Implications for Southwest Greenland from a Warming Arctic

Jeffrey D. Auger[1, 2], Sean D. Birkel[1, 2], Paul A. Mayewski[1, 2], Kirk A. Maasch[1, 2], Keah C. Schuenemann[3]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Environmental and Atmospheric Sciences, Metropolitan State University of Denver.*

Abstract: The Arctic is warming at an alarming rate with respect to the northern hemisphere. The enhanced near-surface warming in the Arctic, or Arctic Amplification (AA), is due to a positive feedback loop involving sea ice, snow cover, albedo, and insolation absorption. Here, we show how Arctic amplification influences weather in Southwest Greenland.

In recent years, the Arctic has warmed at nearly double the rate of the northern hemisphere (Serreze *et al.*, 2009). Sea ice loss and decreased snow cover, are the mechanisms driving the enhanced Arctic warming, or Arctic amplification (AA; Serreze *et al.*, 2009). Here, we show that AA is accompanied by changing precipitation patterns in Southwest Greenland.

In climate model simulations, the atmosphere response to AA is a weakening of the meridional pressure gradient. A relaxed pressure gradient leads to a decrease in zonal wind speeds and an increase in the meridional component. Francis and Vavrus (2015) show that circulation patterns at 500 hPa have become wavier due to AA, since 1995.

Comparing results from Francis and Vavrus (2015) to Greenland blocking, we find a transition near 1995 from rare blocking events to a marked increase in blocking. With the increase in meridional flow, moisture is advected to higher latitudes increasing precipitation. Auger *et al.* (in review) show a statistically significant ($p > 0.05$) increase in both precipitation amount and variability in Southwest Greenland, also starting in 1995 (Fig. 1).

As the Arctic continues to warm at an enhanced rate, it is expected that the large-scale atmospheric waves will move more slowly and with larger amplitudes. Increased frequency of blocking events will slow westerly wind speeds and advect more heat and moisture to higher latitudes, further increasing temperatures in the Arctic. Southwest Greenland has already shown a marked increase in both amount and variability of precipitation and is likely to increase with the enhanced Arctic warming into the future.

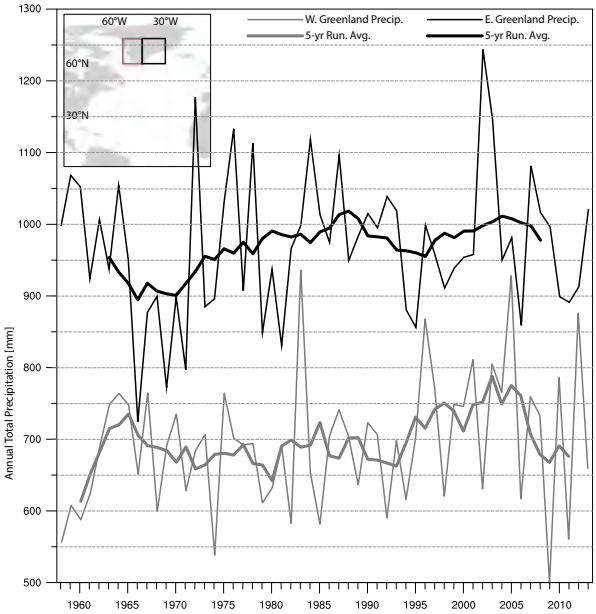

Fig. 1 Precipitation in southwest (gray) and southeast (black) Greenland from JRA-55.

Acknowledgements: This work was supported by NSF award PLR-1417640.

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Direct Geologic Constraints of the East Antarctic Ice Sheet During the Pliocene

Alexandra Balter[1,2], Gordon Bromley[1,2], Holly Thomas[2], Greg Balco[3]

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

Abstract: To understand how the East Antarctic Ice Sheet (EAIS), the largest ice sheet on earth, will respond to future warming, we must resolve its sensitivity to warmer climate regimes in the past. We will exploit the glacial-geologic record in the central Transantarctic Mountains (TAMs) to delineate the former thickness and configuration of the EAIS during past periods of warmer-than-present climate. Specifically, we will use the Pliocene (~3-5 Ma), when global temperatures were 2-3°C higher than today[1], as an analog for our greenhouse future.

