Bio-Physical and Socio-Political Vulnerabilities: A Case Study from World's One of the Most Climate Vulnerable Regions, Karnali Nepal

Suman Acharya[1, 2, 3]

1. *Climate Change Institute, University of Maine.*
2. *Department of Anthropology, University of Maine.*
3. *Himalayan Conservation and Research Institute, Dolpa, Nepal.*

Abstract: Climate change presents extreme challenges to both social and ecological systems. It is important that we consider both socio-political and bio-physical climate vulnerabilities. However, studies on vulnerability to date are highly focused on biophysical aspects ignoring the social, political, or economic determinants of vulnerability. This study tries to erase some of the gaps using Nepal as an ethnographic case. This paper results that both the farmers' perception and climate reanalyzer data agree that the temperature of Nepal is rising and precipitation has become erratic resulting in vulnerabilities. The social, political, and economic vulnerabilities have impacted the agrarian communities, however, these dimensions of vulnerability do not come into open discussions. This paper concludes that effective adaptation policies and programs for climate change should consider both biophysical and sociopolitical dimensions of vulnerabilities.

Nepal is considered one of the most climate-vulnerable countries. It is undeniable fact that the high mountains of Nepal are rapidly melting, and it is facing several disasters including landslides, floods, erosions, etc. This has enhanced the vulnerability of farmers in Nepal. Furthermore, the differentiation of community members based on caste, political party affiliation, economic status, geographic location, and gender has furthered vulnerability in agrarian and resource-dependent rural communities.

Employing ethnographic methods for a year, this research found that the temperature of the Karnali region of Nepal is on an increasing trend with the highest temperature in 2016 (Fig. 1) whereas the precipitation remained erratic but increased in trend. The perception-based data also shows that 76% of farmers observed an increase in total annual temperature in the past 30 years. Whereas their perception did not match with the precipitation as they perceived that the precipitation was in decreasing trend. Similarly, due to this Karnali has experienced extensive droughts throughout time due to which the soil quality and crop productivity have reduced. Furthermore, due to erratic and short-intense rainfall, the frequency of landslides, floods, and soil erosion has dramatically increased. Several forms of adaptation-based activities are implemented to adapt to biophysical changes.

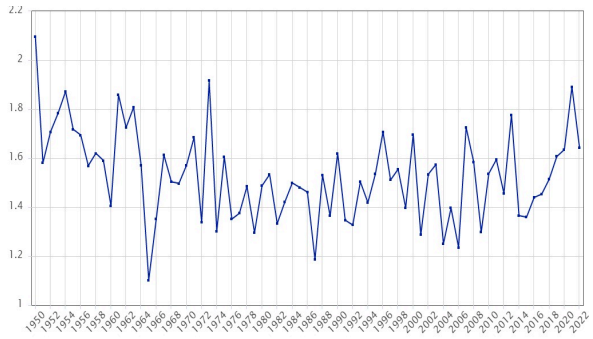

Fig. 1. ERA5 annual 2m-temperature in °C of Karnali (1950-2022). (CCI, 2023).

However, the vulnerabilities created due to social, political, and economic determinants have exacerbated the vulnerability of Karnali region. The low-caste, women, poor, and politically poor households face enhanced vulnerability. However, most of the adaptation-based organizations in Nepal are focused in Karnali, adaptation policies and programs did not progress in reducing social vulnerabilities. This paper argues that to robust policies, there should be consideration of both socio-political and biophysical dimensions of climate change. Focusing on only one dimension will not result in better adaptation outcomes.

Acknowledgments: Dr. Cindy Isenhour, Dr. Paul Mayewski, Dan and Betty Churchill Exploration Funds, Lambda Alpha Research Grant, GSG grants, local collaborators, and research participants.

Sediment Plume Geometry in Response to Retreating Tidewater Glaciers: Qalerallit Imaa, South Greenland

Sydney J.N. Baratta[1,2], Kristin M. Schild[1,2], Lee Karp-Boss[3], Emmanuel Boss[3]

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

Abstract: **With accelerated mass loss of the Greenland Ice Sheet, some of the retreating tidewater glaciers in South Greenland have transitioned to land-terminating. Fjords with tidewater glaciers at the head are highly productive and sustain fisheries that are important to local communities, while land-terminating fjords are not. In this study, we focus on establishing a record of sediment plumes at retreating tidewater glaciers in Qalerallit Imaa, as sediment plume concentration and geometry directly affect light availability, therefore fjord productivity.**

Fjords connect tidewater glaciers to the ocean and serve as a critical passageway in heat transport to a tidewater glacier terminus and the movement of glacially eroded, nutrient-rich sediment to the ocean. As atmosphere and ocean temperatures are projected to increase, the amount of meltwater, solid mass loss, and glacially eroded sediment entering the fjord are likely to change, which would impact the resulting fjord circulation, nutrient input, water turbidity and consequently primary productivity. Additionally, the transition of tidewater glacier to land-terminating glacier may also occur, leading to a fundamental difference in fjord dynamics as solid mass contribution disappears and sediment-rich meltwater will enter the fjord at the surface rather than at depth. Concerningly, the impact of this change in forcing on fjord circulation, nutrient input, and primary productivity has not been well studied. Our study shows that sediment plumes in Qalerallit Imaa, a south Greenland fjord with four tidewater glacier termini at different stages, show spatially distinct and variable differences (Fig. 1). We found that the higher suspended sediment samples, coinciding with a higher surface reflectance, are in front of the land-terminating glacier while sediment plumes are relatively absent in front of the tidewater glacier. We used our 47 collected suspended sediment samples to calibrate and validate a remote sensing algorithm to achieve a more accurate technique for deriving sediment plumes from satellite imagery (Landsat, 30 m). From here, we will be able to extend the record back in time through available imagery to gauge how long it takes for sediment plume dynamics to change in response to retreating tidewater glaciers. Our results demonstrate more concentrated sediment plumes at land-terminating glaciers. By returning in June 2023, we will collect biological samples alongside suspended sediment to explore how the primary producers may be spatially distributed in relation to sediment plumes. We anticipate that with a transition to land-terminating, sediment plumes will become more concentrated and further extending, decreasing productivity in fjords as a result. Establishing a response time between retreat and changes in sediment plumes through remote sensing techniques is critical considering a warming climate, especially since local communities living in Greenland rely on fjords for their food. We hope that our work will be used to both inform communities and aid in the advancement of remote sensing science in the Arctic.

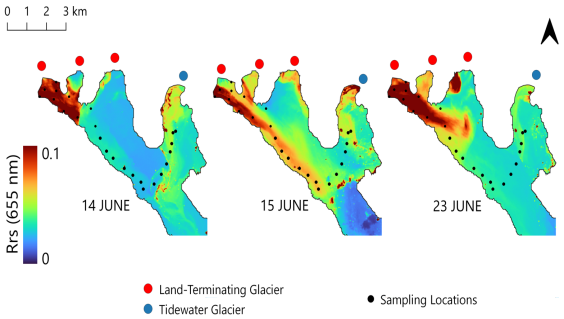

Fig. 1. Qalerallit Imaa Fjord surface reflectance (at 655 nm) over the *in situ* sampling period (June 2022).

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Quantifying Spatial and Temporal Variability in Temperate Snowpack Properties and Meltwater Runoff from Two Study Sites in Southeast Alaska

Keegan Bellamy[1,2], Mikaila Mannello[1,2], Renée Clavette[1,2], Mari Fromstein[1,2], Emma Erwin[1,2], Ingalise Kindstedt[1,2], Seth Campbell[1,2]

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

Abstract: **We will use various geophysical and in-situ observations to compare the spatial and temporal distribution of snowpack properties and onset of melt in glaciated and non-glaciated watersheds in southeast Alaska. Improved characterization of these properties will be used to drive temperature index and advanced snowpack models to improve understanding of melt onset in these temperate environments and produce meltwater runoff estimates. High uncertainty rates currently exist for the aforementioned properties and runoff estimates; therefore, the goal of this research is to reduce these uncertainties.**

Alpine glaciers and snowpacks act as water reservoirs for downstream environments, providing meltwater to over a quarter of the global population for human consumption, agriculture, and hydroelectric power. Unfortunately, these areas are sensitive to climate change and estimating changes to meltwater availability is an ongoing challenge. Alaska and western Canada have recently been identified as regions with the highest meltwater estimate uncertainties due to the nature of the snowpacks, large regional variability, remote high-altitude locations, and lack of field observations, therefore offering an opportunity to fill in existing research gaps (Kim et al., 2021).

Our team will collect mass input (accumulation) and loss (ablation) data from one glacierized (Lemon Creek) and one non-glacierized (Fish Creek) watershed in southeast Alaska using a range of geophysical and in-situ observations (Figure 1). These data will be used to improve the characterization of temperate snowpack properties and quantification of liquid water content. Temperature index models and more advanced snowpack models (e.g. Vionnet et al., 2012) will then be used to estimate the onset of snowmelt and compare these results to measured meltwater runoff at gauge stations from these locations. Results from this study will be used to reduce the aforementioned uncertainties in meltwater volume estimates and help constrain snowpack and meltwater runoff models.

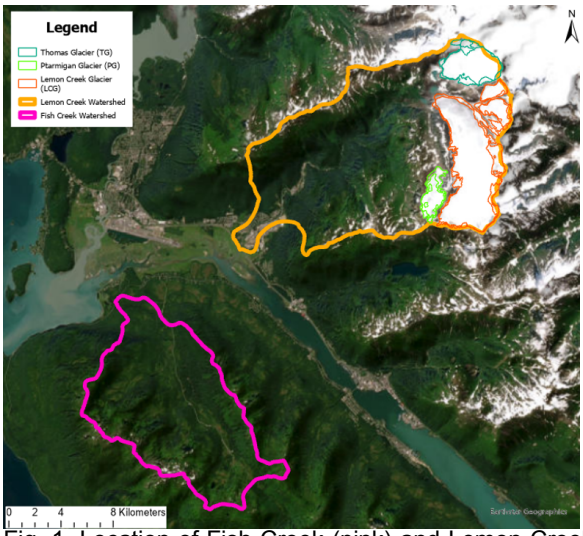

Fig. 1. Location of Fish Creek (pink) and Lemon Creek (orange) watersheds with Thomas Glacier (blue), Ptarmigan Glacier (green), and Lemon Creek Glacier (red) outside of Juneau in southeast Alaska.

Acknowledgements: We thank the Juneau Icefield Research Program and Dr. Eran Hood from the University of Alaska Southeast for continuing to support this research.

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What Controls Iceberg Abundance and Distribution Around Northwest Greenland?

Allie Berry[1,2], Kristin Schild[1,2], Siddharth Shankar [3], Leigh Stearns[3]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Department of Geology, University of Kansas.*

Abstract: Icebergs contribute a significant amount of freshwater flux to global oceans. Despite this understanding, models often neglect the influence of icebergs on global freshwater flux. To begin addressing this issue we first need to understand and be able to predict iceberg distributions. Here we use Sentinal-1 SAR imagery to construct a time series of iceberg distribution in Northwest Greenland between May 2017 – December 2021. We use this time series in conjunction with metrics of environmental and glacier behavior to predict the environmental controls on iceberg abundance.

Introduction

Icebergs can account for up to 50% of freshwater flux from tidewater glaciers, but are not currently well constrained in global circulation models (GCMs)[1]. As icebergs calve into the ocean, they not only contribute to global sea level rise, but their localized freshwater injection can alter fjord circulation as they move and melt[2].The rate of mass loss from polar regions has been increasing, therefore determining the impact of icebergs on broader oceanic circulation is increasingly important. Inherently, their impact depends on their size and spatial distribution; however, despite this understanding, GCMs do not accurately account for the freshwater flux generated by icebergs. This knowledge gap is in part due to the challenge of predicting iceberg abundance and size distribution, which is needed to properly inform the models.

Methods

Here, as a first order step in a larger effort to improve iceberg meltwater flux in models, we examine the environmental controls on iceberg abundance and distribution around Northwest Greenland, spanning the years 2017-2021. Iceberg metrics are obtained by applying an automated detection algorithm to Sentinel-2 imagery, and classifying icebergs by size and location. These distributions are then compared against a suite of environmental and glaciological variables, including atmospheric conditions, sea ice presence, and glacier dynamics, through a random forest analysis.

Preliminary Results

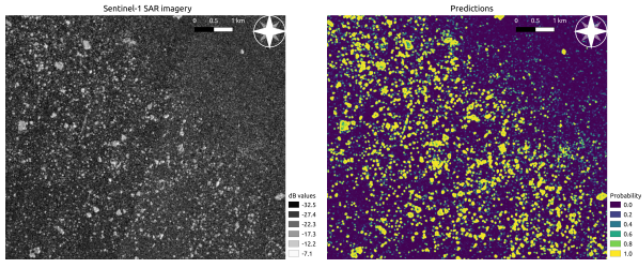

Figure 1. (Right) Raw Sentinel-1 SAR image. (Left) Automated detection algorithm of icebergs in SAR image.

Scientific Implications

By highlighting the main environmental and glaciological controls on iceberg distribution in Northwest Greenland we will be able to better predict iceberg abundance and distribution, which will in turn, help to constrain the impact of freshwater flux on global ocean circulation.

Acknowledgements: This work is funded by NASA grant NNH20ZDA001N-NIP.

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Digitizing the Archaeological Record: The Ostra Collecting Station

Emily M. Blackwood[1,2]

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

Abstract: This research explores digitizing techniques used to visualize archaeological data at a mid-Holocene site on the northern coast of Peru. Virtual reality (VR) and photogrammetry were used to simulate and analyze the site, artifacts, and mollusks recovered. Incorporating VR and photogrammetry in site visualizations can provide a way to experience the site without having to be 'in the field'.

Background:

The Ostra Collecting Station (OCS) site was selected for this research due to its age, location, and context. The site is radiocarbon dated ~6,500 cal years B.P. and sits at the edge of an ancient sea cliff. In present day, the Pacific ocean is located 5km west of the site, but during occupation the site marked the shoreline (Figure 1). The impression of a 9x8meter structure is visible and was confirmed through excavation and its size, in the context of time, can be considered monumental. This site also has a unique set of artifacts which suggest it could be the oldest site in the America's with defensive strategies. Digitizing material recovered through excavation has always been crucial to archaeological research and incorporating virtual reality (VR) and photogrammetry is a natural progression. Digital models are powerful visualization tools that can be viewed and shared globally (with permission) that are 3D, in color, rotatable, and to scale. This differs from 2D, black and white, static figures commonly found in publications.

Methodology:

Archaeological data were recovered through survey and excavation of a 1x1 meter unit. Radiocarbon dates were derived from charcoal twigs. Drone imagery was used to create a DEM for the base model in the VR simulation and imported into Unity 3D game engine. The Polycam app was used to create 3D models of shells and artifacts recovered from the site.

Discussion:

The Andean Mountains to the east and location of the ocean during occupation to the west highlights this sites' accessibility restrictions and its defensibility potential. Direct access could be monitored and would have been limited to either from the north or the south. The structure dimensions are inconsistent with other structures dating to this time, which raises the question of its purpose. Radiocarbon dates in stratigraphic order suggest the site has not been reoccupied or disturbed (within this structure) since abandonment. The presence of diagnostic artifacts links this site to the Ostra Base Camp (3km to its south) and this connection is important to the overall narrative for this area; pearls have not been recovered (to date) from any other site in Peru, except from the Ostra Base Camp. Following this, the shell heap matrix consists of molluscan species no longer available at this latitude which have been digitized using the Polycam app (Figure 2).

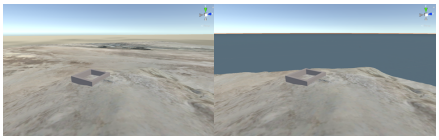

Fig. 1. Simulation of OCS with view looking towards the west. Left panel: OCS in present day. Right panel: OCS during occupation.

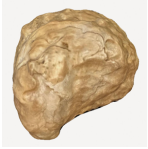

Fig. 2. 3D model of oyster shell recovered from OCS.

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Field Team Members: Cecilia Mauricio, Dan Sandweiss, Alice Kelley, Paul "Jim" Roscoe Gloria Lopez. VEMI Lab, Dr. Nicholas Guidice.

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Long-term Arctic Land Use Patterns and Global Climate Change Modeling

Joseph Boots-Ebenfield[1, 2], Jacquelyn Gill[1, 2]

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

Abstract: The temporary and seasonal land use patterns associated with most of the peopled history of the circumpolar north are underrepresented in global land use and change models, limiting our understanding of how these relationships influence and interact with ecological and global climate processes. Paleoecological approaches could be used to elucidate the long-term impacts of caribou hunting and herding on Arctic region vegetative structure, improving global change models and our broader understanding of social-ecological relationships.

Recognition of people's crucial role to the development and maintenance of important ecosystems across the world has spurred calls for further research on long-term social-ecological relationships and their effects on landscape structure, to better understand their roles in global ecological and climate processes[1]. The Arctic region is of special significance as the most rapidly warming region in the world, a process linked to fast changes in local ecosystem and landscape structures[2]. The circumpolar north is also underrepresented in global change models, the most current of which underestimate the impacts of seasonal or temporary land use, both of which are predominant throughout the peopled history of northern regions. In global change models, tundra and boreal forest are often the only biomes/anthromes designated as still >50% wildlands or wilderness, suggesting a lesser extent of human impact on surrounding environment[3] (Figure 1). New research is needed to provide deeper understandings of how long-term human land use patterns may influence high-latitude ecosystem structure, and how social-ecological relationships could be impacted by, and provide ecological resilience to, global climate change.

Emergent paleoecological techniques have revealed complex relationships between large herbivores and Arctic terrestrial landscape structure, suggesting that stable large herbivore presence can prevent tundra shrubification, also known as Arctic greening, which itself is linked to increasing local permafrost thaw rates and greenhouse gas emissions[4]. Given the long history of caribou hunting and herding in the circumpolar north, it is plausible that the cultural relationships between people and caribou have wide-ranging effects on Arctic landscape structure. Paleoecological analysis of vegetative structure in long-term hunting/herding areas could reveal previously obscure links between these practices and ecological stability, and could be used to improve global change models such as the HYDE dataset.

