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CLIMATE CHANGE INSTITUTE

FY2025 Annual Report

Research Activity for the period

July 1, 2024 - June 30, 2025

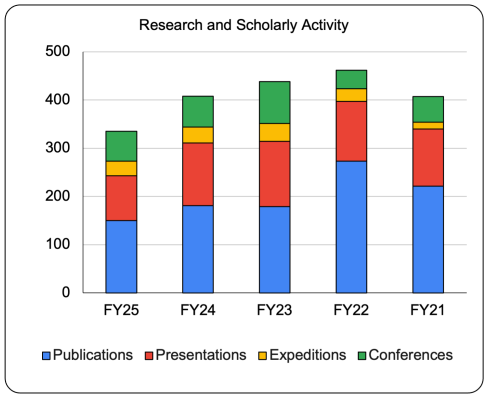
Climate Change Institute (CCI)

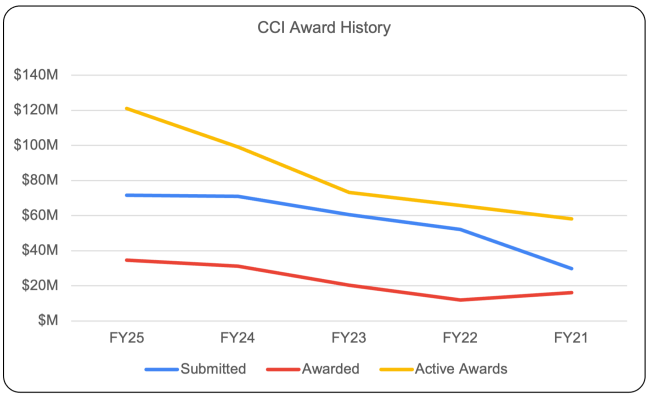
Faculty FTEs: 9.76 Faculty Affiliates: 53 Staff: 6 Doctoral Students: 39

Mission Statement

THE CLIMATE CHANGE INSTITUTE fosters learning and discovery through excellence in graduate academic programs, addresses local and global needs through basic and applied research, and contributes research-based knowledge to make a difference in people's lives. It is dedicated to improving the quality of life for people in Maine and around the world, and promoting responsible stewardship of human, natural and financial resources, now and in the future.

Key Performance Indicators





CCI appointed and affiliated faculty participated in awards submitted: $71M, awarded: $34M, and active: $121M in FY25.

Results to further CCI's core values: exploration, knowledge, education, collaboration, innovation, inclusion, and service

1. Expeditions (Maine, Antarctica, Arctic, South America, Asia) to understand past, present and predict future climate.
2. Innovations in hyperspectral imaging, laser ablation mass spectrometry, research and publicly available software.
3. Examples of CCI faculty and student awards include: UMaine honorary PhD (Denton), Maine Governor's Award (Sorg), Royal Asiatic Society (Norchi), NSF Arctic Dissertation Award (Gavin), National Museum of Archaeology Peru Sandweiss), UM Libra Professor (Sandweiss), American Quaternary Association (Gill).
4. Examples of major media releases include: Washington Post, Maine Calling, Seattle Times, CBC, Portland Press Herald, USA Today, Kennebec Journal, Boston Globe, Forbes, Fox, ABC, WGME, New York Times, Climate Monitor.
5. Examples of publications in major peer-reviewed journals include: Nature Communications, Science Advances, Journal of Maine Medical Center, Journal of Glaciology, Proceedings of the National Academy of Sciences, Nature Geoscience.
6. Major involvement in Maine Climate Council activities.
7. ROI: FY2025 (47.88), FY 2024 (38.98), FY2023 (29.12), FY2022 (20.22)

Top Achievements. Ticks, health. Nature comms, Science Advances COP 29. DOD

1. Arctic research (Greenland, Alaska, Scandinavia) and education (eg., NSF NRT Systems Approaches to Understanding and Navigating the New Arctic that will ultimately support and train >25 graduate students and Juneau Icefield Research Program training program).
2. Interdisciplinary Problem-Solving Partnership and complex problem course that introduces graduate students to major challenges and methods to approach solutions. (CCI, UM Law School, Portland Gateway).
3. Graduate Certificate in Climate Science and Adaptation (remote, CCI and Division of Lifelong Learning), student/faculty involvement in expeditions, UM RLE activities, and United Nations Conference of the Parties.

Supporting R1

Supported **39** PhD students in FY25 for over **$1.4 million** in stipend, tuition, and other related support.

Goals for Next Year

1. Continue to enhance CCI-UM Law School polar and ocean collaboration, CCI-Maine College of Engineering and Computing sensor and AI climate prediction (ESAC initiative), CCI climate and sustainability research in collaboration with UM Cooperative Extension, Interdisciplinary Complex Problem-Solving initiative activities with Portland Gateway, Law and Business Schools.
2. Continue to seek improved infrastructure facilities for the health of CCI personnel and instrumentation.
3. Commercialize *ClimateReanalyzer* software.

Impact in Maine

CCI Climate Reanalyzer and *10Green* publicly available software tools, *Climate On Tap* lecture series in Bangor, *Human Dimensions of Climate Change* Film Series, tick research, coastal climate action and resilience, recycling/reuse, local climate organization groups, on-site and virtual tours, public lectures, website educational tools.

FY2025 CCI Faculty Listing

Name	Administrative Title	Affiliation
Robert Ackert	External Associate	CCI
Ahmed Aboelezz	Associate	CCI/Mechanical Engineern
Guleed Ali	Ford Foundation Postdoctoral Fellow	CCI
Katherine Allen	Coop. Assistant Professor	CCI/SECS
Daniel Belknap	Professor Emeritus	CCI/SECS
Nancy Bertler	Adjunct Assistant Research Professor	CCI/Victoria University of Wellington
Tiago Carrilho Bilo	Associate	CCI/Marine Science
Sean Birkel	Research Assistant Professor	CCI/Cooperative Extension
Pascal Bohleber	External Associate	CCI/University of Venice
Scott Braddock	Assistant Researh Professor	CCI
Gordon Bromley	External Associate	CCI/NUI Galway
Benjamin Burpee	External Associate	CCI/Ecosystem Consulting Service
Seth Campbell	Research Assistant Professor	CCI/SECS
Ryan Cassotto	Research Assistant Professor	CCI
Sudarshan Chawathe	Coop. Associate Professor	CCI/SCIS
Aaron Chesler	External Associate	CCI
Kiley Daley	Associate	CCI
Ronald Davis	Professor Emeritus	CCI/SBE
George Denton	Professor	CCI/SECS
Phillip Dickens	Associate Professor	CCI/SCIS
Daniel Dixon	Research Assistant Professor	CCI/Office of Sustainability
Alice Doughty	External Associate	
Rick Eason	Associate	CCI/Electricial & Computer Engineering
Sarah Ebel	External Associate	CCI/Idaho State University
James Fastook	Coop. Professor	CCI/SCIS
Ivan Fernandez	Distinguished Maine Professor	CCI/SFR
Jennifer First	External Associate	CCI/University of Tennessee
Jacquelyn Gill	Associate Professor	CCI/SBE
Katherine Glover	External Associate	CCI/Stanford University
Bjorn Grigholm	External Associate	CCI
Brenda Hall	Professor	CCI/SECS
Sarah Hall	Adjunct Research Professor	CCI/College of the Atlantic
Daniel Hayes	Associate Professor	CCI/SFR
Vaclava Hazukova	External Associate	CCI/University of Umea, Sweden
Michael Howard	External Assocaite	
Gabriel Hrynick	External Associate	CCI/University of New Brunswick, Fredericton, CA
Cindy Isenhour	Associate Professor	CCI/Anthropology Dept.
George Jacobson	Professor Emeritus	CCI/SBE
Shaleen Jain	Coop. Professor	CCI/CEE
Raymond Jennings	External Associate	CCI
Lee Karp Boss	Associate	CCI/Marine Science
David Keefer	External Associate	CCI
Alice Kelley	Research Associate Professor	CCI/SECS
Joseph Kelley	Professor Emeritus	CCI/SECS
Bess Koffman	External Associate	CCI/Colby College
Peter Koons	Professor Emeritus	CCI/SECS
Karl Kreutz	Professor	CCI/SECS
Andrei Kurbatov	Associate Professor	CCI/SECS
Justin Lapp	Associate	CCI/Dept. of Mechanical Eng.
Danielle Levesque	Coop. Assistant Professor	CCI/SBE
Amanda Lynch	External Associate	CCI/Brown University
Kirk Maasch	Professor	CCI/SBE
Caitlin McDonough MacKenzie	External Associate	CCI
Matthew Magnani	Assistant Professor	CCI/Anthropology Dept.
Natalia Magnani	Assistant Professor	CCI/Anthropology Dept.
Paul Mayewski	Director/Distinguished Maine Professor	CCI/SECS
Brian McGill	Coop. Assistant Professor	CCI/SBE
Lou McNally	Research Assistant Professor	CCI/UMaine Machias/UMaine Augusta
Alessandro Mereghetti	Postdoctoral Research Associate	CCI

Nicholas Micinski	Associate	CCI/SPIA & Political Science
Kimberley Miner	External Associate	CCI/JPL Caltech
Anthony Moffa	Associate	CCI/Maine School of Law
Alexander More	Assistant Research Professor	CCI/Harvard University/ Long Island University
Peter Neil	Research Associate	CCI/World Ocean Observatory
Bonnie Newsom	Assistant Professor	CCI/Anthropology Dept.
Charles Norchi	Coop. Professor	CCI/Maine School of Law
Robert Northington	External Associate	CCI/Elizabethtown University
Stephen Norton	Professor Emeritus	CCI/SECS
Andrea Nurse	Research Associate	CCI
Brian Olsen	Associate Professor	CCI/SBE
Gordon Oswald	Research Professor	CCI
Andrew Pershing	Adjunct Professor	CCI/Gulf of Maine Research Institute
Mariusz Potocki	Postdoctoral Research Associate	CCI
Aaron Putnam	Assistant Professor	CCI/SECS
David Reidmiller	External Associate	CCI/GMRI Climate Center
Laura Rickard	Assistant Professor	CCI/Dept. of Communication & Journalism
Paul Roscoe	Professor Emeritus	CCI/Anthropology Dept.
Kennedy Rubert-Nason	Associate	CCI/UMaine Fort Kent
Katharine Ruskin	Associate	CCI/EES
Daniel Sandweiss	Professor	CCI/Anthropology Dept.
David Sanger	Professor Emeritus	CCI/Anthropology Dept.
Jasmine Saros	Professor/Associate Director	CCI/SBE
Joerg Schaefer	Adjunct Professor	CCI/Columbia University
Rachel Schattman	Associate	CCI/SFA
Molly Schauffler	Assistant Research Professor	CCI/SECS
Jessica Scheick	External Associate	CCI/UNH
Kristin Schild	Assistant Research Professor	CCI/SECS
Anton Seimon	Adjunct Assistant Professor	CCI/Appalachian State University
Jefferson Simoes	Visiting Professor	CCI/Universidade Federal do Rio Grande do Sul
Sharon Sneed	External Associate	CCI
Kristin Sobolik	Adjunct Professor	CCI/University of Missouri-St. Louis
Marcella Sorg	Research Professor	CCI/MCSPC
Jeff Thaler	Associate Faculty	CCI/Maine School of Law
Andrew Thomas	Coop. Professor	CCI/SMS
Jiaze Wang	Associate	CCI/SECS
Dominic Winski	Assistant Research Professor	CCI
Manuel Woersdoerfer	Associate	CCI/SCIS
Marie Zahn	External Associate	CCI/JPL
Gregory Zaro	Associate Professor	CCI/Anthropology Dept.
YongJiang Zhang	Associate	CCI/SBE

FY2025 CCI Doctoral Student Listing

Name	Doctoral Status	Advisor
Acharya, Suman	PhD Candidate	C. Isenhour
Berry, Allie	PhD Student	K. Schild
Blackwood, Emily	iPhD Candidate	D. Sandweiss & R. Corey
Broccolo, Jay	PhD Student	S. Campbell & K. Kreutz
Brooks, Hanna	PhD Candidate	K. Kreutz
Brown, Eric	PhD Student	D. Levesque
Clavette, Renee	PhD Student	S. Campbell
Gadrani, Lela	PhD Candidate	P. Mayewski & A. Kurbatov
Gavin, Amanda	PhD Candidate	J. Saros
Grindle, Thomas	PhD Student	J. Saros
Guthrie, Kayla	PhD Student	J. Saros
Hall, Tricia	PhD Student	A. Putnam
Hamley, Catherine	PhD Candidate	J. Gill
Hantson, Wouter	PhD Candidate	D. Hayes
Hazukova, Vaclava	PhD Candidate	J. Saros
Heller, Sky	PhD Student	D. Sandweiss
Huston, Grayson	PhD Student	J. Saros
Kim, Jaeheon	PhD Student	K. Evans
Kindstedt, Ingalise	PhD Candidate	K. Kreutz
Lamb, Avery	PhD Candidate	J. Saros
Landrum, Madeleine	PhD Candidate	J. Gill
Leclerc, Elizabeth	iPhD Student	D. Sandweiss
Limberger, Cory	iPhD Candidate	P. Mayewski
Lineman, Braedon	PhD Student	D. Mierelas
Mannello, Mikalia	PhD Student	S. Campbell
McGrath, Deirdre	PhD Student	B. Newsom
McLaughlin, Bailey	PhD Candidate	B. McGill
Miles, Maraina	PhD Candidate	B. Hall
Naveria, Ligia	PhD Candidate	P. Mayewski
Pahadi, Pratima	PhD Student	Y. Zhang
Rezk, Alexander	PhD Candidate	C. Isenhour
Royer, Mark	PhD Candidate	S. Chawathe
Skelton, Emma	PhD Candidate	K. Kreutz, S. Campbell
Spoth, Meghan	PhD Candidate	B. Hall
Tirrell, Andrea	PhD Student	J. Gill
Villacis, Leonardo	PhD Student	J. Saros
Walters, Samuel	PhD Student	C. Gerbi/P. Koons
Whiteman, Nicholas	PhD Student	P. Koons
Woods, Madelyn	PhD Candidate	K. Allen
		TOTAL # of Doctoral Students: 39
External Funding Dollars		
PhD Stipend Minimum (12 months) = $26,667 * 39		$1,040,013
Tuition (13 credit hrs – Fall & Spring & Summer * $557/credit hr * 39)		$282,399
Health Insurance ($3,157 * 39)		$123,123
Total External Funding Dollars		**$1,445,535**

FY2025 CCI Master Student Listing		
Name	**MS Program**	**Advisor**
Andersen, Mackenzie	Quat/Climate Studies	B. Newsom
Anderson, Morgan	Biological Sciences	J. Gill
Baumgartner, Samantha	Quat/Climate Studies	P. Mayewski/A. Kurbatov
Bellamy, Keegan	ERS	S. Campbell
Boerch, Mathilde	Quat/Climate Studies	K. Schild
Bradshaw, Elijah	Biological Sciences	J. Gill
Brocchini, Nikhil	Quat/Climate Studies	J. Gill
DeCamillis, Claudia Saldana	Biological Sciences	D. Levesque
Dodge, Derek	Interdisciplinary Studies	K. Maasch/D. Sandweiss
Fromstein, Mari	Quat/Climate Studies	S. Campbell
Goodwin, Michael	Quat/Climate Studies	A. Putnam/G. Denton
Hoover, Kelly	Quat/Climate Studies	D. Sandweiss
Johnson, Katelyn	Quat/Climate Studies	D. Sandweiss
Nesbitt, Ian	ERS	S. Campbell
Norstad, Abigail	ERS	B. Hall
Olson, Olivia	Quat/Climate Studies	B. Newsom
Rumsey, Roisin	Quat/Climate Studies	A. Kurbatov
Seixas, Miranda	Ecology/Env Sciences	J. Saros
Sohn, Sicely	Quat/Climate Studies	S. Campbell/K. Kreutz
Stanley, Wyatt	ERS	S. Campbell
Thomas, Sera	ERS	B. Hall
Towns, Erin	ERS	S. Campbell
Trueba, Ana	Quat/Climate Studies	S. Birkel
Wiggins, Tahi	ERS	S. Campbell

Human Behavior in the Northeast Landscape of the Little Ice Age: A Faunal Analysis of Long Point Preserve, Machiasport, Maine

Mackenzie Andersen[1,2], Bonnie Newsom[1,2]

1. *Climate Change Institute, University of Maine.*
2. *Department of Anthropology, University of Maine.*

Abstract: Environment and climatic conditions influence the way in which humans use the landscape. We plan to use faunal analysis to understand land use and subsistence practices during the Little Ice Age at Long Point Preserve in Machiasport, Maine. This study aims to enhance the history of human-nature interactions and behaviors during the Little Ice Age in Maine.

The Little Ice Age (LIA) was a cold period from 1300 C.E. to 1850 C.E. amidst the trend of climate warming during the Holocene (1). European settlers in New England had not experienced the region's cooler climate, only coming to the North American continent 100 to 300 years following the onset of this cooling event. They experienced variable seasons and agricultural hardships that led to difficulties in establishing settlements (2).

There is ample ecological evidence for 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 after the settlement of colonists in North America is under explored (2). Sea surface temperatures in the Gulf of Maine cooled during LIA and seasonal temperatures became more distinct (3). The Northeast experienced longer, harsher winters and more droughts, ultimately affecting settlement patterns, agriculture, and human behavior.

Fig. 1. Fragment of an animal mandible

Archaeological sites ME-257-048 and ME-62-58 on Long Point Preserve were excavated in 2024 during the University of Maine's biennial field school. Two components at this location reflect both historic and pre-contact occupation. One site includes an old apple orchard and house foundation, and the other is a Passamaquoddy shell heap. These two sites may pre-and-postdate the LIA, making it an excellent location to study land use and subsistence patterns in Maine during this cooling period. To explore how the LIA influenced human behavior at this location, this study aims to explore faunal remains recovered from the two sites. Fauna can aid in the historical, environmental, and climate record of the area, revealing how people responded to a changing climate.

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

Bibliography:

(1) Hughes, Drew Shindell, Caspar Ammann, Greg Faluvegi, and Fenbiao Ni. "Global Signatures and Dynamical Origins of the Little Ice Age and Medieval Climate Anomaly." Science 326, no. 5957 (November 27, 2009): 1256–60. https://doi.org/10.1126/science.1177303.

(2) Rockman, Marcy. "New World with a New Sky: Climatic Variability, Environmental Expectations, and the Historical Period Colonization of Eastern North America." Historical Archaeology 44, no. 3 (September 2010):4–20. https://doi.org/10.1007/bf03376800.

(3) Wanamaker, Alan D., Karl J. Kreutz, Bernd R. Schöne, and Douglas S. Introne. "Gulf of Maine Shells Reveal Changes in Seawater Temperature Seasonality during the Medieval Climate Anomaly and the Little Ice Age." Palaeogeography, Palaeoclimatology, Palaeoecology 302, no. 1–2 (March 2011): 43-51 https://doi.org/10.1016/j.palaeo.2010.06.005.

Uncovering Long-Term Responses to Climate Change in the Gulf of Maine

Morgan E. Anderson[1,2], Jacquelyn Gill [1,2]

1. *Climate Change Institute, University of Maine.*
2. *School of Biology and Ecology, University of Maine.*

Abstract: **Seabirds play a crucial role as ecosystem engineers on coastal islands, influencing nutrient cycling and vegetation dynamics. This study investigates the long-term responses of seabird populations to climate change in the Gulf of Maine through paleoecological methods. By analyzing sediment cores from island sites, we aim to reconstruct seabird presence and link it to past climate variability using isotopic and heavy metal analyses. Modern guano samples will refine these methods, providing insight into contemporary seabird ecology and informing conservation efforts.**

Background:

Seabirds are apex predators and key contributors to island ecosystems, depositing nutrients and trace metals through guano, which influences terrestrial and marine productivity.[1] Their nutrient inputs, rich in nitrogen and phosphorus, enhance plant growth and impact island food webs. The Gulf of Maine, a biodiversity hotspot, has experienced significant climatic shifts, including rising sea surface temperatures, changing fish distributions, and increased storm frequency, all of which impact seabird populations. Understanding past seabird responses to environmental change is essential for predicting future ecosystem dynamics and guiding conservation strategies, especially as seabird colonies face pressures from habitat loss and shifting prey availability.

Methods:

This study will use sediment cores from coastal Maine island peat bogs (Figure 1) 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 and its relationship to climate variability. Elevated nitrogen isotope (^{15}N) levels and bioaccumulative metals will serve as indicators of seabird presence.[1] Modern guano samples from Great Duck Island will provide reference isotope and metal signatures for interpreting paleo records. Comparing data across sites will reveal whether seabird population changes were consistent across the region or driven by local environmental factors.

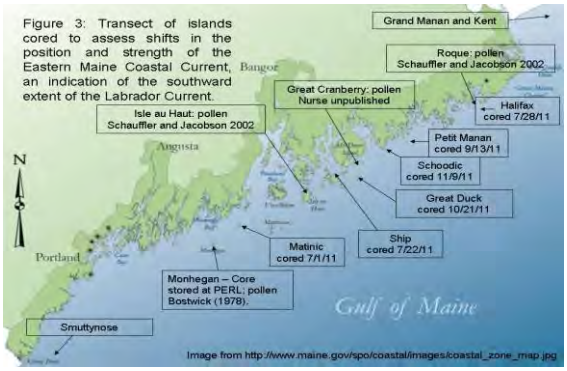


Fig. 1. Map displaying cored sites in the Gulf Maine. Adapted from A.Nurse.

Expected Outcomes and Impacts:

This research will clarify how seabird populations in the Gulf of Maine responded to past climate fluctuations, revealing whether colonies expanded during warmer periods and contracted during cooler phases. These findings will enhance our understanding of seabirdclimate interactions, inform habitat management strategies, and provide valuable insights for conservation efforts as seabird colonies face mounting environmental pressures.

Acknowledgements: NSF SAUNNA NRT

Bibliography:

1. Dulcinea V. Groff *et al.*,Seabird establishment during regional cooling drove a terrestrial ecosystem shift 5000 years ago.*Sci. Adv.*

Finance COP, Gender COP: Approaches from India and Bangladesh

Sarah Ball[1]

1. *School of Policy and International Affairs, University of Maine.*

Abstract: South Asia is a region particularly vulnerable to climate change. As the gendered impacts of climate change become more prominent, how states address gender in climate negotiations becomes an important question. Approaches from India and Bangladesh vary, despite a shared concern for potentially disappointing outcomes of COP29.

As COP29 came to a close late in the early hours Sunday morning in Baku, India was the first delegation to raise objections to the finance goal that was agreed – $300 billion USD by 2035. Dubbed the finance COP, with loft goals, this largely fell short. India, as with most non-Annex I states, found this number insufficient to meet the needs of climate change financing. Earlier in the COP, needed financing was being discussed as around $1.3 trillion USD.

In other negotiations, such as the global stocktake, India sided against the Global North again, this time to remove language around gender. The global stocktake is the mechanism through which states examine collective progress to meeting the goals of the Paris Agreement.

The lead negotiator for Bangladesh led one such event on the gendered impacts of climate change. One finding of the research presented was a 39% increase in child marriages directly following climate disasters. As livelihoods were impacted, familial patriarchs married their daughters quicker as an adaptation mechanism. There is also a correlation between climate disasters and removing girls from school.

This is a stark difference between how the India delegation and Bangladesh delegation approached the gendered impact of climate change, despite both delegations vocally opposing the quick and rushed end to COP29, as well as oppositions to the negotiating style of the Global North. India's delegation elected to negotiate against measurements of gendered impacts of climate change through the GST. In other negotiations, such as the new collective and quantified goal on climate finance, language "urged" the inclusion of women and other marginalized groups in the climate considerations, a looser piece of language to integrate gender.

As the domestic politics of each state shift and climate impacts worsen, the consideration of gender will become an unavoidable aspect of policy. How states are able to manage domestic interests, group memberships such as the G77 and LDCs, and urgent needs for climate financing will be important questions.

Acknowledgments: This research is supported by the Climate Change Institute and the University of Maine School of Policy and International Affairs.

Bibliography:

Srivastava, Roli. "India Fires Warning Shot with Rejection of Finance Deal at COP29." Climate Home News, November 25, 2024. https://www.climatechangenews.com/2024/11/25/india-fires-warning-shot-with-rejection-offinance-deal-at-cop29/.

Staff, Carbon Brief. "COP29: Key Outcomes Agreed at the UN Climate Talks in Baku." Carbon Brief, November 24, 2024.

