

Archaeological Investigations of the Material Culture of the Little Ice Age from Long Point Preserve, Machias, Maine

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Abstract: People have an intimate relationship with their environment. During the Little Ice Age, the climate cooled in much of the Northern Hemisphere, resulting in resource and subsistence changes among past peoples. These potential changes are explored in this study, which focuses on an archaeological site in Machias Bay, Maine.

The Little Ice Age (LIA) was a period of cooling that lasted from approximately the 1300s to the 1800s B.P. During this time, changes in ecosystems and biodiversity occurred, resulting in resource and subsistence shifts.

There is ample ecological evidence of the LIA in North America, but there is an incomplete history of the response of humans to a changing climate in the Americas compared to Europe. The historical record of temperature and weather in North America regarding the LIA is underexplored. Sediment cores and shell analyses have shown that sea surface temperatures cooled during LIA and seasonal temperatures became more distinct (1). Yet further research is needed to understand the impact of this event on humans.

This study focuses on exploring the LIA through a material culture analysis at two sites in Machias, Maine; ME-62-58 and ME-257-048. These sites, located in the Passamaquoddy homeland, show both pre-contact and post-contact use of this location. The artifacts identified at these sites are shown in Fig. 1. This

research focuses heavily on faunal analysis to identify changes in the ecosystem over time (3). It will also allow us to understand how human practices and behavior shifted with climatic changes.

Mammals	Moose, Deer, Pig, Raccoon, Sheep, Cow, Bear, Grey Squirrel, Skunk
Avians	Herring Gull, Canada Goose, Common Loon, Cormorant, Crow
Fish	Sturgeon

Table 1. Species present at ME-257-048 and ME-62-58.

Acknowledgements: Donald Soctomah, Tribal Historic Preservation Officer, Passamaquoddy Tribe, Maine Coast Heritage Trust (MCHT), and the CCI Graduate Assistantship.

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Proportion of Artifact Classes at Site ME-62-58 & ME-257-048

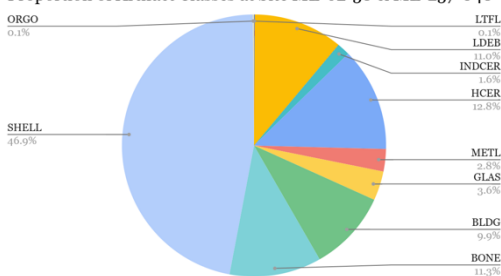


Fig. 1. Artifacts represented ME-257-048 and ME-62-58.

Reconstructing Holocene Seabird Colony Dynamics in the Gulf of Maine Using Stable Isotope Records

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Abstract: Seabirds are important ecosystem engineers on coastal islands, transporting marine-derived nutrients to terrestrial ecosystems through guano deposition. These nutrient inputs influence vegetation dynamics, soil chemistry, and island food webs. This study investigates long-term seabird responses to climate change in the Gulf of Maine using paleoecological methods. Sediment cores preserve geochemical signatures of seabird activity that can be reconstructed using stable isotope and trace metal analyses. In July 2025, sediment samples were processed at the Keck Stable Isotope Laboratory at the University of Wyoming to measure nitrogen ($\delta^{15}\text{N}$) and carbon ($\delta^{13}\text{C}$) isotopes. These proxies will help identify past seabird presence and link colony dynamics to climate variability.

Background:

Seabirds are apex predators and major contributors to island nutrient cycling, depositing nitrogen- and phosphorus-rich guano that alters soil chemistry and plant productivity.¹ Because seabirds feed in marine food webs but nest on land, their colonies transfer marine-derived nutrients to terrestrial ecosystems. The Gulf of Maine is experiencing rapid environmental change, including warming sea surface temperatures and shifting fish distributions that affect seabird foraging and breeding success. Reconstructing long-term seabird population history provides important context for understanding how colonies respond to environmental change.

Methods:

This study will use sediment cores from coastal Maine island peat bogs and guano samples from active seabird colonies to investigate long-term population dynamics. Radiocarbon dating will establish core chronologies, while stable isotope and heavy metal analyses will reconstruct past seabird activity during climate events like the Little Ice Age. Elevated nitrogen isotope (N^{15}) levels and bioaccumulative metals will serve as indicators of seabird presence.¹ Modern guano samples from Great Duck Island provide reference isotope and metal signatures for interpreting paleo records.

Expected Outcomes and Impacts:

This research will reconstruct long-term seabird population dynamics in the Gulf of Maine and evaluate how colonies responded to past climate variability. Identifying periods of seabird expansion or decline will link marine productivity, climate change, and seabird ecology. Preliminary isotope results show higher $\delta^{15}\text{N}$ values at Ship Island compared to Petit Manan, suggesting stronger seabird-derived nutrient inputs and potentially larger or more persistent colonies at that site.

Acknowledgements: NSF SAUNNA NRT, Sturgis Family Foundation Exploration Fund, Geological Society of America

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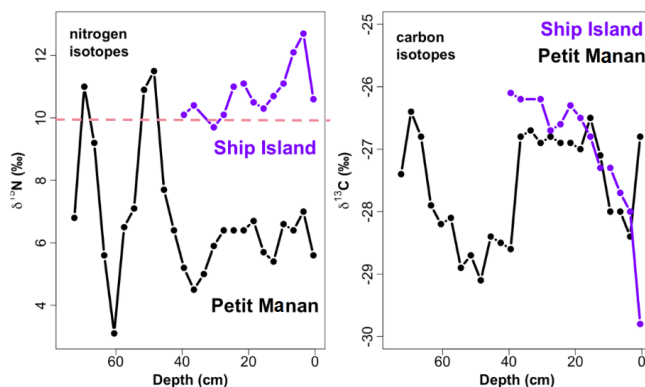


Fig. 1. Adapted from D. Groff Nitrogen and carbon Isotopes of Ship Island and Petite Manan. N^{15} 0/00 > 10 indicate likely seabird presence.

Tuning Hyperspectral Imaging for Cryptotephra in Ice Cores

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Abstract: Hyperspectral imaging may be utilized as a non-destructive method for capturing unique spectral signatures in ice cores. Applying hyperspectral imaging to tephra detection has the potential for improved identification of micron-sized particles that form nonvisible volcanic deposits. Hyperspectral imaging has already been successfully applied to tephra detection in ice and sedimentary archives, here we focus on optimizing an ice core specific workflow and constraining detection limits for cryptotephra particle

Background:

Microscopic tephra particles, or cryptotephra, are traditionally detected in ice cores by their co-occurring sulfate spikes. If these spikes are not detectable, cryptotephra deposits can be missed. Likewise, the detection of sulfate spikes does not always result in the presence of particles due to variations in atmospheric pathways.

Hyperspectral imaging has successfully been applied for tephra detection, and offers a rapid, non-destructive method for improved detection of cryptotephra deposits [1]. A hyperspectral image of a tephra-bearing ice core is shown in figure 1. Reducing uncertainty in cryptotephra detection would benefit paleoclimatic timelines as well as improving ice core preservation.

Methods:

Samples containing tephra will be embedded in resin and analyzed by Scanning Electron Microscopy / Energy Dispersive Spectroscopy (SEM-EDS). Particle morphology will be determined by backscattered electron images and elemental mapping will be performed.

Full spectrum hyperspectral scans will be collected from each sample in its natural matrix (neither ice, nor resin). These raw scans will serve as calibration data and reference spectra when assessing cryptotephra in ice cores.

Artificial ice cores will be produced to investigate ice matrix effects on the detection of cryptotephra. By applying varying concentrations of particles to mimic deposition, we will be able to assess the detection limits of cryptotephra by hyperspectral imaging in ice cores.

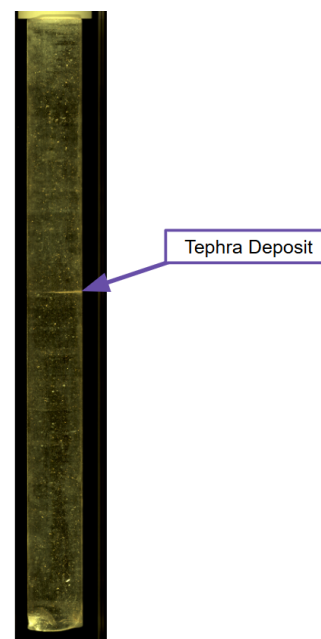


Fig. 1. Hyperspectral Image of an ice core that contains a tephra deposit. Ice core SPC14, section 1317. Image collected by Kurbatov.

Acknowledgements:

NSF Grant 2149519, COLDEX, NSF Grant 2019719, ICF Staff, Curt Labombard, Richard Nunn, Roisin Rumsey, Mikhail Zhizhin, and Geoff Hargreaves.

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Let's get Visual on the North Coast of Peru

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Abstract: This research explored the use of two photogrammetry techniques in creating 3D models of archaeological features at a MidHolocene site on the north coast of Peru.

Background:

The Ostra Collecting Station is a shell heap site on the north coast of Peru radiocarbon dated to ~6,200-6,700 calibrated years B.P. The mollusk, faunal, and cultural materials that constitute its assemblage are quite curious within the context of the region and the coast of Peru in general. To date, this (and its associated Ostra Base Camp site) are the only sites in Peru that contain these assemblages. The mollusks and other faunal remains reflect warm water species with oyster shells as the most prevalent. Dozens of incised / planed pebbles have been recovered from the surface (objects that have not been found anywhere else in South America) as well as the identification of ~60 slingstone piles positioned in two lines (~30 piles per line) with the two lines separated by 180 meters. The southern line of piles are positioned along the top of a 15 meter high sea cliff and the northern line of piles extend across a non-elevated space. Line of site and angle of incidence are two factors that are key in understanding the viewshed of these pile locations and simulate the deadly effectiveness of utilizing this strategy.

Methodology:

A drone was flown over the site to capture and create a digital elevation model (DEM). This DEM serves multiple purposes. First, it can be used as the base layer of the simulated environment I am constructing in virtual reality as part of my dissertation research. Second, it can be used to visually demonstrate the drastic elevation differences experienced within the site. Third, GIS can be used to assess line of sight and angle of incidence.

3D models of slingstones were created using the Polycam app. These models will be incorporated into the virtual simulation of the site including being used by a line of slingers to demonstrate

what a person would have experienced from both the advancing and defending perspectives.

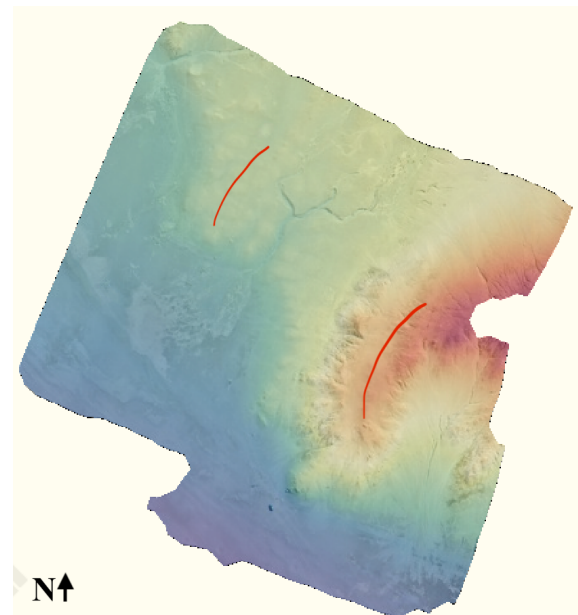


Fig 1. DEM of the Ostra Collecting Station with the northern and southern lines of slingstone pile locations marked with red lines.

Acknowledgements:

I am grateful for my field work funding which was provided by the Robert and Judith Sturgis Family Foundation. I express appreciation to Drs. Cecilia Mauricio and Gabriel Prieto for continued site access and support and to my field team members Drs. Dan Sandweiss, Alice Kelley, Shaleen Jain, and Allen Gontz, and Ramiro Acosta, and Kate Johnson whose help was instrumental!

Estimating Spatial Variation of Snowmelt to Enhance Understanding of Meltwater Input and Storage in the Snowpack at Taku Glacier, Juneau Icefield, AK

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Abstract: Globally, glaciers are melting at an accelerating rate and threatening coastal communities worldwide. However, a critical, yet understudied, component of this process that may delay or mitigate sea-level rise is firn, porous snow that can act as a temporary reservoir for meltwater. When excluding the continental ice sheets and the impact of thermal expansion of the ocean, the Arctic region of Alaska and Northwest Canada are projected to experience the greatest rates of mass loss and contribute to global sea-level rise proportionally. However, an uncertainty remains in our predictions of future sea-level rise: the extent to which the projected increases in melt will contribute directly to sea-level rise, or what proportion may instead be stored in existing pore spaces within the snowpack. The aim of this study is to estimate the spatial variation of snowmelt to enhance understanding of meltwater input and storage in the snowpack at Taku Glacier, Juneau Icefield, AK.

Motivation. By improving the estimates of meltwater input through better understanding spatial variation of snowmelt, we aim to refine predictions of meltwater storage in firn and contribute to more accurate hydrological modelling for the region.

Methods. We collect and analyse drone-based repeat surveys at two distinct elevations along T'aakú Kwáan Sí't'l (Taku Glacier) to capture the weekly spatial variation of snowmelt. These surveys were conducted in the ablation zone on the lower Taku Glacier and in the accumulation zone further inland (Matthes-Llewellyn-Tulsequah glacial divide). In total seven surveys were conducted. Two at the Divide and five in North Basin. The surveys were completed using an AltaX Drone with a Routsene LiDAR system to get 1 cm spatial accuracy. To ensure such accuracy, an Emlid GPS rover and base station system was used to ground truth the survey with four ground control points. To compare the drone results a transect across North Basin with ablation stakes was done and is shown in Fig. 1.

Future work. We plan to finish analysing the drone data and compare to the ablation stakes and use our findings as input to hydrological models for the region. This work is part of the broader collaborative research in North Basin, with particular focus on understanding melt processes, firn dynamics, and water storage within the snow and firn and beneath the ice.

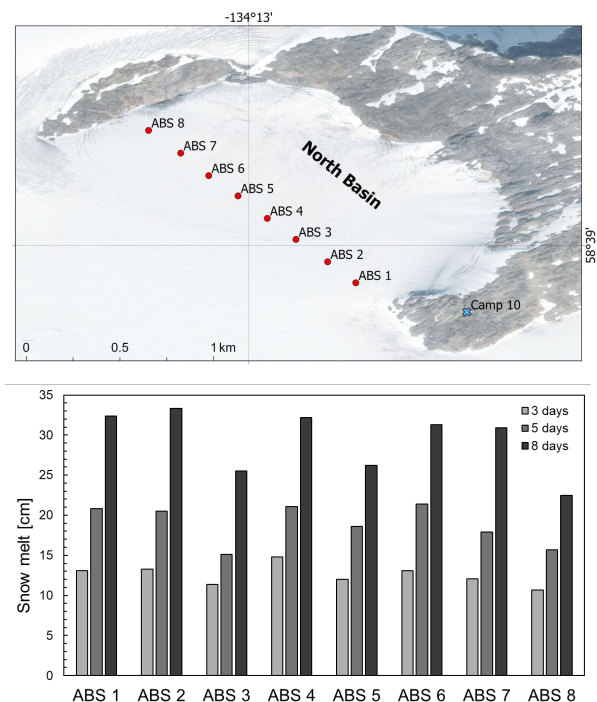


Fig. 1. Top: Red dots represent the eight ablation stakes (ABS) across North Basin on Taku glacier. Bottom: The snow melt measured at each ABS over 8 days.

Acknowledgements: This work was possible thanks to the assistance of the Dan and Betty Churchill Exploration Foundation, DOD, NSF and the Graduate Student Government at UMaine.

Glacier Slope Steepens as Marine-terminating Glaciers Retreat onto Land

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Abstract: Glaciers are retreating at an accelerating rate due to climate change, contributing to global sea-level rise with significant economic consequences and increasing risks to coastal communities. However, a critical yet underexplored aspect of this glacier retreat is the widespread transition of glaciers from marine- to land-terminating terminus environments. Since the 1980s, hundreds of marine-terminating glaciers in Greenland have retreated onto land, but the impact on glacier dynamics and projected sea-level rise remains unclear. Here, we examine five neighboring glaciers in southern Greenland over the past 83 years as they retreat and transition. Our results indicate that drastic steepening of the glacier terminus is a defining characteristic of this transition.

Introduction: 258 marine-terminating glaciers in Greenland have retreated onto land since the 1980s (Børch and Timotej, 2023). By 2100, 44–57% of all marine-terminating glaciers, excluding those connected to the Greenland and Antarctic ice sheets, are expected to transition to land and omitting this transition from predictive models may lead to less accurate predictions of future sea-level rise, as initial projections suggest (Rounce et al. 2023). In our study, we have created nine historical DEMs from available historical aerial photographs from US and Danish surveys of Greenland using a structure-from-motion (SfM) photogrammetry workflow (Child et al. 2021). By comparing these historical DEMs to modern satellite-derived DEMs, we have created an 83-year-long 3D glacier record covering the retreat (QA, N; Fig. 1), and for two of the glaciers,

the full transition (Nt, QB; Fig. 1). By utilizing a longitudinal record of remotely sensed data we identify characteristics of glaciers undergoing transition to better inform future sea-level rise projections. In comparing surface profiles and calculations of driving stress, we find a drastic steepening of the slope in the first 1000 m of the terminus for the transitioned glaciers (QB: 2.1° to 18.0°, Nt: 8.4° to 19.5°), while the following 1000 m remains largely unchanged.

Acknowledgements: This work was funded by a CCI fellowship, the Sturgis Exploration Fund and the NSF SAUNNA NRT.

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Rounce, David R., Regine Hock, Fabien Maussion, et al. 2023. “Global Glacier Change in the 21st Century: Every Increase in Temperature Matters.” *Science* 379 (6627): 78–83. <https://doi.org/10.1126/science.abo1324>.

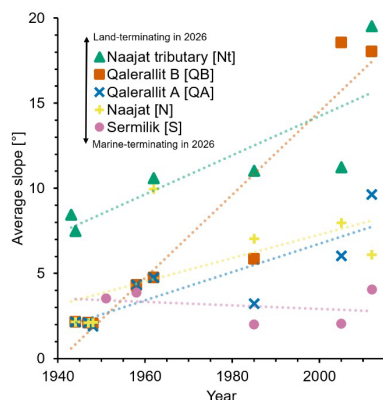


Fig. 1. The average slope of the first 1000 m from the glacier terminus and up glacier of the five study glaciers in south Greenland from 1942 to 2012. Today, Nt and QB are fully land-terminating, QB and N transitioning, and S is still fully marine-terminating.

The Juneau Icefield as a Polar Proving Ground for Collaborative Science, Technology Development, and Workforce Training

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3. *Juneau Icefield Research Program, Foundation for Glacier and Environmental Research.*

The Juneau Icefield serves as an accessible polar proving ground where interdisciplinary research integrates with the development and testing of emerging geophysical and remote sensing technologies. Through coordinated field research, complementary sites in Alaska and the northeastern United States, and hands-on training programs including the Juneau Icefield Research Program and a new graduate field course, these efforts support collaborative science, technology development, and workforce training for future polar research.