Project goals

The EAIS contains >50 m sea-level rise (SLR) equivalent. Resolving the sensitivity of the EAIS to warmer-than-present climate conditions is therefore critical for modeling future SLR. During the Pliocene, global temperatures were ~2-3 °C higher than today, making this period a plausible analog for our greenhouse future. However, the EAIS' resilience during Pliocene warming has long been disputed: some studies call for a reduced EAIS footprint during the Pliocene[2], while others argue for the EAIS's inherent stability[3]. Our research will provide direct geologic evidence of the Pliocene EAIS extent in the TAM (Figure 1), addressing this enduring debate and providing robust constraints for SLR modeling.

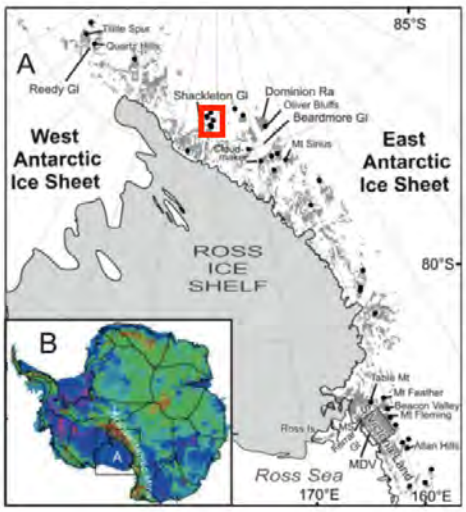

Figure 1: A) Location of Roberts Massif (red box) at the head of Shackleton Glacier. B) Map of Antarctica.

Objectives of this project are to 1) determine past EAIS extent by mapping the distribution of relict glacial features deposited by the EAIS at Roberts Massif, an ice-free area of the central Transantarctic Mountains (TAM) and 2) date these features using exposure-age dating. Moraine sequences of Pliocene age will show that the ice sheet was more extensive than present, suggesting the EAIS is stable in a warmer regime. Conversely, the absence of Pliocene moraines will suggest glaciation was less extensive during that period, raising the possibility that the EAIS is vulnerable to collapse in a warming climate.

Methods and Preliminary Results

Over 200 samples have been collected from boulders perched atop moraine crests at Roberts Massif. These samples will be analyzed using helium-3, neon-21, and beryllium-10 surface exposure-age dating techniques to determine the time that has elapsed since the boulders were deposited by the EAIS. Preliminary results indicate that moraines of Pliocene age and older are present at Roberts Massif.

Acknowledgements

National Science Foundation grant #144332.

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Bird Abundance in the *Ascophyllum* Habitats in the Maine Rocky Intertidal Zone

Amy M. Baron[1, 2,3], Brian J. Olsen[1, 2,3], and Amanda Klemmer[1, 3]

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

Abstract: *Ascophyllum nodosum* provides many essential ecological services to the Maine intertidal ecosystem, including habitats for coastal birds at their southern range-edge margins. Ocean warming and macroalgal harvest have the potential to impact bird communities within the Gulf of Maine. Here we describe associations between birds and macroalgae in the intertidal zone. *Ascophyllum* cover positively affects bird abundance in all regions along the Maine coast.

Along the Maine coast, *Ascophyllum nodosum*, also known as rockweed, is a dominant primary producer in sheltered rocky intertidal areas and provides many essential ecological services to the intertidal ecosystem. *Ascophyllum* supports organisms through direct grazing, through additions to the detrital food web, and as three-dimensional structure. Invertebrates living among this macroalgae get protection from heat, desiccation, and predation at low tide. Its expanded floating canopy at high tide provides a habitat for invertebrates, a predation refuge for juvenile fishes, and a foraging site for coastal birds. *Ascophyllum* possesses a primarily North Atlantic distribution, and ocean warming combined with commercial harvest in the Gulf of Maine could impact the southern limit of this foundational taxon.

Although the ecological values of *Ascophyllum nodosum* to marine invertebrates have been well-studied, less is known about its ecological values as habitats to vertebrates. To determine how loss of this species within the Gulf of Maine might impact coastal birds, we conducted bird and algal surveys at 60 sites along the Maine coast between June and September 2016. Bird counts were modelled as a function of the species composition of the macroalgal community (*Ascophyllum nodosum* versus *Fucus spp.*, or rocks), geographic region, wave conditions, calendar day, and tidal cycle.

The percent coverage of *Ascophyllum* is positively correlated with bird abundance in the rocky intertidal areas along the entire coast of Maine (R^2 = 0.359, p = 0.00005) (Fig. 1). Birds are significantly more abundant in the intertidal areas with higher percent coverage of *Ascophyllum*, but less abundant in the areas with higher percent coverage of *Fucus*, and rocks (Table 1). These results suggest that declines in *Ascophyllum* at its southern range edge, due to ocean warming or unsustainable harvesting practices in the face of climate change, have the potential to adversely impact multiple bird species along the Maine coast.

