PACLIM 2025

Human Perspectives on Water in the West
Past, Present, and Future

31st PACIFIC CLIMATE WORKSHOP

HUMAN PERSPECTIVES ON WATER IN THE WEST: PAST, PRESENT, AND FUTURE

Asilomar State Conference Grounds
Pacific Grove CA
February 23-26, 2025

PACLIM is a multidisciplinary workshop that broadly addresses the climatic phenomena occurring in the eastern Pacific Ocean and western North America. The purpose of the workshop is to improve our understanding of climate effects in this region by bringing together specialists from diverse fields including physical, social, and biological sciences. Timescales from modern to the Quaternary are addressed in both oral and poster presentations.

Funding for the workshop and travel grants for students and early career scientists was generously provided by:

- U.S. Geological Survey's Land Use Change Program
- U.S. Geological Survey's Office of the Southwest Regional Director
- The Desert Research Institute: **In Memory of Kelly Redmond**
- A private donation **In Memory of Wolf Berger**

We are also grateful for additional donations from Scott Mensing, Kathleen Springer, Jeff Pigati, Don Sullivan, Megan Walsh, Susan Zimmerman, and Anna Klimaszewski-Patterson.

In 2023, Friends of PACLIM (or FOPAC) was established as a 501(c)3 non-profit corporation for the purpose of advancing scientific understanding of past, present, and future Pacific climate and to support the Pacific Climate Workshop in perpetuity. The current board consists of Jeff Pigati and Kathleen Springer (co-Presidents), Jessica Oster (Secretary), Susan Zimmerman (Treasurer), Anna Klimaszewski-Patterson (Communications Officer), and Scott Starratt (PACLIM Volume Editor). The position of Fundraising Coordinator is currently vacant.

The 2025 PACLIM Workshop was organized by the FOPAC board with the help of Organizing Committee members Scott Mensing, Marie Champagne, Chris Soulard, and Megan Walsh.

Asilomar State Beach and Conference Grounds sits in the ancestral territory of the Indigenous Esselen and Rumsen speaking First Peoples. We acknowledge and honor Indigenous Peoples ancestral connection to this land.

HUMAN PERSPECTIVES ON WATER IN THE WEST: PAST, PRESENT, AND FUTURE

Registration

Check in at the Asilomar main lobby for your room assignment

Meeting registration will occur in the Fred Farr Room Sunday between 4:30 and 5:30 pm

Meeting Schedule

Sunday
- **Evening**

Monday
- **Morning**
- **Afternoon**
- **Evening**

Tuesday
- **Morning**
- **Afternoon**
- **Evening**

Wednesday
- **Morning**

Posters

Abstracts

ORAL PRESENTATIONS WILL TAKE PLACE IN THE FRED FARR ROOM

POSTER SESSIONS WILL BE IN THE KILN ROOM

SCHEDULE

SUNDAY EVENING, February 23rd

4:30-5:30 pm	MEETING REGISTRATION
6:00-7:00 pm	DINNER – Crocker Dining Hall
7:15-7:20 pm	**Welcome and Opening Remarks**
	Jeff Pigati and Kathleen Springer. U.S. Geological Survey
7:20-7:30 pm	**Introduction – Kelly Redmond Keynote Presentation**
	Jeff Pigati. U.S. Geological Survey
7:30-8:30 pm	**Keynote talk: Current state of the climate in the western U.S.**
	Daniel McEvoy, Desert Research Institute
8:30-10:00 pm	**POSTERS AND SOCIALIZING**

MONDAY MORNING, February 24th

7:30-8:30 am	BREAKFAST – Crocker Dining Hall
8:45-8:50 am	**Opening Remarks**
	Jeff Pigati and Kathleen Springer. U.S. Geological Survey
8:50-9:40 am	**Invited talk: Atmospheric rivers in the western United States under past and future climate change in the high-resolution Community Earth System Model**
	Sophia Macarewich, U.S. Geological Survey
9:40-10:30 am	**Invited talk: ARkStorm: past, present, and future**
	Anne Wein, U.S. Geological Survey

10:30-10:50 am	BREAK
10:50-11:10 am	**Lake Manix carbonate stable isotope record documents climate change in the Mojave Desert across four glacial terminations** Jessica Oster, Vanderbilt University
11:10-11:30 am	**Reconstructing the upwelling history of the California Current system over the last 21,000 years: a status update** Jason Addison, U.S. Geological Survey
11:30-11:50 am	**Progress toward quantitative estimates of past rainfall during the last glacial cycle from Ca isotopes in two coeval California speleothems** Cameron de Wet, Middlebury College
12:00-1:00 pm	LUNCH – Crocker Dining Hall

MONDAY AFTERNOON, February 24th

1:15-2:05 pm	**Invited talk: Timing, rates, responses, and geomorphic signatures of climate change in the Great Basin, USA** Kenneth Adams, Desert Research Institute
2:05-2:55 pm	**Invited talk: High-resolution regional modeling of western North America for the past 21,000 years** Jay Alder, U.S. Geological Survey
2:55-3:25 pm	BREAK AND GROUP PHOTO
3:25-4:15 pm	**Invited talk: A tale of two annual cycles: the remarkable change in Pacific cold tongue seasonality under orbital forcing** John Chiang, University of California Berkeley
4:15-4:35 pm	**Preliminary results from the Bering Land Bridge coring expedition** Beth Caissie, U.S. Geological Survey

4:35-4:55 pm	**Large amplitude SST variability in the Gulf of Alaska during the Holocene**
	Jessica Tierney, University of Arizona
6:00-7:00 pm	DINNER – Crocker Dining Hall

MONDAY EVENING, February 24th

7:20-7:30 pm	**Introduction – Evening Keynote Presentation**
	Susan Zimmerman, Lawrence Livermore National Laboratory
7:30-8:30 pm	**Keynote talk: Inner GPS, homing in**
	Marc Chavez, Native Like Water
8:30-10:00 pm	**POSTERS AND SOCIALIZING**

TUESDAY MORNING, February 25th

7:30-8:30 am	BREAKFAST - Crocker Dining Hall
8:45-8:50 am	**Opening Remarks**
	Jeff Pigati and Kathleen Springer. U.S. Geological Survey
8:50-9:40 am	**Invited talk: Recent developments and combined use of climate and satellite data for operational natural resource monitoring and advanced process understanding**
	Justin Huntington, Desert Research Institute
9:40-10:30 am	**Invited talk: Political ecology and critical physical geography: frameworks for thinking critically about drought and water management**
	Alida Cantor, Portland State University

10:30-10:50 am	BREAK
10:50-11:10 am	**Coeval Holocene stalagmites record linkages between ENSO and Rocky Mountain hydroclimate for the past 2800 years**
	Bryce Belanger, Vanderbilt University
11:10-11:30 am	**Holocene peatland stratigraphy in the Sierra Nevada, California and the southern Rocky Mountains: climate implications**
	Donald Sullivan, University of Denver
11:30-11:50 am	**Matching acceleration in rate of glacier changes on Mount Hood, OR and Mount Baker, WA 1980-2023**
	Nicolas Bakken-French, Oregon Glaciers Institute
12:00-1:00 pm	LUNCH – Crocker Dining Hall

TUESDAY AFTERNOON, February 25th

1:15-1:35 pm	**Misalignment between objective and perceived risks exacerbates vulnerability to extreme heat**
	Jennifer Marlon, Yale University
1:35-1:55 pm	**Paleoenvironmental investigations of permanent water features in sagebrush steppe ecosystems in the Columbia Basin, Washington**
	Megan Walsh, Central Washington University
1:55-2:15 pm	**Environmental change over the past 2000-4000 years in the central Sierra Nevada, California**
	Theodore Dingemans, Augustana College
2:15-2:35 pm	**Pre-Columbian human influences on a mixed-conifer forest, Sierra National Forest, CA**
	Anna Klimaszewski-Patterson, Sacramento State University

2:35-2:55 pm	**Using lidar and satellite imagery to evaluate meadow channel geometry and vegetation dynamics**
	Chris Soulard, U.S. Geological Survey
2:55-3:15 pm	BREAK
3:15-3:35 pm	**Fog water collection along the central California coast**
	Daniel Fernandez, California State University, Monterey Bay
3:35-5:15 pm	**FIELD TRIP TO THE MONARCH GROVE SANCTUARY**
	Stuart Weiss, Creekside Science
	Asilomar is ~ 1 km from a premier overwintering site at Monarch Grove Sanctuary. Stuart Weiss has been undertaking research at the sanctuary since 1997. The Sanctuary is a 3-minute drive or 15-minute walk. Stuart will discuss how the structure of the forest and microclimate affect Monarch butterflies. https://www.pgmuseum.org/monarch-viewing
	This fieldtrip is optional.
6:00-7:00 pm	DINNER – Crocker Dining Hall

TUESDAY EVENING, February 25th

7:20-7:30 pm	**Introduction – Evening Keynote Presentation**
	Kathleen Springer, U.S. Geological Survey
7:30-8:30 pm	**Keynote talk: Lessons in climate change storytelling**
	Rosanna Xia, Environmental Reporter for the Los Angeles Times
8:30-10:00 pm	**POSTERS AND SOCIALIZING**

WEDNESDAY MORNING, February 26th

7:30-8:30 am	BREAKFAST - Crocker Dining Hall
8:45-8:50 am	**Opening Remarks**
	Jeff Pigati and Kathleen Springer. U.S. Geological Survey
8:50-9:10 am	**North Pacific decadal variability during the Common Era and its impacts on ecosystems**
	Samuel Mark, University of Buffalo
9:10-9:30 am	**Impact of antecedent fuel alterations on wildfire severity measurements in California's coniferous forests**
	Benjamin Nauman, University of California, Los Angeles
9:30-9:50 am	**High-resolution western US hydroclimate reconstruction for hydrological modeling and water resources management**
	Jakob Jones, University of California, Los Angeles
9:50-10:10 am	**The past and future of the Truckee River: a 500-year tree-ring reconstruction of river streamflow**
	Victoria Harris, University of Iowa
10:10-10:30 am	**At the crossroads: the Colorado River in the age of climate change**
	George Rhee, University of Nevada, Las Vegas
10:30-10:50 am	BREAK
10:50-11:10 am	**Identifying vulnerable stands and refugia of vegetation under aridification: climatic water deficit limits and the trailing edge of vegetation shifts**
	Stuart Weiss, Creekside Science
11:10-11:30 am	**Introducing geographically scalar climatic entities and their associated and nonrepresentationally realist climatic objects**
	Charles Jackson, New Mexico State University

11:30-11:50 am	**Compilation of 1984 - 2022 PACLIM proceedings, reports, and abstracts**
	Arndt Schimmelmann, Indiana University
11:50-11:55 am	**Closing Remarks**
	Jeff Pigati and Kathleen Springer. U.S. Geological Survey
12:00-1:00 pm	LUNCH – Crocker Dining Hall

POSTERS

The role of the Western North Pacific (WNP) as an El Niño–Southern Oscillation (ENSO) precursor in a warmer future climate

Krishna Borhara, Utah State University

Earth, wind, and fire: disturbance events recorded in subalpine lake sediments of the interior Rocky Mountains

Christy Briles, University of Colorado Denver

The flaming frontier: grassland and sagebrush contributions to fire activity in northern New Mexico over centennial to millennial timescales

Molly Burke, University of Utah

A multi-proxy late glacial to early Holocene environmental reconstruction from a Clear Lake, CA sediment core

Marie Champagne, U.S. Geological Survey

Exploring the variability of precolonial wildfire activity: preliminary results from the western Klamath Mountains

Gabriela Cuellar, California State University – Sacramento

Wildfire in the central Baja peninsula: a ~13,500-year charcoal record

Samuel Enke, University of Utah

Paleoclimate signals in Last Glacial Maximum sediments from New Mexico

Anna Fatta, University of Arizona

Lacustrine record from Summit Lake, NV, USA, shows a period of sustained drought associated with Medieval Climate Anomaly

Ayowole Fifo, University of Nevada, Reno

Holocene fire-human-climate interactions near Progresso Lagoon in northern Belize

Bronwen Hardee, Central Washington University

Comparison between sedimentary charcoal and wildfire indicators from a transient climate model for the western US over ~15 ka

Piper Harring and Aiden Pape (co-first authors), Middlebury College

Paleoecological history of the Bear River Massacre Site

Kylee Haslam, University of Utah

Exploring fire dynamics in the northern Rocky Mountains during the Holocene

Lauren Isom, University of Utah

Using sediment pH to infer paleo fires: exploring ash impact

Rohit Joshi, California State University, Sacramento

Anthropogenic disturbance and hurricanes explain the timing and magnitude of hydrologic change on an atoll island ecosystem

Clarke Knight, U.S. Geological Survey

A fire history for Palo Atravezado Ciénega, Sierra de San Pedro Martir National Park, Baja California, Mexico

Emma Layon, University of Utah

Late Holocene water quality reconstruction in Lily Pond Lake, Colorado

Sandra Lee, University of Colorado Denver

Paleoenvironmental Information about a ~12,000-year-old human trackway site in the West Desert of Utah

Melanie Osuna, University of Utah

A suppression cost comparison of three classes of wildland fires in the U.S.