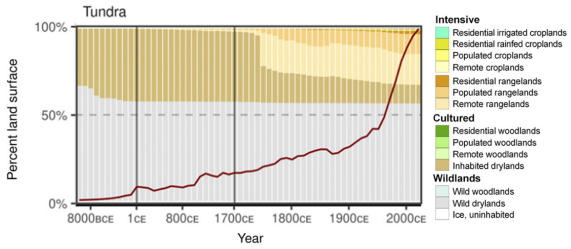

Figure 1. Anthrome change through time in the tundra, modeled using the HYDE 3.2 dataset (Adapted from Ellis et al. 2021).

Acknowledgements: NSF/NRT-NNA, Award # 2021713.

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Ground-Penetrating Radar Survey of the Upper Kahiltna Glacier, Denali National Park, Alaska

Scott Braddock[1,2], Seth Campbell[1, 2]

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

Abstract: We collected 13.4 km of ground penetrating radar data between 3350 and 2000 m above sea level on the Kahiltna Glacier, Denali National Park, Alaska. The Kahiltna Glacier is the longest glacier in the Alaska Range and has been identified as an ideal site for radar studies to monitor snow, firn, and mass balance properties because of its steep elevation gradient over a short distance. Our radar transect imaged the upper 50 m of the glacier and will be compared with previously collected data from 2010 to quantify changes in firn thickness and other properties.

Introduction:

Our goal was to measure the depth of the snow-to-firn transition on a high-relief, high-elevation glacier. Ground-penetrating radar (GPR) is one method to measure firn and snow properties and thickness changes in glacier environments (e.g. [1]). In temperate environments where water is retained in firn within voids, in spaces between grains of ice and snow, or within conduits[2], radio wave velocities are dependent on both density and water[3]. To address the question of *how water content within glacier firn and snow changes over time as well as with elevation,* we conducted a GPR survey along the Kahiltna Glacier, Alaska (Fig.1).

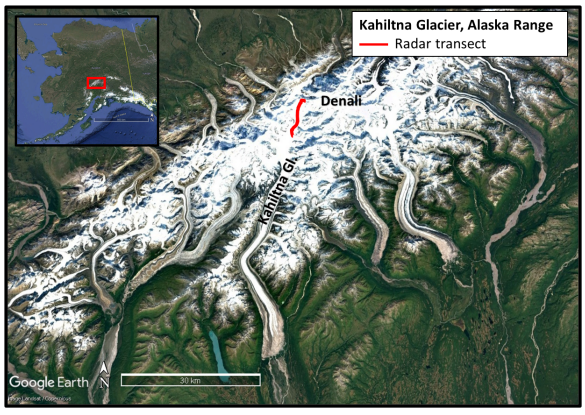

Fig. 1. Google Earth image of field site. The Kahiltna Glacier is the longest in the Alaska Range. Red line indicates location of 13.4 km radar transect.

Results:

We collected 13.4 km of GPR data on a center line transect of the Kahiltna Glacier using a ski-towed 400 MHz antenna. Collection started at Camp 2 on the West Buttress route of Denali at ~3350 m and ended ~2000 m on the main branch of the Kahiltna Glacier. Results show stratigraphy down to 50 m at elevations between 3400 and 2800 m asl. Around 2300 m asl, our data no longer displays stratigraphy, and this is likely due to water content in the snowpack and thin firn which exists at lower elevations of Kahiltna Glacier. Higher water content results in radar signal attenuation. Our next step is to quantify temporal changes in firn thickness and its associated capacity for water storage. To account for temporal changes in the snow and firn packs, we are in the process of comparing the 2022 dataset with GPR data collected along the same route in 2010.

Acknowledgements: This research was supported by The Robert and Judith Sturgis Family Foundation, the Maine Space Grant Consortium, and the American Alpine Club. Field team: Emma Erwin, Ingalise Kindstedt, and Liam Kirkpatrick. Logistical support: Talkeetna Air Taxi & Denali National Park Service.

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Megafaunal Non-Extinction: An Agent-Based Modeling Approach

Nikhil R. Brocchini[1], Jacquelyn Gill[1,2]

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

Abstract: In the last hundred thousand years, most large terrestrial mammals on earth went extinct. Investigation of the causes and consequences of this event – called the Late Quaternary Extinctions (LQE) – has propelled much of the field of paleoecology in the past four decades. Investigation into the mechanisms allowing modern megafauna (e.g. elephants, giraffes, rhinoceroses) to survive has been quite limited. I plan to use an agent-based modelling (ABM) approach to attempt to simulate plausible behavioral-evolutionary dynamics that could clarify the global extinction dynamics of the LQE.

Without a well-developed understanding of the factors allowing some megafauna to survive the LQE, the dynamics of the extinction will remain incompletely understood. Most literature on the topic attributes survival of African megafauna to their coevolution alongside humans (Koch and Barnosky 2006). The flipside of the 'naïve megafauna' hypothesis, which suggests that megafauna in Eurasia, North America, and Australia were easily hunted because of their inexperience with humans, the coevolution hypothesis suggests that African megafauna evolved some unnamed traits or behaviors that allowed them to survive. This convenient-sounding explanation contains within it a multitude of implicit arguments and assumptions which have gone largely uninterrogated. Even papers which attempt to address this issue with more complex biogeographic and climatic dynamics invoke coevolution as a partial explanation (Mann et al. 2019). Most papers completely fail to acknowledge South Asian megafauna.

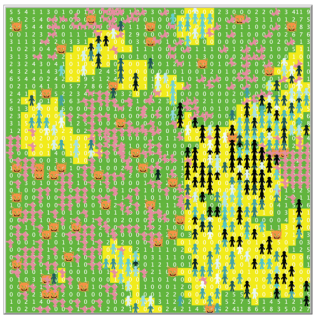

Fig. 1. Landscape partitioning in an early model run.

One underexplored component of the naïve megafauna hypothesis is the relationship between humans and large predators. Predators that evolved alongside hominins could have been more efficient hunters of early humans, potentially impacting human use of the landscape. I plan to use an agent-based modeling approach to explore how predator's human-hunting efficiency impacts the survival of a shared prey resource. By modeling the evolution of human foraging behavior in high- and low-risk predation environments, I aim to explore whether coevolved large predators could have produced 'behavioral refugia' for megafaunal herbivores. Early results indicate that predation risk has a very limited impact on human foraging behavior in the model.

Acknowledgements:
Thank you to the Climate Change Institute, the BEAST lab, and Dr. Tim Waring.

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Evaluation of Public Policy and Covid-19 Pandemic Impacts on Historic Asian Pollution Emissions Using Alaskan Ice Core Lead Data

Hanna L. Brooks[1,2], Michael Handley[2], Jacob I. Chaliff[3], Erich C. Osterberg[3], Dominic A. Winski[1,2], Karl J. Kreutz[1,2], Kimberley R. Miner[4], Andrei V. Kurbatov[1,2], Christopher Gerbi[2], Cameron P. Wake[5]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Department of Earth Sciences, Dartmouth College.*
4. *Jet Propulsion Laboratory, California Institute of Technology.*
5. *Institute for the Study of Earth, Oceans, and Space, University of New Hampshire.*

Abstract: In my dissertation study, I am examining changes in lead (Pb) isotope values over the past two millennia (340 to 2022 CE) using ice cores from Begguya (Mt. Hunter), Alaska.

Project Goals: We can analyze natural climate change in the North Pacific with two ice cores extending to bedrock (Den13-A and Den13-B, 210 meters, ~10,000 years) that were collected in 2013. Two shallow cores – from 2019 (Den19-A; 50 meters) and 2022 (Den22-A; 20 meters) – extend this record to 2022, through the onset and duration of the Covid-19 pandemic. Winds travel west to Begguya, carrying dust and pollution from Asia across the North Pacific. Critical changes in culture (industrialization, globalization of world markets, Covid-19 pandemic), technology (industrial recycling), and policy and legislation (phase out of leaded gasoline) have a direct impact on Pb transported to and deposited at Begguya.

Methodology: A high-resolution ~1,700 year dataset of natural and anthropogenic Pb isotope variability recorded at Begguya will be created from Den13-A, Den19-A, and Den22-A ice cores. In Spring 2022, we melted each ice core using a melting system and ultra-clean sample preparation procedures[1] at Dartmouth College. We sampled the ice every 20 cm, resulting in decadal resolution at 345 CE and weekly resolution at 2022 CE. Combined, the three cores create a dataset of 1,070 samples (Fig. 1) spanning ~1,700 years of natural and anthropogenic variability in the North Pacific. With the new, state-of-the-art Thermo Scientific Element XR ICP-MS in the CCI ICP-MS lab, we will be able to more accurately detect low elemental concentrations, have higher sensitivity and improve isotope ratio precision. The Denali Pb samples will be analyzed for trace metal concentrations and Pb isotope ratios following established methodologies[2] on the new ICP-MS. This data will fill a critical gap in knowledge about changes in Pb levels over the last two decades in the North Pacific.

Following data collection, I will investigate historic trends in the data, tracking Pb emission sources, and look for correlations between Begguya and other Pb deposition datasets. To determine the impact of Covid-19 on Pb deposition at Begguya, I will construct a model of Pb isotope ratios with respect to time across the last 1,000 years and test the difference between modeled and measured data for 2020-2021.

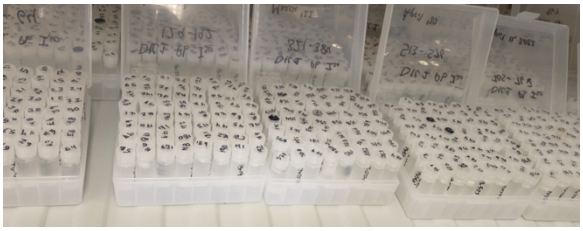

Fig. 1. Samples awaiting ICP-MS analysis.

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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ScandEntropy: Modeling Treeshrew Climatic Niches

Eric Brown[1,2,3], Danielle Levesque[1,2,3], and Jayasilan Mohd-Azlan[3]

1. *Climate Change Institute, University of Maine.*
2. *School of Biology and Ecology, University of Maine.*
3. *Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak.*

Abstract: Treeshrews' evolutionary history and ecology make them a unique candidate for investigating the impacts of climate change on tropical mammals. Here we used MaxEnt climatic niche modeling to find that precipitation contributes most to the habitat suitability of *Tupaia tana* and *Tupaia minor* in Borneo, but temperature variation is more important to *T. minor* than *T. tana*. This baseline will inform future mechanistic models that incorporate species' thermal physiology.

Background:
Increasing global temperatures and extreme weather present a unique thermoregulatory challenge to tropical mammals. Treeshrews constitute the understudied mammalian Order Scandentia, a clade endemic to subtropical-tropical South-Southeast Asia whose ecology is poorly understood due to a lack of field studies. Scandentians are phylogenetically proximal to primates, morphologically similar to ancestral mammaliaforms, and today experience a climate similar to that of basal Jurassic mammals, making them a unique model for questions about the evolution of mammalian thermal physiology. Here we make use of historical collections data to model select treeshrew species' climatic niches in Borneo to provide a baseline for our mechanistic models.

Methods:
We predicted species distributions of *Tupai tana* and *Tupai minor* in MaxEnt v3.4.1 with 38 *T. tana* and 31 *T. minor* occurrence records drawn from the Sarawak Museum mammal skins collection (Kool and Nawi 1995). We used WorldClim v2.1 bioclimatic (19) and elevation (1) variables as environmental layers and withheld 25% of samples for testing while default model settings were otherwise kept.

Preliminary Results and Next Steps:
Precipitation metrics were the most important variables for *T. tana*, particularly of the wettest month. Isothermality expressed some influence, but temperature metrics overall gave no considerable contribution to the model. Similarly, precipitation metrics were the most important predictors for *T. minor* distribution, particularly metrics of the wettest month, though temperature variation (seasonality and isothermality) contributed considerably more to the *T. minor* model than the *T. tana* model.

During future field seasons we will collect ecophysiological and microclimate data for free-ranging treeshrews. Mechanistic models (e.g. NicheMapR endotherm model) that incorporate physiological and microclimate data will supplement the correlative models presented here. We will then extend this hybrid approach to past and future climate scenarios.

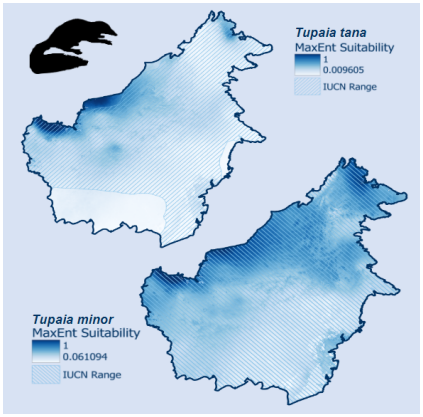

Fig. 1. Suitability of habitat for *T. tana* and *T. minor* in Borneo.

Acknowledgements: Thanks to IBEC at UNIMAS for providing the workspace for this project and Lara Boudinot for digitizing the collections data. Funding for this project was provided by the NSF (CAREER Grant #2045785).

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The Juneau Icefield Research Program: A 'New" Earth & Planetary Sciences Polar Proving Ground & Training Program

Seth Campbell[1,2], Scott Braddock[1,2], Mikaila Mannello[1, 2], Emma Erwin[1,2,3], Erin Towns[1,2], Renée Clavette[1,2], Keegan Bellamy[1,2], Jacob Holmes[1,2], Mari Fromstein[1,2]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *ERDC-Cold Regions Research & Engineering Laboratory.*

Abstract: **The Juneau Icefield Research Program (JIRP) was established in 1946 as a Polar expeditionary training and research program. The program is currently thriving due to federal funding and a collaborative network of institutions, scientists, and educators supporting research and education initiatives. Below, we summarize these initiatives and future directions.**

Summary

JIRP operates eleven field stations on the Juneau Icefield (JIF) in Alaska and Canada with the largest station capable of housing up to 70 personnel. In 2020, we proposed a 'new' Polar Earth & Planetary Sciences Proving Ground and Training Program to make JIRP facilities and other resources available for use by the broader Polar science and education community. This proposal resulted in expanded U.S. and international participation with JIRP and also resulted in federal funding from NASA, NSF, the Department of Defense, and other non-profit organizations. Current initiatives developed as part of this concept includes: 1) atmosphere, glaciology, and geology research; 2) geophysical, drone, subsurface drilling and other instrument R&D; 3) planetary ice and microbiology research using the JIF as an analog testbed, 4) opportunities for scientists to collaborate and pool resources for mutually valuable R&D; 5) large scale community science experiments; and 6) extensive training opportunities for Early Career STEM professionals including low income and first-generation college students through to graduate students and postdoctoral associates. Future initiatives JIRP and UMaine are co-developing include: 1) the acquisition of new research equipment (e.g., airborne LiDAR, radar, and Hyperspectral cameras, & ground-based interferometry) to study Earth surface and near-surface processes in high spatial and temporal resolution; 2) support for Earth surface numerical modeling; 3) an institutional consortium which will fund student training opportunities to advance Polar education in the U.S.; 4) seed grant funding for early career scientists interested in testing research ideas within the JIRP collaborative network; 5) new partnerships with indigenous communities and other stakeholders to co-develop impactful research and education in Alaska and Canada; and 5) new environmentally sustainable field stations which rely on renewable energy and materials, in collaboration with the Advanced Structures and Composites Center.

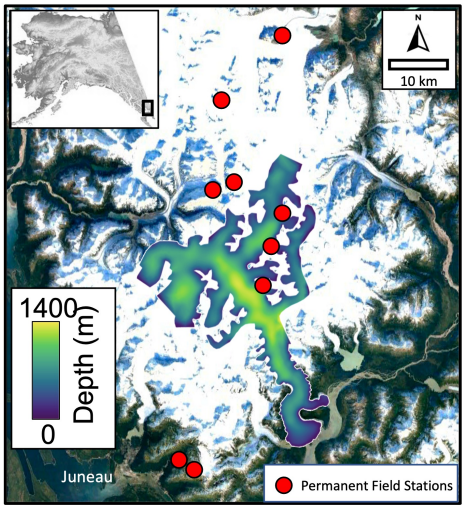

Fig. 1. Map of Juneau Icefield, Alaska (inset) and U.S. and Canadian JIRP Field Stations. Two Stations in Canada owned by JIRP are excluded from this map. Map also shows ice thickness of Taku Glacier.

Acknowledgements: We thank the Foundation for Glacier & Environmental Research, Tongass National Forest, the University of Maine Climate Change Institute, and University of Maine School of Earth & Climate Sciences for their collective support of these initiatives.

Charge-Augmenting Modes for Plugin Hybrid Electric Vehicles

Sudarshan S. Chawathe[1,2]

1. *Climate Change Institute, University of Maine.*
2. *School of Computing and Information Science, University of Maine.*

Abstract: This note calls for charge-augmenting modes in plugin hybrid electric vehicles (PHEV).

Transportation activities are significant contributors to global greenhouse gas emissions and climate change. These activities are also among those that are most affected by disruptions caused by extreme weather events and other consequences of climate change. Therefore, improvements in the efficiency and robustness of transportation are important for both curtailing the rate of anthropogenic climate change and adapting to a changing climate.

Plugin hybrid electric vehicles (PHEV) offer a pragmatic option for reducing fossil-fuel consumption and tailpipe emissions while permitting long-range travel in regions with little or no electric-vehicle charging infrastructure. It is therefore not surprising that they have received much attention in commercial and research arenas, and are also the focus of this work. For propulsion, such vehicles are equipped to use a combination of electrical energy from an onboard battery and motor and chemical energy from fuel and an internal-combustion engine (ICE). For replenishment, the onboard battery may be charged using energy from either the ICE (when running) or an external charging station (when parked), while fuel for the ICE is replenished in the conventional way at fueling stations. This array of options for propulsion and replenishment permits diverse modes of operation and strategies for optimizing for fuel consumption, emissions, energy consumption, operating cost, driver and passenger comfort, and more.

Commonly available vehicles of this kind support two primary modes of operation. The first, called *charge-depleting (CD) mode*, refers to operating the vehicle primarily using the onboard battery for energy, optionally supplemented by the fuel and the ICE for short durations when the power demand exceeds what the battery-motor system alone can provide. The second, called *charge-sustaining (CS) mode*, refers to operating the vehicle using a combination of the onboard battery and fuel for energy in such a way that the *level of charge (LoC)* of the battery remains within a few percentage points of its value when the mode this initiated. In addition to these two primary modes, vehicles also commonly support mixed modes that attempt to blend the above modes to maximize fuel economy or other metrics.