"Bangladesh: IRC Study Reveals a Staggering 39% Surge in Child Marriage Due to Climate Change International Rescue Committee (IRC).".https://www.rescue.org/pressrelease/bangladesh-irc-study-revealsstaggering-39-surge-child-marriage-due-climatechange.

Allan Hills, Antarctica Climatic Shift Indicated by Water Isotopes, Dust, and Iron

Samantha Baumgartner[1], Andrei V. Kurbatov[1,2], Paul A. Mayewski[1,2], Michael Handley[1], Elena V. Korotkikh[1], Abigail Hudak[3], Asmita Banerjee[3], Jacob Chalif[4], Miranda Miranda[5], Ed Brook[3], & Christo Buizert[3]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *OSU Ice Core & Quaternary Geochemistry Lab, Oregon State.*
4. *Department of Earth Sciences, Dartmouth College.*
5. Department of Earth System Sciences, UC Irvine.

Abstract: Allan Hills (AH) blue-ice area provides access to some of Earth's oldest ice, offering an archive of past atmospheric and climatic conditions. Characterized by unique glaciological dynamics, AH requires the use of advanced analytical techniques such as laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) and continuous flow analysis (CFA) to resolve stratigraphy and glaciochemistry. Water isotopes, dust concentration, and iron are analyzed in this study to assist in quantification of temperature trends.

Introduction

AH is a prime candidate for analysis because of the long temporal coverage of 6 million years [1]. Establishing an ice stratigraphic record in these regions is challenging due to the low accumulation rate and ice thinning. To assist in these difficult conditions, LA-ICP-MS's ultra-high-resolution in combination with CFA data, starts to offer an understanding of past conditions. This combination dataset shows a transition of warm conditions to cool conditions.

Methods

The Climate Change Institute's W. M. Keck Laser Ice Facility uses a specially built LA-ICP-MS to analyze trace elements. To cater to the environmental and climatologic implications of the AH ice, 56Fe was focused on. In addition to LA-ICP-MS data, CFA water isotope (δ18O) and dust concentration data was analyzed at Oregon State University.

Results and Discussion

The δ18O values show a trend of warming to cooling as depth increases (Figure 1). This is further demonstrated by the dust and 56Fe data. Higher particle and 56Fe fluxes indicate warmer conditions, conversely lower values indicate colder conditions [2]. Further dating of this core would assist in interpretation of this climatic shift.

Acknowledgements: The National Science Foundation (NSF) Grant: PLR–2019719, Center for Oldest Ice Exploration (COLDEX).

Bibliography: [1] Cutts, E. (2024). Oldest ice offers view of Earth before the ice ages. Science, 384(6694), 368–369. https://doi.org/10.1126/science.adq0311.
[2] Edwards, R., Sedwick, P. N., Morgan, V., Boutron, C. F., & Hong, S. (1998). Iron in ice cores from Law Dome, East Antarctica: Implications for past deposition of aerosol iron. Annals of Glaciology, 27, 365–370. https://doi.org/10.3189/S0260305500017742.

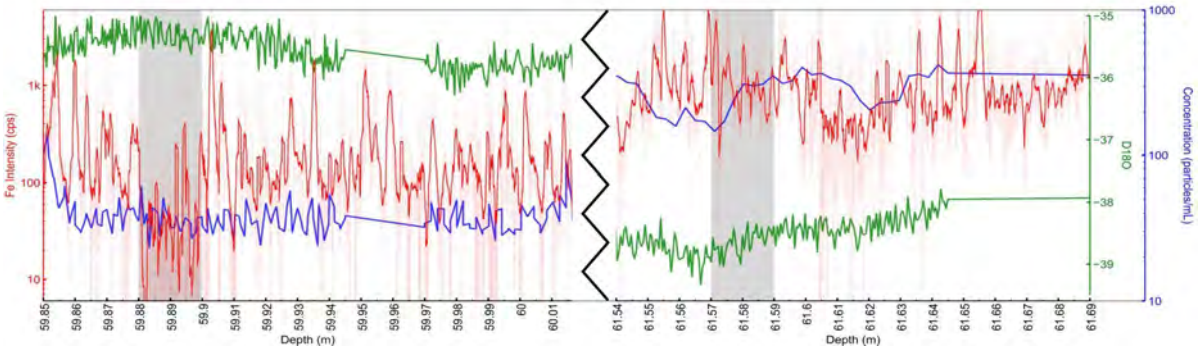


Fig. 1. A combination dataset for ALHIC2201 with water isotopes (green), particle concentration counts in particles/mL (blue) and LA-ICP-MS ^{56}Fe intensity data (light red raw data, darker red 20 point smoothed data). Data is shown from 59.58 m to 60.01 m with a break in analysis from 60.01-61.54 m, continuing with 61.54 m to 61.69 m.

Meteorology Starts with Weather Observations

Nikki Becker[1,2]

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

Abstract: **Weather observations are an essential part of the process for forecasting, analysis, decision making, risk management, and defining trends in Earth's dynamic atmosphere. For the last 175 years countries across the world have collected, maintained, and preserved weather observations to protect, provide and advance societies.**

Meteorology affects every aspect of life from shelter to food to safety. Dating back to 1216 B.C., the Chinese have the longest series of historical weather observations.[2] The Greeks were the first to think meteorology was a science, and Aristotle (around 334 B.C.) wrote linking 'meteorological observations to a physical reality and not a divine action'.[2] Before 1400s, weather observations were qualitative and became quantitative with the invention of meteorological instruments. See Table 1: Brief History of Meteorological Instruments.

Instrument	Year Invented
Rain Gauge	1441
Anemometer	145
Thermoscope	1607
Mercury Barometer	1643
Mercury Thermometer	1714
Hygrometer	1783

Table 1. Brief History of Meteorological Instruments.[2]

Weather observations were being collected, maintained, and preserved around the world starting in 1850. This led to the meteorological societies and government organizations formation of the International Meteorological Organization (IMO) in 1873, which became the World Meteorological Organization (WMO) in 1951.[4]

The United States (US) created the US Weather Bureau in 1890 to provide weather observations for near and long timeframes to support forecast and warnings; and to measure variations in US climate.[3] The weather elements to be collected and preserved with standardized equipment, maintained, and installed by the government were daily maximum and minimum temperature, snowfall and 24-hour precipitation totals.[3]

Since 1951, the preservation of weather observations authorized by WMO and country governments to define global weather trends of temperature and precipitation are first collected using standardized equipment (varies between countries) that is sited and maintained before data processing. After data processing, historical weather observations are stored in their original format and available in a digital format from the National Center for Environmental Information (NCEI) in the US.[3]

As a transition from analog to digital, there is a potential loss of weather observations from qualitative and quantitative sources across all sectors that the owner may not know the significance of the daily weather log their great grandparent kept could be instrumental in saving people's lives in the future.

Acknowledgements: This project was supported by NSF-NNA (award 2021713) and NSF EPSCoR RII Track-2 FEC (award 2316399).

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Evaluating the Spatiotemporal Variability of Temperate Snowpack Properties across the Southern Juneau Icefield using Multi-Offset Ground-Penetrating Radar

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Abstract: **Repeat mid-frequency (500 MHz) multi-offset ground-penetrating radar (MO GPR) transects were collected in June 2024 on the southern Juneau Icefield to quantify the spatiotemporal variability of temperate snowpack properties (e.g., velocity, permittivity, density and liquid water content (LWC)).**

Mountain glaciers and snowpacks are sources of freshwater for downstream environments, providing meltwater for over a quarter of the global population [1]. Variations in density and liquid water content (LWC) heavily influence the ability to accurately estimate the amount of water held within these frozen reservoirs, especially with geophysical methods such as multi-offset ground-penetrating radar (MO GPR).

Bordering southeast Alaska and northwest British Columbia in the Coast Mountains, the Juneau Icefield offers a phenomenal opportunity to observe spatial variations in snowpack properties across a range of elevations (0-2,300 m asl) and transitions from a maritime to continental climate.

A 20 m-long MO GPR system with an array of eight transmitter and receiver pairs at varying offsets was towed behind a snowmobile to collect two 32.5 km-long radar transects, repeated exactly one week apart, and coupled with in-situ measurements of velocity, permittivity, density and LWC from end-member firn cores.

Preliminary estimates from these repeat transect from the ablation area on the lower T'aakú Kwáan Sít'I (Taku Glacier) to a high accumulation zone further inland (Matthes-Llewellyn-Tulsequah glacial divide) show an up-glacier shift in snowpack properties, with the most significant shifts occurring in the shallow snowpack at lower elevations after one week (Figure 1). Wet density and LWC present shifts spanning the entire transect area, with the greatest changes occurring along the interpreted firn-ice transition. Overall, these findings emphasize the important role LWC plays in accurately estimating and measuring snowpack properties with geophysical methods.

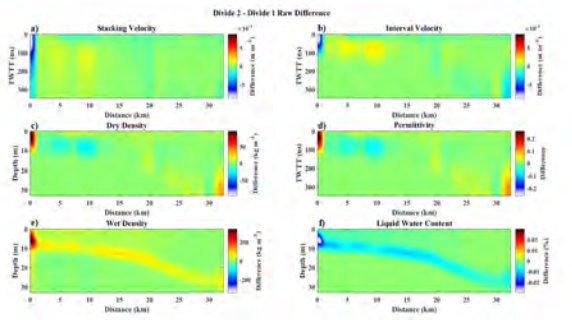

Fig. 1. The difference in (a) stacking velocity, (b) interval velocity, (c) dry density, (d) permittivity, (e) wet density and (f) LWC from repeat 500 MHz MO GPR surveys show the spatial variability of these properties after one week.

Acknowledgements: We thank the Juneau Icefield Research Program for their continued support of this work and for laying the foundation upon which we hope to continue building.

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The Influence of Fjord Dynamics on Iceberg Distributions in NW Greenland

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Abstract: **Icebergs contribute up to 50% of the freshwater flux (FWF) from Greenland's tidewater glaciers and have the capacity to impact ocean circulation. Despite this, they are often poorly represented in large-scale climate models. This project serves as a case study to investigate how different fjord systems affect iceberg distributions, to better understand the proportion of icebergs that reach the open ocean. We use iceberg distributions derived from Sentinel-1 SAR imagery from 2017 to 2021 across six distinct subregions of the northwest (NW) Greenland drainage basin. These distributions are compared with varying environmental conditions to assess how icebergs within different fjord systems respond to change.**

Motivation: Icebergs account for up to 50% of (FWF) from global ice sheets and have significant implications for sea level rise and ocean circulation. Previous studies have demonstrated the impact of iceberg FWF on fjord circulation.[1] Despite these findings, icebergs are largely unaccounted for Earth system models (ESMs), hindering our understanding of how iceberg FWF influences open ocean circulation and on what timescales. Current modeling practices include FWF from liquid discharge only, where any solid discharge is instantaneously melted and injected into the surface at the ice-ocean interface. While these approaches are representative of meltwater runoff and the FWF of icebergs that reside solely within the fjord (if considering discharge from Greenland Ice Sheet to include fjords), these assumptions are not representative of icebergs that move beyond the fjord and into the open ocean. These representations of FWF ultimately lead to an over-attribution of freshwater in the fjords and neglects the contribution of iceberg FWF in the open ocean. This project will better constrain estimates of how much ice is moving out of fjords that is currently misattributed to FWF in fjords.

Methods & Results: Here, we use icebergs identified from Sentinel-1 SAR imagery to determine the influence of fjord dynamics on iceberg distributions, specifically focusing on large icebergs (area > 10^4 m^2), due to their significant volume as well as their likeliness to transit beyond the fjords and enter the open ocean. As a case study, we investigate iceberg distributions in the NW drainage basin from 2017 -2021. The region is divided into six subregions based on differing fjord characteristics, including length and depth. We find that regions with long and deep fjords have negligible relationships between iceberg distribution and environmental variables, whereas regions with short fjords (more connected to the open ocean) have closer relationships to changes in environmental conditions (Fig. 1). These results suggest that fjords can act to buffer the impact of changes in environmental conditions on iceberg distribution.

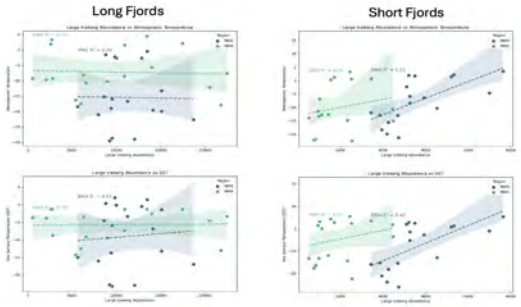

Fig. 1) Large iceberg distributions in regions with long fjords (left) and short fjords (right) compared to atmospheric temperature (top) and sea surface temperature (bottom).

Acknowledgements: This work is supported by NASA NIP Award 80NSSC21K0945 and the NSF SAUNNA NRT Award 2021713.

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"Site-seeing" Archaeological Features on the North Coast of Peru

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Abstract: This research explored the effectiveness and use of photogrammetry techniques in creating 3D models of archaeological features while in the field at two MidHolocene sites on the north coast of Peru. These two sites differ in age by approximately 1,000 years, offer evidence of climate change, and contain components strongly suggestive of early monumental architecture.

Background:

Archaeological sites encompass an enormous amount of data both above and below the surface. It can be difficult to envision what these spaces look like without having experienced a site for oneself, but it is also challenging to remember or accurately describe all the details even as the lead archaeologist. However, what if it were possible to make powerful visualizations that communicated these spaces on their own?

The enticement of creating 3D models of archaeological features and spaces is that they are accurate representations of the original object that can be viewed, handled, and shared. This provides a huge potential for increasing public awareness, discussion, education, and protection of archaeological resources. It also creates the opportunity to examine and analyze artifacts and structures that are difficult to access once out of the field or must remain in their country of origin.

Methodology:

Two modes of photogrammetry techniques were used in the field to assess their effectiveness in capturing archaeological data. The first was the use of a GoPro mounted to a pole to record an area while walking back and forth with the photos later stitched together when processed at the lab (Figure 1). The second was the use of the LiDAR and photogrammetry capabilities of the Polycam app on an Apple iPhone 15 with 3D models processed while in the field (Figure 2).

The 3D models created using either method can be used individually as photos, videos, and also accessed as interactive assets within the Polycam app. They can also be incorporated collectively as assets within virtual reality environments representative of the sites.

Fig 1. Kelly Hoover using a GoPro.

Fig 2. 3D model of a ventifact created using Polycam.

Acknowledgements:
Field work funding was provided by the Dan and Betty Churchill Expedition Fund. I thank Dr. Cecila Mauricio for site access and support; my committee Dan Sandweiss, Rick Corey, Alice Kelley, Kirk Maasch, Torben Rick, and Allen Gontz; and Kelly Hoover whose help was instrumental!

Transition of Marine-terminating Glaciers to Land under a Warming Climate: Implications for Driving Stress

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Abstract: Globally, glaciers are retreating at an accelerated pace, with the Arctic experiencing warming nearly four times faster than the global average since 1979. Here we examine four neighbouring glaciers in Southern Greenland over the past 82 years, as they retreat and transition from marine-terminating to land-terminating. By utilizing a longitudinal record of remotely sensed data and applying methods of structure-from-motion photogrammetry to historical aerial imagery, we will quantify the changes in driving stress. We will assess the relationship between changes in driving stress with regional climate data, comparing the timing and magnitude of change.

Motivation: Since the 1980s, hundreds of marine-terminating glaciers in Greenland have retreated onto land (Børch and Timotej, 2023), and it is projected that a thousand more will transition by 2100 under a +2.0°C global temperature change scenario. Nevertheless, a gap remains as it is unknown how this transition in terminus environment will change glacial behaviour as currently, marine- and land-terminating glaciers have only been studied separately and not while in a transitioning state.

To address this gap, we examine how glacier dynamics change with a change in terminus environment by examining the stress balance evolution for four neighbouring glaciers prior to, at the onset of, during, and, where possible, after transition from a marine-terminating environment to land.

Methods: We conduct a longitudinal remote sensing case study spanning the past 82 years to capture the full transition of the four neighbouring glaciers in southern Greenland by utilising a long record of available historical and modern satellite imagery (Fig. 1, bottom panel). To quantify the observed changes, we calculate the driving stress (τ_d, Fig. 1) by examining variations in surface slope and ice thickness. This involves combining remote sensing data with in situ measurements, including Digital Elevation Models (DEMs) to assess slope and fjord bathymetry data to estimate ice thickness (Fig. 1, top panel).

The driving stress will be compared to the stage of transition using terminus position from the historical and satellite imagery to study the evolution of driving stress and assess the relationship with regional climate data, comparing the timing and magnitude of both.

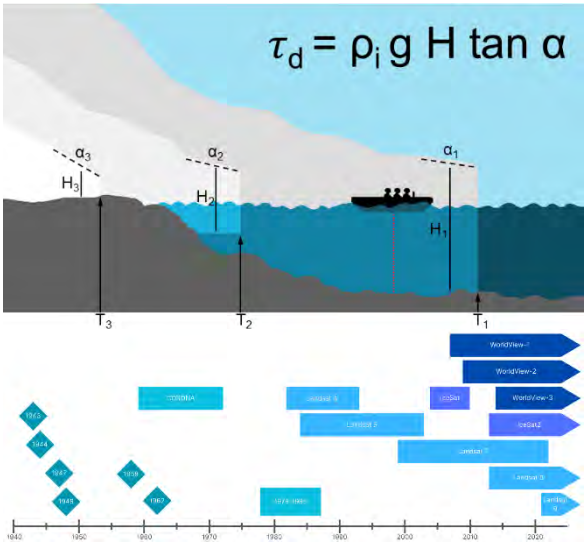

Fig. 1. Top: The driving stress equation and the elements of surface slope (α) and ice thickness (H) changing as glacier retreats onto land. Bottom: Temporal distribution of historical aerial photos and satellite imagery covering the study area.

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

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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 plan to conduct a field germination experiment along with modelling Pleistocene habitats for both megafauna and pawpaw populations to better understand the influence of long distance dispersal in the spatial dynamics of pawpaw over the last twenty thousand years.**

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. An example of this fruit phenomena is *Asimina triloba*, or common pawpaw. Despite the loss of potentially important megafaunal dispersers, the range of pawpaw significantly expanded northward. The range dynamics of common pawpaw since the Late Quaternary extinctions remain poorly understood. There is currently no clear evidence of frugivory by extinct megafauna that indicate an association. The regions of predicted habitat suitability during the Late Pleistocene would have likely consisted of fire prone 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 will be conducted on seeds of *Asimina triloba* to observe how digestion by mammals, fire, and water dispersal may impact successful germination (Figure 1). Ripe fruits will be collected and scarified by heat to simulate habituation in fire-adapted systems, water soaking to test water dispersal capacity, and acid treatment to test mammalian gut passage. Following scarification, these seeds will be planted in situ and revisited the following year to observe successful germination. A joint species distribution model will be used to assess range overlaps in pawpaw and extinct megafauna. Pollen abundance of pine species will be used from existing records to estimate species composition and canopy openness.

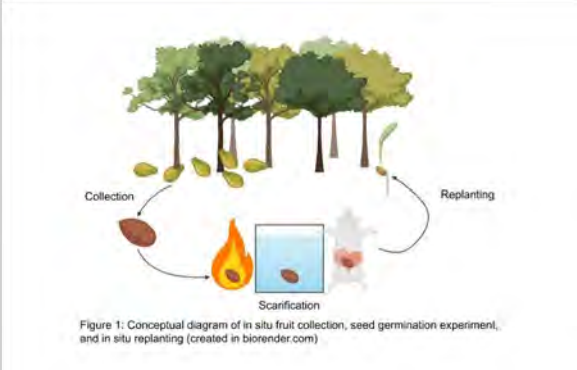

Figure 1: Conceptual diagram of in situ fruit collection, seed germination experiment, and in situ replanting (created in biorender.com)

Expected Outcomes & Impacts

We expect to observe pawpaw habitat refugia of closed canopy and streamsides within late Pleistocene forests. It is expected that germination success will decrease with fire, so we do not expect populations to exist in open-canopy savanna systems. However we expect water and gut passage to increase germination success, showing an association with stream habitat and dispersal by frugivorous megafauna. With pine pollen abundance we expect to see higher pollen abundances of pine and hardwood species in areas of higher pawpaw habitat suitability, indicating more closed-canopy habitat.

Citations

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Advancing Wind Modeling in Complex Terrain with a Particle-Based Physics Framework

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2. *Climate Change Institute, University of Maine.*

Abstract: **Accurately modeling wind flow through complex terrain remains a significant challenge due to limited observational resolution and the poor representation of small-scale dynamics. This proposed research will develop a particle-based physics framework to simulate wind behavior in complex mountain and polar environments, using the White Mountains and Mount Washington Observatory as a testbed. By combining high-resolution mesonet data with physically grounded modeling techniques, this work aims to improve wind prediction in extreme, data-sparse regions.**

Understanding wind behavior in complex terrain remains a major challenge for atmospheric scientists, forecasters, and operational decision-makers. Most models miss fine-scale wind dynamics due to computational limits and sparse observations—particularly in Arctic and mountain regions. Yet, improved modeling in these environments is essential for applications ranging from avalanche forecasting and aviation safety to climate diagnostics and military operations.

This proposed PhD research addresses this gap by developing a physics-based modeling framework that applies small particle dynamics to simulate wind flow through rugged terrain. Drawing on recent advances in hybrid Euler–Lagrange integration schemes (Wei et al. 2024), the model treats air parcels as particles interacting with terrain-driven flow fields (Figure 1). This approach enables efficient, high-resolution simulation of terrain-influenced wind behavior. The White Mountains and Mount Washington Observatory provide an ideal natural lab for testing.

Observations from MWOBS's mesonet, combined with mobile weather stations and LiDAR, will support model initialization and validation. These high-resolution datasets will allow for accurate representation of wind flow across varying terrain features and under a range of synoptic conditions. The resulting framework will be scalable to Arctic and sub-Arctic environments, where improved wind modeling remains critical and observational data are sparse.

This effort builds on foundational work examining subgrid-scale interactions in alpine climates (Schär and Müller 2005). By integrating these insights into a physically intuitive, particle-based tool, this research aims to enhance predictive skill, support risk mitigation, and improve understanding of boundary-layer processes in extreme terrain.

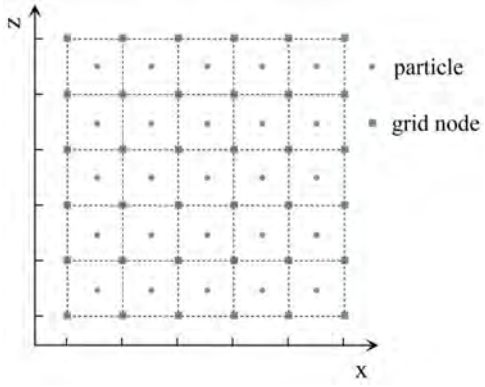

Figure 1. Schematic diagram of the Euler–Lagrange hybrid model (Wei et al. 2024).

Acknowledgements: This conceptual research is supported by the Climate Change Institute at the University of Maine and the Mount Washington Observatory. Instrumentation development is funded in part by the U.S. Air Force, and mesonet expansion is supported through Congressional Directed Spending.

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From Past to Present: Uncovering Pollution Trends in Alaskan Glaciers Over the Last Millennium

Hanna L. Brooks[1], Michael Handley[1], Karl J. Kreutz[1], Jacob I. Chaliff[2], Erich C. Osterberg[2], Ursula A. Jongebloed[3], Dominic A. Winski[1], Liam Kirkpatrick[3], Bess G. Koffman[4], Cameron P. Wake[5], Margit Schikowski[6], Emma Skelton[1], David Ferris[2]

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2. *Dartmouth College.*
3. *University of Washington.*
4. *Colby College.*
5. *University of New England.*
6. *Paul Scherrer Institute.*

Abstract: **Using lead (Pb) as a viewing lens, we evaluate the gross change in Pb deposited in the Alaska (using Pb concentration) and the source of that pollution (Pb isotopes).**

The study of Pb in ice cores reveals critical changes in culture, technology, policy, and global health that have impacted Pb emissions through time. **We evaluate changes in North Pacific Pb emissions and determine pollution source trends using a newly developed dataset of ice core Pb concentration and isotope ratios spanning from 800 to 2022 CE.** We used ice cores collected from Begguya (Mt. Hunter), Alaska: DEN-13A and DEN-13B (210 m, drilled 2013), DEN-19A (51 m, drilled 2019), and DEN-22A (21 m, drilled 2022). Cores were melted at Dartmouth College[1] and analyzed for trace metal concentrations and Pb isotope ratios following established methods[2] at the UMaine Climate Change Institute.