Our current research on the Juneau Icefield spans several interdisciplinary areas, including atmospheric science, terrestrial snow processes, glaciology, hydrology, landscape evolution, and the development and testing of new polar engineering technologies. Field efforts incorporate instruments such as ground-penetrating radar for mapping snow and ice structure, terrestrial radar interferometry for detecting surface change, and UAV-based payloads carrying optical, LiDAR, and meteorological sensors to study atmosphere–surface interactions. The icefield also serves as a testbed for geophysical method development and polar instrumentation, supports planetary and icy-world analog research, and provides an ideal environment for calibration and validation of airborne and satellite remote sensing observations under controlled field conditions.



Fig. 1. Gamma Terrestrial Radar Interferometer viewing the Juneau Icefield to capture movement and spatial-temporal variations in surface melt.

Elements of the polar proving ground extend beyond Alaska to include complementary field sites in Maine (Baxter State Park) and New Hampshire (Mt. Washington). Training the next generation of Earth and climate scientists and engineers is a major focus of our efforts. Undergraduate students from the long-established Juneau Icefield Research Program integrate into funded research activities annually. In addition, a new Juneau Icefield graduate course will commence in June 2026 with 15 participating students from across the United States. These graduate students will gain hands-on experience with equipment and methods while learning field safety and best practices for participation in interdisciplinary remote field teams.

Together, these activities are establishing the Juneau Icefield and its partner sites as a scalable polar proving ground for interdisciplinary research, technology development, and workforce training. Our ongoing efforts aim to expand observational capabilities, test emerging polar sensing technologies, and build a sustained pipeline of scientists and engineers prepared to work in the rapidly changing environments of the Arctic and Antarctic.

Acknowledgements: Funding for these efforts comes from NASA, NSF, Battelle, and the U.S. Army Engineer Research and Development Center (ERDC).

Investigating the Spatiotemporal Patterns of *Asimina triloba* since the Last Glacial Maximum

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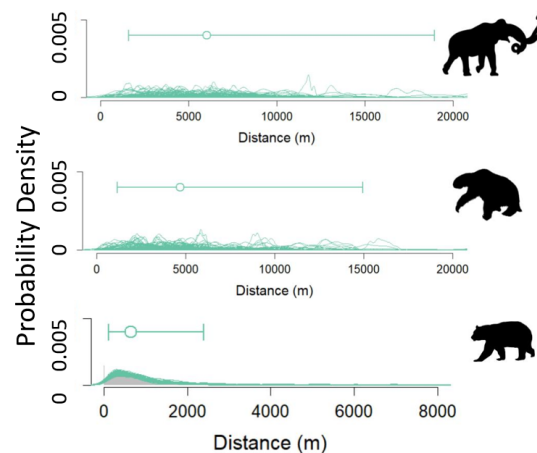
Abstract: *Asimina triloba* (common pawpaw) is a large fruited understory tree that may have relied on megafaunal dispersal before the Late Quaternary Extinctions. We conducted a field germination experiment, and simulated dispersal and landscape reconstruction of Pleistocene habitats for both megafauna and pawpaw populations to better understand the influence of long distance dispersal in the spatial dynamics of pawpaw since the Last Glacial Maximum.

Introduction & Background

It is hypothesized that the evolution of large, fleshy fruits was influenced by frugivory by extinct megafauna (Janzen & Martin, 1982). Larger fauna are often able to digest and disperse seeds longer distances. We present a paleo-ecological case study through a spatiotemporal analysis of the common pawpaw (*Asimina triloba*) from the Last Glacial Maximum to the Late Quaternary Extinctions. Producing the largest berry in the North American flora, pawpaw offers insight into the importance of seed dispersal services that may have been provided by now-extinct Pleistocene megafauna. Regions of predicted habitat suitability during the Late Pleistocene would have likely consisted of dry pine savannas, which would have inhibited the germination success of pawpaw seedlings. It is possible however that pawpaw existed in streamside refugia in these regions, similar to their current habitat.

Methods

A field germination experiment was conducted on 400 seeds of *Asimina triloba* to observe how digestion by mammals, fire, and water dispersal may impact successful germination in both natural and greenhouse settings. 103 fruits were collected and scarified by heat to simulate habituation in fire-adapted systems, water soaking to test water dispersal capacity, and treated with HCL to test mammalian gut passage. A dispersal simulation model (figure 1) was used to assess interactions in pawpaw and extinct megafauna. Pollen abundance of pine, grass, and alder was used from existing records to estimate species composition and canopy openness.



Outcomes & Impacts

From landscape reconstruction analysis we interpolate that the inland Southeast was composed of mainly open canopy pine savanna ecosystems. In the early growing season, we have observed six germinated seedlings in the UMaine greenhouse across all treatment groups. Based on species distribution models and dispersal simulations however, we find that pawpaw likely interacted with a diverse megafauna dispersal guild that facilitated long distance dispersal into bottomlands refugial habitat inland.

Citations

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Acknowledgements

Funding support for this project was gained from the Robert and Judith Sturgis Family Foundation.

The Sunda Node: Hints of Non-torpid Heterothermy in Bornean Squirrels

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Abstract: Squirrels have been a model group for studying mammalian thermoregulation due to their near-global distribution and diversity. What remains is to resolve tropical geographic and phylogenetic gaps in our understanding of the group's thermophysiology. We collected data from three Bornean squirrel species to test their metabolic responses to varying thermal challenges. Our data indicate that these species exhibit flexibility in body temperatures, resting metabolism, and water loss across a range of ambient temperatures.

Background:

Squirrels (Family Sciuridae) are geographically, ecologically, and physiologically diverse and exhibit the full range of endothermic phenotypes from strict homeothermy to hibernation. The evolutionary history of sciurid thermal ecology and physiology remains obfuscated by historical sampling biases, including sampling in regions with considerable seasonality. Here we offer preliminary assessments of the thermal phenotypes of three diurnal species of squirrels in the stable Indomalayan tropics (subfamily Callosciurinae). We expect that *Callosciurus notatus* (arboreal, ~215g), *Lariscus insignis* (terrestrial, ~175g), and *Sundasciurus lowii* (semi-arboreal, ~95g) will lessen energetic costs with some degree of thermal flexibility.

Methods:

We trapped squirrels in community forests of Bau District, Sarawak, Malaysia in 2014 and 2023-24. We measured resting metabolic rate, subcutaneous temperature, and evaporative water loss during 8-12 hour overnight steady-state respirometry trials using the Field Metabolic System (FMS; Sable Systems International) in circuit with a LI-840A CO₂/H₂O Gas Analyzer (LI-COR Biosciences) on adult males and non-reproductive females at varying ambient temperatures.

Results:

Preliminary data indicate an aggregate circadian range of normothermic body temperature in *C. notatus* of ~5°C, in *L. insignis* of ~3°C, and in *S. lowii* of ~2.5°C, reflective of diurnal activity patterns in each species (Figure 1). All three species show an inverse relationship between ambient temperature and resting metabolic rate;

as temperatures increase, resting metabolic rate tends to decrease. The opposite seems to be true for ambient temperature and evaporative water loss in *L. insignis* and *S. lowii*, which show a positive relationship, although no trend is discernable for *C. notatus*. The data suggest a slight positive relationship between ambient temperature and subcutaneous temperature in *C. notatus* and *L. insignis*, but not in *S. lowii*. Overall, these initial data support the notion that flexible normothermy is an ancestral trait in small tropical mammals. Such flexibility allows individuals of these diurnal species to tolerate higher body temperatures while active, and to offload excess heat to the environment while at rest.

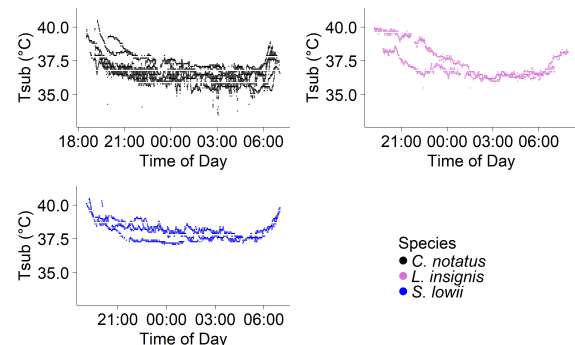


Figure 1. Aggregate subcutaneous temperature (°C) traces during respirometry in 2014 and 2023-25. Each trace shows a decrease in body temperature when entering the rest phase and an increase just before the initiation of the active phase.

Ethics: This study was conducted in accordance with IACUC Protocol #A2021-06-01 and Sarawak Forestry Corporation Permits SFC.810-4/6/1 - 077 and SFC.810-4/6/1 (2023) - 207.

Acknowledgements: Funding for this project was provided by the National Science Foundation (IOS#2045785).

Internationally Transferred Mitigation Outcomes and Land Conservation at COP30 Amazonia

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Abstract: Consistent with COP30's implementation theme, the 2025 UN Climate Change Conference held workshops for countries to share lessons learned from participation in an international carbon credit market enabled by the Paris Agreement. With proper safeguards, trading credits grounded in land conservation initiatives abroad is one tool countries may consider to reach emission reduction targets.

The City of Belém is often described as the 'gateway to the Amazon.' Located in Brazil's northern Pará state, heavy and sporadic rainfall provides a daily reminder of the city's proximity to the world's largest 6.7 million square-kilometer rainforest, which by some estimates holds over 400 billion trees and stores between 150 and 200 billion tons of carbon.

Particularly from the perspective of a law student researching land use and conservation law, Belém also felt like the perfect city to host the 30th Conference of the Parties (COP30) in November 2025. Marking the tenth anniversary of the Paris Agreement, COP30 was widely branded as the 'implementation' COP, placing emphasis on the importance of concrete, multilateral action on global climate policy.

Consistent with that theme, COP30's agenda included two 'Ambition Dialogues' for Article 6.2 of the Paris Agreement, a provision which in effect enables a global carbon credit market. By its language, Article 6.2 allows countries to voluntarily participate in 'internationally transferred mitigation outcomes' (ITMOs) to help achieve 'nationally determined contributions,' also known as NDCs, or country-specific emission reduction commitments.

The Ambition Dialogues provided a forum for countries to exchange information on successes and lessons learned from Article 6.2. For example, the Republic of Korea, Australia, and Japan all shared experiences related to participation (or lack thereof) in this international carbon credit system.

Land conservation can serve a vital role as an ITMO under Article 6.2. For instance, in 2025, Singapore announced its plans to procure 2.17 million metric tons of CO₂ equivalent in credits to help reach its NDC, all sourced from natural

resource protection initiatives in Peru, Paraguay, and Ghana.

Carbon credit markets as a climate solution, however, are not immune to shortcomings. With that in mind, Article 6.2 requires parties engaging in ITMOs to "ensure environmental integrity and transparency" and "apply robust accounting to ensure, inter alia, the avoidance of double counting." Importantly, this provision seeks to prevent ITMOs from being counted towards the NDCs of both countries in a transaction, helping to ensure a more meaningful reduction of emissions globally. As with any climate policy, Article 6.2 requires reliable oversight and proper accountability mechanisms. Additional reflection and discussion at future COPs could also promote its effectiveness.

Acknowledgements: This research is supported by the Climate Change Institute and the University of Maine School of Law.

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Paris Agreement to the United Nations Framework Convention on Climate Change, art. 6(2), adopted December 12, 2015; entered into force November 4, 2016.

Abbreviating Names

Sudarshan S Chawathe^{1,2}

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Abstract: This work briefly explores this problem: Given a set of names, how may we abbreviate each name in a manner that eases recovery of the original from the abbreviation, with additional desiderata such as brevity and mnemonics?

A popular quote in some circles (attributed to Leon Bambrick [1]) is: "There are 2 hard problems in computer science: cache invalidation, naming things, and off-by-1 errors." This work addresses the second problem. In more detail, it addresses the problem of shortening names while preserving uniqueness within a group and other properties. Such shortening of names has several applications both within and beyond computer science. Examples include mapping long names of attributes to shorter ones more suited for use in database systems and choosing concise labels for graphical depictions.

One aspect of this problem is precise from the start: There must be a one-to-one correspondence between names and their abbreviations. Other aspects are not precise as stated and require further development. If all we care about is the correspondence, then the problem may be trivially solved by associating the integers with the names in the set and maintaining an array with the element at index being the name mapped to. In the motivating applications, such numerical abbreviations may be technically valid in some cases (e.g., database systems will not complain about tables with columns named C0, C1, etc.), but are unsatisfactory for human efforts because there is no intuitive mapping from the integers back to the names. Different ways of formalizing the additional requirements lead to variants that are interesting for both theoretical and pragmatic considerations.

Motivated by the desirability of the abbreviation of a name being as similar as possible to that name, while also being brief and unambiguous, we may consider a variant that requires all abbreviations to be generated by selecting a few letters, at fixed locations, from the names. In more detail, a solution for this variant consists of

a set of indices, listed in ascending order. Its interpretation is that the abbreviation of each name is generated by concatenating the letters of that name that are at positions i_1, \dots, i_k . When a name has fewer letters than some index, its abbreviation uses a suitable alternate (such as an underscore or hyphen) for that position. The problem may then be stated as that of minimizing the number of selected indices, k , while ensuring uniqueness of the abbreviations.

This variant has the desirable property of being simple and precise. It also incorporates some aspects of maintaining intuitive correspondence between names and abbreviations, since each abbreviation is derived from its name using a simple rule. In simple instances of this problem, such as one in which the names are distinguishable using the first few letters, this variant should produce the intuitively appealing result of using those letters as abbreviations. For example, abbreviating the names used by the International Radiotelephony Spelling Alphabet [2, 5.2] (Alfa, Bravo, Charlie, ..., Zulu) should yield the corresponding letters A through Z.

In general, this variant of the problem is computationally difficult (NP-hard, by reduction from the minimum hitting-set problem for instance). However, since the number of names is not expected to be very large, and since the problem also admits a simple 0-1 integer programming formulation that may be solved using a large collection of efficient software developed over many decades, this computational difficulty is unlikely to impede the envisioned uses.

Ice Thickness Estimates Across the Juneau Icefield from Ground-penetrating Radar Surveys

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Abstract: To better quantify ice thickness across the Juneau Icefield, a temperate icefield located in Southeast Alaska, we conducted low frequency ground-penetrating radar (GPR) surveys targeting Taku Glacier and its tributary glaciers. Despite prevalent challenges in radar interpretations at this site from liquid water inclusions, signal interference, and clutter, our results show ice thicknesses exceeding 1,000 meters at key locations on the icefield.

Introduction: Alaska and Northwest Canadian glaciers are losing mass faster than any other mountain glacier system on Earth, and this trend is expected to continue throughout this century¹. Glaciers act as a crucial water resource for about one-third of the global population and impact downstream watersheds, marine ecosystems, ocean circulation, and sea level rise². However, to predict the effects of future glacier change and the associated downstream impacts, ice thickness measurements, and thus volume, must be better quantified.

Estimates of glacier thickness and ice volume on various spatial scales are typically collected from ground and airborne-based geophysical surveys, including radar, and numerical modeling. To better constrain ice thickness estimates across the Juneau Icefield, in June of 2025, we collected ~250 km of ground-based radar transects. Our surveys targeted regions with greater uncertainties and at important transitions between glaciers' tributaries and their main trunks. In this study, we present data obtained from a low frequency, 1 MHz, GPR system. Preliminary findings suggest ice thicknesses up to ~1100 m in some locations (Fig. 1), however we encounter challenges from radio interference, clutter resulting from off-nadir reflections from surface and subglacial topography, and liquid water inclusions that scatter the radar signal, obscuring depth measurements in some locations³.

Therefore, a comparison of these results with existing datasets from airborne radar and modeled ice thicknesses may reduce our overall uncertainties in determining ice thickness and volume in a temperate glacier environment.

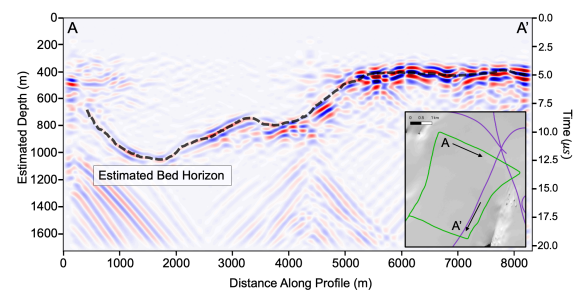


Fig. 1. Radargram from 1MHz transect collected at the Matthes-Llewellyn Divide with inset location map showing transect (green line) and arrows indicating travel directions.

Acknowledgements: We would like to acknowledge field and data support from Michael Christoffersen (Georgia Tech), Martin Truffer (University of Alaska, Fairbanks), and Jack Holt (University of Arizona). This research is supported by funding from NASA. We also thank the Juneau Icefield Research Program for logistical support.

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Technological Innovation through COP's Technology Mechanism: Balancing Mitigation and Monitoring Efforts with Long-Term Impact

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Abstract: This year's COP 30 seemed to embrace technological solutions with several panels and discussions raising the issue. Through my research on the ground, I sought to examine how certain technological solutions were certainly effective in their mitigation efforts, while others raise new issues of their own for states—particularly those in the Global South.

Following the International Court of Justice's advisory opinion in affirming states' obligations to avoid significant environmental harm and adhere to the nationally determined contributions (NDCs) identified in the Paris Agreement, this year's COP was underpinned by the responsibilities owed to other states. By hosting the conference in Belém, Brazil—a city at the heart of the Amazon with indigenous communities directly affected by climate change—the world was reminded who is most affected and what is really at stake in climate negotiations.

To accelerate climate change mitigation efforts, technology solutions have offered promising support. For example, this year's COP announced the creation of an AI Climate Institute. However, particularly where geopolitics are intertwined with technology investment, technological solutions to climate change may introduce separate issues of their own.

Encouraged Technology Adoption:

The Technology Mechanism was established in 2010 to facilitate climate technology development and adoption to support states on the road towards 1.5°. The Technology Mechanism consists of the Technology Executive Committee (TEC) and the Climate Technology Centre Network (CTCN) which work together to develop recommendations and policy proposals and implement them in states. Panelists from states like Senegal, Uganda, Belize, and the Maldives spoke about the different ways they engage the TEC and CTCN to facilitate collaboration amongst innovators and local community members.

Emphasis is placed on allowing local communities to take the lead in addressing their climate challenges with their own technological solutions. Some examples of competitions for

youth or local developers were highlighted to show how communities are often best poised to understand the challenges their own towns are facing. However, the implementation of these ideas poses new challenges and requires even more funding that Western countries seem reluctant to provide.

New Solutions Introduce New Issues:

Apart from critiques that a lack of funding leads to ineffective implementation of the Technology Mechanism—particularly for the least developed countries (LDCs)—some of the technological solutions posed present environmental challenges of their own. For example, AI and accompanying data centers are known to be heavy consumers of energy and water. Further, with technological investment from countries or companies in the Global North, LDCs may feel a future risk to digital sovereignty unless local communities are left in control of their own implementation.

While technology can allow for unmatched insight, prediction, and modeling for under-resourced communities to mitigate and respond to climate change, the long-term impact of incorporating these technological solutions should be weighed.

Acknowledgements: This research was supported by the Climate Change Institute and the University of Maine School of Law.

