USA, bpl7@uw.edu; PAITZ, P., ETH Zürich, Zürich, Switzerland, patrick.paitz@wsl.ch; WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürich, Switzerland, fabian.walter@wsl.ch; SIEGFRIED, M. R., Colorado School of Mines, Colorado, USA, siegfried@mines.edu; MARTIN, E. R., Colorado School of Mines, Colorado, USA, eileenrmartin@mines.edu

Monitoring glacier dynamics is essential for understanding climate change impacts, safeguarding water resources, and protecting communities from related hazards. Distributed acoustic sensing (DAS) provides a unique opportunity to observe these dynamic environments with high spatial and temporal resolution. However, creating comprehensive seismic event catalogs from DAS data requires the development of efficient, automated tools. This study leveraged DAS technology, machine learning (ML), and cloud computing to generate a detailed catalog of cryoseismic events at Rhonegletscher, Switzerland. We developed a robust preprocessing pipeline to address challenges posed by noise, coupling inconsistencies, and large data volumes. Our feature extraction was based on covariance matrix analysis, allowing us to characterize wavefield properties using the following metrics: the first eigenvalue, coherency function, and eigenvalue variance. We compared unsupervised and supervised approaches, highlighting the strengths and limitations of each method. Although unsupervised methods provided valuable insights into inherent data patterns, their performance was hindered by dataset imbal-

ance and noise. In contrast, supervised methods, trained on manually labeled data, demonstrated higher classification accuracy and reliability, with random forest emerging as the top performer. By leveraging cloud and parallel computing for efficient data processing, we established a scalable framework for analyzing DAS data, paving the way for future investigations into glacier dynamics. The resulting comprehensive catalog of cryoseismic events provides a valuable resource for scientists, fostering advancements in cryosphere monitoring and hazard assessment within the context of a changing climate.

Geophysical and Biogenic Signals from the Oceans, Surface Water and Atmosphere

Oral Session • Wednesday, 15 October • 1:30 PM Pacific
Convener: Seth Carpenter, University of Kentucky (seth.carpenter@uky.edu); Robert Dziak, National Oceanographic and Atmospheric Administration (robert.p.dziak@noaa.gov); Chu-Fang Yang, University of Michigan (chufan@umich.edu)

Using Seismology for Non-earthquake Signals

TSAI, V. C., Brown University, Rhode Island, USA, victor_tsai@brown.edu

Seismology has been the preeminent tool for studying earthquakes and interior Earth structure for primarily two reasons. First, seismic waves are sensitive to key earthquake source and Earth interior features in known ways; and second, the theory for understanding how to convert a ground motion measurement into a useful constraint on key parameters is well established. While seismic signals are also caused by many other phenomena including sediment transport, ocean waves, rain and animals, these signals are often more difficult to distinguish from each other and the theory needed to interpret the data quantitatively is not currently well developed. In this contribution, I highlight some of the key successes of non-earthquake seismology and provide my thoughts on the path forward to be able to better address the two key challenges outlined above. Although many of the specific directions are very different depending on the seismic sources of interest, there are several shared challenges as well as many consistent themes in making progress towards understanding a wide range of interesting phenomena. For example, understanding the role of Earth structure is key for all applications, as is quantifying the stresses caused by the source physics. Unfortunately, it is also often necessary to quantify many of the sources of less interest in order to make progress on the sources one cares about.

Decadal Analysis of Nonlinear Internal Waves in the South China Sea Using Satellite and Ocean Bottom Pressure Data

SYAMSUL, A., University of California, Santa Cruz, California, USA, nasa@ucsc.edu; BRODSKY, E., University of California, Santa Cruz, California, USA, brodsky@ucsc.edu; DAVIS, K., Stanford University, California, USA, kristen.davis@stanford.edu; CRUME, H., Santa Cruz Geophysics, California, USA, heather@scgeophysics.com

Oceans are stratified by density gradients resulting from vertical variations in temperature and salinity, creating a medium for internal gravity waves. Nonlinear internal waves can form and propagate hundreds of kilometers before breaking in shallow water. Nonlinear internal wave activity is modulated by climate change and plays a critical role in numerous oceanic processes, including vertical thermal mixing, nutrient supply, sediment transport, and acoustic transmission. Despite their importance, nonlinear internal waves remain difficult to detect over large spatial and temporal scales. We perform a 10-year analysis of nonlinear internal waves using remote sensing, ocean bottom seismometer (OBS) data, and geophysical methods. In this study, we (1) generate a decade-long dataset of propagation speeds and back azimuths of nonlinear internal waves generated in the eastern Luzon Strait of the South China Sea — home to some of the world's largest amplitude internal waves — using Himawari-8 geostationary satellite data from the Japan Meteorological Agency (JMA); (2) analyze the pressure amplitudes recorded during wave passages over the OBS deployed offshore of Dongsha Atoll in 2020; and (3) explore the relationship between OBS pressure amplitude and satellite-derived wave propagation speeds. Our results show that wave propagation speeds, corrected for background currents in the direction of travel, generally decrease as the waves approach shallower depths. We observe a consistent depth-dependent relationship between pressure amplitude and propagation speed, although we note that the exact form of this relationship may vary with future refinements to the dataset. Overall, this work provides a long-term observational framework for understanding the seasonal dynamics of nonlinear internal waves through the lens of seismology and contributes to the broader effort to quantify their role in oceanic processes.

Effect of Wide Excitation and Multipath Propagation of T-wave for Ocean Tomography

ZHANG, S., California Institute of Technology, California, USA, sdz@caltech.edu; PENG, S., Massachusetts Institute of Technology, Massachusetts, USA, speng3@mit.edu; ERVIK, H. L. L., California Institute of Technology, , USA, haakon@caltech.edu; SHEN, Z., Woods Hole Oceanographic Institution, , USA, zhichao.shen@whoi.edu; WU, W., Woods Hole Oceanographic Institution, , USA, wenbo.wu@whoi.edu; ZHAN, Z., California Institute of Technology, , USA, zwzhan@caltech.edu; CALLIES, J., California Institute of Technology, , USA, jcallies@caltech.edu

Acoustics can be used to remotely sense the electromagnetically opaque interior ocean, complementing point measurements with path integrals. Recently, a new acoustic tomography approach was developed based on the travel time of sound waves naturally excited by earthquakes, so-called T waves. This approach has been applied successfully to repeating earthquakes off Sumatra and Japan to estimate temperature variations integrated over a 2,900 to 4,400 km range, which are generally consistent with and complement existing sparse in situ data. In both regions, however, many T waveforms from repeating earthquakes have low coherence, which prohibits reliably measuring a travel time shift. We find that the low coherence is not caused by location differences between repeaters. Instead, the coherence is determined by the T waves being excited over a wide region and propagating along multiple paths through a changing ocean dominated by mesoscale eddies. Furthermore, we demonstrate how to leverage this multipath propagation to measure temperature changes over a fan-shaped area, beyond a single source-to-receiver path.

Monitoring Alongshore Coastal Processes in South Island, New Zealand Using Distributed Acoustic Sensing

LAI, V., Australian National University, Acton, Australia, voonhui.lai@anu.edu.au; MILLER, M. S., Australian National University, Canberra, Australia, meghan.miller@anu.edu.au; TOWNEND, J., Victoria University of Wellington, Wellington, New Zealand, john.townend@vuw.ac.nz

A major challenge in coastal monitoring is the ability to observe and quantify dynamic processes such as wave action and sediment transport, which are key drivers of coastal evolution and exhibit complex spatial and temporal variability along coastlines.

Distributed Acoustic Sensing (DAS) offers a promising approach to address this observational gap, by transforming existing fiber-optic cables into dense seismic arrays and enabling continuous, high-resolution observations along the coast. As part of the 'South Island Seismology at the Speed of Light Experiment' (SISSLE), we deploy a DAS array along an 18-km long dark fiber on State Highway 6 near Haast in south Westland, New Zealand. This fiber runs parallel to the West Coast of South Island, facing the Tasman Sea, at a distance of approximately 150 to 800 meters from the shoreline. Approximately three days of DAS strain-rate recordings were obtained in February 2023 (midsummer) and May 2023 (early winter).

With DAS's high spatial and temporal resolution, we analyzed the strain-rate recordings across various domain, including time, frequency-wavenumber, and curvelet, identifying distinctive features of several signals embedded in the recordings. Notably, we observed strong low-frequency (1-10 Hz) seismic waves induced by waves breaking at the coastline and propagating as surface waves to the fiber. These seismic signals strongly correlate with coastal measurements including significant wave height, barometric pressure, and tidal measurements. The wave-induced signals coincide with distinctive sediment transport signals, which can be interpreted as Rayleigh waves generated by sediment grains impacting the ground and can be described using mechanistic model of bedload transport. The signals are most prevalent and strongest in the data recorded in the early winter.

High-resolution DAS observations and seismic characterization constitute a first step toward quantifying coastal processes at meter-scale along the coastline and describing the relationship between sediment dynamics and wave interactions.

Behind the Curtain: Characterizing the Nisqually Watershed of MORA as a Means to Explore the Use of Non-contact Data Sources in Mountain Hydrology

KENYON, T. R., University of Waterloo, Washington, USA, t2kenyon@uwaterloo.ca

Impacts from a changing climate are affecting the hydrology, geomorphology, and overall variability of rivers around the world. Upland watersheds are

especially prone to these effects. Mountainous rivers are experiencing significant shifts in precipitation patterns and the storage of snow and ice in source areas, resulting in stark changes to hydrologic variability, sediment transport, and fluvial morphodynamics. Most hydrology methods have been developed for use in rivers with a slope of <0.001 m/m, and the advancement of knowledge relevant to steeper rivers with has followed slowly in comparison. This research aims to address gaps in mountain hydrology associated with the measurement of discharge and bedload sediment transport in mountain rivers with a slope ≥0.02 m/m, seeking means to improve our ability to observe hydrologic trends and morphodynamics.

Containing widely distributed low-resilience infrastructure, significant increases to precipitation intensities, and glacial recession rates greater than 0.1 m/day, the Nisqually River within Mount Rainier National Park (MORA) exemplifies a nexus of modern land management issues driven by climate stressors of the Pacific Northwest. With this study we seek to further characterize observable surface processes in the Nisqually watershed within MORA, and begin considering new methods and frameworks enabling reliable monitoring of steep mountain rivers.

We consider the use of seismic, infrasound, and video analysis data as non-contact methods to measure discharge and sediment transport in steep mountain rivers. The primary non-contact data series can then be supported by remote LiDAR products and Sentinel-1 data to assess changes in the source areas and their potential impacts on observable behaviors. Initial data shows signals in the seismic/infrasound that seem to correlate to both water flow and bedload transport. We hypothesize there will be observable correlations with topography and snowmelt timing seen though remote sensing analysis, but also anticipate site-to-site variability based on substrate and local morphology.

Turbulent Seismoacoustic Imprints of a Hurricane Landfall

JI, Q., Stanford University, California, USA, qingji@stanford.edu; DEY, I., University of Reading, Reading, United Kingdom, i.dey@reading.ac.uk; DUNHAM, E. M., Stanford University, California, USA, edunham@stanford.edu

Beyond earthquakes, seismometers continuously record the vibration of the ground, the seismic ambient noise. One of the strongest natural sources of seismic noise is tropical storms. Their energy can be transferred into the solid Earth through ocean wave interactions, and after their landfalls through fluctuating atmospheric pressure beating the ground. The coupling among the atmosphere, ocean and lithosphere opens the opportunity for monitoring a wide range of natural processes through the lens of seismology.

We investigate the seismoacoustic imprints of Hurricane Isaac's landfall along the Gulf Coast, United States, in August 2012. The seismic Transportable Array (TA) stations, equipped with barometric pressure and infrasound sensors in addition to seismometers, witness the passage of Hurricane Isaac. The in-situ surface measurements of pressure fluctuations and solid Earth ground deformation reveal the hurricane eye and eyewall, and we identify distinct contributions to seismic signals from the ocean and atmosphere in different period bands respectively. We focus on the seismic signals within the atmospheric band (~ 20-100 s), which are dominated by local quasi-static response to the turbulent atmospheric pressure.

We present a data-constrained interdisciplinary modeling workflow that combines large-eddy simulation (LES) of turbulence, calibrated by atmospheric datasets, with quasi-static elastic deformation modeling. Both infrasound pressure and vertical displacement spectra are well matched. The LES-derived turbulent pressure field connects the spatial and temporal scales, which is crucial for using point-measured data to invert for subsurface elastic properties from the pressure-displacement transfer function. Our LES results also constrain turbulent mixing under hurricane landfall conditions. Years of continuous data at multi-instrument seismic stations have the potential for novel applications in atmospheric studies for turbulence analysis and inertia-gravity waves observation.

High-latitude IMS Infrasound Station Noise and Seasonal Sea-ice Extent

SCHAIBLE, L. P., Sandia National Laboratories, New Mexico, USA, dpschai@sandia.gov; ALBERT, S., Sandia National Laboratories, New Mexico, USA, salber@sandia.gov; FREDERICK, J. M., Sandia National Laboratories, New Mexico, USA, jmfrede@sandia.gov; ROESLER, E., Sandia National Laboratories, New Mexico, USA, elroesl@sandia.gov; BROWN, M. G. L., Sandia National Laboratories, New Mexico, USA, merbrow@sandia.gov

The IMS infrasound network is critical to the detection of atmospheric nuclear tests. Signals of interest, however, must be detected in competition with the microbarom, globally ubiquitous and ever-present infrasonic noise created by the world's oceans. As the oceans globally trend increasingly energetic, the microbarom may grow in strength and thereby affect the network's detection capabilities. Microbarom noise may also increase because of the decline in seasonal high latitude sea ice extent, which is thought to inhibit the growth and passage of waves and thereby suppress noise. Here we analyze ten years of infrasound data collected at six high latitude IMS stations and hemispheric sea ice extent to understand noise amplitude as it relates to sea ice extent. We also calculate secular trends at each site to understand if the microbarom is changing in strength over the period analyzed. We find at all sites that microbarom power is out of phase with sea ice extent, with peak microbarom power occurring 2-4 months prior to maximum sea ice extent. We find negative trends in microbarom power at three sites, positive at the other three. We understand that hemispheric scale sea ice is not the primary driver of microbarom power. Our results motivate expanding this work to the full period of record for each of the 53 currently operational IMS infrasound sites.

Anthropogenic and Urban Seismology

Oral Session • Thursday, 16 October • 8 AM Pacific

Convener: Biondo Biondi, Stanford University (biondo@sep.stanford.edu); Elita Li, Purdue University (elitali@purdue.edu); Verónica Rodríguez Tribaldos, GFZ Potsdam (veronica.rodriguez.tribaldos@gfz.de)

Machine-learning Ground Motions for Infrastructure Risk Reduction

ASIMAKI, D., California Institute of Technology, California, USA, domniki@caltech.edu

When it comes to earthquake ground motions, engineers have access to two testbeds to evaluate possible solutions that withstand the passage of time and the extreme loads of hazards: observations, which sample the ground truth but are spatiotemporally limited and do not occur on demand; and simulators, with unprecedented capabilities that nonetheless reflect the input accuracy of their constituent models and in their most high-fidelity versions, require supercomputers and expert users. Recent advancements in machine learning show promising potential to combine the best of both worlds: the between- and within-event variability from observations that encapsulate the physics and variability not mapped in the simulator input models; and the spatial coverage and scaling constraints of rare scenarios from simulations for the scenarios that matter in design -- the catastrophic events that have yet to occur. In this talk, I will present new algorithms that we have been exploring to overcome challenges in learning ground motion ensembles and generating new content for earthquake scenarios yet to happen using generative algorithms; and to quantify the epistemic uncertainty in exascale ground motion datasets for purposes of spatially-varying seismic hazard characterization using Gaussian Process Regression. Methodologies presented in this talk can open new avenues in fusing regularly spaced simulation results and sparse observations into wavefields that realistically depict between- and within-event variability and high frequency statistics; and can generate event-level ground motions at a fraction of the time and computational expense of cutting-edge computer simulators.

Scalable Urban Sensing and Monitoring via Telecom Fiber Networks with DAS

LIU, J., Massachusetts Institute of Technology, Massachusetts, USA, jingxiao@mit.edu; **NOH, H.**, Stanford University, California, USA, noh@stanford.edu

The analysis of urban vibration and seismic signals offers valuable insights into both the built environment and societal activity. However, capturing these signals at the city scale is constrained by the high cost of deploying ultra-dense seismic arrays. In this study, we turn a 50-kilometer telecommunication fiber-optic cable in San Jose, California, into a Distributed Acoustic Sensing (DAS) array to enable scalable, high-resolution urban monitoring. Using DAS, we generate spatiotemporal maps of Seismic Source Power (SSP), allowing accurate localization of seismic sources such as traffic, construction, and school operations. This approach overcomes the spatial limitations of traditional networks and reveals strong correlations between SSP patterns and urban features, including land use, demographics, and environmental noise levels. We further demonstrate DAS for infrastructure monitoring by capturing low-frequency Lamb waves in bridge box girders. Through ambient noise interferometry, we reconstruct virtual shot gathers from traffic-induced vibrations, revealing both standing and propagating wavefields whose dispersion characteristics align with theoretical models.

Investigating Subsurface Changes in a Quick Clay Risk Area with Urban Seismic Noise and Low-cost Seismic Sensors

BRULAND, C., NORSAR, Kjeller, Norway, charlotte.bruland@norsar.no; DICHIARANTE, A. M., NORSAR, Kjeller, Norway, anna.dichiarante@norsar.no; KÖHLER, A., NORSAR, Kjeller, Norway, andreas.kohler@norsar.no; OYE, V., NORSAR, Kjeller, Norway, volker.oye@norsar.no; BEVER, I. V., NORSAR, Kjeller, Norway, ivan.vanbever@norsar.no; LAROSE, E., University of Grenoble Alpes, Grenoble, France, eric.larose@univ-grenoble-alpes.fr

Urban seismic noise opens for various approaches to monitor cities, from source identification to structural investigations. We show the potential to monitor cultural activity and quick clay failure in Oslo, Norway, using three-component Raspberry shake sensors. To track seismic velocity variations in the near subsurface, we apply seismic interferometry to three years of urban noise (1–4 Hz) recorded at four sensors, two in a quick clay risk area. Despite the urban noise variability, we achieve daily temporal resolution by stacking over different component combinations. The retrieved velocity variations reveal changes in the ground due to freezing and thawing, as well as due to pore pressure variations related to snowmelt and rainfall. Along with anti-correlation of velocity variations and pore pressure, we observe hysteresis associated with the soils water retention under different moisture conditions. This could provide insights into potential landslide hazard. We observe a sharp velocity drop accompanying the heavy rainfall associated with an extreme weather event. The observations give us insights into what subsurface changes can be resolved and expected over longer time periods. This will allow us to identify unusual and permanent changes in the shallow subsurface, potentially related to quick clay instability. Theoretical dispersion curve modeling shows that lowering the velocity in a section of the sedimentary layer, reduces surface wave velocities within the frequency range of interest. This suggests that measuring velocity variations at our study site might have the potential to detect quick clay instabilities.

Investigating Geothermal Energy Potential in Singapore and Central Java, Indonesia

TONG, P., Nanyang Technological University, Singapore, Singapore, tongping@ntu.edu.sg; BAI, Y., Nanyang Technological University, Singapore, Singapore, yiming.bai@ntu.edu.sg; HAO, S., Nanyang Technological University, Singapore, Singapore, shijie.hao@ntu.edu.sg

Singapore is actively pursuing geothermal energy as part of its strategy to meet growing energy demands and achieve net-zero emissions by 2050. Although elevated heat flow and the presence of hot springs indicate significant geothermal potential, deep geothermal sources beneath Singapore remain poorly understood due to limited subsurface imaging. We applied ambient noise tomography and converted/reflected body-wave imaging to newly acquired seismic data from northern Singapore. Our findings reveal a fractured, fluid-saturated shallow geothermal reservoir southeast of the Sembawang Hot Spring in the Yishun district. These results position Yishun as a promising candidate for future deep geothermal drilling and contribute valuable insights into the broader thermal architecture of medium-to-low enthalpy geothermal systems across Southeast Asia. In parallel, Indonesia is experiencing a critical energy transition driven by rapid population growth and national decarbonization goals. Indonesia holds immense geothermal potential. We will present updates from our ongoing seismic monitoring efforts in the Dieng geothermal field in Central Java, which aim to support safe and efficient geothermal development through improved subsurface characterization.

Monitoring Wind Turbine Vibrations with Ground-based Seismic Sensors for Subsurface and Structural Insight

MUKHERJEE, S., Purdue University, Indiana, USA, mukher55@purdue.edu; LI, Y., Purdue University, Indiana, USA, li4017@purdue.edu; STUMPF, A., Illinois State Geological Survey, Illinois, USA, astumpf@illinois.edu

Wind turbines generate continuous seismic signals that reflect their structural dynamics and interactions with the surrounding environment. In this study, we explore the feasibility of using a single ground-based seismic sensor to monitor wind turbine vibrations and detect both structural changes and near-subsurface variations. Our deployment included multiple three-component seismic sensors at two wind farms in Illinois: Hoopeston and Pioneer Trail. Over a 16-month period, we recorded ambient seismic noise and extracted the peak vibration frequency associated with the vibration of the turbine tower.

Our analysis reveals that the peak vibration frequency exhibits clear seasonal trends and small short-term fluctuations. Correlation with environmental data shows that air temperature, wind speed, and soil moisture content are all linked to frequency variation, suggesting that these environmental factors drive long-term, seasonal changes. Temperature influences the material stiffness of the tower structure, affecting vibration frequency, while soil moisture affects the interaction between the tower and its foundation. Wind speed introduces periodic loading through mechanisms such as tower shadowing and vortex shedding, further influencing vibration characteristics. A linear model incorporating these variables successfully captures long-term frequency variation, and the model residuals isolate short-term fluctuations that may reflect local anomalies.

We examined seismic records surrounding a turbine collapse event that occurred near one sensor. While no definitive precursor was observed in the short-term frequency residuals, ongoing analysis seeks to better characterize potential failure indicators. These findings suggest that passive seismic monitoring holds promise as a cost-effective approach for detecting shallow subsurface changes, including critical zone soil moisture content, and for exploring the potential to identify structural anomalies in wind turbine systems.

Daily Groundwater Monitoring Using Vehicle-DAS Elastic Full-waveform Inversion

LI, H., Stanford University, California, USA, haipeng@sep.stanford.edu; LIU, J., Massachusetts Institute of Technology, , USA, jingxiao@mit.edu; MAO, S., The University of Texas at Austin, Texas, USA, smao@jsg.utexas.edu; YUAN, S., Stanford University, California, USA, syyuan@sep.stanford.edu; CLAPP, R., Stanford University, California, USA, bob@sep.stanford.edu; BIONDI, B., Stanford University, California, USA, biondo@sep.stanford.edu

Continuous groundwater monitoring is paramount for comprehending the hydrologic cycle and ensuring sustainable water management, particularly as climate extremes intensify. Despite advancements in geophysical monitoring techniques, limited high-resolution imaging and subsurface monitoring constrain our understanding of aquifer structures and dynamics. We introduce a novel, non-invasive method for high-resolution groundwater monitoring, enabling daily measurements of groundwater table fluctuations through time-lapse elastic Full-Waveform Inversion (FWI). This approach leverages existing telecommunication fiber-optic cables as dense seismic sensor networks and vehicular traffic as repeatable Rayleigh wave sources.

We demonstrated this method over a two-year monitoring period along Sandhill Road, California, capturing spatiotemporal variations in S-wave velocity. Our results revealed a 2.9% decrease in S-wave velocity, corresponding to an estimated 9.0-meter water table rise, driven by severe atmospheric river storms during Water Year 2022-2023. Notably, we detected a rapid water table increase following the intense rainfall on December 31, 2022. Spatial variability in seismic velocity changes correlated with surface conditions, showing minimal reductions beneath paved areas and more significant decreases under permeable grassy regions. This highlights the role of land use in modulating groundwater recharge. Our findings, validated through in-situ hydraulic head measurements and poroelastic simulations, demonstrate the potential of employing daily FWI with Vehicle-DAS surface waves for high-resolution groundwater monitoring, with the capability of quantitative aquifer characterization.

Novel Approaches for Environmental Seismology

Oral Session • Thursday, 16 October • 11:15 AM Pacific

Convener: Clément Hibert, University of Strasbourg (hibert@unistra.fr); Ethan Williams, University of California, Santa Cruz (ethan.williams@ucsc.edu)

Integrated Fiber-optic Sensing—Technological Developments and Potentials for Environmental Applications

FICHTNER, A., ETH Zürich, Zurich, Switzerland, andreas.fichtner@erdw.ethz.ch; BOGRIS, A., University of West Attica, Athens, Greece, abogris@uniwa.gr; WANG, Y., ETH Zürich, Zurich, Switzerland, yuhawang@ethz.ch; NOE, S., ETH Zürich, Zurich, Switzerland, sebastian.noe@erdw.ethz.ch; MUELLER, N., ETH Zürich, Zurich, Switzerland, nilmueller@student.ethz.ch; HUSMANN, D., Federal Institute of Metrology, Bern, Switzerland, dominik.husmann@metas.ch; SIMOS, C., University of Thessaly, Thessaly, Greece, christos.simos@uth.gr; SIMOS, I., University of West Attica, Athens, Greece, simos@uniwa.gr

Integrated fiber-optic sensing (IFOS) is an emerging alternative to widely-used distributed fiber-optic sensing (DFOS) technologies, among which Distributed Acoustic Sensing (DAS) is the most common. IFOS measures deformation-induced optical phase delays of laser signals transmitted through standard optical fibers to infer axial strain integrated along the fiber. The out-

standing advantages of IFOS, compared to DAS, are interrogation distances of up to thousands of kilometers, concurrent operation with telecom services, and around 10 times lower cost of the interrogation unit. These advantages are balanced by lower spatial resolution, and therefore a different application niche. In this presentation, we highlight two different technical implementations of IFOS and outline their respective potential for future environmental applications.

Phase-noise cancellation (PNC) suppresses deformation-induced perturbations of high-precision metrological frequency signals transmitted through standard telecom fibers. The real-time correction frequency is proportional to the strain rate integrated along the transmission line and can be shown to record earthquake-induced ground motion with high accuracy. Furthermore, a single PNC time series contains sufficient information to constrain the location, timing and moment tensor of regional earthquakes, suggesting it as a long-range complement to DAS that comes at zero additional cost.

Microwave-frequency fiber interferometry (MFFI) detects phase delays of microwave-modulated laser signals propagating through a looped fiber. Despite being in their prototype-phase, MFFI units are highly portable low-cost devices that produce integrated strain data that are in excellent agreement with DAS recordings. In recent experiments, MFFI recorded regional earthquakes with magnitudes as low as 1, using a submarine telecom fiber. These early results indicate that dense MFFI networks, similar to networks of dense seismic nodes, are within reach.

Exploring the Use of Soft Matter Physics Frameworks for Environmental Seismology

WRIGHT, V., University of California, San Diego, California, USA, vwright@ucsd.edu

The ground beneath our feet shifts over time, sometimes slowly creeping, sometimes flowing like a fluid, and sometimes suddenly failing. Sudden shifts in the shallowest parts of the ground produce geohazards (e.g., landslides, ground fissures, and liquefaction) that often cause loss of life and destroy infrastructure. Current state-of-the-art methods can not forecast these events, largely because we lack reliable ways to incorporate grain and mesoscale information into failure models. This presentation will discuss results from a series of studies that aims to use several statistical mechanical frameworks for inferring mesoscale changes in natural and lab-reconstituted sediments.

Nature-informed Seismology: Biomimetic Method Improves Detection and Location Accuracy of Geomorphic Events

URSICA, S., GFZ Postdam, Potsdam, Germany, stefania.ursica@gfz.de; HOVIUS, N., GFZ Postdam, Potsdam, Germany, hovius@gfz.de

How can we better pinpoint unwitnessed geomorphic events that cascade destructively and intensify under surging climate volatility? These events incessantly remodel landscapes, yet remain poorly quantified, impeding scientific understanding and disaster response. Their seismic signatures are nonlinear and emergent, defying earthquake-focused location methods tailored for crisp waveforms. To transcend this impasse, we present an algorithm merging geophysics and biomimicry, mathematically translating animal search strategies to sharpen event location by up to an order of magnitude.

Our method has two innovations: (1) a multi-detector seismic onset picker—five orthogonal techniques, each attuned to unique signal emergence facets: statistical structures, ;complexity, energy, morphology, and pattern shifts; and (2) a bio-inspired locator combining a coarse geophysical initialization with biomimicking agent optimization. We encoded over a dozen animal foraging strategies, such as falcon stooping, firefly light-following, and elephant herding memory. Driven by evolutionary dynamics, this agile collective explores and then refines to home in on the most plausible source by simulating forward modeling and survival-of-the-fittest dynamics

Benchmarking against a global dataset of 30+ recorded geomorphic events, our method slashes location errors from main deviations of over 40 km (standard methods) to 4 km, with sub-300 m uncertainty ellipses and over fourfold standard deviation gains. The quintet picker shows higher sensitivity to signal emergence, bracketing the ground truth within ±20 s deviations, outperforming the STA/LTA picker variability [−100; +300] s. The algorithm is training-free and yields local velocity models as a byproduct. With ~10-second runtimes, it offers viable rapid perception of events for actionable early warning.

By embedding biomimetic intelligence into environmental seismology, our approach redefines time and location fidelity, offering a scalable foundation for disaster readiness and efficient landscape change monitoring under shifting boundary conditions.

Monitoring Rain and Temperature-driven Stress Changes in a Limestone Cliff with Ultrasonic Testing and Resonance Frequency

STARKE, J., Institute of Earth Sciences, University of Grenoble Alpes, Grenoble, France, starkej@univ-grenoble-alpes.fr; ROUSSEAU, R., Institute of Earth Sciences, French National Centre for Scientific Research, Grenoble, France, romain.rousseau@univ-grenoble-alpes.fr; BAILLET, L., Institute of Earth Sciences, University of Grenoble Alpes, Grenoble, France, laurent.baillet@univ-grenoble-alpes.fr; LAROSE, E., Institute of Earth Sciences, French National Centre for Scientific Research, Grenoble, France, eric.larose@univ-grenoble-alpes.fr

Rockfalls threaten nearby infrastructure and lives; they originate from weathering processes that impose sub-critical stresses, progressively weakening rock masses until failure. Resonance frequency analysis is routinely used to follow stress evolution at the cliff (decameter) scale, but it cannot resolve the surface layer specifically where weathering first acts. We therefore complement resonance frequency monitoring with high-frequency ultrasonic testing to capture local stress changes in the surface layer of the rock.