At this point, some readers, especially those not overly conditioned by experience with current vehicles, may share this author's curiosity regarding the lack of a *charge-augmenting (CA) mode*. As the name suggests, such a mode uses fuel and the ICE to increase the level of charge of the onboard battery (in addition to providing propulsion). Apart from providing a level of symmetry, which some may find less than compelling, a charge-augmenting mode enables additional vehicle-operating strategies that are both interesting to study and pragmatic in application, as illustrated by the following anecdote: A driver is traveling to a school to pick up a child. The congested driving in the area near the school as well as the choreographed pickup procedure to be executed by dozens of vehicles in the vicinity are almost ideal cases for operating on battery power (charge-depleting mode). However, the current level of charge of the battery is already too low for such an operation and the school is a few miles away. Switching to a charge-augmenting mode at this point would enable a charge-depleting mode later, when it is most beneficial. While it may be less than obvious that such a strategy results in overall savings of fuel, costs, etc. (because of the complexities of the physical and financial aspects) what is quite obvious that it provides enhanced driver, passenger, and bystander comfort. While this brief note uses primarily such anecdotal information for motivating the charge-augmenting mode, there are several other motivations that are readily discovered once the option is considered.

Identifying and Monitoring a Subglacial Lake Under Temperate Ice on the Juneau Icefield, Alaska

Renée Clavette[1,2], Seth Campbell[1,2], Emma Erwin[1, 2], Jacob Holmes[2]

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

Abstract: We plan to quantify and monitor water fluxes and volume change of a subglacial water reservoir located in North Basin on Taku Glacier (Juneau Icefield), Alaska. We will use common offset ground-penetrating radar and Autonomous phase sensitive radar to characterize observations indicative of basal meltwater and GPS-derived surface deformation observations to capture associated ice surface elevation changes. This will advance our understanding of the hydrologic linkages between the surface and bed and impact of subglacial water changes on ice dynamics in a temperate glacier system.

The storage and transport of meltwater within glaciers fundamentally impacts ice dynamics, glacier mass balance, and thermal properties[1,2]. Meltwater discharge also has downstream effects on watersheds, marine ecosystems, and communities that rely on meltwater-fed streams[3]. However, we lack a complete understanding of how quickly and by what mechanism surface meltwater reaches the glacier bed and transports into down-glacier environments.

Taku Glacier is the largest glacier within the Juneau Icefield in Southeast Alaska and houses a small (~1 km wide) basin called North Basin (Fig. 1). Building on previous 10 and 100 MHz GPR transects collected in 2021, we will repeat these transects multiple times throughout spring and summer 2023 to obtain a time series of basal reflectivity, a metric used to infer basal conditions, and measure the extent of the subglacial lake over time. Continuous measurements of basal reflectivity (amplitude and phase) will be collected from ApRES, which has millimeter-scale range precision of englacial targets. The amplitude and phase are expected to change depending on basal conditions. Concurrently, GPS units will be deployed to measure ice surface elevation increases or decreases, which would correspond with increased (lake filling) or reduced (lake draining) hydrostatic pressure (lake filling) through time. These data will allow us to characterize the timing of water inflow and outflow, and total volume.

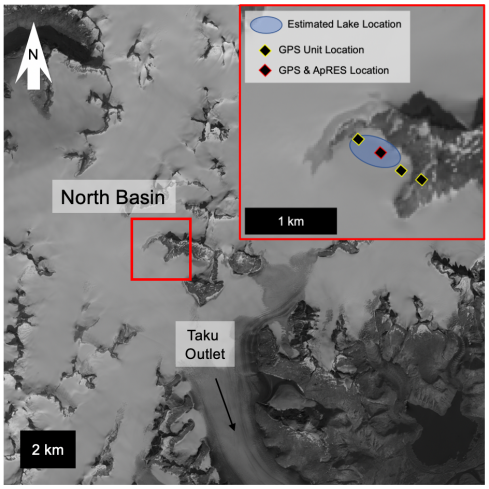

Fig. 1. Landsat-8 Imagery of the Juneau Icefield with Taku Glacier outlet and North Basin labeled. Zoomed in box shows North Basin with the location of our 2023 study site and proposed locations of GPS and ApRES units.

Acknowledgements: This research is supported by funding from NASA We also thank the Juneau Icefield Research Program for logistical support and students to assist with this field research.

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Using Past Glacial Response to Climate Change to Predict Water Scarcity in the Western US

Tricia Hall Collins[1,2], Aaron Putnam[1,2]

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

Abstract: The Wind River Range (WWR) is considered a water tower as the headwaters of the Green River, the largest of the Colorado River's tributaries. Gaining a better understanding of how this region responds to hydrological changes associated with a warming climate has implications for western U.S. water resource management. The WWR presents opportunities for full chronologies of past glaciations, including the Last Glacial Maximum (LGM), with well-preserved glacial landforms. ^{10}Be surface exposure age dating techniques will be used to quantify the timing and rate of glacier fluctuation along the western front of the WWR during the LGM and the subsequent termination. This glacial reconstruction will provide model metrics for thermal and hydrological impacts of the effects of changing atmospheric patterns in the western U.S.

The Soda Lake area along the western side of the WWR (fig. 1) presents an opportunity to develop moraine chronologies that will provide insight into the drivers of the termination of the LGM, which was the most recent significant global warming event prior to human-induced warming. Glaciers are highly sensitive to changes in atmospheric temperature, thus, documenting the timing and rate of glacier change within the WWR will help to discern past temperature changes in this region.

I collected samples from the Soda Lake glacial system during 2022 for ^{10}Be surface exposure age dating. I sampled surfaces from boulders deposited on or near the crest of terminal and lateral moraines that showed evidence of glacial polish or smoothing with limited subsequent weathering. I documented physical relationships between glacial landforms, and these relationships will be confirmed with ^{10}Be exposure age dates that will be available later in 2023.

In addition to constraining drivers of millennial-scale climate change, my research will improve projections of regional changes in Northern Hemisphere jet streams and storm tracks, which the IPCC Sixth Assessment Report (Ch. 8, Water Cycle Changes) characterizes with 'low confidence'. One I reconstruct how the Soda Lake glacier system changed following the L GM, I will go on to provide model metrics for thermal and hydrological impacts of the effects of changing westerlies in the western U.S. These winds govern precipitation and heat delivery patterns that determine the availability of water resources from mountain water towers for downstream users and ecosystems.

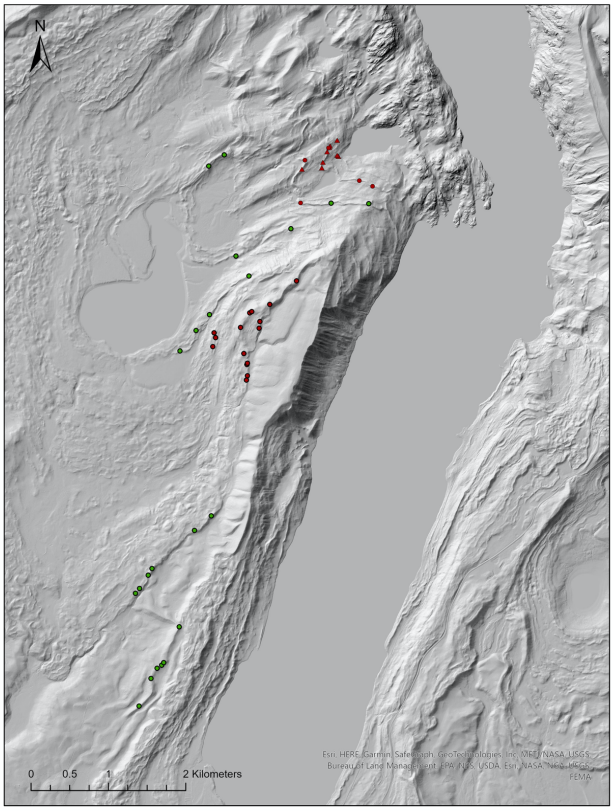

Fig. 1. Sample locations from 2022 field season in the Soda Lake area in the WWR.

Acknowledgements: Comer Family Foundation.

Reconstructing the Paleotempestology Record from the Tibes Indigenous Ceremonial Center at Ponce, Puerto Rico

Karina M. Cortijo-Robles[1]

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

Abstract: The study proposed here will address the paleotempestological record of the indigenous ceremonial center Tibes in Ponce, Puerto Rico, using the analog model approach through sediment cores.

Introduction & Objectives

Tibes, on the south side of Puerto Rico, is one of the best preserved Antillean indigenous ceremonial centers, and ongoing studies have shown its undeniable role as a site of past human-environment dynamics[1] (Figure 1). Hurricanes are not unknown to Antilles populations, being now more present due to climate change[2]. New emerging disciplines, such as paleotempestology, have tried to understand how hurricanes have affected the landscape and human communities in the past[3,4]. The study proposed here will address the paleotempestological record of the indigenous ceremonial center Tibes in Ponce, Puerto Rico, using the analog model approach through sediment cores. The objectives of the research are to understand the impact of major hurricanes on cultural development by (1) identifying the significant features of the two most recent catastrophic hurricanes (Hurricane Maria in 2017 and Not Named in 1929) and (2) reconstruct a paleotempestological record for Tibes and interpret how the population could have adapted to the hurricanes or how they led to the abandonment of the site.

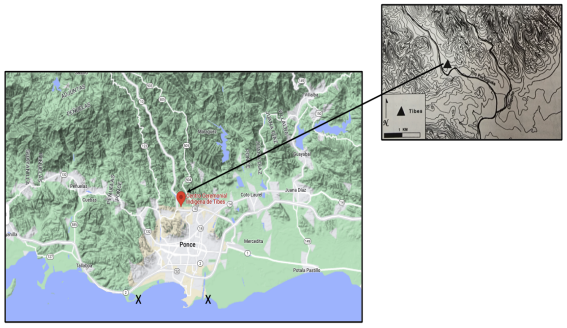

Figure 1. Study area map with X's representing possible coastal water bodies to collect sediment cores and a triangle symbol representing Tibes[1]

Proposed Methodology

The overwash deposits preserved in the sediments of coastal lakes and marshes are the most accurate and widely used methodology of paleo-tempestological research[3]. The proposed methodology is to take at least two sediment cores each near the Portugues River, the Tibes archaeological site, and a selected coastal water body. Specifically, in the sediment core taken from a coastal water body, a loss on ignition (LOI) test will be undertaken. Laboratory methods will include radiocarbon dating and grain size analysis. If no organic matter is found for dating, I will seek additional funds for 210Pb, 137Cs, and/or optically stimulated luminescence dating (OSL) tests to determine the dating of the cores.

Acknowledgments: Churchill Fund (Proposed).

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Household Water Insecurity in the Arctic: Surveillance, Analysis of Causes and Consequences, and the Evaluation of Mitigation Efforts

Kiley Daley[1], Angela Daley[2], Kathleen P. Bell[2], Shaleen Jain[1,3]

1. *Climate Change Institute, University of Maine.*
2. *School of Economics, University of Maine.*
3. *Department of Civil and Environmental Engineering, University of Maine.*

Abstract: In high-income countries such as the United States and Canada, it is generally believed that water is clean, reliable, and universally accessible. However, these 'water myths' do not necessarily hold among Indigenous Peoples in the Arctic. This project aims to measure household water insecurity in a comparable way across Arctic settings and time, and to assess the full range of drivers and impacts.

Project Background: Water insecurity can be defined as the inability "to access and benefit from affordable, adequate, reliable, and safe water for wellbeing and a healthy life"[1]. Within Arctic communities, water contamination and scarcity has been attributed to environmental (e.g., climate change, extreme weather events), infrastructure (e.g., obsolete water systems, contaminated home water storage tanks; see Fig. 1) and socioeconomic factors (e.g., population growth, housing shortages)[2]. Past studies have elucidated water challenges in the Arctic, but they are standalone case studies that do not permit comparisons across communities or time. Thus, surveillance of water insecurity has been inadequate, and it is difficult to assess the impact of mitigation efforts. Also, there is limited research regarding the impacts of water insecurity on human health as this information is rarely collected together in Arctic settings.

Approach and Methods: We propose to adapt the Household Water InSecurity Experiences (HWISE) scale[3] for Arctic households, and to augment it with supplementary data on the causes and consequences of water insecurity. These data and analyses will help to identity 'leverage points' where mitigation (e.g., improved infrastructure, health and social policies) can be targeted to make meaningful progress on this issue, and to assess the impact of such efforts. We will first obtain proof of concept in two Inuit regions of Arctic Canada (Nunavut and Nunavik). In December 2022, we participated in a water security panel at the ArcticNet Annual Scientific Meeting in Toronto, Ontario. Through this initiative, we established collaborations with local governments, Inuit representation organizations, and food security nonprofits. These partners have all described how improved water security would advance the mission of their organizations and have expressed support for this project.

Fig. 1. Household water tank in Nunavut.

Acknowledgements: This work is supported by a UMaine Arctic seed grant, the Climate Change Institute, and the USDA National Institute of Food and Agriculture, Hatch project 1016011.

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Capturing Englacial Deformation on the Begguya (Mt. Hunter) Plateau, Denali National Park, Alaska

Emma Erwin[1,2,3], Ingalise Kindstedt[1,2], Seth Campbell[1, 2], Scott Braddock[1,2], Liam Kirkpatrick [4]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Cold Regions Research and Engineering Laboratory (CRREL).*
4. *School of Earth and Space Sciences, University of Washington.*

Abstract: Here, we present ice depths measured across the Begguya plateau with 10MHz GPR and englacial deformation rates captured using Autonomous Phase Sensitive Radar (ApRES). These data will be incorporated into a 3D flow model to calculate independently derived depth-age scales to improve interpretation of the full extent of the Denali ice core record.

Background

Surface to bedrock ice cores extracted from Begguya in 2013, referred to as the Denali ice cores, provide potential Holocene-length climate records; however, limitations in dating ice near the bed require alternate methods for assessing depth-age in basal proximal ice. Constraining ice flow dynamics with three-dimensional modeling constrained by geophysical measurements allows for improved analysis. The Autonomous phase-sensitive Radio Echo Sounder (ApRES) enables calculation of vertical strain rate through measurement of englacial deformation over time[1]. Constraining a three-dimensional ice flow model using these measurements will produce the most highly constrained alpine ice flow model to date.

Results

During the summer 2022 field season, 22-point measurements were collected with the ApRES across the Begguya plateau (Fig 1.) Measurements were repeated after 14-days and processed using ImpDAR[2] to produce measurements of vertical velocity at all deployment locations. Vertical strain rates calculated from the gradient of vertical velocity measurements range from -0.037 to 0.005 a^{-1}. High-frequency (10 MHz) ground-penetrating radar (GPR) was used to survey the site to confirm ice depths and basal reflectors. Ice depths range from 120 m to 260 m in depth across the Begguya summit plateau. ApRES measurements reveal strong basal reflectors consistent with basal topography. Coherence between temporally repeated ApRES measurements is strong down to 100 - 150 m depth at all locations and is less coherent in the bottom 50 m of the icepack.

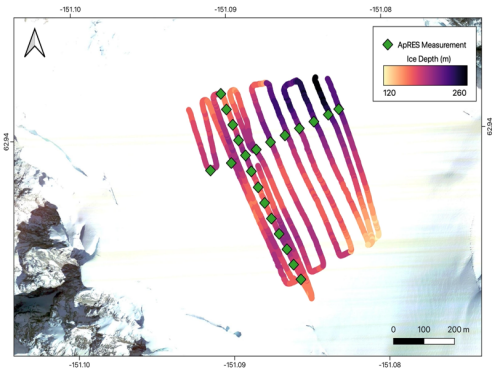

Fig. 1. Ice depths measured with 10 MHz GPR across the Begguya plateau. ApRES measurement locations shown in green.

We hypothesize the lack of resolvable vertical deformation at depth may be due to the short time interval between repeat measurements and plan to repeat measurements after a year-long interval during the 2023 field season to capture deformation in basal proximal ice.

Acknowledgements: The Robert and Judith Sturgis Family Foundation, Maine Space Grant Consortium, American Alpine Club, Dartmouth University, NOLS.

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Quantifying Glacier Dynamic Change Using an 81-year Record of Remote Sensing

Jordan E. Farnsworth[1], Kristin M. Schild[1], Sarah F. Child[1, 2]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *CIRES ESOC, University of Colorado Boulder.*

Abstract: The Greenland Ice Sheet (GrIS) has lost substantial mass in recent decades and is predicted to continue this behavior under elevated atmospheric and oceanic temperatures. Due to its location, Southern Greenland is particularly susceptible to warning; thereby, in better understanding the glacier response to climatic forcing, we may be better able to predict future conditions farther north. In this study, we use remote sensing (historical aerial photos and satellite imagery) to construct a time series of glacier behavior from 1942-2022 of five tidewater and land-terminating glaciers in Southern Greenland.

Motivation: The tidewater and land-terminating glaciers in South Greenland have undergone retreat and thinning much earlier than glaciers to the north, suggesting that the current behavior of south Greenland glaciers may become the future behavior of those to the north. In better understanding the response and recovery of glaciers in south Greenland, we will be better able to predict changes to the rest of Greenland. We will focus our study on five tidewater glaciers in south Greenland.

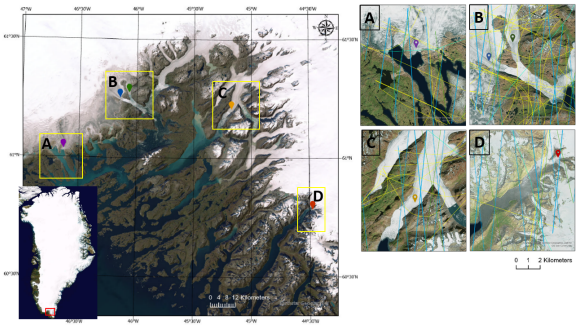

Fig. 1. Map of South Greenland glaciers with ICEBridge, ICESat, and historical aerial flight tracks.