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COP30 – Turning Promises into Action (Sort of)

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Abstract: If COP21 was about setting ambitious global goals to fight climate change, then COP30 was about turning pledges to both adapt to climate change today and mitigate it in the future into action. This mini-paper focuses on the negotiations and adoption of the Global Goal on Adaptation indicators and suggests that meaningful progress at future COPs is still possible.

Nearly a decade after the Paris Climate Agreement established a global framework to limit climate change, the world arrived in Belém, Brazil to confront the difficult task of turning those commitments into action. That work had to be answered in one of the most complex geopolitical moments in recent history. The absence of a formal United States delegation raised questions about whether the remaining parties could sustain the ambition and financial commitments needed to operationalize the agreement and make meaningful progress to reduce global emissions. Despite this, meaningful progress was made in tracking adaptation.

Global Goal on Adaptation

The Global Goal on Adaptation is a collective commitment under Article 7.1 of the Paris Climate Agreement to improve countries' capacity to adapt to, become more resilient to, and less vulnerable to the impacts of climate change. After eight years with no meaningful progress, negotiators reached an agreement on an overarching framework at COP28.

Coming into COP30, negotiators were meant to review metrics (called "indicators") selected by a team of leading scientific experts, ranging from issues on water, food, public health and the health of ecosystems, national infrastructure, and poverty. The process began with roughly 10,000 indicators and was reduced down to 100 to help facilitate negotiations.

Negotiators were tasked with finalizing these indicators so that nations have a better idea about where climate adaptation investments are working, and where they aren't. This work is especially important for developing nations, many of whom are experiencing compounding effects of sea level rise, desertification, drought, increasingly intense and frequent weather

events, and a lack of financial resources to adequately respond.

COP30 ended with the adoption of fifty-nine indicators that ultimately omitted certain topics and significantly deviated from the initial language proposed by scientific experts. Notably, the indicators were introduced by the Brazilian Presidency in the final hours of negotiations, and adopted despite objections from the EU, Canada, and several Latin American nations. Significant compromises that were necessary to get the plenary to adopt these indicators may ultimately make them more difficult to use today. Despite this, their adoption provides a starting point for the international community to track global progress on climate resilience and tangible efforts in critical areas like food, water, and public health.

In the meantime, these indicators will theoretically provide a way for nations to measure progress towards adaptation efforts and make a case for more targeted financial and technical support to meet their goals. Expect this to be a significant focus for future COPs.

Acknowledgements: This research is supported by the Climate Change Institute, the University of Maine School of Law, and the Mitchell Institute.

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Variable Carbon-nutrient Dynamics in Subarctic Lakes Across a Land-use Gradient in a Rapidly Warming Region

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Abstract: We used bulk and stable isotope analyses of carbon (C) and nitrogen (N) to quantify how the introduction of agriculture and onset of abrupt climate change in the 20th century compounded to alter nutrient cycles in subarctic lakes. Preliminary results show that the trend and magnitude of sediment C and N vary across lakes with different degrees of agricultural influence.

Lake sediments are one of the largest storage sites of C in the northern hemisphere and have contributed to widespread increases in C burial rates in the last century (Heathcote et al. 2015; Anderson et al. 2020). Increases in C burial across the Arctic tundra are attributed to increasing air temperatures, whereas anthropogenic nutrient additions from land management are predominant controls at lower latitudes (Anderson et al. 2020). Unprecedented warming trends are predicted to shift agricultural production north, yet the interactive effect of climate change and agriculture on the C cycle in Arctic regions is poorly constrained.

South Greenland is a lake-rich region that is home to the earliest known example of agriculture in the Arctic, distinguished by its unique blend of Norse and Inuit food sovereignty practices involving animal husbandry. We used bulk and stable isotope analyses of C and N to quantify how the introduction of agriculture in the early 20th century and onset of abrupt climate change in the late 20th century compounded to alter C and N cycles in subarctic lakes. To quantify changes across a gradient of land-use patterns, we compared sediment records from six lakes with various levels of sheep grazing and fertilization within the watershed.

Preliminary results show abrupt increases in organic carbon accumulation rates and $\delta^{15}\text{N}$ in the late 20th century in the lake with the strongest agricultural influence, Igaliku. In contrast, responses were variable across lakes with moderate or no agriculture in their watershed (Fig 1).

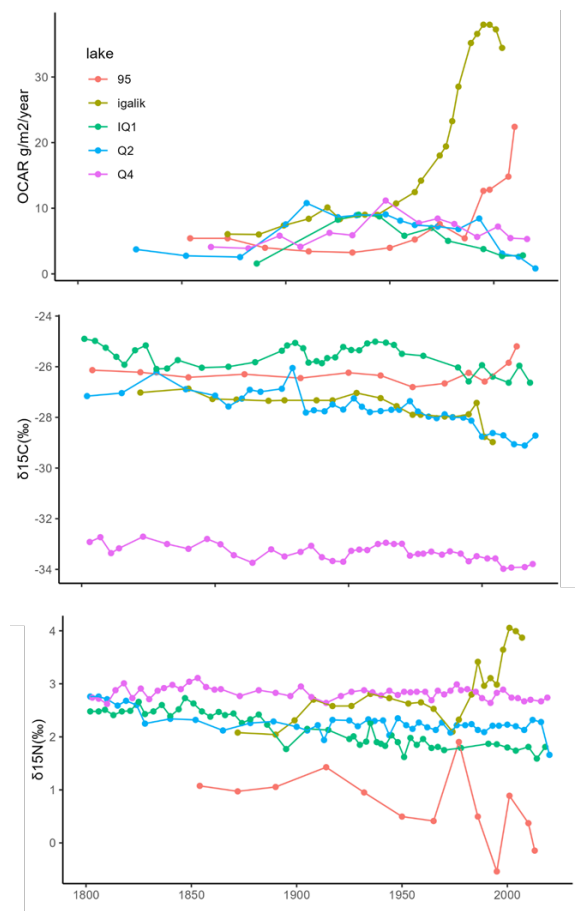


Fig. 1. Lake sediment profiles from 5 lakes in South Greenland; from top to bottom: organic C accumulation rate (OCAR), $\delta^{13}\text{C}$, and $\delta^{15}\text{N}$.

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Investigating Global Synchrony - The Esmark of the South?

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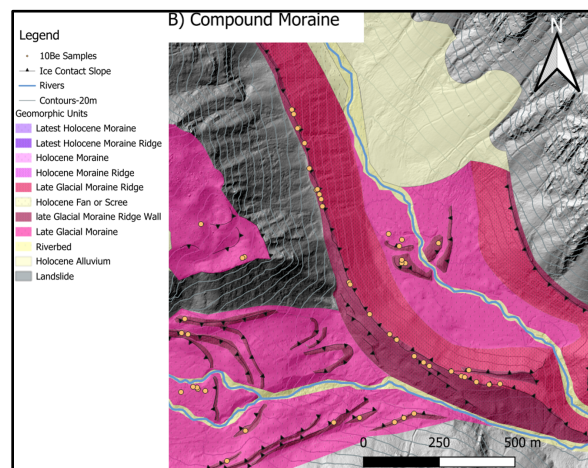
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Abstract: Mountain glaciers are highly sensitive indicators of climate variability and record millennial-scale fluctuations in global temperature. However, the mechanisms responsible for these climate oscillations remain debated. In this study, we examine competing hypotheses for late-glacial climate variability through geomorphic mapping and cosmogenic ¹⁰Be surface-exposure dating of the mid-valley moraine complex at Whale Stream, New Zealand. Cosmogenic ¹⁰Be dating allows us to determine how long glacially deposited boulders have been exposed at Earth's surface, providing exposure ages for glacial landforms. A prominent set of moraines preserved in the Whale Stream valley records a significant glacier resurgence that interrupted deglaciation following the Last Glacial Maximum. Our objective is to establish a ¹⁰Be exposure-age chronology for these late-glacial moraines and compare it with regional and global paleoclimate records to evaluate the climatic drivers responsible for glacier fluctuations during the last glacial termination.

Mountain glaciers are sensitive indicators of global temperature change and record millennial-scale climate variability. The causes of these oscillations remain debated. One hypothesis attributes them to a bipolar seesaw¹ of oceanic heat exchange between the polar hemispheres, which would produce asynchronous glacier responses. Alternatively, the “Zealandia Switch” hypothesis proposes that shifts in the Southern Hemisphere westerly winds drive global climate changes, resulting in synchronous late-glacial moraine formation in both hemispheres².

To evaluate these hypotheses, we investigate the mid-valley moraine complex at Whale Stream, a tributary of Lake Pukaki in the central Southern Alps of New Zealand. Although previously interpreted as recording linear retreat after the Last Glacial Maximum³, the moraine morphology reveals several nested ridges, suggesting repeated ice-margin fluctuations at similar valley positions. Fieldwork conducted in January 2025 included detailed geomorphic mapping and sampling of moraine boulders for cosmogenic ¹⁰Be surface-exposure dating. We aim to develop a high-resolution ¹⁰Be chronology of moraine construction and compare it with well-dated Northern Hemisphere moraine systems, including the Esmark and Lysefjord moraine belts

in southwestern Norway⁴, to better understand the drivers of late-glacial climate variability.



Acknowledgments: Thank you to the Comer Family Foundation, and the E.R. Quesada Foundation for financial support.

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Changing Susceptibility of Dissolved Organic Carbon to Photodegradation and Photobleaching Following an Extreme Weather Event in West Greenland

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Abstract: In the fall of 2022, extreme wet and warm conditions resulted in a transformation of the lakes near Kangerlussuaq, West Greenland from “blue” (clear) to “brown” (high color) states, owing to a large influx of dissolved organic carbon (DOC) into lakes from permafrost thaw. A series of light exposure experiments demonstrated higher reactivity of DOC to ultraviolet light following 2022, providing insight into the nature and potential longevity of the browning.

Background:

During the autumn of 2022, Kangerlussuaq, West Greenland and the surrounding area was impacted by compound extremes of warmth and precipitation. Late-season rainfall flushed large quantities of material into lakes, which rapidly and coherently browned across the landscape. DOC is a principal driver of browning; it is the carbon backbone of dissolved organic matter (DOM), a matrix of complex organic compounds.

Prior to 2022, the DOC concentrations in these lakes were relatively high but low in color. Using experiments, the susceptibility of DOC in the lakes to UV-induced photo-degradation-shortening of the average chain length, and photobleaching- loss of aromatic complexity, was very low, indicating a highly bleached DOC pool (Fowler et al., 2018). We sought to replicate these experiments on an annual basis following the browning event, as initial observation of the lakes of the region indicated longer carbon chains and increased aromaticity in DOC pools (Saros et al., 2025).

Methods:

We replicated and expanded on methodology developed in Fowler et al. (2018). Surface samples from three lakes were filtered and separated into light and dark treatments. Light treatments were placed in UV-transparent plastic bags; dark treatments were placed in the same type of bag and then wrapped in foil to block light. These bags were placed outside for one week exposed to the 24-hour Arctic summer sun. Spectroscopic analyses of experiment water were compared to initial frozen samples to determine changes in spectral slope (S_R), a

proxy for chain length, and UV-absorption at 254 nm ($SUVA_{254}$), a proxy for aromaticity.

Results and Discussion:

Initial observation reveals a DOC pool that has transformed following browning. Prior to the browning, S_R and $SUVA_{254}$ showed very little response to light exposure. After 2022, the DOC pool showed signs of photodegradation and photobleaching across multiple years (Fig. 1).

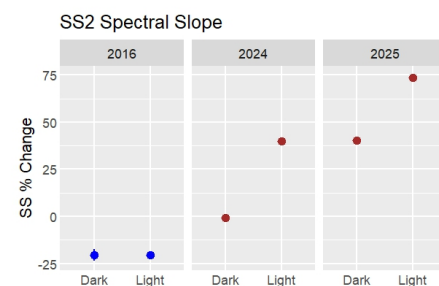


Fig. 1. S_R sensitivity to photodegradation of DOC in lake SS2 in 2016 (blue), and 2024 and 2025 (brown).

Acknowledgements: We thank the Saros Lab for their assistance, and Dr. Rachel Fowler for her work on the study design.

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Assessing Recovery from Acid Deposition in Alpine Lakes in Central Norway

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Abstract: In Norway, sulfur (S) and nitrogen (N) deposition have declined in recent decades. In contrast, recent monitoring of river and coastal surface waters have revealed increases in total organic nitrogen (TON). However, lake systems at high elevation have not yet been quantified. By combining diatom assemblages, $\delta^{15}\text{N}$ isotope analysis, and water chemistry data, this work aims to investigate the relationship between recovery from acid deposition and changing N availability in high elevation lakes in central Norway.

Background:

As systems recover from long-term acidification, material once previously stored in soil can be transported to nearby freshwater. This influx of material may alter the physical and chemical composition of a lake. Most notably, organic nitrogen, an essential nutrient, can stimulate productivity by providing a readily available source of N.



Fig. 1. Sediment core collected from Hornsvatnet to be extruded on the shore.

While monitoring of river and coastal systems has shown increases in TON, there is a noticeable lack of monitoring lakes in alpine systems. Lakes in these regions are highly responsive to changes in the environment, and may show signs of recovery from acidification earlier than their terrestrial counterparts. Additionally, diatoms,

microscopic algae living in water, are highly sensitive to changes in the environment, and may be useful in understanding changes in nitrogen.

The aim of this project is to examine the link between recovery from acid deposition and lake browning in three alpine lakes in central Norway. In order to achieve this, we will use a comparative analysis of current surface water chemistry with historical values (1), and sediment cores will be used to evaluate changes over a broad period of time.

Methods: Relative abundances and diversity of diatom taxa will be assessed in lake sediment cores spanning the last 300 years. Water samples were collected and analyzed for total nitrogen, nitrate, and ammonium. Additionally, sedimentary $\delta^{15}\text{N}$ will be analyzed to differentiate between natural and anthropogenic sources.

Acknowledgments: Thank you to the Robert and Judith Sturgis Foundation for providing financial support for this research. Thank you to Jacob Yde, Torgeir Røthe, and Sigurd Nerhus for their assistance on this research, and to Miranda Seixas and Misa Saros for assistance in the field.

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Scandinavian Ice Sheet Behavior During the Last Deglaciation and the Late-Glacial Climate Reversal

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Abstract: Lysefjord in southwestern Norway contains well-preserved glacial features that provide the basis for a chronology of Scandinavian Ice Sheet behavior throughout the Late Glacial period. My chronology of temperature-sensitive glacier behavior within Norway will allow for a broader assessment of climate dynamics in a warming world, as my chronology can be compared to other temperature proxies to gain a global perspective. I employ ¹⁰Be surface-exposure dating to constrain the age of moraine and glacial erratic deposition within Lysefjord and the surrounding highland plateaus, which constrains the ice front location and ice thickness during the Late Glacial period. One of the big unanswered questions in paleoclimatology is what caused a cold reversal between ~14.6 and 11.6 thousand years ago that interrupted the otherwise rapid warming of the last termination, and my results show that the Scandinavian Ice sheet readvanced during this time.

I travelled to Lysefjord, Norway during the summer of 2023. Researchers have long recognized that Lysefjord contains significant and well-preserved features of past glaciations, but there had not yet been a comprehensive effort to establish the chronology of glacier behavior within Lysefjord, which was an outlet of the Scandinavian Ice Sheet. This work allows us to better understand climate dynamics in a warming world – the last glacial termination provides an excellent experiment to test how climate systems change during rapid atmospheric warming. Glaciers are highly sensitive to changes in atmospheric temperature, meaning that my chronology can be compared to other temperature-sensitive proxy records to assess global climate responses to atmospheric warming.

During my summer 2023 field campaign, I collected 68 samples for ¹⁰Be surface-exposure dating from moraines and erratic boulders within Lysefjord and the surrounding highland plateaus. These sample locations constrain the position and thickness of the ice front within the fjord and in time.

One of the big unanswered questions in paleoclimatology is what caused a cold reversal during the last termination between ~14.6 and 11.6 thousand years ago. Potential mechanisms that have been proposed include a ‘bipolar seesaw’, that redistributed heat between the hemispheres via changes in deepwater formation, and a shift in the westerly wind belts

that released significant heat from the Southern Ocean. The ‘bipolar seesaw’ mechanism would require an antiphase response between the hemispheres while a shift in the westerly wind belts would necessitate a simultaneous response across the hemispheres. My chronology directly tests whether this cold reversal was recorded in the Northern Hemisphere as it is in the Southern Hemisphere.

My results indicate that the Scandinavian Ice Sheet experienced a resurgence during the rapid warming of the last termination, which indicates that there was a period of colder climate during what was otherwise a period of significant warming.

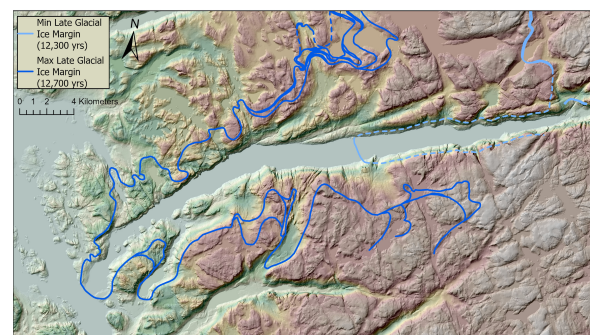


Fig. 1. Lysefjord field area with the ice margin of the Scandinavian Ice Sheet shown during the Late Glacial period.

Acknowledgements: Comer Family Foundation, Sturgis Exploration Fund

Ground Truth and Direct Observation of Subglacial Hydrology and Sediment Controls on Basal Stability at Taku Glacier (T'aakú Kwáan Sit'i)

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3. *Juneau Icefield Research Program.*

Abstract: Subglacial hydrology and sediment rheology strongly influence glacier dynamics, basal traction, and stability in deformable-bed systems. Yet these processes remain poorly constrained due to limited direct observations at the ice-bed interface. This study integrates instrumented hot-water-drilled (HWD) boreholes, ice-penetrating radar (IPR), and seismic surveys to characterize basal conditions at two contrasting sites on the Taku Glacier terminus.

Basal shear stress is commonly expressed in terms of effective pressure, accounting for the difference between ice overburden pressure and basal water pressure. However, in addition to water pressure, glacier beds also respond to sediment thickness, grain-size and distribution, permeability, and bed geometry. In temperate systems, these factors produce spatially variable deformation and basal resistance (Iverson 2010). Subglacial drainage systems shift between distributed and channelized configurations depending on water input and hydraulic gradients (Walder and Fowler 1974).

Taku Glacier provides a natural laboratory for investigating these properties. The lower terminus is thought to overlie thick deformable sediments (Zechmann et al. 2021), yet spatially variable seasonal velocities (Fig. 1) suggest that basal conditions are not uniform (Truffer et al. 2009). The two sites examined here capture that contrast: one where sediment is known to be present, and one where the basal material and drainage configuration remain unresolved.

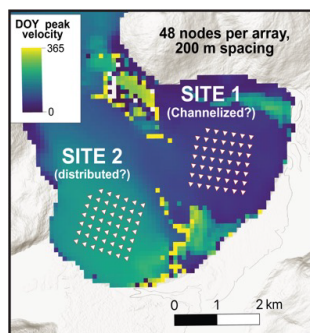


Figure 1. (Source: Hansen et al., Proposal 2518991) Proposed study sites with intended seismic arrays at Taku Glacier terminus.