We examined Pb concentration trends over the top 1600 years of the Begguya record. The Pb concentrations remained at preindustrial levels from 800 to the 1950s, when Pb concentrations rose, reflecting trends in Asian ice core sites[3]. Beginning in the late 1970s, the record shows a large increase (Fig. 1; ~10 to ~100 ng/g), coincident with the industrialization of China over the last 45 years[4]. These trends contrast with trends observed in Greenland ice cores, which show a large increase in Pb concentration associated with the European and American industrial revolutions (1750s – 1840s), followed by a decline after ~1970[5]. We are currently examining the Pb data to interpret pollution source changes over time. Interestingly, Pb isotope data indicate regional variation in Pb isotope ratios recorded across the North Pacific -- implying a change in sampled air masses between North Pacific sites.

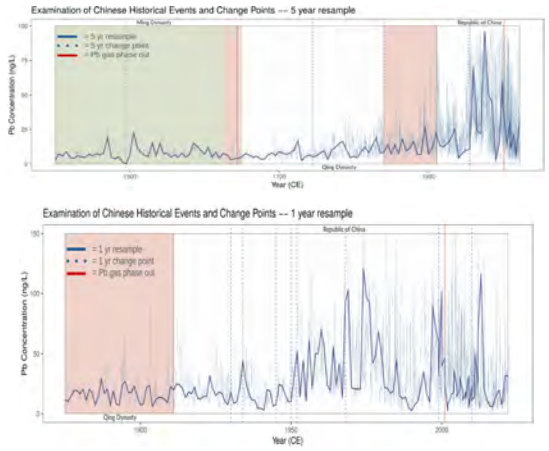

Fig 1. Two views of the Begguya Pb concentration record examining 1850 to 2022 CE (top) and 1400 to 2022 CE (bottom). Key historical events are highlighted – using red boxes to show periods of economic collapse or famine and green boxes to show periods of economic growth. Statistically significant changes in the Pb record are indicated with dashed lines.

Acknowledgments: The Denali Ice Cores were recovered near the summit of Begguya, within the traditional homelands of six sovereign nations who have occupied the region for thousands of years before our study. This work is funded by NSF (AGS-2002483; AGS-1806422; OPP-2002470), the UMaine GSG, and the Maine Space Grant Fellowship program.

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Thermal Windows in the Southern Flying Squirrel (*Glaucomys volans*)

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Abstract: The morphology and nocturnal ecology of flying squirrels presents a unique thermoregulatory challenge. We used thermography to determine whether northern individuals of *Glaucomys volans* use their gliding membrane (i.e. patagium) for heat exchange. Our preliminary findings suggest that other thermoregulatory mechanisms such as social nesting behaviors may be more critical than thermal windows.

Background:
Squirrels in seasonal environments can have varying endothermic phenotypes. North American flying squirrels are capable of both torpid and non-torpid heterothermy, but do not employ hibernation through winter. Flying squirrels are distinct in at least two ways from other squirrels: 1) they are nocturnal and 2) they have a patagium—an expanse of skin that stretches between appendages—that enables them to glide. The increased surface area of patagia likely contributes considerably to heat loss during nocturnal activity and thus implies utility in scenarios of overheating. Previous observations suggest the potential for heat dissipation in the patagium in southern *Glaucomys volans* (southern flying squirrel) populations (Neumann 1967), so we expect to see use of this "thermal window" under an acute heat challenge.

Methods:
We caught *G. volans* in the University of Maine Demeritt Forest and used a temperature-controlled chamber and infrared thermography to measure heat loss across a range of ambient temperatures over 3-4 hour trials.

Results:
Our individuals did not use their patagia as a thermal window at high temperatures (Figure 1). This is in contrast with observations of other hyperthermic gliding mammals and Neumann's (1967) southern *G. volans*. The paws, though, do act as thermal windows in northern *G. volans*. Previously described variation in the species' nesting behavior along latitudinal gradients suggests that nest choice and sociability serve as a primary mechanism for thermoregulation in *G. volans*. Our findings indicate that thermal windows, either through paws or patagia, likely play a minor role in northern populations which have only recently faced high temperature extremes. We conclude that the cavity-nesting and nocturnal aspects of the species' ecology are likely to have a more dominant role than morphology in the species' thermoregulatory physiology, particularly in the northern reaches of the species' range.

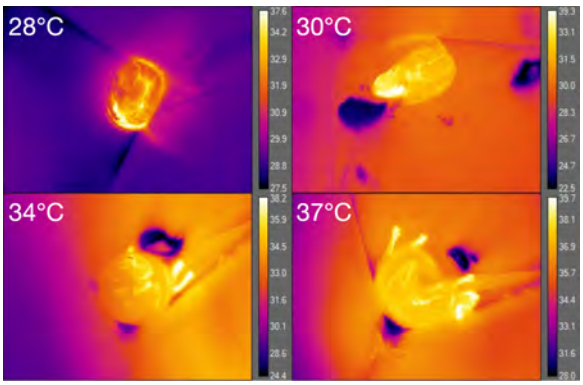

Figure 1. Thermal images of the southern flying squirrel (*Glaucomys volans*) during a heat stress trial. Subplots demonstrate changes in behavior to increase surface area in response to increasing ambient temperature. Notably, the patagium is not employed.

Ethics: We performed all handling, containment, and release methods in accordance with IACUC Protocols #A2020-05-01 and #A2022-03-27.

Acknowledgements: This project was supported by the USDA National Institute of Food and Agriculture, Hatch project numbers ME021623 and ME 021911 through the Maine Agricultural & Forest Experiment Station.

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Adapting Applications to Increasingly Structured Semistructured Data

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Abstract: **This paper reports early work on methods to automatically transform code in order to adapt to database schema that evolve from less structured to more structured forms.**

In this work, *structured data* refers to well-organized tabular data, more technically relational data that has been normalized to the fourth normal form [1]. In contrast, *semistructured data* refers to data that has structure that is partial, nonuniform, and changing over time, and is therefore difficult to map to rigid database schema and often represented in more fluid formats such as XML and JSON [2]. Structured data brings many benefits, such as ease and efficiency of querying and consistency-checking, and can draw upon several decades of significant progress. However, when data comes from a source that is not inherently well structured, wrangling that data into a well structured form is often so cumbersome and error-prone as to be practically impossible. It is in these situations that semistructured databases can save the day, by permitting the use of database techniques and systems, albeit with more modest abilities when compared to structured databases.

Given the above properties, an attractive approach for managing semistructured data is to initially work with its native semistructured schema and, over time, modify the schema gradually to a more structured one in order to incrementally derive the benefits of the structured approach in proportion to effort spent on structuring the data. This approach is facilitated by database management systems that support both kinds of data. For instance, the widely used *SQLite* system [3], while primarily a relational database management system, includes functions to work with semistructured data, specifically in the JSON format, as well.

The effort required for structuring the data includes tasks such as designing a suitable more structured database schema and mapping data from the old to new schemas. These tasks are not the focus of this work, which focuses instead on the task of adapting code that uses the database from the older, less-structured form to the newer more structured one. A simple but cumbersome method for this task involves a human expert making the modifications to the code after carefully reviewing the changes to the database structure. While sometimes a workable solution, this method does not scale to larger databases or more frequent changes, motivating methods that are at least mostly automated.

The proposed method is based on automated transformation database-access code, specifically queries in SQL and similar query languages, based on transformation rules defined as the more structure is added to the database. For example, data previously stored in JSON array in stored in a relational table instead, JSON path (sub)expressions for the array-based access may be mapped to subexpressions of SQL queries that yield the same data.

Acknowledgements: This work was supported in part by the U.S. National Science Foundation.

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Liquid Water Distribution Within and Beneath Temperate Ice on the Juneau Icefield, Alaska

Renée Clavette[1,2], Seth Campbell[1,2], Emma Skelton[1,2], Kailey Mannello[1,2], Keegan Bellamy[1,2]
Scott Braddock[1,3], Mari Fromstein[1,2], Tahi Wiggins[1,2]

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2. *School of Earth and Climate Sciences, University of Maine.*
3. *Cold Regions Research and Engineering Laboratory.*

Abstract: **To understand the ice thickness and liquid water distribution across the Juneau Icefield, we conducted ground-penetrating radar (GPR) surveys at high spatial resolution across a small semi-enclosed ice basin (North Basin) located on Taku Glacier (Juneau Icefield, AK). We calculated ice bed depth and geometrically corrected basal return power. Our results indicate the presence of subglacial drainage pathways, consistent with surface observations of meltwater runoff entering the glacier system.**

The storage and flux of meltwater in glacier systems vary over small spatial and temporal scales, however, the amount and location of water that is stored remains broadly unknown. Liquid water in glacier systems impacts ice dynamics, glacier mass balance, and thermal properties[1,2]. Meltwater runoff also affects watersheds, marine ecosystems, downstream communities[3].

North Basin is a small (~1km^2) ice basin semi-enclosed by mountains and is connected to the Juneau Icefield's largest glacier, Taku Glacier. In this study, we present 10MHz and 40MHz common-offset GPR results of depth and basal return power across North Basin. In June 2024, we obtained ~100 km of survey lines at high spatial resolution and repeated a subsection of these lines to capture temporal changes. This region acts as a case study to test these data collection and processing methods for expansion across the Juneau Icefield. From these data we infer maximum depths in North Basin of ~300 m. Using radar-derived depth values and the associated power losses as the radar waves travel through ice, we calculated bed return power (Fig. 1). In general, higher basal return power is associated with subglacial water[4]. The observed spatial patterns in the geometrically corrected bed power suggest the presence of subglacial meltwater drainage pathways.

In addition to North Basin being a location to test our methods, it is also the focus of a NASA-funded drilling effort to sample subglacial water. These data will aid in drill site selection.

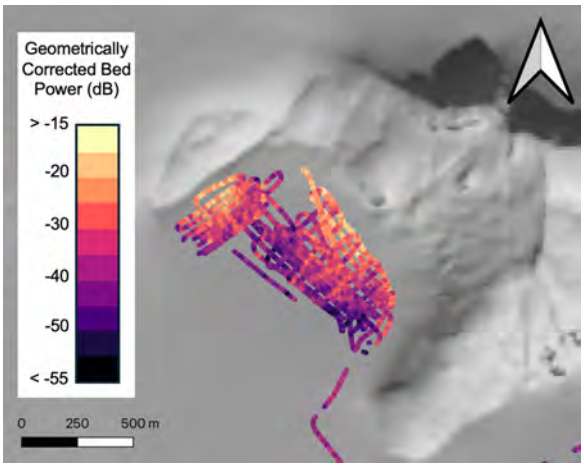

Fig. 1. Basal return power corrected for geometric spreading losses from 10MHz radar data across North Basin (Taku Glacier, Juneau Icefield).

Acknowledgements: This research is supported by funding from NASA. We also thank the Juneau Icefield Research Program for logistical support.

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Keep Ignoring the Ocean—That's Actually a More Effective Climate Law

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Abstract: COP29 was billed as the 'finance COP' and it aimed to assign financial responsibility by party, including identifying and agreeing on the financing needed to ensure climate change adaptation, mitigation, and resiliency. This mini-paper covers the relevancy of COP and the UNFCCC to oceans issues and other international legal instruments relating to the ocean.

I attended the twenty-ninth Conference of Parties (COP29) this past November as a member of the University of Maine group of observers. The COP represents the annual decision-making event for the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC is a large, unwieldy legal instrument that does not simply change year to year, but grows with each iteration along with the scale of the Conference. Despite this, our global ocean is woefully underrepresented, both in the legal text and therefore in COP negotiations, too.

With this in mind and a background oceanography and other marine experience, I made my focus of COP29 the ocean. This meant attending more side events and expert panels than main events or official negotiations, as there was nothing directly ocean-related to negotiate in terms of climate finance.

This is not the case generally across international law, though. There are many other legal instruments—agreements, treaties, and the like—that address our ocean and its shared, transboundary governance and protection.

Take, for example, the London Convention, the London Protocol (both addressing ocean dumping), the International Convention for the Prevention of Pollution from Ships (MARPOL), or the newer Biodiversity Beyond National Jurisdictions (BBNJ) Agreement.

The science is clear and has been for decades. Climate change is causing unprecedented global temperature rise, and 2 °C of warming is a maximum "critical threshold" for abating severe and irreversible effects. Global surface temperature has already risen 1.1 °C, with emissions continuing to increase. Even worse, the production and burning of fossil fuels is the largest contributor to this warming, and "CO_2 emissions from existing fossil fuel infrastructures without additional abatement already exceed the remaining carbon budget for limiting warming to 1.5 °C." (IPCC, 2023).

Our ocean acts as a global temperature regulator. But when extra CO_2 emissions are absorbed by the ocean, they lead to warmer waters and sea level rise; and they decrease the ability of the ocean to keep our atmosphere cool by absorbing excess heat. Changing seas, in turn, throw off global thermohaline circulation, thus leading to the more varied, less predictable weather we experience as some parts of the ocean, warm faster than others.

The small aim of the UNFCCC and the minimal ocean actions at COP29 are noble efforts but ultimately toothless. With what feels like incrementally smaller amounts of progress achieved at each COP, addressing the ocean by building up its presence in the UNFCCC would just slow the overarching process even more. It would also not achieve much in combatting the effects of climate change on the ocean or pollution of the ocean, because the ocean would be an ever smaller piece of the growing whole.

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

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Agreement under UNCLOS on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction.

Vulnerability to Climate Change and Effects of Circadian Rhythm and Rest-Site Selection in Small Tropical Mammals

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Abstract: Adjusting to high temperatures during climate change can come at a high energetic cost for mammals. Tropical mammals must cope in hot temperatures and can differ depending on many variables. Behavioral adaptations such as modifications to activity phase and sleep sites may play a role in survivability in a changing climate.

Background:
Tropical mammals are adapted to heat but are not necessarily more prepared for rising temperatures than non-tropical species. Both activity phase (e.g. diurnal or nocturnal) and rest site selection can influence possible reactions to climate change. Circadian rhythms may pose a challenge for behavioral coping mechanisms to heat when animals cannot modify their activity phase. This makes rest site selection important for such animals and may impose variable energetic costs due to physiological thermoregulation We compared the responses of diurnal species (*Tupaia tana* and *Tupaia minor*) with nocturnal species (*Cephalopachus bancanus* and *Sundamys muelleri*) to determine the effect of activity phase and rest site selection on energy expenditure.

Methods:
Flow through respirometry was used to measure metabolic heat responses and temperature-sensitive PIT tags measured body temperature . We compared the thermal profiles, resting metabolic rates (RMR), and evaporative water loss to determine their potential responses to climate warming.

Results:
We find that body temperature and metabolic rate increases during increasing atmospheric temperatures in *C. bancanus*. Both diurnal species (*T. minor* and *T. tana*) showed thermolabile responses to heat while maintaining stable metabolic rates (Levesque D. L., 2018 & Thonis, A., 2020). *S. muelleri* has blunted thermolability but stable RMR based on preliminary results (Figure 1. B; Breit , A. M, 2023). Rats, though predominantly nocturnal, can be cathermal and modify their activity patterns and change rest sites. Their ability to change foraging strategies and inhabit different rest sites may help blunt metabolic response to high temperatures. Further study comparing different Murid rodent species that presumably have different sleep sites and behavioral patterns may help assess the importance of thermally isolated sleep sites versus energetic heat responses.

Ethics: We performed all handling, containment, and release methods in accordance with IACUC Protocols #A2020-05-01 and #A2022-03-27.

Acknowledgements: This project was supported by the National Science Foundation IOS-2045785. CAREER: Physiological and Behavioral Determinants of Energy Use in Tropical Mammals.

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Indigenous Rights in Climate Governance: Challenges & Advocacy at COP29

Holly Fain[1]

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Abstract: **Indigenous Peoples represent a critical role in climate governance but face systemic barriers to formal participation in UNFCCC negotiations. At COP29, the Facilitative Working Group (FWG) of the Local Communities and Indigenous Peoples Platform advocated for policies that recognize their sovereignty, integrate Traditional Knowledge, and ensure meaningful participation.**

The 29th Conference of Parties (COP29) in Baku, Azerbaijan, highlighted critical gaps in global climate governance, particularly concerning Indigenous Peoples' rights and participation. Despite managing 80% of the world's biodiversity, Indigenous communities remain largely excluded from formal decision-making processes within the UNFCCC framework. Their absence as credentialed negotiating parties limits their influence over policies that directly impact their lands, cultures, and livelihoods.

A key focus of COP29 was the Global Goal on Adaptation (GGA) and Article 6 negotiations, which have significant implications for Indigenous communities. While adaptation measures are intended to support vulnerable populations, financial mechanisms such as carbon markets often disproportionately harm Indigenous groups. These market-driven solutions, promoted by developed nations, frequently result in land dispossession, economic exploitation, and the erosion of Indigenous sovereignty. The negotiations surrounding these frameworks underscored the importance of precise language in legal texts, with Indigenous advocates pushing for terms such as Free, Prior, and Informed Consent (FPIC) to safeguard their rights.

The Indigenous Peoples' Caucus and the International Indigenous Peoples Forum on Climate Change (IIPFCC) played a crucial role in mobilizing grassroots activism at COP29. Leaders from across the world engaged in strategic advocacy to integrate Indigenous Knowledge into adaptation and mitigation policies. Their efforts were reinforced by informal networks and rapid-response organizing, ensuring that Indigenous voices were represented in high-stakes negotiations despite structural barriers.
Discussions at the IIPFCC pavilion further highlighted the disproportionate burden of climate change on Indigenous communities. Representatives from the Pacific Islands, the Amazon, the Arctic, and other frontline regions shared firsthand accounts of environmental degradation, biodiversity loss, and forced displacement. Despite these challenges, Indigenous communities continue to lead in climate resilience through sustainable land management, traditional ecological knowledge, and community-driven conservation efforts. Their approaches provide effective, time-tested solutions.

The events of COP29 reinforced the urgent need for a more inclusive and equitable climate governance framework. Recognizing and elevating Indigenous leadership is not only a matter of justice but also a crucial step toward effective climate action. As negotiations continue, ensuring Indigenous Peoples' full participation and legal protections will be essential in addressing the ongoing climate crisis.

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

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Lava Loading and Melting on Martian Glaciers: Moulin Formation and the Fate of Meltwater

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2. *Earth, Environmental and Planetary Sciences, Brown University.*

Abstract: **Lava on the surface of glaciers generates a water-filled moat that can both spill onto the surface and drain to the bed. We address three questions: 1) Under what conditions will cracks propagate to the base of the glacier to drain the meltwater, and 2) How much of that water spills onto the surface, and 3) How much drains to the bed?**

Introduction:

The "icy-highlands" hypothesis **[1,2]** proposes that ice deposited at higher elevations in an adiabatic atmosphere can serve as a reservoir for the release of liquid water, potentially creating landforms such as valley networks and open- and closed-basin lakes. One mechanism to release liquid water from the icy-highlands reservoirs is the increased volcanism that occurred in the late Noachian and early Hesperian.

Following White's **[3]** treatment of flow through a narrow pipe draining a larger container, we quantify how the melted moat that forms surrounding lava drains to the bed. The diameter of the conduit is obtained from a solution for the elastic response of a water-filled crack forming in a region of extending tension **[4]**.

Any crevasse that is more than 97% full can propagate to the bed as the pressure of the heavier water overcomes the hydrostatic pressure in the ice. A full crevasse can penetrate and remain open to the bed, but as the water level drops, the crevasse narrows and pinches off at some level below the surface.

Simulations of lava thicknesses ranging from 10 to 200 m capable of melting 45 to 900 m of ice, with ice thicknesses ranging from 100 to 1000 m are summarized in **Figure 1**.

One mechanism for release of water from the moat is the spilling of melt water onto the ice surface as the lava slab initially melts into the ice until the top of the slab is even with the ice surface. **Figure 1A** and **1B** show the amount of water spilled and the duration of the spilling event. Approximately 20% of the water produced is spilled through this mechanism.

A second mechanism is draining through a crevasse that reaches the ice bed. **Figure 1C** shows the amount of water drained through a single crevasse, with the most resulting from thinner lava slabs on top of thicker ice. Volumes are an order of magnitude less than is spilled, but more than one crevasse can form. **Figure 1D** shows the duration of the draining events, which can last over 1000 years. Those below the solid black line are draining events where the crevasse never pinched off, so the draining duration was dictated by the simulation run time. These were generally for thinner lava in thinner ice. Typical times when the crevasse pinched off range from 50 to 500 years.

Acknowledgements: I am a retired Emeritus, so Social Security.

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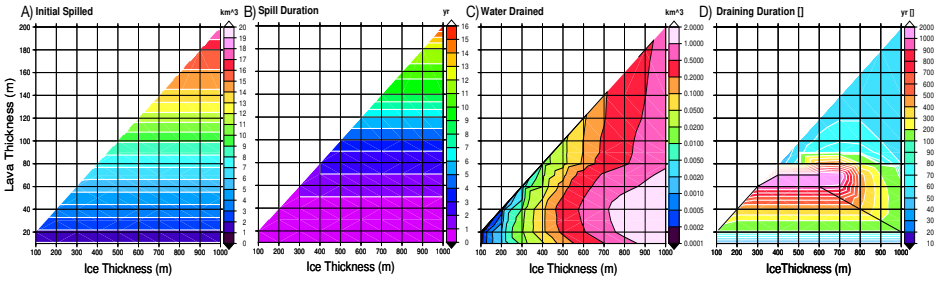

Figure 1: A) The amount of water spilled during the initial melting of the lava slab into the ice. B) The duration of the spilling event. C The amount of water drained through the crevasse. D) The duration of the draining event.

Comparing Measured and Modeled Glacier Ice Thicknesses Using In-Situ Ground Penetrating Radar Measurements on Jarvis Glacier, Eastern Alaska

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

Abstract: We have collected ice thickness datasets for several alpine glaciers across Alaska and northwest Canada using ground-penetrating radar (GPR). These ongoing GPR surveys are used to understand the current extent of glaciers in this region, track the ongoing changes experienced by glaciers in this region and worldwide, and reduce uncertainty in ice volume estimates. We compare the measured ice thickness to an existing ice thickness model to determine the accuracy of the model in predicting ice thicknesses.

The vast majority of freshwater across Alaska and Canada is frozen in glaciers and icefields. Any changes to these glaciers will have significant downstream impacts. Estimates of the total ice volume of mountain glaciers in this region range significantly. Only a handful of these glaciers have been studied well enough to understand the true volume of the ice and associated meltwater equivalent.

Between 2008 and 2024, our team has collected a large amount of ice thickness data in the form of common offset (CO) GPR surveys across the Central and Eastern Alaska Range and the St. Elias and coastal ranges in southeast Alaska and Northwest Canada. These data were collected with antenna frequencies of 1, 5, 10, and 100 MHz, corresponding to the depth penetration of each different radar system.

GPR analyses result in comparisons between the estimated depth of bedrock. Using measured ice thicknesses and geospatial processing tools, we compared these measured ice thicknesses to model outputs and conducted statistical analyses to determine the efficacy of the model (Farinotti and others, 2019; Figure 1). Here, we use Jarvis Glacier in the Eastern Alaska Range as a test case. These in-situ data are a crucial component in reducing uncertainty in modeled ice thicknesses. Our next steps involve processing the available ice thickness data on the Juneau Icefield and comparing it to the model outputs.

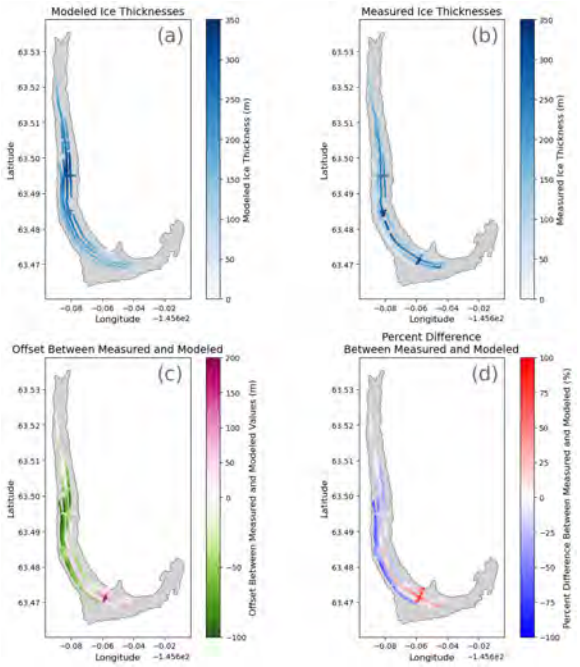

Fig. 1. Comparison between measured (a) and modeled (b) ice thickness and offset (c) and percent difference (d) between measured and modeled ice thicknesses along 10 MHz GPR survey lines on Jarvis Glacier.