Stephanie Overla, Central Washington University

The geochronology of the human footprints at White Sands is resolved

Jeff Pigati, U.S. Geological Survey

Expression of Dansgaard-Oeschger warming events in the California Current region

Summer Praetorius, U.S. Geological Survey

Automated imaging and the application of machine learning to enhance quality and speed of sedimentary charcoal quantification

Liubov Presnetsova, U.S. Geological Survey

How do fires and earthquakes impact Late Holocene sediment flux in the Transverse Ranges?

Katherine Scharer, U.S. Geological Survey

Late Holocene vegetation change at Range Creek Canyon Utah

Marti Sorensen, University of Utah

An early Holocene wet period in the southwestern United States

Kathleen Springer, U.S. Geological Survey

Increased monsoon activity during the Last Interglacial on the southern California Margin

Allie Thompson, Syracuse University

Fire history and climate responses in Fish Lake, Utah

Maya Upton, University of Utah

Exploring paleohydrology with XRF in the west desert

Madelyn Vorkink, University of Utah

Characterizing biological communities of the Bering Land Bridge using sedaDNA

Ciara Wanket, University of California, Santa Cruz

Deciphering two-phase global hydroclimate patterns during Heinrich Stadial 1

Zoe Zenker, University of California, Davis

Reconstructing hydroclimate patterns in coastal Central California using coeval stalagmite records from White Moon Cave

Aida Zyba, Vanderbilt University

2025 PACLIM ABSTRACTS

Timing, rates, responses, and geomorphic signatures of climate change in the Great Basin, USA

Kenneth D. Adams

Desert Research Institute, 2215 Raggio Parkway, Reno, NV 89512, kadams@dri.edu

This presentation focuses on climate-induced hydrologic and geomorphic changes in the Great Basin of the western US since the late Pleistocene and how these types of changes may have influenced early inhabitants in the region. There are many different dynamic geomorphic systems in the Great Basin that have responded to and recorded climate changes through time, including closed lake basins, the rivers that feed them, and alluvial fan complexes. Each of these systems responds in their own ways and probably own rates, but an underlying theme to this talk is that the different geomorphic systems seem to rapidly respond to even relatively minor climate changes. Documenting past changes and response times provide an important perspective for understanding the potential effects of current and future climate changes.

Determining the approximate age of a geomorphic feature, such as a beach ridge in a pluvial lake basin for example, is relatively straight forward, but figuring out how quickly that shoreline formed or how long it was washed by waves or how long it took for the lake to rise and then fall from that level is more challenging. From a geoarchaeological perspective, one would like to know the answers to these questions because they provide the context for archaeological sites and provide clues as to what people might have been doing there and for how long.

The issues associated with defining rates of landform formation and change are more acute for older landforms or deposits because of the inherent uncertainties associated with most types of dating. One approach to better quantifying timing and rates of change in different geomorphic systems is to focus on more recent events and responses, when dating approaches are generally more precise. As an example, radiocarbon ages of young shorelines can be refined using moisture-sensitive, annually resolved tree ring records. These same records can also be used as input into paleohydrologic models to simulate the timing, rates, and magnitudes of past stream flows and lake-level changes. The insights gained from these studies, in turn, can inform the pace of climate and landscape changes deeper in the past.

Return to Monday afternoon schedule

Reconstructing the upwelling history of the California Current system over the last 21,000 years: a status update

Jason Addison [a] , Jay Alder [a] , Beth Caissie [a] , Summer Praetorius [a] , John Barron [a] , David Bukry [a] , Bruce Finney [b] , Amy Wagner [c] , Charlie Paull [d] , Roberto Gwiazda [d] , Eve Lundsten [d] , Maureen Walton [e]

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The California Current System (CCS) stretches for more than 3,000 km along a narrow band offshore from Vancouver Island to the southern tip of the Baja California Peninsula. A defining characteristic of this eastern boundary current is seasonal wind-driven coastal upwelling that brings cool water and dissolved nutrients to the surface ocean, which are crucial to support the vibrant and diverse marine ecosystem that much of the US West Coast relies upon for commercial fisheries resources, recreational fishing, tourism, and other economically important activities. Furthermore, CCS dynamics also play an important role in maintaining the Mediterranean climate that much of coastal California experiences with cool, dry summers and mild, wet winters.

This work will present findings from a compilation of new and previously published marine sediment proxy data sets generated by the USGS and cooperators from offshore sites along the CCS in: Tanner Basin (SR1703-06-12JPC; 32.8°N, 119.9°W, 1173 m water depth); Pt. Conception and Morro Bay (BH1909-19JPC; 35.4°N, 121.5°W, 839 m water depth); Monterey Bay (PS1410-06GC; 37.3°N, 123.4°W, water depth 2165 m); and Eureka, CA (TN062-O550; 40.9°N, 124.6°W, 550 m water depth). Data types include a combination of biogenic geochemistry (opal, organic carbon, $\delta^{13}C$ and $\delta^{15}N$ isotopes), scanning X-ray fluorometry, 3D computerized tomography (CT) scanning, and selected diatom and silicoflagellate micropaleontology results, along with new high-resolution age-depth models that permit centennial-scale interpretations. To place these data into a broader regional context, we compare these analyses with simulations from the global GENMOM paleoclimate climate model downscaled with the RegCM5 regional model to calculate Ekman pumping using downward surface wind stress as an estimate for coastal upwelling intensity.

Preliminary results show that: (1) the scale of Last Glacial Maximum versus Holocene upwelling changes dwarf any observed during the Holocene alone; (2) smaller magnitude Holocene changes observed in the sedimentary record are not captured by climate modeling output; and (3) the seasonality and latitudinal northern boundary of CCS upwelling has varied throughout the last 21,000 years. Taken together, these data illustrate the large magnitude of variability that is possible in the CCS, much of which exceeds the changes seen in modern instrument-based observations.

Return to Monday afternoon schedule

High-resolution regional modeling of western North America for the past 21,000 years

Jay Alder [a], Steve Hostetler [b], Jason Addison [a]

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[b] *U.S. Geological Survey, Emeritus*

Paleoclimate simulations are typically performed with relatively low-resolution Global Climate Models (GCMs) to span long time periods under varying global boundary conditions. Modelers often need to balance the complexity of processes simulated and spatial resolution with the amount of computer capacity and time needed to produce long simulations. Regional Climate Models (RCMs) provide a tool where higher-resolution simulations are performed over a limited area using input derived from GCMs, although RCMs have not been widely applied in paleoclimate research. By leveraging USGS Advanced Research Computing supercomputer capacities, we were able to run the RegCM5 regional model over Western North America to produce a continuous 51-year simulation of the present day driven by ECMWF Reanalysis v5 (ERA5) data, and 100-year simulations at 3 ka intervals from for 21 ka to 0 ka using 6-hr input derived from our previously conducted global simulations. RegCM5 was configured on 50 km horizonal grid and the output was stored at 6-hr intervals. We developed and applied an automated Atmospheric River (AR) detection algorithm to study the changing characteristics of ARs over the past 21 ka. We find that orographic blocking and circulation changes associated with the large glacial icesheets displace ARs and thus cold-season precipitation southward from the preindustrial position.

In a second suite of simulations, we apply RegCM5 once more at the finer resolution of 15 km for a region encompassing the coastal zones of Western North America to simulate the dynamics of the California Current System during glacial and interglacial periods. These simulations use a technique called regional model nesting, where the 50 km simulations become input to the 15 km simulations over a smaller region at a higher resolution. Surface windstress fields are used to calculate Ekman pumping, which is an approximation for upwelling. Our preliminary results indicate Spring-Summer coastal Ekman pumping is greatly reduced during the glacial period from Monterey Bay, CA, to southern Oregon, but little changed in southern California. Taken together, these new 50 km and 15 km paleoclimate simulations provide a wealth of opportunities for additional analysis and Western North America data-model syntheses.

Return to Monday afternoon schedule

Matching acceleration in rate of glacier changes on Mount Hood, OR and Mount Baker, WA 1980-2023

Nicolas Bakken-French [a], Mauri Pelto [b], Anders Carlson [c], Jill Pelto [d], Megan Thayne [c], Steven J. Boyer [c]

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Mount Baker is the most glaciated peak and highest mountain in the North Cascade Range, Washington and Mount Hood is the most glaciated and highest peak in Oregon. On both mountains, glaciers experienced a period of growth and/or stability from 1950-1980. At that point, both mountains had 12 named glaciers. On Mount Baker the glaciers covered 42 km^2 in 1984. On Mount Hood in 1981 glaciers covered 9.67 km^2. Annual field observations of mass balance have been completed on three Mount Baker glaciers since 1984, revealing an acceleration of loss from -0.5 m/year from 1984-2012 to -1.5 m/year from 2013-2024. This led to rapid retreat averaging 550 m from 1984-2023, and area decline to 37 km^2 in 2015 and 32.5 km^2 in 2023, a 25% decline since 1984 with nearly half occurring in the last decade. From 2003-2023 on Mount Hood there was dramatic retreat of all glaciers, with one glacier disappearing. The area of the seven largest glaciers on the volcano declined from 7.1 km^2 to 4.3 km^2 during this period, a 40% area loss. Comparison to historic records of glacier area and retreat rate on both mountains back to the start of the 20th century shows that this 21st-century retreat is unprecedented. This 21st-century volume and area loss of these glaciers is due to a warming climate, with the regional 30-year average temperature now having increased more than 1.0 C. The rate of loss indicates the glaciers are in disequilibrium with the current climate and many will not be preserved. The loss of glaciers on Mt. Baker and Mt. Hood will have cascading impacts on the surrounding areas. Loss of glacial melt water from Mt. Hood and Mt. Baker will starve their respective watersheds of late summer meltwater, impacting salmon migration, a keystone species in the surrounding ecosystems. In addition, this loss of water will alter agriculture fed by glacial melt water in these areas.

Return to Tuesday morning schedule

Coeval Holocene stalagmites record linkages between ENSO and Rocky Mountain hydroclimate for the past 2800 years

Bryce K. Belanger [a], Warren D. Sharp [b], Christopher W. Kinsley [b], Yanjun Cai [c], Cameron B. de Wet [d], Bryan McKenzie [e], Jessica L. Oster [a]

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The El Nino Southern Oscillation and Pacific Decadal Oscillation (PDO) are key drivers of cool-season precipitation variability in the western United States, including the Rocky Mountains. Together, they help modulate the north-south "precipitation dipole", a regional climate pattern operating on multi-decadal timescales which leads to dry conditions in the north when the south is wet, and vice versa. We investigate the natural evolution of this climate pattern using two precisely-dated (5,900 years ago to present), multi-proxy, coeval stalagmite records of hydroclimate change from Titan Cave, Wyoming, located just north of the modern-day dipole transition zone. Consistent trace element (Sr/Ca, Mg/Ca, Ba/Ca, P/Ca) and stable isotope ($\delta^{13}C$, $\delta^{18}O$) records from the two stalagmites reflect the amount and seasonality of regional precipitation, documenting decreased winter snowfall and dry conditions over multi-decadal intervals characterized by the warm phase of the PDO and more frequent and stronger El Niño events.

Return to Tuesday morning schedule

The role of the Western North Pacific (WNP) as an El Niño–Southern Oscillation (ENSO) precursor in a warmer future climate

Krishna Borhara [a], Boniface Fosu [b], S.-Y. Simon Wang [c]

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Extratropical air–sea interactions have become increasingly involved in promoting the transition to El Niño–Southern Oscillation (ENSO) with climate change. In this study, we break down the effects of future warming on the 1-year lead relationship between a cold western North Pacific (WNP) phase and El Niño development the following winter. We apply a conditional probability approach and sea surface temperature (SST) budget analysis on historical and Shared Socioeconomic Pathway 3–7.0 (SSP370) model runs. With enhanced warming, cold WNP SST anomalies in the boreal winter further strengthen summer westerly anomalies in the western equatorial Pacific, which promote the intensification of surface convergence and anomalous Ekman and geostrophic advection, and positive SST anomalies in the central equatorial Pacific in the seasons prior to the El Niño. Downwelling equatorial Kelvin waves induced by the westerly wind stress facilitate entrainment of subsurface water into the mixed layer during the transition period to trigger stronger thermocline feedback in the central–eastern equatorial Pacific. As a result, the amplitude and frequency of El Niño and its tropical precursors are projected to increase with warming under the WNP influence. ENSO diversity modulated by this relationship depends on the relative strength of advective and thermocline feedbacks, as well as the background state at the time of the event. The intensification of positive Pacific Meridional Mode (PMM) southwesterlies during the WNP–ENSO transition suggests a strengthened three-way link between WNP, PMM and ENSO under enhanced warming that may promote stronger and/or more frequent El Niños.