We installed an array of six ultrasonic transducers (four receivers and two emitters) across a few square meters on a 50-meter-high limestone cliff above the Chauvet Cave in southeastern France. This setup allows us to track local variations in sonic velocity, which are sensitive to stress changes near the rock surface. Our results show a clear diurnal pattern in velocity linked to temperature-driven opening and closing of micro-fractures. Additionally, we recorded a ~10% drop in sonic velocity following a major rain event in summer, indicating a significant temporary reduction in local rock rigidity.

These findings demonstrate that ultrasonic testing captures localized, climate-driven stress changes that may not be visible in whole-cliff resonance measurements. Repeated stress drops, like those induced by rainfall, can accelerate fracture growth and contribute to long-term instability. This highlights the value of combining ultrasonic and resonance monitoring for a more complete understanding of damage evolution in rock slopes.

An Unprecedented View of Lake Waves in Motion Using Video InSAR

ABBOTT, R. E., Sandia National Laboratories, New Mexico, USA, reabbot@sandia.gov; WEST, D., Sandia National Laboratories, New Mexico, USA, rdwest@sandia.gov; BILLSON, A., Sandia National Laboratories, New Mexico, USA, atbills@sandia.gov; ROHWER, J. A., Sandia National Laboratories, New Mexico, USA, jarhowe@sandia.gov

We present results from a May, 2025, data collect using a unique Ku-band synthetic aperture radar (SAR) system with multiple antenna phase centers making it capable of instantaneously collecting interferometric SAR pairs many times per second (dubbed Video InSAR). In a first-of-its-kind attempt, the Video InSAR system, developed by Sandia National Laboratories, was flown in a De Havilland DHC-6 Twin Otter over Elephant Butte Reservoir in southern New Mexico, USA. There, we recorded videos of wind-driven water waves. Beyond a simple visualization of the waves, the InSAR videos allow for reconstruction of wave height, period, direction, and speed. The imaged footprint of the InSAR system depends on acquisition geometry (altitude, grazing angle, etc.); videos presented here have image sizes that are approximately 300 by 400 meters and thus capture hundreds of individual waves. Similarly, acquisition geometry drives system performance. We present results from the collect at faster than 30 frames-per-second, sub-meter lateral resolution, and millimeter-scale vertical sensitivity.

We will also introduce plans for a 2026 mission to record ice flexural-gravity waves in the Beaufort Sea off the North Slope of Alaska. Dispersion observed in the flexural-gravity waves will be used to invert for sea ice thickness. In addition, other possible targets for on-scale recording of displacement time series will be proposed. These include high-yield chemical explosions, large earthquakes, avalanches, and volcanic activity.

Supported by the LDRD Program at Sandia National Laboratories. Sandia is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

Existing and Envisioned Environmental Seismic Models to Leverage our Understanding of Landscape Dynamics

DIETZE, M., Georg August University of Göttingen, Göttingen, Germany, michael.dietze@uni-goettingen.de

Throughout the last years, several physically based models have been introduced that allow to estimate the seismic signatures of environmental processes. Hence, in an inverse way, we can turn seismometers into efficient probes of earth surface dynamics that are otherwise hard to quantify, such as snow avalanches, debris flows, river sediment transport, rain intensity and large scale atmospheric pressure systems. In addition, seismic noise cross correlation approaches are increasingly utilised to probe the water fluxes as well as geomorphically driven material property changes within the shallow to deep subsurface. However, most of these approaches and models operate with sometimes very simplified process-geomorphic concepts, constraints on Critical Zone architecture, water flow paths, and hydrological concepts. Here, I survey relevant geomorphic processes and landscape dynamics that are already represented by environmental seismic models and summarise, which unique insights they allow beyond what classic survey techniques can deliver. I also point out important processes that hitherto lack a proper representation. I argue for an alliance across disciplines to close these gaps in knowledge, skill and application, to further boost our scientific capabilities to understand landscape reaction to ongoing change.

Subsurface Monitoring and Imaging

Oral Session • Friday, 17 October • 8 AM Pacific

Convener: Voon Hui Lai, Australian National University (voonhui.lai@anu.edu.au); Shujuan Mao, University of Texas at Austin (smao@jsg.utexas.edu)

Recent Advances in the Understanding and Forecasting of Induced Seismicity

AVOUAC, J., California Institute of Technology, California, USA, avouac@caltech.edu

Subsurface reservoir operations and hydraulic stimulations can activate faults and trigger earthquakes as evidenced by the spectacular rise of earthquakes induced by oil and gas production and waste water disposal in the mid-US over the last two decades. A better understanding of the processes determining the occurrence and magnitude of induced earthquakes is needed as many effort to reduce the impact of energy production on CO2 emission involve subsurface fluid injection or extraction, for CO2 storage or geothermal energy production in particular. Hydraulic stimulation has long been viewed as a way to unlock the vast potential of geothermal by providing a mean to create artificial hydrothermal systems. It is now very clear that the current inability to control induced seismicity is a major roadblock to the development of geothermal energy production. The risk of induced earthquakes and leakage along reactivated faults is also a threat to geological CO2 storage at the Gigaton scale needed for this technology to have a significant impact on CO2 emissions. These considerations have driven our efforts to understand better induced seismicity and to develop and validate stress-based forecasting methods. The presentation will show recent advances in that direction based on the study of case examples using seismological and remote sensing observations combined with reservoir and geomechanical modeling. We will review the insight gained on earthquake physics, see that seismicity rate can be forecasted well based on current understanding, but that forecasting earthquake magnitudes remain a difficult challenge.

Monitoring Groundwater Dynamics Using Seismic Attenuation Variations from Train Signals

PINZON RINCON, L., GFZ Postdam, Potsdam, Germany, lau.pinzonrincon@gmail.com; NZIENGUI BÂ, D., Febus Optics, Pau, France, destin.nziengui@febus-optics.com; MORDRET, A., Geological Survey of Denmark and Greenland, Copenhagen, Denmark, aurmo@geus.dk; RODRÍGUEZ TRIBALDOS, V., GFZ Postdam, Potsdam, Germany, verort@gfz.de; COUTANT, O., Institute of Earth Sciences, Grenoble, France, olivier.coutant@univ-grenoble-alpes.fr; BRENGUIER, F., Institute of Earth Sciences, Grenoble, France, florent.brenguier@univ-grenoble-alpes.fr

Groundwater systems are key to sustaining urban water supply, yet their dynamics remain difficult to monitor at high temporal resolution. We present a novel single-station method to continuously track near-surface seismic attenuation using train-generated seismic signals as a stable and repetitive noise source. The method relies on quantifying the relationship between signal frequency content and amplitude variations over time, providing an indirect measure of subsurface attenuation changes.

We applied this approach at the Lyon water catchment in France, a strategic site supplying more than 90% of the city's drinking water through a complex system of artificial recharge basins. Over a four-week deployment, two major hydrological events occurred: a flood caused by upstream dam release and a controlled 8-day infiltration experiment. By comparing seismic attenuation variations with environmental observables such as rainfall, infiltration basin levels, piezometric data, and velocity changes derived from ambient noise correlations, we observe consistent links between attenuation and groundwater system responses.

Our results demonstrate that anthropogenic noise sources such as trains can be repurposed to monitor aquifer dynamics continuously. This passive, cost-effective technique offers new opportunities to study subsurface hydrological processes in urban and sensitive environments, contributing to improved groundwater resource management. Furthermore, the methodology can be applied to other settings where opportunistic repetitive anthropogenic seismic sources are present, enabling its application in diverse hydrogeological contexts.

Soil Slope Monitoring with Distributed Acoustic Sensing Under Cyclic Drying and Wetting Cycles

KANG, J., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürich, Switzerland, kjh1919k@gmail.com; WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürich, Switzerland, fabian.walter@wsl.ch; HALTER, T., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürich, Switzerland, tobias.halter@wsl.ch; PAITZ, P., Grun Stadt Zurich, Zürich, Switzerland, patrick.paitz@wsl.ch; FICHTNER, A., ETH Zürich, Zürich, Switzerland, andreas.fichtner@eaps.ethz.ch

Hydromechanical soil responses to moisture variations reflect complex subsurface dynamics critical for geoengineering, slope stability, and other soil health-related fields. While laboratory experiments have provided insights into soil behavior under varying wetness and loading conditions, field-scale observations with high spatial and temporal resolution remain limited.

In this study, we use Distributed Acoustic Sensing (DAS) to monitor hydromechanical processes on a natural grass-covered hillslope located in Wasen im Emmental, Switzerland, with high spatiotemporal resolution for 2 months in the summer. DAS recordings were complemented by two soil moisture point-sensors that measured soil wetness and pressure conditions, enabling direct validation of the observed hydromechanical relationships. We find that both shear wave velocity and strain responses are influenced by effective stress variations driven by soil moisture fluctuations. Moreover, coda wave interferometry yields dv/v measurements that correlate with rock physics model predictions using a simplified two-layer ground structure model. This correlation links seismic velocity fluctuations to soil moisture variations. Last but not least, the effective stress-strain coupled analysis reveals long-term soil consolidation during drying phases, as well as daily cyclic "soil breathing" deformations in the micro-strain scale. The observed soil "breathing" featuring daytime contraction and nighttime expansion indicates that hydrological processes rather than thermal effects dominate soil deformation.

Our investigation provides first-of-their-kind observations of small-magnitude soil deformation that are highly resolved in both space and time and distributed over a field-scale extent. This work is particularly beneficial to the agricultural and soil science communities. It also contributes to the DAS research community by expanding the interpretation of low-frequency signals in near-surface applications.

A Novel Near-surface Geophysics Approach to Constrain Material Porosity and Moisture Within Critical Zone Structure in Central Puerto Rico

HUANG, M., University of Maryland, College Park, Maryland, USA, mhhuang@umd.edu; PERKINS, J., U.S. Geological Survey, California, USA, jperkins@usgs.gov; HUDSON RASMUSSEN, B., University of Texas at Austin, Texas, USA, hudsonb@utexas.edu

Near-surface geophysics has been widely used in Critical Zone (CZ) research for imaging subsurface properties related to material porosity and moisture distribution. Seismic velocity inverted from active source surveys is commonly used for inferring thickness of regolith, while electrical resistivity could be a proxy for material moisture. Because material porosity and water content both contribute to seismic velocity and resistivity, individual inversions of seismic velocity or resistivity alone yield ambiguous results where the trade-off between moisture and porosity is difficult to interpret. Here we develop a joint inversion technique using active source seismic refraction (SR) and electrical resistivity (ER) to constrain material moisture and porosity. This method utilizes a transdimensional hierarchical reverse-jump Markov Chain Monte Carlo (rjMCMC) approach in a Bayesian framework, which creates a set of 2D porosity and moisture models that can fit both the observed P-wave arrival in SR and the differential electric potentials in ER at a higher likelihood. It provides a better understanding of the plausible models and the uncertainty associated with the data. We conduct several SR and ER surveys across the Utuado batholith in central Puerto Rico comprising an incised plateau. Both deep-seated and shallow landslide characteristics vary between

low-relief plateau surface and the more recently incised plateau escarpment. From the joint rjMCMC inversions, we find a relatively shallow (<15 m) and laterally heterogeneous regolith layer along the plateau escarpment, consistent with active weathering of fresh bedrock that was visible in the both the active channel and at shallow soil depths. Plateau hillslopes have a uniformly higher porosity and a uniformly lower moisture content than escarpment hillslopes, indicating that they tend to dry out between hydrologic events. These hillslope weathering patterns are consistent with theoretical models of transient critical zone evolution for granitic landscapes and have implications for both hillslope hydrology and slope stability.

Advancing Critical Zone Science with Nodal Seismic Arrays

HOLBROOK, S., Virginia Polytechnic Institute and State University, Virginia, USA, wstevenh@vt.edu; BEMIS, S., Virginia Polytechnic Institute and State University, Virginia, USA, sbemis@vt.edu; EPPINGER, B., Virginia Polytechnic Institute and State University, Virginia, USA, beppinger@vt.edu

The critical zone is Earth's breathing skin, the thin layer between atmosphere and rock that supports virtually all terrestrial life. Progress in critical zone science relies in part on geophysical images of shallow subsurface structure in a wide variety of environments, which will require continued advances in our ability to collect and analyze near-surface seismic data. The current state of practice in critical zone seismics is dominated by cabled geophone systems, which, especially for systems with large numbers (100's) of geophones, are heavy and bulky, and thus time-consuming and cumbersome to deploy, severely limiting the kinds of seismic data that can be acquired in the critical zone. However, recent developments in seismic nodal technology offer potentially game-changing instrumentation for many kinds of seismic surveys in academic science, including critical zone science. Here we summarize two years of experience using the Stryde nodal system for critical zone science, assess the advantages and disadvantages of the system for academic users, and present examples of data and imaging results from several active critical zone study sites. We suggest that seismic nodes represent a transformative technology for near-surface and critical zone seismic studies. Using nodes instead of cabled systems vastly increases the number of receivers that can be feasibly deployed in typical field campaigns, opening up new possibilities, such as time-lapse, 3D, and very-high-resolution studies. Especially when combined with advances in full-waveform inversion, nodal technology opens new frontiers in imaging critical zone processes at multiple scales.

Unraveling Arctic Cryosphere Processes with Distributed Acoustic Sensing: Signals from Sea Ice and Permafrost

ZHU, T., Pennsylvania State University, Pennsylvania, USA, tyzhu@psu.edu; SANTOS, G., Pennsylvania State University, , USA, grd5166@psu.edu; WANG, Z., Pennsylvania State University, , USA, zfw5324@psu.edu; MARTIN, E. R., Colorado School of Mines, , USA, eileenrmartin@mines.edu; XIAO, M., Pennsylvania State University, , USA, mzx102@psu.edu

Rapid changes in Arctic sea ice and permafrost driven by global warming present major challenges for monitoring and prediction, primarily due to the scarcity of continuous, high-resolution observations. Our group leverages Distributed Acoustic Sensing (DAS) and Distributed Temperature Sensing (DTS) on a 2-km fiber-optic array in Utqiaġvik, Alaska, to advance the environmental seismology of the Arctic. In this presentation, we report a joint effort of analyzing DAS and DTS continuous data. We focus on three major discoveries from our ongoing research: (1) Sea Ice Collision Dynamics: We captured previously unobserved seismic signals generated by sea ice collisions. Harmonic tremors were found to arise from interactions involving larger, thicker, and more consolidated ice floes, while broadband, chaotic tremors were associated with collisions among thinner, more fractured ice blocks. These signatures provide unique insights into the mechanics and variability of sea ice behavior near the coast. (2) Ice-Wedge Cracking Events: Our continuous DAS recordings revealed over two thousand ice-wedge cracking signals during winter months, mapped across two years. The spatial variability of these events indicates heterogeneous thermal stresses within frozen ground, as extreme cold induces tensional fractures and abrupt stress release. This work provides direct seismic evidence for a key process shaping Arctic permafrost landscapes. (3) Seasonal Permafrost Velocity Variations: Through time-lapse ambient noise interferometry, we tracked surface-wave phase velocity changes over two years. Results show strong seasonal patterns linked to freeze–thaw cycles of the active layer: higher velocities in winter as soil freezes and stiffens, and lower velocities in summer during thaw and softening. Together, these findings underscore the transformative potential of DAS/DTS as a scalable, efficient platform for real-time monitoring of Arctic ice and permafrost dynamics.

Diffusion in the Field: A Real-world Application for Velocity Change Localisation

DE WIT, T., Colorado School of Mines, Colorado, USA, tjaartdewit@mines.edu; TAYLOR, G., Institute of Mine Seismology, Hobart, Australia, goerge.taylor@imsi.org; SNIEDER, R., Colorado School of Mines, Colorado, USA, rsnieder@mines.edu

Localising Time-Lapse Velocity Changes in Tailings Storage Facilities

Tailings storage facilities (TSFs) are engineered structures used to contain the waste products of mining operations. While seismic noise interferometry has shown potential for probing the internal structure of TSFs, the resulting real-time, pair-wise velocity variations can be difficult for operators to translate into actionable insights. To improve the utility of seismic interferometry for monitoring TSFs, this study focuses on the spatial localisation of time-lapse velocity changes, which could provide critical information about evolving instability. We present a methodology to address this challenge by developing an approach to inverting 3D changes in seismic velocity using an analytical expression derived from the diffusion approximation of seismic energy. We explore the diffusive nature of the wavefield in estimating scattering parameters and assess the influence of the diffusion constant on our 3D velocity inversion. This work lays a foundation for improved spatial understanding of velocity changes and holds promise for the enhanced detection of precursory signs of TSF instability.

Seismic Investigation of Mass Movements

Oral Session • Friday, 17 October • 1:30 PM Pacific

Convener: Micha Dietze, Georg-August University Göttingen (michael.dietze@uni-goettingen.de); Liam Toney, U.S. Geological Survey (ltoney@usgs.gov)

The Societal Relevance of Landslide Seismology

ALLSTADT, K., U.S. Geological Survey, Colorado, USA, kallstadt@usgs.gov

Landslide seismology may sometimes feel like a niche specialization, falling between the cracks of more prominent research domains. Yet, the field is growing for a reason: there is considerable demand for what landslide seismology has to offer. Early warning systems for lahars, debris flows, and tsunamigenic landslides increasingly incorporate seismoacoustic monitoring. Operational regional seismic monitoring for large, catastrophic landslides is on the horizon. Seismic data already provide key dynamical and timing constraints for forensic investigations and are being used to help improve numerical runout model development and calibration, a fundamental tool for landslide hazard characterization. Despite these relevant applications and an exponentially growing body of scientific literature, society sometimes demands products that precede the fundamental research and development required to make these systems reliable, robust, and well-integrated with other tools. Successes receive most prominence in the literature, yet for practical and operational applications, we also need to learn from the failures and limitations that are less commonly published. Exciting, creative new approaches and applications give the field energy and momentum, but excess hype can mislead about true capabilities. In this talk, I will highlight existing societally relevant applications of landslide seismology and future possibilities. I will conclude by exploring how we, as a scientific community, can balance visionary innovation and practicality to fully realize the capabilities of these techniques.

Seismic Precursors Reveal the Role of Internal Processes in Driving Slow-to-fast Transition of the 15th June 2023 Brienz/Brinzauls Rockslide Collapse

DASH, S., GFZ Postdam, Potsdam, Germany, dash@gfz-potsdam.de; DIETZE, M., Georg August University of Göttingen, Göttingen, Germany, michael.dietze@uni-goettingen.de; ZHOU, Q., GFZ Postdam, Potsdam, Germany, qi.zhou@gfz-potsdam.de; MAKUS, P., GFZ Postdam, Potsdam, Germany, peter.makus@gfz-potsdam.de; WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürich, Switzerland, fabian.walter@wsl.ch; FULDE, M., Geo Inventure, Thalwil, Switzerland, m.fulde@geo-inventure.com; TUROWSKI, J. M., GFZ Postdam, Potsdam, Germany, jens.turowski@gfz.de; HOVIUS, N., GFZ Postdam, Potsdam, Germany, niels.hovius@gfz-potsdam.de

Slow-moving landslides can unpredictably accelerate into catastrophic failure, sometimes without clear external triggers. We investigate the drivers of a slow-to-fast transition in the Brienz/Brinzauls rockslide, Switzerland, where a compartment accelerated from 50 mm/day in late April to over 5000 mm/

day before collapsing on 15 June 2023. We address three key questions: How do shear zone and bulk properties co-evolve at depth? How do the roles of internal processes and external meteorological drivers change over time? And, can we detect the critical transition point that precedes rapid acceleration and failure?

Using an XGBoost model trained on features of near-field seismic data, we detect precursory surface rockfalls and subsurface microseismicity associated with basal slip and internal deformation. In combination with observations of surface motion, the data allow studying internal processes of the slide. The Brienz rockslide compartment transitioned from rainfall-driven external control to internally driven acceleration under dry conditions. This shift began ~37 days before collapse as the sliding interface entered a progressively weakening frictional regime, as indicated by a continuously declining rate of subsurface microseismicity relative to displacement, likely reflecting the progressive erosion of basal asperities and a corresponding reduction in frictional resistance. Surface rockfall activity rose after a 9-day delay, likely due to upward stress transfer from accelerating basal slip, indicating progressive fragmentation. Rate weakening and fragmentation progressively led to catastrophic failure, independent of external triggers. This highlights the need for spatially extensive monitoring of rock-internal processes to understand the non-linear dynamics of large slope instabilities during failure preparation, beyond precipitation-based models. Our results also open a window on seismic-based early warning of slope failure as a complement to classic approaches based on surface observations.

Illuminating Debris Flow Dynamics at Illgraben, Switzerland with Distributed Seismic Measurements

WETTER, C., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, christoph.wetter@wsl.ch; WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, fabian.walter@wsl.ch; MCARDELL, B., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, brian.mcardell@wsl.ch; BLUMENSCHEIN, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, felix.blumenschein@wsl.ch; AICHELE, J., ETH Zürich, Zurich, Switzerland, johannes.aichele@eaps.ethz.ch; SPIELMANN, R., ETH Zürich, Zurich, Switzerland, raffaele.spielmann@eaps.ethz.ch; AARON, J., ETH Zürich, Zurich, Switzerland, jordan.aaron@eaps.ethz.ch; FICHTNER, A., ETH Zürich, Zurich, Switzerland, andreas.fichtner@eaps.ethz.ch

In recent years, the destructive impact of debris flows in alpine regions, including densely populated areas in Central Europe, has become increasingly evident. Surge fronts and roll waves within debris flows increase peak discharge and the dynamical complexity, which contributes much to the hazard potential. Hence, detailed understanding of surge dynamics is crucial for managing debris flow hazards and designing protective measures for the population and infrastructure.

In the present work, we explore the possibility of using Distributed Acoustic Sensing (DAS) as well as a geophone array for debris flow monitoring. For this, we collected data at the Illgraben debris flow observatory maintained by the Swiss Federal Institute for Forest, Snow and Landscape Research WSL in the Rhône valley. In 2024, we installed 33 geophones several meters away from the torrent along a 2-km channel section, and we trenched a 1000 m long optical fiber cable at the same location. In total, we recorded nine debris flows. Their seismic records are characterized by high-frequency (> 1 Hz) signals caused by particle-ground impacts within the flow. Additionally, steps in torrent geometry (check dams) produce a strong, low-frequency (1–10 Hz) background signal that is detectable up to few kilometers distance. We record debris flow evolution from the mobilization in the catchment to subsequent surge formation and deposition during outflow. Flow instabilities lead to the formation of a rich variety of flow dynamics, including meter-high surge waves, which are comparable to roll waves in inclined open water channels.

Distributed seismic measurements offer a novel quantitative perspective on debris flow evolution in space and time over kilometer scales, which, to the best of our knowledge, has never been done before. They furthermore enable us to refine our understanding of the seismogenesis of torrential processes, which is often only investigated with single stations or sparse sensor networks.

Characterizing Surges from a Debris Flow Induced by a Glacial Outburst Flood at Mount Rainier, USA

CONNER, A. E., University of Oregon, Oregon, USA, aconner2@uoregon.edu; BIEGEL, K., University of California, Davis, California, USA, kmbiegel@ucdavis.edu; THOMAS, A. M., University of California, Davis, California, USA, amt.seismo@gmail.com; THELEN, W. A., U.S. Geological Survey, Washington, USA, wthelen@usgs.gov; IEZZI, A. M., U.S. Geological Survey, Washington, USA, aiezzi@usgs.gov; ALLSTADT, K., U.S. Geological Survey, Colorado, USA, kallstadt@usgs.gov; COLLINS, E. A., U.S. Geological Survey, Colorado, USA, ecollins@usgs.gov; BEASON, S., National Park Service, Washington, USA, scott_beason@nps.gov; TODD, C., California State University, San Bernardino, California, USA, claire.todd@csusb.edu

On 15 August 2023, a small debris flow occurred in Tahoma Creek on the southwest side of Mt. Rainier National Park, Washington, USA. The debris flow originated from an outburst flood from the South Tahoma Glacier. Multiple instruments installed in the Tahoma Creek drainage recorded evidence of the debris flow, including nodal and broadband seismometers, infrasound sensors, a laser rangefinder located about 3.4 km downstream of the glacier, and a timelapse camera that captured images of the glacier terminus. In particular, nodal seismometers with a sampling rate of 500 Hz were deployed roughly every 350 m along approximately 2 km of the stream. After initiation of the debris flow, we find evidence in the seismic data of at least three debris flow surges due to either additional small outbursts from the glacier or the debris flow separating into multiple surge fronts caused by wave development from flow instability. Though the arrivals of the surge fronts are often obscured by higher-frequency signals contributed by the full debris flow, we find that the surges can be tracked as they travel downstream. From the seismic data, we are able to approximate where and when the surges merged or separated from the main flow and estimate the flow velocity of each surge front. As the fronts of debris flows generally contain the largest and most damaging materials in the flow, each surge front increases the hazard associated with an event. The dense instrumentation in the Tahoma Creek drainage allows for an in-depth analysis of the evolution of debris flow surges, providing information on how similar debris flows may behave in the future and contributing to the overall understanding of how debris flows evolve over time.

Seismological Monitoring of Sandstorms and Sand Dune Migration via High-frequency Seismic Signals in the Taklamakan Desert

LIANG, X., Chinese Academy of Sciences, Beijing, China, liangxf@mail.iggcas.ac.cn; ZHAO, L., Chinese Academy of Sciences, Beijing, China, zhaolulu3jlu@163.com; MENG, H., Southern University of Science and Technology, Shenzhen, China, menghr@sustech.edu.cn

Monitoring sandstorms and dune migration in desert regions is critical for mitigating environmental degradation, safeguarding infrastructure, and understanding regional climate dynamics. This urgency is particularly pronounced in the Taklamakan Desert, China's largest desert and a dominant source of aeolian activity in Central Asia. In this study, we investigate the seismological detection and characterization of wind-driven sand dune migration in the Taklamakan Desert using high-frequency seismic data from a network of 32 stations during a major wind event on October 17–19, 2018. Time-frequency analysis reveals prominent energy clusters within the 18–25 Hz and 25–40 Hz bands at 21 stations, coincident with sustained wind speeds exceeding 5 m/s. These signals are interpreted as seismic vibrations generated by wind-driven sand movement. Polarization analysis indicates directional coherence between seismic particle motion near 30 Hz and meteorological wind vectors near surface, with deviations likely modulated by local topography and dune morphology. Notably, stations deployed near complex geological settings exhibited distinct spectral features characterized by upward-shifting peak frequencies. These frequency shifts and their different responses on three component waveforms for the high-frequency noise might reflect the distance from the moving dunes to the station and their moving directions. Comparisons with meteorological data confirmed that high-frequency seismic signals correlate temporally with peak wind speeds, supporting the hypothesis that these signals originate from wind-driven sand impacts and dune migration. The findings highlight the effectiveness of seismic networks in resolving aeolian processes and provide a robust framework for real-time monitoring of sandstorms and dune migration in arid environments. This interdisciplinary approach enhances environmental monitoring capabilities and has important implications for hazard assessment and climate studies in desert regions.

Locating Pyroclastic Flows Using Seismic Amplitudes: Rebuilding a Lost Monitoring Tool from Soufrière Hills Volcano

THOMPSON, G., University of South Florida, Florida, USA, thompsong@usf.edu

In early 2000 at the Montserrat Volcano Observatory (MVO), we implemented a real-time seismic amplitude-based source location (ASL) technique to estimate the origin of pyroclastic density currents (PDCs). The method used observed seismic amplitudes distributions at multiple stations and com-

pared them to theoretical seismic amplitudes on a 2D horizontal grid, ignoring topography and elevation. It performed best for isolated events where the source was compact and well separated in time from other activity. Like traditional travel-time-based methods, its accuracy degraded with sparse station coverage and large azimuthal gaps. Nonetheless, it provided timely location and magnitude estimates for PDCs in near real time, supporting situational awareness and alarm systems at MVO during a critical phase of the eruption.

This automated system was never published and was lost during software transitions in 2003. We are now rebuilding it in Python using ObsPy within a modular framework that supports different inversion strategies and misfit functions. Retrospective testing on the MVO archive is underway with encouraging results. Current development focuses on expanding the method to 3D, and quantifying location uncertainty as a function of network geometry.

ASL remains a lightweight, efficient tool for tracking near-surface mass movements. It complements traditional phase-based location techniques, especially for emergent, high-energy surface events. We advocate for its reintegration into modern observatory workflows, particularly at volcanoes prone to PDCs, and lahars.