Acknowledgements: Thank you to NSF-OPP (award #2119883), University of Maine Climate Change Institute, Maine Space Grant Consortium, Maine Graduate Student Government, and University of Alaska-Fairbanks collaborators for support of this research.

Bibliography: Farinotti, et al. “A Consensus Estimate for the Ice Thickness Distribution of All Glaciers on Earth.” *Nature Geoscience* 12, no. 3 (2019): 168–73.

Development of Artificial Ice Standards for LA-ICP-MS Analysis

Lela Gadrani[1,2], Andrei V. Kurbatov[1,2], Michael Handley[1], Elena V. Korotkikh[1], Paul A. Mayewski[1,2]

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Abstract: **This study reports the development of artificial ice standards for the quantification of trace elements in ice core samples using Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) at the W. M. Keck Laser Ice Core Facility, Climate Change Institute, University of Maine. We compare two newly developed approaches -rapid freezing and filter-based methods -and discuss calibration methodology. This new method enables the quantification of Fe concentrations at ultra-high resolution in ice cores, enhancing the reconstruction of past environmental conditions.**

Introduction: Accurate quantification of impurity concentrations in ice cores is essential for reconstructing past environmental conditions. Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) enables ultra-high-resolution chemical measurements but requires frozen ice standards with a range of concentrations. To address this need, we refined a standard preparation method originally developed at Ca' Foscari University of Venice (Bohleber et al., 2024) and adapted it for the UMaine LA-ICP-MS system.

Methods: LA-ICP-MS analysis was conducted using a New Wave UP-213 laser coupled with a Thermo Element 2 ICP-MS, housed in a clean room with a cryocell maintained at -22°C. Laser ablation was performed in continuous firing mode with a 100 µm spot size, an argon carrier gas flow of 1.2 L/min, and four parallel ablation lines spaced 200 µm apart. Multiple elements (Cu, Pb, Fe, and Mg) were analyzed; however, this study focuses on Fe calibration. The experiment followed a three-step sequence: (1) Pre-Calibration – initial measurement of artificial ice standards; (2) Allan Hills ice core measurement; and (3) Post-Calibration – re-analysis of artificial ice standards to assess instrumental drift (Fig. 1). Frozen filter standards were prepared by soaking filters in a multi-element solution of varying concentrations and freezing them onto the surface of ice made from Milli-Q water. Additionally, rapidly frozen standards were prepared using liquid nitrogen, following the method of Bohleber et al. (2024). All prepared standards were shaved in a -24°C clean room to remove contamination and were analyzed immediately after to minimize sublimation.

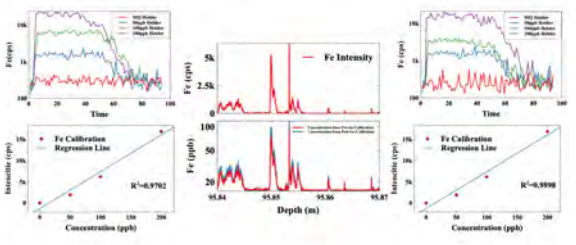

Fig. 1. Calibration of artificial ice standards for Fe analysis using LA-ICP-MS. (Top left & right) Fe intensity (cps) over time for Milli-Q (MQ) and artificial ice standards (50, 100, 200 ppb) acquired before and after measuring Allan Hills BIA ice. (Bottom left & right) Calibration line for Fe intensity vs. concentration (R^2 = 0.9702). (Center) Developed Fe concentration profile for Allan Hills ice core section.

Results: The artificial ice standards enabled the development of a linear calibration model (R^2 = 0.97) to convert Fe intensity counts into concentration (Fig. 1). We will discuss preliminary results and evaluate the effectiveness of using multiple artificial ice standards for LA-ICP-MS calibration.

Acknowledgements: We Thank the National Science Foundation (NSF) Grant number: 1745007.

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Multi-scalar Approach Towards a Holistic Understanding of Lake Level in an Agricultural, Drought-Prone Sub-Arctic Landscape

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Abstract: We used gradients in land-use and hydrologic connectivity in South Greenland to quantify the effect of abrupt climate change on lake level water in a sub-arctic, agricultural setting across multiple timescales. Lake level was highly coherent across lakes of varying hydrologic connectivity, which demonstrates the importance of climatic forcing on water availability in lakes in the permafrost-free zone.

Although the disappearance of the Norse settlement in South Greenland has been a topic of interdisciplinary, scientific debate for decades, the impact of anthropogenic climate change on the past, present, and future of Inuit sheep farming communities remains unexplored. Lakes are abundant in South Greenland, where they provide drinking water sources for humans and grazing animals, irrigation sources for hayfields, and hydropower to generate electricity (Vésteinsson 2016). As sentinels and integrators of climate change, lakes respond quickly to environmental change and record historical climatic, watershed, and in-lake conditions (Williamson et al. 2009). As such, lakes are an ideal system for evaluating changes within an agricultural system across scales.

Using lake level as a proxy for water availability, we evaluated the drivers of lake level at varying temporal frequencies to understand lake system response to an intensifying hydrological cycle. Indigenous Knowledge interwoven with paleolimnological and high-frequency lake level provide a holistic understanding of lake level, and hence water availability, across timescales. Semi-structured interviews with sheep farmers contributed to site selection, historical lake level observations, and lake level response to weather events. Diatom-inferred lake level and three-dimensional bathymetry modeling were used to reconstruct decadal trends in lake level that predate contemporary agricultural operations (Stone and Fritz 2004). High-frequency lake level sensors were used to quantify water availability drivers on a daily, seasonal, and interannual scale. Preliminary results show strong lake level coherence across a gradient of hydrological connectivity (Figure 1) and lake level response to weather events that vary seasonally. The strong coherence in lakes of varying hydrology and morphology suggests regional climate is the dominant driver (Magnuson, Benson, and Kratz 1990).

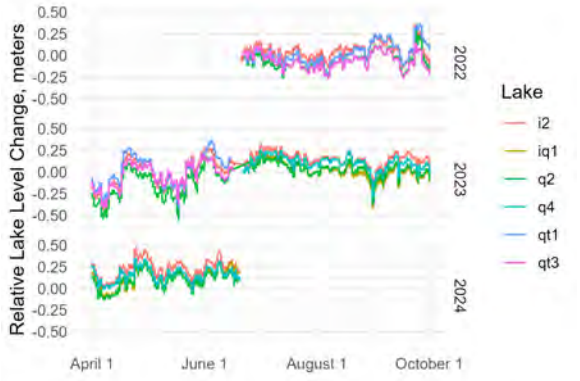

Figure 1. Relative change in lake level in lakes from April 1 to October 1 in 2022, 2023, and 2024.

Acknowledgements: NSF SAUNNA NRT; Maine WRRI 104(b); NSF DDRIG

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Developing a ^{10}Be Chronology of a Late-Glacial Moraine Complex in Whale Stream, New Zealand

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

Abstract: Mountain glaciers are highly sensitive to changes in global temperature. Using 10Be surface-exposure dating techniques, one can ascertain the amount of time glacially deposited boulders have been exposed to the atmosphere, thus deriving an 'exposure age'. This method can be applied to glacial landforms. A prominent set of moraines constructed in the Whale Stream valley of the Ben Ohau Range, central Southern Alps, New Zealand, indicate a major glacier resurgence that interrupted the last glacial termination. Here, we aim to develop a ^{10}Be chronology for late-glacial moraine construction that can be compared to other paleoclimate records and therefore used to diagnose underlying climate drivers.

Mountain glaciers are highly sensitive to changes in global temperature, reflecting millennial-scale climate change. The causes of these climate oscillations remain uncertain. A widely accepted hypothesis suggests that millennial-scale changes were driven by a bipolar-seesaw of oceanic heat between the polar hemispheres[1]. This mechanism would predict asynchronous glacier responses between the hemispheres. On the other hand, Denton et al. (2021) suggested that shifts in the Southern Hemisphere westerly winds drive global climate changes. Dubbed the "Zealandia Switch," this hypothesis posits the simultaneous construction of late-glacial moraines in both hemispheres[2]. Here we seek to address these hypotheses from the mid-latitude Southern Hemisphere in the Southern Alps of New Zealand. We targeted for study the mid-valley moraine complex of Whale Stream, a tributary valley of Lake Pukaki in the central Southern Alps. The moraines at Whale Stream were originally thought to show a linear recession after the last glacial maximum[4]. However, the moraine morphology indicates several nested moraines, indicating several ice-margin fluctuations to a similar location in the valley. We aim to develop a detailed chronology for these moraines to gain new insights into the structure of climate variations during late-glacial time at austral mid-latitudes. In January 2025, we undertook fieldwork in the Whale Stream valley. We conducted detailed mapping of the moraine complex. We will compare the prospective Whale Stream chronology to moraine belts in the Northern Hemisphere that have been dated using the same approach, such as the Esmark moraine and the Lysefjord moraine belt in southwestern Norway[3]. This comparison should afford insight into the climatic mechanisms that produced late-glacial climate reversals in both hemispheres.

Acknowledgments: Thank you to the Comer Family Foundation, the E.R. Quesada Foundation, the School of Earth and Climate Sciences, and the Climate Change Institute for financial support in this project. Alexzander Roman for efforts during the field campaign.

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How do Lakes in West Greenland Recover from Abrupt Lake Browning Following a Compound Climate Extreme Event?

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2. *School of Biology & Ecology, University of Maine.*

Abstract: **In the fall of 2022, Kangerlussuaq, West Greenland was impacted by a compound extreme heat and precipitation event. Rain on the landscape saturated the underlying permafrost and washed soil and organic material into the lakes of the region, which very swiftly browned. We are investigating trajectories of recovery of the factors contributing to browning, iron (Fe) and dissolved organic carbon (DOC), to better understand the dynamics of lake browning events.**

Background: Kangerlussuaq and the surrounding region is situated in Qeqqata, West Greenland, and was the site of a compound extreme event that strongly affected the landscape and lakes of the area. In 2022, the combination of record heat and rainfall flushed large quantities of materials from thawed permafrost into lakes of the region (Fig. 1). This Fe-rich material included organic matter. In the months following this event, dozens of previously clear, blue lakes across the landscape rapidly browned.

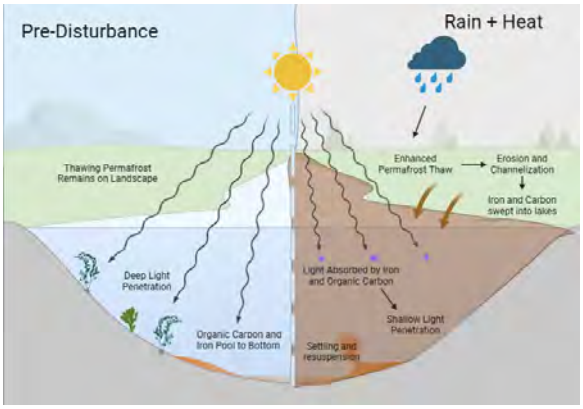

Fig. 1. Browning is a complex process that results from external inputs of terrestrial materials, that can then alter internal lake dynamics.

The underlying chemical conditions that principally drive lake browning are mobile Fe and DOC transferred from the landscape. We aim to understand how these materials will change in the post-event period by examining internal Fe cycling and determining rates of DOC degradation by photobleaching.

Methods: The lakes around Kangerlussuaq have been the focus of long-term study, and detailed data sets exist prior to the disturbance. We will leverage these to understand how the internal chemical conditions of lake systems are changing post disturbance and may impact factors affecting browning.

Dissolved oxygen dynamics affect iron cycling, as the chemical state of iron impacts the rate at which rust Fe sediments out of the water column, and the rate at which it is resuspended. We will observe iron fractionation within the water column via fixing mobile Fe and quantifying Fe.

Pre-disturbance lakes contained high concentrations of low-color (non-brown) DOC whose chemical signatures indicated an origin internal to the lake. In response to the event, the pool of DOC changed: the DOC is more colored, more complex, and likely originated outside the lake. Dr. Rachel Fowler (SBE) characterized the impact of prolonged sun exposure on pre-disturbance DOC. We will determine how the new pool responds to sunlight, and the extent to which photodegradation drives recovery in the post-disturbance period.

Results: Preliminary results indicate a change in internal oxygen dynamics, and likely active iron resuspension at the bottom of lakes. Post-disturbance DOC tends to show greater degradation and bleaching than pre-disturbance DOC.

Acknowledgements: Systems Approaches to Understanding and Navigating the New Arctic NSF Research Traineeship; NSF Arctic Natural Sciences RAPID Grant (#2348144); The Dan and Betty Churchill Exploration Fund.

Nutrient Shifts in Lakes Located in Central Norway: From Acidification to Browning

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Abstract: **Lakes in central Norway have been historically affected by acid deposition. While policy implementation has decreased industrial emissions and nitrogen from acid deposition, increased levels of dissolved organic nitrogen (DON) are detected in surface waters, suggesting enhanced terrestrial export of dissolved organic material (DOM). This process, known as browning, alters the ecology of lakes and can have implications for sensitive freshwater organisms. Sediment core and water chemistry analysis will be conducted to assess whether increasing DON delivery to lakes is driving shifts in nutrient availability.**

Background:

Acid deposition can alter the balance between nitrogen and other nutrients, potentially shifting the limited nutrient and thereby altering nutrient cycling. Lake acidification occurs when large quantities of sulfur and nitrogen enter the system, often resulting in habitat degradation. Norway, along with much of Europe, was significantly impacted by acid deposition from industrial emissions. With the implementation of policies like the Gothenburg Protocol, acid deposition has been reduced, resulting in less nitrogen to lakes delivered by atmospheric deposition.

For rivers in central Norway, there has been an increase in DON in surface waters, potentially due to enhanced terrestrial export with recovery from acid deposition. This recovery is driving an increase in the transport of DOM into aquatic ecosystems, a process known as browning. The recovery of acidified lakes has been linked to lake browning depending on local climate and terrestrial productivity, however changing DON in lakes is not yet documented. The terrestrial transport of nitrogen to previously acidified systems can have large implications for microbial communities and higher trophic organisms. Transport of dissolved organic carbon (DOC) can further affect nutrient cycling and microbial communities depending on the quantity and quality.

Our project will focus on collecting sediment cores from three lakes in central Norway (Figure 1) to examine the link between recovery from acid deposition and lake browning, and to specifically assess whether increasing DON loading is occurring. Sediment cores show the changes in lake composition over time, and comparing multiple lakes across central Norway will allow us to investigate the relationship between individual lake catchment and biogeochemistry.

Fig. 1. Location of lakes in central Norway, rendered from Google Earth.

To achieve our objectives, we will analyze diatom assemblages and isotopic composition of lake sediments, as well as water chemistry. Identifying the changes in diatom community composition will provide insight to the nutrients and chemistry present at each point in time, whether under a period of acidification or browning.

Acknowledgements: Fellowship support from NSF DGE 2021713.

A Glacial Chronology from Lysefjord, Southwestern Norway – Evidence for a Cold Reversal During the Termination of the Last Ice Age

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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 ^{10}Be 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 initial 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 (Figure 1). This work will allow 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.

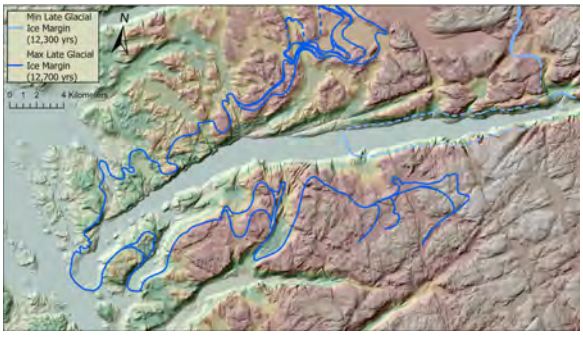

Fig. 1. Lysefjord field area with the ice margin of the Scandinavian Ice Sheet shown during the Late Glacial period.

During my summer 2023 field campaign, I collected 68 samples for ^{10}Be surface-exposure dating from moraines and erratic boulders within Lysefjord and the surrounding highland plateaus. These sample locations will 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 initial 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.

Acknowledgements: Comer Family Foundation, Sturgis Exploration Fund.

Glimmers of Resilience at COP29

Clea Harrelson[1]

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Abstract: **The making of resilience occurs across scales – within the lobster industries of Maine and Atlantic Canada and within global forums of climate negotiations such as COP29 in Baku, Azerbaijan. Through COP29, I explored the characteristics of the resilience-making process at the global scale to understand actors and actions that influence resilience and the utility of sites such as COP29 to hyperlocal questions of the future of lobstering in the Northwest Atlantic Ocean.**

Research Context:

The forces shaping resilience discourse in Maine and Canada lobster fisheries are not limited to Western Atlantic communities. Global climate meetings play an integral role in defining goals, language, and action for resilience activities that then percolate through a range of actors and institutions to influence industries like lobstering.

Through travel to the 29th United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP29), held in Baku, Azerbaijan in November 2024, I was able to explore the characteristics of the resilience-making process live through one of the most prominent forums of climate change decision making. Over 50,000 people attended this event, and each conference of parties (COP) since the inaugural event in 1995 has served as a focal point for defining the climate goals of environmental organizations, countries, and heads of state. Using methods of participant observation and what Anna Lowenhaupt Tsing (2015) calls the art of noticing, I participated in COP29 in person for one week, attending negotiation sessions, side events, and other informal gatherings through which individuals, organizations, and countries grappled with and defined issues of resilience.

Glimmers of Resilience

My experiences at COP29 left me with three key entry points for understanding how resilience is animated in the global space and how the versions of resilience – both in definition and in action – that are crafted in the global worlds of climate politics traverse documents, websites, government speeches, and management plans (or not) to influence resilience definitions and actions in the lobster industries of Maine and Atlantic Canada. First, country delegates and other actors from the Global South employ non-cooperative behavior to both hasten and slow the momentum of business as usual and open possibilities of alternative futures. While COP negotiations are often discussed as dominated by Global North interests, representatives from countries in historically weaker positions utilize the pace of negotiations as a tool of resilience that counteracts the, at times, overwhelming narrative of climate urgency that can enable business as usual actions. Second, COP29 was a space in which people and countries acted at both ends of the spectrum of imagining resilience possibilities. In some instances, these were untethered, collaborative, and a sharp contrast to current modes of clinical climate assessment and action. At other times, resilience was referenced as a clear re-labeling of other ongoing finance, policy, or other climate work – a signal of continuance and minimal disruption to the status quo. Third, as Naveed Khan (2023) has written about in other COP events, I witnessed some people in COP events enact forms of accumulation and relationship counter to the common understandings of capitalism through moments of patient solidarity and gift giving.

Acknowledgements: Thank you to the UMaine School of Policy and International Affairs and the College of Liberal Arts and Sciences for their support for this trip.

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Assessing Subglacial Conditions and Stability of Taku Glacier, Southeast Alaska

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Abstract: **This study intends to investigate the subglacial environment of Taku Glacier, Southeast Alaska, to determine its potential for stability or rapid retreat. Utilizing a hot water drill, we will access subglacial structures to reach bedrock and collect detailed borehole data near the glacier terminus. We will employ comprehensive geophysical surveys around each drill site to complement this data. Seasonal comparisons of englacial and subglacial changes, informed by integrated drilling, radar, and seismic data, will provide critical insights into glacier dynamics and the future behavior of the Taku Glacier.**

Subglacial environments play a critical role in glacier dynamics by serving as reservoirs for the storage and flux of meltwater. Their extreme environments also have potential for modeling icy planetary conditions, providing valuable insights for Astrobiological research and the search for extraterrestrial life. In addition, the subglacial domain preserves historical records of glacier fluctuations, erosion, deposition, and other geological and biological processes. However, accessing these environments is extremely challenging due to technological limitations and harsh Arctic environments.

Herein, we propose to study the subglacial environment of Taku Glacier in Southeast Alaska – the thickest temperate glacier on Earth and primary outlet glacier for the Juneau Icefield – to contribute to determining if it is likely to stabilize or continue its rapid retreat. During this effort, we will upgrade our 1990s-era hot water drill system, converting it from analog to digital, adding new sensors, and increasing its maximum depth capability. I will deploy the upgraded drill to access subglacial regions near the terminus of Taku Glacier to characterize the underlying structure (e.g. type of sediments or bedrock). Lastly, we will compare the digital recordings of glacier properties obtained during drilling to 5 MHz Ice-Penetrating Radar (IPR) and seismic survey observations collected during the field season, thus validating spatial-temporal interpretations of the subglacial environment.

We tested the drill system on Echo Glacier on Juneau Icefield in June 2023 (Fig. 1), successfully reaching bedrock at 272 m and 273 m during two consecutive borehole operations. The drill system functions by heating water and pumping it through a high-pressure hose to melt ice, creating a clean and efficient borehole. This method allows for rapid access to subglacial environments without introducing foreign contaminants.

Fig. 1. UMaine Hot Water Drill deployed to Echo Glacier on the Juneau Icefield in June of 2023

The upgraded drill will include a digital data logger, borehole caliper, bedrock sampler, sediment sampler, ice core sampler, drill head thermometer and inclinometer, water sampler, borehole camera, borehole LiDAR, and an additional 300 m of Synflex hose.

Acknowledgements: We appreciate support from the Juneau Icefield Research Program and NASA grant 21-PSTAR21_2-0033.

Using Geophysical Survey to Reveal Patterns in Monumental Construction at Los Morteros, Peru

Kelly E. Hoover[1]
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Abstract: **Following previous geophysical survey and archaeological excavations at Los Morteros beginning in 2010, an updated GPR survey was performed in 2024 by myself and returning team members. For this research, I interpret nearly 60 kilometers worth of data over the 200m x 150m x 15m mound and integrate GPR data with the excavation records to virtually reconstruct terminal phase monumental architectural features.**

Background: Los Morteros was first recorded in a larger archaeological investigation of Pampa de las Salinas in 1976 as a naturally formed dune with human occupation within the Late Preceramic Period (5,800-3,600 BP)[1]. Los Morteros remained largely untouched by archaeologists until geo-radar surveys performed by Sandweiss's team in 2006 and 2010[2]. Ground-penetrating radar (GPR) profiles collected in 2010 were used to identify monumental features buried by sand leading to the site being identified as a built mound, though aeolian sand remains interspersed throughout the construction sequences. Research on the adobe bricks recovered from the site indicate an early evolutionary stage of clay use in monumental construction associated with dates older than 5,100 cal yr B.P[3].

In July 2024, our team collected GPR data on Los Morteros, Peru. Our surveys collected nearly 20 km of 600 MHz and 170 MHz GPR data over the mound site with a dual frequency antenna (Fig. 1). Preliminary interpretations suggest the presence of a drape of aeolian sand over anthropogenic structures, including walls, rooms and floors of various sizes.From this research, we have identified evidence of man-made structure underneath the surface of the mound at Los Morteros, contributing to a preliminary understanding of the timeline for human construction at one of the earliest monumental structures in the Americas.

Fig. 1. Kelly Hoover at Los Morteros taking notes with GPR in frame. Image captured by Gontz, 7/18/2024.

Methodology: Processing of 2010 data includes adjusting gain and filters, such as band passing and background removal to clarify any potential monumental architecture while simultaneously reducing additional noise that obscures vital information to accomplishing my objectives. I will interpret the results of the survey and build a timeline of the phases of construction, in context with surrounding environmental conditions visible in the geological record.

Acknowledgements: Thanks to Dan and Betty Churchill for funding this research via the Dan and Betty Churchill Exploration Fund. Thanks to Ana Cecilia Mauricio, Allen Gontz, Gladys Pantoja, Emily Blackwood, Alice Kelley, and Dan Sandweiss for their assistance in this research.

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Characterizing Fish Sedimentary DNA Accumulation and Degradation Rates to Better Monitor Species on the Move

Grayson P. Huston[1,2,3], Jasmine E. Saros[1,2,3], Michael T. Kinnison[2,3]

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2. *Maine Center for Genetics in the Environment, University of Maine.*
3. *School of Biology & Ecology, University of Maine.*

Abstract: **We conducted a system-wide fish sedimentary DNA (sedDNA) manipulation experiment to determine brook trout (*Salvelinus fontinalis*) sedDNA accumulation and degradation rates in a natural system. Target species DNA was detected in sediment samples within 24 hours of introduction and persisted for over 70-days following fish removal, highlighting the long-term detection capability of sedDNA.**

Freshwater fish are some of the most vulnerable species to climate change, with increasing water temperatures driving poleward shifts in many species' distributions. As fish ranges expand into new regions and retract in others, resource managers need efficient and accurate methods – beyond traditional surveys – to monitor changing presence, abundance, and distributions.