Access to the glacier bed is the main limitation in testing these processes. Boreholes drilled using the University of Maine HWD provide that access. Borehole depth measurements are compared directly with IPR-derived thickness to ground-truth IPR estimates. Sediment coring determines whether the bed consists of deformable till or a hard substrate, while pressure sensors record

basal water pressure, enabling calculation of effective pressure over time. Optical televiewer imaging documents basal structure, including sediment deformation, clast fabric, and bed roughness.

These borehole observations are collected alongside radar surveys and co-located seismic arrays, allowing direct measurement of basal pressure, sediment properties, and bed structure to be interpreted with geophysical datasets. This reduces ambiguity in radar interpretation and provides constraints for hydropotential modelling of subglacial drainage. By combining HWD-enabled access with depth calibration, sediment coring, televiewer imaging, and in situ pressure measurements, this study constrains how sediment properties and effective pressure interact to control basal traction and glacier dynamics.

Acknowledgements

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Calibrating Isotopic Analysis of *Trachycardium* Shell Material as a Proxy for ENSO Behavior in North Coastal Peru

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Abstract: Variability in the El Niño Southern Oscillation (ENSO) in coastal Peru is measured through sea surface temperature (SST) and upwelling changes. Existing literature investigates how mollusks can be a source of proxy data for ENSO SST and upwelling changes. This project calibrates a method of using carbon and oxygen isotope proxies from modern and archaeological mollusk specimens (*Trachycardium procerum*) to track ENSO variability in coastal Peru.

Introduction: For decades, research teams have tracked ENSO behavior in coastal Peru through archaeological proxy methods¹⁻⁶. My work builds on this research by calibrating a method of using isotopic signatures in mollusk shells as a metric of ENSO behavior. Some mollusk species (e.g., *Trachycardium procerum*) exhibit resilience to ENSO variability and continue to deposit calcium carbonate shell material once or twice daily despite unstable environments³. Carbon and oxygen isotopes taken up during shell deposition serve as proxies for upwelling and sea surface temperature (SST) changes, respectively, two variables affected by ENSO behavior^{1,3,5}. I analyze the isotope signatures of modern shells with known environmental conditions to calibrate the method and then apply this method to archaeological shells with unknown conditions to reconstruct past changes in ENSO behavior.

Methods: In July 2025, I collected 10 *T. procerum* samples at Playa El Dorado, which document the 2023-2024 coastal El Niño and neutral conditions. These shells add to an existing collection, including ones collected from the same and nearby sites in 2017, documenting the 2015-2016 El Niño and the 2017 coastal El Niño (EN1 and EN2), 2019, documenting neutral conditions (N1 and N2), and 2021, documenting the 2021 extended La Niña (LN1 and LN2). Following collection, I sampled carbon and oxygen isotopes^{1,5} at one-millimeter increments along the length of two 2025 shells, 9B and 10B, and two mid-Holocene shells from coastal Peru from the existing collection, OS1 and OS2.

Results/Discussion: The results of this project are divided into four phases: 1) determining isotopic similarity of shells with like conditions, 2) determining isotopic difference between shells with unlike conditions, 3) assessing the accuracy of ENSO events recorded in modern shells, and 4) comparing the Holocene and modern shell isotopes. I discuss some initial results from Phase 1 below. For carbon, the only temporal pair (color-coded) with statistically similar values is 9B and 10B, evident by the overlapping confidence intervals (Fig. 1a). For oxygen, EN1 and EN2, and LN1 and LN2, have statistically similar values (Fig. 1b). Aside

from 9B-O and 10B-O, the non-overlapping pairs are barely separated, which suggests that, upon further analysis and future replication, additional points of similarity may be observed between pairs. Briefly addressing Phase 2, the carbon and oxygen isotopes of the El Niño shells distinctly separate from the other samples. This supports the hypothesis that the *total* shell carbon and oxygen shell isotopes could alone distinguish ENSO events, especially El Niño. However, *total* shell isotope data (Fig. 1) averages and masks variability across each isotope record. Therefore, in Phase 3, I temporally constrain the modern shell isotope records and split the values by ENSO condition to account for the concealed variability.

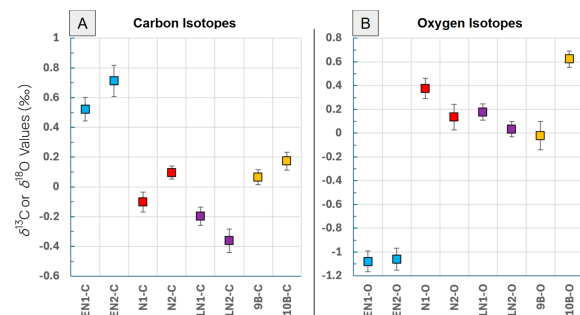


Figure 1: Mean isotope values (‰) for each *T. procerum* sample (data points). Error bars for each mean value indicate the 95% confidence interval.

Acknowledgements: Thanks to the Robert and Judith Family Foundation. Thanks to Alan Wanamaker, Kirk Maasch, and Dan Sandweiss for guidance. Thanks to the UMaine Department of Anthropology and the CCI for project facilitation.

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Contextualizing Copper Assemblages in Two Coastal Pre-Contact Sites

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Abstract: Artifacts created from native copper (high-purity, naturally occurring copper ore) are relatively uncommon yet remarkable components of Ceramic/Woodland period (~2700 to ~500 years BP) Northeast sites. Two sites in Maine (Jones Cove in Gouldsboro, Holmes Point West in Machiasport) show evidence of copper use by pre-contact Indigenous peoples for both aesthetic and utilitarian purposes. Through a combination of material culture and geochemical analyses, this study will explore the temporal context of copper use by Past Wabanaki peoples in the region.

Background:

The manner in which the pre-contact (prior to ~500 years Before Present) Indigenous populations of North America utilized copper varies depending on time and location. Undoubtedly the most well known example of extensive copper use is found on and around the Keweenaw Peninsula in what is now the Upper Peninsula of Michigan. The abundance of raw materials and artifacts associated with the Great Lakes region has somewhat obscured potential alternative sources in Eastern North America; the relative sparsity in the Maritime Peninsula is perhaps most easily explained by the mechanics of long-distance trade. Recently, however, alternative sources of native copper in the Maritime Peninsula, such as the Minas Basin in modern-day Nova Scotia, have received greater attention (Hanley et al. 2022). These alternative sources suggest distinct local traditions and complicate the picture of the pre-contact copper trade in Eastern North America.

Sites:

Analysis will center on two coastal shell-heap sites, including Jones Cove (ME 44-13) in Gouldsboro, Maine, which was first excavated in 1929, and again during the 2006 season of the University of Maine MAPI Field School. Further east, Holmes Point West (ME 62-8) has hosted numerous excavations during Field School seasons beginning in 1973. Based on artifact inventories, both sites suggest peak activity during the Ceramic Period (~2700 to ~500 BP).

Methods:

This study will undertake a comparative analysis of material culture from the two selected sites to contextualize copper use within the culture

history of Wabanaki peoples. It will also incorporate geochemical analysis of unmodified copper performed with Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) to determine sourcing, drawing upon databases created by Hanley et al. (2022).



Fig. 1. Two copper beads (left) from Holmes Point West; a copper needle/gorge (bottom) and nugget (right) from Jones Cove.

Acknowledgements:

Supported by the Climate Change Institute at the University of Maine. Assistantship funding provided by Acadia National Park.

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Onsite Logistics and Community Outreach Preparation for Eclipse Icefield 2027 Ice Coring Campaign

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Abstract: The 2025 field season at Eclipse Icefield (Yukon, Canada) focused on building the logistical and community foundation for a 2026–2027 ice coring campaign. The team strengthened partnerships with local First Nations, engaged students through hands-on outreach, shared research plans with the public, and coordinated permitting needs with park staff. These efforts fostered collaboration, incorporated community perspectives into research planning, and established a framework for an inclusive, community-engaged ice coring project.

Project Goal

The goal of this field season was to lay the groundwork in terms of logistics and local relationship building for a 2026-2027 ice coring campaign at Eclipse Icefield (Yukon, Canada).

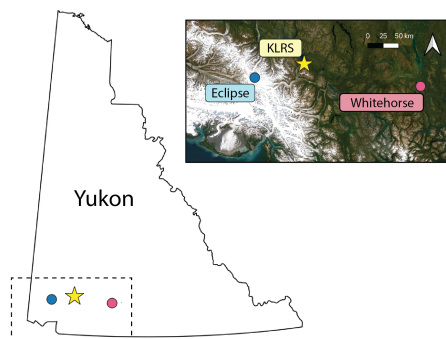


Fig. 1: Locations of Whitehorse, Kluane Lake Research Station (KLRS) and Eclipse Icefield (Eclipse) in the Yukon.

Results & Significance

Our team accomplished four objectives during our 2025 visit.

First, we connected with representatives from Kluane First Nation (KFN) and Champagne and Aishihik First Nation (CFN) to discuss local research interests and participate in more informal community building by assisting with some planting in a local greenhouse.

Second, we spent a day with the Haines Junction sixth grade class running an interactive ice core

learning activity, touring a local hydroponics system, completing a native language scavenger hunt, and getting to know the students and teachers over a game of soccer.

Third, we presented on the past and potential future at Eclipse at a research outreach event that was open to the public and hosted by Kluane Lake Research Station.

Finally, we met with Kluane National Park and Reserve (KNPR) ranger Jonny Cromwell to discuss the scope of our 2027 work and establish any park or permitting requirements needed to accomplish that scope. This included standard science and mountaineering permits, as well as any additional considerations related to transporting heavy equipment and personnel to and from the icefield such as specialized aircraft requirements.

All four of these objectives communicated our motivations for drilling a deep ice core at Eclipse with various community groups, and provided venues for input in the development of the project and research priorities. In addition, the face-to-face conversations we had during our visit have set the tone for an ice coring campaign that prioritizes community engagement, interests, and continued involvement in the research process.

Acknowledgements: University of Maine Climate Change Institute; Robert and Judith Sturgis Family Foundation.

Using Integrated Paleolimnological Proxies to Reconstruct 150 Years of Genus-Specific CyanoHAB Responses to Seasonal Temperatures

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Abstract: Using sediment cores from nine lakes in Maine, USA that span trophic and climate gradients, this research uses cyanobacterial pigments and sediment DNA to characterize drivers of cyanobacterial harmful algal blooms (cyanoHAB) at finer taxonomic (genera) and temporal (seasonal) scales.

Cyanobacterial harmful algal blooms (cyanoHABs) are intensifying in temperate lakes, yet the seasonal mechanisms, especially during winter-spring transitions, remain poorly understood. Here, we will reconstruct ~150 years of cyanobacterial abundance for three genera across nine lakes in Maine, USA, spanning trophic and climate gradients. Using photosynthetic pigments and sedimentary DNA, we will test whether seasonal (vs. annual) temperatures better explain cyanoHAB variability, and whether trait-based life history strategies (e.g., akinete formation) mediate responses to winter warming. Our focal taxa, *Gloeotrichia*, *Dolichospermum*, and *Microcystis*, span trophic conditions and include both akinete-forming and non-akinete-forming genera (Fig. 1).

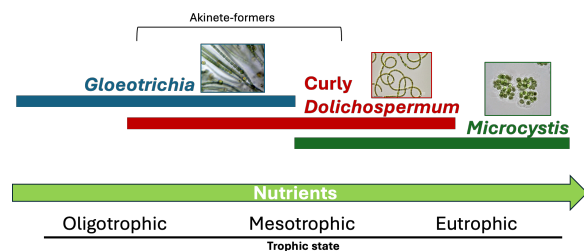


Figure 1. Trophic state preferences of the three cyanoHAB taxa measured (*Gloeotrichia*, *Dolichospermum*, *Microcystis*). *Gloeotrichia* and *Dolichospermum* can both overwinter in the sediment as akinetes.

Warmer winters can lead to earlier ice-off, increased light and temperatures, and stronger spring mixing, all of which promote and extend akinete recruitment from sediments. Recruited akinetes can mobilize phosphorus from sediments and can fix nitrogen into bioavailable forms (Fig 2). Therefore, we predict that winter and spring temperatures will better explain *Gloeotrichia* and *Dolichospermum* abundances than summer or annual means, reflecting their reliance on overwintering akinetes and spring

recruitment. In contrast, we expect *Microcystis*, which does not form akinetes, to respond primarily to summer warming, especially in eutrophic systems.

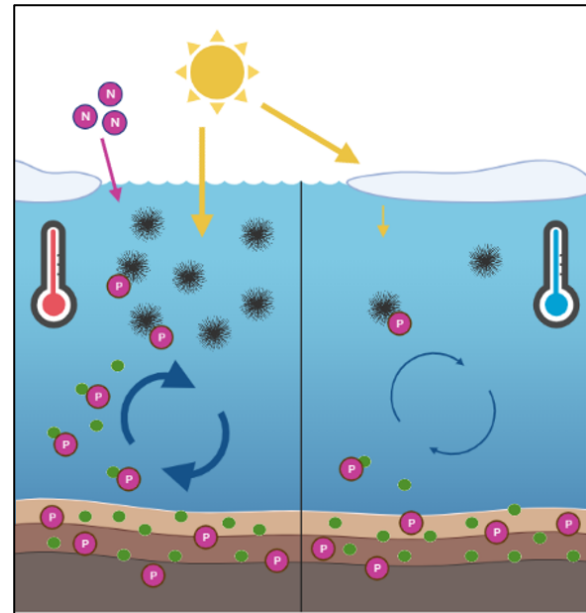


Figure 2. Conceptual diagram of the effects of warmer (left) and cooler (right) winter-spring temperatures on akinete-producing cyanobacteria (e.g., *Gloeotrichia* and *Dolichospermum*).

This research will test whether seasonal thermal trends better capture drivers of cyanobacterial community change at fine taxonomic scale and underscore the importance of incorporating trait-based and season-specific drivers into predictions of bloom risk under future climate change.

Acknowledgements: USGS Grant Award #G21AP10180-00. Additional team members: Denise Bruesewitz, Peter Countway, Charlie Culbertson, Michael Kinnison.

From Exploitative to Equitable Carbon Dioxide Removal

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Abstract: Carbon dioxide removal (CDR) is increasingly presented as necessary for meeting climate targets. This research examines how the IPCC frames land-based, engineered, and ocean-based CDR across assessment reports. It argues that the dominant framing remains largely techno-economic, emphasizing scale, cost, and optimization while giving less attention to uncertainty, justice, and socio-political risk. As a result, CDR can be normalized in ways that prolong fossil-fuel dependence and reproduce inequitable climate governance.

IPCC Assessment report 6 presents CDR as serving three major climate functions: lowering net emissions in the near term, counterbalancing residual emissions from hard-to-abate sectors, and enabling net-negative emissions when removals exceed remaining emissions. This language appears neutral, but it can narrow debate by prioritizing carbon accounting and deployment metrics over broader ethical and political questions.

For land-based CDR, especially afforestation and reforestation, the IPCC often emphasizes mitigation potential and relative affordability. Risks such as leakage, sink reversal, and land competition are acknowledged, yet they are frequently treated as technical problems that can be solved with better accounting and standards. This framing can obscure how carbon forestry shifts burdens onto particular places and communities while allowing high-emitting actors elsewhere to continue fossil-intensive practices.

implying that future negative emissions can compensate for present emissions. Market-based crediting also treats fossil emissions and removals as interchangeable units, even though that commensurability is politically and ecologically contested.

Ocean CDR extends the same pattern. Early IPCC reports described the ocean primarily as a carbon sink whose uptake might weaken with warming, whereas later assessments increasingly consider active enhancement through blue carbon, alkalinity enhancement, and related approaches. Treating the ocean as technical climate infrastructure risks sidelining ecological uncertainty, transboundary governance concerns, and distributive justice for coastal communities and small-scale resource users.

A more equitable approach would treat carbon flows as heterogeneous rather than fungible, evaluate removals through justice and governance criteria as well as cost, and constrain the offset use of removals so they do not erode primary mitigation. Recognizing that IPCC framings are political choices, not neutral descriptions, opens space for mitigation strategies centered on precaution, ecological integrity, and just transition pathways rather than technocratic delay.

Acknowledgements: This research was done as part of the One Ocean Expedition Climate Action Field Course, organized in 2025 by the University of Bergen. Participation in this course was possible thanks to the assistance of the Dan and Betty Churchill Exploration Fund and NSF SAUNNA NRT.

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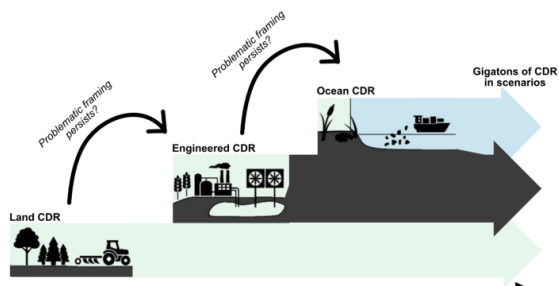


Fig. 1 Schematic overview of how land, engineered, and ocean CDR become more prominent across IPCC assessment reports.

Engineered CDR, especially Bioenergy Carbon Capture and Storage (BECCS) and Direct Air Carbon Capture and Storage (DACCS), is similarly advanced through integrated assessment models that optimize for cost and enable overshoot pathways. Because many of these removals remain speculative at scale, their inclusion in pathways may encourage delay by

Partial Least Squares Regression Coefficient Estimation from Alpine Plants: Creating a Model Suite of PLSR Coefficients for Plant Trait Estimation from Spectra

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Abstract: Alpine plants are a rare, unique, diverse, and highly valued community type of plants. In the Northeastern U.S. the plants in this system are under threat and limited in their abundance, and highly conserved. Spectral analysis of plant traits is a valuable tool for studying these rare and endangered communities with minimal disturbance. Partial least-squares coefficients are necessary for the inference of plant traits from spectra, and given the uniqueness of the northeast alpine, should be developed for this specific system.

Alpine plants have limited distribution and fascinating history in the Northeastern U.S. For hundreds of years (Pease 1917) these unique glacial relics have drawn ecologists, botanists, and explorers to the high peaks and the White Mountains of New England. Despite this long history, broad-scale ecological studies across peaks have remained limited, given the short field season, and rough terrain. Reflectance spectroscopy is a relatively newer method when applied to studying plant diversity but provides fast and ample data including leaf chemical & physical traits, and evolutionary history (Meireles et al. 2020; Kothari et al. 2023). These spectral data require derived coefficients for the effective measure of these traits, using a partial least-squares regression analysis. There are global efforts in deriving these coefficients from both fresh and dried plants, but few to no efforts have focused on alpine plants. We plan to measure the physical and chemical traits of approximately 300 samples representing the species in our broader alpine study to build these PLSR models for accurate trait inference from spectral data.