Return to posters

Earth, wind, and fire: disturbance events recorded in subalpine lake sediments of the interior Rocky Mountains

Christy Briles [a], Andrew Sirois [a], Jacob Casey [a]

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Paleoecological records from subalpine lake sediments in the interior Rocky Mountains capture a range of disturbances, including geomorphic events, insect outbreaks, fire, and human activity. This study examines sediment records from Decker Lake (Sawtooth Mountains, ID), Cottonwood Lake (Taylor Park, CO), and Lily Pond (Taylor Park, CO) to evaluate the utility of various proxies in reconstructing forest disturbance events.

At Decker Lake, pine pollen levels decreased significantly five times over the past 10,500 years, coinciding with mountain pine beetle outbreaks and mistletoe infestations, particularly during periods of drought and increased fire activity. Analytical techniques such as superposed epoch analysis and cross-correlation analysis offer insights into the ecological response to these disturbances.

Cottonwood Lake preserves evidence of geomorphic events, including avalanches, floods, and density currents caused by mass movements. Despite challenges in sedimentation dating due to rapid deposition rates, a multi-proxy approach—including particle size analysis, magnetic susceptibility, and geochemical methods—provides a robust framework for classifying these events.

At Lily Pond, human activities such as mining during the Gold Rush profoundly impacted the watershed, raising lead concentrations, increasing clastic inputs, and altering the pond from oligotrophic to eutrophic conditions. Pollen, diatoms, charcoal, and geochemical analyses illustrate the consequences of historical land use and its temporary recovery when mining ceased briefly between 1906–1916 CE. However, the ecosystem recovery was short-lived due to the return of mining and ongoing pressures from grazing, logging, and recreational use in Taylor Park.

Windthrow events, including microbursts and tornadoes, remain underexplored. Potential proxies for these events include sedimentation rate increases, erosional indicators, and pollen accumulation changes. Future research should emphasize quantitative methods and modern analogs to refine the reconstruction of these understudied disturbances.

This research underscores the importance of integrating multi-proxy approaches to reconstruct a wide range of disturbance events, enhancing our understanding of how subalpine forest ecosystems respond to long-term environmental and anthropogenic changes.

Return to posters

The flaming frontier: grassland and sagebrush contributions to fire activity in northern New Mexico over centennial to millennial timescales

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Covering over 120 million acres across western North America, sagebrush steppe provides vital ecosystem services including carbon sequestration and soil stabilization while serving as critical wildlife habitat. In general, sagebrush steppe ecosystems are at risk due to a combination of anthropogenic pressures, including overgrazing, land clearance, and threats from the impact of climate change. Contemporary land stewardship models assess land health by comparing conditions to a set baseline. However, defining the historical range of variability for sagebrush steppe is difficult since management strategies largely rely on landscape reconstructions based on ecological surveys and land descriptions recorded after the introduction of European livestock in 1850 AD. A longer-pre-Euro-American settlement environmental record that includes climate variability is needed to better quantify the drivers of change for vegetation variability and fire histories in sagebrush steppe.

To establish a more comprehensive baseline for sagebrush steppe ecosystems, this study collected two sediment cores from a semi-arid, high-altitude site on the Anderson Ranch property, located just outside the Rio Grande del Norte National Monument in Northern New Mexico. Using charcoal and pollen as proxies, we aim to explore patterns in past fire activity and reconstruct preliminary plant assemblages, providing insights into the historical fire regimes and vegetation dynamics of the region. A robust chronology was established through a combination of radiocarbon and plutonium dating techniques, ensuring precise age control for the sediment layers. This project is part of a broader initiative to integrate palaeoecological records spanning thousands of years into land management strategies for sagebrush ecosystems, helping to inform future conservation and restoration efforts in these fire-prone systems.

Return to posters

Preliminary results from the Bering Land Bridge coring expedition

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Over the course of the Pleistocene, the Bering Sea has fluctuated between a marine gateway connecting the Arctic and Pacific Oceans and a land bridge connecting North America to Asia. Little research on the paleoceanography of this region has been done and it is controversial whether the central Bering Land Bridge (BLB) was arid mammoth steppe like the highlands of Beringia in Alaska and Russia or if it was more mesic.

In 2023, aboard the R/V Sikuliaq we collected sediment cores from 36 sites on the Bering Sea shelf. These cores record the environment of the now submerged BLB as well as the marine transgression and flooding of these sites. Sedimentology, diatom assemblages and stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) were used to determine the terrestrial to marine transition. Terrestrial sediments are laminated and have low $\delta^{13}C$ values, high C/N, and a mix of marine and freshwater diatoms, which we attribute to the erosion of underlying ancient marine sediments by rivers. Marine sediments have higher $\delta^{13}C$ values, low C/N and are composed of more than 90% marine diatoms. Age control is complicated by this mix of autochthonous and allochthonous deposition in terrestrial sediments as well as by ancient carbon stored in permafrost environments. Despite these complications, the terrestrial sediments range in age from 9.4 cal kyrs old to more than 49 cal kyrs old. Wetlands on the BLB are commonly found between 15 and 22 ka, while very few wetlands were found between 22 and 25 ka.

A Chirp subbottom profiler explored the shelf and commonly found small basins (100s of meters wide) or channels below blankets of marine sediments. This suggests that the central BLB was likely more analogous to the modern-day Yukon-Kuskokwim Delta with a network of anastomosing streams, thermokarst ponds, and associated wetlands. Pollen and sedimentary ancient DNA support this conclusion and indicate the BLB was a mesic tundra environment with pockets of shrubs and woody plants.

Return to Monday afternoon schedule

Political ecology and critical physical geography: frameworks for thinking critically about drought and water management

Cantor, Alida

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Managing water resources sustainably and equitably is a complex social-environmental problem that requires many types of scientific expertise spanning social and physical sciences. Political ecology is a useful framework that encourages a focus on power relations, equity, differential vulnerability, and the political and economic structures that shape management decisions. In recent years, physical scientists have incorporated such critical understandings of social power to understand social-environmental problems through the use of critical physical geography. This talk uses examples from the Western US to show how political ecology and critical physical geography can be useful in thinking about issues of drought and water management.

Return to Tuesday morning schedule

A multi-proxy late glacial to early Holocene environmental reconstruction from a Clear Lake, CA sediment core

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The timing and magnitude of terrestrial climatic changes during the late Pleistocene in California remains uncertain west of the Sierra Nevada region due to a paucity of continuous sediment records greater than 12,000 years old. Some existing terrestrial proxy records suggest impacts of abrupt climate events, such as the Younger Dryas, while other records indicate a muted, mixed, or no response. Sediments from Clear Lake, located in the Coast Ranges of northern California, offer a unique opportunity to address this uncertainty. Cores from Clear Lake were studied by the USGS in the 1970-80s, but the ability to fully understand the reconstructed climate variability was hampered by limited age control.

Here we present data from a 150 m-long core that was collected in 2012 with the aim of developing a strong age-depth model and applying modern analytical techniques to refine and augment the Clear Lake paleoclimate record. Several proxy datasets have been developed from the full glacial through the early Holocene to elucidate how global climate excursions may have been expressed in California. Techniques used include pollen analysis; x-ray fluorescence; particle size analysis (PSA); stable isotope ($\delta^{13}C$, $\delta^{15}N$) analysis; loss on ignition (LOI); and magnetic susceptibility. A robust chronology for the late glacial and deglacial period is based on 19 AMS radiocarbon ages obtained from concentrated conifer pollen, three from macroscopic charcoal, and one from wood.

Beginning around 22,000 BP, full glacial conditions are represented by abundant pine pollen, the presence of fir, limited oak pollen, and less organic matter. A definitive transition from a cool glacial climate to warmer conditions begins around 15,000 years ago, indicated by pollen, LOI, and PSA data. Specifically, pollen data show a permanent shift from conifer forest to more open-canopy oak woodland. During the period from 15,000 to 11,700 BP, the dramatic change in arboreal pollen is accompanied by variations in aquatic vegetation, an increase in the clay fraction, and increased organic matter in the sediment. Shorter term climate events, i.e. Heinrich 1, Bølling–Allerød, and Younger Dryas, are muted or indistinct. Ecological change slows by the beginning of the Holocene (11,700 BP), but an increase in silt and sand as well as decreasing aquatics suggest a shift in local hydrology.

Return to posters

A tale of two annual cycles: the remarkable change in Pacific cold tongue seasonality under orbital forcing

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We show the existence of a dynamic annual cycle of the Pacific cold tongue driven by earth-sun distance changes from Earth's orbital eccentricity (hereafter the Distance Effect), in addition to the known annual cycle of the cold tongue arising from Earth's axial tilt (hereafter the Tilt Effect). The dynamics of the two annual cycles are distinctly different, with the former arising through a seasonal zonal shift in the Walker circulation and subsequent wind forcing on the equatorial thermocline akin to that experienced by ENSO. The amplitude of the cold tongue annual cycle driven by the distance effect is significant even at today's low eccentricity and is comparably large as the annual cycle driven by the tilt effect when Earth's orbital eccentricity is at the larger end of its possible range ($e > 0.05$). The two cold tongue annual cycles also possess slightly different periodicities as the annual cycle from the tilt effect follows the Tropical year whereas the one from the distance effect follows the Anomalistic year; as a consequence, the superposition of the two annual cycles leads to pronounced changes in the net seasonality of the cold tongue over a precessional cycle. We will discuss the implications of this new cold tongue annual cycle for tropical Pacific paleoclimate, and more generally how Earth-Sun distance works its influence on Earth's seasonal climate.

Return to Monday afternoon schedule

Exploring the variability of precolonial wildfire activity: preliminary results from the western Klamath Mountains

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California forests have been heavily shaped by different fire regimes, which have changed significantly under shifts in land management practices. A transformation from indigenous stewardship characterized by frequent low-intensity fires to Euro-American policies of fire suppression and exclusion has contributed to a modern crisis of large, high-intensity fires which threaten communities and forest resources throughout California. This preliminary study seeks to reconstruct the spatial variability of past wildfire activity using sediment cores from three lakes in the Bluff Creek watershed in the Western Klamath Mountains. The cores were collected in summer 2024 by a team of undergraduate students and analyzed in the laboratory in the context of an eight-week mentored research program. Preliminary chronologies for the cores were developed by aligning magnetic susceptibility and loss on ignition data with those from a previously published pollen study with high-resolution Pb-210 chronologies. Contiguous-interval charcoal counts were performed on 500 and 250 micrometer fractions in each core. The results from all cores indicate high precolonial fire frequency with corresponding declines from post-colonial fire suppression, but there is considerable intersite variability in the charcoal data. Intersite variations of charcoal influx could suggest the possible influence of changing sedimentation rates, historic watershed modifications, or dating uncertainties. These results affirm previous findings of high precolonial fire activity linked to indigenous stewardship followed by historical fire exclusion practices that largely removed fire from the landscape. It also clarifies the direction of further extended research to acquire longer cores for additional analyses and high-resolution chronology through Pb^{210} and radiocarbon dating to gain more insight into the spatial variability of fire in the watershed Finally, this study highlights how time-limited undergraduate research mentorship programs can be used to derive meaningful data to direct future research.

Return to posters

Progress toward quantitative estimates of past rainfall during the last glacial cycle from Ca isotopes in two coeval California speleothems

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Previously collected proxy data ($\delta^{13}C$, $\delta^{18}O$, trace element ratios) from two coeval stalagmites (LSC2 and LSC3) from Lake Shasta Caverns (LSC) that grew from ~35,000 to 14,000 years BP suggest that northern California experienced wet conditions during interstadial warm periods and during HS1, and drier conditions during the Last Glacial Maximum (LGM). Here we present new Ca isotope data ($\delta^{44}Ca$) from stalagmites LSC2 and LSC3 to better understand moisture dynamics during these key intervals.

Variations in stalagmite $\delta^{44}Ca$ above a drip site can be modeled as a Rayleigh fractionation process to estimate the amount of Ca remaining in solution at the time of calcite formation (f), a metric for prior calcite precipitation (PCP). When calibrated with $\delta^{44}Ca$ data and rainfall measurements from the modern system, stalagmite $\delta^{44}Ca$ shows promise as a semi-quantitative proxy for paleorainfall. However, the estimation of PCP can be complicated by variable stalagmite growth rates, which influences isotopic fractionation between drip water and calcite, as well as variability in $\delta^{44}Ca$ measurements from the modern cave system that are applied to the stalagmite data.

We use Rayleigh fractionation equations to estimate PCP during stalagmite growth and observe f values greater than 1 (i.e. > 100% of initial dissolved Ca remaining in solution) during the intervals of fastest stalagmite growth. To address these implausible f values, we develop a novel Bayesian proxy system model (PSM) to systematically adjust the isotopic fractionation factor that is applied to the stalagmite records to account for fluctuations in stalagmite growth rates. Using the Bayesian PSM, we estimate close to 0% Ca removal via PCP during HS1 and 40-50% during the LGM. We then use the relationship between rainfall amount and modelled PCP in the modern cave system to provide semi-quantitative estimates of rainfall variability throughout the last glacial cycle.