Sedimentary DNA is one such approach that targets species DNA (i.e., scales, feces, etc.) that has become incorporated in surface and deeper sediments. Aquatic sediments are capable of preserving DNA for extended periods (months to years), offering the potential for wider temporal windows of detection and reducing the need for frequent sampling. Previous studies have reported fish sedDNA detections within 24-hours of introduction as well as signals persisting for 12 months following removal (1). However, these and other studies focused on mesocosm-scale experiments where many biotic (e.g., microbial activity) and abiotic factors (e.g., temperature) were controlled, creating uncertainty in applications to larger, more dynamic systems.

To better characterize fish sedDNA dynamics in a natural environment, we conducted a system-wide sedDNA manipulation experiment at Eskutassis Lake, Maine. In June 2024, 50 brook trout were introduced to an open mesh enclosure situated 1-m above the sediment bottom. Samples were collected regularly for 2 weeks before all brook trout and their enclosure were removed from the lake on experiment day 15. Replicate samples were routinely collected following fish removal until the brook trout sedDNA signal fell below our limit of detection.

Contrary to our hypothesis, brook trout sedDNA was detected within 24 hours of introduction; however, peak concentrations were not detected until experiment day 16 (Figure 1). Unlike previous studies, our final brook trout detection occurred on experiment day 88, with brook trout DNA absent from all sample locations by experiment day 139. While more work is needed to understand the distribution patterns and effect of season on fish sedDNA dynamics, our results highlight the use of fish sedDNA as an innovative method to track shifting species distributions in a warming climate.

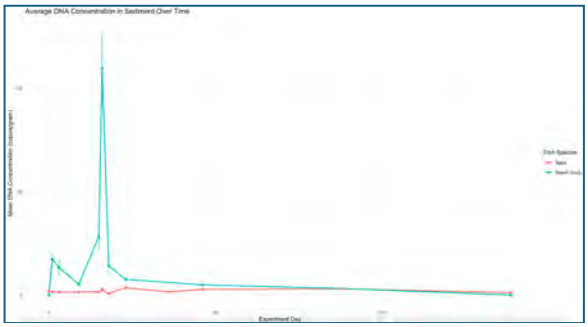

Fig. 1. Comparison of brook trout (temporarily introduced) and largemouth bass (resident species) sedDNA concentrations (copies/g) over time.

Acknowledgements: The National Science Foundation award #OIA-1849227 to Maine EPSCoR at the University of Maine; Kinnison & Saros Labs; Alex Thiboutot.

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Calibrating Isotopic and Trace Element 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 manifests as changes in sea surface temperature (SST) and upwelling. Existing literature investigates how mollusk species in north coastal Peru can be a source of proxy data for ENSO SST and upwelling changes. This project will further calibrate the method using isotope and trace element proxies from modern and archaeological specimens of the mollusk *Trachycardium procerum* to track ENSO variability in coastal Peru.

For decades, research teams have tracked ENSO (El Niño Southern Oscillation) behavior in coastal Peru through archaeological proxy methods[1-6]. I build on this prior research by further calibrating a novel proxy method, analyzing isotopic and trace element signatures in mollusk shells as a metric for ENSO manifestations, using modern specimens.

Some mollusk species (e.g. Trachycardium procerum) are resilient to El Niño and continue to deposit calcium carbonate shell material once or twice daily despite environmental stressors[3]. Isotopes and trace elements taken up during shell deposition are proxies for upwelling and sea surface temperature (SST) anomalies, both parameters affected by ENSO behavior[1,3,5].

I will add the mollusks I collect to an existing collection of Trachycardium specimens collected at Playa el Dorado and nearby sites from 2017, which documented the end of the 2015-16 El Niño as well as the 2017 coastal El Niño; 2019, which documented neutral conditions; and 2021, which documented an extended La Niña (Figure 1). In addition, I also have market collected shells documenting the 1982-83 El Niño[4].

Fig. 1. Map of study area. I will collect Trachycardium procerum at Playa El Dorado.

Following collection, I will analyze growth increments[5], stable isotopes (carbon and oxygen)[1,5], and trace elements–for example, Mg/Ca ratios as a proxy for SST threshold and barium and cadmium as a proxy for ENSO-driven upwelling[3]. By analyzing the stable isotope and trace element signatures of modern shells with known environmental conditions, I will help further calibrate the method of using mollusk shells as a proxy for ENSO behavior. Future research can apply this method to shells with unknown environmental conditions from archaeological and geological contexts, to reconstruct changes in ENSO behavior over time.

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

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Evolution of Eclipse Icefield Firn Column in Response to Atmospheric Temperatures

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Abstract: **Warming in high alpine regions is leading to an increase in glacier surface melt production, firn temperature, and firn liquid water content, altering regional hydrology and climate records contained in the ice. Here we use the Community Firn Model to forecast the evolution of the top twenty meters of firn at Eclipse Icefield (St. Elias Mountains, Yukon, Canada) over the coming decade. Results show that firn at 15 m depth has a 9% likelihood of becoming temperate (reaching 0°C) by 2033 with no change in present climate. The likelihood of Eclipse developing temperate firn at 15 m depth by 2033 increases to 15% with 0.1°C warming over that period, to 62% with 0.5°C warming over that period, and to 100% with 1°C warming over that period.**

Project Goal & Motivation

The goal of this project is to evaluate the likelihood of Eclipse Icefield developing a temperate firn pack over the coming decade. Prior and ongoing work shows Eclipse may contain a 10,000 year climate record in its deepest ice; however, in situ observations show increases in firn temperature and density over the last decade, which may compromise both the preservation of climate records in the ice and their recovery via ice cores. Here we use the Community Firn Model (CFM) to forecast the evolution of the top twenty meters of firn at Eclipse over the coming decade.

Community Firn Model

The CFM is an open source modular model framework available on Github. We force the CFM with air temperatures from a weather station near the ice divide between the Kaskawulsh and Hubbard Glaciers ("Divide AWS"; Fig. 1), surface melt calculated using a simple degree day model, and mean annual accumulation rate of 1.4 m w.e. a^{-1}. We first tune the model to in situ observations from 2016 and 2023. Then, using the settings that best replicate observations, we run fifty replicate model runs for each of several climate scenarios of interest. We calculate the likelihood of Eclipse developing temperate (0°C) firn at 15 m depth under each climate scenario as the percentage of those fifty runs for which this occurs (Fig. 2).

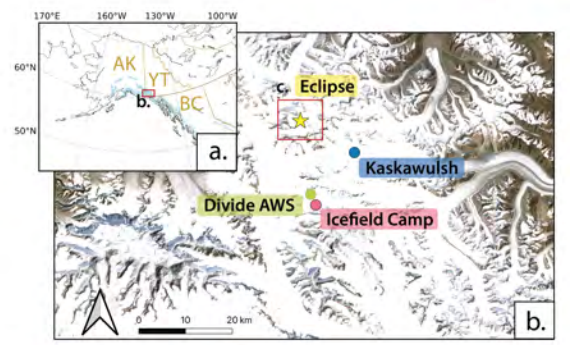

Fig. 1. Location go Eclipse Icefield with nearby sites of weather station or in situ firn observations shown.

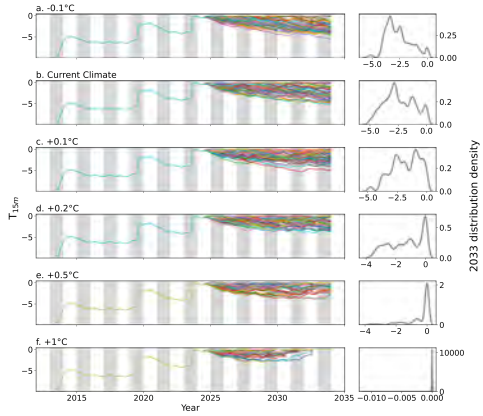

Fig. 2. Firn temperature at 15 m depth for fifty replicate model runs under six different climate scenarios. The distribution firn temperatures in 2033 under each scenario is shown in the righthand panels.

Acknowledgements: University of Maine Climate Change Institute; Robert and Judith Sturgis Family Foundation; American Alpine Club, American Geophysical Union, Geophysical Survey Systems Inc., University of Maine Graduate Student Government, University of Maine Sea-to-Sky Program.

Using Paleolimnological Approaches to Disentangle the Long-term Nutrient and Climate Drivers of Harmful Cyanobacterial Blooms

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Abstract: **Increased nutrients and temperature are considered the most important drivers of global cyanobacterial increases, but nutrient-temperature interactions and scale-dependent ecological considerations (e.g., specific cyanobacteria taxa, longer timescales, or more specific climate metrics like seasonal warming) can determine their relative importance. This research uses paleolimnological approaches to investigate the long-term nutrient and climate drivers of changes in cyanobacteria communities in Maine lakes.**

Paleo, contemporary, and modeling-based limnological studies have documented and forecasted global increases in harmful cyanobacterial blooms. Characterizing the strength of nutrients and temperature as drivers of cyanobacterial blooms is complicated by differences in species' responses to environmental change and insufficiently long time series. Furthermore, there is little consensus about how nutrients and temperature may interact to affect cyanobacterial abundance, with the degree and direction (synergistic, antagonistic, additive) often scale-, taxon-, and trophic state-dependent.

We employ a multiproxy paleolimnological approach using photosynthetic pigments and environmental DNA (eDNA) metabarcoding to investigate cyanobacteria in Maine lakes that span different climate zones and trophic states. These sediment reconstructions can be used to disentangle the effects of nutrients, temperature, and their interactions on cyanobacterial communities in Maine lakes over the past 125 years. **Specifically, we address: 1. Are nutrients or temperature a better predictor of cyanobacterial abundance and diversity in Maine's temperate lakes? 2. Do nutrients and temperature interact to affect cyanobacterial abundance and diversity, and if so, how?**

To investigate, 12 sediment cores were collected from lakes that span a range of climate zones (Northern, Central, Coastal Maine), trophic states (oligotrophic, mesotrophic, eutrophic), and underlying geology (presence/absence of P-rich Presumpscot formation). Photosynthetic pigments, including canthaxanthin and zeaxanthin (indicative of cyanobacteria), and sediment DNA were analyzed to determine any timing, direction, and magnitude of algal community change at different taxonomic resolution (Fig 1).

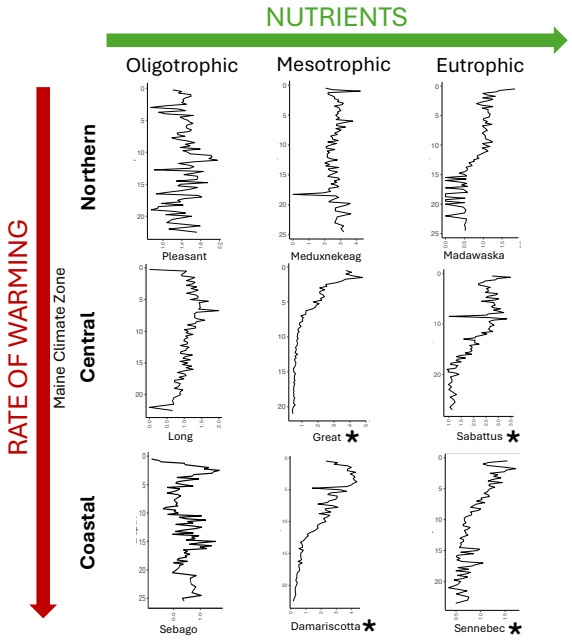

Fig. 1. Sediment profiles of canthaxanthin (photosynthetic pigment indicative of cyanobacteria) from 12 lakes in Maine across various trophic states (nutrients) and rates of warming (NOAA Maine Climate Zones). Canthaxanthin profiles are plotted by depth (y-axis) and in units of μmol g dry sed^{-1} (x-axis). * indicates lakes with Presumpscot formation in lake watersheds.

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

Don't Leave Feeling Hollow: Methods for Successfully using Small Hollows to Reconstruct Anthropogenic Fire History

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3. *Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado at Boulder.*
4. *NOAA's National Centers for Environmental Information (NCEI).*

Abstract: Distinguishing anthropogenic fires in the paleorecord can be challenging, as it requires the detection of spatial and temporal changes in fire and vegetation, evidence that these changes are not due to climate, and evidence that changes coincide with human history. We analyzed sediment charcoal alongside historical and archaeological records to identify anthropogenic fire events and fire extent throughout the mid- to late-Holocene. Our results indicate that small hollows are able to capture anthropogenic fire events, and at finer spatial scales than lakes.

Study, Results, and Interpretation:

Fire has been a key ecological process shaping ecosystems for millions of years, influencing the evolution of plant traits[1,2], vegetative community assemblage[3,4], and biogeochemical cycles[5]. Throughout the Quaternary, sources of ignition have included lightning, volcanic activity, occasional meteor strikes, and human activity[2]. In forested biomes with a long history of fire activity, reconstructing historical fire regimes can show how climate and human activity have influenced forest composition and resilience, providing critical information that can be used to develop new management strategies and buffer forests from the negative effects of altered fire regimes due to climate change and increased human activity. One proxy for reconstructing fire history is sediment charcoal, which quantifies charred vegetation preserved in sediment layers[6]. In this study, we compared sediment charcoal records from a pond (Witch Hole Pond; WIHO21) and a collection of small hollows in Acadia National Park (ANP; Fig. 1) with local logging records. When we paired the charcoal records with historical logging records, we found the fire history of MDI is complex, reflecting both natural fire events, particularly before 6,000 BP, and anthropogenic fire regimes in the mid-to-late Holocene. The logging records allowed us to tie fire intensity to charcoal morphotype assemblage. After this 'calibration' with logging records, we saw that the pond record was reflecting the same morphotypes as small, slash pile fires, rather than the morphotypes associated with fires in areas that were not logged and likely burned due to lightning strikes.

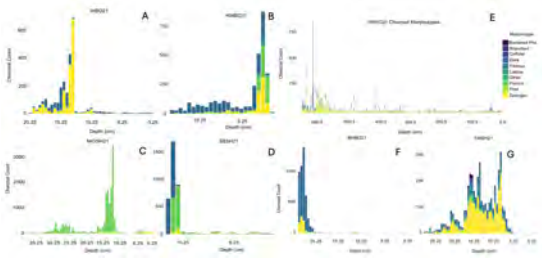

Fig. 1. Charcoal morphotypes from a) Isle au Haut, b) Kebo Mountain, c) Man o' War Brook Trail, d) Schoodic Head, e) Witch Hole Pond, f) Blueberry Hill, g) Flying Mountain.

This indicates that anthropogenic, rather than lightning-ignited fires occurred around WIHO21. Our findings emphasize the importance of interpreting these records within a broader multisite and historical context. Rather than disregarding small hollow records due to their challenges, they should be integrated with lake cores and other long-term records to reconstruct fire history.

Acknowledgements: Thanks to ANP. *Funding:* NSF GRF, Churchill Exploration, CSD, GSA, and GSG.

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Spatial Distribution of Trace Metal Chemistry in Saline Surface Water in West Greenland

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Abstract: This study presents a geochemical characterization of marine waters sampled across a latitudinal gradient spanning approximately 66.95° to 69.22° N and longitudes from 54° to 50.4° W. The dataset describes the spatial distribution of trace elements (e.g., Li, Rb, Sr, Zr, Mo, Cd, Ba, and a range of rare earth elements).

This study contributes to the establishment of a baseline of water quality in the coastal surface waters of western Greenland through the recovery and analysis of trace and heavy metals in coastal surface water across a broad spatial array from Sisimiut, Greenland, to just North of Disko Bay, Greenland (Figure 1).

Trace metals are integral to numerous biogeochemical processes within marine environments. However, their inherent toxicity and, in some cases, radioactivity can pose risks to both ecosystems and human health. Consequently, it is crucial to thoroughly understand the mechanisms that regulate these metals' cycling, distribution, and ultimate fate to maintain a healthy marine environment (Taufiqurrahman et al., 2022).

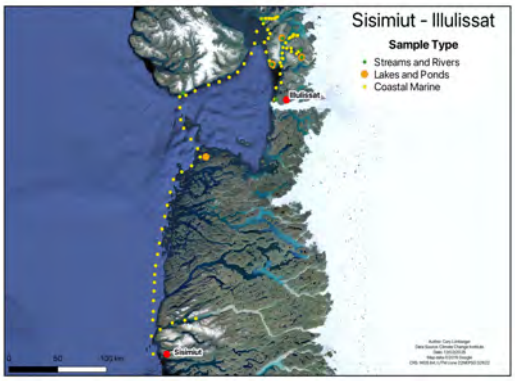

Fig. 1. Overview of sampling location using QGIS.

We collected and analyzed 165 surface water samples, including 103 seawater samples, 43 streams/rivers samples, and 19 lakes/ponds samples. Analysis included the chemical composition of surface water for major soluble ions, major/trace/rare elements, stable water isotopes (δ18O and δD), Conductivity, Salinity, and Temperature.

Internationally, numeric health standards for marine waters have been set for four trace elements: Copper, Cadmium, Chromium, Lead, and Iron.

Preliminary results from the coastal samples in this study indicate elevated concentrations of Cu throughout the spatial array as compared to health standards in Canada (2.9 µg/L), the USA (3.1 – 4.8 µg/L), and Australia/New Zealand (1.3 µg/L). Copper concentrations in the sample region ranged between 14 and 122 µg/L, and the region averaged 21 µg/L (Figure 2).

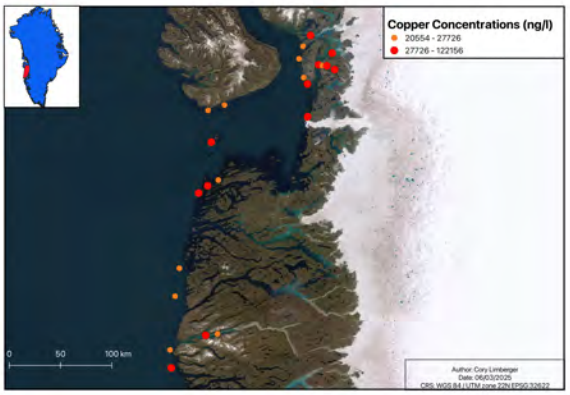

Fig. 2. Display of copper concentrations (ng/l) greater than the interquartile range of all Cu concentration values using QGIS

Acknowledgments: Thank you to Ms. Elizabeth Crowley and the NSF NRT-NNA System Approaches to Understanding and Navigating the New Arctic (SAUNNA) program (PI Saros) and Arctic/Earth Crew Magnus and Julia.

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Spatial and Temporal Variability in Density and Liquid Water Content in Wet Firn on Juneau Icefield, Alaska

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Abstract: **Sub-seasonal variability in density and liquid water content (LWC) in wet firn is not well understood. To determine the magnitude and effect of this variability, we collected repeated surveys of wet firn on Juneau Icefield, Alaska using common-offset ground-penetrating radar (GPR). Results demonstrate high temporal variability in LWC.**

Alaskan mountain glaciers are currently experiencing mass loss and contributing to sea-level rise at high rates compared to other alpine glaciers.[2] The capacity of firn to store meltwater buffers contributions to sea-level rise through short- or long-term water storage and refreezing. [1] Liquid water content (LWC) and density impact and, at times, reduce the meltwater storage capacity of wet firn. By 2100, the Greenland & Antarctic Ice Sheets are expected to see increased firn LWC.[3] The accuracy of non-destructive observations of (wet) firn using ground-penetrating radar (GPR) depends on our ability to constrain LWC and density, as crucial conversions from two-way travel time are affected by these parameters. This work seeks to quantify the variability of density and LWC in firn on Juneau Icefield (JIF).

Methods and Results. In June 2024, we collected 250 km of 400 MHz common-offset radar, 125 km of 500 MHz multi-offset radar, repeated firn cores measuring density and relative permittivity, and wide-angle reflection and refraction surveys at firn core sites to quantify how liquid water content and density vary across JIF. These results focus on the 400 MHz data.

Preliminary results of repeated 400 MHz common-offset data analysis over repeated glacier centerline transects across the study site indicate differential ablation and variable liquid water content in the subsurface (Figure 1).

Future work includes processing and analyzing the remaining 400 MHz common-offset data and 500 MHz multi-offset data and comparing these results of LWC and density to our ground-truth methods of firn cores and wide-angle reflection and refraction surveys.

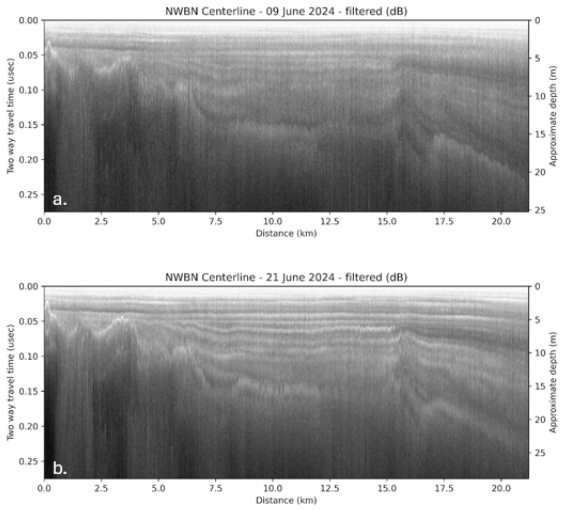

Fig. 1. (a) First and (b) third 400 MHz GPR surveys of Northern-Northwest Branch from 09 June and 21 June, respectively. The increasing layer definition with time is an indication of a change in the liquid water content.

Acknowledgements: This research was supported by NSF Award #2239668. This extensive data collection was made possible through the work and with the expertise of Tate Meehan, Keegan Bellamy, Annika Horlings, Juliana Reuf, and Bradley Markle. This research was conducted on the territory of Áak'w Kwáan on Lingít Aaní.

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[2] Forster et al., "Extensive liquid meltwater storage in firn within the Greenland ice sheet," 95.
[3]The Firn Symposium Team, "Firn on Ice Sheets," 5.

At Macroecological Scales and Across Coarse Climate Gradients the Realized Climatic Niche of U.S. Trees is Conserved Across Life History

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Abstract: Describing the role of climate as a biogeographic control on species distributions has important relevance to how we understand and accurately define species' ecological niches. Most efforts to estimate the climatic component of the ecological niche rely on information gleaned from adult or age-unspecified distribution data, ignoring the possibility that species might maintain different climate tolerances across life history. Here, we test whether juvenile and adult climatic niches differ at biogeographic scales, across coarse climate gradients. We estimate and compare the realized climatic niche of 215 U.S. tree species partitioned into their distinct life-history stages. We evaluate within-species niche differences between life stages to assess climatic niche shifts as changes in niche centers, changes in niche breadths, and changes in niche boundaries. We summarize this data across all 215 species and find little difference in species' life-stage-partitioned climatic niches. We interpret these results as indicating stability in the realized climatic niche of trees across life history.

Understanding and interpreting how species are influenced by and interact with their environments defines an active area of research, within which the ecological niche is an important organizing concept.[1,2] However, the complete bounds of the ecological niche are often elusive and difficult to define. An aspect of the niche that is readily measurable in a multi-species context is the *realized climatic niche*, which describes the set of climate conditions in which a species can and does survive.[1] Accurately defining the realized climatic niche has important predictive and applied relevance.

Potentially compromising this accuracy, however, is the notion that species might experience different climate tolerances as they mature from juveniles into adults. If true, life-history differences should be considered when mapping, interpreting, and applying the niche. Acknowledging this, Grubb (1977)[3] suggests that species have a *regeneration niche* which is expected to differ from and be subset within their *adult survival niche*.

Here, we build on and broaden Grubb's idea by presenting a quantitative, macroecological-scale test of the regeneration niche in a multi-species context. To do this, we estimate the realized climatic niche of the seedling, sapling, and adult life stages of 215 U.S. trees using tree occurrence data from the Forest Inventory and Analysis (FIA) database and climate data from the PRISM database. We evaluate within-species differences in niche centers, breadths, and boundaries. We summarize within-species trends among species to detect broader patterns.