From Seismic Waves to Landslide and Tsunami Processes

MANGENEY, A., Paris Institute of Earth Physics, Paris Cité University, French National Centre for Scientific Research, Paris, France, mangeney@ipgp.fr; MARBOEUF, A., Paris Institute of Earth Physics, Paris Cité University, French National Centre for Scientific Research, Paris, France, marboeuf@ipgp.fr; LUCAS, A., Paris Institute of Earth Physics, Paris Cité University, French National Centre for Scientific Research, Paris, France, lucas@ipgp.fr; HIBERT, C., Institute Land And Environment De Strasbourg, French National Centre for Scientific Research, University of Strasbourg, Strasbourg, France, hibert@unistra.fr; STUTZMANN, E., Paris Institute of Earth Physics, Paris Cité University, French National Centre for Scientific Research, Paris, France, stutzmann@ipgp.fr; WETTER, S., Paris Institute of Earth Physics, Paris Cité University, French National Centre for Scientific Research, Paris, France, wetter@ipgp.fr; DE PINHO DIAS, N., Paris Institute of Earth Physics, Paris Cité University, French National Centre for Scientific Research, Paris, France, depinhodias@ipgp.fr; SVENNEVIG, K., Geological Survey of Denmark and Greenland, Copenhagen, Denmark, ksv@geus.dk; HICKS, S. P., University College London, London, United Kingdom, stephen.hicks@ucl.ac.uk; LOVHOLT, F., Norwegian Geotechnical Institute, Oslo, Norway, finn.lovholt@ngi.no; FORBRIGER, T., Karlsruhe Institute of Technology, Karlsruhe, Germany, thomas.forbriger@kit.edu; LECOCQ, T., Royal Observatory of Belgium, Brussels, Belgium, thomas.lecocq@seismology.be; WIDMER-SCHNIDRIG, R., University of Stuttgart, Stuttgart, Germany, widmer@gis.uni-stuttgart.de; FERNÁNDEZ-NIETO, E. D., University of Malaga, Malaga, Spain, edofer@us.es; CASTRO-DÍAZ, M. J., University of Seville, Seville, Spain, mjcastro@uma.es; DE ROSNY, J., Institut Langevin, Paris, France, julien.derosny@espci.fr; TOUSSAINT, R., Paris Institute of Earth Physics, Paris Cité University, French National Centre for Scientific Research, Paris, France, renaud.toussaint@unistra.fr; JIA, X., Institut Langevin, Paris, France, xiaoping.jia@espci.fr

As they crash, burst and flow down the slope or travel in the ocean, landslides and tsunamis generate seismic waves that propagate for 100's of km from the source. In effect, the potential energy of a landslide is dissipated across a granular medium at intermediate scales down to the grain scale, giving rise to waves that span a broad range of frequencies. Beyond mere detection and locating of landslides, full deciphering of this huge amount of high-accuracy wave data should provide invaluable clues to the complex characteristics and dynamics of landslides and related hazards.

Advanced numerical models of the source coupled with wave propagation codes provide unique tools for extracting information about source processes from the recorded seismic waves. Indeed, by comparing simulated and recorded signal characteristics, it is possible to discriminate the signature of the different processes on the seismic signal (mass, topography, friction, presence of fluid, etc.).

Here, I will demonstrate how landslide-tsunami models were pivotal in explaining the origin of a 9-day monochromatic seismic signal recorded worldwide. The source, located in Greenland, was a landslide triggered by climate change. The landslide flowed into a complex fjord system, generating tsunami waves that turned into a seiche oscillating within the fjord. A comparison of the characteristics of the simulated and recorded signals shows how sensitive the frequency content of the signal is to the detailed bathymetry used in landslide-tsunami models. We demonstrate the importance of the numerical method and its dissipation properties in capturing long-duration seismic sources such as seiches in fjords. Finally, I will discuss the challenges of extracting information from high-frequency seismic waves and demonstrate how laboratory-scale experiments involving granular flows and generated acoustic waves can provide valuable insights into the mechanisms at grain scale that originated this signal.

Poster Presentation Abstracts

Presenting author is in bold.

Cryoseismology [Poster]

Poster Session • Tuesday and Wednesday

Convener: Małgorzata Chmiel, Géoazur Laboratory (malgorzata.chmiel@geoazur.unice.fr); Nathan Maier, Los Alamos National Laboratory (nmaier@lanl.gov)

POSTER 1

Development and Testing of a Very Broadband Seismometer Package for Deployment at 2.4 km Depth Within the Icecap at South Pole, Antarctica as Part of the IceCube Neutrino Observatory

ANTHONY, R. E., U.S. Geological Survey, New Mexico, USA, reanthony@usgs.gov; DUVERNOIS, M., University of Wisconsin–Madison, Wisconsin, USA, duvernois@icecube.wisc.edu; WEBER, J., University of Wisconsin–Madison, Wisconsin, USA, jweber@icecube.wisc.edu; SANDSTROM, P., University of Wisconsin–Madison, Wisconsin, USA, perry.sandstrom@icecube.wisc.edu; GRULKE, S. L., University of Wisconsin–Madison, Wisconsin, USA, sgrulke@wisc.edu; ASTER, R. C., Colorado State University, Colorado, USA, rick.aster@colostate.edu; BAINBRIDGE, G., Nanometrics Inc., Kanata, Canada, geoffreybainbridge@nanometrics.ca; BASTIEN, P. C., U.S. Geological Survey, New Mexico, USA, pbastien@usgs.gov; BRAUN, J., University of Wisconsin–Madison, Wisconsin, USA, jbraun@icecube.wisc.edu; CHERWINKA, J., University of Wisconsin–Madison, Wisconsin, USA, jcherwinka@psl.wisc.edu; KROMER, E., KBR-ASL, New Mexico, USA, ekromer@contractor.usgs.gov; RINGLER, A. T., U.S. Geological Survey, New Mexico, USA, aringler@usgs.gov; STOUP, V., KBR-ASL, New Mexico, USA, vstoup@contractor.usgs.gov; TANNER, G. C., U.S. Geological Survey, New Mexico, USA, gtanner@usgs.gov; TELESHA, T. A., U.S. Geological Survey, Colorado, USA, ttelesha@usgs.gov; TRERICE, N., Nanometrics Inc., Kanata, Canada, neiltrerice@nanometrics.ca; WILSON, D. C., U.S. Geological Survey, New Mexico, USA, dwilson@usgs.gov

The U.S. government has operated a seismometer at South Pole, Antarctica (SPA) since the construction of Amundsen-Scott station in 1957. The current station (QSPA, installed in 2002) has been widely utilized for the detection and location of global earthquakes and nuclear explosions, studies of swell activity and sea ice around Antarctica, and cryoseismology. However, long-period (> 40 s) noise levels compromise ambient ground motion observations on all three of the station's borehole broadband seismometers. These high noise levels arise from both instrument self-noise and susceptibility to magnetic field variations, ultimately compromising the ability to make unique normal mode and tidal loading observations at the rotation axis of Earth. To improve long-period seismic observations at the South Pole, the U.S. Geological Survey is collaborating with the IceCube Neutrino Observatory to install a Nanometrics Trillium 360 GSN seismometer at 2.4 km depth within the Antarctic icecap. This presentation will discuss the development and testing of the technology to emplace a sensor at such depths within a water column before being subsequently frozen in place. This will include an overview of drilling technology used within IceCube, the pressure vessel design to house the seismometer and digitizer, and software and hardware solutions to communicate with the digitizer and provide it with accurate Coordinated Universal Timing information over a single twisted wire pair. The seismometer is scheduled for deployment in December of 2025 and, if successful, would be the deepest known broadband seismometer installation in the world and would occupy a unique and critical location on the planet for earthquake monitoring and deep Earth imaging.

POSTER 2

Tracking Seasonal Growth of Sea Ice Thickness Using Seafloor Distributed Acoustic Sensing and Flexural-gravity Wave Dispersion

BAKER, M. G., Sandia National Laboratories, New Mexico, USA, mgbaker@sandia.gov; ABBOTT, R. E., Sandia National Laboratories, New Mexico, USA, reabbot@sandia.gov; STANCIU, C., Sandia National Laboratories, New Mexico, USA, astanci@sandia.gov; FREDERICK, J. M., Sandia National Laboratories, New Mexico, USA, jmfrede@sandia.gov

We present a novel method for measuring sea ice thickness from the seafloor, utilizing distributed acoustic sensing (DAS) on a trenched seafloor telecommunications cable in the Beaufort Sea, Alaska. We apply a frequency-slowness transformation to seafloor DAS observations of wind-driven flexural-gravity waves to extract phase velocity dispersion curves, which we then invert to estimate sea ice thickness using a grid search across ice thickness and rigidity space. We use flexural-gravity waves recorded during wind storms from January through March, 2023, and show that our DAS-derived estimates of sea ice thickness increase throughout the season and are consistent with thicknesses measured at co-located ice boreholes in April 2023, and also with estimates from an air temperature cumulative freezing-day model. This method enables continuous, high resolution, multiyear monitoring of sea ice thickness in shallow coastal or lacustrine waters without the risk or burden of annual deployments of instrumentation to the sea ice surface.

Supported by the LDRD Program at Sandia National Laboratories. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

POSTER 4

Towards Automatic Detection of Snow Avalanche Activity with Distributed Acoustic Sensing

BRULAND, C., NORSAR, Kjeller, Norway, charlotte.bruland@norsar.no; SOLBAKKEN, E., Norwegian Public Roads Administration, Oslo, Norway, emil.solbakken@vegvesen.no; HUMSTAD, T., Norwegian Public Roads Administration, Oslo, Norway, tore.humstad@vegvesen.no; ECKERSTORFER, M., Norwegian Public Roads Administration, Oslo, Norway, markus.eckerstorfer@vegvesen.no; OYE, V., NORSAR, Kjeller, Norway, volker.oye@norsar.no

Snow avalanche activity is an important indicator of current avalanche risk. We use distributed acoustic sensing technology on existing telecommunication fiber to detect avalanches along a road in Grasdalen, Norway. Along the 1 kilometer fiber stretch, we observe signals originating from cars, snow plows, explosions, earthquakes and avalanches. The signal amplitude varies across the array, with higher sustained amplitudes at cattle grids, a bridge and tunnels as vehicles pass over the array, and a lower signal-to-noise ratio in the center of the array. The amplitude also changes throughout the seasons, with lower amplitudes when the ground is frozen. First, we use the STA/LTA algorithm to detect events and make the signals more coherent across channels. We apply dynamic thresholds over time and space to take into account differences in coupling and ground conditions along the fiber and seasonal variation. Then, the radon transform is used to distinguish between cars and avalanches based on move-out, while spectral analysis is applied to sort out signals from peaked spectra associated with anthropogenic activity, such as machinery, and resonances. Lastly, the signal duration is used to discriminate between avalanches and vehicles. For the winter season of 2022 (January to May), we detect two avalanches that are confirmed by infrasound and four interpreted avalanches that are not associated with any infrasound detections. We have 22 false detections. The false positives mainly come from vehicles, particularly vehicles stopping. Nine avalanches reported from visual observations or infrasound, are missed by the distributed acoustic sensing system. However, the four additional potential avalanches detected on the fiber, suggest that including distributed acoustic sensing in avalanche monitoring systems can help provide a more complete picture of avalanche occurrence, which is important for understanding avalanche danger and the processes that lead to avalanche release.

POSTER 5

The Detectability of Explosively Formed Craters Russian Arctic Permafrost

CARMICHAEL, J., Los Alamos National Laboratory, New Mexico, USA, joshuac@lanl.gov; KINTNER, J. A., Los Alamos National Laboratory, New Mexico, USA, jkintner@lanl.gov; CARR, C. G., Los Alamos National Laboratory, New Mexico, USA, cgcarr@lanl.gov

Analysis of explosively formed permafrost craters observed in the Russian Arctic since 2014 demonstrates that little remains confirmed about their mechanism, size, energetics, and origin time. Seismic detection methods may constrain the origin of craters that are already identified by satellite imagery, if such sources are sufficiently energetic to be detectable. Our work uses crater size, depth, and simple strength relationships to estimate the explosion yield of such crater-forming events to model them as sources of (seismic) Rayleigh waveforms. We then use these models to generate synthetic signals that originate from these sources, at permafrost locations that appears in quality-controlled literature. This modeling process samples a range of distinct seismic parameters that reflect the unknown seismic coupling, yield, and media gas porosity. We then inject these synthetic waveforms into noisy data recorded at station NRIK (~400-700km away) and run demonstrated seismic detectors against this "augmented" dataset. Our exercise assesses that gas porosity, range, and yield have the strongest control on the detectability of any explosion-triggered Rayleigh waveforms. Our detection curves suggest that most these craters should be detectable, if the explosions are sufficiently fast to generate seismic Rayleigh waveform motion.

POSTER 6

Seismic Properties of Mélange in an Ice Shelf-penetrating Rift from the ARROW Deployment at the Ross Ice Shelf

DAPRÉ, K., University of Maryland, College Park, Maryland, USA, kat.dapre@gmail.com; UDELL-LOPEZ, K., University of Maryland, College Park, Maryland, USA, kudell@umd.edu; SCHLOSSNAGLE, Z., University of Maryland, College Park, Maryland, USA, zschloss@terpmail.umd.edu; HUANG, M., University of Maryland, College Park, Maryland, USA, mhhuang@umd.edu; SCHMERR, N., University of Maryland, College Park, Maryland, USA, nschmerr@umd.edu; HURFORD, T., NASA, Maryland, USA, terry.a.hurford@nasa.gov

Ice mélange acts as infill material in ice shelf rifts and accumulates at calving fronts to provide a stabilizing, buttressing effect against seaward ice sheet flow. The material properties of mélange are therefore an important factor in modeling the mass balance of the cryosphere, but seismic investigation of these properties has been historically limited by the difficulty of instrument deployment. In 2022-23, the Antarctic Rift Research for Ocean Worlds (ARROW) project, funded by NASA, deployed 16 seismic and 12 co-located GPS stations in a km-scale network centered near the eastern tip of the Western Ross 4 rift (WR4) for 38 days. WR4 is an approximately 100-km-long rift in the Ross Ice Shelf with a width in the study region of up to 400m, and is infilled by mélange. This experiment therefore presents a valuable opportunity to use seismic techniques to investigate the properties of mélange and ice shelf materials with sufficiently fine station spacing to resolve rift-scale features.

We present results using seismic ambient noise tomography to retrieve velocity structures for the rift zone and surrounding ice shelf, using station pairs distributed across the mélange as well as parallel to the rift strike. We find a reduction in seismic velocity for phases propagating across the rift compared to those parallel to rift strike. We also search for variation in our velocity results with time, and compare these observations with tidal phase and associated strain rate, measured at the GPS stations, as well as considering environmental factors such as temperature and pressure. Our results show sensitivity to the seismic phase chosen for inversion due to the different propagation paths and characteristic frequencies of different wave types. Our findings are significant in determining mélange strength and can support future ice sheet modeling efforts incorporating this heterogeneity in ice shelves.

POSTER 7

Using Icequakes to Pin Point the Crack Tip Locations of Water-filled Crevasses on Helheim Glacier, Greenland

DUNCAN, K. N., State University of New York at Buffalo, New York, USA, kniyadun@buffalo.edu; POINAR, K., State University of New York at Buffalo, New York, USA, kpoinar@buffalo.edu; SANDVOL, E., State University of New York at Buffalo, New York, USA, easandvo@buffalo.edu; CSATHO, B., State University of New York at Buffalo, New York, USA, bcsatho@buffalo.edu; ZOET, L. K., University of Wisconsin–Madison, Wisconsin, USA, lzoet@wisc.edu

In the far upstream aquifer that can theoretically propagate crevasses to the bed. Previous modeling efforts have shown that this phenomenon could occur, but to date, there are no direct field observations of crevasse depths in this area. Therefore, it is not known whether water from the aquifer is driving crevasses to the bed. If the crevasses are fracturing to the bed because of the firn aquifer, how often and at which locations on the ice sheet is this occurring? Brittle deformation within the ice, such as crevasse propagation, causes icequakes. The origin of the icequake can be traced in X Y Z space to locate the epicenter and hypocenter of the event. The icequake depths provide the answer to our research question: if they occur below the water table, this is direct evidence that aquifer water is filling and deepening crevasses. During the July 2024 field season, we briefly deployed three 1-component Raspberry Shake seismometers and detected icequake activity at Helheim Glacier. In June 2025, we will deploy seven 3-component seismometers alongside the three 1-component Raspberry Shakes for an eight-day period. This project will use passive seismic to measure the depth of crevasses at Helheim Glacier, from which we can infer the depths of crevasse propagation, including whether they deliver aquifer water to the bed. Constraining the spatiotemporal patterns of drainage of the aquifer is significant because as meltwater reaches the bed of the glacier, it can influence the seasonal dynamics of the basal water system. This in turn is a first-order effect on glacier flow rates, which determines the ice flux into the ocean and affects global sea levels.

POSTER 8

Characterizing Ambient Seismic Noise in the Labrador Sea

GONG, J., Indiana University, Indiana, USA, gongjian@iu.edu

The Labrador Sea represents a unique environment for studying ambient seismic noise due to its location at the confluence of major ocean currents, seasonal sea ice cover, and dynamic climatic forcing. In this study, we analyze long-term seismic recordings from seismometers deployed near the coast of northeastern Canada and the coast of western Greenland around the Labrador Sea to characterize the spectral and temporal properties of ambient seismic noise across different frequency bands. We observe distinct seasonal variations in secondary microseism energy as well as strong spatial variations. Stations in northeastern Canada shows stronger secondary microseism between July and November 20 db higher than other months in 0.5 to 5 Hz band. Stations on the west coast of Greenland observes temporal noises at 1.6 and 4 Hz between July and September. We will analyze ambient noise polarizations and compare with wave height, sea ice extent, and storm activity.

POSTER 9

Interrogating Crevasse Source Physics and Subsurface Fracture Extent using Distributed Acoustic Sensing

HUDSON, T. S., ETH Zürich, Zurich, Switzerland, thomas.hudson@eaps.ethz.ch; NOE, S., ETH Zürich, Zurich, Switzerland, sebastian.noe@eaps.ethz.ch; ZUNINO, A., ETH Zürich, Zurich, Switzerland, andrea.zunino@eaps.ethz.ch; WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zurich, Switzerland, fabian.walter@wsl.ch; KENDALL, J., University of Oxford, Oxford, United Kingdom, mike.kendall@earth.ox.ac.uk; FICHTNER, A., ETH Zürich, Zurich, Switzerland, andreas.fichtner@eaps.ethz.ch

Crevassing plays an important role for the stability of glaciers and ice shelves. Hydrofracture-driven crevassing, where water can drive fracturing deeper than otherwise possible, has the potential to destabilise glaciers and drive rapid ice shelf disintegration. However, the physical hydrofracture mechanism is seldom observed and methods of assessing subsurface fracture extent do not yet exist. Here, we present an icequake Distributed Acoustic Sensing (DAS) dataset from an active crevasse field, at Gornergletscher, Switzerland. A 1 km fibre was deployed in a 100x100m 2D grid. This data was collected during a time of high meltwater production, providing an ideal opportunity to study the fundamental hydrofracture mechanism.

We detect 951 icequakes over a 24 hr period. These icequakes originate within tens of metres of the surface, generating strong surface-waves. We first use Rayleigh waves to derive the azimuthally anisotropic velocity structure of the crevasse field. This is useful not only as a reference model for full-waveform source inversion, but also provides a means of quantifying fracture density and extent. We then estimate focal mechanisms using full-waveform inversion, which combined with DAS-derived amplitude information can be used to quantify fracture mode and volumetric opening extent. We find that events typically exhibit tensile crack opening, consistent with expected crevasse fracture mechanisms. We isolate the spatial origin of strong coda in the waveforms, showing that it is likely dominated by wavefield scattering from the crevasse field rather than fluid resonance.

The dense sampling provided by fibreoptic sensing allows us to interrogate fracture mechanisms in detail and quantify subsurface fracture extent. Our results also highlight a new generation of tools for interrogating seismic sources and quantifying subsurface anisotropy, which are also applicable in other geological settings beyond glaciers.

POSTER 10

Glacier Quakes and Calving Dynamics: A 20-year Analysis of Columbia Glacier

JOHN, S., University of Alaska Fairbanks, Alaska, USA, sjohn19@alaska.edu; WEST, M. E., University of Alaska Fairbanks, Alaska, USA, mewest@alaska.edu

We present a largely underutilized catalog of glacial earthquakes compiled by the Alaska Earthquake Center through routine seismic data processing, spanning over two decades. These events show significant variations in rate and amplitude at different glaciers. Studies using this valuable dataset to understand long-term glacier dynamics are either sparse or nonexistent. We show how terminus position, glacier geometry, and fjord bathymetry affect the trend of recorded seismicity, using the Columbia Glacier as a case study. Columbia serves as an ideal test glacier because of its highly dynamic terminus, a wealth of previous studies, and the availability of diverse datasets.

Using catalog data, satellite imagery, Digital Elevation Models (DEMs), bed maps, glacier velocities, precipitation rates, and sea surface temperatures, we investigate a 20-year record (2005-2024) of calving at Columbia Glacier. We compare these parameters with the observed rate of glacial quakes. We find that the bedmap of the glacier is the most crucial control on glacial quake rate. A grounded glacier is dominated by frequent serac failure-type calving, while a floating or near-floating glacier calves in a less frequent, flexure-dominated fashion (Goliber et al., 2024; Walter et al., 2010). We find that the calving of the former type is crucial in generating glacial quakes observed on a regional scale (Bartholomaus et al., 2012; O'Neel et al., 2010; Qamar, 1988). Glacier velocity also appears to have a positive correlation with the number of recorded seismic events. At the Columbia Glacier, we find that environmental parameters are less significant in determining the rate of calving events observed regionally in seismic data.

POSTER 11

When River Ice Breaks Faster Than Expected: One Week of Distributed Acoustic Sensing Monitoring on the Sävar River

KANG, J., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürich, Switzerland, kjh1919k@gmail.com; WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürich, Switzerland, fabian.walter@wsl.ch; LAPORTE, S., Umeå University, Umeå, Sweden, sophia.laporte@umu.se; SJÖBERG, L., Umeå University, Umeå, Sweden, lina.polvi@umu.se; BLUMENSCHEIN, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zürich, Switzerland, felix.blumenschein@wsl.ch; MASON, R., Umeå University, Umeå, Sweden, richard.mason@umu.se; TUROWSKI, J. M., GFZ Postdam, Potsdam, Germany, jens.turowski@gfz.de

Rivers in cold climates are affected by ice for several months a year, seasonally transforming hydraulic and hydrological conditions, which in turn impact channel morphology and ecology. In the current climate warming context, river-ice extent is declining, with changing freeze-up and break-up patterns. River ice break-up in the spring is considered the most dynamic period of the year. It is driven by thermal processes (e.g., surface melting from rising temperatures) or mechanical forces (e.g., increased discharge and flow-induced fracturing). However, these processes remain underexplored due to challenging field measurement conditions.

We deployed a Distributed Acoustic Sensing (DAS) system along a 400-meter, regulated reach of the Sävar River in northern Sweden (~64° N). The fiber-optic cable configuration included a longitudinal section mid-channel on the river ice and a sawtooth pattern across the channel. Additionally, we installed eleven 3C geophones at key cable crossing points to collect benchmark data. During our field campaign (26 March–3 April 2025), we successfully captured the complete breakup of ice. Ice failure began on 30 March, and the channel was ice-free on 3 April.

STA/LTA detection and visual inspection revealed over 2000 ice cracking events. Frequency–wavenumber analysis of the DAS data along the longitudinal cable indicates the presence of the fundamental quasi-symmetric mode (QS0) and the quasi-Scholte (QS) mode. The spectral characteristics and mode coupling vary between events, suggesting diverse fracture behavior. Ongoing work focuses on event localization and waveform modelling to advance the characterization of crack intensity and orientation (longitudinal vs. cross-channel). We will also include a coupled analysis with river discharge and temperature data to identify environmental factors influencing the breakup process. By resolving fine-scale ice fracturing processes, we aim to inform knowledge of river-ice dynamics and associated consequences.

POSTER 12

Seismic Constraints on Glacier Density

LANTERI, A., ETH Zürich, Zurich, Switzerland, ariane.lanteri@eaps.ethz.ch; KEATING, S., ETH Zürich, Zurich, Switzerland, scott.keating@eaps.ethz.ch; GEBRAAD, L., ETH Zürich, Zurich, Switzerland, lars.gebraad@mondaic.com; KLAASEN, S., ETH Zürich, Zurich, Switzerland, sara.klaasen@eaps.ethz.ch; PIENKOWSKA-COTE, M., ETH Zürich, Zurich, Switzerland, mbpienkowska@gmail.com; EISEN, O., Alfred Wegener Institute, Bremerhaven, Germany, olaf.eisen@awi.de; ZUNINO, A., ETH Zürich, Zurich, Switzerland, andrea.zunino@eaps.ethz.ch; JONSDOTTIR, K., Icelandic Meteorological Office, Reykjavik, Iceland, kristin.jonsdottir@vedur.is; HOFSTEDE, C., Alfred Wegener Institute, Bremerhaven, Germany, coen.hofstede@awi.de; ZIGONE, D., University of Strasbourg, Strasbourg, France, zigone@unistra.fr; FICHTNER, A., ETH Zürich, Zurich, Switzerland, andreas.fichtner@eaps.ethz.ch

Glaciers are important regulators of climate and sea level variations. They influence the water cycle, provide fresh water and energy for human society, and form the living basis for numerous ecosystems. Understanding the structure and dynamics of glaciers requires knowledge of their mass density distribution, which is essential for estimates of total mass loss, ice discharge, surface melt and the temporal resolution of ice core climatology. Here we combine densely sampled fiber-optic sensing data from strong serendipitous anthropogenic sources with Hamiltonian Monte Carlo sampling to extract direct seismic constraints on glacier density. Our approach avoids biases introduced by subjective regularization choices, does not require empirical scaling relations from seismic wave speeds to density, and provides reliable uncertainty estimates. We demonstrate that high-quality surface-wave overtone data are the key to infer density variations to around 100 m depth, and that common scaling relations fail to reproduce resolvable details of glacial density structure.

POSTER 13

Disentangling the Contribution of Surface and Bed Hydrology for Single-station Seismic Data

MAIER, N., Los Alamos National Laboratory, New Mexico, USA, nmaier@lanl.gov

In glaciers and ice sheets emissions from ice fracturing, surface and subglacial hydrology, and bed motion occur simultaneously generating a complex wavefield that is rich with information. Of particular interest is seismic tremor, generated by water flowing at the surface, within, and underneath glaciers. While supraglacial streams that ultimately route meltwater to the bed are commonplace, often tremor is interpreted through the lens of subglacial drainage to infer conditions that drive dynamics. Here, we present results of a finite-element modelling experiment to understand temporally overlapping surface and bed hydrology can complicate interpretation when using single seismometers or sparse arrays. We show how you can use polarization analysis to associate data with either bed or surface hydrology. We apply this increased understanding to valuable seismometer records collected in Greenland to discriminate between surface and bed hydrology and identify pulses of water during winter drainage events.

LA-UR-25-24722

POSTER 14

Glacial Earthquakes in Thwaites Glacier Detected by Short Period Surface Waves

PHAM, T., Australian National University, Canberra, Australia, thanhson.pham@anu.edu.au

In polar regions, the capsizing, or vertical rotation, of icebergs freshly calved from near-grounded ice shelves produces seismic sources, characterized by the absence of high-frequency signals, known as glacial earthquakes. Previous searches using the global seismograph network, although routinely detecting globally significant events in Greenland glacier outlets, yielded scarce detections in Antarctica. Here, we employed a detection method utilizing the coherence of Rayleigh waves at relatively short periods, ranging from 17 to 25 seconds, as registered by temporary seismic networks onshore Antarctica. As a result, more than 300 seismic events along West Antarctica's coastline between 2010 and 2023, with the majority located at the Pine Island and Thwaites Glaciers, were detected. Further analysis on refining source location and centroid single-force inversion verified their association with glacial processes at the glaciers. Complementary evidence from satellite images and InSAR measurements suggested the nature of capsizing icebergs for Thwaites Glacier events, while the Pine Island Glacier events are subject to further investigation. The new detection promises a novel understanding of the discharging process of ice from the largest and most active glaciers in Antarctica.

POSTER 15

Seismic Signatures of Ice-wedge Cracking from DAS in Arctic Permafrost

ROCHA DOS SANTOS, G., Pennsylvania State University, Pennsylvania, USA, grd5166@psu.edu; ZHU, T., Pennsylvania State University, Pennsylvania, USA, tuz47@psu.edu

Ice wedge polygons are characteristic landforms in permafrost regions, formed by repeated cycles of thermal contraction cracking during winter and subsequent crack infilling during spring snowmelt. Despite their importance in shaping Arctic landscapes, the cracking process itself remains poorly documented due to rare direct field observations. In this study, we report the detection of over two thousand high-amplitude seismic events during winter months, recorded by a Distributed Acoustic Sensing (DAS) system in Utqiaġvik, Alaska. These events are short in duration and exhibit center frequencies between 5 and 30 Hz. Clear body wave arrivals followed by surface waves suggest that the sources are shallow and located near the fiber. We observed a strong correlation between the daily occurrence of these events and periods of extreme ground cooling, supporting the interpretation of these signals as cryoseisms originating within the permafrost. During intense cold spells, thermal stress in frozen ground can induce tensional fracturing, leading to a sudden release of stress in the form of seismic waves, commonly referred to as frost quakes. To map event locations, we applied Matched Field Processing (MFP), resolving spatial patterns of seismicity across wet and dry tundra environments. We further conducted source mechanism inversion to characterize the physical processes driving these cryoseisms and compared candidate models with the observed waveform characteristics. Our results demonstrate the effectiveness of DAS as a tool for detecting and characterizing thermally induced fracturing in permafrost, offering valuable insight into Arctic landscape dynamics under changing climate conditions.

POSTER 16

Seismic Signatures of Pack Ice Collisions with Landfast Ice Near Utqiaġvik, Alaska

ROCHA DOS SANTOS, G., Pennsylvania State University, Pennsylvania, USA, grd5166@psu.edu; ZHU, T., Pennsylvania State University, Pennsylvania, USA, tuz47@psu.edu

Landfast sea ice plays a critical role in Arctic coastal ecosystems and Indigenous subsistence activities. It forms when drifting pack ice undergoes repeated collisions and becomes grounded along the seafloor. As climate change accelerates ice thinning, monitoring interactions between drifting pack ice and landfast ice is increasingly important for understanding coastal ice stability. While satellite remote sensing captures surface ice motion, it cannot resolve the internal deformation or fracturing occurring during ice collisions. In this study, we investigate the seismic response of landfast ice to dynamic collisions with drifting pack ice near Utqiaġvik, Alaska, using a combination of marine radar, a broadband three-component seismometer, and Distributed Acoustic Sensing (DAS). We analyzed two collision events in January and April 2022. We found that seismicity increases as ice motion slows, suggesting growing compressive stress and internal deformation. Harmonic tremors were observed during interactions involving larger, thicker, and more consolidated ice floes, while broadband chaotic tremors were associated with thinner, more fractured, and fragmented ice blocks. Using polarization analysis of three-component seismometer, we identify wave types and estimate tremor locations. DAS observations provide high spatial resolution constraints on tremor azimuths and phase velocity information. These analyses revealed distinct source radiation patterns for harmonic and broadband tremors, reflecting differences in ice thickness, integrity, and floe size. These findings highlight the potential for integrating seismic and remote sensing techniques to improve Arctic ice monitoring.