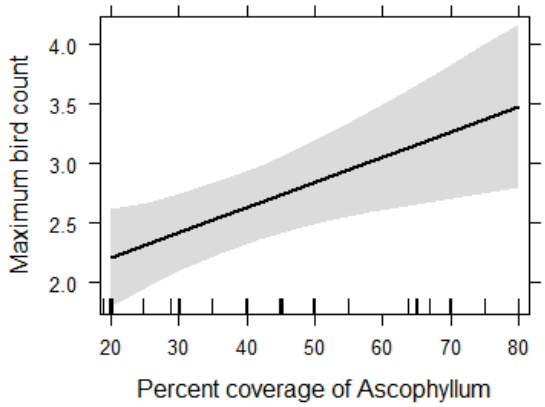

Fig. 1. Higher coverage of Ascophyllum positively affects bird abundance.

Table 1. Linear regression and ANOVA results for bird use in all habitat and substrate types.

	R^2	*p*-value
Ascophyllum nodosum	0.208	0.0002
Fucus spp.	0.0006	0.852
Rocks	0.05	0.086
Ascophyllum nodosum and *Fucus spp.*	0.2095	0.0003, 0.829 0.809*
Ascophyllum nodosum and rock	0.2089	0.0003, 0.926 0.818*
Fucus spp. and rock	0.0737	0.849, 0.074 0.295*

**p*-value based on interaction terms

Acknowledgements: This research is supported by US Fish and Wildlife Service.

Changes in Atmospheric Circulation from Volcanic Aerosol Forcing as Key Driver of North Atlantic Sea-Surface Temperature Variability

Sean D. Birkel[1,2], Paul A. Mayewski[1,2], Kirk A. Maasch[1,2]

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

Abstract: Sea-surface temperature (SST) variability across the North Atlantic is most commonly thought to arise from internal ocean dynamics. However, some workers suggest key forcing from volcanic aerosols and atmospheric circulation. We investigate this problem using historical SST, atmospheric reanalysis, and stratospheric aerosol optical depth data. Our results indicate that cool (warm) intervals in the North Atlantic correspond to periods of high (low) volcanic aerosol loading and strong (weak) atmospheric circulation associated with modes of the North Atlantic Oscillation (NAO). Likewise, SSTs in the subpolar gyre region beneath the westerlies are modulated by strength of the Icelandic Low and advection of cold flow from the Labrador Sea. A volcanic-aerosol origin of North Atlantic SST variability implies that anthropogenic-sourced warming could be temporarily offset during future periods of major eruptive activity.

SST and Volcanic Aerosols

Basin-wide SST is represented by the Atlantic Multidecadal Oscillation (AMO). Cool AMO phases (late 1800s to mid 1920s, and mid 1960s to mid 1990s) correspond with increased aerosol loading in the stratosphere (Fig. 1). Notable eruptions during cool intervals include Krakatau (1883), Santa María (1902), Novarupta (1912), Agung (1963), El Chichón (1982), and Pinatubo (1991). The major eruptions of Nabro and Grímsvötn in 2011 caused the largest aerosol loading in the stratosphere since Pinatubo (Bourassa et al. 2012), and may have trigged observed cooling across the North Atlantic 2011-2015 (Fig. 2).

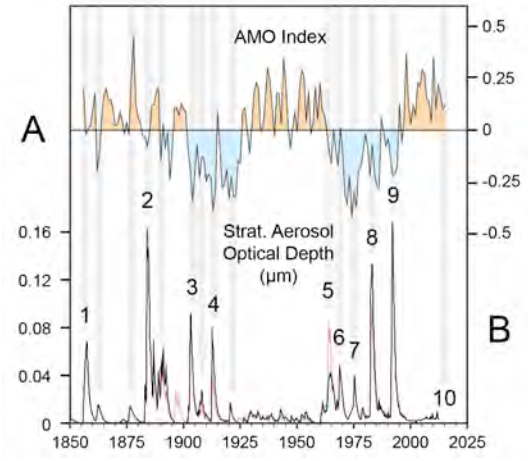

Fig. 1. (A) AMO index and (B) stratospheric aerosol optical depths (Sato et al., 1993; NASA GISS).

Atmospheric Circulation

Volcanic eruptions project onto the North Atlantic Oscillation (NAO) as sulfate aerosols in the lower stratosphere absorb heat over the tropics and steepen the poleward temperature gradient. As a result, atmospheric circulation strengthens, and SST anomalies propagate basin-wide from advection, upwelling, and increased albedo from dust entrainment (Fig. 2).