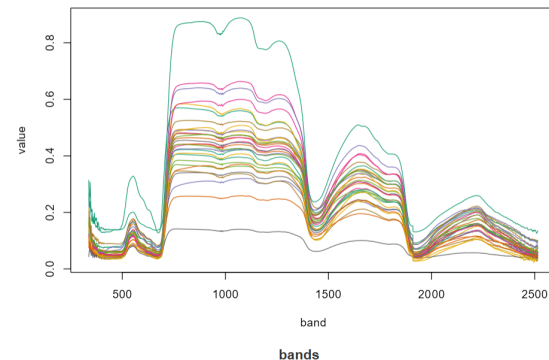


Figure 1: Collection of fresh leaf spectra measured on Saddleback, July 2025

Acknowledgements: This work is supported by NSF 23-542-2326020

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How COP30 Represents—And Fails to Represent—The Islands on the Frontlines of Climate Change

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Abstract: At the UNFCCC COP30, the Secretariat issued a synthesis report of Nationally Determined Contributions under the Paris Agreement for 2025. This mini-paper covers how Small Island States are inadequately represented by the framework of the negotiations and the incentives of climate adaptation and mitigation. The Nationally Determined Contributions presented at COP30 fell short of the meaningful climate action, particularly for the interests of Small Island States.

The 30th Conference of Parties (COP30) to the United Nations Framework Convention on Climate Change (UNFCCC), held in Belém, Brazil in November 2025, has highlighted a fundamental flaw in the implementation of global climate governance. Despite historically contributing the least to climate change, nations with the least ability to adapt to the effects of climate change are feeling its effects most acutely. In particular, the Alliance of Small Island States (AOSIS) is comprised of member-states on the frontlines of climate change.

For developed nations, climate change is an issue that can be mitigated, or in the alternative, adapted to. Wealthy nations have options which will allow them to exist alongside the effects of climate change. Fundamentally, Small Island States, and particularly Small Island Developing States (SIDS), have fewer options to combat climate change than most other nations. To SIDS, sea level rise is an existential issue, not simply a problem that can be addressed through adaptation. Therefore, AOSIS and its constituent members have a greater stake in mitigation than other nations.

AOSIS began COP30 with a statement refusing to “endure the excuses of bigger countries while SIDS struggle with debilitating losses from disproportionate climate change impacts.” AOSIS dubbed the lack of will of wealthier countries to increase mitigation efforts the “ambition gap,” with many member states making “ambition” a theme of their Nationally Determined Contributions (NDCs).

These unequal incentives to mitigate climate change came to a head in the presentations of NDCs at COP30. Between January, 2024 and September 2025, 64 Parties to the UNFCCC

submitted NDCs, plans that a nation develops which lay out a roadmap for how they plan to reduce greenhouse gas (GHG) emissions. Not only do the current NDCs not put the world on track to remain below 1.5 degrees of warming, but 73% of the new NDCs include components of adaptation.

In order to stay on track for a goal of less than 1.5 degrees of warming, NDCs would need to be seriously revised to increase climate finance, emission reductions, and funding for a just energy transition. Current commitments fall short of achieving justice for SIDS, putting the world on track to escalate the damages that SIDS will face without adequate support. By the end of COP30, there was no resolution to the ambition gap.

Acknowledgements: This research is supported by the Climate Change Institute and the University of Maine School of Law.

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The Anticipation of Infrastructure in the Arctic

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Abstract: In the Indigenous homelands of Sápmi, in northern Fennoscandinavia, Sámi communities must cope not only with climate change, but also with the impacts of new state policies and land-use directives that respond to melting sea ice and the growing demand for green energy. Combining ethnographic and archaeological perspectives establishes anticipation of future transformations as a significant driver of contemporary material change.

Materials of Anticipation

Material culture—the things that people make, use, modify, and surround themselves with—is broadly sensitive to transformations in social networks and environments. In the northern Scandinavian regions of Sápmi, the homeland of Indigenous Sámi peoples, centuries of state pressures are compounded by climatic changes: not only the physical transformations that manifest across the local landscape through changing snow and ice conditions, but also through changes in climate policy that direct state-designated land use.

Our methods incorporate long-term perspectives from the archaeological record with ethnographic methods like participant observation (Magnani and Magnani 2026). We examine how the development of infrastructure—from ports and railways to dams and roads—coming on the heels of melting sea ice and broader calls for a green energy shift, impacts the lives of Indigenous communities and their material worlds.

For instance, reindeer camps grow denser and more permanent to ward off state appropriation of land for the construction of state projects, including new port and rail infrastructure. Yet, reindeer antlers grow more porous and fragile, becoming less usable for craft used to signal community belonging, as herd profiles deviate from historical norms.

Intersecting with the impacts of a shifting climate itself, we show how the *anticipation* of upheaval from new infrastructural development is a major driver of cultural transformation across Sápmi and the broader circumpolar north (Magnani and Magnani 2026). Significant portions of the

landscape are reshaped not based on present conditions on the ground, but on what is expected in the decades to come. To understand the human dimensions of climate change, we focus on adaptations that occur both in response to, and in advance of these transformations.



Fig. 1. A hydroelectric dam in the vicinity of Jokkmokk, Sweden.

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Evolution of Temperate Firn Under Melt Conditions

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Abstract: The evolution of temperate firn under melt conditions – changes in firn volume, variability in liquid water content, and the rate of densification – is relatively understudied and remains unquantified on Juneau Icefield, Alaska. Observing temperate firn behavior in Alaska is important for constraining sea-level rise (SLR) contribution predictions and has implications for observations on current polar ice bodies including the Greenland Ice Sheet as the climate warms.

Outside of the Greenland and Antarctic ice sheets, about 20% of global glacier mass loss and contributions to SLR is attributed to the Alaska region.¹ Quantifying glacier mass and volume change are important for accurate predictions of SLR and availability of water resources. Firn, snow that has survived one ablation season, acts as short term-meltwater storage, buffering immediate contributions to SLR from melt.² Meltwater in firn is expected to increase due to atmospheric warming by the end of the 21st century even on polar ice sheets.³ There is a community need for addressing uncertainties in firn meltwater storage and in-situ measurements of firn densification.³

This work seeks to (1) quantify the change in firn thickness and volume between 2012 and 2025; (2) quantify the variability of density and liquid water content (LWC) in firn; and (3) quantify firn densification rates during the melt season on Juneau Icefield (JIF).

Methods and Anticipated Results. To evaluate the change in firn thickness and volume through time, we will use repeated 400 MHz ground-penetrating radar glacier centerline profiles in 2012, 2015, 2021, 2023, 2024, and 2025. For calculating LWC and density, we will use 500 MHz multi-offset annual and sub-seasonal radar surveys collected in 2024 and 2025. We will use a stationary 1-3 GHz frequency-modulated continuous wave radar to measure vertical deformation during the melt season at ice divides on JIF. These methods are constrained with in-situ firn cores for density and relative permittivity.

Based on previous work and increasing average annual temperatures on JIF, we anticipate a decrease in firn over this time. We anticipate the variability in LWC will be correlated with

topographic characteristics and meteorological events (Fig. 1).

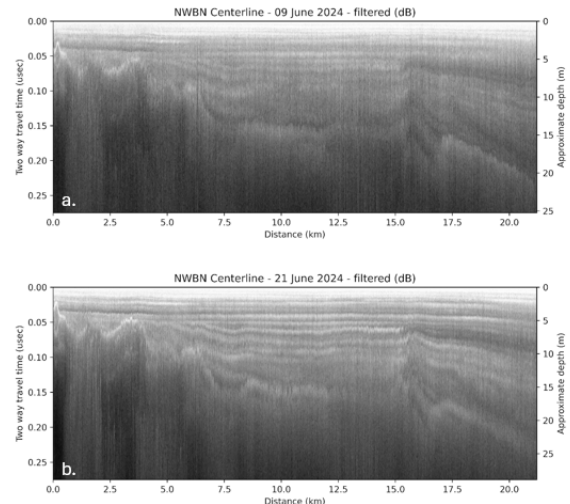


Fig. 1. (a) First and (b) third 400 MHz GPR surveys of Northern-Northwest Branch from 09 June and 21 June, respectively. The increasing layer definition with time is an indication of a change in the liquid water content.

Acknowledgements: This research was supported by NSF Award #2239668. Special thanks to experts Tate Meehan, Annika Horlings, Juliana Reuf, Dylon Swan, Naomi Ochwat, and Bradley Markle. This research was conducted on the territory of Áak'w Kwáan on Lingít Aaní.

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² Harper et al., “Greenland ice-sheet contribution to sea-level rise buffered by meltwater storage in firn,” 240.

³ The Firn Symposium Team, “Firn on Ice Sheets,” 5.

Historic Preservation Policy Development in Land Conservation Contexts: A Case Study in Wabanaki Homeland

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Abstract: Models suggest many coastal archaeological sites in Maine may suffer total destruction in the next 20-30 years due to climate change-induced effects. Methods derived from policy sciences and anthropology, in addition to remote sensing, will be applied to develop archaeology co-stewardship best practices with Acadia National Park and land trust organizations. Developing co-stewardship policies with Wabanaki Nations and land trusts is necessary to ensure heritage is cared for appropriately by resources managers.

Acadia National Park is located on the western edge of the Gulf of Maine, a body of water warming faster than 99% of the world ocean due to the effects of climate change (Pershing et al. 2015). Coastal portions of Acadia are experiencing sea level rise, flooding and extreme weather events. Vulnerable archaeological sites located on the park's shoreline have suffered from storm-induced erosion. These sites are affiliated with the Federally-recognized Wabanaki Nations: Maliseet, Mi'kmaq, Passamaquoddy, and Penobscot.

- Houlton Band of Maliseet Indians
- Mi'kmaq Nation
- Penobscot Nation
- Passamaquoddy
- Federally Owned
- State of Maine
- Land Trusts
- Privately Owned

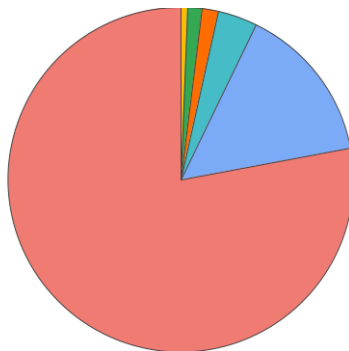


Fig. 1. Private, Conserved, and Tribal Lands in Maine, by Acres. Note: Maliseet control 0.0068% and Mi'kmaq 0.0136% of the acres in the state, rendering them invisible on this chart.

Climate projections suggest coastal archaeological sites in Acadia may suffer total destruction in the next 20-30 years due to climate change (Newsom et al. 2023). These patterns of damage and destruction are identical at sites managed by land trusts. Due to the importance of these sites to Indigenous communities within the context of expropriation in the State of Maine [fig. 1], conservation organizations must build

relationships and develop co-stewardship policies with Wabanaki Nations to ensure cultural heritage preservation. However, the structures of colonialism which persist today in conservation policy must also be considered.

Co-developed adaptation plans for multiple environmental scenarios are therefore necessary. Not enough data documenting erosion has been collected to inform mitigation decision-making with Wabanaki involvement. Therefore, a planned multi-phased research program applying Decolonial Participatory Action approaches and unmanned aerial vehicle (UAV) surveys will produce annual measurements of erosion to inform cultural vulnerability planning and consultation with Wabanaki Nations.

Acknowledgements: NSF GRFP #2236416

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Potters' Choices and Wabanaki Socio-Spatial Organization: An Archaeological Exploration of the Kennebec River Boundary Hypothesis

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Abstract: This research explores the Kennebec River Hypothesis, a long-standing regional archaeological convention that posits the Kennebec River as a socio-spatial boundary among past Wabanaki peoples. By analyzing the technological choices made by pre-colonial Wabanaki potters across 631 ceramic vessels, this project seeks to examine past Wabanaki social organization by examining how potters' choices reflect patterns of interaction and connectivity across the region.

The Kennebec River Hypothesis

For decades, the Kennebec River has been interpreted as a geographic boundary dividing past Indigenous groups—specifically horticultural groups to the west and hunting/fishing/gathering groups to the east¹. This interpretation has not been tested and has led to problematic real-world impacts, such as challenges in cultural affiliation debates under NAGPRA. This project serves as an initial foray into examining these narratives by centering Indigenous agency in ceramic manufacturing and the intentional choices of Wabanaki potters.

Methodology

The primary methodology consisted of a comparative, attribute-based analysis of legacy archaeological ceramic collections housed at curatorial institutions across Maine. The dataset included ceramics from the Kennebec and Penobscot River valleys, as well as the Damariscotta River and Frenchman Bay. Analysis focused on specific attributes indicative of technological choices: temper type and density, surface treatment, and vessel morphology (specifically rim thickness and eversion). To provide temporal and dietary context, the study integrates radiocarbon dating and stable isotope analysis ($\delta^{13}\text{C}$) of encrusted food residues on pottery sherds.

Preliminary Findings and Discussion

The analysis of potters' signatures revealed a mosaic of shared and localized practices. While granite was the preferred temper material across all studied sites, regional variations emerged: quartz was the primary temper for 63.4% of vessels at the Penobscot's Eddington Bend,

whereas feldspar (46%) and quartz (43%) were comparable at Kennebec River sites.

Ceramic morphological and decorative data suggest broad shared conventions rather than hard divides. Excurvate rims appeared at strikingly similar frequencies at both Fort Halifax on the Kennebec (56.3%) and Eddington Bend on the Penobscot (53.6%). The radiocarbon dates (2680 BP to 360 BP) and $\delta^{13}\text{C}$ values (-26.59‰ to -17.46‰) provide additional insights into Indigenous use of these river valleys.

Conclusions

The similarities in decorative techniques and vessel forms point toward some level of shared technological strategies. Rather than acting as a rigid socio-spatial divide, the Kennebec may have served as a unifying connector—an artery for movement and the exchange of knowledge among Wabanaki communities. This research, while in preliminary stages, demonstrates the utility of ceramic analyses in understanding past Indigenous socio-spatial organization.

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Acknowledgements

This research was supported by the Wenner-Gren Foundation (Grant #: 8981886375). Thank you to undergraduate student, Brooke Lyden, for assistance with pottery analysis.

Subglacial Erosional Features in the Dry Valleys from the East Antarctic Ice Sheet

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Abstract: We can improve our understanding of East Antarctic Ice Sheet (EAIS) behavior in a warmer-than-present climate by determining how the ice sheet reacted to past warming. Erosional landforms in the Dry Valleys region of the Transantarctic Mountains (TAMS) are suggestive of large amounts of subglacial meltwater produced by growth of an extensive ice sheet that covered the TAMS. Preliminary estimates of the timing of this event place it under conditions warmer than at present. If correct, it would suggest some sectors of the EAIS thicken under warm climates.

Introduction:

Glacial landforms give information on past ice-sheet extent and behavior. A suite of widespread erosional features across the top of the TAMS and in adjacent valleys consists of channel systems, scoured bedrock, ribbed bedforms, pothole-like features, escarpments, basins, and streamlined bedforms (Sugden et al., 1991; Marchant et al., 1993; Sugden and Denton, 2004, 2005). For example, ribbed bedforms on the floor of Wright Valley cut into both bedrock and adjacent till (Fig. 1). In the Asgard Range, large areas of bare bedrock, channels, and potholes lead to an expansive scoured bedrock zone with a sharp escarpment cut into an adjacent drift sheet (Sugden et al., 1991; Marchant et al., 1993; Sugden and Denton, 2005). These features resemble those seen in subglacial meltwater corridors in areas formerly beneath the Scandinavian Ice Sheet (Verite et al., 2023) and suggest the former presence of a large ice sheet over the tops of the TAMS.



Fig. 1: Satellite image of Wright Valley, showing the eastern end of Lake Vanda with ribbed bedforms carved into the bedrock obliquely to the trachyte dikes. Eroded till patches, which also display ribbed bedforms, occur just to the south (bottom of image).

Dry Valleys region that appears to have been formed by significant subglacial water under a larger-than-present ice sheet. I will produce a detailed map of the landforms and determine the origins and ages, absolute and relative, of different erosional features.

Initial results:

I have started mapping features throughout Wright Valley and the adjacent Asgard Range and have observed all the features mentioned above. Further, these bedforms show morphostratigraphic relationships with alpine moraines being crosscut by some and cut by others. Relationships such as these will allow me to bracket the age of the erosional landforms.

Future Work:

I will finish the map of the erosional features and the compilation of age data. I will use absolute and relative ages to constrain the age of this large erosional event and EAIS expansion.

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 Sugden and Denton, 2005. *Geog. Ann.*
 Verite et al., 2023. *ESPL Wiley*

Objectives:

My objective is to re-examine the origin and age of this unique set of erosional landforms in the

How Do Large Scale Climatic Gradients Influence Coordination Among Leaf Economic Spectrum Traits Across Tree Species?

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Abstract: Climate change is rapidly altering forest ecosystems in the northeastern United States, potentially shifting species distributions and plant resource-use strategies. Using a common garden experiment across six climatic gradients in Maine, we examined how climate variation influences coordination among key Leaf Economics Spectrum (LES) traits. Across sites, photosynthetic rate was positively related to leaf nitrogen and negatively related to leaf mass per area, consistent with global LES patterns. However, the slopes of relationships involving LMA varied with mean annual temperature, suggesting climate-driven shifts in plant resource allocation strategies, while the photosynthesis and nitrogen relationship remained relatively conserved.

Project Goals:

To evaluate how variation in environmental conditions across climate, edaphic, and canopy light gradients shapes the relationships among key leaf economic spectrum traits, thereby influencing plant resource use strategies.

Climate change is rapidly altering forests in the northeastern United States through rising temperatures, changing precipitation patterns, and increasing disturbances such as pests and extreme weather (Dale et al., 2001). These changes are expected to shift species distributions and alter forest composition, potentially threatening ecosystem functions (McDowell et al., 2020). Leaf functional traits are sensitive indicators of environmental change and can reveal how plants adjust their resource-use strategies under shifting climates (Garnier et al., 2001). The LES describes coordinated trade-offs among leaf traits related to resource acquisition and conservation (Wright et al., 2004). Understanding how climate gradients influence LES trait relationships can therefore improve predictions of forest responses to climate change.

Results

LES trait relationships across the six common garden sites were generally consistent with global LES patterns but showed variation in strength and slope across climatic gradients. Photosynthetic rate (A_m) was positively related to leaf nitrogen (N_m) and negatively related to leaf mass per area (LMA), while N_m also declined with increasing LMA across all sites. The strength of these relationships was high within sites, indicating strong coordination among LES traits despite environmental variability. However, standardized major axis (SMA) slopes varied with mean annual temperature for some trait pairs, particularly A_m and LMA and N_m and LMA, suggesting climate-driven shifts in resource allocation strategies.

In contrast, the slope of the A_m and N_m relationship showed little variation across the temperature gradient, indicating that this core LES relationship remained relatively conserved across environmental conditions.

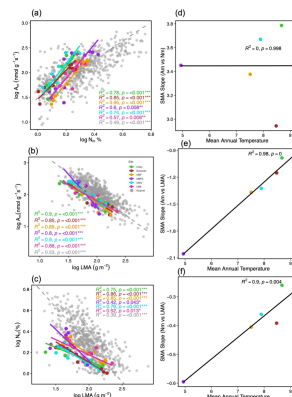


Figure 1. Mass-based photosynthetic rate (A_m) in relation to leaf nitrogen concentration (N_m ; a), and leaf mass per area (LMA; b), and N_m in relation to LMA (c) for the six study sites. Slope of A_m and N_m (d), A_m and LMA (e), N_m and LMA (f) with mean annual temperature.