POSTER 17

Ice-bed Healing Between Subglacial Seismic Slip Events: Connecting Lab Results to Observations from Whillans Ice Plain

SALTIEL, S., Cornell University, New York, USA, ssaltiel@cornell.edu; BARCHECK, G., Cornell University, New York, USA, grace.barcheck@cornell.edu; MCCARTHY, C., Columbia University, New York, USA, mccarthy@ldeo.columbia.edu

Whillans Ice Stream is a rare natural glaciological system that is currently decelerating and gaining mass, thus slowing global sea level rise. It has been suggested that increasing basal shear stress is the driving cause of this stagnation, but our observations and understanding of bed processes are limited by their relative inaccessibility. One of the main sources of spatially-distributed information from the Whillans bed is high-frequency seismic waveforms emitted during ice-plain-wide unstable slip events that occur regularly, modulated by the tides. Inter-event times of these large-scale unstable slip events vary between ~7 and 25 hours, giving information about how the bed heals during variable stagnant time periods. Interpretation of these field data can be enhanced with connections to lab experiments of ice-bed slip under a range of controlled conditions. In the lab, healing rates can vary greatly for debris-laden and clean ice on till and rock interfaces over relevant subglacial temperature ranges, providing a way to constrain the conditions and processes causing healing in the Whillans Ice Plain, which potentially contribute to the ice stream's slowdown.

POSTER 18

Near Surface Shear Velocity Structure Showing Ice, Sub-ice, Ground, and Seasonal Hydrological Characteristics from Teleseismic Single Sensor Recordings

SCHULTE-PELKUM, V., University of Colorado Boulder, Colorado, USA, verasp@colorado.edu; SHEN, W., Stony Brook University, New York, USA, weisen.shen@stonybrook.edu; WU, H., Stony Brook University, New York, USA, hanxiao.wu@stonybrook.edu

Seismic shear velocity structure at depths from 10s of meters to several kilometers is of interest in studies of seismic hazard, ice cap and sub-ice structure as well as permafrost, and hydrological signals. Established measurement methods require multisensor deployments and sometimes active seismic sources. We present single sensor methods for near surface shear velocity estimation and structural imaging using high frequency teleseismic receiver functions. We perform iterative time domain deconvolution using a high Gaussian filter factor, which preserves absolute Ps conversion amplitudes and allows sub-km depth resolution. Amplitudes of the direct P arrival at zero delay time allow calculation of near surface shear velocity via the free surface effect on particle motion. Ps conversions sample shallow discontinuities such as the bottom of an ice or unconsolidated surface layer. For near surface velocity estimation from the direct P arrival amplitude, results using the Transportable Array show close correlation with surface cover and compare well to shear velocity in the top 10s of meters in the USGS National Crustal Model. Interestingly, time-dependent measurements show strong variations in near surface shear velocity, possibly driven by hydrology. At stations on ice caps in Antarctica and Greenland, seasonal variations reach up to 20% of shear velocity. When comparing surface sensors with co-located deep borehole sensors, close correspondence between the two suggests that the temporal variations are a true structural signal rather than surface noise such as sensor tilt. Moreover, shallow discontinuities and the compositions of the layers between them can be constrained using receiver function arrival polarities, amplitudes, and timing in the first few seconds of the waveform. We compare single station results across Antarctica with results from a nodal deployment. Polarities in particular may allow us to infer sub-ice structure such as the presence of water and sediment. We also test for temporal variations of this signal at multiseason stations and present initial results.

POSTER 19

Seismic Investigation to the Pensacola-pole Basin of Antarctica

SHEN, W., Stony Brook University, New York, USA, weisen.shen@stonybrook.edu; WU, H., Stony Brook University, New York, USA, hanxiao.wu@stonybrook.edu; DONG, S., Stony Brook University, New York, USA, sheng.dong@stonybrook.edu

Subglacial basins and associated hydro systems are critical components in the study of Earth Sciences in polar regions. The sedimentary basin preserves the geological history of the continent beneath; The presence of a less-rugged surface of sedimentary basins contributes to the ice flow dynamics by serving as a "well lubricated" bed. Additionally, if saturated with melted water, the high-porosity sedimentary rocks contribute to the ice-stream instability through groundwater discharge, and have the potential to alter the GHF by allowing hydro-circulation. In this presentation, I will showcase a seismological investigation of one of the less-studied sedimentary basins in Antarctica: the Pensacola-Pole subglacial basins (PPB). By collecting densely-deployed seismic nodes in the South Pole region of the basin in 2023-24 and 2024-25 field seasons, we have accumulated observations of both teleseismic events and ambient noise for over 50 days of continuous data along two 200-300 km long transects. One of the transects, crossing the PPB through its grid south-western boundary into the southern Transantarctics, exhibits a clear signal of slowed seismic velocity compared with the prediction from basement rocks. Additional modeling of the waveforms indicates that high-porosity sedimentary rocks saturated with melted water present a plausible mechanism to

interpret the data. A joint ambient noise surface wave and receiver function analysis further provides constraints to the thickness, porosity, and other attributes of the sedimentary basin. We conclude that such observations provide the first-order constraints on the subglacial basins in the Antarctic interior.

POSTER 20

Rock Falls, Glacier Failure and Ensuing Avalanche: The 28 May 2025 Catastrophe at Blatten, Switzerland

WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, fabian.walter@wsl.ch; TONEY, L., U.S. Geological Survey, Colorado, USA, ltoney@usgs.gov; ALLSTADT, K., U.S. Geological Survey, Colorado, USA, kallstadt@usgs.gov; KANG, J., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, jiahui.kang@wsl.ch; MANGENEY, A., Paris Institute of Earth Physics, Paris, France, anne.mangeney@gmail.com; LUCAS, A., Paris Institute of Earth Physics, Paris, France, lucas@ipgp.fr; SATRIANO, C., Paris Institute of Earth Physics, Paris, France, satriano@ipgp.fr; CHARDON, T., Paris Institute of Earth Physics, Paris, France, chardon@ipgp.fr; KRAFT, T., Swiss Seismological Service, ETH Zurich, Zürich, Switzerland, toni@sed.ethz.ch; CLINTON, J., Swiss Seismological Service, ETH Zurich, Zürich, Switzerland, jclinton@sed.ethz.ch; DIEHL, T., Swiss Seismological Service, ETH Zurich, Zürich, Switzerland, tobias.diehl@sed.ethz.ch; DIETZE, M., Georg August University of Göttingen, Göttingen, Germany, michael.dietze@uni-goettingen.de

On 28 May 2025, a multimillion cubic meter rock–ice avalanche destroyed much of the village of Blatten in Switzerland's Canton Valais. The avalanche was triggered by failure of a debris-laden glacier and its deposits immediately dammed the river Lonza at the valley bottom, which lead to additional property loss due to inundation. A central question is which part of the ice–rock system first ruptured to produce the catastrophic failure, and the timeline of this failure. Blatten had been evacuated, reducing human exposure, as increased rockfall activity in the preceding weeks had drastically thickened the glacier's debris cover, leading authorities to consider a catastrophic failure likely. Moreover, in the hours before failure, the glacier moved at speeds of greater than one meter per hour. This event shows how different types of instabilities can exacerbate each other to produce a failure chain with amplified destructive potential.

A range of observational techniques were deployed prior to the rock–ice avalanche. This included interferometric radar, automatic cameras, airborne imaging and a dense broadband seismometer network with the closest station only 5 km away from the event. It is clear that this event was exceptionally well documented. Preliminary data analysis indicates that the avalanche mass underwent a rapid acceleration as full waveform inversion of the broadband seismograms yields high maximum forces acting on the Earth. An added debris layer whose surface is parallel to the ice surface should increase Coulomb friction enough to keep up with added driving stress. However, the deposits and/or glacier bed surface may have been steep enough to induce shear-stresses that exceeded the bed and/or ice strength leading to catastrophic failure. We discuss further details about the failure and runout, mining the rich data set available for this event.

POSTER 21

Tracking Seasonal Shear-wave Velocity Variations of Permafrost Freeze–thaw Using Distributed Acoustic Sensing

WANG, Z., Pennsylvania State University, Pennsylvania, USA, zhinongwang0814@outlook.com; ZHU, T., Pennsylvania State University, Pennsylvania, USA, tyzhu@psu.edu

Permafrost regions are experiencing rapid degradation as the balance of freeze–thaw processes is increasingly disrupted by global warming—raising concerns about subsidence and ecosystem change. Understanding whether seismic methods can sensitively track these changes is a pressing question, yet field evidence has been limited. In this study, we employ Distributed Acoustic Sensing (DAS)—an emerging seismic monitoring technology that transforms standard fiber-optic cables into dense arrays of thousands of seismic sensors—to characterize spatiotemporal variations in permafrost properties in Barrow, Alaska. Over a two-year period, continuous DAS recordings were analyzed using ambient noise interferometry to retrieve noise cross-correlation functions (NCFs) between fiber channels. For each month, we applied quality control to select NCFs with high signal-to-noise ratio surface-wave signals, which were then stacked to produce stable monthly NCFs. We then performed dispersion analysis on the stacked monthly NCFs to track the seasonal variations in surface-wave phase velocities. Our results reveal pronounced seasonal velocity variations associated with the freeze–thaw cycle of the active layer. During winter, when air temperatures fall below freezing, water in the near-surface soil freezes, increasing the soil stiffness and resulting in higher phase velocities. In contrast, the summer thaw softens the soil, leading to a significant decrease in phase velocities. These findings demonstrate the sensitivity of shallow seismic velocities to environmental changes and underscore the potential of DAS as a scalable and efficient tool for long-term permafrost monitoring, with important implications for infrastructure resilience and Arctic ecosystem stability.

POSTER 22

Location and Source Studies of Recurrent Antarctic Icequakes

WIENS, D. A., Washington University in St. Louis, Missouri, USA, doug@wustl.edu; AZIZ ZANJANI, F., Washington University in St. Louis, Missouri, USA, zanjani@wustl.edu; MATULKA, P., Washington University in St. Louis, Missouri, USA, pmatulka@wustl.edu

The operation of various temporary seismic arrays for seismic imaging purposes in Antarctica over the past 25 years provides a unique dataset for investigating the occurrence and mechanisms of larger icequakes. We compile a catalog of Antarctic seismic events using the machine learning detection algorithm Phasenet. Because of the sparse nature of most of the arrays, we use a detector trained on regional phases (Aguilar Suarez and Beroza, 2025). The resulting catalog shows recurrent seismicity at many Transantarctic Mountains outlet glaciers, including David, Mulock, and Skelton Glaciers. These icequakes often have magnitudes greater than M_L 3, so are much larger than typically observed in studies of mountain glacier icequakes. The icequakes are concentrated in heavily crevassed regions associated with steep bedrock topography. Future work will focus on determining whether these events are associated with stick-slip events at the bed of the glacier and/or crevasse formation near the surface.

Moment tensor inversion can provide valuable insights into the mechanism of icequakes and glacial deformation. We analyze waveforms from icequakes occurring along the Ross Ice Shelf Rift WR4 (Olinger et al., 2019; Huang et al, 2022) and perform full moment tensor inversion using the Computer Programs in Seismology (CPS) package. The modeling incorporates the layered structure of the ice shelf by computing accurate Green's functions for a medium bounded by a firn layer at the surface and a sub-ice water layer. All centroid depths are shallower than 60 meters, indicating near-surface failure within the ice shelf. Preliminary results suggest a combination of tensile crack opening and normal faulting, consistent with extensional stresses across the rift zone.

POSTER 23

Mapping Subglacial Sediments Beneath the Greenland Ice Sheet with Seismic Receiver Functions

YANG, Y., University of California, San Diego, California, USA, yanyang@ucsd.edu; FAN, W., University of California, San Diego, California, USA, wenyuanfan@ucsd.edu; BEHN, M. D., Boston College, Massachusetts, USA, behnm@bc.edu; DAS, S. B., Woods Hole Oceanographic Institution, Massachusetts, USA, sdas@whoi.edu; MCGUIRE, J., Woods Hole Oceanographic Institution, Massachusetts, USA, jmcguire@usgs.gov

Understanding Greenland Ice Sheet dynamics requires better constraints on subglacial conditions, particularly the role of deformable sediments in enhancing basal sliding. We apply high-frequency receiver function analysis to seismic data collected across Greenland and find consistent time delays indicative of low-velocity layers at the ice-bed interface. These features are best explained by subglacial sediments, with estimated thicknesses up to ~200 m. Sediments appear widespread, with thicknesses generally corresponding to independently inferred thawed basal conditions, though northeastern Greenland shows large spatial variability. Our results highlight the heterogeneous distribution of potentially deformable sediments beneath the GrIS and their importance in modulating the ice sheet's response to climate forcing.

POSTER 24

Seasonal Fluctuations in Subsurface Seismic Velocity Cross Permafrost of the Tibetan Plateau

ZHAO, L., Chinese Academy of Sciences, Beijing, China, zhaolulu3jlu@163.com; LIANG, X., Chinese Academy of Sciences, Beijing, China, liangxf@mail.iggcas.ac.cn; MENG, H., Southern University of Science and Technology, Shenzhen, China, menghr@sustech.edu.cn

The freeze–thaw cycle plays a critical role in controlling the seasonal evolution and spatial heterogeneity of active layer dynamics in permafrost regions. The Tibetan Plateau, which hosts the largest extent of permafrost in the mid- and low-latitude regions globally, serves as a natural laboratory for investigating these processes. In this study, we utilize continuous seismic records from 76 broadband stations operating between November 2013 and March 2017 and apply seismic autocorrelation techniques using both ambient noise and teleseismic P-wave codas to monitor seasonal variations in subsurface seismic velocities (dv/v) across the permafrost region of Tibetan Plateau. We estimate dv/v by tracking the relative time shifts of P-wave reflections from subsurface velocity discontinuities. Both ambient noise and teleseismic coda-based measurements reveal that stations located near lakes exhibits pronounced increase in dv/v during winter, with amplitudes reaching up to 5% in the 2–4 Hz frequency band. This increase likely reflects the effects of enhanced subsurface rigidity due to freezing. While teleseismic coda results yield slightly lower amplitudes, they consistently capture similar seasonal fluctuations associated with ground freezing processes. Furthermore, the amplitude of the wintertime dv/v variations systematically decrease with increasing distance between the station and the nearest lake within a radius of 10 km, highlighting a strong local hydrological influence on freeze–thaw dynamics. In contrast, other stations show dv/v variations predominantly driven by thermoelastic responses to temperature fluctuations or poroelastic effects related to episodic precipitation. These distinct behaviors likely reflect the spatial variability in the distribution of seasonal frozen ground and permafrost. Our findings underscore the potential of seismic monitoring for characterizing freeze–thaw processes and distinguishing among diverse environmental controls in permafrost regions.

POSTER 50

Seismic Site Response in Discontinuous Permafrost Environments: Examples from Dakwakada (Haines Junction), Yukon, Canada

GOSSELIN, J., Natural Resources Canada, Sidney, Canada, jeremy.gosselin@nrcan-rncan.gc.ca; DETTMER, J., Yukon Geological Survey, Whitehorse, Canada, jan.dettmer@yukon.ca; LIPOVSKY, P., Yukon Geological Survey, Whitehorse, Canada, panya.lipovsky@yukon.ca; CRONMILLER, D., Yukon Geological Survey, Whitehorse, Canada, derek.cronmiller@yukon.ca

Southwestern Yukon, Canada, hosts significant natural hazards that are influenced by an evolving landscape and near-surface processes. Earthquake shaking intensity and duration are influenced by site properties at local scales (site effects). In this work, we provide constraint on sediment rigidity properties to quantify earthquake site effects. We use passive seismic recordings from 14 sites in the Dakwakada (Haines Junction) area to extract surface-wave dispersion measurements and probabilistically infer 1D subsurface shear-wave velocity (Vs). We use the Vs models to classify sites according to proxies for site rigidity. We also propagate these models, including rigorous uncertainty quantification, into estimates of linear site amplification factors for earthquake ground motion determination. Our work indicates that much of the area can be characterized by site class C and modest amplification potential. We note that spatial variability in inferred earthquake site effects is predominantly linked to hydrologic and cryospheric processes. Specifically, the presence of permafrost in the area may currently mitigate amplification of earthquake shaking. Our results point to the need to understand long-term and seasonal changes in earthquake site effects, particularly in response to permafrost thaw within the warming climate. The results from this work will also contribute to strategic community planning that mitigates natural hazards in the Dakwakada area, and other seismically active areas throughout the global North.

Geophysical and Biogenic Signals from the Oceans, Surface Water and Atmosphere [Poster]

Poster Session • Tuesday and Wednesday

Convener: Seth Carpenter, University of Kentucky (seth.carpenter@uky.edu); Robert Dziak, National Oceanographic and Atmospheric Administration (robert.p.dziak@noaa.gov); Chu-Fang Yang, University of Michigan (chufan@umich.edu)

POSTER 25

Primary Microseism Weekly Maps for Monitoring Near Coastal Oceanic Swell Activity

ALOISI, G., ETH Zürich, Zurich, Switzerland, giacomo.aloisi@eaps.ethz.ch; ASTER, R. C., Colorado State University, Colorado, USA, rick.aster@colostate.edu; FICHTNER, A., ETH Zürich, Zurich, Switzerland, andreas.fichtner@eaps.ethz.ch; ZUNINO, A., ETH Zürich, Zurich, Switzerland, andrea.zunino@eaps.ethz.ch

Understanding ocean wave dynamics has become increasingly important in light of the reported intensification of swell and atmospheric activity associated with climate change. From a seismological perspective, microseisms provide a link between observable continuous seismic signals and natural interactions between ocean waves and the seafloor, which generate them. In particular, primary microseisms between 14–20 seconds period can serve as a sensitive proxy for near-shore conditions, because they arise from the direct impact of ocean waves near the coastline and have extensive geographic averaging properties.

To investigate primary microseism sources, we adapt a full-waveform ambient noise inversion framework originally developed to track secondary microseism sources. Using daily cross-correlations from a global network of broadband seismic stations, we generate weekly maps of primary microseism power spectral density, offering a spatially and temporally resolved view of near-coastal wave activity.

This work complements existing oceanographic observation systems and enables consistent monitoring of swell energy over time. By integrating seismic noise analysis with environmental applications, the framework contributes to improved understanding of coastal dynamics and supports efforts to assess climate-driven changes in oceanic and atmospheric systems.

POSTER 26

Global Annual Variations in Primary and Secondary Microseism Intensity

ASTER, R. C., Colorado State University, Colorado, USA, rick.aster@colostate.edu; LEE, T. A., Princeton University, New Jersey, USA, thomaslee@princeton.edu; SIMONS, F. J., Princeton University, New Jersey, USA, fjsimons@princeton.edu; RINGLER, A. T., U.S. Geological Survey, New Mexico, USA, aringler@usgs.gov; ANTHONY, R. E., U.S. Geological Survey, New Mexico, USA, reanthony@usgs.gov

We investigate signatures at 73 long-running stations from the Global Seismographic Network and GEOSCOPE to examine the global distribution of annual primary microseism (PM) versus secondary microseism (SM) variation, including variable amplitude and phase relationships that illuminate geographically distinct annual microseism source and ocean wave interactions. Earth's microseism wavefield determines global background noise levels between ~4 to 20 s period and contains geographically integrated information regarding periodic and secular changes in ocean gravity wave energy spanning many decades. The surface wave-dominated microseism spectrum results from two specific ocean-wave seismic source processes. Between ~14 to 20 s the PM source mechanism dominates, which arises wherever direct coupling of ocean wave tractions at the seafloor (at depths less than ~600 m) occurs and generates seismic waves at causative ocean wave periods. Between ~4 to 10 s period the much (~20 dB) stronger SM signal dominates with seismic wave periods of half that the causative ocean wave periods. The SM is solely generated when and where interfering ocean waves of similar period are present. PM and SM signals display distinct (North-South hemisphere polarity inverted) seasonally averaged amplitude variations that may exceed 500% between quiet summer to noisy winter conditions. This intensity cycle principally reflects the annual periodicity of hemispheric extratropical storm activity. Characterizing these annualized variations over decades across the Earth provides station-distinctive seasonal PM-SM wavefield signatures.

POSTER 27

Using Seismic and DAS Observations to Characterize Rock Impact and Motion in Controlled Flume Experiments

BILEK, S. L., New Mexico Institute of Mining and Technology, New Mexico, USA, susan.bilek@nmt.edu; ROTH, D., University of Colorado Boulder, Colorado, USA, danica.roth@colorado.edu; JOHNSON, J., University of Texas at Austin, Texas, USA, joelj@jsg.utexas.edu; CADOL, D., New Mexico Institute of Mining and Technology, New Mexico, USA, daniel.cadol@nmt.edu; MCLAUGHLIN, J. M., New Mexico Institute of Mining and Technology, New Mexico, USA, john.mclaughlin@student.nmt.edu; LUONG, L., New Mexico Institute of Mining and Technology, New Mexico, USA, loc.luong@student.nmt.edu

Characterizing bedload transport in rivers is important for understanding channel processes, including erosion and deposition patterns but is challenging because of limited direct measurements. Proxy measurements, such as bank-side seismic or acoustic observations, are complex because they record both energy from bedload impacts and from noise sources such as turbulent water flow. Theoretical models provide some framework for linking seismic

signals generated by bedload sediment impacts and turbulent flow. However there have been few controlled tests to verify these models and characterize the seismic signals of bedload impacts and subsequent transport.

For such a test, we collected seismic and DAS data during controlled flow experiments within an outdoor in-ground flume (~1.5 m wide, 36 m long) at UT-Austin to capture seismic signals associated with turbulent water flow and bedload transport. We installed 214 m of cable both within and adjacent to the concrete flume and used an OptaSense ODH4+ DAS interrogator from UT-Austin NHERI to collect data sampled at 10 kHz with a spatial sampling interval of 1.02 m and a 2-channel gauge length. We installed eight high-frequency (2000 Hz sampling) 3C nodal seismographs adjacent to the flume, and collected data on water discharge and flow velocities, as well as from "smartrocks", artificial rocks with embedded accelerometers that constrain impact frequency and intensity. During a portion of the experiment, we placed rocks, including the smartrocks, of variable sizes into the flow to record the impact signal and transport mode of the particles, keeping written and video records of the placement location and timing. We present examples of the waveform characteristics and seismic power associated with the impacts of different size particles and examine particle motions with the video records and internal smartrock motion data. Cable coupling varied along the flume length, so we also explore how coupling modifies the impact signals. We also explore the potential to develop effective detection tools for rock impacts.

POSTER 28

Evaluation of Geophysical and Anthropogenic Sources of Hydroacoustic Noise in the Alaskan Arctic

NIKLASSON, S., New Mexico Institute of Mining and Technology, New Mexico, USA, siobhan.niklasson@student.nmt.edu; ROWE, C. A., Los Alamos National Laboratory, New Mexico, USA, char@lanl.gov; BILEK, S. L., New Mexico Institute of Mining and Technology, New Mexico, USA, susan.bilek@nmt.edu

Quantifying the ocean soundscape is crucial for ocean-based seismoacoustic monitoring purposes; it sets a baseline for the kinds and sizes of signals that can be detected over the background noise. As Arctic sea ice recedes, human activity in and around the Arctic Ocean is expected to increase, elevating both sound levels in the Arctic and the importance of monitoring this heightened activity. Here, we analyze the soundscape over seven years of Arctic Ocean passive acoustic recordings from a NOAA Ocean Noise Reference Station (NRS) hydrophone located north of Point Barrow, Alaska, focusing on frequencies between 1-100 Hz, a band of interest for detecting earthquakes and similar events. We correlate sound in sub-bands within 1-100 Hz to geophysical and anthropogenic sources and examine seasonal and other variations in the soundscape. We find that sea ice concentration is a keystone feature of the Arctic Ocean acoustic environment, controlling or contributing to seasonal ambient sound levels at all frequencies studied. Additionally, seismic airgun surveys are a prominent feature of the soundscape between 5-40 Hz during low-ice periods. We discuss the implications of this baseline soundscape for seismoacoustic event detection in the Alaskan Arctic.

POSTER 29

Relationship Between the 2024–2025 Los Cabos Earthquakes and Geohydrological Potential: A Multidisciplinary Opportunity for Hydraulic Conductivity Calibration Models

ORTEGA, R., Center for Scientific Research and Higher Education in Ensenada, La Paz, Mexico, ortegarobe@gmail.com; QUINTANAR, L., National Autonomous University of Mexico, Mexico CIty, Mexico, luisq@igeofisica.unam.mx; CARCIUMARU, D. D., Center for Scientific Research and Higher Education in Ensenada, La Paz, Mexico, carciumaru@cicese.mx; ESPINDOLA, V. H., National Autonomous University of Mexico, Mexico City, Mexico, victore@sismologico.unam.mx

This study analyzes the 2024–2025 seismic sequence in the Los Cabos, Baja California Sur, Mexico region, proposing a novel interpretation where seismicity may reflect subsurface fluid flow processes triggered by a single significant rainfall event. Following this isolated meteorological input, a clear migration of seismicity is observed—shifting from deeper hypocenters to a newly formed group of shallower, anomalous aftershocks. The timing and spatial pattern of these shallow events, as well as the quiescent periods between the rain and the onset of the anomalous seismicity, align remarkably well with theoretical predictions derived from the Richards equation, based on Darcy's law.

This behavior suggests that the delay between infiltration and seismic reactivation can serve as a natural metric for estimating the hydraulic conductivity of the subsurface. By treating seismic responses as indirect observations of pore pressure diffusion, the study opens a new path for integrating seismology with quantitative hydrogeology. The findings enable a multidisciplinary approach, wherein the spatiotemporal characteristics of seismic sequences are used to calibrate hydraulic conductivity models. This is further advanced through the development of numerical flow models—such as those using FEFLOW—which incorporate data-driven insights from both seismic and hydrological domains. Ultimately, the work demonstrates that seismic monitoring, under certain hydrogeological conditions, can act as a diagnostic tool for subsurface flow characterization, bridging disciplines and enriching our understanding of coupled Earth systems.

POSTER 30

Seasonal Variability in Microseismic Energy Associated with Waves, Wind and Surface Conditions in the Saint Lawrence River, Canada

PERRY, H. K. C., Natural Resources Canada, Ottawa, Canada, claire.perry@nrcan-rncan.gc.ca; KOPER, K. D., University of Utah, Utah, USA, koper@seis.utah.edu; NATH, A., YOU-Oceans, California, USA, artash@stanford.edu; MCNAMARA, D. E., EarthScope Consortium, District of Columbia, USA, daniel.mcnamara@earthscope.org

In the absence of direct instrumental sea-level observations, we explore the potential use of existing real-time seismic systems in the Canadian National Seismic Network (CNSN) to monitor changes in water and ice conditions in the St. Lawrence River (SLR). River and lake waves are associated with seismically recorded short period microseismic energy (1 s). We conduct a multidisciplinary experiment to study the source of short-period (0.5-1.5 s) energy visible on broadband seismometers proximal to the SLR, using a combination of weak motion seismic data, marine and atmospheric observations including wind, wave height and sea ice concentrations in the region. Seasonal variability in the short period microseismic energy is observed and shown to be associated with water waves in the SLR locally coupling as seismic energy into the solid Earth. Using a decade of continuous seismic data from land-based CNSN weak motion instruments along the SLR from Québec City to Cap-Chat, Québec, we show that seismic spectral energy with period of around 1 s is strong in summer months, and drops to a near quiescence in winter months, where abrupt energy damping occurs in this band when the SLR freezes. Single-station polarity analysis of the seismic data points to the river as the source of the observed short period microseismic energy. This energy is observed at stations proximal to the SLR and dissipates rapidly at stations beyond ~60 km. Correlation of the seasonal variability of the river microseismic energy with wind, wave height and sea ice concentration provides the basis for developing real-time monitoring of SLR ice and water conditions using an existing seismic network.

POSTER 31

Science Monitoring And Reliable Telecommunications (SMART) Cables: Advances in Global Seismic Modeling, Earthquake and Tsunami Early Warning and Ocean Observing

ROWE, C. A., Los Alamos National Laboratory, New Mexico, USA, char@lanl.gov; BEGNAUD, M. L., Los Alamos National Laboratory, New Mexico, USA, mlbegnaud@lanl.gov; NIKLASSON, S., Los Alamos National Laboratory, New Mexico, USA, sniklasson@lanl.gov; HOWE, B. M., University of Hawai'i at Manoa, Hawaii, USA, bhowe@hawaii.edu; CONLEY, A. C., Sandia National Laboratories, New Mexico, USA, acconle@sandia.gov

Global seismic models suffer from heterogenous source and receiver distributions. The greatest gaps are beneath the oceans, ~70% of the Earth's surface. Most teleseismically observed earthquakes occur at plate margins, while most seismic sensors are on land.

Ocean Bottom Seismometers (OBSs) offer some improvement in sensor distribution, but OBS deployments are limited in extent and duration. In a year-long deployment there may be ~100 earthquakes of magnitude >6, but many are nearly co-located, reducing added ray coverage. Near-shore cabled arrays of OBS have longer lifetimes but do not offer novel sampling for teleseismic arrivals. We thus analyze teleseismic records from ~240 earthquakes, providing over 4000 P phase arrivals using abyssal OBS data from the Ocean Bottom Seismic Instrumentation Pool (OBSIP) experiments, and added these to our database. These provide some novel paths for tomography, with modest improvement in resolution and travel-time uncertainty.

Future seismic data from Science Monitoring And Reliable Telecommunication (SMART) Cable sensors will revolutionize seismology in terms of more complete global models, better distribution of sensing, and significantly improved resolution and travel time uncertainty estimates. We compare global models with and without OBS, and we examine model resolution and travel time uncertainty improvements with the SMART sensors.

In addition to seismic sensors, the SMART Cables will host seafloor pressure sensors and temperature sensors, adding valuable information for hydroacoustic propagation, monitoring sea level changes and offering real-time early warning capabilities for offshore earthquakes and tsunamis. We will present the SMART Cables projects underway and some of the anticipated gains therefrom, those planned for the future, and will highlight observations from the test deployment currently operating offshore from Sicily.