Methods: In this study we focus on constraining multi-decadal time series of changes in glacier thickness, stress-strain regimes, calving rates, and environmental forcing. To do this, we will use declassified aerial imagery to constrain the termini positions, stress-strain regimes, and elevations of our focus glaciers in 1942. In combination with satellite data from the 1960's, 1985 and the present day, glacier dynamic change over the past 81 years will be quantified.

Fig. 2. Historical aerial imagery scans of Qooqqup Sermia glacier.

Preliminary Results:

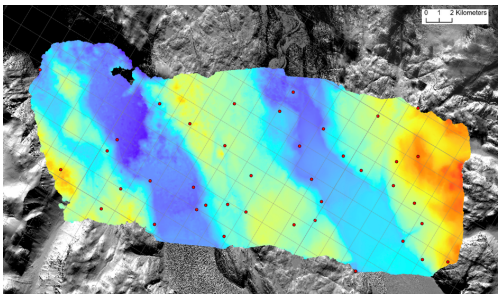

Fig. 3. Dense point cloud created from the historical photograph set displayed in Figure 2.

Acknowledgements: This work is funded by the NSF/NRT-NNA, Award # 2021713, NSF/EAGER, Award # 1561064, NSF/EAGER Award # 2135018.

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Exploring Agritourism as an Adaptation to Climate Change

Katherine C Follansbee [1, 2, 3]

1. *Climate Change Institute, University of Maine.*
2. *Systems Approaches to Understanding and Navigating the New Arctic (SAUNNA) National Research Traineeship (NRT), National Science Foundation.*
3. *School of Economics, University of Maine.*

Abstract: **This research uses qualitative research methods to explore agritourism as an adaptation to climate change. Results suggest future research of how farmers overcome challenges related to internet connectivity, time and labor, and technological literacy could inform future strategies for adaptation.**

Background

Climate and economic changes are disrupting the agricultural sector globally[1]. Inspired by the challenges of sheep farmers in Southwest Greenland, and motivated by concerns over research fatigue in the Arctic, this exploratory work uses qualitative methods to glean and evaluate insights from Maine sheep farmers about agritourism as an adaptation strategy. Agritourism in Southwest Greenland builds on current traditional practices and values, as sheep farming has been a key lifeway in this largely Inuit community for generations[1]. The 37 sheep farms in Greenland provide meat to the country and sustain Indigenous traditions of farming in the area[1]. However, as climate change makes farming more expensive, farmers struggle to keep their flocks[1]. Bringing in another income stream, agritourism, could support their primary business and way of life, farming.

Research Goals

This research looks at successful agritourism practices in regions such as Maine and Arkansas to glean challenges, lessons learned and best practices. The point of this work is to offer information for stakeholders and to inform future research. Our research question is: What are the challenges farmers face when pursuing agritourism and what can they do to be more successful?

Methods

We used qualitative mixed methods (semi-structured interviews and participant observation) to address our research question. As a response to feedback regarding research fatigue in Greenland, we intentionally focused on other regions to take the burden off the Greenlandic sheep farmers. Instead, we spoke to farmers in Maine (7) and Arkansas (2) as well as 1 Greenlander. The participant observation was a six week internship on a guest farm in Arkansas, where we also conducted interviews. We are in the process of analyzing our data with a combination of inductive and deductive coding.

Results

The results of our exploratory study to date is that success is linked with overcoming several main challenges that agritourism providers face: poor internet connectivity, time and labor shortages, and a lack of technological literacy. In our interviews and observations, we have noted some potential solutions to these challenges that could greatly benefit budding agritourism providers such as mentoring or interning programs, skill sharing, technology classes, and more.

Acknowledgements: Thank you to the National Science Foundation Systems Approaches to Understanding and Navigating the New Arctic National Research Traineeship, the University of Maine School of Economics and the Maine Agricultural and Forest Experiment Station for funding this research and to Dogwood Hills Guest Farm for hosting me as an intern.

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Calibration Methodology for Laser Ablation of Ice Core Samples

Lela Gadrani[1,2], Pascal Bohleber[3], Michael Handley[1], Elena V. Korotkikh[1], Andrei V. Kurbatov[1,2], Paul A. Mayewski[1]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Department of Environmental Sciences, Informatics and Statistics, Ca'Foscari University of Venice.*

Abstract: We present preliminary results to refine determination of concentrations in ice core samples using the Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) system developed at the W. M. Keck Laser Ice Core Facility at the Climate Change Institute (CCI), University of Maine (UMaine).

Introduction

Only a few published studies (Avak, Sven Erik 2019; Sneed et al. 2015; Bohleber et al. 2020), have reported concentrations of impurities determined by ultra-high-resolution laser ablation sampling of ice cores. Two major barriers are: a) the complex interaction of the laser beam with the ablated ice, and b) the availability of homogeneous low concentration frozen ice standards with known levels of impurities. In this study we evaluated the applicability of a new methodology for producing artificial ice standards, to be used for calibrating in-situ LA-ICP-MS measurements of 1-meter long ice core sections.

Methods

We tested a methodology developed in the laboratory at Ca' Foscari University of Venice for frozen standard preparation. The method relies on rapid chilling of known aqueous standard solutions in small aluminum chambers using liquid nitrogen. A commercially available "Multielement solution 2A" (5% HNO_3) was diluted in Milli-Q water to concentrations: 20, 60 and 100 ppb. Immediately before lasering, the frozen surface was shaved with a clean ceramic scraping tool inside of a -24°C clean cold room to avoid surface contamination. The artificial ice standards were measured frozen inside of the LA-ICP-MS sample holder for 50 seconds to calculate intensities of Na, Ca, Al, and Pb. During the data reduction step, the first 8 seconds of measured background were removed. We also removed signal washout time before calculating the mean value of the intensity for each element. We used an exponential regression to correlate signal intensities to the corresponding sample concentrations (see Fig.1).

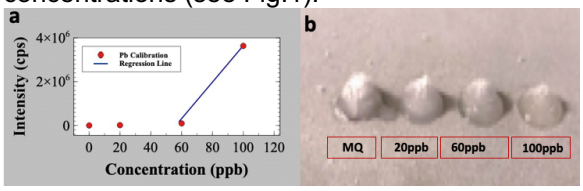

Fig.1. a. An example of the plot from one of the early experiments. b. Photo of the aluminum sample holder for rapid freezing of the standards.

This work will contribute to data quality assurance through interlaboratory comparison of different LA-ICP-MS sampling methods.

Acknowledgements: The National Science Foundation (NSF) Grant number: 1745007.

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Changing Ice-on Phenology of Mountain Ponds in the Northeast US Linked to Arctic Oscillation

Amanda Gavin[1,2], Jasmine, Saros[1,2], Rachel Hovel[3], Sean Birkel[1], and Julia Daly[3]

1. *Climate Change Institute, University of Maine.*
2. *Ecology &Environmental Sciences, University of Maine.*
3. *Earth and Environmental Sciences, University of Maine-Farmington.*

Abstract: Increasing air temperature in the Arctic has been linked to cooler, stormier autumn and winters in the mid-latitudes. Preliminary results show that ice-on dates in a subset of Maine mountain ponds are correlated with the Arctic Oscillation climate index.

Mountain ponds are sentinels of regional and global environmental change; however, the strength of climate change in mountain regions and its impact on aquatic phenological processes remain unclear (Moser et al. 2019; Nelson et al. 2021). Over the last century, winter in Maine has warmed more than other seasons, and this warming may affect the formation dates of ice cover (STS MCC 2020; Kalff 2002).

Arctic Amplification, an accelerated warming of surface air temperatures in the Arctic, is a recent phenomenon that is linked to a negative shift in early winter Arctic Oscillation and subsequent cooler, stormy autumn and winters in the mid-latitudes. Despite many studies that have demonstrated impacts of teleconnections on aquatic phenological shifts, particularly ice-off, comparatively little is known about the drivers of autumn mixing phenology and ice-on and the role of shifting Arctic teleconnections.

Our analysis will use a thermal structure dataset (2008-2021) from nine sub-alpine (>600m ASL) ponds in Maine that show a coherent, decadal shift towards earlier ice-on dates to understand the impact of Arctic-driven teleconnections on the phenology of autumn mixing and onset of ice-on. Maximum cumulative air temperature in November is the best predictor for ice-on in Maine mountain ponds, and when compared to a suite of climate indices, this weather metric is related to the Arctic Oscillation. However, there is a unimodal relationship between the Arctic Oscillation Index and final ice-on dates in the subset of Maine mountain ponds, which warrants future investigation. This research will utilize sentinel mountain ponds to begin to understand the novel ways that Arctic warming may modulate northern hemisphere warming patterns and aquatic phenology.

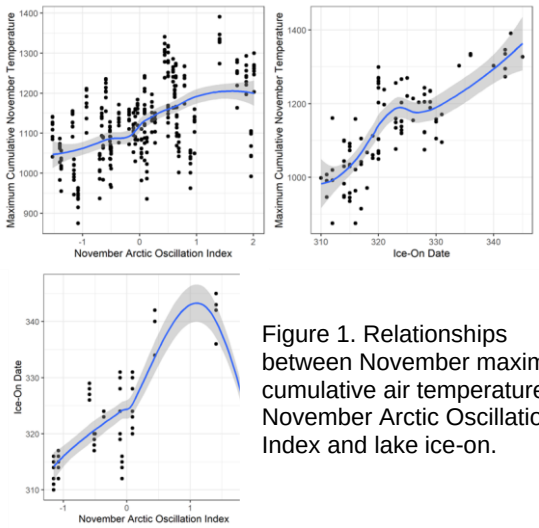

Figure 1. Relationships between November maximum cumulative air temperature, November Arctic Oscillation Index and lake ice-on.

Acknowledgements: NSF SAUNNA NRT.

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The Anthropocene: A New Epoch, a Geologic Event, or an Informal Concept?

Jacquelyn L. Gill[1,2]

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

Abstract: Since 2009, efforts have been underway to formally define the Anthropocene, a concept popularized by environmental chemist Paul Crutzen in 2000. As the Anthropocene Working Group nears a final vote, a recent series of papers have discussed possible candidate start dates, but also whether the Anthropocene—as a concept—serves science best as a geologic event, or even an informal concept. This talk will synthesize the state of the science of defining the Anthropocene, as well as the implications of any formal date or definition.

What is the Anthropocene?

Environmental chemist Paul Crutzen first popularized the concept of the Anthropocene in 2000, to describe the fact that humans have become such a dominant force in shaping the atmosphere as to constitute a new geologic era. In the ensuing decades, scientists, humanists, journalists, activists, and others have used the term as an informal concept that characterizes an era of widespread anthropogenic impacts.

In 2009, the Subcomission on Quaternary Stratigraphy (SQS) of the International Commission on Stratigraphy (ICS) formed an Anthropocene Working Group (AWG), tasked with preparing a proposal to establish the Anthropocene as a new chronostratigraphic series and a formal geologic epoch within the geologic time scale. A wide range of candidate start dates have been proposed, spanning the late Pleistocene to as recent as the year 1964 CE. As the AWG concludes their work, it appears likely that they are converging on the "Great Acceleration" following the second World War (ca. 1950). As with all "golden spike" candidates, this requires activity sufficient to leave a global stratigraphic signature of human activity that is distinct from the Holocene Epoch.

However, a number of scholars across disciplines have raised concerns about attempting to define or formalize an Anthropocene as a new geologic epoch. Some geoscientists have cited the diachronous nature of human activities in the stratigraphic record, suggesting that it would be better characterized as a geologic event (Gibbard et al., 2022). Others in the social sciences and humanities have challenged the ways that human activities and historic processes are understood and incorporated within a geological classification (Ellis et al., 2016). Still others have argued that the Anthropocene serves society best as an informal concept (Swindles et al., 2023), which is how it's been used across disciplines for decades.

In this talk, I'll briefly outline the history of the concept of the Anthropocene, provide and overview of the work of the AWG and some of the most-discussed candidate start dates for an Anthropocene Epoch, and summarize arguments for and against the Anthropocene as an epoch and a diachronous geologic event. I'll also explore the broader implications any definition would have on shaping our understanding of human-environment relationships from an interdisciplinary perspective.

Acknowledgements: This work was catalyzed by a collaboration with geographer Erle Ellis, and we are indebted to the work of the Anthropocene Working Group and our many coauthors for clarifying our own thinking on the term, and its role in society. And of course, I am grateful to the late Paul Crutzen, who first coined the term "Anthropocene," a concept that launched a thousand conversations.

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Glacially Fed Lakes: Sinks of Nutrients and Heavy Metals?

Ansley Grider[1,2], Jasmine Saros[1, 2]

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

Abstract: This study is designed to assess differences in nutrient and heavy metal concentrations between glacially fed and snow/groundwater-fed lakes in Arctic regions of Greenland and Norway. One of our goals is to assess whether glacially fed lakes are sinks of nutrients and heavy metals.

Introduction:

Glaciers are located at an interface between the atmospheric and terrestrial environments, making them potential hot spots for atmospherically derived materials.[1] Atmospherically derived materials, such as nutrients, metals, and contaminants, can accumulate in glaciers over hundreds or even thousands of years.[2] However, the materials that have accumulated in glaciers over many years are melting out at high rates due to warming temperatures in the Arctic.[2]

As glacial melt increases, meltwater flux to downstream ecosystems, such as lakes, has risen. Global glacial-lake volume increased dramatically – by 48% –between 1990 and 2018.[3] In addition, the biogeochemistry of these lakes might also be changing due to the rapid release of glacially derived material in meltwater. Past studies have found nutrient concentrations in glacial lakes to be significantly higher than concentrations in nearby non-glacially fed lakes.[4] Additionally, levels of heavy metals appear to be increasing in glacial lakes.[5] However, few studies have investigated whether glacially fed lakes are acting as sinks of nutrients and heavy metals.

To fill this knowledge gap, our research has three objectives. The first is to study how glacially fed lakes alter the flux of nutrients and heavy metals from glacial to marine systems. The second is to analyze the temporal changes in nutrients and heavy-metal concentrations in glacially fed lakes and snow/groundwater-fed lakes. Lastly, this research will assess lake ecosystem impacts of nutrients and heavy metals by examining diatom community structure and morphology.

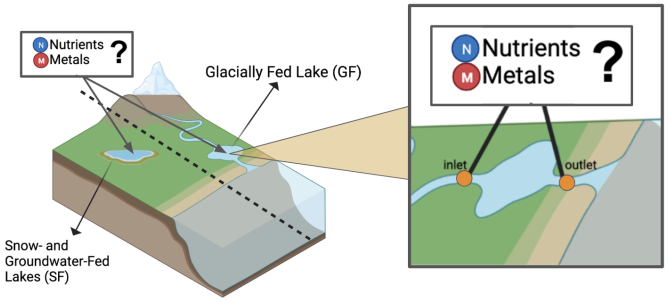

Figure 1. Conceptual diagram of the two main research questions.

Methods: This research will be conducted in West Greenland and Norway. At each glacially fed lake, we will collect water samples in three locations (inlet, mid-lake, and outlet), and analyzed for nutrient and heavy-metal concentrations. We will also collect lake sediment cores from both glacially fed and snow/groundwater-fed lakes, which will be analyzed to understand how nutrients, heavy metals, and diatom communities have changed from past to modern times.

Acknowledgements: Ansley Grider's graduate traineeship is funded by the NSF SAUNNA NRT.

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Reconstructing the Paleoenvironmental Context of the Sebasticook Lake Fish Weir Complex

Kit Hamley[1,2], Reuben Hudson[3], Ruvan DeGraf[3], Megan MacKay[1], Bonnie Newsom[1,4], Jacquelyn Gill[1,2]

1. *Climate Change Institute, University of Maine.*
2. *School of Biology and Ecology, University of Maine.*
3. *College of the Atlantic.*
4. *Department of Anthropology, University of Maine.*

Abstract: Understanding Maine's past ecological and human history has important implications for modern land management efforts and for Indigenous sovereignty. Here we use traditional and novel sedimentary lake core proxies to reconstruct the paleoenvironmental context of the oldest fish weir complex in North America.

Reconstruction of paleoenvironmental contexts at culturally important sites has implications for both management and Indigenous sovereignty. Fecal biomarkers extracted from sedimentary contexts are an emergent proxy that can directly identify Indigenous connections to the cultural landscape. This is the first study to test whether fecal biomarkers are a viable proxy in lake core sediments from the Northeastern United States.

In the fall of 2021, we retrieved a 432 cm sediment core from Sebasticook Lake in the deepest basin adjacent to the fish weir complex at the mouth of the Sebasticook River. We processed the core for charcoal and lipid biomarkers (reported here) as well as other paleoenvironmental proxies (not reported here).

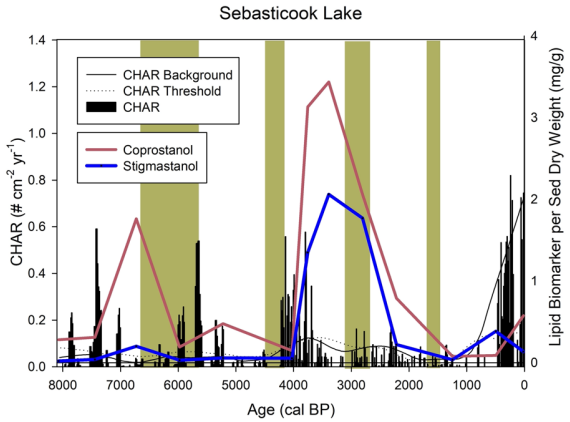

Fig. 1. Sebasticook Lake charcoal (black bars), coprostanol (pink), stigmastanol (blue) and fish weir activity (gold bars).

A ratio of coprostanol:stigmastanol greater than 1 (Fig 1) indicates human presence. Therefore, preliminary fecal biomarker data suggest that human activity may have been more continuous at the fish weir complex than previously indicated by radiocarbon dating (Fig. 1: gold bars indicate heightened activity). Critically, these results demonstrate that fecal biomarker analysis is viable in Maine sediments. They also show the utility of this novel proxy to provide a more complete understanding of cultural activity through time than the archaeological record alone. Preliminary charcoal data suggests there was a shift in fire regime around 5000 years ago, at the time of widespread hemlock decline and supposed hydrological shifts. Further analysis is necessary to understand the paleoenvironmental complexities of this culturally important site, but taken together fecal biomarker, charcoal, and other proxies provide a promising way forward.