Return to Monday morning schedule

Environmental change over the past 2000-4000 years in the central Sierra Nevada, California

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Climate change and anthropogenic landscape modification continue to transform the biological and climatological systems of California, making it more important than ever that we understand how these systems varied in the past. Multi-millennia pollen analysis of middle-elevation meadows in the Sierra Nevada provides an opportunity to evaluate the impacts of changing climate as well as changing human impacts over a variety of climate regimes and helps strengthen our understanding of the interaction between climate, humans, and the environment over long time scales. Here we present two pollen records, a 4.4 kyr record from Markwood Meadow in Sierra National Forest, and a 2.2 kyr record from Hodgdon Meadow, Yosemite National Park. Both reveal dynamic variation in the vegetation composition of the meadow in response to changing conditions, and major shifts in the modern period resulting from Euro-American settlement and land-use practices. This latter finding highlights how the modern landscape of the Sierra Nevada is not a good analog for the past, and that to understand natural responses to climate change we must reconstruct environmental change over long periods of time.

Return to Tuesday afternoon schedule

Wildfire in the central Baja peninsula: a ~13,500-year charcoal record

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In March of 2024, a 79 cm terrestrial sediment core (AC24-B) was extracted from an arroyo in the central Baja Peninsula, BC, Mexico. The core was processed, and an age model was constructed using Accelerator Mass Spectrometry radiocarbon (^{14}C) ages, obtained from the organic carbon harbored in preserved pollen grains, and through measure of the concentration of residual plutonium from historic nuclear testing. Dating back to ~13,500 cal BP, AC24-B encapsulates localized paleoenvironmental data, and the prehistoric/historic prevalence of wildfire has been modeled and analyzed through macroscopic charcoal influx. While a broader paleoclimatic analysis with multiple indices will eventually be conducted for AC24-B, this concentrated investigation uses charcoal data to draw additional conclusions of seasonality and intensity of precipitation in the central Baja peninsula through the Holocene. Applications of this research aim to provide global climate models with a paleoclimatic calibration site from a largely understudied region of North America to increase the accuracy of forecasting and to inform land management initiatives.

Return to posters

Paleoclimate signals in Last Glacial Maximum sediments from New Mexico

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Human footprints were recently discovered at White Sands National Park in southern New Mexico, and they were dated to approximately 23,000 years Before Present (BP), making them the oldest evidence of humans in North America. These footprints were discovered in layers of playa sediment which were deposited along the edge of an ancient lake, Paleolake Otero. The footprints correspond with a shift in sediments from paleolake facies to drier, evaporitic surfaces, suggesting warming and drying. While this warming coincides with a known glacial period warming event recorded in the Greenland Ice Core, Dansgaard-Oeschger event 2, its intensity seems to be greater in New Mexico. Geochemical analysis of leaf waxes and bacterial membrane lipids found in the playa sediment layers can quantify temperature and precipitation regimes in the area at the time. We analyzed biomarkers in White Sands National Park and another Last Glacial pluvial deposit from New Mexico. The initial results from both sites show evidence of large changes in hydroclimate that may correspond to known millennial-scale climate events.

Return to posters

Fog water collection along the central California coast

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For the past 15 years, I have been engaging with students and other regional colleagues in the collection and measurement of fog water along the Central California coast. The method used involves deployment of what are known as standard fog collectors (SFC's) which are devices consisting of an appropriate mesh material mounted in a 1.00 square meter frame and supported such that it is between 2.0 and 3.0 meters above the ground. A trough delivers the water to a receptacle or, in this case, a rain gauge where the volume of water collected is recorded. This measurement provides an estimate of the amount of water collectable as a function of location and time. It is of relevance for better understanding the impact of fog on ecosystems as well as the potential to harvest fog water for anthropogenic purposes.

This talk will summarize some of the measurements made throughout the years, highlighting both local measurements from the Monterey region (where this conference takes place) as well as a much-foggier region in the city of Pacifica, just south of San Francisco. One of the key takeaways from the many measurements is the significant spatial variability associated with fog water collection. Even locations several dozen meters apart may collect volumes that differ by 50% or more from each other. I will also highlight an extensive national fog monitoring network that has been established in Chile.

If there is interest, following the conference I would be happy to tour some of the fog collectors deployed on or near the campus of California State University, Monterey Bay, about 15 minutes from the conference venue.

Return to Tuesday afternoon schedule

Lacustrine record from Summit Lake, NV, USA, shows a period of sustained drought associated with Medieval Climate Anomaly

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Summit Lake, a mesotrophic terminal desert lake in northwestern Nevada, holds significant ecological and cultural importance to the Summit Lake Paiute Tribe, historically known as *Agai Panina Ticutta* (Summit Lake Fish Eaters). We present diatom and preliminary ancient DNA data from a sediment core taken at 10 m water depth near the depocenter of the lake. The upper 125 cm of core was examined, and we observed a notable sedimentary transition at 115 cm from high density crumbly mud to low density homogeneous opaline mud. This transition is interpreted as a desiccation event followed by refilling of the lake. Age control was established by combining ^{14}C and ^{210}Pb, with ^{137}Cs and ^{234}Am as stratigraphic markers for validations and shows that the density transition correlates to the end of the Medieval Climate Anomaly (MCA), dated at~1280 C.E. with a 100 yr 2-sigma uncertainty. Ancient DNA analysis of preserved genetic material below the sedimentary transition at the MCA lend further support to periodic desiccation throughout the Holocene. There is a dramatic shift in the diatom assemblage following the desiccation, changing from a benthic community dominated by *Amphora copulata, Nitzschia amphibia*, and *Brachysira* sp. to a mixed epithyte-phytoplankton flora dominated by *Cocconeis placentula*, *Stephanodiscus minutulus*, and *Fragilaria*. This mixed flora persists until ~16cm (~1975 C.E.), followed by an anthropogenically driven increase in a large species of *Stephanodiscus*, the dominant phytoplankter in the lake today. The large *Stephanodiscus* species is morphologically similar to *S. yellowstonensis*, sharing a general ecology in terms of seasonal growth and trophic preference. Future research will expand this analysis and integrate these data with additional proxies, including tree rings, to provide a comprehensive reconstruction of the lake's historical environmental conditions. This integrated approach will support the development of informed and resilient watershed management strategies for the Summit Lake Paiute Tribe.

Return to posters

Holocene fire-human-climate interactions near Progresso Lagoon in northern Belize

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This research uses multiproxy paleoenvironmental data to infer how humans living near Progresso Lagoon in northern Belize interacted with fire, climate, and vegetation changes during the Holocene, specifically filling a gap in our understanding of these interactions during the early to middle Holocene. Charcoal records are especially important to this investigation given the use of fire in agriculture throughout the region, and the rarity of natural fire in the region's tropical lowland broadleaf forests. We are reconstructing past fire activity using macroscopic charcoal analysis on five sediment cores collected from the Progresso Lagoon area. These efforts have produced the first macroscopic charcoal analysis-based fire history reconstructions for any site in northern Belize, one of only three such studies in Belize as a whole. Preliminary charcoal results show widespread use of fire during the past four thousand years and clearly illustrate the reduced level of burning following the Maya Collapse. However, low levels of burning occurred near Progresso even before Maya populations inhabited the area, starting as early as ~6400 years ago. When combined with pollen, sedimentological, and climatic data, this research will provide needed Holocene paleoenvironmental context to the archaeological findings from the Progresso Lagoon region.

Return to posters

Comparison between sedimentary charcoal and wildfire indicators from a transient climate model for the western US over ~15 ka

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Many studies have compared moisture-sensitive proxy records to climate model output for the western US, but few have done the same for proxy records of wildfire. The goal of this study is to gain a better understanding of trends in western US wildfire through the deglacial and Holocene period based on lake sedimentary charcoal records and compare this data with output from a transient climate model (TraCE-21k II). This study focuses on the climatic transition into the Holocene when climate and vegetation patterns were likely to have been the dominant drivers of fire behavior, as opposed to the human dominated regime today. Here we compile published charcoal records from lakes in California, Oregon, and Washington and compare these records with output from the TraCE-21k II climate model simulation. We calculate Fire Weather Index (FWI) using monthly output for precipitation, temperature, relative humidity, and wind speed. FWI is used today to track climatological susceptibility to wildfire and has been looked at in historical model simulations from the Climate Model Intercomparison Project (CMIP6), but has not yet been applied to simulations of the deglacial or Holocene. We also consider outputs from the dynamic vegetation component of the model (percent burn area and carbon flux), which provide a more direct relation to relative burned biomass from the sedimentary charcoal layer. Sedimentary charcoal records can cover millennia at high resolution providing a site-specific analysis of paleofire, or be compiled into regional trends. TraCE-21k II covers the same timescales and takes into account the global climate system. Comparisons between the two can advance our understanding of how climate, vegetation, and fire interact over long timescales and may help improve how wildfire is treated in climate models in the future.

Return to posters

The past and future of the Truckee River: a 500-year tree-ring reconstruction of river streamflow

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Located on the Nevada-California border, the Truckee River Basin is an area of hydrologic extremes, subject to both multi-decadal droughts and devastating floods. It provides water for a population of over 400,000 people and is vital for the local economy; thus it is essential to understand these extremes and plan for future ones. However, due to the Truckee River's brief instrumental record, our understanding of its full range of variability is limited. Trees are living archives, and their rings have long been shown to capture past hydroclimatic conditions, often extending hundreds of years beyond instrumental records. In this study, we present a new Truckee River streamflow reconstruction, building upon the first study by Hardman and Reil (1936). Incorporating their original 1930s tree cores as well as newly sampled material, we developed three new site chronologies which were then combined with other regional chronologies to produce a 1491 to 2003 reconstruction of Truckee River streamflow, an over 400-year extension of the instrumental record and 230 years longer than their original reconstruction. In addition to evidence of extended droughts and extreme high streamflow years, this reconstruction shows a marked hydroclimatic shift centered around the 1850s. Prior to then, the Truckee River experienced decadal to multi-decadal periods of higher than average streamflow; subsequently, these periods have been decreasing in length with only two instances above three consecutive years of high streamflow since 1900. Whether this represents a fundamental shift to a new hydroclimatic regime remains unclear. However, with the combined influence of climate change and rising global temperatures, fewer long-term high streamflow episodes may have lasting impacts on water availability and future sustainability of the Truckee River Basin.

Return to Wednesday morning schedule

Paleoecological history of the Bear River Massacre Site

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The Bear River Massacre occurred on January 29, 1863, in Preston, Idaho. The massacre involved Colonel Patrick E. Connor, who led a group of California volunteers to attack the winter camp of Chief Bear Hunter's Shoshone tribe near Battle Creek, resulting in the fatalities of at least 250 men, women, and children, with some estimates suggesting the number could be closer to 400. The land has since been returned to the tribe, and they are interested in restoring the area. This project will investigate long-term climate and vegetation records for the Bear River Massacre site, which is located at the northeastern end of the Great Basin. These paleoecological records will be used by the Northwest Band of the Shoshone tribe in their restoration efforts of the area. Having insight into the pre-massacre vegetation is essential to the tribe's comprehension of the natural evolution of how climate drove vegetation changes in the region throughout the Holocene. In addition to understanding the pre-massacre vegetation, the tribe is interested in knowing how long the springs have been active in the area and how long their ancestors may have used them. Data proxies such as magnetic susceptibility, charcoal, x-ray fluorescence, pollen, chronology analysis, and loss on ignition will be utilized to create this model. The main research question for the project is to address the timing of the onset of spring activity and reconstruct the environmental and climatic history from before the massacre.

Return to posters

Recent developments and combined use of climate and satellite data for operational natural resource monitoring and advanced process understanding

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In recent years, numerous gridded climate, weather, and satellite remote sensing products have been developed to address the needs of both natural resource managers and scientists, in turn enhancing scientific knowledge and strengthening resource inventories, monitoring, and early-warning systems. However, these data are largely inaccessible for a broader segment of users given the scientific programming and computational demands of big data. New cloud computing applications and data repositories in which programmers and non-programmers alike can easily access and process satellite and climate data in combination, and can create, view, and download maps and time series are now available. This is a new paradigm for natural resource and geospatial data science. This presentation will give an overview of ClimateEngine.org, OpenET, and other initiatives, and highlight how data produced from these initiatives are being used by NOAA, USGS, BLM, state water agencies, and academics for operational drought monitoring, water resource management, and basic and applied research.