POSTER 32

Characteristics of Seismic Noise Recorded by a Dense Seismometer Array During the September 2024 Heavy Rainfall Event in the Noto Peninsula, Japan

SAWAZAKI, K., National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan, sawa@bosai.go.jp; P.C., S., National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan, shakti@bosai.go.jp; TAKAGI, R., Tohoku University, Sendai, Japan, ryota.takagi.c1@tohoku.ac.jp

From September 21 to 23, 2024, the Noto Peninsula in Japan was suffered by extremely heavy rainfall, causing severe damage and resulting in 16 fatalities. This disaster occurred while the region was still recovering from the magnitude 7.6 Noto Peninsula earthquake that occurred on January 1 of the same year. At the time of the heavy rainfall, a dense temporal seismic observation network "NotoNode" had been deployed. We identified a significant increase in seismic noise level associated with the heavy rainfall at multiple seismic stations.

We analyzed seismic noise of vertical motion seismograms from 21 NoteNode stations and 6 Hi-net permanent stations deployed across the Noto Peninsula. The power spectrum was calculated for each one-minute time segment, and the minimum power within each consecutive ten-minute window was adopted as the representative noise power. This procedure effectively reduced transient signals caused by earthquakes.

We observed a remarkable increase in noise power particularly in the northern part of the Noto Peninsula, where the rainfall was especially heavy. By comparing the time series of noise at multiple frequency ranges with the records of rainfall and significant wave height, the following three factors were identified as potential noise sources:

1. Below approximately 2 Hz, the noise level correlated well with significant wave height, indicating the oceanic wave as the main source of the noise.

2. In the range of 2 to several tens of Hz, the noise level increased rapidly and decreased slowly. This pattern is typically observed in river discharge, indicating the flood as the main source of the noise.

3. Above several tens of Hz, the noise level tended to correlate with rainfall, which could be the main source of the noise. This correlation was not identified at all Hi-net stations possibly because they are installed at the borehole bottom.

Acknowledgements: This study was supported by Japan Society for the Promotion of Science (Kakenhi Grant-No. 22K03742). Noto Peninsula Node seismic observation data was used in this study.

POSTER 33

Identifying Tornado Seismic Signals (TSS) from the December 10th-11th, 2021, Central U.S. Tornado Outbreak

THOMPSON, S. C., University of Kentucky, Kentucky, USA, scth227@uky.edu; **CARPENTER, N. S.**, University of Kentucky, Kentucky, USA, seth.carpenter@uky.edu; WANG, Z., University of Kentucky, Kentucky, USA, zmwang@uky.edu; WOOLERY, E. W., University of Kentucky, Kentucky, USA, woolery@uky.edu

Tornadoes cause extensive property damage and endanger lives. While Doppler radar can indicate the potential for tornado development, it cannot confirm when a tornado has actually made ground contact. Once a tornado touches down, a significant amount of its energy may be transferred into the earth as seismic vibrations; thus, seismometers have the potential to detect tornado touch-down. The December 10th-11th, 2021, tornado outbreak in the Central U.S. spawned 66 tornados, including an EF-4 that tracked 129 km through the New Madrid Seismic Zone. Nine broadband seismometers captured anomalous ground motions within 50 km of this EF-4 tornado's track, two of which were located less than 4 km away. To interpret the data from those two stations, NWS meteorological data were analyzed alongside the waveforms. Initial observations showed that waveform amplitudes increased as the tornado approached, peaked when the tornado was closest, and decreased as the tornado departed. Corresponding spectrograms revealed bands from 0.001–5 Hz of high intensities when the tornado was closest. Bandpass filtering indicated that waveform amplitudes in the 1–3 Hz range aligned most consistently with the tornado's proximity. Radial- and transverse-vertical particle motions in the 1-3 Hz band showed mostly elliptical to semi-elliptical trajectories during the tornado's approach and departure. During the time when the tornado was closest, particle motions become primarily vertical. These motions suggest that Rayleigh waves dominate, supporting previous work asserting that turbulent pressure fluctuations producing primarily vertical forces on the free surface are a predominant mechanism for generating TSSs. Future work will involve evaluating data from additional tornadoes, outbreaks, and seismometers, including short-period data, two-station cross-correlations, and polarization analysis. The thresholds at which TSSs can be recorded based on distance and EF rating are also being investigated.

POSTER 34

Mechanical Modeling of Long-term Earthquake Clustering in the Dead Sea Basin in Response to Climate-induced Lake Level Variations

UTHAMAN, M., Florida International University, Florida, USA, mitutm710@iitkgp.ac.in; WDOWINSKI, S., Florida International University, Florida, USA, swdowins@fiu.edu; HIGGINS, M., Florida International University, Florida, USA, mhiggins@fiu.edu; MARCO, S., Tel Aviv University, Tel Aviv, Israel, shmulikm@tauex.tau.ac.il

The Dead Sea Basin (DSB), a pull-apart basin located along the Sinai-Arabia transform plate boundary, provides a unique opportunity to study long-term temporal variability in earthquake occurrence through its detailed paleoseismic record, spanning the past 220,000 years. The record derived from borehole and outcrop observations of seismites—sediments deformed by earthquake shaking in the lakes of DSB. Initial analyses revealed significant correlation between long-term earthquake occurrence and lake levels, suggesting a climatic impact on earthquake frequency. Observed correlation can be explained by various processes, some related to earthquake generation and some to sediment response to seismic shaking. In this project, we investigate the impact of lake level variations on earthquake occurrence frequency using mechanical models. Our initial study is based on a 3D boundary element model (BEM) of a pull-apart basin bounded by two parallel strike-slip and orthogonal normal faults. Calculated Coulomb Failure Stress changes (CFS) during an interseismic period of 1000 years resulted in the transform fault accumulating 10kPa CFS due to horizontal shear. We then evaluated the impact of lake level increase on both strike-slip and normal faults in response to surface load and pore pressure changes. Consideration of hydrological loading during high lake stands results in accumulation of 100kPa on inclined normal faults, but no changes on vertical strike-slip faults. Whereas, considering pore pressure causes an accumulation of 100kPa along both normal and strike-slip fault systems. Since BEM cannot account for a complex fault geometry and impact of additional fault parameters, including pore volume fraction, pore compressibility, and porosity memory in time, we intend to harness 3D finite element modelling (FEM) to refine the model. FEM will aid in constraining complex and realistic models using simple geometry of an idealized pull-apart basin. The simplified models will be modified to include geometric complexities of the DSB to discern impact of earthquake location and its timing.

POSTER 35

Seasonally Varying Seismicity in Sikkim Himalaya

UTHAMAN, M., Indian Institute of Technology Kharagpur, Kolkata, India, mitutm710@iitkgp.ac.in; SINGH, C., Indian Institute of Technology Kharagpur, West Midnapore, India, chandrani@gg.iitkgp.ac.in; SINGH, A., Indian Institute of Technology Kharagpur, West Midnapore, India, arun@gg.iitkgp.ac.in

The segment of the Himalayas passing through the northeastern state of Sikkim in India has been prone to large earthquakes with anomalous mechanisms as compared to the rest of the Himalayas. Deployment of a dense network of broadband seismometers in the Sikkim Himalayas from April 2019 to May 2023 enabled continuous monitoring of seismic activity in the region. Seismicity is observed to vary spatially with peculiar faulting mechanisms given the complex tectonic setting. Along with the spatial variability, seismicity is observed to vary temporally with changing seasons. Seismic activity is observed to get suppressed at the onset of monsoon. Analogous seismic behaviour is observed in neighbouring Nepal Himalaya as well, where increase in hydrological loading is invoked as a possible mechanism for the decrease in seismic activity. Seasonal variation of seismicity in Sikkim Himalaya can be accredited to variation in hydrological loading as seismic velocity variation computed from ambient noise cross-correlations depict a decrease in wave speed during monsoon corroborating with the decrease in seismicity. The variations are observed to be prominent in the central Sikkim, where seismicity is attributed to originate in the fluid-enriched shear zone along the Main Himalayan Thrust (MHT). Variation of hydrological surface load could possibly be affecting fluids at MHT and inducing changes in interseismic strain accumulation and pore-pressure at MHT, similar to that observed in Nepal. Sensitivity kernels determined from ambient noise cross-correlations subjected to multiple filters reveal the magnitude of seismic velocity variations decrease with increasing depth. We plan to further validate the results through numerical analysis to determine its correlation with seismicity patterns and deduce whether the observed temporal trends contribute to the seismic hazard potential of the study region.

POSTER 36

Various Comments on the Excitation of Earth's Hum Motivated by DAS Observations of Infragravity Waves

WILLIAMS, E. F., University of California, Santa Cruz, California, USA, ethan.williams@ucsc.edu

Since the discovery of ambient excitation of Earth's free oscillations in 1998, commonly referred to as "hum," many mechanisms of atmospheric and oceanic forcing have been proposed. Most recently, Ardhuin and colleagues have shown that infragravity wave interaction with sloping bathymetry across the continental shelves can reproduce the observed temporal variability of hum amplitudes, at least for the spheroidal (or equivalently, Rayleigh) modes. Motivated by DAS observations of infragravity waves across a 92-km transect of the Oregon shelf, I offer several comments on the model of Ardhuin and one testable hypothesis. First, the sharp gradient of infragravity wave pressure across the surf and swash zones, including non-resonant wave energy bound to swell groups, suggests a dominant source at the beach—not the shelf. Second, the broad directional spread of infragravity waves on the mid-to-outer shelf incoherently refracted across irregular bathymetry inhibits coupling into low-order modes whereas near-shore narrowing of the directional spectrum by coherent refraction promotes it. Finally, strong tidal modulation of infragravity wave reflection (and generation) at the beach suggests that Earth's hum should be tidally modulated and that, insomuch as coastal reflection mediates the directional spectrum of infragravity waves all across the shelf, this tidal modulation should clearly distinguish between the primary (single-frequency) and secondary (double-frequency) excitation mechanisms.

POSTER 37

Deep Ocean Thermometry Using Scholte and T-waves

WU, W., Woods Hole Oceanographic Institution, Massachusetts, USA, wenbo.wu@whoi.edu; SHEN, Z., Woods Hole Oceanographic Institution, Massachusetts, USA, zhichao.shen@whoi.edu; CALLIES, J., California Institute of Technology, California, USA, jcallies@caltech.edu

The global ocean absorbs more than 90% of the excess heat trapped on the planet by greenhouse gases. Its heat uptake plays a key role in regulating global warming. The global and decadal-scale warming trend in the upper ocean (< 2000 m depth) has been largely constrained thanks to data collected by autonomous Argo floats. The deep ocean (> 2000 m depth) is generally thought to have also absorbed a substantial amount of heat. These estimates of deep ocean warming are much more uncertain than those for the upper ocean, however, because they are derived from sparse ship-based hydrographic sampling. We propose leveraging seismic T waves and Scholte waves generated by naturally repeating earthquakes to improve the constraints on the basin-scale warming of the deep ocean. Travel times of T waves are sensitive to mid-depth temperatures, but their sensitivity decays exponentially into the abyss. In contrast, Scholte waves—interface waves propagating along the seafloor—are most sensitive to temperature variations near the seafloor and have rapidly decaying sensitivities toward the surface. The complementary sensitivities of these two seismic waves makes them ideal for deep-ocean thermometry. We apply this method to the Southwest Pacific using repeating earthquakes in the Fiji–Tonga subduction zone recorded at a permanent seismic station on the Cook Islands. Archived data dating back to 1992 enable us to reconstruct historical deep-ocean warming in the Southwest Pacific. Using a wavelet cross-spectrum technique, we quantify travel time shifts and associated uncertainties for both Scholte and T waves, detecting changes of up to 0.2 s over ~1,500 km ocean paths. Our preliminary inversion reveals a decadal deep-ocean warming trend in this region, in agreement with previous data. The better-constrained estimates enable us to better understand the dynamics driving the deep ocean's response to climate forcing.

POSTER 38

Probing Underwater Turbulence Using Distributed Acoustic Sensing

YANG, C., University of Michigan, Michigan, USA, chufan@umich.edu; FUJISAKI-MANOME, A., University of Michigan, Michigan, USA, ayumif@umich.edu; VAN HAREN, H., Royal Netherlands Institute for Sea Research, Den Burg, Netherlands, hans.van.haren@nioz.nl; SPICA, Z., University of Michigan, Michigan, USA, zspica@umich.edu; MIAO, Y., University of Michigan, Michigan, USA, yaolinm@umich.edu

Underwater turbulent motions play a crucial role in influencing nutrient dynamics in the nearshore areas, which in turn affect ocean and lake productivity and water quality. Understanding how turbulence interacts with environment is challenging because its generation involves conditions like wind, temperature gradients, and topography and occurs across multiple scales. Observing these complex interactions is difficult due to the lack of suitable instruments capable of providing the long-term, high spatiotemporal resolution measurements necessary to fully understand these processes. However, Distributed Acoustic Sensing (DAS), which measures strains through offshore telecom fiber-optic cables, may depict the turbulence evolution at scales of a few meters and hundreds of hertz, improving our understanding of complex turbulent dynamics. Here, we analyzed the DAS data (0.001-0.01 Hz) collected from Lake Ontario and observed vortex and meandering turbulence structures over the north shore. The energy cascade in spectra shows strong signals associated with shear turbulence along the north slope toward Toronto and the south slope toward Lockport. Moreover, the windy conditions in January are associated with higher strain energy compared to those in June. The preliminary results suggest that, in addition to traditional vertical measurements from CTDs or moorings, DAS observations provide valuable insights into turbulent mixing processes across horizontal spatial dimensions over seasonal changes.

Novel Approaches for Environmental Seismology [Poster]

Poster Session • Tuesday and Wednesday

Clément Hibert, University of Strasbourg (hibert@unistra.fr); Ethan Williams, University of California, Santa Cruz (ethan.williams@ucsc.edu)

POSTER 40

Multidisciplinary Geophysical Stations: A Next Generation Tool Kit for Environmental Seismology

THOMSON, M., Nanometrics Inc., Kanata, Canada, mairithomson@nanometrics.ca; **BAINBRIDGE, G.**, Nanometrics Inc., Kanata, Canada, geoffreybainbridge@nanometrics.ca

As cross-disciplinary science becomes increasingly critical to understanding environmental change, a multidisciplinary geophysical approach is essential for integrating instrumentation and ensuring reliable and efficient data acquisition for successful scientific outcomes.

The Environmental Seismology community requires adaptable solutions for the co-location of diverse sensor types. Deploying such instruments in remote, volatile environments while ensuring reliable, continuous data acquisition presents additional challenges. The complexity and cost associated with deploying, operating and maintaining remote stations are significantly increased if using multiple independent sensors, each with dedicated acquisition infrastructure. Recent efforts, like the European Plate Observing System, seek to address this by integrating multidisciplinary geophysical applications into unified and efficient deployments.

Modern seismic data loggers, such as the Nanometrics Centaur Gen5, support integration of a wide range of sensing elements, while maintaining ultra-low power consumption, precise timing, local data storage and reliable real-time data transmission. Automatic outage recovery ensures maximum data availability at the data center, for all data types, as part of a single, coordinated acquisition system.

The challenges of Environmental Seismology also demand robust sensors to ensure ongoing data quality in harsh deployment conditions. The Nanometrics Trillium Compact Horizon 20s triaxial seismometer delivers high-quality broadband seismic data in a rugged, corrosion-proof form factor, with a wide tilt range useful in dynamic environments, and ultra-low power consumption that simplifies station design.

A reference design is presented for a multidisciplinary, environmental monitoring station that leverages these capabilities to enable reliable and efficient data collection. The multidisciplinary station configuration and end-to-end data pipeline, from remote sensing to science doorstep in the data center, are discussed.

POSTER 41

Desert Seismology: Multi-modality Datasets for Ultra High Frequency Ambient Seismic Wavefields in Particle Rich Environments

CHAPUT, J., University of Texas at El Paso, Texas, USA, jchaput82@gmail.com; HERNANDEZ, A., University of Texas at El Paso, Texas, USA, ahernandez126@miners.utep.edu; KARPLUS, M., University of Texas at El Paso, Texas, USA, mkarplus@utep.edu; GILL, T., University of Texas at El Paso, , USA, tegill@utep.edu

We present an overview of a novel ultra high frequency nodal dataset collocated with high resolution environmental wind and weather data and prototype boundary layer particle sensors, with the aim of constraining sublte effects related to surface particle saltation, rain, vegeation excitation, and turbulence, on the ultra high (< 1000 Hz) ambient seismic spectrum. We present a systematic study of instances of various environmental forcing effects, and show that different overlapping effects can be separated and thus learned with the goal of quantifying and modeling boundary layer sources in delicate arid environments.

Notably, we show how various particle impact and transport events in the Jornada desert, NM, a strong producer of airborne particulates, can be modeled and understood by leveraging adaptions of spectrum excitation models for bedload transport with the eventual goal of designing a purely seismic framework for estimating boundary layer saltation and erosion in desert environments. This project is a collaborative effort between the Meteorological Sensor Array (ARO/ARL) and UTEP, leveraging access to the Jornada Experimental Range (JER) managed by New Mexico State University and the USDA.

POSTER 42

Artius: A Revolutionary Broadband Node to Further Enable Passive Seismology

LINDSEY, J. C., Guralp Systems Ltd., Reading, United Kingdom, jlindsey@guralp.com; WATKISS, N., Guralp Systems Ltd., Reading, United Kingdom, nwatkiss@guralp.com; HILL, P., Guralp Systems Ltd., Reading, United Kingdom, phill@guralp.com; RESTELLI, F., Guralp Systems Ltd., Reading, United Kingdom, frestelli@guralp.com

The Artius broadband node represents a transformative innovation in seismic instrumentation, designed to bridge the gap between traditional broadband seismometers and popular nodal systems. While broadband seismometers offer unparalleled sensitivity and frequency range, their cost and complexity often limit large-scale and dense deployments. Conversely, geophones provide cost-effective solutions for high-frequency applications but lack sensitivity to low-frequency seismic signals, critical for many research and monitoring purposes. Artius provides a cost-effective compromise, delivering the increased sensitivity and a true broadband frequency range at an economic price point.

Designed by Güralp Systems off the back of 40 years of experience, Artius integrates a compact force-feedback seismometer with an environmentally sealed anodised aluminium enclosure, ensuring optimal performance and robustness across diverse geophysical applications. Boasting a response of 30 seconds to 200 Hz, Artius greatly outperforms geophone-based systems while still being perfectly suited to rapid temporary deployments, where it can be either pushed or staked into the ground and connected to an external power supply. Artius pushes the limits of versatility, facilitating real time data monitoring, as well as passive data collection. Artius has an onboard SEEDlink server, compatible with all standard seismological monitoring techniques, truly setting it apart from anything on the current market.

Artius is designed to be docked into an eight-node capacity docking station for data validation and mass data download. The docking station also serves as a 'huddle' system for configuration and testing prior to deployment, ensuring each node is performing optimally prior to deployment. The Artius nodes are intended to be deployed in large arrays, perfect for passive seismology, ambient noise studies and earthquake studies.

POSTER 43

Güralp Stratis—a Commercial 6 Degree of Freedom Seismometer for Academic and Research Applications

LINDSEY, J. C., Guralp Systems Ltd., Reading, United Kingdom, jlindsey@guralp.com; HILL, P., Guralp Systems Ltd., Reading, United Kingdom, phill@guralp.com; WATKISS, N., Guralp Systems Ltd., Reading, United Kingdom, nwatkiss@guralp.com; RESTELLI, F., Guralp Systems Ltd., Reading, United Kingdom, frestelli@guralp.com

Traditional research grade 3-component seismic sensors are sensitive to both translational ground movement and rotational (or tilt) motion. This is most prevalent in the horizontal components of sensors which are most sensitive to tilt of the ground. The outputs of traditional seismometers represent a sum of rotation and displacement information. Most applications processing the data make the assumption that the outputs are proportional to purely displacement although this is not strictly the case in commercial devices.

New technologies are now allowing for accurate and precise discrimination between the two components which make up the vast majority of seismic records.

Stratis is the world's first integrated seismic sensor offering simultaneous output of both rotational and displacement data in all 3 axis. Stratis offers six concurrent outputs providing Z, N and E ground displacement channels proportional to velocity (Metres/second) and rotation channels in the Z, N and E planes proportional to velocity in rotation (Radians/Second). The provision of the measurement of the six degree of freedom now permits derivation of the Elasticity Tensor from a single sensor.

The Stratis displacement output removes these rotation effects and gives a 'pure' displacement measurement. This is unique in the seismic sensor marketplace, providing true displacement data that is uncontaminated by rotational signals. This will therefore allow for higher fidelity seismic measurements, improving our analysis and understanding of earthquake processes.

These six parameters are measured at a single point in the geometric center of the sensor. Use of multiple separated sensors to derive rotation can only approximate true rotation at the same point as displacement. By integrating these measurements into a single instrument, the installation process is also greatly simplified thereby enabling wider access to rotational seismic data. Naturally, the separation of rotational information from the displacement outputs also gives a pure displacement sensor – something unique for the seismological community.

POSTER 44

Unveiling Volcanic Eruptions with Geometric Phase Sensing of Seismic Waves

LUO, B., University of Arizona, Arizona, USA, 896359862@qq.com; BECK, S., University of Arizona, Arizona, USA, slbeck@arizona.edu; DEYMIER, P., University of Arizona, Arizona, USA, deymier@arizona.edu; RUNGE, K., University of Arizona, Arizona, USA, krunge@arizona.edu; HUETTMANN, F., University of Alaska Fairbanks, Alaska, USA, fhuettmann@alaska.edu; MISSOUM, S., University of Arizona, Arizona, USA, smissoum@arizona.edu; LATYPOV, M., University of Arizona, Arizona, USA, latmarat@arizona.edu; WHITNEY, E., University of Alaska Fairbanks, Alaska, USA, ewhitney5@alaska.edu; WANG, J., University of Arizona, Arizona, USA, jw1011@arizona.edu; SCHABIB, S., University of Arizona, Arizona, USA, sinanschabib@arizona.edu

Volcano eruptions are often preceded by subtle changes in subsurface ground conditions, making it challenging to capture these precursory changes in a timely manner. Seismic noise interferometry has increasingly been used to monitor active volcanoes; however, current seismic monitoring rarely provides robust and continuous monitoring across different volcanic episodes due to the complexity of magmatic processes.

In this study, we introduce an innovative geometric phase sensing technique based on seismic noise interferometry, focusing on the monitoring of the Kilauea volcano on the Hawai'i Island. By implementing this technique with data recorded on the seismic stations at the Kilauea summit, we observe significant pre-eruptive peaks and co-eruptive step changes in the geometric phase from 2018 to 2024. These changes correlate with successive deflation-inflation magmatic processes and major caldera collapse events. Our observations reveal both transient and long-term subsurface ground changes due to elastic deformation and permanent structural fractures over the past seven years, insights that have not been captured in previous seismic monitoring efforts.

Unlike conventional phase velocity sensing methods, the geometric phase captures subtle variations in the wavefield recorded by a set of spatially distributed sensors. The geometric phase is quantified as a rotated angle of a field state vector in an abstract space. This state vector effectively samples variations in the empirical Green's functions by cross-correlating seismic noise from multiple sensor pairs. We conduct a synthetic test for the geometric phase during pre-eruptive magma pressurization, detecting several deflation-inflation events. In addition, we investigate that the geometric phase sensing technique exhibits higher sensitivity than seismic wavespeed perturbations under the same applied pressure. Our findings highlight the strong capability of the geometric phase sensing technique to detect volcanic transitions due to magmatic processes and provide precursory information for impending eruption events.

POSTER 46

Transdimensional Bayesian Inversion of Multi-component Rayleigh-wave Dispersion

OMAR, S. M., Colorado School of Mines, Colorado, USA, somar@mines.edu; SHRAGGE, J., Colorado School of Mines, Colorado, USA, jshragge@mines.edu; SIEGFRIED, M. R., Colorado School of Mines, Colorado, USA, siegfried@mines.edu

Determining the shear-wave velocity (V_s) of subsurface materials is a fundamental step in mapping geologic structure and evaluating formations for various exploration, geotechnical, and engineering applications. This V_s largely governs the velocities and dispersion (frequency-dependent velocity variation) of Rayleigh waves propagating along the Earth's surface and as such, an inverse problem can be formulated to estimate V_s both laterally and with depth. Bayesian inversion offers an advantage over traditional deterministic methods like multichannel analysis of surface waves (MASW) by using a probabilistic framework that generates an ensemble of model solutions and provides a quantitative assessment of uncertainty. Moreover, the framework can accommodate a variational inference strategy — referred to as transdimensional Bayesian (TDB) inversion — that treats the number of layers in the model solutions as an unknown parameter, which is particularly important when little a priori information is known about the model space and inappropriate parameterization can significantly bias the results. Here, we demonstrate the value of TDB inversion when coupling the inversion to multi-component (MC) Rayleigh-wave dispersion analysis, which outperforms traditional single-component frameworks in complex environments. We develop a set of three synthetic firn-aquifer glacier models and leverage MC data to reveal subtly different dispersion curves, which we then use as input into the inversion. Additionally, we use a MC survey conducted on the Saskatchewan Glacier in the Canadian Rocky Mountains to compare V_s-depth profiles estimated by MASW and TBD inversions. Our field results emphasize the value of MC dispersion analysis and highlight the advantage of TBD inversion in exploring a wider model-solution space and enabling uncertainty quantification.

POSTER 47

Recent Advances in Seismic Detections of Rock Exfoliation Events at Arabia Mountain, Georgia

PENG, Z., Georgia Institute of Technology, Georgia, USA, zpeng@gatech.edu; SI, X., Georgia Institute of Technology, Georgia, USA, xsi33@gatech.edu; REYNOLDS, A., Georgia Institute of Technology, Georgia, USA, ereynolds42@gatech.edu; QIAN, Y., Chongqing University, Chongqing, China, qianyy@cqu.edu.cn; MACH, P., Georgia Institute of Technology, Georgia, USA, pmach3@gatech.edu; DING, C., Georgia Institute of Technology, Georgia, USA, cding64@gatech.edu; LANG, K., Georgia Institute of Technology, Georgia, USA, karl.lang@eas.gatech.edu; EPPES, M. C., University of North Carolina, North Carolina, USA, meppes@charlotte.edu; NI, S., Chinese Academy of Sciences, Wuhan, China, sdni@ustc.edu.cn

Some rock domes around the world are renowned for their exfoliation sheets—thin, curved layers that peel away from the outer surface. Over the past two years, multiple rock exfoliation events have been recorded in a former Lithonia Gneiss quarry near Arabia Mountain, Georgia, including a major event occurring around noon on July 17, 2023. Field measurements and high-resolution DEM differencing revealed that fractures associated with this event extended across an area of approximately 250 m^2 with vertical displacements of up to 30 cm locally, and forming compressive tent-like structures along the fracture perimeter. To monitor additional exfoliation events, a suite of sensors were deployed in May and June 2024 and remain in operation. These include time-lapse cameras, air and rock surface/subsurface temperature sensors, borehole stressmeters to measure relative change in surface-parallel rock stresses with depth, and 26 Smartsolo geophones to record ongoing fracture events. Geophones were both buried in shallow soils surrounding the exfoliation fracture as well as anchored directly to the rock surface. Additionally, we utilized recordings from a broadband seismic station (N4.Y52A) and its auxiliary pressure sensor located~20 km north of the study site to examine potential events outside of the periods of dense recordings. We applied deep learning methods to burst-like events from the continuous waveform recordings of geophones at the exfoliation site and the nearby broadband seismic station. Detected events were subsequently classified using clustering methods into categories such as rock cracking/exfoliation events, mine blasts, and human activities such as traffic noises. Based on confirmed exfoliation events witnessed by the research team, we identified two exfoliation events and compared their occurrence with stress and temperature measurements. Our methods provide new insights into the mechanisms of progressive, low-stress rock fracturing, advancing our understanding of the physical processes driving time-dependent cracking and exfoliation.

POSTER 49

Leaking Mode Dispersion from Distributed Acoustic Sensing

WANG, Z., Pennsylvania State University, Pennsylvania, USA, zhinongwang0814@outlook.com; ZHU, T., Pennsylvania State University, Pennsylvania, USA, tyzhu@psu.edu

Compared to conventional normal modes associated with real-valued roots of the dispersion function, leaking modes—corresponding to complex-valued roots—have received increasing attention in recent years. While leaking mode dispersion has been successfully extracted from conventional geophone and broadband seismometer data, its identification and application using ambient noise recorded by Distributed Acoustic Sensing (DAS) remains largely unexplored. In this study, we utilize ambient noise interferometry to extract leaking mode dispersion from DAS data acquired by the Fiber Optic foR Environmental SEnsEing (FORESEE) array in State College, Pennsylvania. From the recovered Noise Cross-correlation Functions (NCFs), we identified distinct types of leaking modes: (1) guided-P waves, related to the P-wave velocity structures, and (2) leaky surface waves, characterized by inverse-dispersion behavior and associated with low-velocity half-space condition. Although these two wave types arise from different physical mechanisms, both correspond to complex-valued roots of the dispersion function and are thus classified as leaking modes. By performing inversion of the extracted leaking mode dispersion curves, we are able to image the subsurface low-velocity anomalies in the shallow subsurface. Crucially, the introduction of guided P-wave dispersion in the inversion process enables us to simultaneously obtain both P-wave and S-wave velocity structures. This provides valuable constraints for inferring subsurface lithology and mechanical properties. Incorporating local geological context and borehole data, we interpret the detected low-velocity anomalies as fractured zones likely caused by karst dissolution of carbonate rocks. These findings prove the potential of DAS-based ambient noise methods to resolve complex subsurface structures through leaking mode analysis.