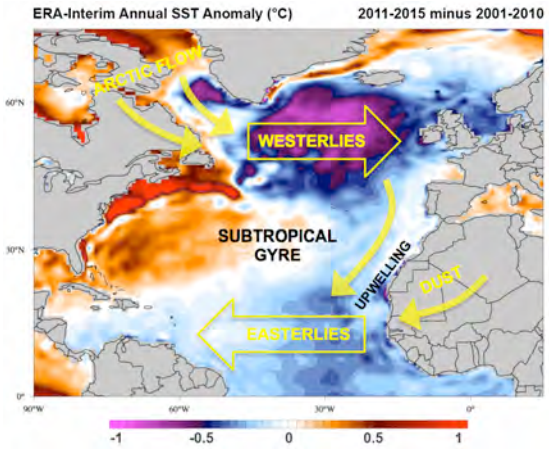

Fig. 2. Schematic relationship between atmospheric forcing and SST anomalies over the North Atlantic.

Acknowledgements: Supported provided by the Climate Change Institute and the USAID.

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Seasonal Analysis of Two Major Archaeological Sites in Eastern Maine using Modern and Excavated Marine Bivalve Mollusks, *Mya arenaria*

Emily M. Blackwood[1, 2], Dr. Brian S. Robinson[1, 2], Dr. Daniel Sandweiss[1, 2]

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

Abstract: Two archaeological sites in Eastern Maine will be analyzed using oxygen isotopic patterns to determine seasonal indicators of the season of occupation at the sites. Determining the season of occupation of a site provides crucial information as to the types of activities that took place and availability of food resources. It has been hypothesized that the first site, Holmes Point West in Machiasport, Maine, was occupied during the summer months, while the second site, Jones Cove in West Gouldsboro, Maine, was occupied during the winter months. Modern monthly samples are being collected from each site to form a comparative baseline for analyzing previously excavated mollusks. The results will be used to determine season of occupation for each site.

Background:

The calcium carbonate present within shells acts as a neutralizer to Maine's very acidic soils, thus allowing for the preservation of organic materials in places where shell middens are present. A shell midden is a collection of discarded materials that were no longer utilized or no longer served a purpose to the Native Americans occupying the area. Two such middens, Holmes Point West in Machiasport and Jones Cove in Gouldsboro have provided a wealth of information and have preserved a piece of ancestral Native American culture that otherwise may not have survived.

Objective:

I have been collecting modern monthly samples from both sites to create a baseline collection with which the previously excavated marine bivalve mollusks, *Mya arenaria* (soft-shell clam), can be compared to. I will be specifically looking for oxygen isotopic patterns through analysis of the mollusks. These patterns will indicate whether the sites were of summer (Holmes Point West) or winter (Jones Cove) occupation. The results of this research are crucial towards understanding the context of the sites; were they continuous occupations or were they as they are hypothesized, summer and winter occupations? This analysis will help to fill in cultural gaps by providing evidence and insights to help characterize past ways of life.

Methods:

I plan to use the methodologies set forth by Dr. Alan Wanamaker for my research involving marine bivalve seasonality analysis. Briefly, this entails sectioning the bivalves, polishing, and then etching them in 0.1 M HCl for 2-3 minutes. After this process is complete, an acetate peel is made for analysis. Both the modern and excavated samples will go through this process and be used for comparison.

Acknowledgements:

I would like to thank the late Dr. Brian S. Robinson for all he has done academically for me and for all he has done for the discipline of Archaeology.

Graduate Assistantship through Dr. Nicholas A. Giudice, Director of the VEMI Lab at UMaine.

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Ecological Effects of Nutrients and Turbidity in Lakes Fed by Greenland Ice Sheet Meltwater

Benjamin Burpee[1,2], Dennis Anderson[1,2], Jasmine E. Saros[1,2]

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

Abstract: Greenland Ice Sheet (GrIS) meltwater contains high concentrations of phosphorus (P), nitrogen (N), and other nutrients and solutes. It is unknown how meltwater affects the ecology of glacially fed (GF) lakes adjacent to the Ice Sheet. Our findings suggest increased nutrient concentrations and turbidity promote increased algal biomass and unique algal communities in GF lakes.