Acknowledgements: This project was conducted/funded in collaboration with Schoodic Institute, and different University of Maine campuses across Maine.

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Holding Space for Eroded Landscapes and Indigenous Cultural Places: A View from the Holmes Point West Site in Passamaquoddy Homelands

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Abstract: Rising sea levels and frequent storms are eroding ancestral Indigenous places in the Maritime Peninsula, spurring efforts to mitigate losses to archaeological knowledge and Wabanaki cultural heritage. This study characterizes erosion at the Holmes Point West Site in Machias Bay, Maine, and considers its implications from multiple perspectives.

Background

In their characterization of erosion risk in the Maritime Peninsula, Hrynicky et al. [1] found that 50 percent of known coastal archaeological sites in the western Quoddy Region of Maine have been destroyed since the 1950s and that 65 percent of sites they examined are likely to be threatened by 2050. Newsom et al. [2:303] emphasize that “[m]arginalization of coastal shell-bearing sites renders Indigenous histories and connections to place socially invisible and contributes to the historic and systemic erasure of Indigenous peoples from the land, waters, and historical narratives.” Several collaborations in Maine are bringing together archaeologists, heritage professionals, and community members to develop assessment and decision-support strategies around the mitigation of threatened ancestral Indigenous places [3, 4].

Research Study and Methods

The Holmes Point West site is a coastal ancestral Indigenous place actively eroding on its south and west margins. The site is the focus of a field school partnership between the University of Maine and Passamaquoddy Nation that supports community resilience to climate change by combining education, archaeological science, language preservation, and community engagement [2]. Although erosion is clearly evident at the site, the extent, future risk, and implications of this erosion have not been assessed beyond anecdotal evidence and the observation that what exists today is likely only remnants of a once larger site [2, 5].

This study applies Hrynicky et al.’s [1] approach for characterizing erosion risk for coastal archaeological sites in the Maritime Peninsula by: 1) comparing present conditions to historical imagery and site descriptions; 2) examining

collections from now-eroded contexts; and 3) modeling local predicted sea level rise. The study extends their approach by also considering local geology, wave action, and human activity in characterizing potential climate change risks.

In considering the implications of erosion for heritage loss and mitigation, the study looks beyond site protection to consider how eroded Indigenous places are dismissed as “lost” or “gone” in academic scholarship. The study seeks interventions that resist this erasure, looking to speculative, cartographic, and visualization approaches that might ‘hold space’ for such places. Such approaches would not only counter the marginalization of Indigenous connections to eroded cultural places but also help archaeologists contend with biases in the archaeological record that erosion produces.

Acknowledgements: Funding provided by the Maine Academic Prominence Initiative.

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Little Ice Age Glacial Advances Found in the Southern Alps of New Zealand at 43°S Suggesting a Global Extent

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Abstract: During the austral summers of 2023 and 2024 I conducted fieldwork in the Southern Alps of New Zealand. Using ¹⁰Be exposure dating I am constructing a glacial chronology of my field areas in order to expand our understanding on the possible extents of the Little Ice Age.

The problem:

The abundant historical records that document the Little Ice Age's impact in Europe along with field evidence from outside that region seem to indicate that its occurrence may not have been confined to the Northern Hemisphere (Grove, 1990). Although paleoclimate records are currently insufficient to fully reconstruct the last 1000 years of climate history in the Southern Hemisphere (National Research Council (U.S.), 2002), the presence of the Little Ice Age has been identified in certain regions. Notably, evidence of its occurrence has been found in Argentina and the Tropical Andes of South America (Espizua & Pitte, 2009), highlighting the significance of the Little Ice Age outside of the Northern Hemisphere. While continuous records may be lacking, sporadic occurrences of the Little Ice Age in South America, albeit in shorter temporal stretches, provide compelling evidence for a global event.

I have conducted fieldwork in the Southern Alps of New Zealand, located at ~43°S, targeting young moraines high in the mountains. Using Birkeland et al. (1982)'s subdivision of Holocene glacial deposits, I targeted the youngest features for Be-10 exposure dating.

My preliminary data is in agreement with previously dated features elsewhere in New Zealand, all of which suggest that New Zealand alpine glaciers did experience an advance during the late Holocene (Kaplan et al. 2013; Putnam et al. 2012; Schaefer et al. 2009). Comprehending and understanding the causes and mechanisms behind this climatic phenomenon becomes critical for discerning the current and future climate trends and uncovering how our climate system functions.

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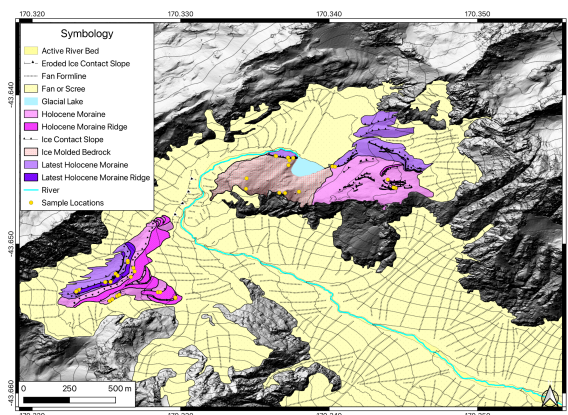


Fig. 1. Geomorphological map of young moraines in the cirques of Ailsa Valley.

Effects of Biochar Quality and Tree Species on Soil Carbon and Water Retention

Kennedy F. Rubert-Nason^{1,2}, Stéphanie Landry², Libin T. Louis², Ling Li³, Tatiana Arce², Hye Rim Choi², Orianna Cort², Saima Khan², Mylei Moli², Riley Prince², Rinaldo Wong²

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Abstract: Biochar produced by suboxic combustion or chemical digestion of wood has potential to increase long-term storage of carbon and retention of water in forest soils.

Introduction:

Biochar, produced by suboxic combustion or chemical digestion of wood, has potential to be applied as a soil amendment to increase soil carbon, water and nutrient holding capacity and decrease mobility of contaminants [1]. We explored the independent and interactive effects of biochar amendment, drought, and tree sapling species on soil carbon and water retention.

Materials & Methods:

Using a manipulative container garden experiment over 1.5 years with 2-year old tree saplings, we explored the independent and interactive relationships among soil amendment with or without three different types of wood biochar (control [S0] or 10% v/v Wakefield® charcoal [S1] or charcoal/ash mix [S2] or acid digested wood pulp [S3]), drought, tree species, and retention of carbon and water in soil. After 1.5 growing seasons (13 months), we measured soil respiration using a Licor-6800® portable infrared gas analyzer equipped with respirometer and Stevens® moisture/temperature probe, quantified soil organic carbon (SOC) gravimetrically using a peroxide digestion assay, and statistically analyzed data using *R* with 'Rcmdr' (version 2.9-5).

Results & Discussion:

Soil respiration rates among all biochar × tree species × moisture treatments were consistently low (1-3 $\mu\text{mol}/\text{m}^2/\text{sec}$; Fig. 1), and SOC concentrations were in the 3-4% range. Soil moisture varied among species ($p < 0.001$) and tended to be higher in biochar-amended soil. Observed effects on soil moisture, and decreasing soil respiration from relatively high at the start of the experiment (10–35 $\mu\text{mol}/\text{m}^2/\text{sec}$) [2] to relatively low after 13 months suggest that amendment of soil with biochar can increase long-term carbon storage and improve water

retention in soil. Future work will quantify the total soil carbon pool (including recalcitrant black carbon) in each experimental group, and assess longer-term soil carbon retention in field trials.

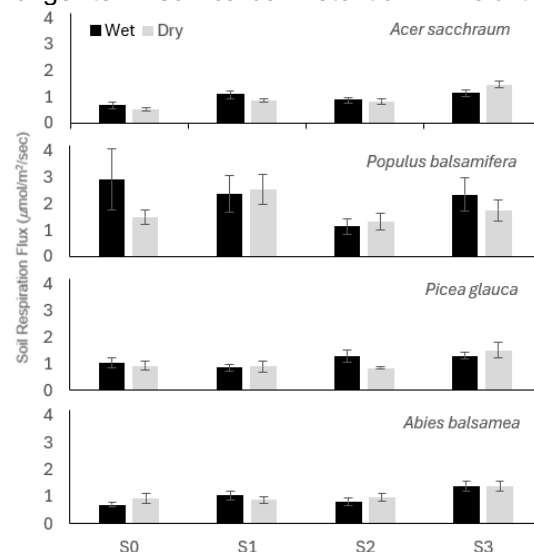


Fig. 1. Influence of biochar type (S0/control–S3), tree species and soil moisture on soil respiration rates.

Acknowledgements: Supported by the Maine Economic Improvement Fund, U.S. National Science Foundation EPSCoR (OIA-2416915; OIA-2412131), and Irving Woodlands, LLC.

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Biogeochemical Cycles of Sub-Arctic Agroecosystems: Quantifying System Properties and Forecasting Future Scenarios

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7. *Innovation South Greenland.*

Abstract: We present a new collaborative project focused on quantifying biogeochemical cycles of socio-terrestrial-aquatic systems of a South Greenland sub-Arctic agroecosystem in partnership with Greenlandic farmers.

Overview:

Climate-driven expansion of agriculture is occurring across the Arctic system as accelerated warming has lengthened growing seasons, allowing for more intensive farming practices and crop diversity. This northward agricultural shift presents potential societal opportunities for improved food security; however, these are counterbalanced by threats to biogeochemical cycles and resilience of the entire Arctic system, some of which remain poorly understood, arising from changes in land use and hydrology.

To quantify biogeochemical cycles of socio-terrestrial-aquatic systems of a South Greenland sub-Arctic agroecosystem, we are conducting research in three work packages, each guided by a primary objective: 1) estimate current freshwater demand associated with agricultural activities and identify challenges associated with changing climate conditions; 2) assess feedbacks among the water, nitrogen, and phosphorus cycles of freshwater systems as influenced by climate forcing and local anthropogenic activity; and 3) develop future climate scenarios for South Greenland and assess future impacts on land surface hydrology from the local watershed to regional scale. We will employ ecosystem models to synthesize these results and enable forecasting. The project integrates expertise and methods from water resources, human dimensions, aquatic ecology, paleolimnology, and climate and watershed modeling. This project was co-developed with farmers in South Greenland, and project out-

comes aim to support food security in this region.

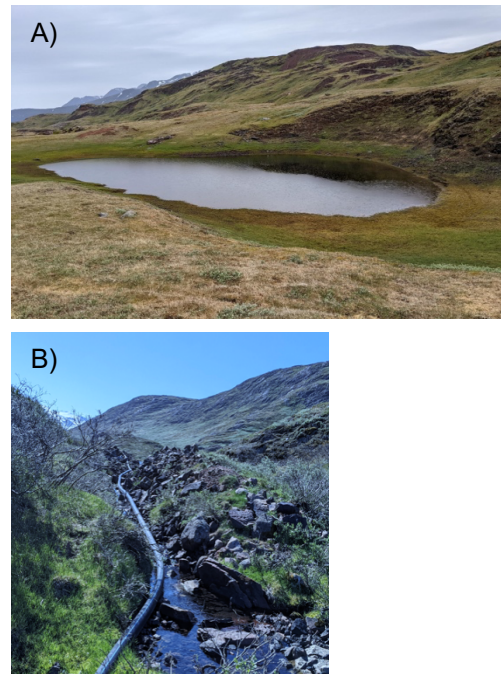


Fig. 1. Water resources in the South Greenland agroecosystem: a) one of the many small lakes in the area, with evidence of lake level changes; b) example of an irrigation system that draws water from lakes to support farm operations.

Acknowledgements: Funded by NSF Arctic System Science (#2518806).

Nutrient Limitation Patterns in Glacially-fed Lakes at Jostedalbreen, Norway

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Abstract: Glacially-fed lakes in the Jostedalbreen region of Norway demonstrate variable nutrient concentrations and limitation patterns with distinct differences between surface and deep water.

Introduction: In response to accelerated warming, new lakes are forming at a rapid rate in the Arctic¹. In Norway, 360 new ice-marginal lakes formed within the span of a year from 2018 to 2019, many at the periphery of the retreating Jostedalbreen Ice Cap². These glacially-fed (GF) lakes are not only increasing in abundance, but also changing in size, depth, temperature, and chemistry³. While the physical and chemical characteristics are well documented, little is known about the biology in GF lakes.

Objectives: This research aims to understand the environmental factors, including nutrient and dissolved organic carbon (DOC) availability, that shape variability in microbial community composition both within and among GF lakes. Three GF lakes that formed in Norway in the mid-1900s were chosen based on previously published nutrient data⁴. Samples from Brevatnet, Nigardsbrevatnet, and Styggevatnet (Fig. 1) were collected in summer 2025 to answer the following research questions: 1) How variable are surface and deep microbial communities in GF lakes? 2) How do nutrient concentration and limitation patterns influence the microbial community composition of GF lakes?

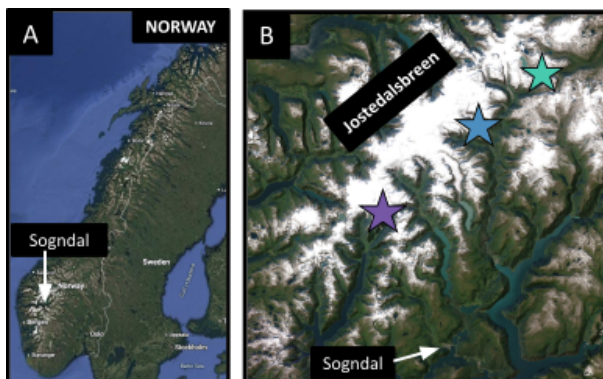


Fig. 1. Map of study sites in Norway. Stars represent lakes with Brevatnet in purple, Nigardsbrevatnet in blue, and Styggevatnet in green.

Preliminary Results & Discussion: Variable nutrient limitation patterns are present in the GF lakes (Fig. 2). Brevatnet and Nigardsbrevatnet follow a similar pattern with N limitation in the hypolimnion and co-limitation in the epilimnion, whereas Styggevatnet is P limited at both depths. DOC concentrations in all three lakes are very low, likely due to a sparsely vegetated watershed, comprised predominantly of exposed granitic bedrock and some small trees. With minimal available carbon, autotrophs will likely dominate the microbial community and nutrient limitation patterns will be important drivers of community variability between lakes and depths. We are awaiting results on the microbial community composition of each lake and will assess these in relation to nutrient patterns.

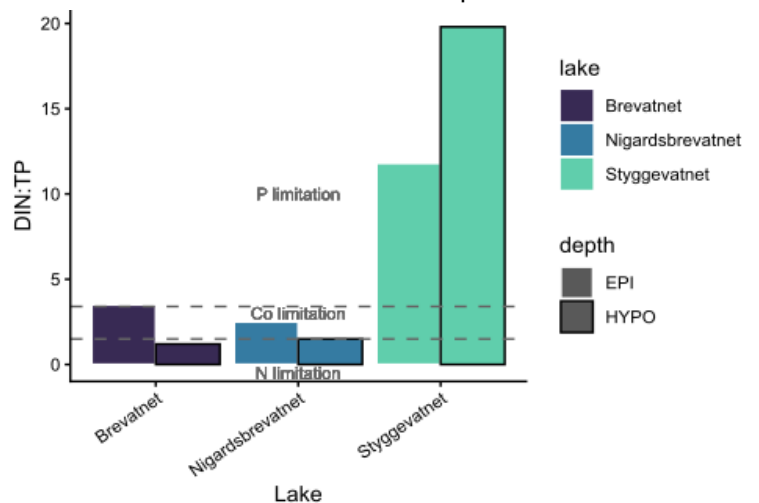


Fig. 2. Nutrient limitation patterns (P-, N-, and Co-limiting) in surface (EPI) and deep (HYPO) waters.

Acknowledgements: Funding is provided by the Robert and Judith Sturgis Family Foundation and the NSF SAUNNA NRT.

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Phase-sensitive Radar Measurements Reveal a Rheologically Distinct Layer at Denali Ice Core site

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Abstract: Combined radar observations and analyses of ice-core structural and geochemical properties reveal a rheologically distinct layer at ~140-170m depth, likely formed during the Medieval Climate Anomaly – Little Ice Age transition, where changes in depositional conditions produce localized softening and enhanced vertical deformation.

We present evidence for a dynamic and climatic transition recorded within the two ~210 m Denali ice cores, revealed through combined analysis of radar-based vertical velocity observations at the ice core site together with ice core structural and geochemical measurements. Phase-sensitive radar measurements (pRES) collected in 2022 show a rapid transition in vertical velocity between ~140-170m depth, indicating localized softening or enhanced deformation within the ice column. To investigate the underlying cause of this rheological change, we integrate polarimetric radar observations of birefringence with electrical conductivity measurements (ECM), hyperspectral imagery (HSI), and ice core chemistry.

Polarimetric measurements reveal a distinct change in birefringence coincident with the depth of enhanced vertical motion, suggesting a reorganization of the crystal orientation fabric and associated change in ice viscosity. ECM measurements show a sharp shift in conductivity near ~160 m depth, consistent with a localized increase in dust or impurity concentration that coincides with the one of enhanced deformation observed in the radar data. Stable isotope measurements show a decrease in deuterium excess (d-excess) aligned with the transition between the Medieval Climate Anomaly (MCA) and Little Ice Age (LIA) (Fig 2), indicating a shift in moisture source conditions. Preliminary HSI observations also reveal increased fracturing in this same section of the core.

Together, these observations indicate the presence of a rheologically distinct ice layer that we interpret as the result of changing depositional conditions during the MCA-LIA climate transition.

These results highlight the coupling between climate forcing, impurity chemistry, and ice rheology in influencing glacier flow dynamics.

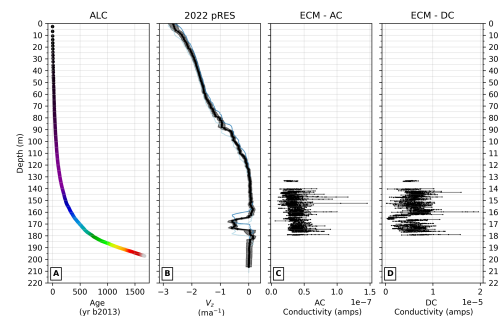


Fig. 1. A) Ice age from annual layer counting (ALC)¹. B) Vertical velocity from phase-sensitive radar (pRES) with depth uncertainty bounds (blue). C) ECM AC measurements. D) ECM DC measurements.

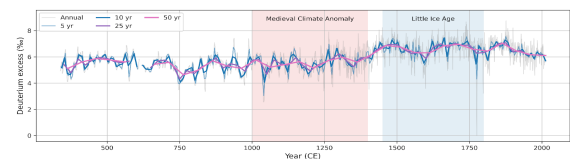


Fig. 2. D-excess in the Denali Ice Core show a clear shift between the MCA and LIA, indicating a change in hydroclimate and moisture source.

Acknowledgements: Field work supported by the Sturgis Exploration Fund, Main Space Grant Consortium, American Alpine Club, UMaine Graduate Student Government, and NOLS; assistance and curation at the US NSF Ice Core Facility (NSF-2041950 and AGS-2002483).