At macroecological scales, as measured along three distinct climatic niche axis, niche centers (see Fig. 1) and breadths remain largely consistent between seedlings, saplings, and adults of the same species. Niche boundaries demonstrate broadly similar patterns. These findings suggest that, at this scale, the realized climatic niche of trees remains relatively stable across life history, a result which is broadly inconsistent with predominant theoretical expectations.

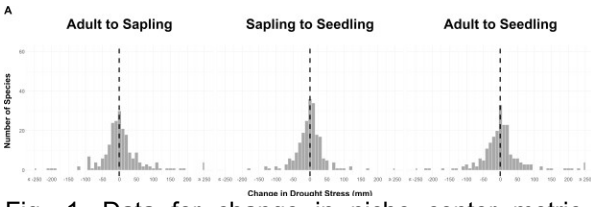

Fig. 1. Data for change in niche center metric along 'drought stress' climatic niche axis.

Acknowledgements: Research supported by NSF, UMaine SBE, and UMaine MAEFES.

Bibliography: [1] Hutchinson 1957; [2] MacArthur 1972; [3] Grubb 1977

Why the "Finance COP" in Baku Missed the Mark

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Abstract: **COP29 was focused on scale but not enough on the how and what of climate finance.**

Last year's UN climate negotiations in Baku, Azerbaijan, were billed as the finance COP, with the hope that states would agree to a new and more ambitious way of funding climate actions around the world.

The delegates at COP29 were tasked to agree to the New Collective Quantified Goal on Climate Finance (NCQG) as an update to the Paris Agreement's target of $100 billion per year. However, states failed to meet the $100 billion goal since, with the exception of 2022.

Discussions were narrowly focused on the size of funding commitments—or the "quantum," as negotiators like to say. The G77 and China started this COP by demanding $1.3 trillion each year to address the needs of climate mitigation, adaptation, and loss and damages. Donor countries balked at this number, instead suggesting $250 billion per year by 2035. The hotly contested, final agreement set at least $300 billion per year by 2035 from developed countries and calls on "all actors" to work together to scale up the financing to developing countries to $1.3 trillion by 2035. But this focus on scale obscures harder questions about the winners and losers within that funding—and what is left out.

Mitigation Versus Adaptation: In 2022, the ratio of North-South climate finance for mitigation versus adaptation was about 70:30. It is a political choice to prioritize mitigation over adaptation: Global North countries care more about mitigation (reducing emission), while the Global South often pushes for adaptation (dealing with current impacts of climate change). The Baku Pact does not specify if the $300 billion is for mitigation or adaptation—rather it affirms that finance should strike a "balance between adaptation and mitigation." But balance does not mean equal.

Public Versus Private: Another big question was the type of funding: Public finance includes government funding through public and multilateral institutions, while private finance comes from private banks or foreign direct investment and comes with different types of strings. Again, the final agreement from Baku went general, stating that the $300 billion goal should be "from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources." This means that some countries will count private funding for their contributions to the goal.

Grants Versus Loans: Countries also are worried about the balance of grants versus loans. The Baku Pact nods toward this debate by urging MDBs to "eliminate conditionalities for access" and invites financial institutions to use a range of tools including "non-debt-inducing instruments." One of the weakest parts of the text merely suggests "considering shifting their risk appetites" and "considering scaling up highly concessional finance." This is why developing countries were outraged by the Baku Pact: instead of concrete commits for public grant-based funding, the text waves at every kind of financial tool with a relatively modest "quantum."

The legacy of Baku might be that the scale of the climate finance increases, but it will not resolve these thornier questions which are ultimately about climate justice and global inequality.

Acknowledgements: This research was generously supported by the Climate Change Institute, the School for Policy and International Affairs.

A version of this article was published by the Carnegie Endowment for International Peace: https://carnegieendowment.org/posts/2025/01/cop29-climate-finance-scale-logistics.

Evidence of a Late Glacial Readvance in North-Central Maine

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Abstract: The termination of the last ice age (17.8-11.7 ka) is the closest geologic analog to modern climate change, and provides a unique opportunity to examine how the global climate system responds to abrupt warming. Extreme seasonality, or unequal temperature changes in summer and winter, may have played a key role in the abrupt climate changes during the termination. Here, we use the glacial-geologic record to investigate whether extreme seasonality affected the North Atlantic region during the termination. Specifically, we examine changes in the extent of the Maine Ice Cap using ^{10}Be exposure ages of a newly discovered moraine sequence in northern Maine, in the lowlands below Katahdin.

Termination 1 (~17.8 – 11.5 ka) marks the most recent analog for our planet's current rapidly warming temperatures. During this time, the last ice age came to a close and temperatures rapidly warmed. However, this warming was not gradual, and Termination I was characterized by abrupt climatic fluctuations during the late glacial period, including the Bølling-Allerød in the Northern Hemisphere and the simultaneous Antarctic Cold Reversal in the Southern Hemisphere (BA and ACR; 14.7 – 12.9 ka). The leading explanation for these fluxes was that climate was anti-phased between the hemispheres due to a 'bipolar seesaw' (Broecker, 1998). However, recent data from alpine glaciers around the North Atlantic region cast doubt on this hypothesis and instead suggest that the hemispheres may have behaved synchronously during these abrupt changes. In 2005, Denton et al., proposed that one possible reason for this discrepancy between records is extreme differences in seasonal temperature.

New LiDAR released in 2019 exposed a previously unknown moraine complex just south of Katahdin (Fig. 1). One radiocarbon age from a nearby pond suggests that this landform may have formed during the BA/ACR. To determine if this moraine did form during the BA/ACR, I collected samples from boulders along the moraine for cosmogenic ^{10}Be exposure dating. Together, the samples have yielded an average age of 14.6 ± 0.4 ka, indicating deposition during the beginning of the BA/ACR. This age resembles those found in the southern hemisphere, suggesting that the Maine Ice Cap advanced synchronously with glaciers in the southern hemisphere. These data add to emerging evidence suggesting globally synchronous climate and eliminating the need for a bipolar seesaw during the late glacial.

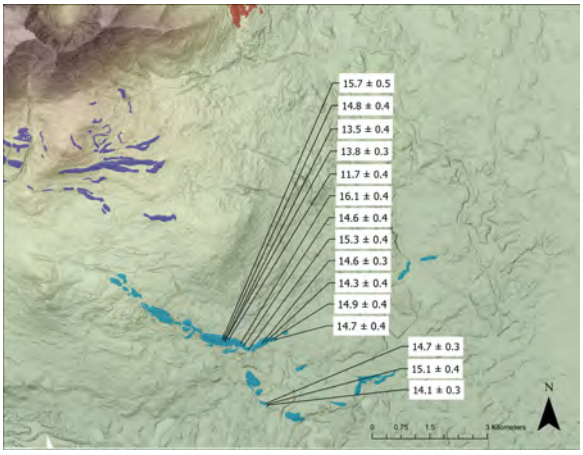

Fig. 1. Newly discovered moraine complex (blue), southern Baxter State Park. ^{10}Be exposure ages indicate deposition at beginning of the BA/ACR (14.7 - 12.9 ka) with an average age of 14.6 ± 0.4 ka .

Acknowledgements: Thank you to the Dan & Betty Churchill Exploration Fund and the Robert and Judith Sturgis Family Foundation for funding this research.

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Polluter Pays and Climate Superfund Law

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Abstract: The Polluter Pays Principle has been a central tenet of environmental policy since the 1970s. However, the principle has only recently been invoked in U.S. climate lawmaking. In 2024, Vermont and New York became the first states to enact laws imposing liability for climate change harms on fossil fuel producers, invoking the Polluter Pays Principle as they did so. As other states look on, the operationalization of these news laws, particularly how they will assess and apportion damages, warrants attention. This paper will take a first look at the different approaches.

The Polluter Pays Principle

The Polluter Pays Principle was first adopted by the Organization for Economic Cooperation and Development (OECD) in 1972 as one of its "Guiding Principles Concerning the International Economic Aspects of Environmental Policies." At its initial inception, it called for the internalization of costs of pollution control. Over time, OECD has clarified that the covered costs can include "preventive measures, restoration, or a combination of both." The OECD has recognized pollution fees as an acceptable economic means of implementing the Polluter Pays Principle. Vermont and New York statutes thus can be understood as imposing fees on climate polluters in the amount of restoration (or adaptation) costs.

Who are the climate polluters?

In 2014, Richard Heede published a groundbreaking study tracing two-thirds of cumulative greenhouse gas emissions from the Industrial Revolution forward to the largest ninety fossil fuel and cement producers. The 2017 Carbon Majors Report updated the findings, tracing over half of global industrial greenhouse gas emissions since 1988 to just twenty-five producers, and over seventy percent of emissions to one hundred producers. Another study from 2017 found that emissions from the ninety carbon majors accounted for between 42–50% of the rise in global mean surface temperature and 26–32% of the rise in global sea level since 1880.

Both Vermont and New York law build on the foundation laid by this research, holding fossil fuel producers responsible for costs of climate change. New York's law even includes a formula for calculating the metric tons of CO_2 equivalent emissions attributable to a responsible party per million pounds of coal, barrels of oil, or cubic feet of natural gas extracted.

What should they pay?

In order to determine the amount of individual payments these climate superfund laws need to assess costs to their state *and* need to determine how to apportion those costs among "potentially responsible parties" (PRP). The basic equation looks like this:

$$\frac{Demand\ to\ PRP}{Cost\ to\ VT\ of\ GHG\ emissions} = \frac{PRP's\ share\ of\ GHG\ emissions}{Total\ GHG\ emissions}$$

$$\frac{Demand\ to\ PRP}{Cost\ to\ VT\ of\ GHG\ emissions} = \frac{PRP's\ share\ of\ GHG\ emissions}{Total\ GHG\ emissions}$$

Vermont law tasks the state treasurer with assessing the total costs to the state (i.e. the left-side denominator). New York law simply sets that figure at $75 billion. Both state laws then rely on the aforementioned attribution science (and prescribed formulas) to determine share of emissions attributable to each PRP, which allows the equation to be solved for the missing variable (the amount of each payment).

Bibliography: OECD, *Recommendation of the Council on Guiding Principles Concerning International Economic Aspects of Environmental Policies.* 10 V.S.A. § 24A 2024 N.Y. Laws, ch. 679

Widespread Presence of Short-Chain PFAS in Greenland

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2. *Greenland Institute of Natural Resources, Nuuk, Greenland.*
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Abstract: Reconnaissance sampling to evaluate the spatial distribution of PFAS in surface waters from South and West Greenland and surface snow from the Greenland Ice Sheet.

Per- and polyfluoroalkyl substances (PFAS) are synthetic fluorinated chemicals widely recognized as persistent contaminants due to their resistance to degradation and potential adverse impacts on human and environmental health. Their resilience has contributed to their global distribution, including in the Arctic. In Greenland, PFAS contamination has been reported in terrestrial biota from East and West Greenland. PFAS levels have also been measured in humans, revealing a linkage between high PFAS concentrations and food intake of traditional Greenlandic food, particularly marine mammals (Muir et al., 2019).

Several mechanisms have been proposed for the long-range transport of PFAS to the Arctic, including ocean currents, marine aerosols, and atmospheric transport of volatile precursors followed by oxidation and subsequent deposition. Volatile precursors include fluorotelomer alcohols (FTOHs) and chlorofluorocarbon (CFC) replacement compounds. By targeting 25 different PFAS analytes, the primary aim of this study is to examine surface water bodies (such as glacier meltwater streams, rivers, and lakes) in the coastal regions (Box a and b – Fig. 1) and surface snow in the Greenland Ice Sheet (GrIS) as quantitative indicators of atmospheric and local sources of PFAS in Greenland.

In total, 45 samples were collected in 2022 and 2024, with PFAS detected in 32 samples. In coastal areas, three PFAS were identified: PFBA (mean: 0.51–3.99 ng/L), PFPeA (mean: 0.517–3.51 ng/L), and PFNA (mean: 0.75 pg/L). On the GrIS, PFBA (mean: 1.05–3.52 ng/L), PFHxA (mean: 0.51–0.53 ng/L), and PFHpA (mean: 0.56–0.86 ng/L) were detected. PFBA was the most frequently found PFAS, present in 24 out of 34 GrIS samples. Results suggest atmospheric sources of PFAS, with deposition strongly correlated to precipitation patterns in the GrIS, likely due to scavenging by snow and rain. To our knowledge, this reconnaissance study represents the first large-scale spatial assessment of PFAS in Greenland.

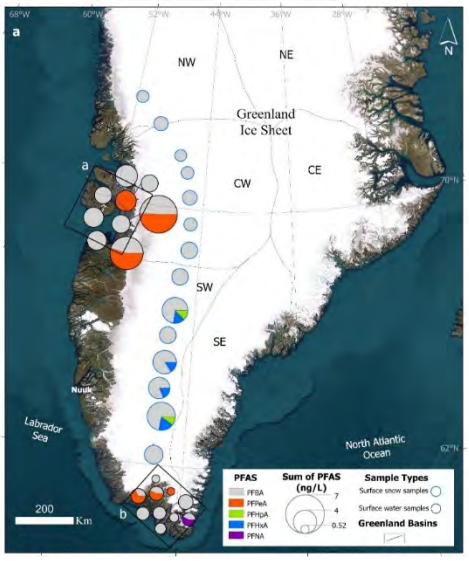

Fig. 1: Map displays PFAS sampling sites. Box (a) West Greenland area (b) South Greenland area.

Acknowledgments: Elizabeth Crowley, Inuit Windsled, Ramón Larramendi, Arctic Earth (Captains Magnus and Julia).

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Birdsong: Multivocality in Human-Bird Relationships during the Ceramic Period in Wabanaki Homeland: A Case Study at Frazer Point (ME 44-49, ACAD 00110), Schoodic Peninsula, Maine

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Abstract: Despite their potential as a lens to examine past socio-ecological dynamics, birds have been neglected in Northeast North American archaeology. I reassessed the Frazer Point site (ME 44-49) avifaunal assemblage as well as ethnohistoric information to contextualize past human-bird relationships. Results indicate that birds were integrated into many aspects of life and were important figures in ancestral Wabanaki lifeways. This research serves as a model for Acadia National Park to expand research programs using "two-eyed seeing" methodologies.

Despite their potential as a lens to examine past socio-ecological dynamics, birds have been neglected in Northeast North American archaeology. This project establishes the first in-depth socio-environmental baseline regarding birds in regional archaeology by investigating the Ceramic period-aged (2700-500 BP) Frazer Point Site (ME 44-49), located in Acadia National Park, which produced a bird bone flute during excavations in the 1970s (Sanger 1981) (Figure 1).

Fig. 1. Bird bone flute found at the Frazer Point site, Winter Harbor, ME.

By combining a traditional faunal analysis of the avifaunal assemblage at the Frazer Point site (Fig. 2), a survey of ethnohistoric literature, and an attribute analysis of regional bird bone flutes, our results indicate that birds were integrated into many aspects of past lifeways from subsistence to spirituality. Faunal analysis results indicate that a diverse group of birds were harvested which contradicts 20th century ethnographic literature defining Wabanaki hunting taboos. Oral histories and information gleaned from Wabanaki languages reveal the cultural values placed on birds. The highly conserved morphology of bird bone flutes in the region throughout the Archaic and Ceramic periods indicate artistic continuity. The significance of birds in past lifeways is diverse and should not be ignored by archaeologists working in Wabanaki homeland.

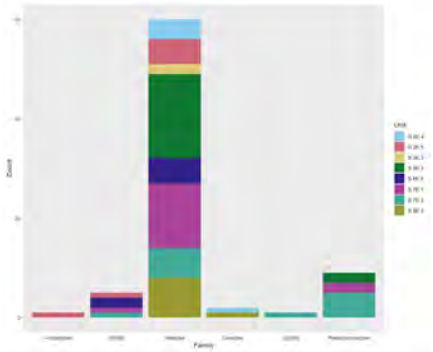

Fig. 2. Number of identified specimens (NISP) by family. The colors correspond to the excavation units.

This research serves as a model for Acadia National Park to expand research programs using "two-eyed seeing" methodologies (Bartlett et al. 2012).

Acknowledgements: Funding for this research was provided by Acadia National Park and the Schoodic Institute.

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Impact of Temperature and Precipitation on Growth and Survival of Tree Seedlings: A Comparative Analysis of Conifer and Deciduous Species

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2. *Climate Change Institute, University of Maine.*
3. *School of Forest Resources, University of Maine.*
4. *Schoodic Institute, Winter Harbor, Maine.*

Abstract: **This study examines the effects of varying temperature and precipitation patterns on tree seedling growth and survival in the Northeast, while considering soil type and planting location. We found that cooler temperatures with less drought stress support the highest survival rates, particularly in large gaps at the forest edge with native soil. Additionally, optimal growth in height and diameter occurred at cooler temperatures, with seedlings in garden soil showing greater relative growth and those in native soil thriving at forest edges. These results highlight the importance of local environmental factors in shaping tree seedling performance under changing climate conditions.**

Project Goals:

To evaluate the effect of varying temperature and precipitation patterns in the Northeast on the growth and survival of tree seedlings, while also considering the influence of soil type and planting location on seedling performance under these changing environmental conditions.

Global climate patterns the have changed significantly will impact forest ecosystems, affecting tree physiology, population dynamics and species distribution (Hatfield and Prueger, 2015). However, the effect may vary across species, with populations in higher latitudes/colder regions potentially benefitting from warming, while those in lower latitudes/warmer regions may suffer (Davis and Shaw 2001). Thus, to understand how individual tree species might respond to changing environmental conditions, we need to assess the impact of climate change across their distributional range.

Results

Our result indicates the highest survival of most tree species at cooler temperatures with less drought stress when planted in large gaps at the forest edge in native soil conditions. We also found that the highest relative and diameter growth of most species occurred at cooler temperatures when planted in the gap of the forest in garden soil and edge of the forest in native soil respectively. The percent of individual that experienced height and diameter decline was found to be highest in warmer sites. Specifically, black cherry, red oak, black oak and chestnut oak exhibited the highest percent individual growth and diameter decline (Figure 1).

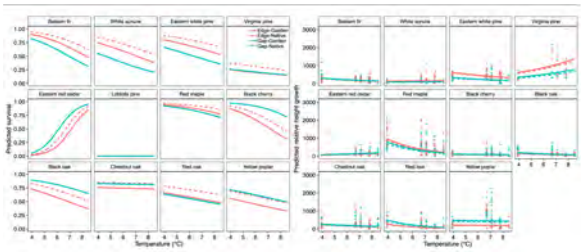

Figure 1. Predicted survival and relative height of tree species based on their growing temperature.

Acknowledgements:

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

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Climate Negotiations and the Finance Imperative: The Role of Small Island Developing States at COP29

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Abstract: At the "Finance COP" in Baku, Azerbaijan, the Parties were tasked with establishing a New Collective Quantified Goal (NCQG) on climate finance and loss and damages. This mini-paper discusses the participation of Small Island Developing States (SIDS) during the finance negotiations as they urged Developed Countries to fulfill their climate finance commitments.

From November 11 to 22, 2024, world leaders, negotiators, delegates, and observers from 196 countries gathered in Baku, Azerbaijan, for the 29th Conference of the Parties to the United Nations Framework Convention on Climate Change, or COP29. During the two week negotiation period, Parties had to set a New Collective Quantified Goal on climate finance. To complete that task, Parties had to decide how much, who would contribute, and what the NCQG would fund. (Earth Negotiations Bulletin, 2024). Developing Countries and Small Island Developing States (SIDS) focused on the first question, calling for an increase from $100 billion per year to trillions of dollars, as well as the third question, advocating to expand the activities the NCQG funds to include loss and damages. Developed Countries, those that contribute to the NCQG, focused on the second question by attempting to increase the number of contributing Parties. (Earth Negotiations Bulletin, 2024). During the opening plenary session, Saint Vincent and the Grenadines representative Carlos James stated:

> "Amidst the colourful diplomatic language of some leaders on this platform, our climate negotiations are disgracefully being held in a metaphoric choke-hold as major historic, and contemporary carbon emitters bob and weave their way out of commitments to reduce carbon emissions and bail-out on climate finance pledges. This is a selfish and unwarranted assault on 65 million people living in SIDS." (2024).

Many other Small island States, as well as their larger negotiating block, Alliance of Small Island States (AOSIS), expressed similar sentiments during their opening statements. Comprised of countries that historically contributed the least to climate change, SIDS face the worst of climate impacts and are particularly vulnerable to extreme weather events. (Gordon-Strachan, 2024). In the final days of COP29, after advocating for a mechanism to compensate SIDS for loss and damages for over three decades, SIDS and other Developing Countries had enough and walked out of the negotiation room. (BBC, 2024). After much coaxing from Developed Countries and the COP Presidency, they returned to the table to finish negotiations, eventually acquiescing to a NCQG of $300 billion per year until 2035 which does not cover loss and damage. (Earth Negotiations Bulletin, 2024).

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

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Research as Heritage Work: A Participatory Action Case Study of Wabanaki Pottery Traditions

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Abstract: This project develops a method for participatory action heritage work, a form of collaborative research that strengthens intergenerational connections while learning about the past. I apply this approach to a case study of social relationality evidenced in ancestral Wabanaki pottery heritage, a crafting tradition that communities are interested in revitalizing today.

Introduction

One of the challenges associated with climate change is the maintenance of intergenerational connection and identity despite alterations to the landscapes and livelihoods that connect community members through a shared sense of place and shared ways of being. For Indigenous communities, this challenge is similar to, and an intensification of, what they have experienced for centuries under settler-colonialism, which has worked to displace, disrupt, and erase Indigenous heritage.

Heritage refers to culturally valued objects and traditions passed down through generations. It is also understood as a social process that, through engagement with tangible and intangible elements of culture, produces a shared sense of identity across generations that imbues these elements with cultural value. Heritage as a process is of interest to archaeologists concerned with identifying and explaining culture change from the material residues of past societies. Yet these same materials must be understood as part of the living heritage of Indigenous communities, mediating social connection into the past and future.

This study develops a method for participatory action research[1] in heritage work, wherein research related to inter-generational connection is developed and implemented with a community so that the research program, both in practice and in knowledge gained, reinforces, restores, and reforges those very connections. I will develop this method through a case study involving pottery traditions among Wabanaki communities, focusing on the archaeological site of Holmes Point West in what is now known as Machias Bay, Maine. Machias Bay is a region of spiritual importance to the Passamaquoddy Nation, which is actively working to sustain and deepen those cultural connections. Members of the Passamaquoddy Nation and other Wabanaki communities are also interested in reconnecting with ancestral pottery traditions, which are evident in the 2500-year archaeological record at Holmes Point West.[2]

Research Goals

In this study I will analyze the pottery assemblage from Holmes Point West to investigate how pottery aided the creation and maintenance of social connections across generations while also answering community questions about pottery production and design to inform revitalization efforts. Although the research design is still in progress, I intend to build the project around multiple community engagement activities incorporating cultural material from Holmes Point West, language, and crafting. One such workshop, planned for July 2025, will bring together Wabanaki crafters interested in revitalizing pottery traditions. Through these kinds of activities, community members will participate in heritage work that connects them to ancestral practices while creating new futures for Wabanaki pottery.

Acknowledgements: Funding provided by the Maine Academic Prominence Initiative, The Honor Society of Phi Kappa Phi, and Lambda Alpha National Anthropology Honor Society.

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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 ^{10}Be 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.

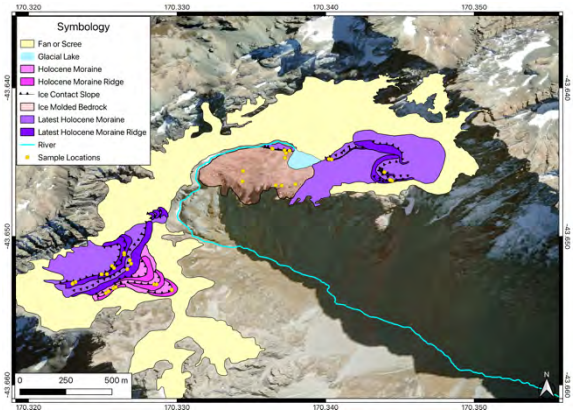

Fig. 1. Geomorphilogical map of young moraines in the cirques of Ailsa Valley; imagery collected from ESRI World Imagery.

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) (Figure 1). 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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Short-Term Impacts of Biochar Soil Amendment Include Increased Carbon Loss

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Abstract: **Amendment of forest soils with biochar has the potential to lower climate-warming atmospheric CO_2 concentrations by increasing long-term carbon sequestration, but a portion of the added carbon is lost back to the atmosphere.**

Introduction:

Biochars, traditionally created by suboxic combustion of plant material and occasionally by chemical oxidation of plant material, have potential to increase long-term carbon storage when applied as soil amendments [1]. Geoengineering practices that remove atmospheric CO_2 and sequester it over long periods of time have potential to decrease climate warming [2]. Here, we investigate the efficacy of using biochar soil amendments to promote long-term carbon storage in forest soils.