Rapid recent warming in southwest Greenland has increased the amount of meltwater discharge from the GrIS (Hanna et al 2008). High concentrations of nutrients (N, P, iron, and silica) and solutes in GrIS meltwater (Hawkings et al 2015) likely affect GF lake algal ecology; increased algal production and decreased biodiversity have been demonstrated in alpine GF lakes with high concentrations of glacially derived N, for instance (Slemmons and Saros 2012). Here, we assess the environmental differences between four GF and four nearby snow and groundwater fed (SF) lakes along the GrIS in southwest Greenland. We evaluated their algal communities by measuring algal biomass and counting diatoms from surface sediments.

GF lakes had higher bioavailable N (DIN) and total P (TP) concentrations, and greater turbidity than SF lakes (see Table 1). SF lakes had higher DOC. The biological demand for C, N, and P was evaluated using microbial extracellular enzyme activity (EEA) assays. EEAs suggested that despite higher TP in GF lakes, P was scarce for microbes and in high demand relative to C or N. Sediment extractions were used to evaluate the bioavailability of P between lake types. They indicated recalcitrant, mineral-bound P dominates the TP pool in GF lakes. GF lake sediments also had high aluminum, which can sequester P from lake water.

Algal biomass (measured by chlorophyll *a*) was higher in GF lakes, but there was no difference in biodiversity between lake types. Diatom species that are associated with N availability (*Discostella stelligera and Fragilaria tenera*) were abundant in GF lakes and suggested N enrichment. Lastly, canonical correspondence analysis demonstrated a clear separation between GF and SF lake diatom communities. This separation was associated with turbidity, TP, and DOC gradients.

GF lakes along the GrIS have distinct physical, and chemical characteristics from SF lakes. Though GF lakes have notably high TP concentrations, chemical and biological indices suggest much of it is likely biologically unavailable. Thus, higher algal biomass in GF lakes may be attributable to moderate DIN concentrations rather than TP. Proglacial lakes along the GrIS are likely to become increasingly common and this study offers important insight into their ecology and biogeochemistry.

	GF lakes n = 4	SF lakes n = 4
DIN (ug L^{-1})	20	9
TP (ug L^{-1})	18*	3
Turbidity (NFUs)	30.8*	1.8
DOC (mg L^{-1})	<1*	7
Chlorophyll *a* (ug L^{-1})	1.7*	1.0

Table 1. Nutrients and algal biomass compared across GF and SF lakes. Asterisks (*) indicate significant differences at p = 0.05.

Acknowledgements: This project was funded by the US National Science Foundation (Grants no. 1203434 & 1144423).

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Functional-Programming with Generic Mapping Tools (fGMT)

Sudarshan S. Chawathe[1, 2]

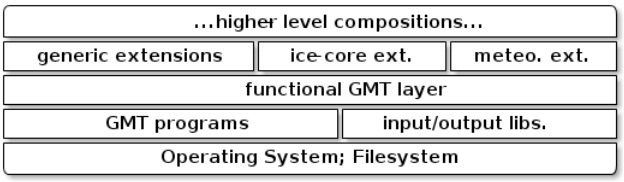
1. *Climate Change Institute, University of Maine.*
2. *School of Computing and Information Science, University of Maine.*

Abstract: We describe *fGMT*, a *functional-programming* interface to the very popular GMT collection of mapping and plotting tools. Our implementation uses *scsh Scheme* and is designed to permit incremental building of higher-level interfaces that incorporate domain-specific knowledge.

Introduction. *GMT (Generic Mapping Tools)* is a very popular collection of software programs used for plotting geo-coded data. Among its many strengths are robustness, longevity (since 1988), and especially good support for map projections. Its use among geoscientists and others continues to rise.

The main mode of interacting with GMT is a collection of command-line programs, each with several options, typically interleaved with file input/output operations and shell script commands. This arrangement has significant benefits (e.g., portability) but also a few notable drawbacks. First, the complicated collections of command-line options, some with their own sub-syntax, poses challenges to newcomers and often leads to errors even with experienced users. Second, and more significantly, it is difficult to compose complex programs that use GMT in a manner analogous to the composition of other programs in a modern programming environment.