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¹ Winski, Dominic, Erich Osterberg, David Ferris, Karl Kreutz, Cameron Wake, Seth Campbell, Robert Hawley et al. "Industrial-age doubling of snow accumulation in the Alaska Range linked to tropical ocean warming." Scientific reports 7, no. 1 (2017): 17869.

Fostering Relationships with Community Members near Klune Lake, Yukon Preceding Deep Core Drilling Plans of the Eclipse Icefield

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Abstract: Our team went to Kluane Lake Research Station (KLRS) in May of 2025 to build lasting relationships with members of the communities surrounding the Eclipse Icefield to prepare for future coring expeditions.

Research Context:

With Far north regions warming faster than the global average and non-polar ice in the Gulf of Alaska carrying nearly 40mm of sea level rise potential (Farinotti et al., 2019), understanding the ice history in this region is a priority for climate scientists at UMaine. To form this understanding, our team has planned a project to drill a deep core on the Eclipse Icefield in the St. Elia Range, Yukon, Canada (Fig. 1). With geophysical evidence suggesting the deepest portion of the ice lies at 700m, this core has the potential to show a climate record of up to 10,000 years.

This project has a timeframe of three years, with the 2026 season focused on conducting a geophysical survey to verify the depth at the intended coring location. The ice-to-bedrock core will be drilled in the 2027 season at the verified location.

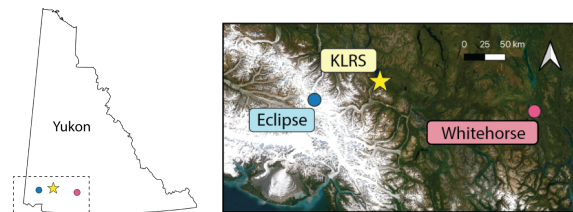


Fig. 1. Whitehorse, Kluane Lake Research Station, and Eclipse Icefield Weather Station Locations. Figure from Inga Kindstedt.

In the 2025 field season our team worked on creating a strong interpersonal foundation with our on-site partners, Kluane Lake Research Station (KLRS), Kluane National Park and Reserve (KNPR), Kluane First Nation (KFN) and Champagne and Aishihik First Nation (CFN).

Western scientists have historically excluded indigenous people while exploiting the land that was stolen from them. As scientists working on

the traditional lands of the Southern Tutchone People, we prioritized highlighting voices that have been excluded and who will be affected by our work. To understand the community better, we did preliminary work through completion of the Yukon First Nations 101 course developed by Yukon University.

With the future coring expedition in mind, we met with members of CFN and discussed possible signals in the ice that would be of interest to them. Through an informal meeting with Hannah Currie, the Natural Resources Manager for KFN, we created lasting connections on site with the community and assisted in planting a greenhouse. We taught a local sixth grade class from Haines Junction about ice cores using a modular activity developed using data from the Denali Ice Core Project and got to know the students and community members better by participating in a soccer game and scavenger hunt of native species after the activity.

We presented our plan to core on the Eclipse icefield to the community at the KLRS community night. Our team met with a KNPR ranger, Jonny Cromwell, to discuss permitting and logistics for the 2027 coring expedition and learned more about how integrated KFN is in the decision process. Our work this summer included many important conversations and vital connections with a community who will be directly affected by our future work on the Eclipse Icefield.

Acknowledgements: Funded by The Robert and Judith Sturgis Family Foundation.

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Combining UAV Remote Sensing with in Situ Snow Pits and Co-located Automated Weather Data to Make High Spatiotemporal Resolution SWE Estimates

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Abstract: To better understand how snow water equivalent (SWE) varies spatially and temporally, we combine UAV LiDAR with in situ snow density and depth measurements and observations, along with co-located automated weather station (AWS) data. This combined approach will allow us to quantify SWE at high spatial and temporal resolution while also enabling interpretations of the effects of vegetation, topography, and weather patterns on SWE and snow depth.

A large portion of the global population relies on snow for drinking water. Additionally, as the climate warms, wet snowpacks and rain-on-snow events are becoming more common. Accurately quantifying SWE is therefore critical for forecasting drinking water availability, flooding, and wildland fire susceptibility. However, current methods for monitoring and estimating SWE have high uncertainty. Many forecasts rely on point measurements of SWE, which are often non-representative of the large areas over which they are extrapolated because snow depth and density vary spatially. Satellite remote sensing has been used to monitor SWE, but current products are typically too coarse for watershed scale applications, with spatial resolutions on the order of 10–30 km². Therefore, there is a clear need for higher resolution near surface remote sensing SWE estimates to ground truth space-based and aerial estimates. In shallow snowpacks, such as what Maine and a large portion of the globe experience, depth varies more than density [1]. Therefore, high-resolution snow depth mapping is a critical step to improving SWE estimates. Currently, we are using UAV LiDAR remote sensing to make highly accurate snow depth maps in Maine. These maps, combined with in situ data, will help us gain a better understanding of how SWE varies spatially in relation to topography and vegetation. Additionally, we are proposing to link automated weather station data that is co-located with our LiDAR surveys. One motivation for these methods is a dataset could validate satellite data, as well as provide new insights into the spatial and temporal variability of SWE, snow depth, and density, and co-located AWS data.

Challenges: Several issues have led to problems with collecting and processing data. As demonstrated in Figure 1, multiple systems as well as data sources need to come together to produce high quality and accurate data. The primary issues we have experienced has been navigational and attitude errors presumably produced by aggressive flight maneuvers. We are actively evaluating equipment choices, testing different flight patterns, as well as testing different workflows and software for processing data.

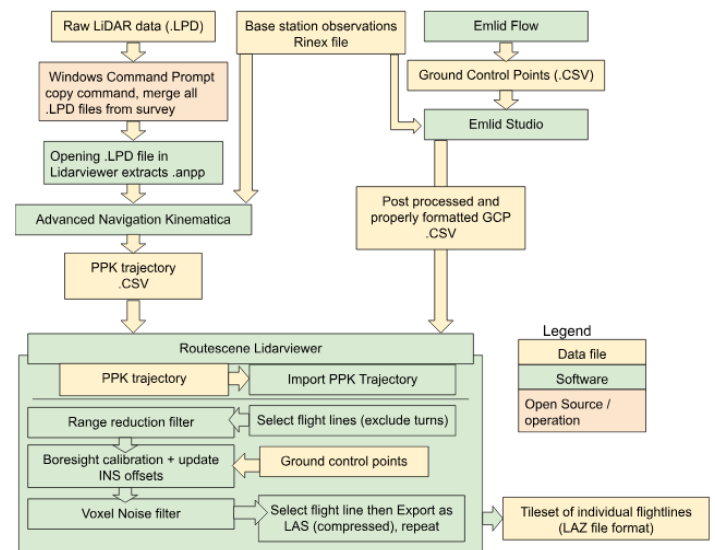


Fig. 1. Workflow for processing UAV LiDAR data into an open-source format that is able to be analyzed.

Acknowledgements: This work was funded by the CRREL Snowpack Project and the NSF SAUNNA NRT.

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An Investigation of the North Atlantic Oscillation’s Impact on Extreme Snowfall Events on Mount Washington

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Abstract: One of the leading modes of atmospheric circulation variability in the North Atlantic region is the North Atlantic Oscillation (NAO). This pattern is most prominent during the winter months and is responsible for the variability of pressure over the northern Atlantic, affecting various weather patterns from eastern North America to western Europe. We explored the impacts of this large-scale variability on the extreme snowfall events on the summit of Mount Washington, New Hampshire. This study finds that the NAO phases do not have a strong influence on the frequency of extreme snowfall events, but rather the intensity and variability of them.

What is NAO?

The North Atlantic Oscillation (NAO) is a prominent intraseasonal and interannual global teleconnection. This pattern is split into two phases, positive and negative, which correlate to inverse weather patterns¹. These patterns are controlled by the Icelandic low-pressure center and the Azores high-pressure center, which strengthen or weaken in correlation with a positive or negative NAO phase, respectively, where the westerly flow across the Atlantic is stronger or weaker, the latter resulting in more variable and extreme snowfall events.

Methodology:

We completed a parametric analysis for the NAO index and the averaged snowfall data to determine if there is a statistically significant difference using the October to April 1979-2023 period. The use of extreme value modeling allows for the study of NAO’s influence on the distribution of extreme snowfall values, not just the mean, when modeling snowfall with extreme value theory.

Results:

The use of a GEV distribution to study the extreme snowfall events during the positive and negative NAO phases resulted in a statistically significant relationship. As shown in Figure 1, the negative NAO phase line is higher when the

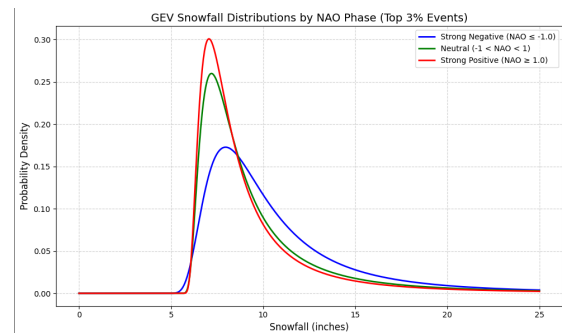


Fig. 1: GEV Model distribution of extreme snowfall events separated by the three NAO phases.

snowfall events are more extreme, compared to the positive phase when the recorded NAO index values are much higher for lesser snowfall values. When comparing statistical analyses, the NAO phases do not have a strong influence on the frequency of extreme snowfall events, but rather the intensity and variability of them.

Acknowledgements:

Support and funding for this work was provided by Mount Washington Observatory.

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Alpine Plant Communities of Katahdin: Resilience and Change After 33 Years of Climate Change and Recreational Visitation

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3. *Harvard Forest.*
4. *Chewonki Foundation.*
5. *Baxter State Park.*

Abstract: Arctic and alpine ecosystems are threatened due to climate change and human-mediated disturbance. Katahdin, located in Baxter State Park, Maine, is home to the largest alpine zone in the state, and harbors many uncommon, rare, or threatened arctic and alpine species. A resurvey effort that sought to better understand changes across Katahdin’s alpine zone revealed a patchwork of resilience and change in plant community composition.

Introduction:

Arctic and alpine ecosystems of the northeastern United States are currently threatened by climate change and human-mediated disturbance¹. Katahdin, located in Baxter State Park, Maine, is home to the largest alpine zone in the state. In 1989, Baxter State Park enlisted researchers Cogbill & Hudson to do a baseline vegetation survey in the alpine zone of Katahdin, in order to establish a quantitative record of Katahdin’s various high elevation natural communities. Cogbill & Hudson established 16 transects across Katahdin’s alpine zone; these transects were then relocated and resurveyed during the summers of 2021 and 2022, with the help of Cogbill, Hudson, and Baxter State Park. By resurveying these transect sites, we can now make direct comparisons in plant presence and coverage after 33 years of climate change and increased hiker visitation.

Results:

Comparisons of the 1989 and 2020’s datasets reveal a patchwork of resistance and change across the massif: while the presence and coverage of some populations and communities have remained relatively unchanged, other areas of the peak appear to have undergone significant community compositional changes. These results illustrate that alpine plant community compositional change in relation to climate and human disturbance may be more or less extreme

depending on microsite characteristics. These considerations will remain crucial to the continued conservation of rare arctic and alpine species across Maine’s largest alpine zone.



Figure 1: Historic photo of a transect completed in 1989 near Katahdin’s summit (Photo by Don Hudson).

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¹ Nomoto, H. A., & Alexander, J. M. (2021). Drivers of local extinction risk in alpine plants under warming climate. *Ecology Letters*. <https://doi.org/10.1111/ele.13727>.

Acknowledgements:

Dan & Betty Churchill Exploration Fund (2022), NSF Biodiversity on a Changing Planet Grant.

Increasing Next Generation Awareness of Local-to-Global Environmental Impacts from Polar Environmental Change: A Field Experience Approach

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4. *The Arctic Institute of North America – Kluane Lake Research Station.*
5. *Mount Washington Observatory.*
6. *Oregon State University.*
7. *Washington State University.*

Abstract: Polar regions are undergoing rapid environmental change with global climate consequences, yet many high school students, particularly those from underrepresented communities, have limited exposure to geoscience and Polar research. This project evaluates whether immersive PolarSTEM field experiences increase student knowledge of Earth systems science and awareness of geoscience careers. Outcomes are measured through assessments, surveys, and student reflections within a program combining field research, experientially based curriculum, and teacher professional development.

Polar regions play a critical role in the Earth system through dynamic interactions among the atmosphere, cryosphere, hydrosphere, and biosphere. Accelerated Arctic change, including glacier mass loss, sea-ice decline, and permafrost thaw, has cascading implications for global climate, ocean circulation, and sea level rise. Despite the importance of these processes, geoscience remains among the least diverse STEM disciplines, and many students have limited exposure to Earth systems science during secondary education.

This study examines how immersive PolarSTEM educational experiences influence students' understanding of climate systems and awareness of geoscience career pathways. Participants include students enrolled in Upward Bound programs and a Maine Arctic Climate Studies course at Edward Little High School in Auburn Maine.

Students engage in field-based investigations in Juneau, Alaska, at Toolik Field Station, Kluane Lake Research Station, and Mount Washington Observatory. These environments provide opportunities to examine glacier dynamics, Arctic hydrology, and atmospheric processes while situating learning within authentic research contexts. Students analyze environmental data and apply geophysical and geospatial techniques, including ground penetrating radar and photogrammetry, while working alongside scientists and near-peer mentors.

To support sustained implementation, the project also develops classroom curriculum modules and teacher professional development aligned with Polar Earth systems science. Program effectiveness is evaluated using pre-and post-content assessments, participant surveys, and qualitative student reflections.

By integrating field research, classroom instruction, and educator training, this research seeks to identify scalable approaches for teaching Polar Earth systems science that strengthen high school students' climate literacy and broaden participation in geoscience pathways.

Acknowledgements: We thank the University of Alaska Southeast, University of Alaska Fairbanks, Toolik Field Station, Mount Washington Observatory, The Arctic Institute of North America, and Kluane Lake Research Station for hosting student activities, and NSF, Battelle, and the Geotrac Foundation for providing funding for summer programming.

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Analysis of the December 18, 2023 Extratropical Cyclone

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Abstract: Wind storms are a primary cause of power outages in Maine and New England. To inform future electrical grid resiliency and emergency response, this project aims to develop storm climatologies and to evaluate the meteorology of recent impactful events. Here, we highlight a case study of the major extratropical cyclone of December 18, 2023, which ranks among the most damaging in Maine state history.

The December 18, 2023 storm developed as a low-pressure system off the coast of Florida on about the 16th and moved up the East Coast as a nor'easter. The storm then tracked north into Quebec as it approached a slow moving high pressure system off Newfoundland and brought southeasterly winds into Maine due to the cyclonic circulation west of the state.

The shift in storm track resulted in damaging southeasterly winds with gusts as high as 91mph in Trescott ME, and precipitation recorded as high as 5.38 inches in East Sangerville, ME (NWS Caribou, N.D.) for the Caribou forecast area. Additionally, ten counties in Western Maine were affected by severe flooding. The combination of high precipitation, snow melt, and runoff resulted in record levels in several tributaries and rivers, some exceeding the previous record from a historic flood in 1987 (USGS, 2024).

Central Maine Power Company reported more than 325,000 power outages, and Versant reported over 91,000 outages in their respective areas (Russell and Terhune, 2023). A major Disaster Declaration was issued on January 30, 2024, and FEMA approved 6.7 million dollars for individual assistance, 36.8 million dollars for public assistance, and 1.0 million dollars for Hazard Mitigation Grant programs (FEMA, 2024).

Ongoing work includes pairing electrical outage temporal/spatial data to observed winds, developing wind climatologies from airport weather station observations extending to at least 1998, and plausible future scenarios.

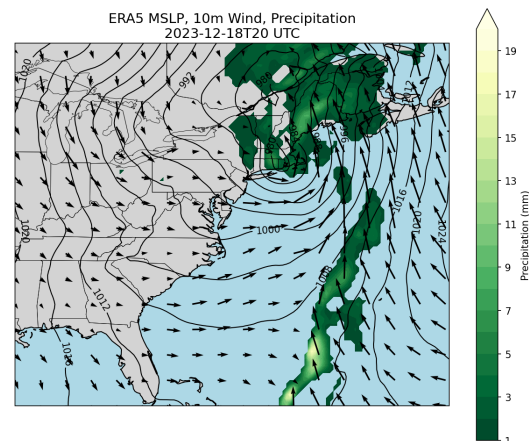


Fig. 1. MSLP, Total Precipitation, and Wind Vectors, using, From ECMWF ERA5. (Hersbach et al., 2020)

Acknowledgements: This Project is supported by NSF EPSCoR RII Track-2 FEC award 2316399.

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From Microclimates to Physiological Risk: Modelling Thermal Landscapes of Birds in a Biodiversity Hotspot

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Abstract: In the Fynbos biome of South Africa, climates are projected to become hotter and drier. These changes are likely to alter thermal landscapes and constrain the ability of animals to balance energy and water budgets. I integrated validated microclimate and endotherm biophysical models to predict evaporative water loss and body temperature for ten bird species across the landscape, and quantified dehydration and hyperthermia risk days over a summer month.

Climate change threatens biodiversity globally. Biophysical models are a promising tool for predicting species responses to environmental change, as these models explicitly represent the heat and water exchange processes governing thermoregulation, at spatial scales relevant to the organism.

I used a biophysical modelling framework to predict operative temperature (T_e) across a Fynbos landscape in South Africa. Predictions were validated against black bulb temperature measurements. The model accurately captured T_e , with differences between modelled and empirical values $\leq 1.14^\circ\text{C}$.

Validated model T_e estimates were then integrated with validated species-specific endotherm models to predict evaporative water loss (EWL) and body temperature (T_b) for ten Fynbos bird species over an average summer month. This was compared to predicted T_b and EWL from black bulb temperature measurements (Fig 1). Averaged across species, 2.5 days with a risk of dehydration were predicted when using model T_e , versus 6.1 days when using black bulb T_e . Less than one hyperthermia risk day was predicted using model T_e , and 1.0 hyperthermia risk days using black bulb T_e .

By integrating validated microclimate predictions of T_e with species-specific physiological responses, I established a mechanistic framework linking environmental heat exposure to thermal risk. With further parameterisation and validation, this approach could be extended across broader biomes under current and future climate scenarios.

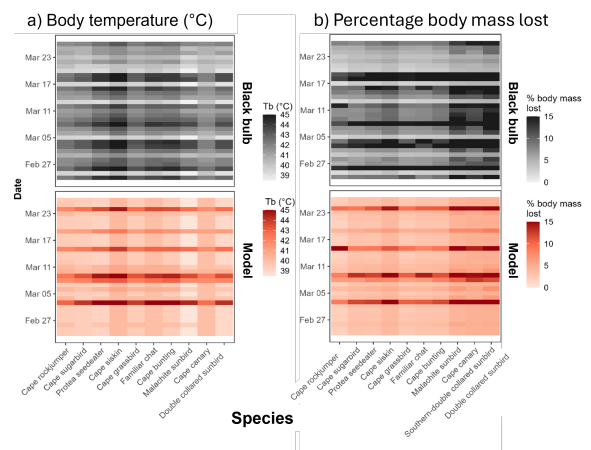


Fig. 1. Body temperature (a), and percentage body mass lost through evaporative water loss (b) for each species. Predictions based on biophysical model operative temperature (red) and black bulb temperature (black) are compared.