Materials & Methods:

In summer, 2024 we amended 128 ea. 10-gallon pots containing homogenized silt loam soil with nothing (control, S0), or with 10% v/v biochar obtained from: a commercial provider (Wakefield, S1), a wood-burning steam generating facility (Clean Maine Carbon, S2), or a cellulosic biofuel production facility (UMaine Forest Biofuels Research Institute, S3). One sapling (*Acer saccharum*, *Picea abies*, *P. glauca*, or *Populus balsamifera*) ranging from 1-3 dm height was planted in each pot to simulate a young forest ecosystem. Two months later, we quantified soil respiration rates in each container using a Licor-6800 portable infrared gas analyzer with soil respiration chamber (6800-09) following established methods [3].

Results & Discussion:

Amendments with biochar significantly increased carbon loss from soil relative to unamended soil ($p < 0.05$), evidenced by increased respiration rates. Notably, respiration rates approximately doubled with charcoal-type biochars and approximately tripled with chemical oxidation-derived biochar (Fig. 1). We present these findings with two major caveats: 1) tillage is widely-known to cause short-term increases In soil respiration, and 2) a mass-balance assessment over a longer time span is needed to contextualize the relevance of these C losses.

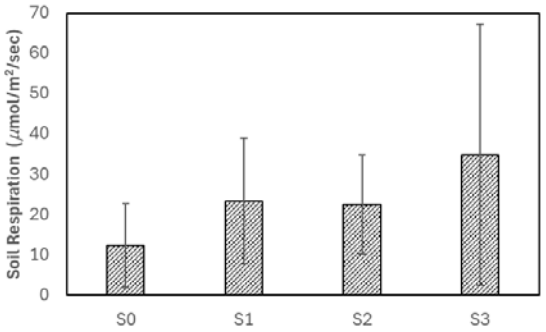

Fig. 1. Soil respiration rates in potted saplings ~2 months after amendment with no biochar (control, S0) or with biochars derived from combustion (S1, S2) or chemical oxidation (S3).

Acknowledgements: This research is supported by the Maine Economic Improvement Fund Small Campus Initiative, the U.S. National Science Foundation EPSCoR program (E-RISE #2416917), and Irving Woodlands, LLC. We are grateful to the undergraduate student interns (Roualdo Wong, Orianna Cort, Nicholas Alpeza) who amended the soil with biochar and collected soil respiration measurements.

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Analyzing Bubbles in Hyperspectral Images of Ice Cores

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3. *University of Maine Presque Isle.*

Abstract: Ice cores preserve long term atmospheric records that are essential for understanding past climate. Air bubbles trapped in ice provide direct samples of ancient atmospheres, but their depth and distribution must be carefully analyzed to ensure accurate interpretations. This study applies hyperspectral imaging techniques to distinguish bubble features in ice cores using transmitted light scans.

Background:

Ice cores contain a vast amount of data that can be used to understand past climates conditions. Air bubbles trapped with ice can offer insight into past accumulation rates and temperatures. The concentration, spatial distribution, size, and orientation of these bubbles have been studied for years. However, traditional imaging techniques for studying bubbles often rely on manual inspection of images from thin sections, which can be subjective and labor-intensive. This research aims to improve method of bubble identification and characterization.

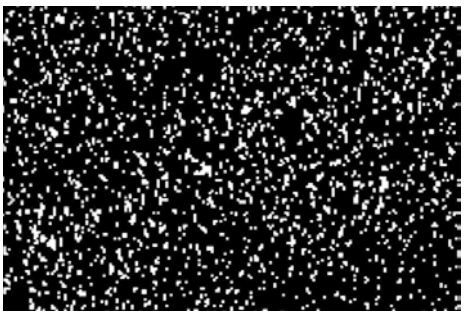

Fig. 1. Binary image of bubbles in ALHIC2302.

Method:

The ICF IceSpec hyperspectral images contain 224 spectral bands or channels. The 96th, 59th, and 16th channels, respectively, correlate to the traditional RGB. To extract information about the bubbles, the hyperspectral images are masked by calculating the background noise and light intensity of each spectral band, and since bubbles reflect more light than the surrounding ice, they can be detected with light intensity thresholds. Based on this threshold, a binary image can be created (see Fig 1), with the white space masked as bubbles, and the black space as ice.

The masked image is further processed, by using a python's "Sci-kit image" library, to calculate the size, orientation, and elongation of each bubble, and the number of bubbles per cm. This information is compiled into a table for ease of interpretation and graphing (see Fig 2).

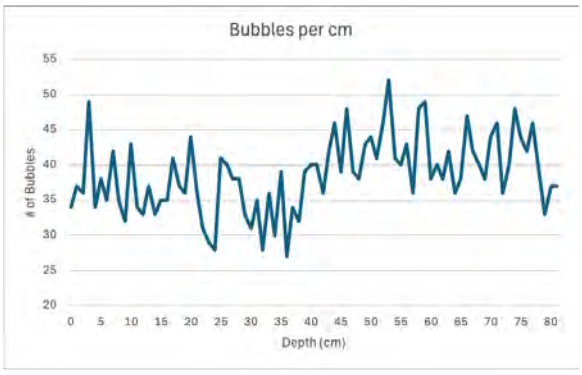

Fig. 2. Graph showing the number of bubbles per cm in ALHIC2302-30.

Acknowledgements: NSF grant 2149519, COLDEX, NSF grant 2019719, ICF Staff, Curt Labombard, Richard Nunn, and Geoff Hargreaves.

Quantifying Changes in Iceberg Response During Extensive Glacier Retreat

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Abstract: Greenland glaciers have undergone rapid acceleration and retreat in the last several decades, including to the transition of glaciers from tidewater to land-terminating. As these glaciers retreat, processes closely linked to the conditions at the ice-ocean interface, such as calving and iceberg production, are also strongly impacted. This change can subsequently modify connected fjord processes such as circulation, stratification, sediment transport, and nutrient availability. While the size, shape, and abundance of icebergs has been physically linked to the glacier conditions that created them, the impact of transitioning tidewater glaciers on iceberg characteristics has yet to be quantified. In this presentation we focus on the transition of Qalerallit Sermiat in South Greenland, over a 71-year period (1953-2023), characterizing changes in iceberg size, abundance, volume, and distribution in Qalerallit Imaa fjord.

Motivation:

Greenland glaciers have undergone a rapid acceleration (doubling to tripling of their speeds) over the last two decades[1], with 35 of Greenland Ice Sheet's tidewater glaciers retreating onto land since the mid-1980s[2].The increasing input of freshwater to the subpolar North Atlantic has significant implications for fjord stratification and circulation. However, the impact of transitioning tidewater glaciers on freshwater input is less clear, as processes governing this transition are largely unknown. Our findings provide a solid foundation for better understanding iceberg response to changes in glacier behavior and aim to improve predictions of future downstream impacts under warming climate conditions.

Approach:

Here we focus on one of the major contributors to freshwater input: icebergs. We utilize a series of remote sensing approaches to quantify the abundance, shape, and size (surface area and volume) of icebergs in Qalerallit Imma fjord, during a >8 km terminus retreat (Fig. 1). We construct this time series of iceberg behavior by utilizing an extensive suite of both remote sensing imagery (historical aerial photographs, Landsat, WorldView, Sentinel-1, SRTM) and data processing methods (machine learning, manual digitization, and SfM photogrammetry).

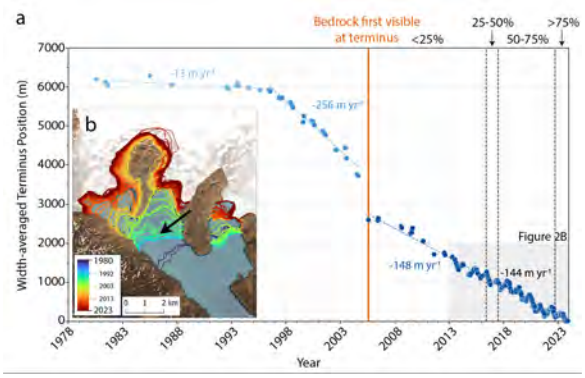

Fig 1. Tidewater glacier retreat of Qallerallit Sermiat[3]

Acknowledgements: Support from NASA NIP award 80NSSC21K0945 and NSF NNA-NRT award 2021713.

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Investigating Microbial Community Composition in Freshwater Systems in West Greenland

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Abstract: Microorganisms are an integral part of biogeochemical processes within freshwater systems in the Arctic, but the variability in those microorganisms is not fully characterized. This study investigates microbial community composition across supraglacial streams, glacial runoff, glacially-fed lakes, and non-glacially-fed lakes in order to understand how relationships between environmental drivers and microbial community composition differ between freshwater systems in West Greenland.

Arctic Lakes: Arctic lakes can be either glacially-fed (GF) or non-glacially-fed (NGF), meaning sourced from snowpack or rainfall.

These lakes vary biogeochemically, one large difference being the level of nitrate, which is found in much higher concentrations in GF lakes when compared to NGF lakes, regardless of the elevation and location of those lakes[1,2,3] (Fig. 1).

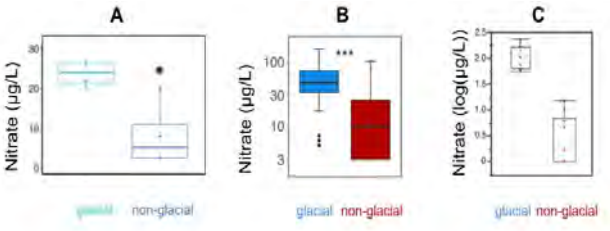

Fig. 1. Total nitrate concentrations in glacial and non-glacial lakes from A) West Greenland[1], B) Glacier National Park, Montana USA[3], and C) Glacier National Park and Beartooth Mountains, Montana USA[2].

Microorganisms: A variety of microorganisms are known to be actively metabolizing nitrate on the surface of the Greenland Ice Sheet[4], but the variability of microbial community composition and metabolism throughout all stages of an Arctic freshwater system is unknown. Additionally, it is not understood if the downstream microbial communities continue to reflect their source or rather, if they gradually become more similar to the communities in neighboring NGF lakes.

Aim: To study the relationships between environmental drivers and microbial community composition in freshwater systems in Greenland (Fig. 2).

Research Questions:

1) How does microbial community composition compare between supraglacial streams, direct glacial meltwater, headwater lakes, and downstream lakes?

2) How does microbial community composition compare between glacially-fed lakes and non-glacially-fed lakes?

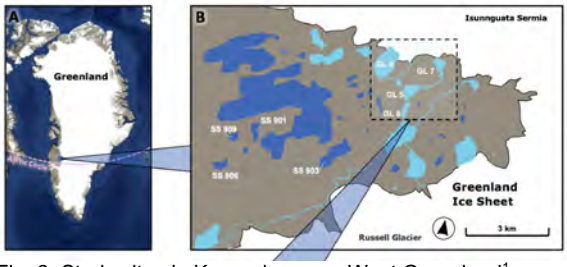

Fig. 2. Study sites in Kangerlussuaq, West Greenland[1].

Expected Outcomes: Microbial community composition will vary in Arctic freshwater systems in response to environmental drivers, such as bedrock type and proximity to glacier.

Broader Impacts: Increased glacial meltwater across the globe is of concern both for ecosystem function and for human health. The results of this study will help inform water management and ecosystem modelling.

Acknowledgements: Funding is provided by the NSF Systems Approaches to Understanding and Navigating the New Arctic National Research Traineeship and the Robert and Judith Sturgis Family Foundation.

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Developing a Full Stokes, 3D Ice Flow Model of the Denali Ice Core Site

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4. *British Antarctic Survey (BAS).*

The Denali ice core offers a long-term climate record of the greater Alaska region; yet, to expand the record to its fullest extent, the age of the bottom-most portion of the core must be determined. Here, we present new efforts to characterize the full age scale of the Denali ice core using a three-dimensional, Full Stokes ice flow model.

Background

Twin surface to bedrock ice cores extracted from the Begguya (Mt. Hunter) in 2013, referred to as the Denali ice cores, have produced a high-resolution hydroclimate history of the greater Alaska region for the last 1200 years[1]. Carbon-14 data now confirm early Holocene-age ice in the bottom 10m of the ~210 m cores, and the full stable isotope records implies late Pleistocene, and possibly Eemian ice near the bed[2]. Still, limitations in dating methods for the deepest, most basal-proximal ice contribute to uncertainty in the stratigraphic continuity of the bottom 10m of ice. Three-dimensional modeling can be used to evaluate the full depth-age profile to improve interpretation of the oldest ice contained within the Denali ice core record.

Methods

A preliminary three-dimensional Full Stokes ice flow model has been developed using the finite-element method in the open-source modeling software Elmer/Ice[3](Figure 1). The geometry for the model is constructed in GMSH using interpolated ice depth measurements from ground-penetrating radar (GPR) data collected in 2022 and surface elevation data extracted from the Arctic DEM. The model first solves for a steady state solution of ice flow by assuming the ice is frozen to the bed with a constant temperature of -18 C. The lateral (outflow) boundary conditions are defined by hydrostatic pressure and an adjustment factor that aligns the horizontal velocity solutions with in-situ surface velocity measurements from 2013[4]. An inverse method is then used to solve for the age of the ice based on the geometry and flow conditions of the steady state solution. Preliminary results of the 3D model reveal ages consistent with discrete age measurements of the Denali ice core in the top ~170 m of the ice. The modeled age profile in the bottom ~30 m, however, deviates from dating horizons acquired from annual layer counting, and carbon-14 dating. Future work will involve refining the 3D model by adjusting the domain, outflow conditions, and accumulation rate.

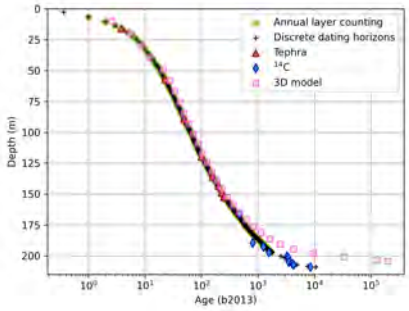

Fig. 1. Preliminary modeled age scale of the Denali ice core.

Acknowledgements: Robert & Judith Sturgis Exploration Fund, Maine Space Grant Consortium, American Alpine Club, University of Maine Graduate Student Government, and NOLS.

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Glacier Retreat and Readvance near Mount Waesche, West Antarctica

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Abstract: **Ground penetrating radar (GPR) performed at Mt. Waesche on the West Antarctic Ice Sheet in 2018 showed evidence of an unconformity that could be the site of the most recent ice retreat and readvance since the last interglacial. A 2024/25 field team performed further GPR surveys and drilled two ~30-meter-long ice cores at the sites of the possible unconformity. Using the radar profiles and stable water isotope analysis of the core samples, we will find the age of the ice at the unconformity and the surface air temperature at that time.**

Background:

Understanding the previous ice extent of the West Antarctic Ice Sheet (WAIS) during past collapse events will inform modeling efforts for future changes in volume and sea level rise (SLR) due to increased warming from anthropogenic climate change. This extent is notoriously hard to extract, however, due to its location beneath the current ice sheet.

In the 2018/2019 field season a reconnaissance mission was completed using ground penetrating radar to find possible sites for bedrock cores. These radar profiles showed englacial unconformities that could represent the low interglacial ice elevation at Mt. Waesche. A second field season was launched for 2024/2025 to verify the site of the previously identified unconformities and drill through those sites of interest. The team successfully drilled two cores totaling 64 meters deep.

Next Steps:

The core samples at this site will be used in comparison with the radar profiles (Figure 1) collected in tandem to constrain the age of the unconformities and estimate the age of the most recent retreat and readvance of WAIS. Core samples are currently in transit from Antarctica, with an estimated arrival of early summer 2025.

The radar data for the Great Wall site (Figure 2) is in pre-processing and shows promising lines for future analysis.

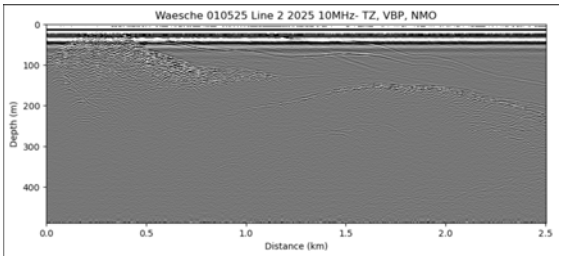

Figure 1. Pre-migration radargram from 10MHz line at Great Wall, Mt. Waesche, West Antarctica.

Figure 2. 10MHz lines at Great Wall, Mt. Waesche, West Antarctica.

Acknowledgements: Funding supported by the National Science Foundation (NSF) Grant number: 2210092. Thank you to the Climate Change Institute and Icy Lab!

Cordillera Darwin Icefield Extent During the Last Termination

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Abstract: The glacial history of the Darwin Icefield, Chile offers insight into the climate shifts of the Southern Hemisphere mid-latitudes over the last 20,000 years. Here we examine glacial features, primarily moraines and erratics, to reconstruct the timing and pattern of ice retreat as a proxy for regional summer temperature. Our well dated moraine complex indicates that deglaciation to the interior of the mountains occurred by 18,000 years ago.

Introduction:

Understanding the climatic drivers of the termination of the last ice age about 20,000 years ago is critical for furthering climate research and building predictive models. The termination serves as a natural experiment to better understand how abrupt shifts in the climate system occur and how it might respond in the future. The timing and magnitude of these shifts associated with deglaciation are important to sort chronologically on both global and regional scales to determine the drivers of climate versus the effects of the termination of the last ice age[1]. This project focuses on the timing, pace, and structure of the last termination in Cordillera Darwin, Chile to evaluate hypotheses for the driver of the termination specific to the southern hemisphere mid-latitudes and, ultimately, to abrupt climate change on a more global scale.

Here, we develop a glacial retreat chronology from exposure age dating of quartz-rich boulders associated with glacial features east of Pía Fjord, Cordillera Darwin. The moraine sequence and associated glacial erratics will serve as an indicator for the timing and pattern of climate change in the region, as glaciers are thought to record primarily changes in summer temperatures[2] over time. These findings will be compared to similar glacial records from New Zealand and more globally to determine possible drivers for the termination of the last ice age and subsequent climate events.

Results:

Field seasons in Spring 2023 and 2024 were conducted to map and collect samples from the deglaciated landscapes of Pía Fjord and the broader region of Tierra del Fuego (Figure 1).

Fig. 1. The surface of boulders on previously glaciated landscape were sampled in the field (Meghan Spoth, left; Maraina Miles, right; Annika Schmidt, photo).

Sites were accessed by boat navigating on the Beagle Channel and then by foot. Mapping was done through a combination of field traverses and drone photography. We sampled 32 rock samples for processing at the UMaine Cosmogenic Exposure Laboratory.

Initial results indicate that glacial retreat had progressed to the interior of the icefield by 18,000 years before present. The multi-moraine complex also tracks the subsequent ice fluctuations until about 13,000 years ago. These results will be compared to the deglacial history of neighboring valleys within our study, along with the climatic events of the Southern Hemisphere.

Acknowledgements: Cordillera Darwin field crew, Ocean Tramp crew, Churchill Exploration Fund, GSG grant, National Science Foundation.

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Investigating Snowpack Thickness Variations in Temperate Regions: Integrating High Accuracy LiDAR Snow Surveys

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Abstract: Measurements of snowpack thickness is a crucial step in reducing uncertainty in temperate snow water equivalent measurements. To better understand the relationship between temperate snowpack depth and terrain characteristics, we collected four high accuracy repeat uncrewed aerial vehicle (UAV) light detection and ranging (LiDAR) surveys in Maine. Future work includes combining methods developed in this project with other simultaneously collected datasets on snowpack in Maine and Southeast Alaska.

Temperate snowpacks are a vital freshwater resource for a large portion of the global population and our attempts at quantifying these water resources still have very high uncertainty because of the spatial variability of snowpack depth, density, and liquid water content within the snow. LiDAR is a proven method for acquiring accurate measurements of snow depth [1] (Figure 1). These types of estimates are crucial for managing freshwater resources around the globe. A good example is snowmelt supplying water from adjacent mountain ranges to Los Angeles, California which has a population of over 3.8 million residents. As the climate warms, temperate snowpacks become increasingly prevalent, therefore understanding how these snowpacks contribute to the hydrologic cycle also becomes more important. This fact is only exacerbated by more erratic climate patterns.

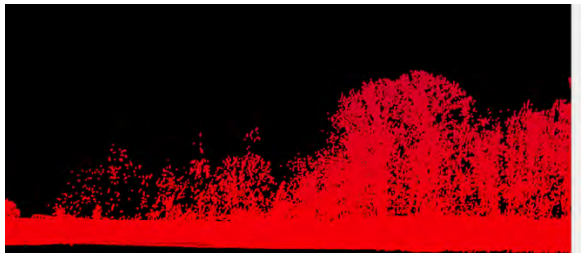

Fig. 1. Example image of a point cloud before any processing in the Routescene software.

Methods: We collected four repeat UAV LiDAR surveys. Three surveys were conducted for three consecutive weeks near what was judged to be peak snow accumulation for the year. One survey was conducted when no snow cover was present. Our study site was located along the University Farm Road in Old Town, Maine. A large portion of this work was developing expertise and methods for working with new equipment and software. We successfully utilized a Routescene LiDAR mapping system onboard a Freefly Systems Alta X to collect these 4 repeat surveys. We are currently in the process of deriving quantitative variations in snowpack thickness across the study region.

Future work: Our goal is to gain a better understanding of snow water equivalent estimates in temperate snowpack. Future work will consist of coupling LiDAR surveys with other data sets such as multi-offset ground penetrating radar, and in situ data such as density and liquid water content measurements. Additionally, there are multiple techniques for increasing LiDAR survey accuracy that have yet to be explored such as calibration flights and updated drone software with Real Time Kinematic Survey geodetic data linked to the drone flight. Lastly, nearly endless possibilities for processing this data remain. One avenue of improvement will be to develop a workflow for obtaining more ground returns through vegetation cover.

Acknowledgements: Funding for this project is through the Maine Space Grant.

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Geochronologic Record of Ice Extent During the Antarctic Cold Reversal at Bahía Penhoat, Chile

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Abstract: **The last ice-age termination (17.8-11.7 ka) is the largest climate change of the last 100,000 years, but the cause of the event is still not understood. Understanding the mechanisms driving the last termination can help us deduce how and why Earth experiences abrupt climate change. The first step towards testing possible driving mechanisms for the last termination is to determine whether it occurred asynchronously or synchronously between the hemispheres. Here, we investigate glacier behavior in the Cordillera Darwin ice field during the Antarctic Cold Reversal to gain insight to its cause. Specifically, we examine glacier fluctuations at Bahía Penhoat, Chile, to compare with other late-glacial records across the Pacific Ocean in New Zealand, and across the Atlantic Ocean, in Norway.**

The Antarctic Cold Reversal (ACR; 12.9-14.7 ka) was identified in Antarctic ice cores and briefly interrupted the last termination with a return to cooler conditions. Historically, this has been considered a southern hemisphere phenomenon, with the northern hemisphere experiencing warming during the simultaneous Bølling-Allerød. It has long been accepted that climate events, such as the ACR, between hemispheres are asynchronous because of a "bipolar seesaw" (Broecker, 1998), which invokes a redistribution of heat through ocean circulation. However, new data from the North Atlantic region calls this apparent asynchrony into question. If, in fact, these new data are correct, then it would imply that there is a global signal for the ACR, and thus whatever mechanism caused it must have had a global reach.

The first step in determining a mechanism for the ACR is to deduce if it is a globally synchronous event. Here, we provide evidence for moraine construction during the ACR at Bahía Penhoat, Chile, through ^{10}Be surface exposure dating (Fig. 1). Exposure ages of erratic boulders and moraines yield and average age of 13.2 ± 0.4 kyr. Based on these data, the age of moraine construction at Cordillera Darwin correlates well with the ages of moraines in western Norway. ^{10}Be exposure ages date the culmination of the ACR in Norway to be 12.8 ± 0.4 kyr (Putnam et al., 2023), which is virtually identical within error to that of Cordillera Darwin. These data support the hypothesis of synchronous behavior of ice masses, and thus climate change, between both hemispheres during the ACR. These data are not consistent with the concept of a bipolar seesaw. Rather, they imply that a global driver is needed to account for climate change during this part of the termination.