Anthropogenic and Urban Seismology [Poster]

Poster Session • Thursday and Friday

Convener: Biondo Biondi, Stanford University (biondo@sep.stanford.edu); Elita Li, Purdue University (elitali@purdue.edu); Verónica Rodríguez Tribaldos, GFZ Potsdam (veronica.rodriguez.tribaldos@gfz.de)

POSTER 1

Structural Health Monitoring of Native American Masonry Architecture

BORG, J., University of Utah, Utah, USA, joseph.borg@utah.edu; MOORE, J. R., University of Utah, Utah, USA, jeff.moore@utah.edu

Application of ambient vibration monitoring and modal analysis offers valuable insights into the conditions under which damage may occur in anthropogenic structures, specifically Native American heritage sites in this study. By linking resonance frequencies with measured vibrational velocities, it is possible to estimate the resulting stresses and strains—providing a foundation for deeper analysis of potential failure mechanisms. Additionally, time series data of frequency shifts can be used to identify non-linear elastic behavior, which serves as an indicator of conditions that may lead to permanent deformation. Threats to these structures include both anthropogenic sources (e.g., helicopters, explosions) and natural sources (e.g., wind, earthquakes). This study aims to establish a framework for assessing risk of vibration-induced damage, with the ultimate goal of protecting and preserving culturally significant indigenous heritage.

POSTER 2

Quantifying Environmental Influence on Building Seismic Response with Dense MyShake Smartphone-based Monitoring

KUMAR, U., University of California, Berkeley, California, USA, utpalkumar@berkeley.edu; ALLEN, R., University of California, Berkeley, California, USA, rallen@berkeley.edu

Earthquake-induced damage detection in structural health monitoring (SHM) typically relies on identifying changes in dynamic system parameters—such as natural frequency or damping—by comparing "before" and "after" states. However, these parameters are not constant; they can vary substantially due to environmental influences such as temperature, humidity, and soil moisture. This time-dependent variability, which occurs over timescales ranging from hours to decades, challenges the core assumption in traditional SHM that deviations from a reference baseline necessarily indicate structural degradation (e.g., Sohn, 2006).

Although researchers have emphasized the need for SHM frameworks that account for environmental and operational variability, such approaches are rarely adopted at scale—particularly in the United States, where continuous long-term monitoring is implemented in only a few hundred buildings, including approximately 340 in California. A key barrier has been the lack of dense, longitudinal datasets that capture building behavior under diverse environmental conditions.

In this study, we utilize the MyShake platform—a smartphone-based seismic network with over 2 million active users in California—to monitor ambient building vibrations using embedded accelerometers. This unprecedented data volume allows us to systematically track temporal variations in dynamic properties across a broad range of buildings, climates, and construction types. This dataset enables systematic analysis of natural frequency variations across buildings, revealing emerging patterns linked to environmental conditions. These insights lay the groundwork for scalable SHM systems that integrate environmental effects into damage detection frameworks (Clinton et al., 2006; Kankanamge et al., 2020).

POSTER 3

Seismic Investigations of Singapore's Subsurface Using Large-N Arrays

LYTHGOE, K., University of Edinburgh, Edinburgh, United Kingdom, karen.lythgoe@ed.ac.uk; YANG, J., Chinese University of Geosciences, Wuhan, China, yaojiayuan@cug.edu.cn; LUO, W., Chinese University of Geosciences, Wuhan, China, luowx28@gmail.com; TONG, P., Nanyang Technological University, Singapore, Singapore, tongping@ntu.edu.sg; WEI, S., Nanyang Technological University, Singapore, Singapore, shjwei@ntu.edu.sg

Singapore is an island city nation, home to ~6 million people. Development of such a densely populated island requires careful urban planning. Seismology, particularly passive nodal surveys, are well suited to urban environments and can play an important role in smart city development. Cities in SE Asia are also vulnerable to ground shaking from nearby large earthquakes, as demonstrated by the collapse of a high-rise building in Bangkok from the Myanmar earthquake.

We conducted an island-wide survey, comprising 88 3C nodes, to image Singapore's crustal structure. Using only 5 weeks of 'noisy' data, we successfully analysed its subsurface structure through a combination of receiver functions, P-wave polarizations and ambient noise tomography. Our results reveal a distinct change in crustal structure on either side of the postulated Bukit Timah fault, with implications for seismic hazard. We derive a sediment model of Singapore, which shows the thickest compacted sediments in the west, negligible sediments in central area and some localized sediments in the east. A low-velocity anomaly beneath a surface hot spring reveals its possible deep heat source, indicating a potential source of geothermal energy.

To detect seismic events, we developed a new data-driven image processing technique, based on detecting coherent and anomalous spectral energy arriving across the array. Local events are principally man-made in origin, some exhibiting repeating waveforms. We detect a small earthquake nearby to Singapore, where no earthquakes have previously been reported. We detect many high-frequency discrete events during thunderstorms that we term thunderquakes since they originate from an atmospheric acoustic wave. Additionally, ground-motion amplification variations caused by local site conditions across Singapore are quantified, showing that areas of soft sediment, particularly reclaimed land, have the highest seismic risk. In addition to large scale seismic imaging, we have conducted more localised passive nodal surveys for near-surface imaging related to geothermal developments.

POSTER 5

Towards Real-time Near-surface Characterization Using Passive Distributed Acoustic Sensing Data

PUNITHAN, N., Colorado School of Mines, Colorado, USA, nikhil_punithan@mines.edu; MARTIN, E. R., Colorado School of Mines, Colorado, USA, eileenrmartin@mines.edu; SHRAGGE, J., Colorado School of Mines, Colorado, USA, jshragge@mines.edu

Changing subsurface properties can damage infrastructure and building foundations. Time-lapse seismic data collection for long-term subsurface monitoring has been enhanced by Distributed Acoustic Sensing (DAS) in some environments where seismic nodal arrays were difficult or impossible to maintain, such as in permafrost regions. The associated monitoring programs includes strategies such as continuous ambient seismic interferometry. The large data volumes generated by DAS can be impractical for manual processing by small teams with limited computational resources, which motivates the development of automated data processing strategies. Changes in subsurface shear-wave properties can be automatically measured through the creation of Noise Correlation Functions (NCFs) that are analyzed using Multichannel Analysis of Surface Waves (MASW) to infer 1D shear-wave velocity profiles. We show several techniques to automatically pre-process passive DAS data and improve the quality of NCFs and the resulting dispersion curve picks. We repeat this process across sub-arrays along a DAS fiber, allowing autonomous construction of a pseudo-2D shear-wave velocity profile on the scale of kilometers. To detect potential subsurface changes prior to failure, and to ensure that field campaigns can be efficiently conducted by small teams, we aim for real-time ambient data processing using edge computing resources at the DAS interrogator location. A resulting profile could be used for rapid assessment of subsurface site conditions and identification of targets that require further geophysical or geotechnical investigation. We present results of the new techniques on a time-lapse DAS dataset acquired in a permafrost region along a roadside.

POSTER 6

Characterizing the Urban Shallow Subsurface using Fiber-optic Sensing and Ambient Seismic Noise for Improved Hazard Assessment

RODRÍGUEZ TRIBALDOS, V., GFZ Postdam, Potsdam, Germany, verort@gfz.de; PINZON RINCON, L., GFZ Postdam, Potsdam, Germany, lau.pinzonrincon@gmail.com; MARTÍNEZ-GARZÓN, P., GFZ Postdam, Potsdam, Germany, patricia@gfz-potsdam.de; HILLMANN, L., GFZ Postdam, Potsdam, Germany, laura.hillmann@gfz.de; BOHNHOFF, M., GFZ Postdam, Potsdam, Germany, bohnhoff@gfz.de; FEYIZ KARTAL, R., Disaster and Emergency Management Presidency, Ankara, Turkey, recai.kartal@afad.gov.tr; KILIÇ, T., Disaster and Emergency Management Presidency, Ankara, Turkey, tugbay.kilic@afad.gov.tr; KRAWCZYK, C., GFZ Postdam, Potsdam, Germany, lotte@gfz.de

Understanding near-surface structure, material properties and dynamics in densely populated areas is crucial to determine exposure to geohazards and their damaging effects. Despite this importance, our current understanding of the near-surface underneath urbanized areas is poor. The complexity of urban environments limits conventional sensing approaches to provide data at the spatial and temporal scales relevant for the design of sustainable urban development approaches and hazard mitigation strategies. Fibre-optic sensing deployed on existing, unused ("dark") telecommunication networks offers an unprecedented opportunity to efficiently investigate the subsurface at high resolution. In particular, Distributed Acoustic Sensing (DAS) enables seismic measurements at a spatial resolution of a few meters over tens of kilometers and at a temporal resolution of a few milliseconds, which would be cost prohibitive and non-viable using conventional seismic sensors.

In this work, we develop approaches to leverage existing fiber-optic cables and anthropogenic seismic noise for DAS-based, high-resolution seismic imaging of the shallow subsurface in urban areas, with the aim to explore the potential of this technology for seismic hazard assessment. We examine over 4 months of continuous DAS ambient seismic noise data recorded on a 17 km-long dark fiber crossing the district of Kartal in Istanbul (Turkey), one of Europe's highest seismic risk areas. We evaluate opportunistic noise sources, such as train tremors and traffic, and asses their effectiveness for DAS-based passive seismic interferometry in a complex array setting, with the objective to generate high-resolution, regional scale velocity models. We also investigate wave propagation properties of local, regional and teleseismic earthquakes to retrieve detailed information on material properties and their relationship with site response. Ultimately, we seek to develop efficient approaches for a comprehensive investigation of the urban subsurface that can provide insights for improved geohazard assessment and sustainable development.

POSTER 7

Monitoring Urban Geohazards and Subsurface Water Flow Using Distributed Acoustic Sensing in Pittsburgh, PA

ZHU, T., Pennsylvania State University, Pennsylvania, USA, tyzhu@psu.edu

Many older cities along the U.S. East Coast face overlapping challenges related to geohazards, aging infrastructure, and increasingly frequent extreme rainfall events due to climate change. As part of the NSF-funded FORESEE-Geohazards project, we deployed distributed acoustic sensing (DAS) on a 26-km-long buried telecom fiber-optic cable to monitor seismic noise in downtown Pittsburgh, Pennsylvania. The system used a Silixa iDAS2 interrogator with 4-meter channel spacing and a fixed 10-meter gauge length, collecting data from July 1 to December 31, 2024. Two seismometers, a flowmeter, and two soil moisture sensors were co-located to support interpretation. In Phase I, we focus on detecting rainfall and flood-related seismic noise. DAS signals show strong correlation with precipitation intensity and sewer discharge, offering a promising alternative to traditional flow meters. In Phase II, we apply ambient noise interferometry to extract Rayleigh surface waves and invert for S-wave velocity profiles along the cable. Preliminary results reveal inverse-dispersion patterns associated with leaky surface waves and a prominent low-velocity anomaly, which we interpret as a fractured zone based on geological context. This study highlights the potential of repurposing existing telecom infrastructure for urban hydrological and geohazard monitoring. DAS offers a scalable, cost-effective means of gaining continuous insight into subsurface water flow and structural changes without the need for invasive instrumentation.

Seismic Investigation of Mass Movements [Poster]

Poster Session • Thursday and Friday

Convener: Micha Dietze, Georg-August University Göttingen (michael.dietze@uni-goettingen.de); Liam Toney, U.S. Geological Survey (ltoney@usgs.gov)

POSTER 8

Seismic Characteristics of the Transition from Debris Flow to Hyperconcentrated Flow, Tahoma Creek, Washington

BIEGEL, K., University of California, Davis, California, USA, kmbiegel@ucdavis.edu; CONNER, A. E., University of Oregon, Oregon, USA, aconner2@uoregon.edu; THOMAS, A. M., University of California, Davis, California, USA, amt.seismo@gmail.com; IEZZI, A. M., U.S. Geological Survey, Washington, USA, aiezzi@usgs.gov; THELEN, W. A., U.S. Geological Survey, Washington, USA, wthelen@usgs.gov; ALLSTADT, K., U.S. Geological Survey, Colorado, USA, kallstadt@usgs.gov; COLLINS, E. A., U.S. Geological Survey, Colorado, USA, ecollins@usgs.gov; BEASON, S., National Park Service, Washington, USA, scott_beason@nps.gov; TODD, C., California State University, San Bernadino, California, USA, claire.todd@csusb.edu

Hyperconcentrated flows and debris flows are two types of high-discharge, highly sedimented flow events. These types of flow can be differentiated by metrics such as the amount of suspended sediment by volume, the maximum size of suspended particles within the flow column, and the critical yield strength of the flow. While there are significant differences in behavior, debris flows and hyperconcentrated flows exist on a continuum, making the transition between them not always clear. In August 2023, a debris flow occurred in Tahoma Creek in Mount Rainier National Park in Washington, USA, due to a glacial outburst coinciding with elevated streamflow from the South Tahoma Glacier. This debris flow occurred contemporaneously with a nodal geophone deployment along Tahoma Creek that allowed for close monitoring of the debris flow's movement through the drainage system. Seismic signals recorded at stations along Tahoma Creek show evidence of the transition from debris flow to hyperconcentrated flow approximately 4.5 km downstream from the glacial source. The waveform characteristics of this transition include the loss of low-frequency energy below 10 Hz, the loss of an abrupt debris flow snout arrival within the main body signal of the flow, and a change in length, shape, and energy distribution within the main body of the signal. This transition from debris flow to hyperconcentrated flow coincides with a gradual flattening of the Tahoma Creek drainage slope and a decrease in the velocity of the debris flow as it moves down the channel. Therefore, the location of this transition in flow state is consistent with the physical system. Identifying this transition in flow state is crucial for assessing the potential hazard posed by debris flows to downstream communities, enabling better forecasts of when such events may lead to heightened hazard or to less impactful flow conditions.

POSTER 9

Toward a Seismic Model of a Debris Flow: Applying and Adapting a Granular Flow Model to the U.S. Geological Survey Experimental Debris-flow Flume

BIEGEL, K., University of California, Davis, California, USA, kmbiegel@ucdavis.edu; CONNER, A. E., University of Oregon, Oregon, USA, aconner2@uoregon.edu; THOMAS, A. M., University of California, Davis, California, USA, amt.seismo@gmail.com; ALLSTADT, K., U.S. Geological Survey, Colorado, USA, kallstadt@usgs.gov; OBRYK, M., U.S. Geological Survey, Washington, USA, mobryk@usgs.gov; FARIN, M., HYGEOS, Lille, France, maxime.farin1@gmail.com; IVERSON, R., U.S. Geological Survey, Washington, USA, riverson@usgs.gov

Seismic recordings of debris flows are complex and noisy signals. However, by understanding these signals, we gain valuable insight into the physical parameters of debris flows. In this study, we aim to produce a working seismic model of debris flows that allows us to quantify the relationship between the physical properties of a debris flow and the characteristics of its seismic signals. To that end, we first adapt a laboratory-validated mathematical model of granular flows to experimental debris flow data recorded at the U.S. Geological Survey large-scale experimental debris-flow flume near Blue River, Oregon. We analyze seismic recordings from several sets of experimental data to adapt and validate this model to larger-scale flows. These experimental debris flows have varying total volumes, particle sizes, recording geometries, and occasionally flume bed composition. In adapting this laboratory flow model to experimental data, we use measurements of the characteristics of the debris flows' constituent parts: the saltating front, the flow lip, the snout, and the main body of the debris flow, each of which contribute to the total power of the debris flow at differing levels. In comparing the modeled power spectrums with the recorded power spectrums, we explore the contributions of specific physical parameters to total power. We adapt the laboratory model to allow for particle diameter distributions rather than a singular particle size and to allow for variable velocities over the flow distance. Finally, we reconstruct the seismic signals of these modeled debris flows using previously calculated Green's functions at the test flume site, comparing these reconstructed waveforms to the recorded signals. The future aim of this research is to define a seismic model for debris flows that can be used to estimate physical properties of debris flows recorded by seismometers in natural settings.

POSTER 10

Understanding Spitze Stei Rockslide Dynamics: A Passive Seismic Approach to Mass Movement Detection, Characterization, and Trigger Identification

CHMIEL, M., Geoazur/French National Centre for Scientific Research, Valbonne, France, malgorzata.chmiel@geoazur.unice.fr; WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, fabian.walter@wsl.ch; HUSMANN, L., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, lhusmann@student.ethz.ch; BELLI, G., University of Florence, Florence, Italy, g.belli@unifi.it; MARCHETTI, E., University of Florence, Florence, Italy, emanuele.marchetti@unifi.it; HIBERT, C., Strasbourg Institute for Earth Physics, Strasbourg, France, hibert@unistra.fr; HÄHLEN, N., Natural Hazard Division of Canton Bern, Interlaken, Switzerland, nils.haehlen@be.ch; KIENHOLZ, C., Geotest, Zollikofen, Switzerland, christian.kienholz@geotest.ch

The active rockslide near Spitze Stei (Kandersteg, Switzerland) consists of around 16 million cubic meters of unstable material and shows displacement rates that can locally exceed 20 cm per day. Its dynamics pose a significant hazard due to the frequent occurrence of various mass movements. A key challenge lies in rapidly and accurately detecting and characterizing these events, and in understanding their triggers to support effective hazard mitigation. Current monitoring methods, including in-situ boreholes (which highlight drivers like permafrost degradation), surface displacement sensors, and interferometric radar (which tracks surface kinematics), provide valuable data, but each comes with limitations. In particular, the point-based nature of in-situ sensors and the surface-focused view of radar make it difficult to continuously monitor and quantify the full range of slope-wide mass movements and to identify the complex triggering mechanisms.

To address these challenges, our study applies a passive seismic monitoring approach. We are developing a machine learning framework that combines seismic and infrasound data to continuously detect a wide range of mass movement events, from rockfalls to debris avalanches. We then integrate time series of mass movements with high-resolution meteorological and kinematic datasets. This integration enables us to identify specific triggers, such as rainfall intensity, snowmelt, freeze-thaw cycles, local seismicity, and internal rock damage, for various types of slope failures, and to better understand the conditions that precede them. By advancing the detection and characterization of mass movements and identifying their triggers, our research aims to significantly improve warning capabilities and advance our knowledge of rockslide dynamics.

POSTER 11

Using Horizontal-to-vertical Spectral Ratio to Characterize Landslides in Complex Terrain

COLLINS, E. A., U.S. Geological Survey, Colorado, USA, ecollins@usgs.gov; ALLSTADT, K., U.S. Geological Survey, Colorado, USA, kallstadt@usgs.gov; COE, J. A., U.S. Geological Survey, Colorado, USA, jcoe@usgs.gov

The horizontal-to-vertical spectral ratio (HVSR) technique is popular within the earthquake community for site characterization. This method uses the ratio between seismic noise or earthquake recordings on horizontal and vertical components to estimate fundamental frequency, site amplification, and derive sediment thickness using a known shear-wave velocity. The method can also be used for other purposes, such as estimating the depth of landslide slip surfaces where fractured, broken material slides on a generally intact substrate. Community standards for HVSR are mainly established for simple, 1D-varying subsurface compositions. Interpretation is less straightforward in more complex terrain that characterizes many landslide settings. There is a need to better understand how to use and interpret HVSR results in these geologically complex settings because the technique can provide useful information at a lower cost, and in a less invasive way, than other geophysical and geotechnical approaches. In this study, we apply the HVSR technique to characterize landslides of varying structural complexity: the Slumgullion slow-moving landslide near Lake City, Colorado; the Bald Eagle sackung near Leadville, Colorado; and two landslides triggered by the February 6, 2023, Türkiye earthquake sequence. We installed one or more 3-component seismometers at each site and conducted rock drops to roughly estimate shear-wave velocity using direct wave arrival times where pre-existing measurements were unavailable. We find that some sites have a single, high-amplitude HVSR peak, while other sites have more complicated HVSR curves with multiple, lower-amplitude peaks. We compare the HVSR curves at the sites, explore the source of their varying degrees of complexity using simple modeling, and interpret the results of each site in context of other available information to characterize the landslide geometry. Through this work, we aim to better understand the usage of the HVSR technique for landslides and other complex geologic settings.

POSTER 12

Ground Motions, Infrasound Signals, and Seismic Velocity Perturbations: Environmental Impacts of the Rock Avalanche Induced by the 2025 Mw 6.5 Jan Mayen Strike-slip Earthquake

DE MELO, G. W. S., GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, gdemelo@geomar.de; HERMANNS, R. L. M., Geological Survey of Norway, Trondheim, Norway, Reginald.Hermanns@ngu.no; BENDLE, J., Geological Survey of Norway, Trondheim, Norway, Jacob.Bendle@NGU.NO; KOPP, H., GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, hkopp@geomar.de; GREVEMEYER, I., GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, igrevemeyer@geomar.de; DO NASCIMENTO, A. F., Federal University of Rio Grande do Norte, Natal, Brazil, aderson.nascimento@ufrn.br; OTTEMÖLLER, L., University of Bergen, Bergan, Norway, Lars.Ottemoller@uib.no; ASLAN, G., Geological Survey of Norway, Trondheim, Norway, gokhan.aslan@ngu.no; BRISSAUD, Q., NORSAR, Kjeller, Norway, Quentin.Brissaud@norsar.no; OYE, V., NORSAR, Kjeller, Norway, volker@norsar.no; CESCA, S., GFZ Postdam, Potsdam, Germany, simone.cesca@gfz.de

The Jan Mayen Island (JMI) is an activate volcano located in Arctic Ocean, at the Jan Mayen transform fault (JMTF). On 10 March 2025, a strong strike-slip Mw 6.5 earthquake occurred in the JMTF, with the fault rupturing for ~40 km long and crossing the north zone of the JMI, indicating the potential for local hazard effects. Local GNSS sensors indicated that JMI moved ~2.4 cm in WNW-ESE direction during the rupture process, corroborating with the ESE rupture direction identified by apparent duration of regional P-waves (1700-2200 km away), and the local epicenter distribution of the >1500 relocated aftershocks. The epicenter of the mainshock was located ~8 km away from Kjerulf Glacier, a long flowing glacier on the outer crater edge of the Beerenberg stratovolcano. An infrasound array located in northern Norway identified a signal arriving ~3 min after the mainshock, with the source of the signal coming with back-azimuth in direction of the Kjerulf Glacier. Additionally, the ambient seismic noise cross-correlation of three local stations, located ~3-16 km distance from the glacier, revealed subsurface velocity perturbations during ~30 min and starting ~3 min after the mainshock. Using Sentinel-2 and high-resolution MAXAR satellite images, we confirmed that the infrasound signal and seismic noise perturbations were generated by a large volume (0.81 – 1.17 x 10^6 m^3) of basaltic rock that detached and collapsed in the slope located in south wall of the Kjerulf Glacier, minutes after the mainshock occurred. The collapse triggered a rock avalanche that scattered debris along the glacier surface and covered most of the ice toward the border of the sea. It may take several years before the glacier surface covered with rock material returns to its previous state. Therefore, in addition to highlighting the synergy of geophysical, remote sensing, and satellite data in characterizing complex submarine fault slipping, this multidisciplinary study shows that earthquakes along oceanic transform faults can pose serious natural hazards through secondary effects, such as large rock avalanches in the land area near the epicenter.

POSTER 13

Heterogeneous Spatial and Temporal Distribution of Small Seismic Signals Associated with the Oak Ridge Earthflow in California

IWASAKI, Y., University of California, Santa Cruz, California, USA, yiwasak2@ucsc.edu; SCHWARTZ, S., University of California, Santa Cruz, California, USA, syschwar@ucsc.edu; FINNEGAN, N., University of California, Santa Cruz, California, USA, nfinnega@ucsc.edu

The mechanics of slow frictional creep in landslides, including the influence of meteorological factors, remain a subject of ongoing debate, and comprehensive seismic investigations in landslide-prone regions are still relatively scarce. To elucidate basal slip processes associated with a slowly moving landslide, we deployed a dense array of 80 seismic nodes at the Oak Ridge Earthflow in California's Diablo Range for approximately three weeks during the rainy season of 2024, a period marked by decimeter-scale displacements. Concurrently, GNSS receivers and piezometers were installed at the same location. During the deployment, the seismometers recorded numerous low-amplitude seismic signals. These events were highly localized, detected exclusively by nearby stations spaced within approximately 100 meters of one another. To investigate their underlying mechanisms, we employed automated detection and analyzed their spatial and temporal distribution. We applied array-based signal processing using Covseisnet (Seydoux et al., 2016) to extract local seismic signals based on the coherence of dominant frequencies across the array, followed by automated phase picking with Quakephase (Shi et al., 2024) and event localization via beamforming (Beaucé et al., 2023). This integrated approach enabled the efficient and accurate identification of local seismic events likely associated with earthflow motion. Additionally, we employed a matched-filter technique to further expand the event catalog. These seismic signals were not continuously observed but exhibited temporal and spatial clustering. By integrating these seismic observations with auxiliary time-series data, including pore fluid pressure, atmospheric pressure, temperature, and surface displacement, we aim to elucidate the processes driving these signals and advance our understanding of the mechanisms governing earthflow dynamics.

POSTER 14

Rock Slope Instability Zonation from Ambient Vibration Array Measurements in Skagway, Alaska, USA

JENSEN, E. K., U.S. Geological Survey, Colorado, USA, ejensen@usgs.gov; MOORE, J. R., University of Utah, Utah, USA, jeff.moore@utah.edu; WACHINO, I. D., University of Oregon, Oregon, USA, iwachino@uoregon.edu; MCCREARY, M. E., University of Utah, Utah, USA, molly.mccreary@utah.edu; SAHAKIAN, V. J., University of Oregon, Oregon, USA, vjs@uoregon.edu; DZUBAY, A., Instrumental Software Technologies, Inc., Oregon, USA, adzubay@gmail.com; ROERING, J. J., University of Oregon, Oregon, USA, jroering@uoregon.edu; CASH, R., Skagway Traditional Council, Alaska, USA, reuben@skagwaytraditional.org; GRECHI, G., Sapienza University of Rome, Rome, Italy, guglielmo.grechi@uniroma1.it

Resonance frequency analyses from in-situ ambient vibration measurements can be used to detect and characterize unstable rock slopes. This minimally invasive technique is well-suited for landslide assessments in situations where other common methods (e.g., satellite interferometric synthetic aperture radar or boreholes) may be impractical. In this study, we used ambient vibration array measurements to assess the stability of a ~1.5 km-long rock slope above a busy harbor area in Skagway, Alaska. We hypothesized that ongoing rock slide activity in an isolated area of the slope could indicate widespread instability, either in the form of a large, deep-seated landslide or as smaller independent blocks. To test this hypothesis, we deployed Fairfield Zland 3C 5-Hz nodal geophones in three spatially overlapping arrays (62 total sensor

locations) and collected ~60 hours of seismic data over the span of three days. Each array consisted of 35 stations and included reference stations at the base and upslope of the potentially unstable area. We conducted spectral and frequency-dependent polarization analyses and assessed site-to-reference spectral ratios to search for resonance frequencies of potential landslide blocks. Preliminary results showed clusters of analogous spectral amplification and noise polarization, revealing both stable areas and potentially unstable blocks situated at the slope crest. These observations provide no evidence of a deep-seated instability at this site. In some areas, high spectral amplifications and strongly polarized motion correspond with mapped open ground cracks, whereas in other areas, seismic data reveal potential instabilities in the absence of visible ground cracks. These findings highlight the value of ambient vibration techniques for mapping incipient rock slope failures, and helped identify previously unknown unstable blocks at this site, providing a basis for future monitoring and detailed hazard assessments.

POSTER 15

Advancing Seismic Monitoring of Landslides in Alaska

KARASOZEN, E., University of Alaska Fairbanks, Colorado, USA, ezgikarasozen@gmail.com; WEST, M. E., University of Alaska Fairbanks, Alaska, USA, mewest@alaska.edu

We present recent advances in a real-time seismic monitoring system for landslides in Alaska. Since 2023, we have been testing a seismic detection algorithm focused on Prince William Sound, which has successfully identified dozens of landslides, including a 2024 landslide that generated a tsunami—demonstrating the system's value for hazard monitoring.

To improve performance, we compiled a test catalog of 80 events—40 confirmed landslides (0.1–60 Mm^3) and 40 earthquakes (M2.3–7.6)—that had triggered detections. Among the various filtering techniques we evaluated, the high-frequency to low-frequency amplitude ratio proved most effective, reducing false detections from earthquakes by 85%. We have also refined our landslide volume estimation scaling relationship using the newly detected events. The updated scaling relationship is now constrained by 22 landslides, including several new events in the 1–10 million m^3 volume range, helping to refine estimates for mid-to-large landslides.

Building on this success, we recently expanded the system beyond Prince William Sound. The original detection grid covered a 220 × 220 km area in this region and used a fixed set of 44 stations. The new system spans 1,000 × 2,000 km and incorporates 220 stations, with dynamic station selection for each grid point. This enhanced framework is in final testing and will soon be deployed in real time.

We will present these improvements and highlight selected landslide detections from summer 2025 using the upgraded real-time monitoring framework.

POSTER 16

Developing a Framework for Time Varying Inversion of Distributed Point Forces for Landslides

KRIER, J., University of Oregon, Oregon, USA, jkrier4@uoregon.edu; MELGAR, D., University of Oregon, Oregon, USA, dmelgarm@uoregon.edu

Landslides are unpredictable hazards that can be catastrophic when they come in contact with communities both rural and urban. They can destroy homes and roads that lead to costly repairs.. Understanding of hazards can be improved by a better categorization of the material moved and forces involved with these events. This study is the framework for an Inversion software, MudPy, which was originally developed for multi-geophysical inversion of slip due to earthquake sources on planar or curved faults and has been modified to also invert for time- varying distributions of single point forces that are representative of a landslide. This software is unique because it does not calculate for a single point to represent the forces of an event but an array of locations along a slide path that varies with time to get a better understanding of the full distribution of energy within the event.The use of the energy distribution allows us to understand more of the complexities within a landslide that are left out from being simplified to a single point force. We hope to be able to see more of a landslide's dynamics including multiple starting trigger points of initiation and bifurcated landslide paths. Verification of this software has been conducted by comparing results with a Single-Force Seismic Inversion Framework for Massive Landslides, Isforce, used on the 2016 Lamplugh rock avalanche calculating a single center of mass force for the event. This landslide will be the test case to verify this software using the center of mass point force calculations and comparing it to our multi-point calculations. Once verified this Time varying inversion of distributed single point forces will be used to look at other massive landslide events. Better characterization of the forces and material displaced by landslides can help with assessment of the hazards associated with prior landslides and help to prepare for future events.