Return to Tuesday morning schedule

Exploring fire dynamics in the northern Rocky Mountains during the Holocene

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Infrequent fire activity has shaped the Northern Rocky Mountains (NRM) subalpine forest ecosystems over millennia. Drier and warmer conditions in the western United States over the last century have raised concerns about future changes to the fire ecology of the region. The historical record of fire activity in NRM consists of high-severity fires occurring at 100–250-year intervals. However, recent fire activity in the NRM has been unprecedented, pushing the limits of the region's expected natural fire regime. As we move beyond the natural climate variability in the following decades, the fire dynamics of high-elevation sites in the NRM become increasingly uncertain. Nevertheless, identifying past fire events on a longer time scale can contribute to a greater understanding of future fire behavior. Few long-term studies of fire reconstructions in the NRM exist on a multi-millennial scale, despite the unique insights they provide about the intersection between fire and climate. This research uses lake-sediment data as a natural climate archive to provide a long-term record of fire dynamics and fire regime changes at a high-elevation alpine lake in the Sawtooth National Recreation Area in central Idaho. This study intends to improve our knowledge of ecosystem change due to fire disturbance in the NRM on a long-time scale.

Return to posters

Introducing geographically scalar climatic entities and their associated and nonrepresentationally realist climatic objects

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All things climatic have an air of artificiality associated with them. They are like pixels in terms of the scorn and contempt they seem to generate. This is no fault of their own, of course, but is instead a direct result of some of the features of climate, climate change and its representations. To begin with, climate is abstruse (for us), that is, climate is hidden and concealed, in that it is continually “thrust away” in our experience by the intensity of presence of weather. While not entirely absent, climatic entities are very rarely present. In this way, any climatic entity is more like the Kantian thing-in-itself than any phenomenon or appearance. It is no surprise then that anything whatsoever regarding climate must be extracted—neither constructed (piled up) nor translated (carried over), but extracted, that is, drawn out or pulled up. To make matters worse, climate and any climatic entity is often treated as if it were nothing more than a statistical one in order to showcase the intensity with which a far more real anomaly deviates from it. Against this, we can now see the utility of geographically scalar climatic objects which, by definition, never correspond with their associated climatic entities. These climatic objects are segmented from gridded climate summaries of North America using the simple and elegant quadtree approach. Fourteen sets of seasonal and annual 30-year maximum temperature climatic objects are classified in six half-degree classes of warming and cooling, beginning with 1981–2010 and concluding with 1994–2023. The four-month seasonals, built from the Daymet monthly climate summaries, are maximally inclusive and overlapping. The annual 30-year climatic objects were extracted directly from the annual gridded climate summaries and are shown for comparison. Both the annual and seasonal 30-year climatic object sets show remarkable and shifting climatic patterns of warming and cooling at the continental scale.

Return to Wednesday morning schedule

High-resolution western US hydroclimate reconstruction for hydrological modeling and water resources management

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Tree ring records from across the western US show several persistent, multi-decadal droughts over the last 1200 years, known as 'megadroughts'. These events were far more severe than anything observed during the instrumental period, such as the driest single year in the tree ring record (CE 1580), which saw California's largest river, the Sacramento, experience an annual streamflow of <30% of the driest year in the observational record. Because these events are part of the region's natural climate variability, the return of such events under current conditions and/or future warming scenarios pose major risks for water management across the west. However, we currently lack the detailed climate data needed to quantitatively assess the hydrological impacts and likely management responses in the case of the return of an extreme drought or flood event from past centuries. Here we address this limitation using an analog-based method to develop a plausible daily 4km meteorological dataset for the entire western US that extends back to CE 1100 based on a novel gridded daily 1951–2024 meteorological dataset (precipitation, maximum and minimum temperature, vapor pressure, surface radiation, wind), from which anthropogenic trends have been removed, and a tree-ring derived gridded summer soil-moisture reconstruction. Although it is impossible to reconstruct the true daily sequence of weather based on annual tree-rings, we interpret our reconstruction as plausible because, if it were to be repeated, it would result in a sequency of summer soil-moisture anomaly patters across the western US very similar to that evident in the reconstruction. Our reconstruction of high-resolution daily meteorology across the entire western US provides a new opportunity to simulate some of the most extreme hydroclimatological events of the past millennium and test how modern hydrological infrastructure and policies would perform under the stress of these extreme events.

Return to Wednesday morning schedule

Using sediment pH to infer paleo fires: exploring ash impact

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Paleoecology often uses charcoal analysis to infer past fires on landscapes, but charcoal does not necessarily represent all types of fires. Fires produce both charcoal and ash through the incomplete and complete combustion of plant materials. While charcoal is preserved in wet environments, ash can dissolve into an acidic solution. This pilot study looks to see how paleo fires may be recorded in the palaeoecological record via changes in pH from ash production. The study involves the burning of various fuel samples in the muffle furnace to create ash, which was then mixed at different concentrations with peat to analyze changes in pH. Data results show variation in pH when different concentrations of ash mixed with peat. These results suggest that variation in pH depends on the structure, moisture, minerals content, and buffering capacity of the fuel samples and peat. Data shows that ash can have an impact on soil's pH. These findings can have practical application in the field of fire ecology and soil science. Further research can be conducted using sediment pH data to analyze the impact of human activities on paleo fires.

Return to posters

Pre-Columbian human influences on a mixed-conifer forest, Sierra National Forest, CA

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Understanding pre-1850s fire history and its impact on forest structure provides valuable insights for fire managers seeking to mitigate wildfire risks in the face of climate change. While climate plays a critical role in California wildfires, pre-Columbian indigenous fire practices may have also shaped historical fire regimes and forest composition in the Sierra Nevada. This study uses pollen-based forest reconstructions, comparative paleoclimatic-vegetation response modeling, and principal components analysis to identify periods of human impact over the last 1300 years at Markwood Meadow in Sierra National Forest, California. Our findings reveal strong evidence of anthropogenic fire between 1550 and 1750 C.E., aligning with archaeological indicators of significant shifts in Indigenous lifeways. It further demonstrates the viability of pollen as a comparative proxy to identify periods of low-severity burning. Comparison with five other paleoecological sites across the central and southern Sierra Nevada suggests widespread Indigenous influence on forest structure in cismontane central California. These results challenge the assumption that late 19th- and early 20th-century forest conditions—often used as a restoration benchmark—represent a purely climate-driven state with no human influences.

Return to Tuesday afternoon schedule

Anthropogenic disturbance and hurricanes explain the timing and magnitude of hydrologic change on an atoll island ecosystem

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Scattered across the tropics, atolls are biological hotspots with large ecological footprints. Anthropogenic disturbances and global climate change, including more intense tropical storms, have put atolls at the forefront of restoration efforts. The US manages nine Pacific Remote Island Areas (PRIAs), all of which lacked long-term human habitation before the twentieth century. Most PRIAs were substantially modified during the WWII era (e.g., dredging, island creation, and land clearance). However, the military's impact on terrestrial and aquatic ecosystems has yet to be described in detail. Here we present findings from a sediment core collected from the West Lagoon on Palmyra Atoll National Wildlife Refuge whose sub-annual sedimentation rate reflects historical events and their impact on hydrologic dynamics between 1890-2009 CE. The most profound change came from military construction that started in 1940. We used 1-mm resolution x-ray fluorescence (XRF) to determine relative elemental composition downcore (e.g., Br, Sr/Ca, Fe/Ca), coupled with an age-model confirmed by the independent chronomarker of 1940 construction. Natural accretion processes were altered coincident with the dredging of a natural shoal in the West Lagoon. Elevated Br from 1945-1990 and fine laminations after 1945 indicate increased organic productivity and anoxic bottom waters likely due to increased nutrient input from anthropogenic sources and the reshaping of the atoll that impeded water circulation. Nearly 6000 military troops abruptly departed in 1945; subsequently, the atoll returned to a low population density, allowing some processes to recover by 1990, as indicated by an overall downward trend of Br values. Fluxes in Sr/Ca after 1945 are interpreted as the erosion and subsequent deposition of dredged material high in Sr-rich aragonite. Large peaks in Sr/Ca, Br, and Fe/Ca (a proxy for terrigenous sediment delivery) in 1959 appear to record a powerful storm in January 1958. This storm likely mobilized terrestrial material whose particles settled out over the next year. Prominent Sr/Ca peaks may be linked to rare major hurricanes passing nearby. For example, category 5 hurricane Celeste (11°N) occurred in 1972 and is consistent with an Sr/Ca peak in 1973. Celeste caused large waves in Hawaii and widespread damage on Johnston Atoll north of Palmyra Atoll. Additional major hurricanes tracking at these latitudes appear linked in time and possibly magnitude to Sr/Ca peaks: three hurricanes in 1994 (wide peak over 1994-95), two hurricanes in 1999 (peak in 2000), and three hurricanes in 2006-2007 (peaks in 2007, 2008). Overall our study shows a new depositional regime with higher Sr/Ca, Fe/Ca, and magnetic susceptibility persists after 1940, suggesting a profound legacy of military development here and at other modified atolls.

Return to posters

A fire history for Palo Atravezado Ciénega, Sierra de San Pedro Martir National Park, Baja California, Mexico

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Ciénegas are wetland ecosystems that exist in arid environments and allow for unique vegetation and native animal species to thrive within desert regions. These areas are beneficial to ecological research as they preserve information on past climate and vegetation through deposition of macrofossils, pollen, and charcoal in the sediment. However, the majority of the ciénegas in the United States have been disrupted, leaving many of them unfit to support the native species, and unsuitable for analysis. This project analyzes charcoal content in a sediment core from a ciénega in the Sierra de San Pedro Mártir National Park (SSPM) in Baja California, Mexico, an area with limited human impact. The charcoal analysis is compared to the loss on ignition (LOI) analysis to determine periods of increased fire activity in order to investigate fuel availability and fire patterns in Baja California, Mexico. We found that when charcoal content increased, the percent organic and percent carbon content also increased. Thus, this record indicates that the fires in this area were being driven by the availability of fuel. Increases in moisture and vegetation were positively correlated with periods of increased fire activity. The data presented here are preliminary and will be combined with additional vegetation data before the final analysis.

Return to posters

Late Holocene water quality reconstruction in Lily Pond Lake, Colorado

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Alpine lakes in semi-arid regions, such as Colorado, are critical for biodiversity and freshwater resources, yet their water quality and susceptibility to anthropogenic impacts are poorly understood. While eutrophication is increasing in U.S. freshwater lakes, Colorado's alpine lakes remain understudied due to sparse monitoring and complex environmental interactions. This research applies paleolimnological methods to reconstruct the last 1000 years of aquatic conditions in sub-alpine lakes using diatoms and geochemical proxies.

Focusing on Lily Pond in western Colorado, previous studies revealed increased heavy metal deposition, charcoal accumulation, and lower lake levels once mining in the watershed started in approximately 1858 CE. Diatom analysis identified *Fragilaria* as the dominant genus during mining and logging activity indicating changes in lower lake levels and more nutrient loads. This study will focus on the species identification of *Fragilaria*, to deepen our understanding of historical nutrient dynamics and anthropogenic drivers in the Lily Pond watershed. These species of interest consist of *Fragilaria vaucheriae*, *F. crotenonensis*, and *F. capucina*, prevalent in freshwater systems across the Western U.S. *F. crotenonensis* was introduced due to human activity, which is an indicator of eutrophication and is commonly distributed in oligotrophic and eutrophic lakes. All three species are often associated with mesotrophic to eutrophic lakes, adapting to higher nutrient levels and tolerating pH levels between neutral to slightly alkaline.

Diatom assemblages are undergoing significant shifts due to the increasing influence of anthropogenic factors. These changes are altering the ecological balance of remote lakes and leading to the homogenization of species assemblages. In Lily Pond, for instance, the rise in eutrophication favors the proliferation of *Fragilaria* species, which exhibits greater tolerance to environmental changes.

Return to posters

Atmospheric rivers in the western United States under past and future climate change in the high-resolution Community Earth System Model

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Atmospheric rivers (ARs) have major impacts on the western United States, bringing essential freshwater and drought relief but also extreme floods and landslides, and are expected to intensify with global warming. Past climate states document environmental conditions that are not captured by historical observations and may be relevant to our future, including large increases in atmospheric CO_2 and substantial weakening of the Atlantic Meridional Overturning Circulation. In this talk, we will explore the environmental drivers and hydrologic impacts of AR activity under a wide range of paleoclimate states, including Heinrich Stadial 1 (~16 ka), Last Glacial Maximum (~21 ka), mid-Pliocene (~3 Ma), and Eocene (~56 Ma), and compare them with a high-emission RCP8.5 global warming scenario using the Community Earth System Model version 1.3 (CESM1.3) to better understand the response of ARs to climate change. Two key advancements in our approach to simulating ARs are (1) the use of a high-resolution version of CESM1.3 with water isotopes tracers (horizontal resolution of ~0.25° for the atmosphere and land models; ~0.1° for the ocean and sea-ice models) that improves the representation of AR integrated vapor transport and orography in landfalling regions and (2) the ability to compare AR activity across a range of climate states in a consistent modeling framework. In the western United States, the frequency and intensity of ARs increases in both past and future climate states with elevated CO_2. Increased AR activity under higher CO_2 is driven by higher specific humidity with warming, while changes in atmospheric circulation slightly dampen increases in AR activity. These simulations are an important step toward improving our understanding of ARs in a warming world by providing estimates of AR activity in extreme climates that can be evaluated against paleoclimate proxy data.