Acknowledgements: We thank the Wabanaki Nations THPOs for continued partnership on this research. We are supported in part by MSGC and NSF CAREER- Grant EAR-1753186.

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An Interdisciplinary Review: How Rapid Climate Change Is Impacting Human Health, Environmental Policy, and Voter Behavior

Douglas M. Hasson[1]

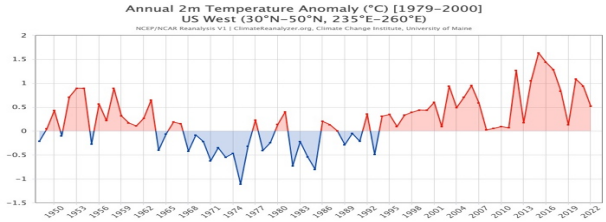
1. *Climate Change Institute, University of Maine.*

Abstract: At the nexus of efforts to address mitigating the impacts of rapid climate change are three broad components: science (including its many disciplines), policy, and politics. While scientists and policymakers have painted a clear picture of the consequences of ongoing anthropogenic carbon emissions, they have at times been held hostage when left to the whims of a fractured, hyper-partisan voting public and the elected officials who represent them. Until elected officials are compelled by voters to prioritize climate policy over other critical issues, meaningful progress will continue to be controlled by modern "Culture War" politics, tribalism, and a political elite driven by their myopic quest for re-election.

Goals: As an interdisciplinary Ph.D. student at UMaine's Climate Change Institute and a 35+ year political operative, I have endeavored to take a three-pronged "case study" approach to research designed to help us gain insights into the aforementioned critical components—science, policy, and politics—as they relate to rapid climate change. Case Study #1, entitled "PFAS in South Greenland Meltwater," relates to findings specific to the 2022 UMaine NSF/SAUNNA NRT expedition to Greenland.

Case Study #2, "The Science, Policy, and Political Implications of Drought in the American Southwest" looks at a) a historical review of drought in the US S.W.; b) an assessment of past and present policy as it relates to water allocations to the Colorado River Basin; c) a scientific analysis of the drivers of the drought in the American southwest; d) an examination of polling data specific to climate change; and e) an analysis, using UMaine/CCI's Climate Reanalyzer, of projected drought conditions and, possible policy and political implications.

Case Study #3: Rooted in the early insights of moral philosophy, Dr. Jonathan Haidt's Moral Foundation Theory suggests individuals come equipped with "intuitive ethics," aka basic moral beliefs about right and wrong used to ground judgments that drive decision-making. Haidt proposes these values are innate and can be traced back over the course of human existence.



Haidt lays out five common virtue frameworks which reflect intuitive ethics, including Harm/Care, Fairness/Reciprocity, Ingroup/Loyalty, Authority/Respect, and the Purity/Sanctity foundation. Haidt's "moral foundations hypothesis" then proposes modern liberals base their decision-making on different moral frameworks than conservatives. Of note, while Haidt proposes these virtues are innate, they are modifiable over time as we each learn local virtues and moral practices. As such, these foundations can influence human motivation to act on vital problems facing society, including climate change. This research attempts to a) repackage the language and lessons of MFT to test Haidt's core hypothesis in the context of climate messaging; b) break down the dominant partisan biases driving decision-making specific to climate change and modern electoral politics.

Acknowledgments: First, my advisory committee Chair Dr. Paul Mayewski (UMaine/CCI), and advisors Dr. Sean Birkel (UMaine), Dr. Mark Brewer (UMaine), Dr. Charles Norchi (UMaine Law), and Dr. Alan Gerber (Yale). Next, the students and scientists affiliated with UMaine's 2022 NSF/SAUNNA NRT Greenland expedition including Dr. Jasmine Saros (PI), Dr. Kristin Schild, Dr. Kiley Daley, Dr. Mariusz Potocki, Dr. Robert Northington (Hussen), Dr. Amanda Lynch (Brown), Mr. Misa Saros, and graduate students K. Anderson, L. Naveira, K. Grimaldi, A. Gavin, V. Hazukova, and A. Crowley (NC State). Finally, Dr. J. Haidt (NYU) and Dr. R. Bloomfield (Cornell), the crew of the research vessel ArcticEarth, as well as the staff at Tasermiut Outfitters.

Earlier Lake Ice-Out Leads to Warmer Bottom Waters and Higher Dissolved Oxygen Concentrations in Small Arctic Lakes in West Greenland

Václava Hazuková[1,2], Benjamin T. Burpee[3], Robert M. Northington[4], Nicholas J. Anderson[5], Jasmine E. Saros[1,2]

1. *Climate Change Institute, University of Maine, Orono, ME.*
2. *School of Biology and Ecology, University of Maine, Orono, ME.*
3. *GZA GeoEnvironmental Inc., Coventry, CT.*
4. *College of Science and Humanities, Husson University, Bangor, ME.*
5. *Department of Geography, Loughborough University, Loughborough, UK.*

Abstract: Arctic lakes in West Greenland respond to more frequent occurrences of earlier ice-out unexpectedly. We found that warmer temperatures in bottom waters of the lake that are observed during years with early ice-out are linked with higher dissolved oxygen concentrations. While the expected, textbook, relationship between dissolved oxygen concentration and water temperature is negative, we observed the opposite—likely as a result of prolonged period of spring mixing during years with early ice-out that allows for full oxygenation of the water column.

Abrupt warming in West Greenland has shifted the average timing of lake ice-out 6 days earlier since the early 1990s (Saros et al., 2019). While trends towards earlier ice-out have been documented globally, it is unclear what the consequences of changing ice phenology are of for lake thermal and biogeochemical structure, especially in high-latitude lakes where ice-out occurs close to summer solstice and spring mixing tends to be short.

We used a unique, long-term dataset of vertical temperature profiles and dissolved oxygen measurements data collected intermittently over the past 20 years from 15 ultra-oligotrophic lakes located near Kangerlussuaq in West Greenland to investigate how changing ice-out affects lake thermal structure and oxygen concentration in lake bottoms.

Early ice-out, especially when followed by cooler weather conditions, is linked to high hypolimnetic temperatures (up to ~13ºC) while the lowest temperatures (~4ºC) were observed during years with late ice-out and high air temperatures that can prevent full spring mixing (Fig. 1A). When ice-out happens early, further from the peak solar insulation, more substantive mixing can occur, leading to higher oxygen saturation in hypolimnion despite warmer temperatures (Fig. 1B).

Acknowledgements: Dan and Betty Churchill Exploration Fund, and NSF 1203434, 1144423.

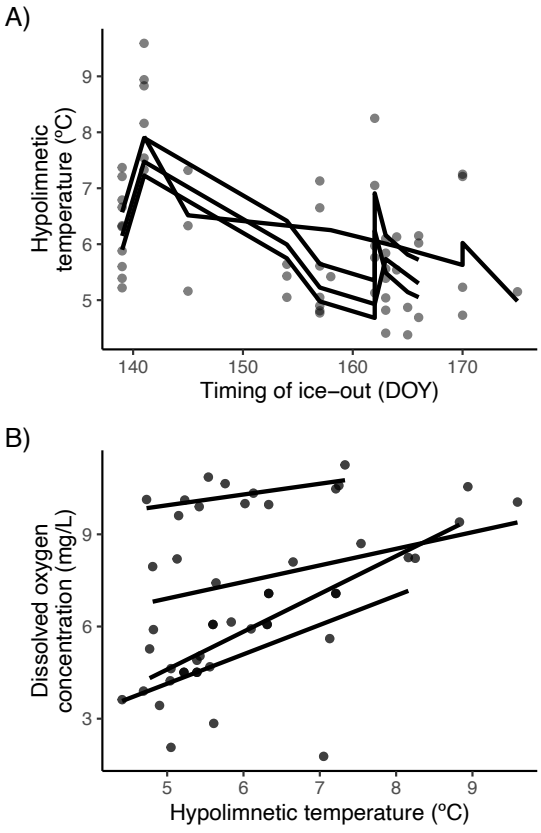


Fig. 1. Predicted relationships between ice-out, hypolimnion temperature (A) and dissolved oxygen (B) in 4 lakes in West Greenland.

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Taking Stock of Global Mitigation Progress in "Light of Equity and The Best Available Science": Should Science "Heat Up" Debates About Equity?

Cindy Isenhour[1,2]

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

Abstract: The Global Stocktake (GST) is the ambition mechanism of the Paris Agreement. Parties agreed that the GST must be designed "in light of equity and the best available science". Based on an extensive analysis of negotiations, we argue that the "best" science must engage with equity.

Background: The Global Stocktake

The Paris Agreement (PA) marked a significant shift in climate negotiations. In contrast to the Kyoto Protocol, which required developed countries to act first based on historical responsibility and capacity, the PA required all countries to set legally binding mitigation targets. Resulting concerns about the injustice of requiring countries with little culpability or capacity to act were addressed through the promise of significant financial support and the provision that commitments would be "nationally determined". The voluntary nature of Paris commitments, however, raised concerns about how to ensure all parties would make fair contributions to the global mitigation effort. The GST was designed to address these concerns by "taking stock" of collective progress every five years. The designers of the Paris Agreement argued that the GST is "key to making it happen" (Espinosa 2022) but must be conducted in light of equity and the best available science.

Method & Theory: "Best Available Science"

Based on observations of negotiations and extensive analysis of all inputs since Paris, our research examines how parties conceptualize an "equitable process" and the extent to which these concepts are making their way into climate Fig. 1.

Session of the Technical Dialogs for the GST Sharm El Sheik, Egypt. November 2022

science. Prominent scholars have argued that conversations about equity are political and thus threaten both scientific neutrality and collective action (Klinsky et al. 2017). From this "consensus" perspective, scientific contributions should deemphasize the politics of equity as a means to "cool down" conversations about mitigation burden sharing. By contrast, a growing number of scholars argue that the best available science cannot ignore the equity and justice-implications of mitigation burden sharing without endangering the Global Stocktake and the success of the Paris Agreement (Lahn 2017).

Results: "Science to Allocate an Equitable Share of the Remaining Carbon Budget"

Our analysis of party inputs suggests that there are multiple conceptualizations of equity and proposals for how science might help to determine a fair allocation of the remaining carbon budget. These include calculations based on per capita shares, historical responsibility, capacity, the need for development, or trade-adjusted emissions. Regardless of the strategy supported, it is clear that the overwhelming majority of parties are insistent that science in support of the GST must directly engage with the politics of equitable mitigation burden sharing, or risk the failure of the Paris Agreement

Acknowledgements: NSF Award #1934426.

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Spatial Dynamics of Maine Lobster Landings in a Changing Coastal System

Jaeheon Kim[1,2], Cameron Hodgdon[3], Keith S. Evans[2], Yong Chen[3]

1. *Climate Change Institute; Ecology and Environmental Sciences, University of Maine.*
2. *School of Economics, University of Maine.*
3. *School of Marine and Atmospheric Sciences, Stony Brook University.*

Abstract: The American lobster (*Homarus americanus*) fishery in the state of Maine is a significant part of Maine's coastal economy, ecosystem, and social identity. To better understand the effects of climate change on fishery productivity, we modelled the expected shift in suitable lobster habitat under different climate scenarios. We then modelled the spatial-temporal distribution of fishery landings in different climate driven habitats.

The Maine lobster fishery is the most valuable single species fishery in the US, and has seen a dramatic rise in productivity over the past 30 years. However, the Gulf of Maine (GoM) where the fishery operates is warming faster than 99% of the rest of the ocean (Pershing *et al*., 2015. Understanding how a climate will affect lobster populations may help understand the Maine lobster fishery's resilience to climate change.

We used a bioclimate envelope model and the ME-NH seasonal bottom trawl survey to estimate suitability indices for lobsters for the following habitat variables: bottom temperature (c), bottom salinity (psu), depth (m), latitude, and longitude (Tanaka and Chen 2016). We used fine scale, modelled environmental data from FVCOM (Finite Volume Community Ocean Model) to interpolate Habitat Suitability Index (HSI) onto the GoM at a management level scale. We mapped HSI for past, current, and future climate using the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways (RCP) 4.5 and 8.5 scenarios. Our analysis shows that habitat has significantly improved from the moderate lobster abundance regime (1996-2008) to a high lobster abundance regime (2009-2018). However, habitat suitability is expected to decrease in the northeast and offshore regions for the Spring, while habitat suitability will increase across the entire coast for the Fall in the near (2028-2055) and far (2072-2099) futures.

We averaged seasonal HSI per lobster management zone and used annual fishery landings to build a Generalized Additive Model (GAM) to predict landings per zone given climate. The model was validated through hindcasting analysis and used to forecast onto IPCC climate scenarios. The model suggests that zones A, B, and C will see an increase in landings, zone D will see a decrease in landings, while zones E, F, and G will not see a significant change in landings (figure 1). These findings have important implications for future management of the lobster fishery under a rapidly changing climate.

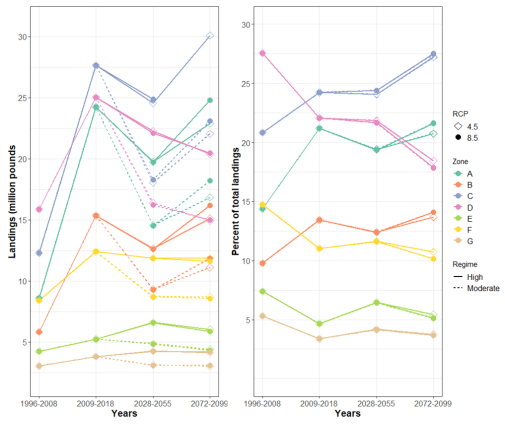

Fig 1. Total and proportional interpolated landings from for historical (1978-2005), baseline (2004-2017), and forecasted (2028-2055; 2072-2099) time periods and RCP 4.5 and 8.5 scenarios.

Acknowledgements: We thank the Chen lab at Stony Brook University for their input. MDMR for input and data. The Chen lab at UMass Dartmouth for FVCOM Data. And my cat.

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The Relationship Between Snow Accumulation and Melt Percolation on Eclipse Icefield, Yukon, Canada

Ingalise Kindstedt[1, 2], Karl Kreutz[1,2], Dominic Winski[1, 2], Emma Erwin[1, 2, 3], Mikaila Mannello[1,2], Renée Clavette[1,2], Seth Campbell[1, 2]

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

Abstract: **The areal extent and behavior of alpine glacier surface melt vary widely in space and time. Here, we present plans to evaluate the effect of snow accumulation on percolation at Eclipse Icefield using firn cores and ground-based radar data.**

Project Goal & Motivation

The goal of this project is to characterize how melt percolation through snow and firn varies with snow accumulation rate across the Eclipse Icefield. Glaciers retain water in the form of snow that over time is condensed into ice. The rate of snow accumulation is effectively the rate at which the glacier reservoir is replenished and sustained for long-term use. For alpine glaciers, the rate of reservoir drawdown is largely controlled by the quantity and behavior of surface melt, which vary with changes in elevation and local topography.[1] There is evidence that melt percolation also varies with accumulation rate thanks to snow's insulating effect on the underlying firn, allowing liquid water to percolate and persist longer before refreezing.[2] However, this relationship remains largely untested due to challenges in accessing high-elevation accumulation zones. Here we present a plan to examine the relationship between snow accumulation and melt percolation with in situ measurements on the Eclipse Icefield.

Data Collection

We will recover two clusters of three shallow (10-15 m) firn cores. We will compare layer densities and melt features between high- and low-accumulation sites. Melt features include discrete ice lenses and melt-affected firn, distinguished by its opaque, bubbly appearance and lack of grain boundaries. We will measure ice lens thickness, intensity, and frequency in each core, as well as the percentage of melt-affected firn. We will use two types of ground-penetrating radar to interpolate near-surface layer thickness between core sites: a traditional common-offset (CO) survey and a multi-offset (MO) survey. MO systems have several advantages over their CO counterparts: an increased signal-to-noise ratio, improved horizontal resolution and imaging of dipping reflectors, and higher sensitivity to changes in water saturation.[3] We will use the CO system to repeat measurements taken in 2016, and test whether the MO system better detects discrete melt features within the firn.

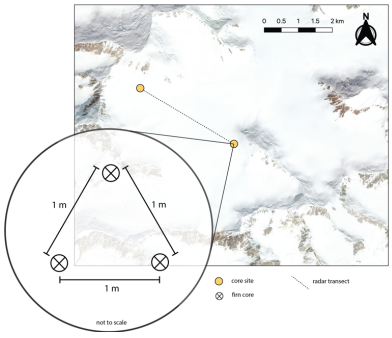

Figure 1. Sampling plan for Eclipse Icefield.

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

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Expanding methods for historical cyanobacterial reconstructions using sedDNA and photosynthetic pigments

Avery N. Lamb[1,2], Jasmine E. Saros[1,2], Michael T. Kinnison[2], Peter Countway[3], Robin Sleith[3]

1. *Climate Change Institute, University of Maine.*
2. *School of Biology and Ecology, University of Maine.*
3. *Bigelow Laboratory for Ocean Sciences, Maine.*

Abstract: Concern over increases in cyanobacterial blooms, the toxins they can produce, and the effect of climate change on these increases are becoming more prevalent in the Northeastern U.S. This research optimizes the concurrent paleolimnological measurement of photosynthetic pigments and sediment DNA (sedDNA) that can be used to assess the drivers of cyanobacterial harmful algal blooms (cyanoHABs) in Maine over the past 150 years.

The state of Maine, USA, is experiencing some of the most significant winter warming in the country. *Gloeotrichia*, a toxin-producing, bloom-forming taxon, has already been identified in many low-nutrient Maine lakes, including drinking water sources and recreational areas[1]. *Gloeotrichia*'s life history makes it especially sensitive to changes in winter temperatures and is therefore of distinct concern in Maine. A multi-proxy paleolimnological approach using established (photosynthetic pigments) and newer (sedimentary DNA [sedDNA]) proxies can provide a deeper understanding of ecological changes driven by climate and/or anthropogenic activities. Sediment collection and sedDNA extraction protocols, however, require optimization for adequate measurement and quantification of concurrent photosynthetic pigments and sedDNA.