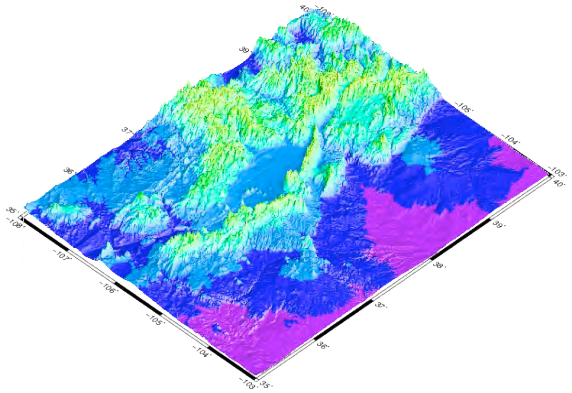
Design. Our design of *fGMT*, a functional (in the sense of *functional programming*) interface to GMT aims to address the above drawbacks. The hypothesis is that a functional interface to these tools not only makes them easier to compose into larger, perhaps specialized, tools but also makes them easier to learn and remember. Further, such an implementation enables higher-level optimizations due to the easier deduction of patterns by human or computer compared to the analogous task in a lower-level shell script. It also permits easier and more robust checking and handling of errors and other exceptional situations by permitting the use of linguistic features (e.g., nested exception handling) that are difficult to use in shell scripts.



Implementation. The current implementation of fGMT is a thin wrapper around the underlying GMT programs, using scsh Scheme. The choice of scsh was motivated by its support for easy integration with shell commands. However, most of the implementation is written in standard R7RS Scheme and is easily portable to other Scheme implementations. It should also be easy to map the implementation to other programming environments, such as Python.

In ongoing work, we are using this framework to build higher-level interfaces to GMT, taking advantage of the ease of functional composition provided by fGMT. Of particular interest are domain-specific interfaces that combine knowledge of the GMT programs with knowledge of a specific scientific domain.

Sample output from the GMT tutorial, recreated using *fGMT*:



Dust and Trace Metal Analysis from SPICE Core, Antarctica

Aaron Chesler[1,2] Karl Kreutz[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 South Pole Ice Core (SPICE) was drilled during the 2014-2016 austral summer seasons. Drilling occurred at 89°S, 98°W and reached a depth of 1751 m (spanning about 50,000 years). Our goal at the University of Maine is to analyze dust particles from the SPICE core for trace metal analysis and particle size distribution. Dust fluxes preserved in polar ice are related to interactions between the cryosphere, oceanic, atmospheric, and biological systems. Researching these fluxes will aid our understanding of circulation changes during glacial/interglacial cycles and abrupt climate changes during and since the peak of the last ice age (~22 kya).

Ice cores drilled in polar ice sheets provide a unique opportunity to study directly previous atmospheric conditions. Dust deposited in Antarctic ice a useful proxy for reconstructing coupled cryosphere, oceanic, biological, and atmospheric interactions. Dust fluxes can also inform our understanding of what drove atmospheric CO_2 (pCO_2) fluctuations during glacial/interglacial periods. One of the major hypotheses for Southern Hemisphere (SH) climate change, is that the southern westerlies expanded equatorward during the last glacial period. There may have been a millennial-scale pulsebeat to the expansion and contraction of the winds as well, with equatorward expansion of the westerly wind system during austral cold periods. When the winds move over land, (ie., Patagonia), higher concentrations of dust are entrained and transported poleward.

As dust is transport toward Antarctica, fallout occurs over the ocean. Because dust is relatively enriched in bioavailable nutrients (i.e., Fe), deposition in the ocean introduces available nutrients for biological utilization. Increased input of dust-derived Fe into the ocean can therefore lead to increased surface ocean productivity, which has been proposed as a mechanism for pCO_2 drawdown (Martin 1990). By measuring bioavailable Fe in dust during the last glacial period, we will be able to address the hypothesis that Fe deposition played a role in pCO_2 removal on various time scales, such as glacial/interglacial periods (~22,000yrs) and during abrupt climate events (100s-1000yrs).

In the SH, fine dust that does not fallout over the ocean is deposited on the Antarctic Ice Sheet, where it is preserved in the ice. We aim to analyze the grain size distributions and trace metal content of dust recovered from the SPICE coring effort. By coupling trace elements and dust particle-size-distribution data to answer questions regarding the timing and influence of each source area's contribution to bioavailable Fe, we hope to elucidate the relationship between dust fluxes and varying pCO_2 concentrations, throughout last glacial period.

Figure 1. Dust deposition on ice.

Acknowledgements: Gratitude for the support of Mark Wells, Bess Koffman, Seth Campbell, and the Continuous Flow Analysis Laboratory at Dartmouth University. Support provided by the NSF award PLR-1443397.

