Earth's climate is intimately connected to Earth's biosphere and landscape. My research seeks to explore and quantify these connections using paleoclimate records, modeling experiments, and statistical analyses. These techniques allow me to pose both societally relevant, fundamental scientific questions such as: **how have the wavelength and amplitude of major oscillating climate systems varied in the past? In what ways do climate models struggle to capture real-world phenomena and how can the geologic record inform future model development? What can the recent past teach us about the strength and frequency of extreme events—such as wildfires and floods—in a warming world?** This work is inherently interdisciplinary and draws on field, laboratory, and computationally based skillsets. To borrow an image from the philosopher of science Ian Hacking, I'm less interested in "building bridges" between academic disciplines and more interested in lowering the water level between them, to the point where geologists or ecologists or archaeologists might walk between hilltops which had previously been islands. I am eager to explore ideas for how to integrate my existing research into the unique local context of the High Sierras, Death Valley, and the arid western US.

Short-term changes over long timescales

Phenomena such as the El Niño Southern Oscillation (ENSO) are responsible for much of the interannual to interdecadal climate variability on Earth. Although changes at this scale directly influence humans and human society directly, our understanding of how these systems change during different background climate states remains rudimentary. On one hand, our instrumental records are relatively short. On the other hand, few geologic materials faithfully archive climate variability at so fine a temporal scale. During my PhD, my colleagues and I developed a series of highly resolved paleoclimate records from lake sediments in the Ecuadorian Andes and the Pacific Northwest to better understand how oscillating climate systems have varied during the past 12,000 years (Mark et al. 2022, Mark et al. 2024). We also collaborated with tree-ring scientists to quantitatively intercompare unrelated lines of evidence and provide a more complete and nuanced story of the past (Mark et al. 2023).

I am currently expanding on this research using recently developed global data-assimilation products. Changes in the spectral characteristics of Pacific climate systems are potential harbingers of major climatic and ecological tipping points. Some recent work has suggested that a "slowing-down behavior", or a lengthening of regimes, in North Pacific temperature patterns over the past 100 years portends the approach of some major threshold. At the 2025 Pacific Climate Workshop, I presented research (which I am hope to develop into a potential NSF proposal) which seeks to explore the degree to which the tempo of oscillating climate patterns in the modern Pacific climate regimes is anomalous in the context of the last 2,000 years.

Feedbacks and carbon cycling in northern landscapes

During my PhD, I participated in a project which employed machine learning techniques to multivariate datasets to quantify and rank the drivers of erosion and permafrost thaw in an Arctic watershed (Shelef et al. 2022). The risk posed by permafrost thaw during future warming—the permafrost carbon feedback—motivated the NSF Postdoctoral Fellowship that's funded my recent research. Using the major warming which occurred from the late Pleistocene to the early Holocene, I synthesized records of permafrost degradation preserved in the geologic record, and used simple numerical modeling experiments enabled by gridded paleoclimate model output, to evaluate how thawing permafrost carbon may have contributed to past episodes of global warming. The resultant manuscript is currently in consideration at *Nature*. I have been invited to present this research this fall online at the University of Massachusetts Amherst Climate Systems Research Center's International Quaternary Webinar, and at the 2025 AGU Fall Meeting.

Other research in this area includes parameterizing a simple wildfire model I developed (Gaglioti et al., in prep) with observed negative feedbacks constraining the ignition and spread of fire. In the boreal forest which comprises much of the Alaskan interior, wildfires produce a complex palimpsest of burn scars, many of which are truncated by interactions with previously existing burns. Younger stands of trees tend to be more fire-averse than older ones, creating an ecological self-regulatory mechanism on fire frequency. The strength of this self-regulation, however, may be limited under warmer climate. By informing a simple model with empirical observations quantifying the strength of such fuel limitations during historical climates and during projected near-future warming, we highlight the growing significance of ecosystem services provided by healthy intact forests.

Past pluvial periods in the arid western US

Despite the conspicuous lack of water today, the landscape of much of the arid west was shaped by enormous lakes which dominated the region during the late Pleistocene. The desiccation of these lakes occurred as storm tracks moved north in response to receding ice sheets as Earth experienced its most recent glacial-interglacial transition. The landscape therefore catalogs evidence of the climate dynamics that accompanied the massive global warming event that precedes the one we're currently experiencing. Such evidence provides important observational constraints on contemporary questions about how the global system responds to major warming. Many of these questions are presently poorly constrained, even in the newest generation of climate models. Synthesizing existing data from the region, which is housed in publicly available repositories, could produce scientifically and societally relevant work. Relatedly, I am interested to learn if and how the College interacts with the nearby Deep Springs Lake Ecological Reserve, and whether this site could serve as either a potential field site or a useful place for a hands-on pedagogical experience.

Opportunities for undergraduate participation in research at Deep Springs

I was pleased to see, per the job description, that faculty at Deep Springs mentor students in independent studies. In the absence of a traditional lab space, there are several projects which could incorporate an interested undergraduate. Such a project would give the student the opportunity to learn (or hone) skills in widely applicable scientific computing software and programming languages such as Python and MATLAB. While the exact project would be subject to a student's interests, the recent proliferation of publicly available climate and environmental data vastly expands the depth and diversity of potential semester or year-long projects. I consider my past success mentoring undergraduates one of my best research achievements, and I hope to continue this success at Deep Springs.