Return to Monday morning schedule

North Pacific decadal variability during the Common Era and its impacts on ecosystems

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North Pacific decadal climate variability is widely understood to drive a variety of significant ecological processes, both in the sea and on land. Recent work has shown that the short-term rates of change in Pacific climate variability has decreased over the 20th century. Increases in short-term autocorrelation and variance are often interpreted as harbingers of a major tipping points in complex systems. Here, we use paleoclimate data to test whether modern North Pacific rates of change are anomalous in the context of the past 2000 years. We find that autocorrelation values over the past 150 years are high, but not unprecedented over the Common Era. The highest autocorrelation values of North Pacific decadal variability occurs during 15th Century. This period was, in fact, a time of major climatic and ecological transition in the North Pacific, with documented shifts in glacial extent, fire activity, and endogamous fish populations. These perspectives allow us to explore how past changes in the amplitude and wavelength of Pacific climate variability have interacted with terrestrial marine ecosystems, providing valuable context for an increasingly volatile future.

Return to Wednesday morning schedule

Misalignment between objective and perceived risks exacerbates vulnerability to extreme heat

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Extreme heat poses an increasing risk to public health, but illness and premature death from exposure to high ambient temperatures is avoidable with appropriate risk mitigation and adaptation behavior. There is geographical variation in the degree to which different areas of the US are vulnerable to extreme heat. However, the extent to which people in different areas accurately perceive their risk is unknown. Here we model the percentage of adults in each contiguous US county who are worried about extreme heat using a large multi-year survey dataset (2018-2022). We compare perceived heat risk with an objective measure of heat hazard and social vulnerability and find large gaps between perception and observations across much of the northern US, especially in the Pacific Northwest, Michigan, Maine, and in the Appalachian region. Underestimating the risk of extreme heat can exacerbate vulnerability. Identifying the gap between perceived and observed risks may allow more effective targeting of risk management and communication.

Return to Tuesday afternoon schedule

Impact of antecedent fuel alterations on wildfire severity measurements in California's coniferous forests

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Due to a century of fire suppression and changes in climate such as increasing vapor-pressure deficits, the annual area burned by wildfire in California has increased by over 500% in the last several decades. Concurrently, there has been an increase in wildfire burn severity in forested ecosystems in the state due to the factors mentioned above. There is also considerable concern that many of the coniferous areas burned in the past decade may convert to either a different forest type or non-forested vegetation, especially given a warmer future climate.

A large amount of research indicates that antecedent fuel alterations such as prescribed fires or thinning have been shown to reduce the burn severity of future fires. Google Earth Engine is a cloud-based platform that has enabled the rapid analysis of burn severity for large datasets of wildfires and has been used extensively in analysis of Western US wildfires. This study has used Google Earth Engine to examine how these previous fuel alterations impacted the subsequent severity of all wildfires in the state that burned coniferous forests in the period of 2011-2020.

Wildfire severity was determined using the spectral indices RBR and RdNBR, as well as from composite burn index (CBI) values determined using based on a random forest model. Preliminary results indicate that antecedent fuel treatments and prescribed fires lead to a significant decrease in these metrics of burn severity. It is important that fuel management techniques be implemented on a scale necessary to protect California's threatened forest ecosystems.

Return to Wednesday morning schedule

Lake Manix carbonate stable isotope record documents climate change in the Mojave Desert across four glacial terminations

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Proxy records from closed-basin lakes in the arid Great Basin and southwestern United States offer essential insights into climate and environmental change in this hydroclimatically sensitive region. The southwestern-most fill-and-spill lakes of this region flourished in the Mojave Desert as the Mojave River intermittently spilled into various subbasins. Of these, sediments from Lake Manix provide a record of Mojave climate from ~500,000 to ~25,000 years ago. Previously published analysis of sedimentology and ostracode assemblages document changes in the seasonality of Mojave River water sources on glacial-interglacial cycles. However, the ostracode stable isotope ($\delta^{18}O$, $\delta^{13}C$) record is of low-resolution and displays large intra-sample variability, precluding the interpretation of these data in a climate context.

To re-evaluate the stable isotope systematics of Lake Manix, we present a new record of authigenic carbonate $\delta^{18}O$ and $\delta^{13}C$ from an existing 45-m core from the central Cady subbasin. We update the age model with newly refined ages for paleomagnetic reversals and excursion tie-points. Our carbonate isotope record covers Terminations II - V at millennial to multi-millennial resolution. Our d ^{18}O values reproduce a small suite of previously analyzed authigenic carbonate muds but are generally more negative than ostracode values. Manix carbonate $\delta^{18}O$ displays peaks at Terminations II - V, suggesting increased evaporation. These are coeval, within age model uncertainties, with peaks in Devils Hole calcite $\delta^{18}O$ for Terminations II - V and δD of long chain n-alkanes from Searles Lake for Termination II, indicating consistent timing of hydroclimate changes across the southern Great Basin. Carbonate $\delta^{13}C$ values are more positive than ostracodes, consistent with authigenic carbonate precipitation in the epilimnion. Carbonate $\delta^{13}C$ decreases during Terminations suggesting decreasing surface productivity during lake contraction. This new record offers insight into the dynamic climate of the Mojave, documenting clear connections with regional and global Pleistocene climate.

Return to Monday morning schedule

Paleoenvironmental Information about a ~12,000-year-old human trackway site in the West Desert of Utah

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This research presents the findings of a sediment core taken in 2022 from the Great Salt Lake Desert of Utah. The sediment core was taken on a ~12,000-year-old human trackway cultural site on the distal Old River Bed Delta (ORBD) in the Bonneville Basin. Through this study we have reconstructed the paleo climate and the potential resources for paleo-indigenous people in the area.

Analysis includes Loss on Ignition (LOI), Magnetic Susceptibility (MS), and charcoal analysis. LOI indicates the productivity of an ecosystem, MS informs us of the erosional and volcanic history of the site, and charcoal analysis is used to reconstruct the fire history of an area. Through these proxies we have reconstructed the paleoclimate and potential resources for the human populations present on the distal ORBD.

Oolitic sands located near the distal portion of the sediment core may indicate the presence a shallow lake, perhaps pre-dating Lake Bonneville. More research is still being done on this section; however, we are very excited about the implications for potential early/pre-Bonneville conditions in this area.

Return to posters

A suppression cost comparison of three classes of wildland fires in the U.S.

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While most wildfires are less than one hundred acres, every year there are much larger fires that burn hundreds of thousands of acres across the U.S. Shifts in the frequency and severity of drought and weather patterns have changed natural fire regimes in numerous ways. Additionally, the spatial complexity of human development patterns within the wildland-urban interface has caused an increase in human-ignited wildland fires, as well as greater difficulty in fighting these fires. Suppress-at-all-costs management techniques of the past limited wildfires' ability to clear dead vegetation, leaving the forests unusually rich in fuel. As a result, more frequent large scale wildfire events have increased national suppression costs. Federal budgeting, forest management policy, state, and local regulations, dictate suppression management, and real-time decision making. The increased suppression costs and heightened pressure on incident management to meet budgets may be limiting factors in protecting life and property during a wildfire event. This study uses area burned and growth criteria for naming conventions of three types of megafires: fires of unusual size (FOUS), extra-large fires (XLF), and large fires (LF), and aims to identify how distinct types of megafires affect suppression costs. Preliminary results concur with previous research in that suppression costs increase with the size of the fire. However, preliminary results also unexpectedly show that the intensity of the fire growth affects suppression costs, specifically that less intense fire spread leads to higher suppression costs. Information learned from this study will help inform local and federal agencies who prepare for these extreme events, with the overarching goal of limiting the loss of life and property.

Return to posters

The geochronology of the human footprints at White Sands is resolved

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Human footprints at White Sands National Park (WHSA) Locality 2, New Mexico, USA, are between ~23,000 and 21,000 years old according to radiocarbon dating of seeds from the aquatic plant *Ruppia cirrhosa*. These ages were controversial in the archaeologic community because of carbon reservoir effects that could potentially compromise their accuracy. To evaluate the veracity of the seed ages, we obtained calibrated ^{14}C ages of terrestrial pollen collected from the same stratigraphic horizons as those of the *Ruppia* seeds, along with optically stimulated luminescence ages of sediments from within the human footprint–bearing sequence. The results confirmed that the chronologic framework originally established for the White Sands footprints is robust and reaffirm that humans were present in North America during the Last Glacial Maximum. Despite these findings, some archaeologists still contend there are many “unresolved issues” with the geochronology of WHSA Locality 2. They suggest there are substantial age offsets due to hard-water effects in the aquatic plants that were dated and that radiocarbon ages of pollen may be anomalously old due to reworking. In their view, the luminescence ages are likely to be maximum ages because of the probable presence of partially bleached quartz grains, overestimation of water content, and stratigraphic position of the samples. They also assert the ages of the footprint trackways are not as internally consistent as suggested and can be interpreted in various ways. We review each of their objections, show they are without merit, and conclude based on multiple lines of evidence that the geochronology at WHSA Locality 2 is resolved.

Return to posters

Expression of Dansgaard-Oeschger warming events in the California Current region

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Paleoclimate records from the Northern Hemisphere show pronounced climatic variability throughout the late Pleistocene, with rapid temperature swings known as Dansgaard-Oeschger (D-O) events that are especially well-defined in Greenland ice core records. Changes in ocean circulation in the high-latitude North Atlantic Ocean have long been invoked as triggers for these fluctuations; however, the clear expression of D-O-like variability in ocean sediment records from the Northeast Pacific, such as the Santa Barbara Basin, warrants a deeper understanding of the role that changes in the North Pacific play in these rapid climate shifts. Specifically, we seek to investigate whether changes in surface water temperatures in the Northeast Pacific during D-O events were coupled to deeper changes in ocean ventilation, which may suggest a more active role for North Pacific Ocean circulation in D-O variability than previously assumed. Here we present new paleoceanographic reconstructions from a marine sediment core raised from Tanner Basin, offshore of Southern California (SR1703-06-12JPC, 32.8°N, 119.9°W, 1173 m water depth), which contains a continuous ~80,000 year record with a sedimentation rate of ~10 cm/kyr. The age model is constructed from over 40 planktic foraminiferal radiocarbon dates covering the past 45,000 years, with paired benthic radiocarbon ages that provide insights into changes in deep water ventilation age. The benthic-planktic (B-P) radiocarbon pairs reveal fluctuations that largely parallel surface ocean changes, as reflected in the planktic $\delta^{18}O$ record (*G. bulloides*) from the same site. Reduced B-P ages (~900 yrs) generally occur during warm periods, whereas larger B-P age differences tend to occur during cold periods (~1,500 yrs or more). These preliminary results suggest that ocean circulation changes in the North Pacific were likely an integral part of abrupt climate fluctuations in the past, rather than merely a teleconnected surface response to North Atlantic changes.

Return to posters

Automated imaging and the application of machine learning to enhance quality and speed of sedimentary charcoal quantification

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Sedimentary charcoal particles serve as important indicators of past fire events in palaeoecological studies. The process of identifying and quantifying macroscopic (>125 μm) fossil charcoal particles in lake sediment samples requires manual enumeration under a microscope, which is time consuming and demands subject expertise. Here we present an approach to enumerating charcoal particles that employs a combination of automated image capturing and machine learning. This Automated Charcoal Enumeration System (ACES) will greatly expedite the tedious process of charcoal counting and identification.

The imaging system, constructed with affordable and commercially available components, is designed to capture high-resolution images automatically. To maximize image quality, we use a macro lens to contiguously capture overlapping sections of the entire sample and repeated imaging with a narrow focal plane through the z dimension. We employ focus staking to keep all focal planes in sharp focus to preserve key details of each charcoal piece. The model was trained using a dataset of manually annotated images, where charcoal particles were categorized into classes based on their morphological features. We use YOLOv8-seg (You Only Look Once) instance segmentation model, configuring it with a standard set of hyperparameters and training for 300 epochs, where each epoch represents one complete pass through the entire training dataset. Data augmentation techniques such as rotation, scaling, flipping, and cropping further improved the robustness of the training data set, comprised of more than 10,000 pieces of charcoal. Preliminary model performance demonstrates a Mean Intersection over Union (M-IoU) value (> 0.85) for binary classification, effectively distinguishing charcoal from non-charcoal particles. The automated imaging and identification pipeline will have the ability to handle large datasets, work with complex image features, and make consistent predictions.