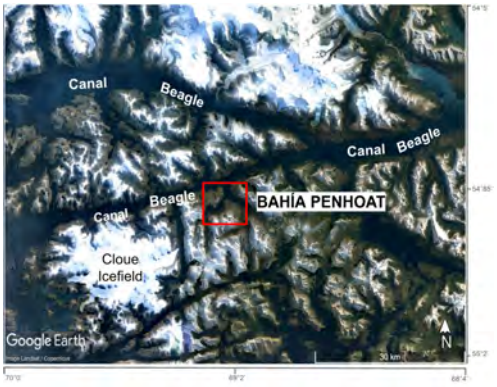

Fig. 1. Map of field area within context of Cordillera Darwin and Cloue Icefield.

Acknowledgements: Cordillera Darwin field crew, Ocean Tramp crew, Dan and Betty Churchill Exploration Fund, UMaine GSG grant, National Science Foundation.

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A Natural Experiment from the Alpine to the Arctic: Evaluating Local Adaptation in Herbarium Specimens Using Spectroscopy

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Abstract: Arctic and alpine ecosystems are threatened due to climate change and human-mediated disturbance. Many alpine plant species of the northeastern United States are also found in the Arctic today, but little is known about local adaptations that might be acquired by Arctic and alpine plants growing across such a large geographic range. We are utilizing herbarium specimens and spectroscopy to better understand plant trait differentiation from the mountains of the northeast, to the Arctic.

Introduction:

Arctic and alpine ecosystems of the northeastern United States and Canada are currently threatened by climate change and human-mediated disturbance[1]. The extent to which these plant communities are threatened depends on how plants adapt, or have adapted, to their changing environments. Many alpine plant species found across the northeastern U.S. and Canada are also found throughout the Arctic, but it remains unclear how individuals of the same species may respond to changes in climate, or photoperiod, across a large geographic range. To better understand how Arctic and alpine species differentiate in their physiological adaptations across geographic space and through time, we utilized spectroscopy techniques to estimate plant traits in herbarium specimens from across alpine and Arctic locations, and across time periods. The use of herbarium specimens in understanding plant traits and distributions is growing in popularity, while the use of spectroscopy to estimate traits in herbarium specimens is a burgeoning methodology, making this research an important frontier (Figure 1).

Results:

We found the utilization of a spectrometer to estimate plant traits was most accurate for species with larger leaves, and for more modern herbarium specimens. We also found that climate and photoperiod are likely to drive differences in plant traits. These methods could be utilized by future researchers to better understand changes in plant traits and physiological adaptations in the face of a changing climate. This research also serves as a natural experiment investigating differences in physiological adaptations in species with a wide geographic range.

Figure 1: Image of a *Diapensia lapponica* herbarium specimen from Maine, an example of a northeastern alpine species that also has an Arctic distribution.

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Acknowledgements:

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

A Pathway to PolarSTEAM: Enhancing Accessibility and Effectiveness of High School Field Curriculum in the Geosciences

Erin Towns[2], Seth Campbell[1,2], Scott Braddock[1,2], Haley Dunleavy[3], Nigel Golden[4], Mari Fromstein[1,2],Tahi Wiggins[1,2], Samantha Baumgartner[1,2], Mathilde Boerch[1,2]

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Abstract: **Educating students about critical changes occurring in polar regions is vital due to the disproportionate impact of environmental change in these areas. Few students in the United States receive comprehensive geoscience and Earth system training at the high school level. In response, summer programming in Juneau Alaska and at Toolik Field Station has been designed to implement a PolarSTEAM (science, technology, engineering, arts, mathematics) field-based curriculum.**

As environmental change disproportionally affects polar regions, educating students about these changes helps raise awareness of broader environmental issues and their global impacts. Unfortunately, less than 25% of high school students in the United States receive Earth system science training and Polar studies represents a very small component of what is taught. Through early engagement with authentic polar research field experiences, students develop scientific literacy, inquiry skills, and familiarity with Polar-related technologies with the goal of encouraging them to consider future careers in PolarSTEAM (science, technology, engineering, arts, and mathematics) fields.

Summer programming in Juneau Alaska, and Toolik Field Station emphasizes the development and implementation of an Arctic Studies curriculum specifically tailored for students enrolled in Upward Bound Programs from Florida, Texas, Washington, Oregon, and Maine. Upward Bound Programs serve as essential partners in recruitment of what will be first generation future college students, prioritizing accessibility for all youth.

Students partake in immersive field experiences alongside graduate students and researchers that allow them to study about climate and ecological shifts in polar regions, and glaciological and permafrost research. This hands-on approach is augmented by the use of innovative technologies such as ground penetrating radar (GPR), drones, LiDAR, photogrammetry and digital photography which serve as essential tools in the collection and analysis of scientific data gathered in polar regions.

To assess the effectiveness of the PolarSTEAM curriculum and summer programs, a robust IRB approved evaluation framework is employed which includes pre and post-tests, student surveys, and qualitative feedback mechanisms.

This comprehensive assessment strategy aims to gauge educational impact of the curriculum on student learning outcomes and the level of interest cultivated in PolarSTEAM fields, particularly among students who may lack access to such educational resources.

Early results indicate a positive shift in understanding and skills acquisition, demonstrating that interactive field-based geoscience curriculum enhances engagement and improves academic confidence among participating students.

Acknowledgements: We thank the University of Alaska Southeast, University of Alaska Fairbanks, and Toolik Field Station for hosting student activities and NSF and Battelle for providing funding for summer programming.

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Possible Teleconnection Between the January 2022 Tonga Eruption and Climate Extremes Observed in 2023

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Abstract: The explosive eruption of Hunga Tonga-Hunga Ha'apai in January 2022 injected an unprecedented amount of water vapor into the stratosphere, increasing the ambient concentration by about 10%. Initial climate impact studies find only minor warming from increased radiative forcing, but the potential for large-scale dynamical response remains poorly understood. Using reanalysis, we identify several unusually large weather and seasonal anomalies in 2022 and 2023 that may be Tonga 'fingerprints'. We hypothesize that Tonga produced global impact by a) nudging the system into a third consecutive year of La Niña in 2022, which led to b) the development of a strong El Niño in 2023; c) temperature and other extremes followed in 2023 as eruption-sourced excess water vapor had spread across both polar hemispheres, trapping heat in the troposphere and weakening atmospheric circulation worldwide.

Methods: ERA5 reanalysis (Hersbach et al. 2020) was used to identify extreme events based on standardized anomalies (σ) for monthly mean temperature, precipitable water (PWtr), wind, and geopotential height. Monthly water vapor vertical profiles were plotted using NASA Aura satellite data (Lambert et al. 2020). Pearson linear correlations were compared for mean sea level pressure and 10m wind speed. Maps and time series plotted using CCI's ClimateReanalyzer.org.

Results: Several extreme events across the globe with record σ values were identified for the 1940-present ERA5 period. Among these are record low PWtr and strong easterly winds in the Bismarck Sea, record cold 30mb temperatures over the Tasman Sea April–October 2022, and strong ridging over western Canada that led to record warmth over the North Atlantic. The vertical profiles show that the Tonga vapor plume reached both poles by mid 2022. Lastly, there is high correlation between the wind speeds east of Bismark Sea and S. Hemisphere westerlies (Fig. 1).

Conclusions: We hypothesize that Tonga-sourced stratospheric temperature anomalies intensified S. Hemisphere circulation, causing SSTs to drop in the equatorial Pacific, maintaining La Niña a third year, which then fueled development of a strong El Niño; in 2023 tropospheric warming was enhanced by Tonga-sourced excess water vapor in the stratosphere.

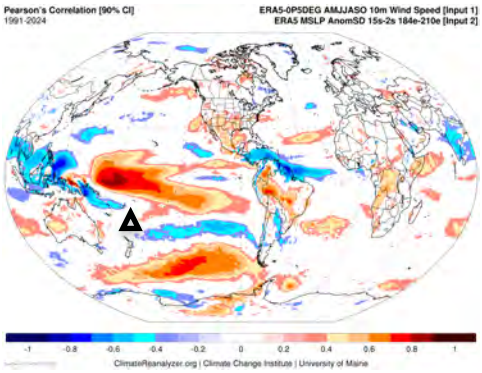

Fig. 1. Pearson linear correlations between mean sea level pressure and 10m wind speed (April–October mean for each year 1991–2024).

Acknowledgements: This project was supported by the SAUNNA NRT (NSF-NNA award 2021713), Maine Climate Science Information Exchange, and STORM (NSF EPSCoR RII Track-2 FEC award 2316399).

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Aligning Circularity and Climate Reduction Goals in Packaging EPR Schemes

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Abstract: While advocates promote circular economy strategies as key to addressing climate change, circularity and sustainability are not always synonymous. Global experts agree packaging Extended Producer Responsibility (EPR) policies should measure recycling rates and incentivize producers to design more recyclable packaging. Yet, recycling rates and landfill diversion alone are not adequate proxies for environmental impacts of packaging; some experts argue we must also report and incentivize climate reductions.

With more than 40% of US GHG emissions stemming from the production, transport, use, and disposal of material goods[1] — circular economy strategies that slow and close resource loops are seen as critical for addressing climate change[2]. To drive circularity, policymakers are turning to EPR schemes that shift the responsibility for end-of-life material management from taxpayers to producers. It is assumed that these policies will motivate producers to design eco-friendly products and packaging[3]. There is little evidence that EPR has driven upstream design change, and policy harmonization across jurisdictions may further weaken design incentives.[4]

Methods

The Delphi Survey is an iterative survey tool used to elicit opinions from experts who are geographically dispersed. It useful for understanding consensus and divergence on a topic and informing decision-making. In Fall 2024, I administered three rounds of questionnaires to a panel of EPR experts actively involved in packaging EPR policies. The questionnaires focused on understanding experts' perspectives on the primary goals, objectives, measures, and producer fee criteria for EPR for packaging programs. Here, I focus on the second survey where participants scored different goals, measures, and fee criteria from extremely important to not at all important on a 5-point Likert scale. Scores are reported as means ± standard deviations.

Results

I received responses from 47 global EPR experts. Beyond shifting management costs to producers, participants rated reducing the environmental impacts of packaging (4.58±0.64) and incentivizing packaging design change (4.5± 0.72) as important goals of EPR. There was less consensus around how to measure and operationalize these goals to reduce environmental impact. Participants saw measuring recycling rates (4.48±0.93) and fees that incentivize designing for recyclability (4.76±0.43) as important elements for packaging EPR. Participants were less aligned on reporting GHG emissions (3.15±1.21) and fees incentivizing reductions in the carbon footprint of packaging materials (3.78±1.18).

Discussion/Conclusion

It appears that recyclability is standing in as a proxy for eco-design in EPR policies. However, recent reports raise questions around the assumption that popular attributes like recyclability, composability, and bio-based are always environmentally beneficial.[5] To ensure EPR does not unintentionally increase climate emissions while driving circularity, some policymakers are integrating Life Cycle Assessments (LCA) into EPR policies to better evaluate environmental impacts of packaging.[6]

Acknowledgements: Dr. Cindy Isenhour

Funding: University of Maine, Chase Distinguished Research Assistantship

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Capturing Temporal and Spatial Dynamics of Diatoms in Crawford Pond, Northern Maine, for Ground-Truthing Stratigraphic Records Involving *Aulacoseira*

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Abstract: **We find distinct seasonality and vertical distribution of *Aulacoseira* species in Crawford Pond, northern Maine. These findings should be taken into consideration when interpreting this genus in stratigraphic records.**

Fossil diatom assemblages are commonly used to reconstruct past environmental conditions. This is made possible by their high species richness, biological sensitivity, and preservation in sediments. However, their use as a proxy relies on accurately documenting the present-day ecological niche of each species, a practice that requires careful taxonomic, temporal, and spatial consideration. Although many studies have focused on the seasonal succession of planktic diatoms in temperate lakes, few have captured the species-level variability of the genus *Aulacoseira* which is often dominant in stratigraphic records[1]. Refining the ecological preferences of this genus is essential to prevent misinterpretations, particularly the oversimplified assumption that its species dynamics are governed by lake mixing[2].

Through biweekly assays of the Crawford Pond (Piscataquis Co., 45°38'N, 69°11'W; 1.4 km^2; 371 m a.s.l.) water column, we were able to show marked seasonal and vertical divergence among species that have differing traits. Namely, the long-chain forming and columnar species, *A. subarctica* and *A. ambigua*, featured the highest density during the spring and fall overturn (Fig. 1A), while the short-chain forming and low mantle *A. pusilla* were recorded during overturning and peak stratified conditions (Fig. 1B). Also, the depths occupied by populations of the latter species differed between early summer and late summer-fall. We hypothesize that metalimnion currents may influence the distribution of *A. pusilla* by providing suitable light, nutrient availability, and suspension within the water column (Fig. 1D). We also recorded the seasonal succession of other relevant taxa that will aid the stratigraphic analysis at this site (Fig. 1C).

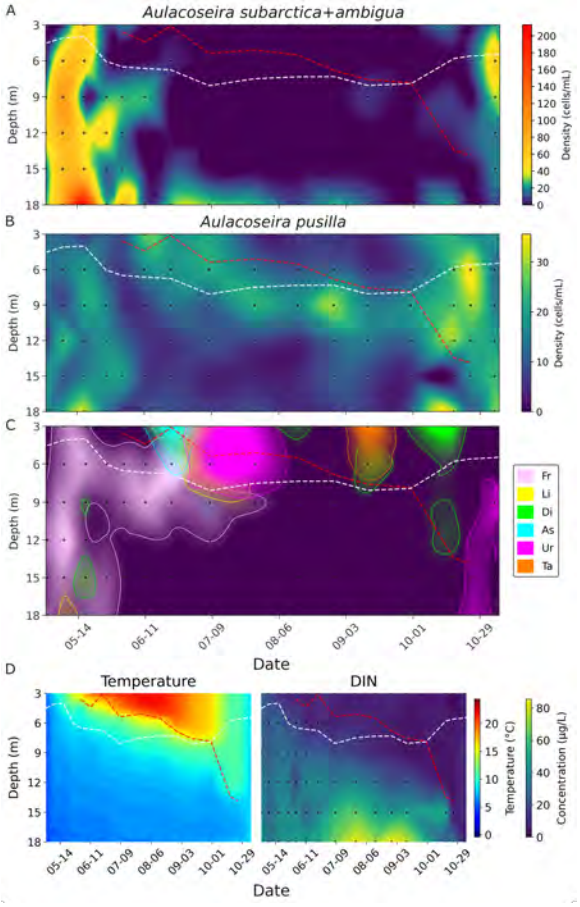

Fig. 1. Water column heat maps of lake variables. (A), (B), and (C) show diatom density modelled by each date-depth measured (black dots). (C) shows species according to color. Fr: *Fragilaria,* Li: *Lindavia*, Di: *Discostella*, As: *Asterionella*, Ur: *Urosolenia*, Ta: *Tabellaria.* (D) shows temperature and dissolved inorganic nitrogen (DIN) profiles. In all plots, white lines indicate 1% photosynthetically active radiation (PAR) depth and red lines indicate the thermocline depth.

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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 punctuated the last glacial-to-interglacial transition in both polar hemispheres remains unsolved. This reversal produced a well-preserved moraine system in western Norway and in the Southern Alps of New Zealand. Tests of various hypotheses for the climate reversal require a detailed chronology of mountain glacier position in each hemisphere throughout the late glacial phase. Preliminary data from Lysefjord Norway suggest moraine construction culminating at 13.1 ± 0.7 k yrs ago. Published data from the Birch Hill Moraines of New Zealand show construction culminating at 13.0 ± 0.3 k yrs (Putnam et al., 2023). This data suggests hemispheric synchrony during the Antarctic Cold Reversal and calls for a global driver of the late glacial millennial scale climate change.**

During the late glacial phase of the most recent ice age, after extensive recession, glaciers readvanced or paused several times. These fluctuations produced prominent moraine belts inside of Last Glacial Maximum moraines, and can be seen in many places throughout the planet. One of these places is at the mouth of Lysefjord in southwestern Norway. These moraines are associated with a cold reversal that occurred between warming intervals of the termination. Determining the timing of their deposition is critical for understanding the mechanism that produced such a cold reversal.

Surface exposure dating of glacial geomorphological features produced during deglaciation is a reliable method to inform this debate. Precise dating of moraines can provide a time when summer temperatures in the northern hemisphere were cool enough to allow glacial stability and/or advance. Glacial erratics provide dates corresponding to periods of glacier instability, and at a minimum, show the position of the glacier margin. Moraine construction in Lysefjord during the B-A would indicate that northern hemisphere glaciers were advancing in sync with the southern hemisphere.

Progress to date is summarized in Figure 1. The mean age of the complex (excluding the outer erratics) is 13,161 ± 661. The 3 outboard erratics yielded an average age of 15,363 ± 319. The outermost moraine dated to 13,570 ± 422 years. The innermost moraine and inner erratics are indistinguishable within uncertainty, with the average age being 12,751 ± 313 years old. The two samples from the middle moraine appear to be out of stratigraphic order. However, more data will later inform the interpretation of these.

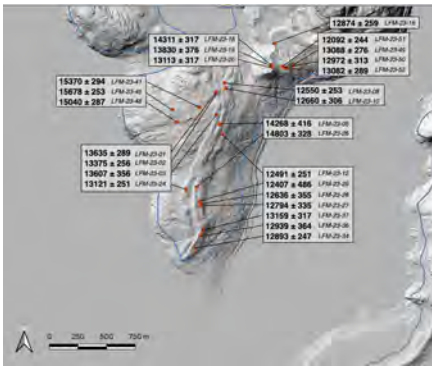

Fig. 1. LiDAR of moraines in Lysefjord Mouth, Norway overlain with ages of boulders.

Putnam et al., 2023 found that geomorphologically similar moraines in New Zealand were constructed at 13.0 ± 0.3 k yrs ago. Within uncertainty, the two hemispheres appear to have the same behavior. This calls for a global driver of late glacial millennial scale climate change.

Acknowledgements: Thank you to the Comer Family Foundation and Peter Quesada for financial support in this project. Thank you also to Tricia Collins for efforts during the field campaign.

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Surface water dynamics at Echo Glacier, Lingít Aaní

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Abstract: **The presence, movement, and storage of liquid water, despite its documented importance to glacier systems, remains poorly constrained. Here, we present field-based, geophysical, and remote sensing datasets of surface water dynamics at a temperate glacier in southeast Alaska.**

Motivation. Water is a crucial component of glacial systems, with effects on ice velocity, glacier ablation, and downstream discharge. The mechanisms of water storage in glaciers—magnitude, duration, and location—are poorly constrained. Much temperate glacier runoff derives from surface meltwater, which in turn influences en- and subglacial hydrological systems.[1] Therefore, observations of glacier surface water dynamics improve our overall understanding of temperate glacier systems, which is vital as glaciers respond climate change. Echo Glacier provides an ideal location to perform these observations: it is well-bounded by accessible bedrock outcrops, does not receive any mass from tributaries, and has a series of supraglacial lakes that fill and drain each summer.

Methods. During summer 2024, we gathered a range of *in situ* records, including lake level, surface velocity, and time-lapse camera (TLC) imagery. Ground-penetrating radar (GPR) surveys supplement these surface observations with data from the subsurface. Additionally, we recorded surface change during four deployments of a terrestrial radar interferometer (TRI) (Fig. 1). Our intensive field observations are complemented and contextualized a 10-year record of supraglacial lake area, drainage onset, glacier velocity (from remote sensing), temperature, and precipitation (from AWS).

Results. TLCs and pressure transducers (PTs) recorded coincident drainage of three lakes on 5 July, but the methods we employed did not detect a discernible velocity response to this event. GPR surveys indicate consistent presence of a high, thickness-variable water table across the glacier. Preliminarily processed TRI datasets possibly record surface lowering (ablation) and change in pixel coherence with melt. Lake area displays interannual variability, with the main control on lake size seeming to be its persistence into the melt season. Years with anomalously large lakes correspond not to any similar anomalies in temperature or precipitation, but rather when lake drainage occurred.

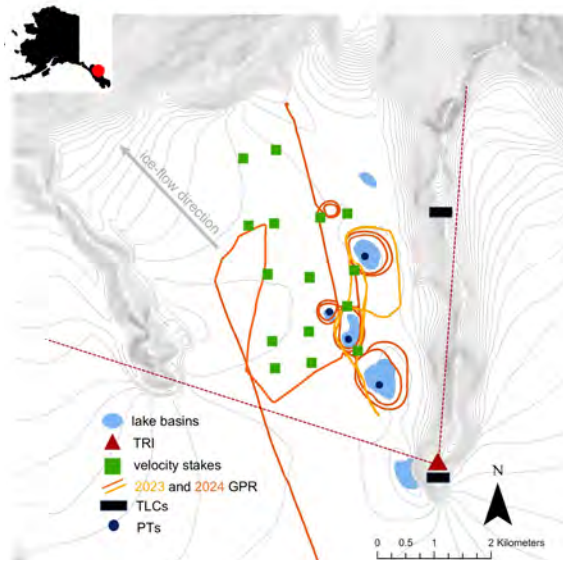

Figure 1. Field-based datasets at Echo Glacier. Dashed line indicates coverage of TRI surveys. Basemap is 10m ArcticDEM contours.

Acknowledgements: This work is supported by the NSF/NRT-NNA #20211713 and the Cold Regions Research and Engineering Laboratory. R. Clavette and K. Mannello collected GPR data. R. Cassotto provided TRI processing advice. Research takes place on the unceded land of the Taku River Tlingit First Nation.

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Green Heritage and the Built Environment: Recognizing and Protecting Local Distinctiveness in a Mediterranean Urban Setting

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Abstract: Urban sprawl in the Mediterranean commonly overlies the ancient agricultural landscapes that once supported the city. Documenting these legacies of green heritage may contribute to both urban resilience and to a city's culturally and historically distinctive landscape.

In the Mediterranean, many ancient cities reflect rapid urban expansion into the modern era, often replacing what has traditionally been a mosaic of green spaces within a homogenized landcover of industrial, commercial, and residential spaces (Salvati and Gargiulo Morelli 2014; Zaro et al. 2023). Although unrecognized by local residents and visitors alike, legacies of this "green heritage" are still reflected in scattered field plots, unkept green spaces, and even within the complex arrangement of streets around the city. Unfortunately, these reflections of past land use are regularly ignored by conservation efforts, which tend to focus on historic urban nuclei and the array of architectural monuments they contain. This work documents the legacies of green heritage within the 3,000-year-old city of Zadar along Croatia's Adriatic coast (Fig. 1).

Fig. 1. Location of Zadar, Croatia.

Utilizing archaeology, aerial imagery, and historic cartography, we identify four legacies of Zadar's green heritage: (1) Living fields at the margins of urban landcover; (2) Relict fields, often seen as unkept green spaces with overgrown drystone walls within the city (Fig. 2); (3) Roman centuriation, a form of Roman era land division; and (4) Spatial organization of streets and alleys that align with historic patterns of land use.

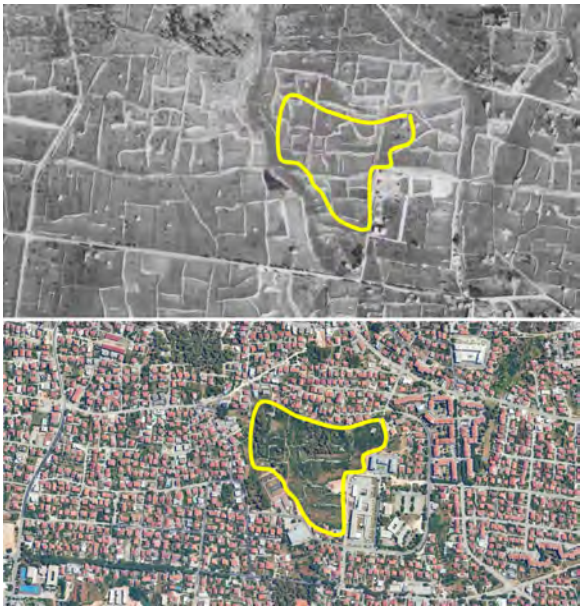

Fig 2. 1944 RAF photo showing former landscape of drystone walls vs 2023 GE image of urban landcover and unkept field today. Same parcel of land is marked.

Legacies of green heritage serve as a valuable archive of urban history. Their documentation also helps to promote a city's distinctive character beyond the historic urban core, where the threat of urbanization toward green heritage is greatest.

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