POSTER 17

Passive Seismic Monitoring of the Åknes Unstable Rockslope: Unveiling the Potential of Borehole Sensors

LANGET, N., NORSAR, Kjeller, Norway, nadege@norsar.no; BOGNER, L., University of Hamburg, Hamburg, Germany, laura.kb@web.de; OYE, V., NORSAR, Kjeller, Norway, volker@norsar.no; BRULAND, C., NORSAR, Kjeller, Norway, charlotte.bruland@norsar.no; ASPAAS, A., The Norwegian Water Resources and Energy Directorate, Oslo, Norway, agas@nve.no; HADZIIOANNOU, C., University of Hamburg, Hamburg, Germany, celine.hadziioannou@uni-hamburg.de

The Åknes rockslide in Western Norway experiences annual movement on the order of a few centimeters. Over the past two decades, the site has been extensively monitored, with both surface and multi-borehole instruments continuously recording slope displacement and groundwater fluctuations. As part of this monitoring system, a borehole has been equipped with eight geophones, which record seismic activity at 1000 Hz to a depth of 50 m, intersecting a sliding plane at approximately 26 m and above another at 60 m. Microseismic events characterised by a very high frequency content and a short duration have been detected. The temporal distribution of these events appears to correlate with displacement measurements from nearby boreholes. Additionally, four distinct bursts of repetitive signals, or "tremors," were observed during the recording period. These tremors are associated with variations in groundwater levels within the shear zones and are interpreted as the result of creeping along asperities. Finally, relative changes in seismic velocity (dv/v) derived from ambient seismic noise correlate well with seasonal variations of environmental factors, and a decrease is particularly visible when the snow melts, corresponding to a more water-saturated rock mass.

POSTER 18

The Impact of Grain Size on Bedload-generated Seismic Signals: Field and Flume Observations

MCLAUGHLIN, J. M., New Mexico Institute of Mining and Technology, New Mexico, USA, john.mclaughlin@student.nmt.edu; BILEK, S. L., New Mexico Institute of Mining and Technology, New Mexico, USA, susan.bilek@nmt.edu; CADOL, D., New Mexico Institute of Mining and Technology, New Mexico, USA, daniel.cadol@nmt.edu; ROTH, D., University of Colorado Boulder, Colorado, USA, danica.roth@colorado.edu; JOHNSON, J., University of Texas at Austin, Texas, USA, joelj@jsg.utexas.edu; LUONG, L., New Mexico Institute of Mining and Technology, New Mexico, USA, loc.luong@student.nmt.edu; LARONNE, J. B., Ben-Gurion University of the Negev, Be'er Sheva, Israel, john@bgu.ac.il

Seismic instruments have emerged as a powerful tool to monitor variations in bedload transport as particles roll, slide, and saltate along riverbeds. Physical models and experiments suggest that grain size is an important factor in the amount of seismic energy produced by moving particles. However, the relationship between bedload grain size and the resulting seismic energy depends on fluvial conditions and bedload properties. Furthermore, the frequency content of bedload-generated signals depends on the nature of particle impacts to the bed. Thus, the total effect of bedload grain size on the frequency and amplitude content of the resulting signals is complex.

To investigate the effects of bedload grain size on the seismic signals they produce, we combine field measurements and flume experiments. For the field measurements, we use a large dataset of bedload flux and grain size collected during flash flood events at a monitored channel with ephemeral flow in central New Mexico. At this location, we have recorded dozens of bedload-transporting events with median grain sizes ranging from <1 to 16 mm. We have found a significant relationship between high frequency (30-80 Hz) power-spectral density and median grain size (D50), with PSD generally scaling with D50 to the power of 1-2. Our flume experiments were conducted alongside an in-ground outdoor flume (~1.5 m wide, 36 m long) at UT Austin. We deployed 5 Hz geophones beside the concrete flume as well as a DAS cable with 10 kHz sampling and 1 meter spatial resolution, placed both inside and outside of the flume, during experiments. We then sorted gravels into bins of roughly equivalent grain size and had them transported past our sensors. By analyzing the spectral content of the resulting signals in both the field and flume environment, we can determine how equivalent masses of differing grain sizes affect the frequency and amplitude of the resulting seismic signals. These findings have implications for seismic bedload monitoring, particularly in environments where grain size varies temporally.

POSTER 19

Avalanche Localization with Distributed Acoustic Sensing Near Milford Sound/Piopiotahi, New Zealand

MICHAILOS, K., Australian National University, Canberra, Australia, konstantinos.michailos@anu.edu.au; LAI, V., Australian National University, Canberra, Australia, voonhui.lai@anu.edu.au; KONIETZNY, S., Technical University of Dortmund, Dortmund, Germany, sebastian.konietzny@tu-dortmund.de; MILLER, M. S., Australian National University, Canberra, Australia, meghan.miller@anu.edu.au; TOWNEND, J., Victoria University of Wellington, Wellington, New Zealand, john.townend@vuw.ac.nz; MORRIS, S., Milford Road Alliance, Te Anau, New Zealand, simon.morris@downer.co.nz; ANDERSON, H., Milford Road Alliance, Te Anau, New Zealand, hans-peter.anderson@downer.co.nz; CLARKE, G., Milford Road Alliance, Te Anau, New Zealand, graham.clarke@downer.co.nz

Snow avalanches, like other gravitational mass movements, are major natural hazards that pose significant risks to alpine environments in terms of safety and infrastructure maintenance, and are often highly unpredictable. Fiordland's Milford Sound/Piopiotahi is part of the Southern Alps/Kā Tiritiri o te Moana, an active orogen characterized by high deformation rates, abundant microseismicity, heavy precipitation, steep glacier-carved topography, and rapid erosion. Milford Sound/Piopiotahi attracts over 400,000 visitors annually, most of whom arrive by road. State Highway 94, the road connecting Milford Sound/Piopiotahi to the rest of New Zealand, is monitored by the Milford Road Alliance, which uses various types of observations (e.g., weather forecasts, meteorological data, web-cameras, infrasound sensors) to manage avalanche risk. While this system provides valuable information for hazard management, the timing and spatial accuracy of avalanche records can be limited, particularly for events occurring farther from the road or during nighttime hours.

As part of the Fiordland Seismological Sounding of Landslides and Earthquakes (FISSLE) project, we repurpose a dark telecommunication fiber running along State Highway 94, crossing several avalanche-prone regions, into a 31 km long Distributed Acoustic Sensing (DAS) array. The DAS array recorded several avalanches, both natural and triggered, between June and September 2024. In this study, we apply signal processing techniques to detect, locate, and characterise avalanche events in the recorded data. These results will form the basis for an avalanche catalog for the 2024 winter season along State Highway 94. After determining the precise timing and locations of the avalanches, we will investigate any potential connections between avalanche activity, meteorological conditions, and local seismicity. This multidisciplinary analysis will enhance our understanding of avalanche-triggering processes and support improved forecasting and risk mitigation efforts.

POSTER 20

Environmental Seismology Applied to Unstable Rock Slopes in Kaafjord, Norway

MISSANA, A. F. J. M., Norwegian University of Science and Technology, Trondheim, Norway, amandine.missana@ntnu.no; HERMANNS, R. L. M., Geological Survey of Norway, Trondheim, Norway, reginald.hermanns@ngu.no; LAROSE, E., University Grenoble Alpes, Grenoble, France, eric.larose@univ-grenoble-alpes.fr; HELMSTETTER, A., University Grenoble Alpes, Grenoble, France, agnes.helmstetter@univ-grenoble-alpes.fr; ASLAN, G., Geological Survey of Norway, Trondheim, Norway, gokhan.aslan@ngu.no; LANGET, N., NORSAR, Kjeller, Norway, nadege@norsar.no; SKREDE, I., Norwegian Water Resources and Energy Directorate, Oslo, Norway, ins@nve.no

Two campaigns of passive seismological recording were conducted on two rock slopes, Njárgavárri (NJGV) and Indre Nordnes (IDRN), Troms and Finnmark, Norway. Both slopes were equipped with geophones and broadband seismometers in autumn 2023 and spring/summer 2024. Using STA/LTA, template-matching detection, automated classification and manual checking, catalogues of slope quakes and rockfalls are built. Continuous videos at NJGV allow to obtain a catalog of rockfalls based on visual observation. These catalogs enable us to evaluate the relative degree of activity of both slopes at the surface and at depth; and to localize cracking and slipping. Ground-based radar data are also available at both sites. The goal is to see how rockfalls relate to subsurface deformation and to better understand the geometry of the rupture surface.

Both rockfall and quake signals from rock fracturing have been recorded. Seismic signals from rockfalls last at least a few seconds, have a cigar shape and no clear arrival, whereas slope quakes are very sudden and impulsive, and last less than a few seconds. They can be described as simple high frequency slope quakes, reaching up to 50 Hz.

For autumn 2023, more than 90 slope quakes at NJGV have been confirmed, only 5 at IDRN, showing a much higher rock fracture activity at NJGV relative to IDRN. It correlates with the difference observed in radar measurements. The slope quake activity at NJGV clearly comes from the upper part where the rock slope is disintegrating. Repeaters were also found to come from this area, indicating slowly moving and creeping of the mass. Slope quake activity could not yet be precisely located at IDRN. Slope quake and repeater detections go in line with rockfall detections. At NJGV, a maximum of 40 rockfall signals per day have been observed compared to 25 at IDRN. These first results suggest that, at both sites, seismologically detected activity at the surface mimics subsurface activity in relative quantity.

POSTER 21

Preliminary Results from a Deployment of Seismic, Infrasound, and Auxiliary Sensors at the Chalk Cliffs, Colorado Debris Flow Site

TONEY, L., U.S. Geological Survey, Colorado, USA, ltoney@usgs.gov; COLLINS, E. A., U.S. Geological Survey, Colorado, USA, ecollins@usgs.gov; ALLSTADT, K., U.S. Geological Survey, Colorado, USA, kallstadt@usgs.gov; HOCH, O., U.S. Geological Survey, Colorado, USA, ohoch@usgs.gov; EINBUND, M., U.S. Geological Survey, Colorado, USA, meinbund@usgs.gov; AGUILERA, N., Red Rocks Community College, Colorado, USA, naguilera2@student.cccs.edu

The Chalk Cliffs of central Colorado are an area of hydrothermally altered rocks which produce regular seasonal debris flows. At Chalk Cliffs, steep catchments store colluvium from erosional processes occurring primarily in the winter. Convective thunderstorms in the summer months mobilize this stored material in the form of debris flows — rapid flows of water and >40% sediment — which occasionally exit the mountain front and cross a nearby road. Chalk Cliffs has long been used as a natural laboratory for debris flow studies because of the reliable occurrence of debris flows each summer. We expand on past work by installing new configurations of seismic instrumentation and infrasound arrays to test complementary methods for debris flow detection and characterization. Such methods have been successfully applied in other areas producing frequent debris flows (e.g., Illgraben, Switzerland) and are being used for monitoring in high-consequence debris flow and lahar settings (e.g., Mount Rainier, Washington State).

In May 2025, the U.S. Geological Survey Landslide Assessments, Situational Awareness, and Event Response Research (LASER) instrumentation team installed equipment at two sites at Chalk Cliffs. The sites were active for four months, spanning the summer debris flow season. The lower site was located just beyond the mountain front near the apex of the debris flow fan and consisted of a three-element infrasound array and a broadband seismometer ~15 m from the channel center. The upper site, located on a steep colluvial slope within the main catchment, hosted another three-element infrasound array, a three-element near-channel (<10 m) geophone line array, a weather station, and a rainfall-triggered video camera and laser rangefinder. Both sites used cell modem telemetry to send all seismoacoustic, weather, and laser rangefinder data in real time. This contribution highlights preliminary findings from this seismoacoustic dataset and additionally discusses applications and lessons learned for near-real-time landslide monitoring using LASER's multi-sensor rapid response kits.

POSTER 22

Source Type Classification of Non-earthquake Signals Commonly Recorded on Regional Seismic Networks: Implementation and Pipeline Development

TONEY, L., U.S. Geological Survey, Colorado, USA, ltoney@usgs.gov; ALLSTADT, K., U.S. Geological Survey, Colorado, USA, kallstadt@usgs.gov; COLLINS, E. A., U.S. Geological Survey, Colorado, USA, ecollins@usgs.gov; YECK, W., U.S. Geological Survey, Colorado, USA, wyeck@usgs.gov

Surficial mass movements, such as landslides and debris flows, have seismic signatures distinct from other routinely-recorded seismic sources like earthquakes and explosions. However, visual similarities between the characteristics of these signals can still make it difficult to practically discriminate between source types during operational seismic monitoring. This ambiguity motivates the development of automated techniques for seismic signal classification, which can lessen the load on earthquake-focused seismic analysts and expand opportunities for non-earthquake event cataloging. Here, we present a machine learning classification scheme for differentiating between regional (< 200 km) seismic signals generated by shallow earthquakes, rock falls, landslides/avalanches, anthropogenic blasts, and glacial events. These source types are commonly recorded on regional seismic networks and therefore present the most useful target for automated classification.

Our signals derive from the Exotic Seismic Events Catalog (ESEC) — a diverse, manually-created database of seismogenic surface events — and the U.S. Advanced National Seismic System Comprehensive Earthquake Catalog. We select earthquake signals such that the source–receiver distance distribution and number of signals are balanced with respect to the ~300 ESEC events. We implement a feature-based approach to classification using metrics — e.g., "rise time", the duration from signal onset to signal maximum — extracted from waveforms. We test feature extraction approaches including both generalized sets as well as specific, manually-engineered features. Feature importance metrics provide insight into the machine learning algorithms we use, which include support vector machines and a random forest classifier. We test our method on real-time seismic data in the context of the USGS National Earthquake Information Center's operational systems. We picture our classification workflow as one modular element of a larger non-earthquake identification pipeline that includes detection and location as preliminary (or concurrent) steps.

POSTER 23

The Disenchanting Effect of Petrichor—The First Rain After a Dry Spell, on a Landslide

VOIGTLÄNDER, A., Lawrence Berkeley National Laboratory, Berkeley, Germany, avoigtlaender@lbl.gov; CHEN, L., Lawrence Berkeley National Laboratory, California, USA, lwchen@lbl.gov; TAIRA, T., University of California, Berkeley, California, USA, taira@berkeley.edu

Landslides and debris flows are frequently associated with precipitation events, particularly following dry periods or wildfires. This leads to the assumption of immediate alterations in material properties and increased pore pressure and thus movement after the rain. But is that really the case? This study investigates the temporal variations of seismic velocity changes in a landslide in the Berkeley hills using seismic interferometry to assess the influence of rainfall on subsurface dynamics. Continuous monitoring with seismic interferometry allows for the detection of subtle perturbations in surface structures and properties.

We deployed an array of geophones on a known landslide in the Berkeley hills on the premises of the Lawrence Berkeley Laboratory from October 2024, the end of the dry season to mid-April 2025, encompassing the entire rainy season and several major atmospheric rivers. The sensor array consisted of 6 three component geophones (Smartsolo) recorded on the slide and 3 as references surrounding it. Similar to a laboratory experiment, the sensors are distributed along the topographic gradient. We use a triangular array pattern to cover most space while ensuring close spacing of the sensors. A frequency-dependent seismic velocity change will provide us with the depth resolution.

The objective was to differentiate seismic velocity changes related to surface wetting versus deeper porewater pressure changes and landslide potential. Our setup of sensors enables us to spatially reference those changes along topographic and depth gradients of the landslide.

Initial results suggest that the immediate effect of initial rainfall ("petrichor") is primarily surficial, requiring sustained precipitation to develop a deeper wetting front, and pore pressure changes.

POSTER 24

Use Small Aperture Nodal Arrays to Capture the Debris Flow in the Bailey Canyon

WEI, X., California Institute of Technology, California, USA, xiaozhuo@caltech.edu; **REID-MCLAUGHLIN, A.**, California Institute of Technology, California, USA, areidmcl@caltech.edu; CHEN, Z., California Institute of Technology, California, USA, zhiang.chen@caltech.edu; GEYMAN, E. C., California Institute of Technology, California, USA, egeyman@caltech.edu; LAMB, M. P., California Institute of Technology, California, USA, mpl@caltech.edu; ZHAN, Z., California Institute of Technology, California, USA, zwzhan@caltech.edu

Debris flow is important, not only because it is a core erosional process that shapes surface geomorphology, but also because it poses a significant geohazard threat to local communities. Los Angeles, where a substantial portion of the city lies at the foot of the San Gabriel and Santa Ynez Mountains, is particularly prone to debris flow hazards. The steep slopes of these mountains, combined with abundant precipitation on their Pacific-facing sides, create favorable conditions for debris flow events. The risk is further amplified by frequent wildfires in the region, which destroy surface vegetation and expose bare soil.

Most recently, in January 2025, a series of wildfires struck the Los Angeles area and again caused significant infrastructure damage. As a rapid response, we deployed two small aperture (10–30 m) nodal seismic arrays along ridge lines above Bailey Canyon, chosen for its accessibility and permitting feasibility. Over a two-day deployment, the seismometers recorded two distinct types of seismic signals. High-frequency (>60 Hz) signals closely tracked precipitation rates and were calibrated via linear regression against nearby rain gauge data, effectively transforming the seismic sensors into high-resolution rain gauges. A second, lower frequency (10–40 Hz) signal correlated with camera observations of debris basin activity, which we interpret as originating from debris flow events.

In total, six debris flow events were detected during two consecutive precipitation pulses. Slant stackin revealed that the flows originated from the eastern side of the arrays, consistent with the main channel of Bailey Canyon as mapped by repeated drone based topographic surveys. One event clearly shows a migrating flow front traveling approximately 370 meters in 100 seconds, yielding a flow speed of ~3.7 m/s, consistent with previous studies.

These results highlight the effectiveness of small aperture seismic arrays for monitoring of both precipitation and debris flow dynamics. Our approach demonstrates their potential as tools for early warning in debris flow prone regions.

POSTER 25

Seismic Characterization of Debris-flow Erosion Dynamics and Channel-bed Elevation Changes in Alpine Environments

ZHANG, Z., Chinese University of Hong Kong, Hong Kong, China, zhenzhang@cuhk.edu.hk; WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zurich, Switzerland, fabian.walter@wsl.ch; MCARDELL, B., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zurich, Switzerland, brian.mcardell@wsl.ch; DE HAAS, T., Utrecht University, Utrecht, Netherlands, t.dehaas@uu.nl; WETTER, C., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zurich, Switzerland, christoph.wetter@wsl.ch

Debris flows constitute major geological hazards in mountainous regions, posing substantial risks to infrastructure and human settlements. Their erosive capacity during runout significantly alters channel morphology, exacerbating hazard potential. A comprehensive understanding of debris-flow erosion processes is critical for both geomorphic evolution studies and hazard assessment. However, the unpredictability of debris flows often limits the availability of high-resolution pre-event topographic data and in situ flow measurements. Here, we analyze seismic signals, flow dynamics, and geomorphic changes from 18 well-documented debris flows in Illgraben, Switzerland (2019–2023). Our results demonstrate a robust correlation between cumulative vertical forces derived from seismic data and observed channel-bed elevation changes, with improved agreement at larger spatial scales. Furthermore, we establish thresholds for erosion and deposition using seismic-derived vertical fluctuating forces. Notably, we identify a strong dependence of debris-flow seismic signal peak frequency on the absolute elevation of the seismic source area, modulated by wave propagation path effects that reflect erosion- and deposition-induced channel-bed alterations. These findings highlight the utility of seismic monitoring in quantifying debris-flow erosion dynamics and tracking real-time channel-bed elevation changes, providing novel perspectives on geomorphic processes and hazard evaluation.

Subsurface Monitoring and Imaging [Poster]

Poster Session • Thursday and Friday

Convener: Voon Hui Lai, Australian National University (voonhui.lai@anu.edu.au); Shujuan Mao, University of Texas at Austin (smao@jsg.utexas.edu)

POSTER 26

Seismic Interferometry-based Monitoring of the Spitze Stei Rockslide

ARIAS, G., Geoazur/French National Centre for Scientific Research, Valbonne, France, arias@geoazur.unice.fr; CHMIEL, M., Geoazur/French National Centre for Scientific Research, Valbonne, France, malgorzata.chmiel@geoazur.unice.fr; WALTER, F., Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, fabian.walter@wsl.ch

The Spitze Stei rockslide, located above the Oeschinen Lake in the Kandersteg region of Switzerland, has shown increased activity in the past year. The slide comprises approximately 16 million m^3 of material within an area of around 0.5 km^2. Sediments that accumulate at the base of the Spitze Stei slope develop into debris flows due to melting snow and intense summer rainfall. This rockslide exhibits displacement rates exceeding 20 centimeters per day, posing a substantial threat to the surrounding area, including the village of Kandersteg. Despite ongoing observations, the precise triggering mechanisms and internal structural changes driving the current acceleration remain poorly understood, hindering predictive capabilities.

In this study, we analyze more than three years of seismic data and employ seismic interferometry based on ambient seismic noise correlations to measure changes in relative seismic velocity within the rockslide. The initial results suggest depth-dependent and lateral sensitivity of the rockslide to hydrologic variations. With this approach, we aim to distinguish between irreversible damage and fracturing, and seasonal, reversible effects attributed to thermoelastic and hydrologic variations.

This analysis is expected to contribute to a deeper understanding of the complex subsurface dynamics of the Spitze Stei rockslide.

POSTER 27

Low-cost, High-impact: Deploying Nodal Seismometers to Study Upper Mississippi Embayment Aquifers

RODRIGUEZ CARDOZO, F. R., University of South Florida, Florida, USA, frodriguezcardozo@gmail.com; **CARPENTER, N. S.**, Kentucky Geological Survey, Kentucky, USA, seth.carpenter@uky.edu; SCHMIDT, J. P., Kentucky Geological Survey, Kentucky, USA, jon.schmidt@uky.edu; ARAJI, A., University of Kentucky, Kentucky, USA, ali.araji@uky.edu; BRAUNMILLER, J., University of South Florida, Florida, USA, jbraunmiller@usf.edu; WOOLERY, E. W., University of Kentucky, Kentucky, USA, ewoolery@uky.edu; WANG, Z., Kentucky Geological Survey, Kentucky, USA, zmwang@uky.edu

Groundwater monitoring using seismic noise is a recently developed application in environmental seismology. By cross-correlating and stacking long time series of seismic noise, Green's Functions (GFs) can be retrieved. Subtle changes in the GF codas can be associated with temporary velocity variations ($\Delta v/v$) due to changes in the subsoil, including groundwater level variations in aquifers. We aim to apply this method to the Upper Mississippi Embayment (UME) aquifer system, which supports the water needs of agriculture, industry, and an increasing population in a five-state region of the central United States. We are undertaking a multi-year investigation of a ~2,000 km2 area in the Kentucky part of the UME, which hosts multiple aquifers from the surface to depths up to ~600 m. Based on previous studies and preliminary work in the larger UME, the necessary resolution requires seismometer spacing of ~10 km or less and ambient noise recordings that include frequencies ≤0.2 Hz. The requirements can be satisfied cost-effectively by deploying a dense array of nodal instruments (nodes) that reliably record weak, low-frequency seismic waves. This work presents results from two preliminary stages of the project. First, we compared the waveforms and power spectral densities from a short-term nodal deployment against observations from co-located broadband seismometers. We found two types of nodes that record ambient vibrations at frequencies ≤0.2 Hz, establishing the usefulness of low-cost nodes for this project. Second, using existing long-term broadband deployments in the study region (stations HICK and CUSSO), we deduced appropriate processing parameters for retrieving stable GFs codas that allow us to obtain reliable $\Delta v/v$ measurements. We will show preliminary results regarding the stability of the retrieved coda waves after cross-correlating and stacking inter-station and inter-component waveforms.

POSTER 28

Integration of Seismic Velocity and Azimuthal Anisotropy from Ambient Noise Tomography for Groundwater Aquifer Characterization

CHEN, L., Lawrence Berkeley National Laboratory, California, USA, lwchen@lbl.gov; CHEN, K., Academia Sinica, Taipei, Taiwan, kxchen@earth.sinica.edu.tw; WU, S., University of Hawai'i at Mānoa, Hawaii, USA, smwu@hawaii.edu; CHEN, Y., National Chung Cheng University, Chiayi, Taiwan, noise0221@gmail.com; GUNG, Y., National Taiwan University, Taipei, Taiwan, ycgung@ntu.edu.tw; NAKATA, N., Lawrence Berkeley National Laboratory, California, USA, nnakata@lbl.gov

Characterizing groundwater aquifer systems remains challenging in regions with complex subsurface structures. Here, we demonstrate how ambient noise tomography (ANT) offers a cost-effective, non-invasive alternative with high spatial resolution for comprehensive aquifer characterization. We deployed 257 seismometers in a dense array configuration, recording ambient seismic noise for one month. By analyzing Rayleigh wave group velocities, we developed high-resolution 3D models of shear wave velocity and azimuthal anisotropy to depths of 250 meters. We then integrated Hudson crack theory to relate observed anisotropy to fracture properties and estimate porosity distributions.

Our results reveal a layered aquifer system with distinct variations. Shallow depths (40-100 m) show low velocities (0.4-0.5 km/s) with various anisotropy strength and patterns. Intermediate depths (100-220 m) display higher velocities with more organized anisotropy patterns. These velocity and anisotropy variations provide key indicators for aquifer characterization. By integrating velocity structure with anisotropy patterns, we identify two distinct aquifer systems separated by a confining layer located at depths of 100-120 m. Systematic differences emerge when comparing recharge and discharge zones, with recharge areas consistently showing higher porosity. Anisotropy orientations display marked differences at shallow depths (-35° in recharge zones versus 20° in discharge zones) before converging at greater depths, consistent with Toth's (1963) hierarchical groundwater flow model. Our results demonstrate that ANT can image subsurface aquifer properties with continuous spatial coverage. This non-invasive approach offers insights into both storage capacity and preferential flow pathways, advancing sustainable groundwater management in complex hydrogeological settings.

POSTER 29

Probing the Full Potential Spectrum of Landslide Thickness

CHEN, L., Lawrence Berkeley National Laboratory, California, USA, lwchen@lbl.gov; VOIGTLÄNDER, A., Lawrence Berkeley National Laboratory, Berkeley, Germany, avoigtlaender@lbl.gov; TAIRA, T., University of California, Berkeley, California, USA, taira@berkeley.edu; GEUDEKER, C. W., University of California, Berkeley, California, USA, cgeudeker@berkeley.edu; TAIRA, R., University of California, Berkeley, California, USA, rinta.taira@berkeley.edu; KAYEN, R., University of California, Berkeley, California, USA, rkayen@berkeley.edu

Landslide hazards impact many areas of California's coastal range. An area which is densely populated, and hosts critical infrastructure. To anticipate and potentially mitigate the hazard, knowledge of the type of the landslide is required. The thickness of a landslide is a good indicator for the type, sensitivity to potential stressors (precipitation, seismicity, erosion), and modes of deformation during failure.

We deployed an array of three-component geophones and distributed acoustic sensing (DAS) techniques on a known landslide in the Berkeley hills on the premises of the Lawrence Berkeley Laboratory/UC Berkeley. We probed the landslide with active and passive seismic methods to characterize subsurface geometry and velocity structure , thereby determining landslide type. Three input sources were utilized: ambient noise, sledgehammer hits, and a shaker apparatus. Ambient seismic noise samples deeper depths with low frequencies, while sledgehammer hits resolve shallower parts with higher frequencies. The shaker apparatus generates controlled frequencies (5-250Hz), sampling both shallow and deeper parts. Integrating these sources provides observational constraints on seismic imaging of velocity structure.

The two independent sensor types improve the seismic wavefield capture, and local overlap of the sensor systems enable direct waveform comparison. In this presentation we will share initial results of subsurface velocity structures, derived from surface wave dispersion measurements, which allows us to determine the landslide thickness.

While the shaker apparatus provides high resolution of the internal properties, especially for shallow landslides, its applicability to less accessible slides is challenging. For these sites, ambient noise and sledgehammer hits are more readily available. In addition, ambient vibration may be the only method to probe properties of deep-seated landslides.

POSTER 30

Ambient Noise Imaging of Offshore Faults Using Distributed Acoustic Sensing in Monterey Bay, California

GOU, Y., University of California, Berkeley, California, USA, yuancong_gou@berkeley.edu; FUKUSHIMA, S., Tohoku University, Sendai, Japan, shun.fukushima.a1@tohoku.ac.jp; TAIRA, T., University of California, Berkeley, California, USA, taira@berkeley.edu; ZHU, W., University of California, Berkeley, California, USA, zhuwq@berkeley.edu; ALLEN, R., University of California, Berkeley, California, USA, rallen@berkeley.edu

Offshore faults in general are less characterized in geological and seismological studies due to limited accessibility. In California, a few offshore faults are considered to be capable of hosting large magnitude earthquakes from their historic seismicity. Compared to the adjacent on-shore faults, the lack of information on these offshore faults pose challenges for reliable seismic hazard evaluation. Traditionally, seismological methods like multibeam and active-source reflection surveys are mostly widely used in mapping and imaging offshore faults. Distributed Acoustic Sensing (DAS) can turn an existing

submarine cable to a dense ocean-bottom seismic array, allowing subsurface imaging with ambient noise interferometry.

We used data from SeaFOAM, a continuous DAS deployment project in Monterey Bay, California with a 52-km submarine cable crossing the offshore San Gregorio fault system to image the shallow fault velocity structures. We performed GPU-accelerated cross-correlation calculation across the DAS array and stacked results over half to one month to retrieve Scholte waves. We applied SPAC (SPatial AutoCorrelation) method to obtain dispersion curves up to 3 Hz. The fundamental mode of the Scholte wave was observed consistently across the array. The second overtone was also extracted in some cable sections, which can provide additional constraint on subsurface velocity structure. Our analysis shows a spatial variation of Scholte wave dispersion curves, suggesting a lateral variation of the seismic velocity structure along the cable. We plan to perform inversions to estimate a quasi-2D velocity map along the fiber cable to investigate the San Gregorio fault zone and previously identified unmapped faults.