Preliminary Results:

Common methods of cleaning and decontaminating equipment (e.g. sodium hypochlorite, or bleach) prior to sedDNA sample collection interfere with photosynthetic pigment preservation. A comparison of decontamination reagents indicates that a rinse with 10% and 70% ethyl alcohol prior to sample collection maintains aseptic conditions while preserving photosynthetic pigments.

Initial quantitative PCR (qPCR) G*loeotrichia* assays successfully amplified cyanobacterial DNA in the sediment. Consistent positive amplification occurred in the surface of sediment cores, however, only one deeper sample deeper within the core positively amplified (Fig. 1). Optimization experiments were completed to determine if a lack of sedDNA *Gloeotrichia* amplification resulted from a true absence or a failure of detection. Methods of increasing the efficacy and accuracy of sedDNA measurement included increasing the volume of sediment extracted, reducing qPCR inhibition with pre- and post-extraction buffers, and including another cyanobacterial qPCR assay as a positive control (e.g., *Cyanobium*).

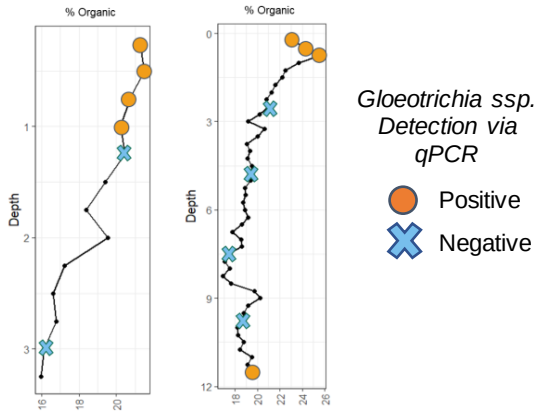

Fig. 1. Positive (orange circle) or negative (blue x) amplification of Gloeotrichia sedDNA in two preliminary sediment cores, Sebago Lake (left) and Long Lake (right).

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

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Reconstructing Maine's Fire History Using Braided Knowledge Systems

Madeleine Landrum[1, 2], Erin Cabral[2], Lena Sorice[2], Jacquelyn Gill[1, 3]

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

Abstract: Though our paleoecological understanding of Indigenous fire use is geographically and temporally limited, historical observations and Indigenous place names indicate that the Wabanaki people used fire to clear land for agriculture and improve hunting grounds. This study aims to expand our knowledge of human and climate drivers of fire regimes in Maine since deglaciation.

Introduction:

The degree to which Indigenous burning shaped vegetation prior to European contact, particularly in New England, is a source of great debate[1,2]. Paleoecological studies are also able to shed light on New England's fire history. However, there is conflict between sedimentary records and interpretations of fire in New England regarding whether the causes of fire were natural or anthropogenic and if they were important drivers for local or regional ecosystem processes[1,3]. This study aims to use high-resolution charcoal records from sediment to examine changes in fire regime around important archaeological sites in inland and coastal Maine.

Methods:

In 2021, we collected sediment cores from Witch Hole Pond (WIHO) in Mount Desert Island, Maine and Perch Pond (PEPO) in Oldtown, Maine. Radiocarbon dates obtained from leaves and twigs show both cores date back to deglaciation. Cores have been processed for charcoal at 1 cm intervals using protocols by Whitlock and Larsen (2002)[4]. Raw charcoal concentrations (pieces cm^{-3}) were converted to accumulation rates (CHAR; particles $cm\ yr^{-1}$) using CharAnalysis in MatLab.

Results:

Charcoal records show high accumulation from 10,500–7,500 years BP at both PEPO and WIHO (Fig. 1). At PEPO, charcoal accumulation rates decline between 7,500–3,200 BP, while at WIHO, it declines between 5,000–400 BP.

Discussion:

Records indicate high variation in charcoal accumulation rates and therefore variation in fire regimes in both inland and coastal sites. More work is needed to determine whether these varying regimes are due to people, climate, both, or neither.

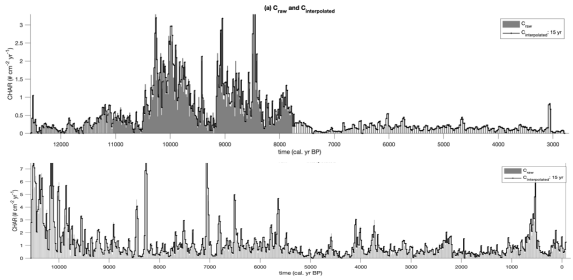

Fig. 1. Charcoal accumulation rates for Perch Pond (above) and Witch Hole Pond (below).

Acknowledgements: Thanks to the BEAST Lab, Andrea Nurse, Bonnie Newsom, Darren Ranco, Donald Soctomah, Isaac St. John, Kendyl Reis, Acadia National Park, and the Hirundo Wildlife Refuge. *Funding:* NSF GRF, Dan and Betty Churchill Exploration Fund, CSD Visiting Graduate Researcher Grant, and GSG Grants.

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Investigating the Influence of Spanish Colonization on Climate Adaptation and Community Resilience on Peru's North Coast

Elizabeth Leclerc[1, 2], Heather Landázuri[3]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Paleowest, LLC, Arcadia, California.*

Abstract: Our project combines history, archaeology, and earth sciences to investigate the legacy of Spanish colonization on the long-term adaptation and resilience of people in north coastal Peru to El Niño climate phenomena, with the goal of identifying strategies to improve resilience to future events. Preliminary work in 2022 evaluated the research potential of the Lambayeque region and seven towns devastated by an El Niño in AD 1578.

The interannual El Niño-Southern Oscillation affects the tropical Pacific, including the desert north coast of Peru where Coastal and Eastern Pacific-type El Niños cause intense rainfall with sometimes devastating consequences. Through millennia of experiencing El Niño disasters, coastal Andeans developed ways of responding to these events (St. Amand et al. in press). However, evidence suggests Spanish colonial governance undermined communities' long-term adaptation and resilience to El Niño. In AD 1578, the first large magnitude El Niño to occur after the arrival of the Spanish in AD 1532 led to the loss of entire villages and thousands of indigenous lives (Alcocer 1987 [1580]).

Methods. In June 2022, we traveled to Peru's Lambayeque region (Figure 1) to gather information about local communities, locate towns affected by the AD 1578 El Niño, and assess the potential for an interdisciplinary research project that will become the core of Leclerc's dissertation work. In each town we documented important public spaces, cultural institutions, and historic architecture. Where research indicated towns were destroyed and relocated after the event, we sought out original town sites to document their archaeological character and degree of disturbance.

Results and Discussion. We confirmed the pre-AD 1578 locations of five towns. Three recovered in place and are heavily developed today (Chiclayo, Lambayeque, and Ferreñafe). Two relocated after the El Niño (Túcume and Jayanca); the original sites are lightly developed and may have intact archaeology. We identified but were unable to visit two additional sites of potential value (Ferreñafe Viejo and Lambayeque Viejo). Next, we will evaluate historical archives in the region and identify suitable locations for archaeological testing. We will also continue to develop connections in pursuit of a community-integrated project.

Fig. 1. Lambayeque region showing notable towns (circles) and archaeological sites (triangles).

Acknowledgements: This research was funded by The Robert and Judith Sturgis Family Foundation, McGillicuddy Humanities Center Faculty Grant Program, and National Science Foundation (Awards #1916910 and #1840992).

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Snow Properties and Observations on the Quintino Sella and Seward Glaciers, Kluane National Park & Reserve, Yukon Territory, Canada

Mikaila Mannello[1,2], Jonathan Maurer[1,2], Seth Campbell[1,2]

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

Abstract: 400 MHz ground-penetrating radar (GPR) surveys were conducted on the Quintino Sella and Seward Glaciers between 2894 to 1706 m a.s.l. in May 2022. We observe no elevational trend and a narrow range of relative permittivity values across the nine ground truth points with an average relative permittivity of 1.37. These values indicate a dry snow pack.

We characterized the near-surface properties of the Quintino Sella Glacier in Canada between May 6-18, 2022 to constrain estimations of snow water equivalent (SWE). We collected 400 MHz ground-penetrating radar (GPR) data which penetrated approximately 10-40 m deep, allowing for the detection of the depth of annual snow accumulation, firn, and the firn-ice transition.

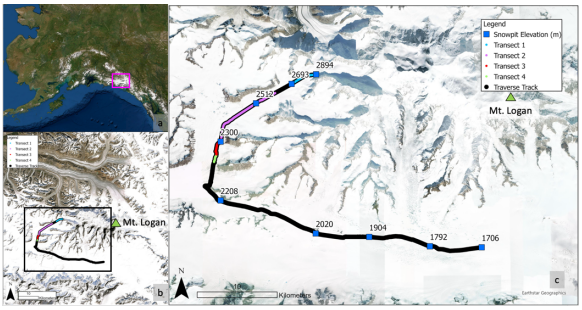

Fig. 1. (a) Study location in NW Canada (pink box); (b) GPS tracks where data was collected on Quintino Sella and Seward Glacier; (c) Snowpit locations with elevations (m a.s.l.) labeled.

Snow pits were dug to the first ice layer at nine snow sampling sites covering the 1200 m elevational gradient. At each site we conducted ground-truthing efforts to constrain radiowave velocity and calculate depth from GPR surveys. Radiowave velocity is affected by density and water content of the snow. Ground-truthing consisted of horizontally inserting a survey-grade snow probe at the bottom of each snow pit, so that it extended into the sampling wall 2.5 m. The depth of the probe, z, was recorded and the GPR was towed perpendicular to the probe, parallel to the sampling wall, at 2.5 m distance from the pit sampling wall along an approximately 8-10 m track. The radiowave two-way travel time (TWTT) to the hyperbola vertex was then used to calculate relative permittivity(ε) of the snowpack.

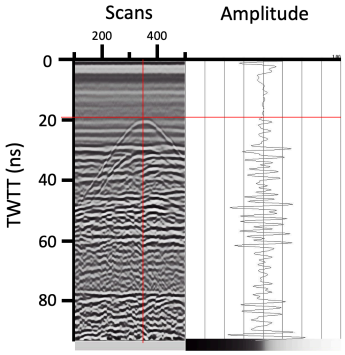

Fig. 2. Example ground truth GPR data. Hyperbola vertex of (red cross hairs) corresponds to the metal probe in the snowpack which was oriented parallel to the snow surface.

Preliminary results show combined snow and firn thickness to range between 5-30 m and no elevational or temporal trend in ε determined from ground-truth observations, with an average of 1.37, corresponding to a radiowave velocity of 0.256 m ns^{-1}. The GPR horizon at the bottom of the annual accumulation was difficult to identify from other layers within the stratigraphic profile. Therefore, estimates of the snow water equivalent (SWE) of the 2021-22 water year are an area of continued work. Future surveying recommendations include collecting continuous GPR transects across the equilibrium line altitude (ELA) to identify an unconformity between the annual accumulation and firn, below.

Acknowledgements: This research was generously supported by the Dan and Betty Churchill Exploration Fund, Mount Logan Ice Core Project, Canadian Ice Core Lab, and Maine Space Grant Consortium. Data was collected by Kira Holland, Jonathan Maurer, Mikaila Mannello, Darren Farley, and Pierre Valero.

Oh, the Places They'll *Grow*!: Do Trees' Climate Tolerances Differ Across Life-History?

Bailey P. McLaughlin[1, 2], Brian J. McGill[1, 2]

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

Abstract: Describing the role of climate as a biogeographic control on species distributions has a long history in the ecological literature and is particularly relevant for understanding a species' ecological niche. To date, most efforts to map, measure, and/or model species' climatic niches rely on information gleaned from adult or age-unspecified distribution data. Such approaches ignore the possibility that a species might experience differences in its climatic tolerances across ontogeny. If conspecific adult and juvenile climatic niches differ, then the implementation and/or interpretation of age-agnostic analyses could be limited. To address this, we estimate, measure, and compare the climatic niches of over 200 U.S. tree species partitioned into their distinct life-history stages (seedling, sapling, adult). We find little difference in species' life-stage-partitioned niches, suggesting relative stasis in species' environmental tolerances across life-history.

Accurately defining a species' climatic niche is of critical interest in ecology. To map and measure a species' climatic niche, geographic occurrence data is coupled with environmental data to characterize a species' distribution in n-dimensional 'climate space.' Understanding a species' distribution in climate space provides insight into its ecological tolerances and has important predictive applications.

Potentially complicating this, however, is the notion that species *might* experience different climate tolerances across ontogeny. If true, life-history differences should be considered when mapping, interpreting, and applying the niche. Acknowledging this, Grubb (1977)[1] suggests a two-part addendum to Hutchinson's (1957)[2] fundamental niche concept in which a species has both a *regeneration niche* and an *adult survival niche*, which are expected to differ. Despite Grubb's postulation and its potential implications, a large-scale, multi-species test of the regeneration niche concept remains missing from the literature.

Here, we build from Grubb's hypothesis to assess whether juvenile and adult climatic niches differ, using trees as a model taxon. We pair geographic occurrence data from the U.S. Forest Inventory and Analysis database with climate data from the WorldClim database to estimate the climatic niche space occupied by the seedling, sapling, and adult life-stages of over 200 U.S. tree species, from which we quantify niche differences between life-stages to evaluate both within- and among- species variation. We define the climate space using three climate variables with documented relevance to tree ecology[3], minimum temperature of the coldest month, mean temperature of the warmest quarter, and annual precipitation.

Preliminary results suggest that, for tree species, climatic niches are relatively stable across life-history.

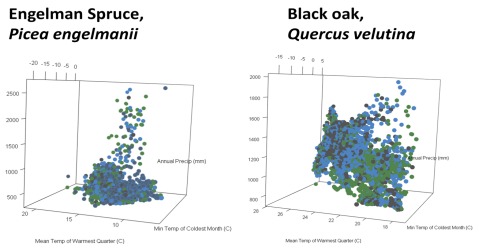

Fig. 1. Example tree distributions, partitioned by life-stage, in climate space. Blue represents seedling occurrences, gray sapling, and green adult.

This work presents a large-scale and standardized evaluation of the regeneration niche concept, with the potential to advance an understanding of ecological niche theory and its myriad applications.

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

Bibliography: [1] Grubb, 1977; [2] Hutchinson, 1957; [3] Prentice et al., 1991.

Reconstructing Extinct Herbivore Community Structure Through High-Resolution Coprolite Analysis: An Insight into the Mammoth Steppe's Coproecology

Alessandro Mereghetti[1, 2], Jacquelyn L. Gill[1, 2]

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

Abstract: During the Pleistocene, the Arctic harbored a diverse community of cold-adapted herbivores that disappeared over the course of the last 20,000 years. The mechanism that allowed the coexistence of a high biomass of different herbivore species (including Mammuthus primigenius, Coelodonta antiquitatis, Bison priscus, Equus sp., Rangifer tarandus) in an environment low in plant diversity and productivity is still a subject of debate. According to niche theory, coexistence between herbivore species is promoted by dietary specialization, with different species feeding preferentially on specific food items. Studies based on fossil bones isotopes give us conflicting results on the degree of overlap of Arctic herbivore diets. To better understand how extinct herbivores partitioned their diet, we conducted a multi-proxy analysis of coprolites (sub-fossil feces) from Yakutia, Siberia, dating back to the Late Pleistocene. We combined both traditional (macrofossils, pollen, phytoliths) and cutting-edge (ancient DNA) paleoecological tools to obtain a high-resolution environmental and dietary reconstruction. We used this unprecedented number of samples to reconstruct the diet of extinct Arctic herbivores with greater accuracy than any other previous work on the subject, shedding light on their diet and environment across more than 30, 000 years of the late Pleistocene.

Project Goals

The objective of this study is to analyze a set of 58 coprolites from Siberia to a) reconstruct the environment of extinct Arctic megaherbivores b) understand how they partitioned their dietary niche and c) investigate if the herbivores environment and/or diet changed over a period spanning 30,000 years and including the Last Glacial Maximum (LGM). Leveraging a synergistic, multiproxy approach that combines traditional (macrofossils, pollen, phytoliths) and cutting-edge (ancient DNA metabarcoding) paleoecological tools allowed us to obtain a high-resolution reconstruction of not only the environment, but also the diet of the herbivores that roamed the site. Our results show the permanence of the mammoth steppe at the site across different intervals of the last glacial period. Additionally, we were able to reconstruct with great accuracy the diet of three extinct species (*Mammuthus primigenius*, *Coelodonta antiquitatis*, *Bison priscus*) over multiple thousands of years at the site. Our preliminary results show that the woolly mammoth was a generalist species, with a niche space that included those of the woolly rhino and the steppe bison, which instead were not overlapping between each other (Figure 1). The analysis of a high number of coprolites allowed us to reconstruct the ecology of the site with unprecedented detail, and to shed light on the mechanisms that shaped the mammoth steppe and allowed the coexistence its dwellers.

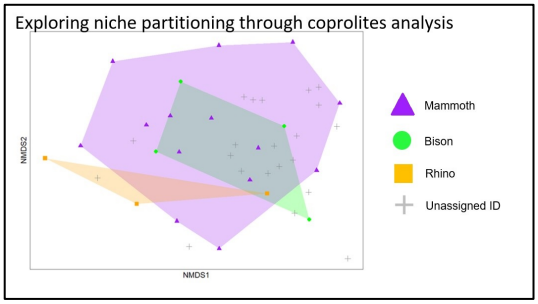

Figure 1. Niche partitioning of M. *primigenius, C. antiquitatis* and *B. priscus* based on pollen analysis.

Acknowledgments

This project is possible thanks to an NSF CAREER grant earned by Dr. Jacquelyn Gill, and thanks to her mentoring and guidance. Additional fundings were received through the Graduate Student Governments and the Geological Society of America.

Abrupt Climate Change in Maine During Termination I

Maraina Miles[1,2], Brenda Hall[1,2], Aaron Putnam [1,2], Thomas Lowell [3]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Department of Geology, University of Cincinnati.*

Abstract: The termination of the last ice age (17.8-11.7 ka) provides a unique view into how the global climate system responds to rapid warming. Extreme seasonality, with drastically unequal temperature changes in summer and winter may have played a key role in abrupt climate changes during the termination, but the full implications - and even the existence - of this seasonality remain controversial. Here, I will test the hypothesis that extreme seasonality affected the North Atlantic region during the termination and that this has skewed our interpretation of iconic climate events, such as the Bølling-Allerød (BA; 14.6-12.9 ka). Specifically, I will use changes in the extent of the Maine Ice Cap, constrained by ^{10}Be exposure ages of a newly discovered moraine sequence in northern Maine to reconstruct summer temperature variations.