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Acknowledgements:

Travel to the University of Maine was supported by a grant from the Organismal Systems Modeling Network (Research Coordination Network grant IOS-1754949 (OSyM)), and the Company of Biologists Travel Grant (<https://www.biologists.com/>).

Recent Warming Following a Century of Intense Local Perturbation Drives Abrupt Shifts in Northern Maine Lake

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Abstract: We find abrupt diatom community responses to log driving and rapid recovery leading to novel assemblages under recent warming. The impact of post-1950 CE warming surpasses that of intense local perturbation and climate variability during the last millennium in northern Maine.

Crawford Pond (Piscataquis Co., 45°38'N, 69°11'W; 1.4 km²; 20 m max. depth) was a prominent landing center for log driving operations in the Jo-Mary Lakes watershed between 1835 and 1935 CE. Multiple dams were constructed and over 10,000 cords of wood were annually transported through the lake by 1930 CE. The use of lake systems for log driving was common in northern Maine, yet the ecological impacts of this type of local perturbation remain understudied. Here we assess the trajectory for Crawford Pond in the context of climate variability during the last millennium. We paired weekly-scale monitoring approaches with stratigraphic analysis to understand the seasonal lake variability in the present and reconstruct the lake ecology in the past using subfossil diatom evidence.

The monitoring results for the year 2024 CE reveal distinct assemblages that can be split into spring (*Aulacoseira* spp.), summer (*Asterionella formosa* and *Urosolenia eriensis*), and fall (*Tabellaria flocculosa*) dominant flora. Figure 1 shows that the timing of the *U. eriensis* bloom closely coincides with the maximum surface water temperature. The sediment core (83 cm) from the same lake spans the last millennium and shows a decrease in *Aulacoseira* spp., *A. formosa*, and *T. flocculosa* coinciding with the period of log driving operations. This is followed by a sharp recovery of spring- and summer-type assemblages, a decline in the fall-centered *T. flocculosa*, and the appearance and rapid increase of peak summer species, *U. eriensis*. Atmospheric temperature recordings for Maine mirror the increase of *U. eriensis*. We interpret that for the last millennium, Crawford Pond featured relatively colder waters, underwent deep reorganization with log driving, and under recent warming, reached a novel ecological composition (i.e., *T. flocculosa* reaching a minimum and *U. eriensis* a maximum).

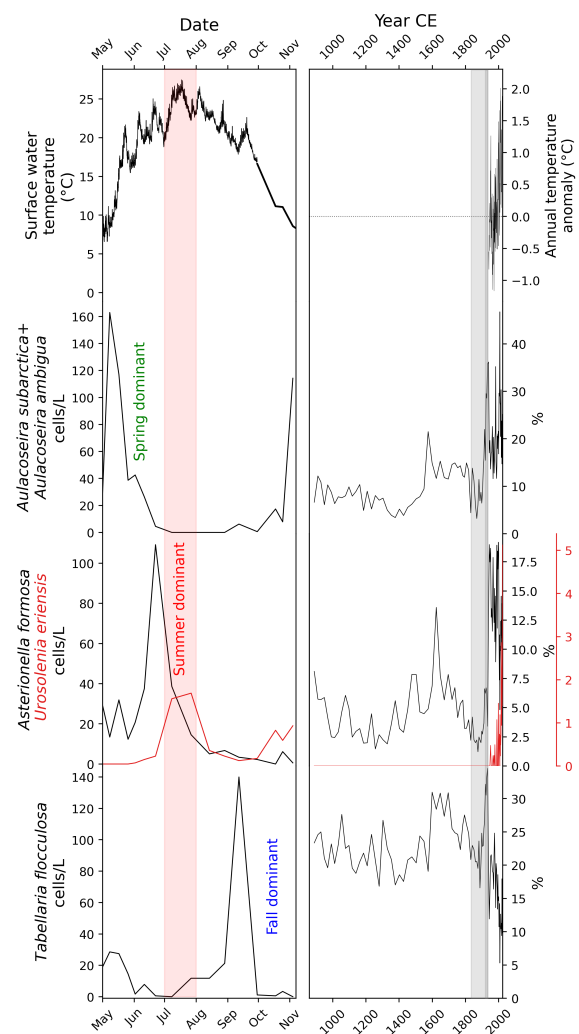


Fig. 1. Left: Crawford Pond data for 2024 CE. We show diatom density obtained from combining water samples at 3, 6, and 9 m depth. Red banner corresponds to maximum surface water temperature. Right: Diatom record from sediment core. Annual temperature anomaly in Maine is shown above. Log driving period (1835-1935 CE) featured in gray.

Acknowledgements: Yoke Ponds Camp Inc.

Unifying Topographic and Hydrodynamic Signals for Bluff Hazard Assessment Using Graphs and Graph Neural Networks

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2. *School of Earth and Climate Sciences, University of Maine.*

Abstract: We construct graph-theoretical abstractions of coastal Maine bluffs and train a graph neural network to predict their hazard category. Bluff erosion is an ongoing process that has intensified due to rising sea levels, higher precipitation variability and an increase of storms, indicating the need for robust and flexible erosion models. This project lays the groundwork for models that can unify earth observation signals across domains and incorporate community-based inputs in collaborative efforts to understand and adapt to bluff behavior.

Until recently, assessing bluff hazards in modern New England has involved geologists assessing the shoreline in person from a small boat [1]. This method is limited by the availability of the researchers, favorable weather conditions, and subjective interpretations; and lacks the ability for spatial and temporal extrapolation of assessments.

We show that a graph neural network (GNN) is able to predict with 82% accuracy the bluff hazard category (stable or unstable) assigned by experts. To do this, we plot steepest-descent graph edges along nodes drawn from a 2m digital elevation model and assign hydrodynamic simulation data to the final pit (sink) node. A GNN then learns to map the graph-theoretical structure and its hydrodynamic features to the hazard label.

This method is limited in its restriction to “stable” or “unstable” categories, in its simplified “steepest descent” construction, and in its omission of properties such as surface material, vegetation and groundwater flow. At the same time, the graph structure provides a robust and flexible platform to incorporate these properties as node or edge features. The graph neural network enables these graph bluff structures to be analyzed and compared quantitatively regardless of differing shapes and sizes, something that is not possible with grid-based methods. A larger model could be expanded with fuzzy logic-based inputs from local observers, which would strengthen the model and scientist-community collaborations.

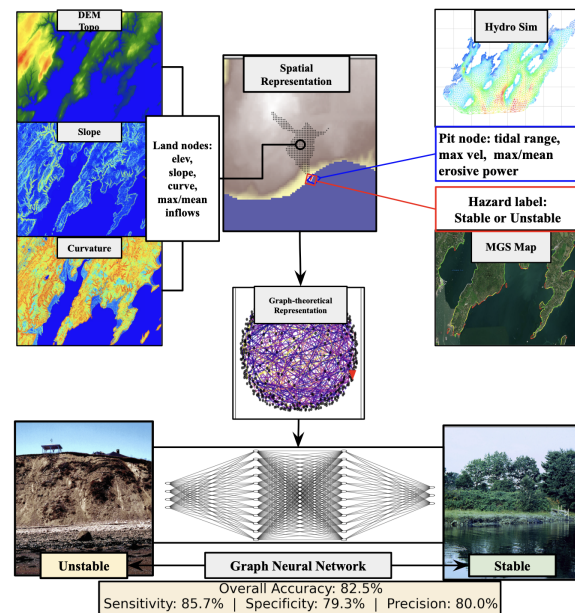


Fig. 1. Building and training hydrotopographic GNNs.

Acknowledgements: Cold Regions Research and Engineering Laboratory

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Voices of the Mountain: Extreme Weather Events as a Linguistic Crisis

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Abstract: Inspired by a panel at COP30, we investigate ways in which modern science may better understand and adapt to extreme weather trends by expanding its process, spatial, and linguistic perspectives through Ancestral Intelligence.

Scientists are turning their attention to Traditional Ecological Knowledge for insights into extreme weather patterns and “nature-based” adaptations [1]. Examples of true collaborations do exist, where new insights strengthened communities and contributed to science [e.g. 2]. Other investigations are limited to “surveys” of how extreme weather affects remote (Indigenous) communities [e.g. 3].

Ancestral Intelligence [4], I propose, offers more than observations of shore ice breakoff or animal migrations, and is rather the very mindset engendered by the culture and language of the communities that produce it. This includes perceiving “relationships” and “clusters of information” [5] compared to attempts to determine *causation* [6, emph. from original authors]; the perception [7] of the world as a sphere vs. a globe (fig. 1); and [8] the possibility that the Hopi language itself is better suited to describe e.g. vibratile phenomena than is advanced physics [8].

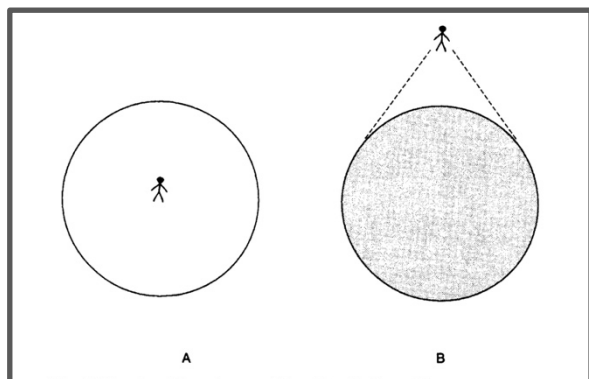


Fig. 1. From Ingold (2003), views of the environment as a lifeworld (A) and as a “globe” (B).

We discuss the risk of extraction and exploitation that a renewed interest in these perspectives could bring, along with the possible long-term implications for science and the benefits to the communities and Indigenous youth in particular.

Acknowledgements: Thanks to the Climate Change Institute for funding the COP30 trip to Belem, Brazil.

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Interhemispheric Comparison of the Late Glacial Climate Reversal

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Abstract: The driver of a prominent millennial-scale climate reversal that interrupted Termination 1 remains unsolved. This reversal produced a continuous and well-preserved moraine system across Scandinavia, including around Lysefjord in southwestern Norway. Tests of various hypotheses for the climate reversal require a detailed chronology of mountain glacier position in each hemisphere throughout the late glacial phase. ¹⁰Be surface-exposure dating of glacial landforms next to Lysefjord document the position of the Scandinavian Ice Sheet throughout the termination. Preliminary data reveal that the culmination of moraine construction closely resembles other late-glacial chronologies in the Southern Alps of New Zealand. This synchrony suggests a global driver of the late glacial millennial scale climate change.

The termination of the Last Glacial Maximum is the most dramatic climate change of the recent past, and yet the cause is still widely debated. A key part of this problem is that intense warming was interrupted by a cold reversal, resulting in the readvance of glaciers and ice sheets. The readvance produced prominent belts of moraines that can be observed all over the world, including around Lysefjorden in southwestern Norway. The cause of this interruption is still a major outstanding problem, but is key to understanding abrupt millennial scale climate change.

Based on observations of divergences between polar ice core records during stadials, Broecker 1998 suggested the cold reversal was caused by a “Bipolar Seesaw” of heat between the hemispheres¹. Other hypotheses suggest the divergence in polar ice core temperature records (particularly during stadials) is due to extreme seasonality, and that the reversal was instead caused by an equatorward shift in the southern Westerly Winds resulting in a cooling of the whole planet². Determining whether or not the reversal occurred synchronously between hemispheres is a way to test these hypotheses.

Surface exposure-dating of glacial geomorphological features produced during deglaciation is a reliable method to inform this debate. Precise dating of moraines provides a time constraint for cold and stable conditions of a given region, and in this case, the timing of the late-glacial cold reversal. Comparing the timing of moraine construction in both hemispheres will test proposed hypotheses and enhance the detail

to which we understand climate changes during Termination 1. Samples from boulders that were deposited on moraines and scoured bedrock surfaces by an outlet glacier of the Scandinavian Ice Sheet (SIS) were collected and analyzed using ¹⁰Be surface exposure-dating techniques. The age of individual boulders was calculated using the Rannoch Moore production rate³ and the culmination of moraine construction was calculated using the arithmetic mean of boulder ages from individual landforms. The ages were finally compared to ¹⁰Be chronologies of the Birch Hill and Chop Creek moraines located in the Southern Alps of New Zealand.

Preliminary results show the SIS margin was stable and producing moraines at the same time as mountain glaciers in the Southern Alps of New Zealand. The synchrony between hemispheres indicate that the Bipolar Seesaw cannot explain the late-glacial cold reversal and that it was caused by a global climate driver.

Acknowledgements: Thank you to the Comer Family Foundation and ER Quesada for financial support to this project.

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Quantifying McMurdo Ice-Shelf Rumples Change and Impacts on Ice-Shelf Stability

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Abstract: The McMurdo Ice Shelf Rumples are a pinning point for the Ross Ice Shelf and help mitigate Antarctica’s contribution to global sea level rise by lateral buttressing. We will quantify ice rumples geometry by building digital surface models of ice rumples evolution using aerial imagery from 1956 to 2000, in tandem with modern satellite data and ground-penetrating radar. With these remote sensing products, we can quantify the ice rumples force balance and deepen our understanding of how Antarctica will contribute to global sea level rise in a changing climate.

Introduction & Significance

Ice shelves are floating extensions of grounded ice sheets that contribute significantly to the stability of the Antarctic Ice Sheet (AIS) (Rignot et al., 2013). The McMurdo Ice Shelf (MIS) buffers the drainage of glaciers flowing from Ross Ice Shelf. Crucially, the MIS ice rumples, which are several-meter-high undulating glacial formations, are a vital source of buttressing due to lateral compressive forces along Ross Island. However, compressive ice margins and the structural integrity of the ice rumples are poorly understood. Therefore, assessing the stability of the MIS by quantifying the changes in geometry and force balance of the ice rumples is critical to understanding ice-shelf dynamics and Antarctica’s contributions to global sea-level rise. In addition, the ice rumples support a road that connects McMurdo Station and Scott Base to the airfield. This airfield is central to the U.S. and New Zealand Antarctic Program logistics.

Methods & Preliminary Results

We use a combination of stereo-derived satellite imagery and historical aerial imagery, applying structure-from-motion (SfM) processing, to create point clouds and digital surface models (DSM) to evaluate surface change as shown in Figure 1. Orthomosaics and DSMs from 1959, 1963-1965, 1974 and 1983-1984 were produced. The area of ice rumples has decreased since 1959, following the retreat of the ice shelf front as seen in the orthomosaics. In addition to historical aerial imagery and modern satellite data, we will use a combination of *in-situ* data (radar, GPS, ice cores) to answer questions such as: are the rumples fully floating (or partially grounded), how thick is the ice shelf, and where is the brine layer?

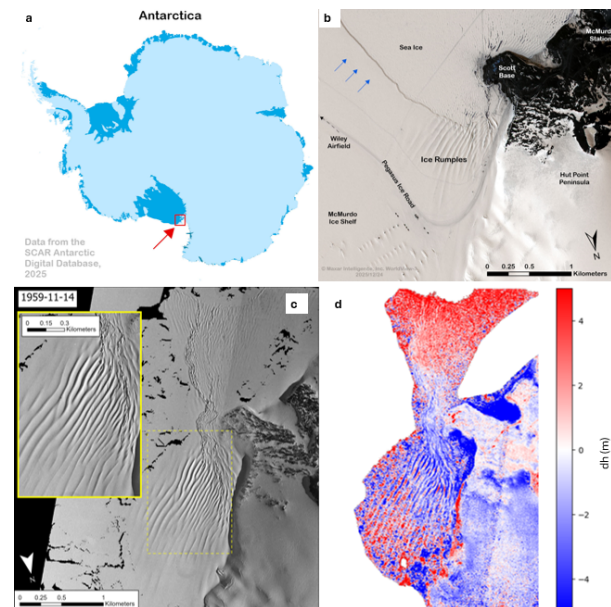


Fig. 1. A and B highlight the study site. Blue arrows show general ice-shelf flow. C: 1959 orthomosaic derived by SfM. D: preliminary differenced DSM between 2016 and 1959 (not tidally corrected) showing elevation change.

Anticipated Outcomes

We hypothesize if ice shelf thinning accelerates, resistive forces from the ice rumples will decrease. This may be identified by increased rumples amplitude and ice surface velocity.

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Paleoenvironmental Reconstruction of the Maruca Site in Ponce, Puerto Rico

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Abstract: In Puerto Rico, sea-level has risen almost 10 cm in the past fifty years because of climate change, eroding beaches and submerging marshes, mangroves, and dryland. Understanding the risk associated with climate change and how sea-level rise could affect coastal morphology and ecology is important for assessing how coastal communities will respond. Using the Maruca site on the south-central coast of Puerto Rico as a case study, this research aims to explore how past communities responded to climate-related changes in coastal morphology and ecological systems to assess how future communities may respond.

Background:

The Maruca site is in a floodplain 1.5 km north of the current coastline and 500 m west of the Río Matilde in Ponce, Puerto Rico (Figure 1). The site was discovered and excavated in the 1990s prior to construction of a shopping center and is one of the oldest sites on the island. During excavations, archaeologist Miguel Rodríguez López identified two occupation phases within the site separated by an abandonment layer¹. Based on radiocarbon dates, the first occupation was from 4568—3905 cal. BP and the second from 3280—2060 cal. BP. The initial occupation of the site falls within the Mid-Holocene, when regional sea-level curves show that relative sea-level was beginning to stabilize after a period of rapid rise². Rodríguez López hypothesized that during the initial occupation the coastline was only a few hundred meters from the site and that over the past several thousand years, alluvium from rivers like the Río Matilde caused progradation of the coastline, resulting in the current landscape. However, no geomorphological studies were conducted within the vicinity of the site. During the second occupation, domesticated and cultivated plants were identified, as well as eleven burials. Currently, the causes of both the first and final abandonment are unknown.

Methods:

This study will use micromorphology samples and soil and sediment cores to reconstruct the environmental conditions surrounding the Maruca site. The two primary research goals are (1) to identify the proximity of the site to the coast during initial occupation and (2) to understand the environmental conditions that could have led to

both abandonments of the site as well as the relation to the introduction of domesticated and cultivated plants. Data recovered from this study will be utilized to address questions related to habitat availability and decision-making strategies, as well as climate change and changing coastal morphology on the southern coast of Puerto Rico.

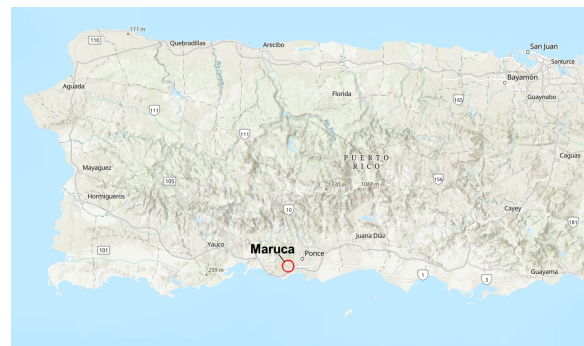


Fig. 1. Location of Maruca, Ponce, Puerto Rico.

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