Return to posters

At the crossroads: the Colorado River in the age of climate change

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The Colorado Basin stands at a crossroads. The reservoir and water management decisional documents are set to expire at the end of 2026. A crisis has arisen due to over-allocation of the river, compounded by population growth, drought and climate change. Scientific knowledge alone will not solve the problem; we must distinguish between science and implementation; science comes first, then policy. We must get the science as right as we can while looking at available options. Politicians and water managers need the best scientific advice while recognizing that much of the science is provisional. Better education is needed so that the public is not taken in by bad science.

Tree-ring data provide a much needed long-term context for the current Colorado Basin drought. Multidecadal droughts in the twelfth and thirteenth centuries disrupted the Ancestral Pueblan civilization. These droughts, which occurred in a warm period, played a role in the almost wholesale abandonment of the Four Corners region in the 1280s. These past upheavals are a distance mirror reminding us of the vulnerability of society to climate change.

The Colorado Basin is one quarter of a century into a drought with no end in sight. The mean annual natural flow of the river, and its uncertainty, are key inputs into river management decisions. As a first step, we examine 800-year paleo reconstructions of Colorado River streamflow. Various methods (KNN, principal component analysis, neural nets) have been applied to infer past annual streamflows. We investigate the source of uncertainty in the derived mean flows as well as temperature reconstructions. We present a new method for computing uncertainty in tree-ring widths and chronologies. Using these results and a gaussian flow model we make predictions of river flows over the next decade.

Return to Wednesday morning schedule

How do fires and earthquakes impact Late Holocene sediment flux in the Transverse Ranges?

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Fire and earthquakes in the Transverse Ranges of southern California are known to impact sediment flux at short timescales. Here we probe late Holocene records of charcoal and sediment flux in two drainages that are crossed by the San Andreas Fault to understand relative impacts of these signals integrated across the last 1300 years. Further, the size of the drainages provides an opportunity to compare upland sediment response in a second order drainage of Frazier Mountain (1 km^2) with the much larger, higher order drainage of Pallett Creek (36 km^2). The study includes new grain size, charcoal counts, and other sedimentological data sampled at 1 cm intervals from both sites, and age control from radiocarbon dating from published paleoearthquake studies. The sedimentation rate at both sites averages about 0.3 cm/yr, with intervals of high (>1 cm/yr) and low (0.05 cm/yr) accumulation. Both systems show a dramatic reduction in sediment accumulation from ~700 to 500 BP, at the transition between the Medieval Climatic Anomaly and the Little Ice Age. Additionally, both systems have high charcoal fluxes after this transition. At Frazier Mountain, sediment accumulation rates from 500 to 300 yrs BP are very rapid whereas Pallett Creek shows only a small increase in sediment accumulation rates during the same period. A simple relationship between earthquakes and sediment flux is harder to discern, perhaps due to the frequency (every ~100-130 years) and quasi-periodicity of earthquakes along this section of the San Andreas Fault. One observation is that sedimentation rates are high when earthquakes like the historic magnitude 7.9 earthquake in 1857 CE, which are modeled in previous studies to rupture both sites, occurred. Based on these observations, we interpret that late Holocene sedimentation rate variability was dominated by fire and landscape response to past climate transitions and secondarily impacted by earthquakes.

Return to posters

Compilation of 1984 - 2022 PACLIM proceedings, reports, and abstracts

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From 1984 to 2025, a series of 31 scientific "*Pacific Climate*" (PACLIM) workshops highlighted multitudinous aspects of Pacific climate and its expressions on climate change, weather extremes, ecosystems, oceanography, geography, and society. PACLIM workshops were held in California in the *Asilomar Hotel and Conference Grounds* on the Monterey Peninsula in Pacific Grove, except from 1998 to 2000 when PACLIM workshops were held at the *Wrigley Institute for Environmental Studies* on Santa Catalina Island. The many hundreds of non-copyrighted PACLIM publications and abstracts are considered "grey literature" and are often hard or impossible to find as hardcopies or electronically, especially much of the older literature prior to 2015. Our team's concerted efforts managed to locate complete copies of all PACLIM literature dating back to the inaugural 1st PACLIM workshop in 1984. All hardcopies were scanned and converted to text-searchable pdf files. All electronic files, in addition to an overall Excel file (offering an overview on PACLIM dates, Chairs/Editors, themes, locations and sponsors) were deposited on a DVD in the *California State Library's Government Publications Section*. The *California State Library*, as well as numerous other libraries and organizations were asked to make the electronic PACLIM files publicly available on their servers but refused owing to perceived concerns about privacy, copyright, and disability-access. The *California Department of Water Resources* published the consecutive 6th to 21st PACLIM workshop proceedings as their respective Technical Reports 23, 26, 31, 34, 36, 40, 46, 53, 57, 64, 65, 67, 69, 71, 72, and 77 of the *Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary*. Some hardcopies and/or electronic versions are available from the *California Department of Water Resources* upon request.

Return to Wednesday morning schedule

Late Holocene vegetation change at Range Creek Canyon Utah

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This study utilizes fossilized packrat (Genus *Neotoma* spp.) middens to reconstruct past vegetation and climatic conditions of Range Creek Canyon (RCC) during the late Holocene. RCC, located in the Colorado Plateau and the Book Cliffs region of east-central Utah, provides a unique opportunity to explore paleoecological conditions by analyzing fossil pollen and macrofossil data (Boomgarden, 2015; Nieminski & Johnson, 2014). Packrat middens can provide precise "snapshots" of previous environmental conditions due to the remarkable preservation of macro and micro-botanical specimens and the intense gathering behavior of packrats that produce the middens (Anderson & Van Devender, 1991; Coats et al., 2008; Dial & Czaplewski, 1990; Spaulding et al., 1990; Vaughan, 1990). The primary objective is to create a comprehensive paleoecological record using dated fossil packrat middens to assess regional and local vegetation patterns and investigate past climates in RCC, focusing on the period of Fremont occupancy.

The series consists of 44 middens spanning elevations from 1399 m to 2157 m. Midden matrices were dissolved to recover macrofossils, followed by traditional palynology processing methods to isolate fossilized pollen grains. Samples from each midden were dated, and macro and micro remains are being identified at the lowest taxonomic level possible in order to reconstruct past vegetation communities. Preliminary results show a well-distributed radiocarbon dating range from 5652 - 114 cal yr. BP (7602 B.C. to 1836 A.D.). With macrofossil identification and fossil pollen analysis complete, data analysis is still ongoing.

This research will culminate in a comprehensive chronology of vegetation and environmental change in RCC, enhancing the understanding of the canyon's climatic history and midden palynology. The findings will inform best practices for fossil-midden paleoenvironmental studies, particularly in arid regions, and contribute to long-term environmental trend analyses. These insights are crucial for informing land management strategies in drought-prone landscapes and advancing discussions on landscape evolution and climate variability in the American West.

Return to posters

Using lidar and satellite imagery to evaluate meadow channel geometry and vegetation dynamics

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Montane meadows--high-elevation non-forested ecosystems--offer essential ecological and hydrologic services like floodwater management and biodiversity. However, anthropogenic and climatic factors are leading to widespread meadow degradation, necessitating tools for land managers to identify degraded areas and monitor restoration efforts over time. This study explores the integration of higher-resolution remote sensing data to improve and standardize two critical components of meadow assessments. The research objectives include 1) developing a meadow stream geometry workflow utilizing the USGS 3D Elevation Program (3DEP) aerial lidar data within three meadows in the Sierra Nevada mountain range (USA), and 2) assessing vegetation health through growing season phenology in three vegetation communities (herbaceous, riparian woodland, and conifer). The vegetation analysis was completed for 2018 to 2023 using high-resolution satellite imagery sources (PlanetScope [3m] and Sentinel-2 [10m] data). The lidar results demonstrate that 3DEP data, combined with open-source tools, effectively delineate main channels in test sites, produce stream channel profiles comparable to existing UAS-derived results, and highlight incised transects that can direct further investigations. Additionally, vegetation metrics generated from both imagery sources provide valuable short-term insights into the health of distinct vegetation communities. The similarity between metrics from both sources indicates that Sentinel-2 imagery may serve as an adequate proxy for PlanetScope data in similar applications. Overall, these findings suggest that combining high-resolution lidar data and satellite imagery can help create standardized meadow assessment protocols, applicable across diverse meadow types, reducing reliance on extensive fieldwork while ensuring effective monitoring and management strategies.

Return to Tuesday afternoon schedule

An early Holocene wet period in the southwestern United States

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During the early Holocene, multiple generations of spring-fed streams traversed ~800 km^2 of the Las Vegas Valley in southern Nevada, depositing an extensive tufa network that dates to between ~10.9 and 8.5 ka. The scale of the network and diversity of tufa morphologies is novel in North America and offers an opportunity to obtain quantitative paleoclimate data for the region. We determined isotopic compositions and estimated past temperatures from clumped isotope data from early Holocene tufa from the valley floor (698 m) as well as tufa forming today at Cold Creek Spring (1856 m) in the nearby Spring Mountains. Modern and fossil tufa yielded comparable $\delta^{18}O$ and $\delta^{13}C$ values, implying similar source waters derived from high-elevation winter precipitation. Clumped isotope temperatures of modern tufa average 15.8±2.5°C, aligning with mean summer temperatures of the emergent spring water, and support equilibrium conditions of tufa formation. The early Holocene tufa yielded similar clumped isotope temperatures, averaging 15.2±3.9°C, meaning it precipitated at temperatures that occur at much higher elevations today. The Las Vegas tufa record, combined with nearby and temporally correlative paleospring, lacustrine, and speleothem records, suggest cool/wet conditions prevailed throughout the Mojave Desert during the early Holocene. These records also demonstrate that spring ecosystems responded to millennial-scale hydroclimate variations that supersede climate change driven solely by insolation. The spatially widespread pattern of ecosystem response to hydroclimate documented here may assist in understanding climate drivers for the early Holocene and provide critical information for the fate of groundwater-dependent ecosystems in the southwestern U.S.

Return to posters

Holocene peatland stratigraphy in the Sierra Nevada, California and the southern Rocky Mountains: climate implications

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Peatland stratigraphy and biogeochemical characteristics preserve a sensitive record of past environmental change. This research aims to reconcile similar Holocene stratigraphic profiles from Sierra Nevada wet meadows and some southern Rocky Mountain fens. Spencer Wood (1975) described the stratigraphy of several low gradient montane and subalpine wet meadows ranging in elevations from 1830 to 2500 m in the Sierra Nevada. The wetlands preserve a sequence of sediment deposition, with organic-rich peaty mud accumulating in the early Holocene, stratified alluvium deposited in the middle Holocene, and peat developing over the last 1200-3000 years. Wood interpreted the changes as reflecting secular variations in watershed hydrology, indicating cooler and wetter conditions in the early and late Holocene maintaining a higher water table, while drier conditions during the mid-Holocene led to a lower water table. During the mid-Holocene warmer/drier period, conditions were too dry for peat to develop, and streams deposited alluvium on forested valley floors. Several subalpine fens in Colorado located below 3100 m elevation show similar stratigraphic patterns. Peatlands in Colorado require a snowpack persisting late into the summer to maintain the water table. Cooler conditions in the early and late Holocene delayed snowmelt and contributed to high water tables in the fens. Mid-Holocene warm conditions produced earlier snowmelt resulting in lower water tables and cessation of peat accumulation. However, fens in Colorado located at elevations above 3100 m display different stratigraphy, with consistent peat accumulation throughout the Holocene. Organic carbon, bulk density, and humification analysis indicate that local hydrologic changes driven by century scale climate fluctuations are responsible for the patterns seen in the stratigraphic records. Differences in the accumulation of organic layers in the higher and lower elevation peatlands have important implications for carbon sequestration and provide evidence of future hydrologic conditions in a warming world.

Return to Tuesday morning schedule

Increased monsoon activity during the Last Interglacial on the southern California Margin

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Hydroclimate is changing in Southern California, creating unprecedented challenges from drought to increased geologic hazards. To plan for future conditions, climate proxy records from the Last Interglacial (~70-130 ka) can be used as an analogue from the past. Here, we present carbon and hydrogen isotope records from plant waxes at ODP site 1012B on the southern California margin. These records reflect past changes in hydroclimate and vegetation during the Last Interglacial. Carbon isotope values fluctuations from 1012B are similar to regional carbon isotope and pollen records suggesting climate-driven vegetation changes on glacial-interglacial cycles. During the peak of the Last Interglacial, hydrogen isotope values are considerably more enriched than the rest of the 1012B record. We propose greater North American Monsoon input as the likely driver of peak interglacial isotopic enrichment. If warmer sea surface temperatures can be linked to North American Monsoon intensity, modern climate change could mean more monsoonal rainfall in southern California moving forward.