The global warming of the last glacial termination (~17.8 – 11.5 ka) marks the most recent analog for our planet's current rapid warming. It was characterized by abrupt climatic oscillations, 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 conventional view is that climate during these abrupt changes was anti-phased between the hemispheres as the result of a 'bipolar seesaw' (Broecker, 1998). However, recent data from alpine glaciers suggest that the hemispheres instead may behave synchronously during these abrupt changes, and that the discrepancy between records is due to increased seasonality (Denton, 2005).

Here, I will test whether the Maine Ice Cap advanced during the BA/ACR in step with glaciers in the southern hemisphere. New LiDAR has exposed a previously unknown moraine complex in the southern section of Baxter State Park (Fig. 1). Preliminary data, including one radiocarbon age from a nearby pond and exposure-ages of boulders located ~30 km south of the moraine suggested that this landform may have formed during the BA/ACR. To determine the timing of ice readvance, I collected samples from boulders along the moraine for cosmogenic ^{10}Be exposure dating which have yielded an average age of 14.6 ± 0.4 ka, indicating deposition during the beginning of the BA/ACR. These data add to emerging evidence that shows globally synchronous climate change during the late glacial, thus eliminating the need for a bipolar seesaw.

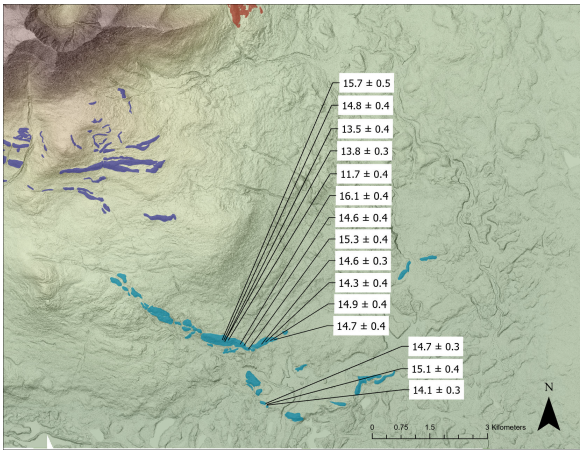

Fig. 1. Newly discovered moraine complex (blue), southern Baxter State Park. ^{10}Be exposure ages indicate deposition at beginning of the BA/ACR (14.7 - 12.9 ka) with an average age of 14.6 ± 0.4 ka.

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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Water Quality in the Rapidly Changing Environment of South Greenland

Ligia Naveira[1, 2], Paul A. Mayewski[1, 2,] Mariusz Potocki[1], Kevin Anderson[1, 2], Douglas Hasson[1], Kristina Grimaldi[3], Douglas Introne[1], Michael Handley[1], Elena Korotkikh[1, 2]

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

Abstract: Reconnaissance sampling reveals the spatial distribution of surface water chemistry and PFAS in South Greenland.

Greenland provides a notable example of rapid climate change in the Arctic. Previous studies of Greenland ice sheet (GrIS) and meltwater chemistry show how shifts to the hydrology and climate affect, and will affect, the export of nutrients, ions, and reactive sediments to polar waters. Consequently, changes in water quality can critically impact human and ecosystem health.

In South Greenland, previous work has demonstrated the importance of glacier meltwater in supplying polar waters with essential nutrients, such as significant inputs of phosphate, ~15% of bioavailable contribution to Arctic oceans, and large concentrations of amorphous silicon (Hawkings et al. 2017). Nonetheless, studies on the water chemistry of South Greenland have been limited in spatial scale and have yet to characterize the impact of local to distant atmospheric inputs.

We conducted reconnaissance sampling in South Greenland in June 2022. We covered approximately 9,500 Km^2 by sailing boat, zodiac, and foot. We collected 216 surface water samples, including 94 samples of seawater, 70 samples of streams/rivers, 42 samples of lakes/ponds, 7 samples of meltwater streams, 2 snow samples, 16 samples of PFAS, 4 microplastic/microfiber samples, and 4 mercury samples. We analyzed the chemical composition of surface water for major soluble ions, major/trace/rare elements, stable water isotopes (δ18O and δD), and 25 types of PFAS. Our study addresses the spatial distribution of water chemistry to set up a baseline study of the water quality in South Greenland and a framework for future monitoring. We aim to improve the understanding of weathering processes and assess the contribution of atmospheric inputs from anthropogenic and natural sources trapped in GrIS and adjacent glaciers. Preliminary results indicate that the most abundant cation in surface water is Ca^{2+}, whereas the main anion is Cl^-. The isotopic concentration ranged from -5 to -18.6 ‰ in δ18O, with more depleted values in streams/rivers fed by glaciers. Two sites presented lead (Pb) above World Health Organization health standards (10,000 ng/L). In freshwater samples, the concentration ranged from 31 to 17,407 ng/L, and in seawater, from 24 to 2,529ng/L (Fig. 1).

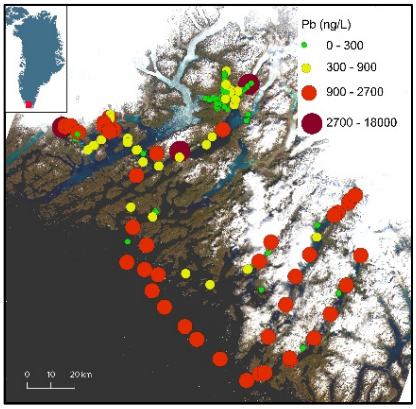

Fig. 1: Map displays sampling sites for Pb.

Acknowledgments: A grant from the NSF NRT-NNA System Approaches to Understanding and Navigating the New Arctic (SAUNNA) program (PI Saros).

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Temporal Instability of Leaf Economic Spectrum Relationships Among the Genotypes of Two Temperate Crop Species

Pratima Pahadi[1,3], Jay Wason[2], Seanna Annis[1], Brian McGill[1,3], Yong-Jiang Zhang[1, 3]

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

Abstract: Leaf economic spectrum (LES) relationships have been studied across many plant lineages and at different organizational scales but the status of the LES relationship across genotypes of a single crop and its stability across years has not been tested to date. We used sixteen genotypes of wild blueberry with high genotypic diversity that were semi-naturally grown in Maine, USA across four years. We found functional traits of wild blueberries fell withing the domain of Glopnet but the LES relationships across genotypes were not always found in all years. Trait syndrome of wild blueberries also shifted by changing environmental conditions across years. These findings could probably be due to a narrow range of trait values and fluctuating environmental conditions across years.

Project Goals:

The goal of this project is to assess whether LES (Fig. 1) relationships exist in a unique agricultural system with high genotypic diversity and to test if leaf functional, nutrient and structural traits demonstrate temporal shifts due to temporal changes in environmental conditions.

The leaf economic spectrum or LES characterizes a strategy for a fast or a slow rate of return on a carbon investment in leaves and reflects a trade-off between long leaf lifespan and high photosynthetic rate. This trade-off works as a general principle governing the development of leaf functional traits (McGill et al. 2006). Although, LES trait relationships have been reported at global scale, and in different plant lineages, the existence of LES has shown mixed results, with some continuing to find it and others failing to find it. Our study provides a new attack on this question by examining the existence of the LES at small spatial scales across genotypes and years.

Results:

We found high variation in leaf structure and physiology among stems, among genotypes, and across years in wild blueberries. Interestingly, the global LES tradeoffs were not always/consistently found in all years. We also found that the trait syndrome was shifted by changing environmental conditions over the years, as suggested by the PCA results. Interestingly, the trait syndromes of two species were separated in one year, but overlapped in other two years, suggesting a temporal dimension in niche separation.

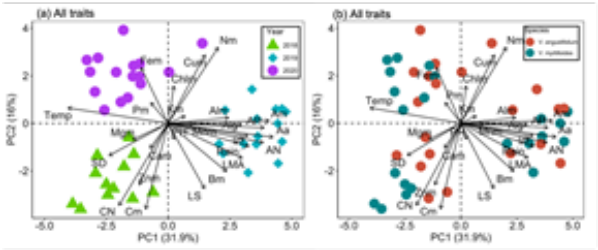

Fig. 1. Principal Component Analysis (PCA) of mean values of the combination of leaf functional traits, leaf structural traits, and leaf nutrient traits combined for 2018, 2019, 2020 with years loading on the background (a) and with species loadings on the background (b).

Acknowledgements: This work was supported by the USDA National Institute of Food and Agriculture, Hatch Project Number ME0-21832 and ME0-22021, and McIntire Stennis Project Number ME0-42121 through the Maine Agricultural and Forest Experiment Station.

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Investigating Climate Drivers of Decreasing Mayfly Populations in Maine

Mica Pugh[1,2], Jasmine Saros[1,2], Serena Laro[2], Robert Northington[1], Hamish Greig[2]

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

Abstract: Mayfly populations may be declining in Maine, based on anecdotal reports from lake fishing groups. We are using paleolimnological approaches to investigate whether warming is altering lake habitat and potentially driving these declines.

Mayfly Populations in Maine

The "burrowing mayfly" (*Hexagenia limbate*; Figure 1.*)* is a keystone prey species. In some remote areas, Maine residents have started to report notable decreases in mayfly populations. In particular, the Yoke Ponds in Maine are a site of concern. We are investigating whether recent warming is altering lake habitat in the Yoke Ponds area, and potentially driving the declines in mayfly populations.

Fig. 1. The burrowing mayfly (*Hexagenia limbate)*. Photo taken by Lynette Elliott (2005).

Warming air temperatures can alter lake summer stratification, both in terms of increasing the length of time the lake is stratified and altering the depth of the surface mixed layer. These changes in turn can affect deepwater oxygen concentrations, with prolonged stratification and/or less deepwater volume leading to lower deepwater oxygen concentrations. These climate-driven lake habitat changes may be involved with the recent declines in mayfly populations.

Our objectives are to assess whether lake thermal structure has changed in the Yoke Ponds area, and whether deepwater oxygen concentrations have changed as a consequence of altered lake stratification patterns.

We will use paleolimnological approaches in two lakes in the Yoke Pond area to address these objectives. The relative abundance of the diatom taxon *Discostella stelligera* will be used downcore to reconstruct lake thermal structure (Saros et al. 2012) over the past 200 years. The assemblage composition of chironomids will be used to assess whether deepwater oxygen concentrations have changed (e.g., Little & Smol 2001). Collectively, these results will help to understand potential drivers of mayfly population declines and inform possible remediation strategies.

Acknowledgements: Yoke Ponds Group.

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Assessing the Compatibility of Climatic Mechanisms Responsible for the Most Recent Ice Age Climate Through Constructing a ^{10}Be Glacial Chronology in the Wind River Range at 44°N

Alexzander Roman[1,2], Aaron Putnam[1,2], Lauren Woods[1,2], Peter Strand[1,2], Tricia Hall[2], Katie Westbrook[2]

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

Abstract: The Boulder Lake moraines at 44° N can be directly compared to moraines in an opposing insolation regime in New Zealand at 44°S, effectively providing a key test on orbital theories for glacial cycles due to each hemisphere having opposing insolation signals. Furthermore, the timing of moraine construction at Boulder Lake can be compared against chronologies for atmospheric CO_2, testing the impact the greenhouse gas had on driving glaciation. Finally, the Wind River Range is located on the periphery of the western sector of the Laurentide Ice Sheet, making it well positioned to test the role the ice sheet had in amplifying the effects of insolation and climate change throughout the Northern Hemisphere.

The Problem:

As evident in recent studies by Marcott et al. (2019) and Tierney et al. (2020), it is widely believed that a combination of orbital parameters, feedback from ice sheets, and carbon dioxide levels were the primary mechanisms behind the most recent ice-age climate and glacial termination. However, there are several problems with these assumptions. For example, mountain glaciers in the Southern Hemisphere achieved maximal positions several millennia before the Northern Hemisphere ice sheets and persisted in an LGM mode throughout the entire insolation cycle[6].

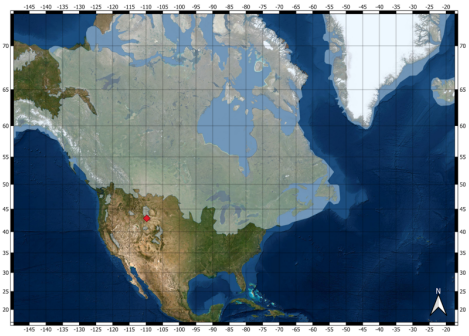

Fig. 1. The maximum extent of the Laurentide Ice Sheet on North America during the last glaciation. The Wind River Range, represented by the red diamond, was located on the periphery of the ice sheet.

I have conducted fieldwork in the Wind River Range in the Western US. The Wind River Range is located 44°N, allowing it to be compared to areas in the Southern Alps of New Zealand, where insolation curves are opposite. The area is also upwind and on the periphery of the western sector of the Laurentide Ice Sheet, resulting in the alpine glaciers encountering and monitoring the same air masses that interact with the ice sheet hours later, acting as natural thermometers. In areas that have already been dated, the ages suggest that the retreat of alpine glaciers and ice sheet margins in the Western US coincided with the same retreat elsewhere in North America, Europe, New Zealand, and South America[1,2,3,4,5].

Acknowledgements: This research is supported by the National Science Foundation and the Comer Family Foundation.

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Observational Evidence for Depth-Dependent Iceberg Ablation Rates Using Apres, Remote Sensing, and in Situ Hydrography

Kristin M. Schild[1,2], David A. Sutherland[3], Irena Vancova[4]

1. *School of Earth and Climate Sciences, University of Maine.*
2. *Climate Change Institute, University of Maine.*
3. *Department of Earth Sciences, University of Oregon.*
4. *British Antarctic Survey.*

Abstract: Greenland glaciers have undergone rapid acceleration, discharging increased mass into the ocean. Icebergs act as point sources, injecting freshwater and modifying circulation as they transit into the open ocean. The degree of impact depends upon the iceberg ablation rate; however these are poorly constrained. Through an intensive field campaign, we are able to compare current methods here.

Motivation:

Greenland glaciers have undergone a rapid acceleration (doubling to tripling of their speeds) over the last two decades (Mouginot et al., 2019), with approximately half of this mass discharged as icebergs. The increasing input of freshwater to the subpolar North Atlantic has significant implications for fjord stratification and circulation. However, the magnitude and timing of this meltwater input has been challenging to quantify because iceberg melt rates are largely unknown.

Approach:

Several approaches have been developed to measure or compute iceberg deterioration, however these methods have been challenged by data availability, unknown subsurface iceberg geometry, and limited opportunities for in situ validation. Here we focus on a single iceberg (SF0419) during an intensive summer 2019 field campaign in Sermilik Fjord, southeast Greenland, and use a combination of remote sensing (drone) and in situ (GPS, multibeam sonar, ApRES, CTD) data to calculate iceberg ablation rates (Fig. 1).

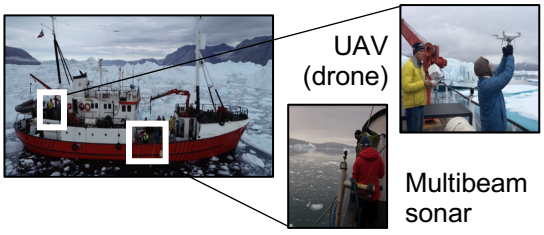

Fig 1. Ship-based measurements collected in Sermilik Fjord, Southeast Greenland in 2019

Results:

Results show there is an order of magnitude difference in the calculated ablation rates across the five methods (Fig. 2); with lower ablation rates if the method focuses solely to melt (ApRES, modeling) vs the inclusion of melt and mechanical deterioration (GPS, drone, multibeam) in the calculation.

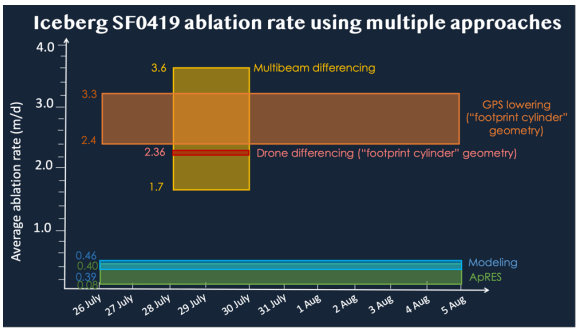

Fig. 2. Calculated ablation rates for Iceberg SF0419 using five different methods.

Acknowledgements: Support for this work was provided by NASA NIP award 80NSSC21K0945 (K.M. Schild) and NSF-OPP Award 1552232 (D.A. Sutherland).

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Tracking Shifts in the Westerlies at Baboon Lakes, Central Sierra Nevada, California Over the Last 12,000 years

Meghan Spoth[1,2], Aaron Diefendorf[3], Megan Corcoran[3], Brenda Hall[1,2], Aaron Putnam[1, 2], Jacquelyn Gill [2,4], Scott Mensing[5]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *University of Cincinnati.*
4. *School of Biology and Ecology, University of Maine.*
5. *University of Nevada, Reno.*

Abstract: The Baboon Lakes record in the Sierra Nevada, California offers insight into the hydrology of the American West over the last 11,500 years. This multiproxy study will facilitate further understanding on migrations of the northern westerlies linked to the pattern of regional droughts.

Introduction:
Extreme drought has led to critical water shortages with increased fire activity in the American West and a need for more accurate climate predictions. The past hydrology of this sensitive region could afford unique insight into potential patterns and mechanisms of future water availability. Latitudinal migration of the westerly winds and associated storm tracks may play a primary role in controlling precipitation patterns over this region. However, few records have documented past shifts in wind patterns independently from precipitation variations. Here, we use plant wax isotopes preserved in lake sediment cores from the high-elevation Baboon Lakes of the Sierra Nevada, California to reconstruct the relative position of the westerlies and hydrologic changes over the last 11,500 years. We pair these analyses with pollen and charcoal data to assess variations in plant communities and fire history.