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Investigating Ultra-High Resolution Glaciochemical Records within Ancient Ice

Heather M. Clifford[1], Douglas S. Introne[1], Andrei V. Kurbatov[1,2], Paul A. Mayewski[1, 2], Sharon B. Sneed[1], Nicole E. Spaulding[1]

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

Abstract: To improve our understanding of past climate, we investigate glaciochemical records within ice cores using an ultra-high resolution sampling method. Using this sampling technique along with stable water isotope measurements, we observe environmental signals preserved within ancient ice from Allan Hills Blue Ice area. In addition, we investigate environmental signals at a sub-annual scale preserved within a Swiss/Italian Alps ice core in connection to historical records from medieval Europe.

Ice cores are a proxy used for paleoclimate reconstructions and provide the most direct and detailed way to investigate past climate and atmospheric conditions. Annual layers within the ice core capture atmospheric concentrations of dust, sea-salts, ash, gas bubbles and human pollutants[1].

Recent advances in instrumentation have allowed for the development of new ice core sampling techniques. Ice-core analysis by laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) provides ultra-high sampling resolution (121 μm)[2] necessary to achieve a robust measure of variability for select glaciochemical species preserved in ice cores. Elements are measured using single-element or multi-element line scans, producing a continuous laser ablated profile along the length of the ice sample. We also examine the old ice using a high resolution stable water ∂18O and ∂D sampling system.

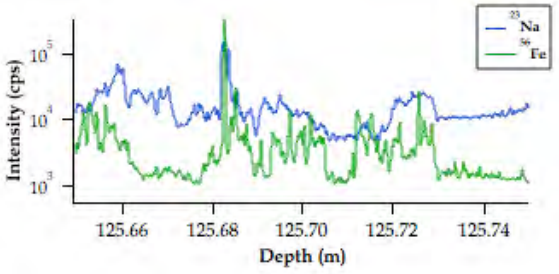

Fig. 1 LA-ICP-MS ultra-high resolution intensity measurements shown by ^{23}Na and ^{56}Fe (100pt smooth) data from Allan Hills site BIT-58 ice core.

Investigating detailed glaciochemical records of ancient ice will enable us to provide a snapshot of the climate before the mid-Pleistocene transition for the first time. The oldest ice yet recovered[4] is found in Allan Hills Blue Ice area, East Antarctica. Using extensive glaciochemical and stable water isotope data, we suggest that environmental signals are preserved within the ~1-Ma old[4] interval. In addition, our observed range of stable water isotope values from several cores in this area are consistent with glacial/interglacial changes in other Antarctic ice cores[3] in our joint CCI-Princeton project.

An ice core drilled from Colle Gnifetti glacier on the Swiss-Italian border is offering insight into human-climate interactions during the first millennium AD through a joint CCI-Harvard project. We are currently developing a continuous ultra-high resolution glaciochemical record which can detect environmental signals at a sub-annual scale, potentially down to storm-scale events. These measurements are combined with a historical geodatabase to investigate potential interactions between European civilizations and their environment.

Acknowledgements: This research was supported by the Arcadia Fund and the following NSF grants: PLR-1443306, 1443461, 1203640, 0838843, 1443263.

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Spatial Structure of Ecological Specialization: Implications for Conservation in a Rapidly Changing Environment

Meaghan Conway,[1,2,3] Adrienne Kovach[4], Brian J. Olsen[1,2,3]

1. *School of Biology & Ecology, University of Maine.*
2. *Climate Change Institute, University of Maine.*
3. *Ecology and Environmental Science, University of Maine.*
4. *Department of Natural Resources and the Environment, University of New Hampshire.*

Abstract: The degree of specialization can influence the distribution of organisms across space. Ecological specialization is synonymous with narrow niche breadth, resulting from trade-offs between the ability of species to exploit a range of resources and their capacity to compete effectively on each one. A short-term competitive advantage over a narrow set of resources may incur a cost of a reduced ability to adapt to changing conditions. However, a species' niche can vary among populations and across spatial and temporal scales. While species may appear generalized over their entire range, individuals may be locally specialized. Hence, determining the scale of variation, and the conditions that might promote variation within populations may help prioritize conservation in rapidly changing environments at both local and regional scales.

Introduction: A species niche is broadly defined as a set of biotic and abiotic conditions in which a species can persist. This species-level definition treats individuals as equivalent, ignoring variation among individuals and populations that occur over a range of ecological conditions. The scale of diversity varies among species, reflecting a variety of mechanisms that generate variation at different scales.