POSTER 31

Monitoring Water in the Shallow Soil Using Ambient Noise Seismology

HAMMOND, J., Birkbeck, University of London, London, United Kingdom, james.hammond@bbk.ac.uk; DAVIDSON, K., Birkbeck, University of London, London, United Kingdom, kevin.davidson@bbk.ac.uk; LANE, V. S., University of Leicester, Leicester, United Kingdom, vl36@leicester.ac.uk; FINCH, L. E., University of Leicester, Leicester, United Kingdom, lef12@leicester.ac.uk; KENDALL, J., University of Oxford, Oxford, United Kingdom, mike.kendall@earth.ox.ac.uk; WALKER, A. M., University of Oxford, Oxford, United Kingdom, andrew.walker@earth.ox.ac.uk; OGDEN, C. S., University of Leicester, Leicester, United Kingdom, chris.ogden@leicester.ac.uk; HAN, C., Jilin University, Jilin, China, hancr@jlu.edu.cn; WU, J. C., Birkbeck, University of London, London, United Kingdom, jwu05@mail.bbk.ac.uk; RYAN, D., Birkbeck, University of London, London, United Kingdom, dlmr1@icloud.com; DOHERTY, K., Stryde, London, United Kingdom, ken.doherty@strydefurther.com; TRANTER, N., Stryde, London, United Kingdom, nick.tranter@stryde.io; O'TOOLE, T., Stryde, London, United Kingdom, tom.otoole@stryde.io

New advances in seismic sensor technology, such as seismic nodes are opening new applications for passive seismology, especially in the field of environmental seismology. In this talk I will introduce a new project that uses seismic nodes to study the critical zone, the so-called skin of our planet between the solid Earth and fluid atmosphere. In a collaboration with Stryde, the UK Centre for Hydrology and Ecology and Scotland's Rural College, we deployed 1600 seismic nodes with 5-10 m spacing in a farm in Dumfries, Scotland. Using seismic ambient noise coda wave interferometry, we can constrain small velocity changes with 10m spatial resolution and 30 minute temporal resolution at seismic frequencies sensitive to the top few metres of the Earth. These velocity changes show remarkable correlations with in-situ measurements of soil moisture. Soil physics models show that these velocity changes are driven by water table fluctuations, with sensitivity to just 10s cm variations in sandy soils to ~1m in clay rich soils. This shows the potential for passive seismology to be a new way to monitor soil moisture that can fill the existing temporal and spatial sampling gap between point measurements and those based on satellite data. Further, we captured a significant period of flooding in the Dumfries area and show that the deeper sensitivity of seismic waves means soil saturation is observable early in the seismic velocity measurements. This suggests it could offer a potential method for monitoring the potential water carrying capacity of soil, valuable information when monitoring potential flood risk.

POSTER 32

Using Ambient Noise to Monitor Groundwater and Industrial Activities in the Delaware Basin of Texas

HUANG, C., The University of Texas at Dallas, Texas, USA, cxh220055@utdallas.edu; ZHU, H., Southern University of Science and Technology, Shenzhen, China, zhuhj@sustech.edu.cn; USHAKOV, N., The University of Texas at Dallas, Texas, USA, nadine.igonin@UTDallas.edu; LUMLEY, D., The University of Texas at Dallas, Texas, USA, david.lumley@utdallas.edu; HENNINGS, P., The University of Texas at Austin, Texas, USA, peter.hennings@beg.utexas.edu; SMYE, K., The University of Texas at Austin, Texas, USA, katie.smye@beg.utexas.edu

Seismic velocity variations (*dv/v*) derived from scattered wavefields demonstrate significant sensitivity to pore pressure changes induced by fluid injection/extraction operations. Through analysis of continuous ambient noise records from the TexNet seismic network in the Delaware Basin, Texas, we quantify groundwater level change using 1D *dv/v* monitoring and subsurface deformation using 2D *dv/v* mapping. The basin-scale *dv/v* estimates, obtained through cross-correlation analysis of station pairs, reveal prominent seasonal oscillations in the low-frequency band (0.2-0.5 Hz) that exhibit strong correlation with regional groundwater level fluctuations and drought index variations. We use the cross-correlation of different stations to obtain the overall *dv/v* change.

At local scales, auto-correlation techniques applied to individual stations elucidate operational impacts from hydrocarbon activities. High-frequency dv/v signals (2-4 Hz) at noise-isolated stations distant from urban/infrastructure interference maintain phase coherence with aquifer dynamics, while exhibiting measurable responses to wastewater injection volumes and liquid production volumes.

Spatial 2D *dv/v* resolves centimeter-scale surface deformation patterns that show spatial-temporal consistency with InSAR-derived displacement fields, particularly in areas with intensive extraction/injection operations.

This multiscale monitoring framework demonstrates the capability of ambient seismic noise interferometry to simultaneously track both natural hydrologic cycles and anthropogenic fluid redistribution processes in sedimentary basins.

POSTER 33

Mapping Hydrologic Dynamics in the Critical Zone using Ambient Seismic Noise at a Legacy Mine in the Colorado Front Range

JAMES, S. R., U.S. Geological Survey, Colorado, USA, sjames@usgs.gov; BALL, L. B., U.S. Geological Survey, Colorado, USA, lbball@usgs.gov; WILSON, G. S., U.S. Geological Survey, Colorado, USA, gswilson@usgs.gov; SNOOK, M. H., Georgia Institute of Technology, Colorado, USA, msnook7@gatech.edu; MANNING, A. H., U.S. Geological Survey, Colorado, USA, amanning@usgs.gov

For lands impacted by the legacy of mining activity, understanding how water moves through the subsurface is of critical importance for restoration decisions. In the Colorado Front Range, the Perigo Mine operated primarily in the late 19th century and produced gold and silver ore from veins emplaced in north-northeast trending mineralized fracture zones within the gneiss bedrock. Low pH and metal-rich groundwater currently drains from the site through the mine tunnels, negatively impacting downstream surface water. To aid remediation plans for the site, we conducted a 1-year passive seismic monitoring study with the goals of 1) characterizing the geologic structure of the critical zone by mapping the thickness of colluvium and weathered bedrock extent, and 2) mapping spatiotemporal patterns in saturation and groundwater levels. From October 2023-2024, we continuously recorded ambient seismic noise on an array of 45 nodal seismic sensors deployed across the hillslope. Using coda-wave interferometry, we calculated cross-correlations between all station pairs which were then used for dispersion analysis to map the shallow geology, as well as for measurements of relative velocity variations (dv/v) as a function of time and frequency. Lastly, we produced timelapse maps of dv/v across the study site. Results from the dispersion analysis reveal colluvium thickens downslope and to the west of the mine tunnel, with shallower bedrock to the east. Comparison to soil moisture, groundwater wells, and precipitation indicate the dv/v timeseries respond to saturation changes related to both infiltration events and groundwater level fluctuations. Timelapse dv/v results at frequencies > 20 Hz show a dominant seasonal signal coinciding with infiltration of spring snowmelt water with the largest decreases in dv/v, indicating increased water saturation, located around the tunnel predominantly on its western side and around the discharge point. These preliminary results demonstrate the value of shallow ambient noise methods for mapping and monitoring subsurface hydrologic conditions.

POSTER 34

Discovering Spatial Variability of Critical Zone Processes at Mount Rainier using DAS

KOEPFLI, M., University of Washington, Washington, USA, koepflma@uw.edu; DENOLLE, M., University of Washington, Washington, USA, mdenolle@uw.edu; GAETE-ELGUETA, V., University of Washington, Washington, USA, velgueta@uw.edu; LIPOVSKY, B. P., University of Washington, Washington, USA, bpl7@uw.edu; SWANN, A., University of Washington, Washington, USA, aswann@uw.edu; CRISTEA, N., University of Washington, Washington, USA, cristn@uw.edu; MONTGOMERY, D., University of Washington, Washington, USA, bigdirt@uw.edu

Mount Rainier (4392 m a.s.l.), an active stratovolcano located ~95 km southeast of Seattle, WA, USA, poses hazards due to its steep glaciated slopes and highly porous volcanic surface. The combination of snowmelt, rainfall, and unstable surface materials frequently triggers debris flows and lahars, threat-

ening downstream communities. At the same time, Mount Rainier's glaciers play a crucial hydrological role, storing water that sustains rivers and therefore agriculture across the heavily populated lowlands during dry summer months.

To better understand the shallow subsurface (critical zone) and its connection to the surface, we collected data using Distributed Acoustic Sensing (DAS) along a ~40 km fiber-optic cable that spans over ~1000 m elevation and crosses diverse lithologies. We analyze ambient seismic noise by using auto- and cross-correlations to image and monitor near subsurface conditions and compare our results with data from nearby weather stations, river gauges, and soil pits.

We identify various coherent fiber sections and link the frequency content of seismic noise sources to local hydrological settings. We also find an increased signal-to-noise ratio for specific lithologies. Observed seismic velocity changes (dv/v) align with nearby ground moisture measurements but vary along the fiber. To explain these spatial variations, we investigate hydrological processes that connect surface conditions and subsurface responses.

POSTER 35

Time-domain Seismic Response Retrieval from Seismic Records of Dams Based on Interferometric Processing

KURODA, S., National Agricultural Research Organization, Tsukuba, Japan, kuroda.seiichiro457@naro.go.jp

The seismometers installed at dams in Japan have recorded numerous seismic events, including significant earthquakes. These records are invaluable for analyzing the response of dams during seismic activities, providing insights into their behavior and allowing for the derivation of indices reflecting the dynamic properties of the structures. Applying the principles of seismic interferometry, we employed its methods to the seismic records of dams, estimating both the properties of seismic wave propagation and the dynamic characteristics of the structures.

We examine the applicability of seismic interferometry to the seismic records of dams, specifically its use with small vibration records obtained from existing dam seismometers. These records encompass data from minor earthquakes, where the maximum acceleration is less than 1 cm/s^2, as well as ambient noise expected to include waveforms of latent micro-tremors. Through waveform analysis spanning over 10 hours, we demonstrate the capability to extract time-domain response waveforms from the records of small vibrations resembling those obtained from seismic records of significant earthquakes (maximum acceleration exceeding 2 cm/s^2). Importantly, these results highlight the potential for interferometric processing to be consistently applied, not only to seismic events but also to seemingly trivial records, such as ambient noise. This aspect has traditionally been overlooked by the existing seismometers of dams are primarily designed to measure seismic waves with strong amplitudes. We will also present a case study involving recent significant earthquake events.

POSTER 36

Alpine Fault Zone Structure Revealed Using Distributed Acoustic Sensing (DAS)

LAI, V., Australian National University, Canberra, Australia, voonhui.lai@anu.edu.au; MILLER, M. S., Australian National University, Canberra, Australia, meghan.miller@anu.edu.au; TOWNEND, J., Victoria University of Wellington, Wellington, New Zealand, john.townend@vuw.ac.nz

The Alpine Fault, which forms the boundary between the Pacific Plate and the Australian Plate, poses substantial seismic hazard to southern New Zealand, with magnitude ~8 earthquakes occurring on <300-year timescales, most recently in 1717 CE. The fault zone architecture is of particular interest, as it is hypothesized to influence coseismic fault rheology and fluid-rock interaction, which in turn affects local fault slip rates, moment release, and rupture propagation patterns.

Resolving the fault zone's architecture, including its geometry and velocity properties, requires high spatial resolution observations that can capture multiple length scales, from meter-scale fault core to kilometer-scale damage zone, and from the top few meters of the sedimentary layer to depths of several kilometers within the dipping fault. Distributed acoustic sensing (DAS), with its dense sensors, provides a unique opportunity to investigate and image the shallow fault zone architecture.

Here we present data and imaging results from SISSLE — the South Island Seismology at the Speed of Light Experiment — which made use of a DAS array running orthogonally across the surface trace of the Alpine Fault near Haast, South Westland, New Zealand. We obtained a shear wave velocity structure down to 500 meter across the fault zone through cross-correlation of a combination of traffic, earthquakes and microseism signals. The resulting model reveals a complex structure characterized by sedimentary deposits from a rich post-glacial depositional history, glacial erosional features, and fault damage zone structure. These findings are supplemented by waveform modeling, which helps explain observed anomalies in local earthquake recordings such as fault zone trapped waves due to distinct fault strands and secondary scattering due to shallow bedrock irregularities. This high-resolution view of the Alpine Fault zone architecture near a paleoseismologically recognized segment boundary enhances our ability to assess seismic hazards and inform mitigation strategies' late in the fault's typical interseismic phase.

POSTER 37

Bayesian Time-lapse Full-waveform Inversion for Geological CO2 Storage Monitoring Using Hamiltonian Monte Carlo

LI, H., Stanford University, California, USA, haipeng@sep.stanford.edu; CLAPP, R., Stanford University, California, USA, bob@sep.stanford.edu; BIONDI, B., Stanford University, California, USA, biondo@sep.stanford.edu

Time-lapse full-waveform inversion (TL-FWI) is a powerful technique for monitoring the migration of CO_2 plumes during geological carbon storage. However, the ill-posed nature of TL-FWI, especially under sparse acquisition typical of real-world deployments constrained by cost, makes the inversion results highly sensitive to noise and prone to non-unique solutions. Quantifying uncertainty is therefore essential for assessing the reliability of monitoring results and supporting confident interpretation. Yet, conventional deterministic TL-FWI lacks uncertainty quantification.

We present a Bayesian TL-FWI framework integrating Hamiltonian Monte Carlo (HMC) sampling with a prior-guided Radial Basis Function (RBF) model-order reduction strategy to quantify uncertainties in CO_2 plume monitoring. HMC is particularly well-suited for inverse problems due to its use of gradient-informed proposals, which enable efficient exploration of high-dimensional posterior distributions. The RBF-based dimensionality reduction further enhances computational efficiency by reducing the number of model parameters while preserving spatial resolution in target zones.

Our workflow begins with constructing realistic CO_2 injection scenarios based on a multi-physics simulation workflow, including the multi-phase flow modeling and rock physics updating of the elastic moduli. We apply this to the geologically complex SEG SEAM model with realistic stratigraphy, simulating CO_2 injection into a depleted reservoir. Applying the proposed Bayesian monitoring method, HMC sampling produces credible uncertainty maps that reveal both well-resolved and ambiguous regions. These maps offer actionable insights for risk-aware subsurface monitoring, such as identifying areas where denser source coverage may be needed to better constrain potential CO_2 leakage zones. Overall, our method enables quantitative assessment of CO_2 plume distribution and uncertainties, especially under sparse acquisition.

POSTER 39

Optimizing 3D Distributed Acoustic Sensing Arrays and Detection Algorithms to Detect Low-signal-to-noise Subsurface Sources

MAIER, N., Los Alamos National Laboratory, New Mexico, USA, nmaier@lanl.gov; DONAHUE, C., Los Alamos National Laboratory, New Mexico, USA, cmd@lanl.gov; WOO, J., Los Alamos National Laboratory, New Mexico, USA, woo@lanl.gov; FRASH, L., Los Alamos National Laboratory, New Mexico, USA, lfrash@lanl.gov

Seismic sources can provide insight into structure and dynamics of subsurface storage reservoirs. For instance, microseismicity can be used to identify pressurized fluid flow pathways, and continuous noise sources can potentially identify geologic leakage points. Here, we present experiments where we use synthetic models to optimize location algorithms for three-dimensional distributed acoustic sensing (DAS) arrays applied to energy storage and production. Because deploying 100's to 1000's of DAS sensors is relatively inexpensive, DAS is quickly supplementing traditional monitoring capabilities applied to subsurface reservoirs. However, the unique properties of DAS mean that traditional location techniques need to be optimized for directionality and spatially integrated nature of the measurements. Here, we present modelling experiments used to optimize matched-field-processing for DAS arrays in an effort to locate low signal-to-noise sources related to reservoir dynamics. We use specFEM3D to generate synthetic noise field and target sources, and test different three-dimensional fiber array configurations. We compare the location results and detection capabilities compared to traditional, but more expensive and laborious to deploy, three-component seismometer arrays. Finally, we apply the methods to preliminary data from a three-dimensional borehole array in an effort to locate fluid noise sources in the Sulfur Springs hydrothermal field located within the Valles Caldera in New Mexico.

LA-UR-25-24721

POSTER 40

Probing Soil Moisture Groundwater Drainage Dynamics in High-relief Environments Using Seismic Velocity Variations

MAKUS, P., GFZ Postdam, Potsdam, Germany, makus@gfz.de; ILLIEN, L. N., GFZ Postdam, Potsdam, Germany, lillien@gfz.de; TEAGAI, K., GFZ Postdam, Potsdam, Germany, kapiolani.teagai@gfz.de; CHANG, J., National Yang Ming Chiao Tung University, Taipei, Taiwan, geomingical@gmail.com; TUROWSKI, J. M., GFZ Postdam, Potsdam, Germany, turowski@gfz.de; HOVIUS, N., GFZ Postdam, Potsdam, Germany, hovius@gfz.de

Many questions concerning the hydrological dynamics in mountainous environments remain open. This is not only due to the system's inherent complexity but also to the inaccessibility of measuring sites, preventing direct observations of surface waters and groundwaters. Here, we explore the influences of drainage dynamics on the seismic velocity. To this end, we compute seismic velocity changes (*dv/v*) from different frequency bands of the ambient seismic noise, targeting processes occurring at multiple depths. At our field site, Taroko National Park, Taiwan, we can compare the composite *dv/v* time series with direct observations of soil moisture, well piezometers, river gauges, and weather data. We exploit these multi-modal observations to develop a conceptual model of the drainage dynamics at our field site and to confine further the physical relationships governing the dynamics of *dv/v*.

POSTER 42

4-Dimensional Characterization of Groundwater, Oil, and Gas Production at the Eagle Ford Basin, TX

PENG, H., University of Texas at Austin, Texas, USA, hrpeng@utexas.edu; MAO, S., University of Texas at Austin, Texas, USA, smao@jsg.utexas.edu

Located in South Texas, the Eagle Ford (EF) Basin has experienced intensive unconventional oil and gas production since 2008, as well as irrigation since the last century. The associated anthropogenic activities, such as hydraulic fracturing, wastewater disposal, and groundwater pumping, compounded by natural precipitation variability, have continuously modified the region's subsurface stress state and medium properties. Their cumulative impact is reflected in increased seismicity and land subsidence in recent years.

To characterize these dynamic processes, we conduct time-lapse seismic velocity monitoring in the central EF Basin using continuous ambient noise records from ~30 seismic stations operating since 2019. We employ ambient field interferometry and advanced coda-wave imaging to monitor subtle changes in seismic velocity (dv/v) over time and space. We apply multiple stacking and denoising strategies to suppress incoherent perturbations in cross-correlation functions (CCFs) and improve the reliability of dv/v time series. The spatial distribution of these changes is imaged through tomography methods based on recently developed coda-wave sensitivity kernels.

Our analysis reveals substantial spatial variabilities in dv/v in the EF basin stemming from different sources. We observe pronounced dv/v seasonality in the southwestern part of the study area, reflecting aquifer recharge and extraction associated with heavy irrigation in the area. In contrast, dv/v in the basin's center exhibits more complicated behavior, likely affected by the intense hydrocarbon production and induced seismicity. These observations suggest different physical mechanisms that dominate dv/v at varying depths and locations. Our study demonstrates the promise of using spatiotemporal dv/v measurements to characterize complex dynamic processes in the shallow subsurface, to aid in hazard assessment and sustainable resource management.

POSTER 43

Imaging Earth's Subsurface with Thunderstorm-generated Seismic Waves

ROTH, N., Pennsylvania State University, Pennsylvania, USA, njr5569@psu.edu; ZHU, T., Pennsylvania State University, Pennsylvania, USA, tuz47@psu.edu; CZARNY, R., Pennsylvania State University, Pennsylvania, USA, rafal.czarny@imsi.org; KIM, Y. C., Pennsylvania State University, Pennsylvania, USA, yvk5286@psu.edu

Thunder generates acoustic waves that couple into the environment, creating seismic signals called "thunderquakes" capable of probing the Earth's shallow subsurface. In this study, we demonstrate that thunderquakes can be effectively used for passive seismic tomography by leveraging hundreds of thunderquakes recorded by Distributed Acoustic Sensing (DAS) to image the subsurface of an urban karst terrain in Central Pennsylvania. The resulting image reveals several previously undetected weak zones, some coinciding with surface subsidence measured by Interferometric Synthetic Aperture Radar (InSAR). The tomographic results are validated by independent borehole logs and engineering surveys. This work establishes thunderquakes as novel, meteorologically-driven sources for passive seismic imaging in regions with limited access to traditional seismic sources.

POSTER 44

Seismology in Abandoned Mine Reclamation—Active- and Passive-source Case Studies from Seven Projects

STEELE, L., Tetra Tech, Inc., Colorado, USA, lincoln.steele@tetratech.com; LEVANDOWSKI, W., Tetra Tech, Inc., North Carolina, USA, will.levandowski@tetratech.com; MIRZANEJAD, M., Tetra Tech, Inc., Nevada, USA, majid.mirzanejad@tetratech.com; O'CONNELL, D. R. H., Tetra Tech, Inc., Colorado, USA, geomgcn@gmail.com

Reclamation of abandoned mine sites presents a wide array of technical challenges. Subsurface imaging can be used to assess the soil and rock conditions at the site, providing geotechnical metrics of soil and slope stability, or allowing volumetric estimates of void space or contaminant. Here we present several case studies of seismic investigations of abandoned mine lands. HVSR and more advanced applications thereof are useful for slope stability analysis. In one case, a mining town built into a ~30-degree slope with pitches as steep as 65 degrees, HVSR was used both for slope stability analysis and imaging. Active-source imaging is applicable as well. We will present two examples of abandoned coal mine imaging—one with P-wave attenuation tomography and one with seismic reflection—and one with full-waveform tomography. Using active and passive seismic methods, we can effectively map out mine workings and assess the condition of the surrounding rock and waste materials, including managing tailings or waste rock storage facilities. In conclusion, we propose a framework that integrates these geophysical methods into mine closure planning, offering a promising path forward for planning environmental remediation efforts.

POSTER 46

Time-dependent Variations of F_0 and ΔV/V in 1D and 2D Sedimentary Structures

TIBONI, B., University of Bologna, Bologna, Italy, beatrice.tiboni2@unibo.it; CASTELLARO, S., University of Bologna, Bologna, Italy, silvia.castellaro@unibo.it

Over the past two decades, single-station ambient noise measurements have proven effective in studying ground dynamics, particularly for identifying the resonance frequency (f_0), which reflects the elastic properties of the subsurface. Recent studies (Lattanzi et al., 2023; Vassallo et al., 2022) show that f_0 and the H/V spectral ratio vary seasonally. Mao et al. (2022) also observed seasonal variations in seismic wave velocity (ΔV/V) using cross-correlation techniques, suggesting a link between ΔV/V and f_0 due to their mutual dependence on ground stiffness. However, this relationship remains underexplored.

This study investigates whether ΔV/V alone can explain observed f_0 variations, using the same Los Angeles Basin dataset as Mao et al. (2022). We analyzed H/V peak frequencies and spectral features at five broadband stations. Under 1D conditions, H/V peaks align with minima in the vertical spectrum, linked to Rayleigh waves, while horizontal peaks relate to S-wave or Love wave resonances (Castellaro, 2016; Castellaro & Musinu, 2022). In 2D cases, H/V peaks match horizontal spectral peaks, indicating S-wave resonances.

Our findings show clear seasonal and diurnal variations in f_0 and H/V peaks. In 1D settings, H/V peaks were anticorrelated with horizontal spectral peaks and correlated with vertical P-wave resonances. In 2D Alpine basins, H/V peaks and S-wave resonances were positively correlated. Notably, resonance frequencies increased in summer in Alpine basins, but behaved differently in Los Angeles, suggesting distinct underlying mechanisms.

The amplitude of frequency variations exceeds what would be expected from ΔV/V alone. The persistent anticorrelation between Rayleigh vertical components and body-wave resonances remains unexplained. These findings imply that seasonal frequency changes cannot be fully attributed to groundwater or stiffness variations, and that multiple, interacting factors must be considered.

POSTER 47

Tracking Spatiotemporal Transportation of Magma Reservoirs Beneath Piton de la Fournaise by Using Ambient Noise Cross-correlation Functions

ZHANG, S., University of Texas at Austin, Texas, USA, shuo.zhang@jsg.utexas.edu; MAO, S., University of Texas at Austin, Texas, USA, smao@jsg.utexas.edu; SEN, M., University of Texas at Austin, Texas, USA, mrinal@utexas.edu; SHAPIRO, N., Institute of Earth Sciences, French National Centre for Scientific Research, University of Grenoble Alpes, Grenoble, France, nikolai.shapiro@univ-grenoble-alpes.fr

Piton de la Fournaise is one of the most active and best-instrumented volcanoes in the world. It serves as a natural laboratory for understanding magma transport and testing advanced volcanic monitoring techniques. The spatiotemporal evolution of subsurface pressure, often associated with pre-eruption pressurization and co-eruption pressure release, can be detected by changes in seismic velocity (dv/v). We measure the temporal and spatial variations of dv/v from 2014 to 2024 based on ambient seismic noise recorded by a dense seismic network around the caldera. We apply multi-frequency analysis to investigate the dynamic processes across depth : shallow dv/v variations, exhibit short-term perturbations that coincide with volcanic tremors and eruptions; in contrast, dv/v measured at greater depths reveal long-term trends that correlate with GPS-derived surface deformation, likely indicating deeper magmatic activity. Using sensitivity kernels of seismic coda-wave, we invert the time shift measured at consecutive lapse times into two-dimensional dv/v maps at multiple depths. Grid meshing based on Voronoi tessellation allows us to optimize the spatial resolution adapted to the irregular station coverage. The imaging results reveal a persistent pressure accumulation on the eastern flank of the caldera between 2019 and 2021, occurring between two major eruptions. Our analyses demonstrate how noise-based spatiotemporal dv/v measurements can be applied to track subsurface pressure changes with high spatial and temporal resolution. These are important for in understanding magma dynamics, and detecting potential precursors prior to eruptions at Piton de la Fournaise and other active volcanic systems.

POSTER 48

Using Coda Wave Interferometry to Monitor Changes of Groundwater, Glacier and Rivers

ZHU, H., Southern University of Science and Technology, Texas, USA, zhuhj@sustech.edu.cn; ZHANG, S., University of Texas at Austin, , USA, shuo.zhang@jsg.utexas.edu; LUO, B., University of Arizona, , USA, bingxuluo@arizona.edu; LUMLEY, D., University of Texas at Dallas, , USA, david.lumley@utdallas.edu

In this presentation, we will demonstrate the applications of coda wave interferometry in exploring the dynamic response of the Earth to various environmental processes. The focus will be on measuring relative seismic velocity changes, indicative of near-surface fluctuations influenced by factors such as temperature, pore space, water saturation, fractures, and faults. Three case studies will be used to show the potential of utilizing seismometers for monitoring environmental phenomena. The first case study examines spatial and temporal variations in seismic velocity, providing valuable insights to groundwater recharge/discharge cycles. Central Oklahoma and West Texas will be used as examples to illustrate the relation between groundwater fluctuation and near surface seismic velocity changes. The second case study involves the usage of long-term seismometers in Greenland to investigate seasonal and long-term changes in seismic velocity, which enhances our understanding of how the Earth's crust responds to loading and unloading cycles associated with ice sheet melting. The final case study explores the potential of utilizing near-surface seismic velocity changes to study baseflow of rivers, illustrated by an example from twelve-year dv/v observation in a watershed of the Yellowstone National Park, which offers valuable implications for river monitoring and mitigation strategies. These case studies show the potential of turning thousands of seismometers to monitor environmental changes.

POSTER 49

Using Water Level Responses to Atmospheric Pressure Variations to Measure and Monitor Vertical Leakage Through Confining Units, With Application to the Jurassic Shaximiao Crust, China

ZHANG, Y., Chinese Academy of Sciences, Beijing, China, eve_041744@163.com; MANGA, M., University of California, Berkeley, California, USA, mmanga@berkeley.edu; YANG, Q., Chinese Academy of Sciences, Shanghai, China, yangqiuye18@mails.ucas.edu.cn

The upper few hundreds of meters of the crust often hosts leaky aquifers. Quantifying leakage is important if those aquifers are used as a water resource. The responses of water level to external forcing such as tides and barometric pressure changes offer the opportunity to measure aquifer hydrogeological properties and monitor possible changes in those properties. Around the Huayingshan faults adjacent to Sichuan and Chongqing provinces, China, inclined fold-and-thrust belts form the crust, and frequent earthquakes might impact aquifers in the shallow crust that are used for drinking water. We introduce a new computational approach for continuous modeling of water level changes in response to barometric pressure variations to identify when the signals are reliable and then determine values of aquifer transmissivity and aquitard hydraulic diffusivity. Computed aquifer transmissivity agrees with values from well tests. We obtain horizontal and vertical hydraulic parameters for more than 10 years (from 2008 to 2019). Of the six wells studied, five have aquitard vertical hydraulic diffusivities at least two orders of magnitude greater than aquifer horizontal transmissivity. Although several regional and tele-seismic earthquakes caused changes in water levels in one of the wells with relatively low vertical permeability, we do not see clear changes in hydraulic properties in response to the earthquakes. We also identify small long-term trends and seasonal variations in hydrogeological properties.

POSTER 50

Monitoring Groundwater Fluctuations in Norway and Sweden Using Ambient Seismic Noise

LOVIKNES, K., University of Oslo, Oslo, Norway, karina.loviknes@mn.uio.no; AIKEN, J. M., University of Oslo, Oslo, Norway, john@xal.no; RENARD, F., University of Oslo, Oslo, Norway, francois.renard@mn.uio.no

As climate change induces more frequent droughts in larger areas, effective groundwater monitoring is becoming increasingly important. Ambient seismic noise can detect groundwater fluctuations through changes in seismic velocity in the subsurface. While this method has been successfully applied using dense networks, new challenges arise when applying it to sparser networks, such as the Norwegian and Swedish seismic networks, due to non-uniform noise sources. This study aims to improve the monitoring of groundwater in central Scandinavia by combining various measurements of groundwater changes, such as groundwater well measurements, GRACE satellite data, and continuous seismic signals recorded in Norway and Sweden.

Index of Authors