Return to posters

Large amplitude SST variability in the Gulf of Alaska during the Holocene

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The Gulf of Alaska (GoA) harbors one of the most productive fisheries in the United States. It is also a climatically dynamic region, subject to large interannual and multidecadal swings in sea-surface temperature (SST) in response to ENSO and the PDO. To gain a long-term perspective on past temperature variability in the Gulf of Alaska, we reconstructed summer (JJA) SSTs for the past 11,000 years using the alkenone $U^{K'}_{37}$ proxy. Chronology is based on ^{210}Pb, tephras corresponding to known volcanic eruptions, and 43 radiocarbon dates. Our record has an average temporal resolution of 25 years over the past 2,000 years, allowing for a detailed comparison to the instrumental record of SST as well as other paleorecords of Common Era climate. We find that the GoA has warmed by 3˚C since preindustrial times, a remarkable amount that makes this region a hotspot for global warming. In general, JJA SSTs closely follow global climate change throughout the Common Era, with a warmer Medieval Period and cooler Little Ice Age. Unlike most SST records (which typically show small changes across the Holocene following changes in the Earth's orbit) the GoA record shows large amplitude changes that are not strictly orbitally driven. Our data show that the GoA is a very sensitive location to climate change, and more broadly that the North Pacific experienced a unique evolution in SST through the Holocene.

Return to Monday afternoon schedule

Fire history and climate responses in Fish Lake, Utah

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This research focuses on a fire history reconstruction for Fish Lake, Utah. The majority of the data presented here are for the fire record. However, the team has also generated high-resolution pollen data that we will use to assess past climate, fuel loads, and other environmental variables. The fire history covers the last 60,000 years, which is the longest fire record in Utah. The sediment from this core was analyzed in half-centimeter increments, allowing for a detailed charcoal analysis of the region. Adjacent to Fish Lake is the Pando Aspen Clone, identified as the oldest (approximately 65,000 years) and potentially largest (single) organism in the world. The fire history shows variability over time, likely associated with the changes in climate, vegetation, and fuel loads over the last 60,000 years. Indigenous peoples have influenced ecosystems by modifying vegetation and making this land more prone to fire (Carter et al. 2021). However, as we look forward, climate change may be the main driver for an increased number of fires. We hope these data will be useful in the current and future land management of this important ecosystem.

Return to posters

Exploring paleohydrology with XRF in the west desert

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New insights from paleoclimate investigations within the Lake Bonneville Basin emerge from X-ray fluorescence (XRF) analysis of sediments. XRF technology allows insight into the geochemistry of the item being scanned, in this case, RSP18B core, one of the most complete records of Lake Bonneville. The raw photon counts were transformed in R to analyze variability from 30,000 years ago to 2019 and investigate the basin's hydrologic history over 30,000 years. XRF-derived elemental ratios were created by exploring positive and negative correlations and the chemistry of certain elements. These ratios provide context for interpreting the region's biotic factors, evaporation, precipitation, mass-flooding events, and salinity.

The results are organized into three distinct periods: Modern, MIS1, and MIS2. Modern data (1850–2022 CE) identified five significant hydrologic events using the XRF-derived Si/Al ratio in conjunction with a precipitation model. The 1982–1984 extreme El Niño event served as a benchmark for defining thresholds of extreme hydrologic activity in the basin. By integrating the Si/Al ratio with precipitation models, Atmospheric Rivers, Climate Community Systems Model (CCSM) data, integrated vapor transport, and reanalysis datasets, a relationship between hydrologic events and land processes was established.

This study bridges sedimentological data from historical and modern records to explore Holocene and Pleistocene hydrologic variability in the Bonneville Basin. The findings enhance understanding of how hydrologic cycles influence the elemental composition of Lake Bonneville sediments, offering critical insights into the region's paleoclimate and management implications for future investigations.

Return to posters

Paleoenvironmental investigations of permanent water features in sagebrush steppe ecosystems in the Columbia Basin, Washington

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The Columbia Basin exists in the driest part of Washington state where natural, permanent water features are rare. An exception to this is the Sun Lakes area near Soap Lake, Washington, where landscapes carved by the Missoula Floods created numerous topographic basins in which natural lakes and wetlands exist today. However given the extremely dry conditions of this sagebrush steppe ecosystem, many of these lakes are alkaline and as a result support little to no flora or fauna. The purpose of this research was to test the feasibility of reconstructing paleoenvironmental histories from three study sites in the Sun Lakes area (Perch Lake, Lake Lenore, and Soap Lake), which range from freshwater to highly alkaline. Short sediment cores of approximately 1 meter in length were extracted from each site and analyzed for pollen, macroscopic charcoal, magnetic susceptibility, and loss-on-ignition. Our results show that sedimentation rates vary widely between the sites, but that all the sediment cores spanned at least the past ~1900 years. Macroscopic charcoal preserved well in all three cores and indicates frequent burning near the sites, with some shifts in charcoal morphotypes within the past few decades highlighting a change in fuel sources. Pollen-based vegetation reconstructions suggest that sagebrush steppe dominated the Sun Lakes landscape during the Holocene and clearly show when and what invasives arrived since Euro-American settlement. Additionally, all three lakes appear to have undergone significant chemical and sedimentological shifts in recent decades associated with alterations in water flow dynamics that accompanied the Columbia Basin Irrigation Project and subsequent land management changes in the Sun Lakes area.

Return to Tuesday afternoon schedule

Characterizing biological communities of the Bering Land Bridge using sedaDNA

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Beringian terrestrial sediment records are well-studied and have yielded insights into the paleoecology of the region. However, the species composition of the Bering Land Bridge (BLB) during the late Pleistocene has remained a mystery due to the challenges of accessing its now-submerged terrestrial sediments. Whether the habitats of the BLB were mostly composed of mesic shrub tundra or arid steppe tundra is still a matter of debate. Few studies have focused on cores from the Bering Sea shelf, and their results are inconsistent. Here, for the first time, we use sedimentary ancient DNA (sedaDNA) techniques to investigate the terrestrial communities of the BLB preserved in two Bering Sea cores collected during expedition SKQ202311S. Both cores feature an upper marine unit over a subaerial Beringian terrestrial sediment unit dating to the late Pleistocene, offering an opportunity to investigate the terrestrial communities of the BLB. To both maximize our chances of finding unexpected taxa and optimize the recovery of ancient arctic taxa, we used a combination of shotgun sequencing and target capture to reconstruct a mesic shrub habitat. For example, we found woody taxa from the families Betulaceae, Salicaceae, and Pinaceae, as well as graminoids from the families Poaceae and Cyperaceae. One advantage to using sedaDNA as a paleoproxy is the potential for identifying animals in the absence of macrofossils. Here, we identified Elephantidae DNA within both cores, suggesting that, although they were grazers, mammoths were present on a shrub tundra BLB. This study offers the first glimpse into the biological communities of the BLB using sedaDNA techniques and affirms the use of marine cores for studying ancient terrestrial environments.

Return to posters

ARkStorm: past, present, and future

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The conference themes of “Past, Present and Future” and “From Paleo to Policy” are captured well by the ARkStorm scenarios. Developed through collaboration among United States Geological Survey, agencies, researchers, and practitioners, the 2010 ARkStorm scenario modeled a modern-day recurrence of a 23-day atmospheric river (AR) storm series to simulate the effects of the 1861–62 California floods. ARkStorm assessed wind, flood, and landslide hazards, projecting $314 billion (in 2007 dollars) in damages to buildings, infrastructure, and agriculture, as well as environmental health risks, the evacuation of hundreds of thousands of people and livestock, and $324–362 billion in economic impacts over five years. This statewide megastorm underscored the importance of testing disaster plans at regional scales, leading to initiatives like ARkStorm@Tahoe, which mobilized emergency managers and stakeholders to address vulnerabilities, mitigation strategies, and science needs. Evaluations revealed widespread media and academic recognition, innovative hazard modeling (e.g., CoSMoS), and advancements in estimating systemwide damages, restoration efforts, and centralized water responses (CalWarn). Lessons learned emphasize effective project management and collaborative partnerships.

Recent research indicates that the probability of such megastorms has doubled with climate change. ARkStorm 2.0 advances scenarios that, translate future climate-adjusted AR meteorology into hazard impacts to improve forecasting and inform policies. This includes balancing water supply and flood risk, exploring insurance mechanisms, addressing infrastructure vulnerabilities, and enhancing emergency preparedness across diverse communities and environments. Additional work includes socioeconomically informed population exposure analyses, the development of time-series tools for exercises, and a primer on incorporating climate projections into emergency management planning. Together, these initiatives aim to strengthen resilience and preparedness in the face of increasing AR-driven hazards.

Return to Monday morning schedule

Identifying vulnerable stands and refugia of vegetation under aridification: climatic water deficit limits and the trailing edge of vegetation shifts

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Vegetation shifts driven by climate change are underway and projected to accelerate. The most robust climate trend in California is aridification –increasing drought stress as the rainy season compresses, and warmer dry seasons increase evaporative demand. This process is captured by Climatic Water Deficit (CWD), which integrates monthly precipitation, potential evapotranspiration, and soil water storage capacity into a single number to characterize the intensity of dry season drought stress. Each vegetation type has a CWD limit, beyond which that type is never found. By overlaying a vegetation map onto a 30-year average CWD map derived from the Basin Characterization Model (BCM), these limits can be quantified with percentiles of a cumulative distribution function (CDF). The results are congruent with our knowledge of California vegetation. Stands close to the upper CWD limit are more vulnerable to aridification than those in the middle or low end. Stands at low end of the CWD CDF are likely climate refugia. Such an analysis has been operationalized in the Bay Area Conservation Lands Network (www.bayarealands.org). A composite map of all vegetation types is characterized by the distance to the 99th percentile of CWD for each vegetation type. These results are accessible to users in the CLN Explorer interface and can be applied to the entire state of California.

Return to Wednesday morning schedule

Deciphering two-phase global hydroclimate patterns during Heinrich Stadial 1

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Heinrich Stadial 1 (HS1; 19–15 ka) was characterized by abrupt global climate perturbations in association with a weakening of the Atlantic Meridional Overturning Circulation (AMOC), which could be used as an analog to understand the Earth’s climate response to future AMOC weakening. However, paleoclimate records reveal a two-phase hydroclimate pattern across many regions, suggesting more complex global dynamics than previously understood. The roles of contemporaneous freshwater events during HS1, including Siku Event 1 (S1; 19-17 ka) in the North Pacific and Heinrich Event 1 (H1; 18-15 ka) in the North Atlantic, have not been systematically examined. In this study, we run freshwater hosing experiments by applying a freshwater flux in the North Pacific and North Atlantic to simulate the impacts of S1 and H1 on global climate systems. Results from these two experiments agree with the two-phase HS1 climate patterns observed in paleoclimate records, showing distinct responses over western North America, the Maritime Continent, East Asia, and South America. These findings indicate that the contemporaneous freshwater forcings in both regions, offset by only one thousand years, were responsible for large scale hydro climate change. Distinguishing the impacts of North Atlantic versus North Pacific freshwater forcing during HS1 is essential for providing insights for future AMOC weakening.

Return to posters

Reconstructing hydroclimate patterns in coastal Central California using coeval stalagmite records from White Moon Cave

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California's Mediterranean climate makes it highly susceptible to "whiplash" events—rapid transitions between wet and dry extremes. Previously analyzed proxy records covering 6,900 to 8,700 years BP from a stalagmite from White Moon Cave (WMC1) in the Santa Cruz Mountains reveal oscillations between extreme wetness and aridity in coastal California, which may be indicative of climate whiplash during the 8.2 ka event and a precursor event at 8,300 years BP. However, high-resolution paleoclimate records encompassing the mid-Holocene in coastal central California remain scarce, precluding the ability to evaluate climate whiplash events during this interval. Here, we present trace element (Mg/Ca, Sr/Ca, Ba/Ca, P/Ca) and stable isotope ($\delta^{18}O$ and $\delta^{13}C$) records from stalagmite WMC5, which grew from ~8,000 to ~6,100 years BP, overlapping with the original WMC1 record. We also extend proxy records for WMC1 to ~350 years BP, encompassing the stalagmite's full growth period. A multi-centennial mid-Holocene drying trend is indicated by $\delta^{13}C$ and trace element records from WMC5 beginning at ~6,400 years BP until this stalagmite stopped growing around ~6,100 years BP. Relative to WMC1, coeval WMC5 carbonate exhibits stable isotope ratios with notable positive offsets (~+2.16‰ mean difference for $\delta^{13}C$, ~+0.83‰ mean difference for $\delta^{18}O$), and both stable isotopes and trace element ratios display greater variability in WMC5. These offsets may result from in-cave disequilibrium effects or from differences in flow path hydrology, as the deeper position of stalagmite WMC5 within the cave and longer flow path may lead to enhanced PCP. This finding also aligns with modern calcite and drip water data, where shallower White Moon Cave drip sites exhibit more negative $\delta^{13}C$ values. However, proxy values from the late Holocene growth interval of WMC1, beyond the period covered by WMC5, trend more positive and display greater overall variability than the early to mid-Holocene WMC1 records. This multi-stalagmite, multi-proxy study offers the ability to examine and account for within-cave processes in a dynamic cave environment, as well as providing a more complete view of hydroclimate variability in coastal Central California throughout the Holocene.

Return to posters