The Sierra Nevada is a key site for studying this problem as the mountains steer incoming storms either north or south of the range (Fig. 1), depending on the location of the westerlies. Thus, this region is not only a potential contributing factor to the spatial pattern of droughts, but also is ideal for tracking of the westerlies, because the isotopic difference in storm tracks between north and south-shifted positions is large. This shift also influences regional precipitation patterns.

Results:
The Baboon Lakes sediment record covers the last 11,500 years and documents fluctuations between low organic clays and more organic-rich

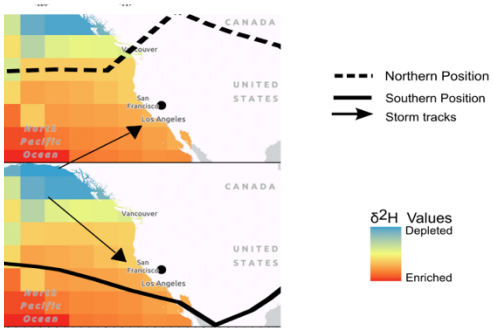

Fig. 1. Conceptual diagram of paleo positions of the westerlies and the effect of shifting wind patterns on precipitation isotopic signatures (IAEA/WMO, 2015).

sediment. Initial plant wax data show plant-derived *n*-alkanes with chain lengths ranging from C_{21}-C_{33}, conifer- specific diterpenoids, and angiosperm-specific triterpenoids are preserved. The $\delta^{13}C$ values are consistent with mixing of plant waxes derived from both conifers and angiosperms and suggest the conifers grew under high water stress conditions. Average chain-length values indicate significant variations in flora through time, which will be tested with pollen data and compared to a charcoal record to better characterize these changes.

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Acknowledgements: Baboon Lakes field crew, The Robert and Judith Sturgis Family Foundation, GSA Graduate Research Grant.

A Sky Island Perspective: New England Alpine Plant Distributions Across the Region

Andrea J. Tirrell[1,2], Michael Cianchette[2], Jacquelyn Gill[1,2]

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

Abstract: New England alpine zones are small and fragmented, which could make them vulnerable to global change. Assessing the near-term vulnerability of alpine plant communities is challenged by a lack of standardized, repeat surveys and long-term monitoring data. Island biogeography theory predicts that alpine species richness is a function of area and connectivity, but this has remained untested for the low-elevation alpine zones of the northeastern United States. We found that connectivity, but not area, had a significant positive effect on alpine specialist species richness, meaning there is likely dispersal between fragmented mountain top sites. We also found that microtopographic features like slope and elevation significantly impacted species richness.

Introduction:
Alpine ecosystems across the globe are changing due to a combination of climate change, human-mediated disturbance, as well as shrubification and treeline advance. In New England, alpine plant communities exist as small remnants of a once vast tundra ecosystem and are often considered "islands" of alpine vegetation. The Equilibrium Theory of Island Biogeography states that the size of an island, along with connectivity between islands, determine species richness and diversity on said island[1]. Microtopographic features are also thought to play a role in species distributions, especially in alpine environments[2]. Therefore, understanding how island biogeography and microtopography determine species distributions across New England's alpine zones could allow for better conservation and management strategies in the face of these threats.

Results:
Our results suggest that alpine species distributions across New England are influenced by connectivity to other peaks, as well as microtopographic features like slope and elevation. These results do not align with traditional island biogeography theory, as area did not have a significant impact on alpine specialist species richness. Higher elevation sites with steeper slopes, in closer proximity to other alpine areas were more likely to have higher species richness. These results may suggest that New England's alpine plant communities are more resilient than previously thought; dispersal as a result of connectivity could prevent extirpation of alpine species from the region, while diverse microtopographic features promote the presence of microclimate refugia.

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Examining the Meteorology and Climatology of Recent Extreme Weather Events

Ana M. Trueba[1], Sean D. Birkel[1,2], Kirk A. Maasch[1,3], Jasmine E. Saros[1,4]

1. *Climate Change Institute, University of Maine.*
2. *Cooperative Extension, University of Maine.*
3. *School of Earth and Climate Sciences, University of Maine.*
4. *School of Biology and Ecology, University of Maine.*

Abstract: Extreme weather events are becoming more common as the climate warms. This project will examine the meteorological development and climate teleconnections for key recent extremes observed in the Arctic and broader North Atlantic. One such example is a pronounced warm wave that caused a record late-season spike in surface melt across the Greenland Ice Sheet on September 3, 2022. Understanding how and why particular extreme events develop may lend to better forecasting and climate impact projections.

Introduction

The Greenland Ice Sheet melt season typically runs April–October, with peak melt occurring between June and August. A record late-season spike in surface melt was observed September 3, 2022, when a high pressure system to the southeast drew warm, moist air over Greenland, raising temperatures up to 15°C. Surface melt area for this event reached 592,000 km^2, compared to the 36,000 km^2 mean for 1981–2000[1]. As global temperatures rise, the melt season will lengthen and Greenland may see more extreme melt.

Methods

ECMWF ERA5 reanalysis[2] was processed using NCAR Command Language (NCL) to calculate standardized anomalies (1979-2000 climatology) for 2-meter temperature and total column precipitable water across Greenland (Fig. 1). Additional work will examine the large-scale weather patterns and climate teleconnections associated with this event.

Results

Precipitable water was over three standard deviations for much of the Greenland. The anomalies were highest in northern Greenland, where values were five standard deviations above average. Standardized 2-meter temperature anomaly was greatest in northern Greenland, between three and four standard deviations.

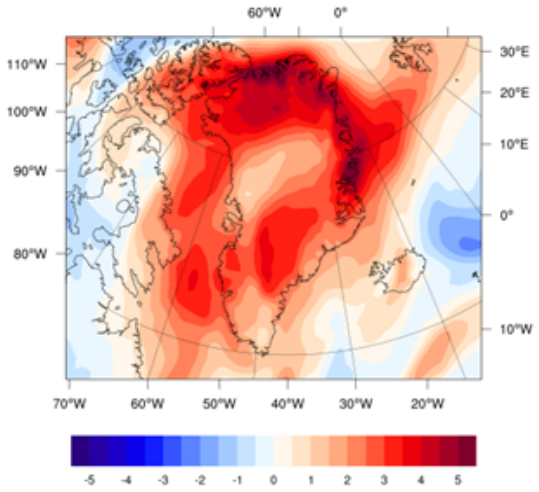

Fig. 1. Standardized Precipitable water anomaly over Greenland, September 3, 2022. Units are sigma, where +/- 3 are typical thresholds for extremes.

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Climate and Waste Management: Calls for Closing Resource Loops

Erin Victor[1, 2, 3]

1. *Climate Change Institute, University of Maine.*
2. *Department of Anthropology, University of Maine.*
3. *Senator George J. Mitchell Center for Sustainability Solutions, University of Maine.*

Abstract: Transitioning to a circular economy may be key to addressing climate change. However, conversations around circularity largely revolve around increasing recycling rates and advancing new technologies such as chemical recycling. I argue that the current focus on slowing resource loops through technological fixes distracts from upstream solutions that close resource loops.

Waste & Climate

Although waste disposal only accounts for 2.7% of greenhouse gas emissions in the U.S.[1], the climate impact of the current throw-away consumer culture is much greater when accounting for the embedded carbon in materials. The Ellen MacArthur Foundation has recently purported that transitioning from a linear "make-take-waste" economy to a circular economy is critical for addressing climate change. They argue that a circular economy, which designs waste out of our economic system through reuse, repair, remanufacturing, and recycling, could address the 45% of emissions attributable to the production, transportation, use, and disposal of material goods[2].

Current Solutions

The average person in the U.S. generates 4.9 pounds of trash daily. In 2018, this amounted to over 290 million tons of municipal solid waste, of which only 24% was recycled.[3] Low recycling rates, both at the state and national level, have encouraged policymakers to consider extended producer responsibility (EPR) policies for packaging that shift the financial and/or operational responsibility for the end-of-life management of packaging to product owners. To date, four states (Maine, Oregon, Colorado, and California) have passed EPR policies for packaging, and over a dozen states are expected to introduce bills this year. Within these EPR policy discussions, determining the role of chemical recycling in waste management is a particularly contentious topic. Chemical recycling is an emerging and diverse set of technologies that use high temperatures or chemical processes to break down plastics into their chemical components through pyrolysis or gasification. Life cycle assessments suggest that chemical recycling has higher climate and environmental impacts than mechanical recycling[4]. Environmental advocates warn that the toxic emissions from chemical recycling will exacerbate health inequalities since facilities are disproportionally located in low-income communities or communities of color[5].

Conclusion

Policymakers must take the climate and environmental justice impacts of different waste management options into consideration when designing policy. That said, recycling, whether mechanical or chemical, merely *slows* resource loops. The current focus on increasing recycling under EPR policies and debates around chemical recycling keep the conversation focused on technological fixes to the growing waste problem. I argue that we must shift our focus to *closing* resource loops through reducing overall consumption and promoting reuse and repair.

Acknowledgments: Dr. Cindy Isenhour.

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Addressing Mercer's Paradox: A Comparison of Mid-Latitude ^{10}Be Glacier Chronologies from Moraines Deposited During the Last Glaciation

Lauren Woods[1,2], Aaron Putnam[1,2], Zander Roman[1,2], Peter Strand[1,2], Tricia Hall[2], Katie Westbrook[2]

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

Abstract: Determining the causes of glacial cycles and their terminations is essential in understanding how the climate system operates. A fundamental problem involves the role of orbital forcing in controlling glacial cycles. Here we present a ^{10}Be chronology of moraines deposited at Soda Lake, western Wind River Range, Wyoming, USA. By comparing this chronology to similar records from mid-latitude glacier systems in the Southern Hemisphere, we find that glacier systems in both hemispheres exhibited simultaneous fluctuations to maximal positions on the millennial scale despite opposite insolation signals.

Introduction: The long-standing hypothesis put forward by Milankovitch (1941) builds on the ideas of Murphy (1869) and suggests that glacial cycles are driven by orbitally modulated redistribution of incoming solar radiation reaching Earth's surface. According to this hypothesis, summer insolation intensity controls melt on glacier ablation zones, leading to advance during periods of reduced insolation intensity and recession during periods of intensified insolation. Because the effects of orbital precession yield asynchronous insolation changes between the hemispheres, by the Murphy-Milankovitch hypothesis glacier systems would have achieved maxima at different times between the polar hemispheres. However, in 1984, John H. Mercer recognized that the Laurentide Ice Sheet and South American mountain glaciers achieved maximum extents around the same time, despite being subject to opposing summer insolation intensity signals. The observations made by Mercer (1984) have been dubbed 'Mercer's Paradox' by Denton et al. (2021).

To evaluate Mercer's Paradox, we present a comparison of ^{10}Be chronologies from mid-latitude glacier systems in the Wind River Range, Wyoming, United States and the Southern Alps, New Zealand. Both of these mountain ranges are at similar latitudes and receive relatively the same amount of summertime insolation but on an out-of-phase basis, allowing for an accurate and reliable comparison. By addressing Mercer's Paradox, we aim to gain insight into the synchronicity of full-glacial conditions, millennial scale fluctuations, and the timing of the termination between hemispheres during the Last Glaciation.

Results: The moraine chronology from Soda Lake is well aligned with records from the Southern Hemisphere mid-latitudes, indicating that full glacial conditions and millennial-scale glacier fluctuations were synchronous between the hemispheres during the Last Glaciation. Glaciers in both hemispheres achieved maximal extents several times throughout a complete insolation cycle. By addressing Mercer's Paradox we find that the Murphy-Milankovitch hypothesis cannot explain the synchronous pattern of glaciation between the hemispheres.

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A Key to Past Ocean Temperatures: Mg/Ca of Foraminiferal Calcite in the North Atlantic (*N. incompta*)

Madelyn N. Woods[1,2], Katherine A. Allen[1, 2]

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

Abstract: The Holocene (0 - ~11,000 Cal. yrs. BP) is a warm interglacial climate mode. Reconstructing ocean temperatures and oxygen isotopes ($\delta^{18}O$) in the Gulf of Maine region could provide essential context for understanding and predicting modern climate change.

Holocene Ocean-Climate Dynamics:

The Holocene epoch has been characterized by long-term shifts in mean conditions (e.g., SST, precipitation, and ocean circulation) punctuated by abrupt ocean-climate events[1]. The causes of these events are not fully understood, but the fairly stable mean annual solar insolation at 45˚N suggests ulterior driving forces caused by internal feedbacks in the ocean-climate system. High-resolution paleo-reconstructions of the North Atlantic (NA) during a warm interglacial climate mode could provide essential context for understanding and predicting modern climate change.

The North Atlantic is an ideal location to understand natural ocean-atmospheric dynamics during an inter-glacial period. The Gulf of Maine (GOM) in particular has the potential to experience major temperature changes due its unique position at the confluence of the Northern Hemisphere Westerlies, the warm, salty Gulf Stream, and the colder, fresher Labrador current[2]. Different water sources entering the GOM are characterized by different seawater oxygen isotope ($\delta^{18}O_{SW}$) signals[3], and changes in North Atlantic ocean circulation are likely to be reflected in temperature and $\delta^{18}O$ values of the GOM.

GOM Reconstructions:

The goal of this project is to generate continuous ocean temperature and $\delta^{18}O_{SW}$ records in the GOM for the past ~11,000 years. A principal proxy used for determining sea surface temperatures is the ratio of magnesium to calcium (Mg/Ca) in foraminifera calcite shells[4]. Temperature is considered the primary factor controlling foraminiferal Mg/Ca, but uncertainty still exists for secondary controls such as salinity and carbonate system influences[6]. We will utilize prior Mg/Ca proxy calibrations and corrections obtained from the North Atlantic to complete paleotemperature reconstructions downcore in the GOM, using the planktonic foraminiferal species *Neogloboquadrina incompta.* A rigorous assessment of Mg/Ca in *N. incompta* from the GOM will improve our paleo-reconstructions and help us to better understand temperature and circulation changes during the Holocene.

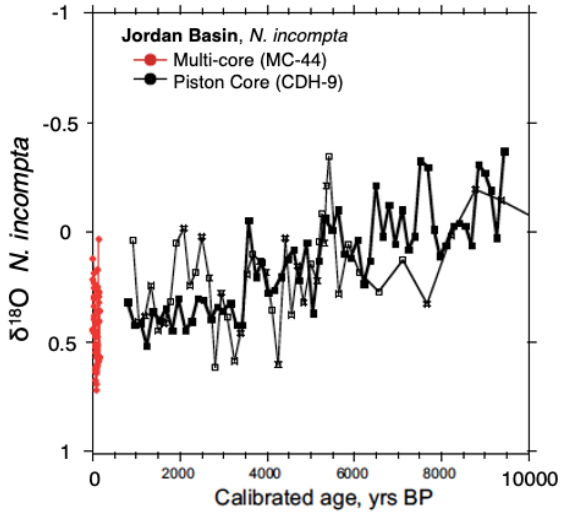

Fig. 1. The $\delta^{18}O$ of calcite from *N. incompta* in sediments from the Jordan Basin, GOM, indicating a possible cooling during the Holocene[5].

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Fleeting Fields of Zadar (Croatia): Tracking Millennial-scale Urbanization, Land Cover Change, and the 'Great Acceleration' of the Twentieth Century

Gregory Zaro[1,2], Ante Blaće[3], Josipa Baraka Perica[4], Filipa Jurković Pešić[4], Martina Čelhar[4], Karla Gusar[4]

1. *Climate Change Institute, University of Maine.*
2. *Department of Anthropology, University of Maine.*
3. *Department of Geography, University of Zadar.*
4. *Department of Archaeology, University of Zadar.*

Abstract: This study draws from archaeological, historical, cartographic, and remote sensing data to detail broad changes in urban landcover and green space around Zadar, Croatia, from prehistory to the present. The deep-time perspective taken here highlights the unprecedented pace of urban change that has occurred over the last half century when compared to its millennial-scale past.

Project Overview

Exploring the persistence of ancient cityscapes can serve to highlight qualities that may have strengthened urban sustainability or resilience through time (Smith et al. 2021). In the Mediterranean, urban landscapes originated as early as the Bronze and Iron ages, and although many now lay in ruin, some continue to persist into the modern era. These historic settlements expand outward from their urban nuclei into the rural countryside, often replacing what has traditionally been a rural mosaic of arable agriculture, orchards, vineyards, pastureland, and woodlands with a homogenized array of industrial, commercial, and residential spaces.

The goal of this ongoing project is to provide an overview of urban land cover change around Zadar, a 3,000 yr old settlement along Croatia's Adriatic coast. Zadar was a major Liburnian Iron Age center in the first millennium BCE and subsequently transformed into a Roman colony by the turn of the millennium. It remained a nucleated peninsular city throughout the Middle Ages and into the Modern Era before rapidly expanding in the late twentieth century (Fig. 1).

Prior to its modern era expansion, Zadar's immediate hinterland was predominantly characterized by green space, including legacies of Roman centuriation, and historic drystone field walls and cairns. Austrian cadastral records from 1826 (ARCANUM 2023) also highlight the predominantly agrarian nature of Zadar's mainland terrain prior to its displacement by expanding urban land cover. Only when Zadar's contemporary growth is projected against the city's millennial-scale past does the unprecedented pace of change come into focus.

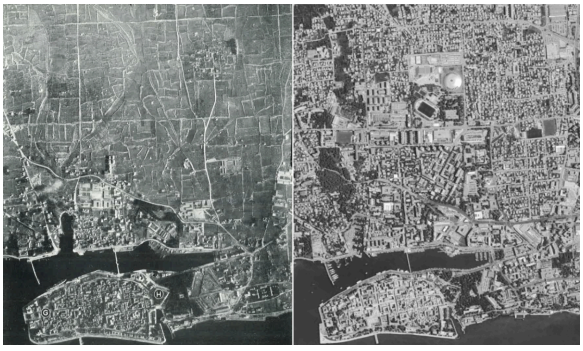

Fig. 1. *Left*: 1944 Royal Air Force image of Zadar and its agrarian hinterland. Orthogonal lines reflect Roman period centuriation (agrarian land survey); irregular linear features reflect historic drystone field walls and terraces (published in Bradford 1957, plate 42). *Right*: 2020 Google Earth image illustrating displacement of green space by urban land cover change in late 20th C.

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