The influence of inter- and intraspecific interactions is explicitly included in definitions of the ecological niche (Hutchinson 1957). A population's niche width is generally thought to reflect a balance between the diversifying force of intraspecific competition and the constraining effect of interspecific competitors (Van Valen 1965). For example, strong inter-specific competition can result in Ecological Character Displacement, where a species niche contracts when a competitor is present. Niche expansion is commonly observed when species from highly competitive environments invade species-poor habitats with fewer interspecific competitors. Van Valen (1965) proposed two mechanisms for niche expansion following release from competition. Every individual in the population could expand its niche, or there could be greater among individual variation. The Niche Variation Hypothesis predicts increased between-individual variation in generalist populations with a wider species-level niche.

Increased intraspecific niche diversity may also arise among, rather than within, populations. Divergent selection arising from differences in environmental factors can be a major cause of phenotypic differentiation (Schluter 2000).

Tidal marshes provide an ideal system to explore the spatial structure of variation. They are highly productive, and possess a gradient in salinity and tidal influence that varies systematically with distance upriver. Six species of Emberizid sparrows have colonized tidal marsh habitats at different time scales (and thus show variation in species-level niche width). We will test predictions of the Niche Variation Hypothesis by comparing variation across spatial scales. This information could have important conservation implications by identifying populations with greater functional diversity. These populations are more likely to possess the potential to persist under changing ecological conditions due to sea level rise.

Acknowledgements: Funding was provided by the U.S. Fish & Wildlife Service, The Garden Club of America, and the University of Maine.

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Implications of Abrupt Climate Change in Chile's Territorial Use Rights in Fisheries Policy

Sarah Ebel[1, 2], Kirk Maasch[2], Christine Beitl[1]

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

Abstract: Co-management approaches to fisheries policy are gaining popularity in many regions of the world to contribute to the creation of resilient and adaptive socio-ecological systems. Yet, abrupt environmental change continues to test the resilience of existing co-management institutions, bringing into question the management regime's capacity to adapt. In 2016 the marine ecosystem in the Los Lagos Region of Chile experienced an abrupt environmental change, resulting in fish kills and widespread fishery closures. This research uses remote sensing data and qualitative interview data to: 1) examine the socio-ecological conditions which led to the significant environmental change, and 2) illuminate its subsequent implications on Chile's TURFs policy.

Project Goals:

Co-management approaches to natural resource management are gaining popularity in many regions of the world to contribute to the creation of resilient and adaptive socio-ecological systems. Yet, abrupt environmental change continues to test the resilience of existing co-management institutions, bringing into question the management regime's capacity to adapt. This paper provides an analysis of a significant environmental change and its implications for co-management fisheries policy in the Lakes Region of Chile.

Chile has one of the largest co-management systems in the world, called Territorial Use Rights in Fisheries (TURFs), in which community-based fishing unions have co-managed inshore fisheries in collaboration with government agencies and scientists since 1991 (Gelcich and Castilla 2008). Over 90,000 fishers participate in the TURFs policy, and TURFs have improved fish stocks and increased fishers' economic prosperity (Moreno and Revenga 2014). In March of 2016, Chile's most fishery-dependent region, the Lakes Region, suffered from a combination of warming waters and nutrients from salmon aquaculture which incited massive fish kills and widespread closures of fishing areas. Several social repercussions including loss of livelihoods and increases in poverty catalyzed fishers' protests where they demanded reparations and began appealing to the government for changes to the TURFS policy.

Fig. 1. Fishers in Estaquilla ready their boats.

This paper utilizes remote sensing data, TURF spatial area delineation, and qualitative interview data to demonstrate the extent of the environmental change on Chile's TURFs policy and its resource users. We then discuss the implications of this abrupt change on the resiliency of Chile's TURFs policy and the future of other co-management fishery policies.

Acknowledgements: Advisor, Dr. Christine Beitl. Dr. Kirk Maasch. NSF Adaptation to Abrupt Climate Change IGERT program grant DGE-1144423.

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What Would You Say is Causing the Increase in Deer Ticks? Views from the Unbridged Islands of Maine, USA

Susan Elias[1,2,3], Benjamin Stone[3], Kirk Maasch[1,2], Laura Rickard[4], Charles Lubelczyk[3], Peter Rand MD[3], Robert Smith MD MPH[3], Eleanor Lacombe[3], Norman Anderson[5], Sara Robinson[6]

1. *Climate Change Institute, University of Maine.*
2. *Dept. of Earth and Climate Sciences, University of Maine.*
3. *Vector-borne Disease Laboratory, Maine Medical Center Research Institute.*
4. *Dept. of Communication and Journalism, University of Maine.*
5. *Anderson Environmental Health, Winslow, Maine.*
6. *Maine Center for Disease Control and Prevention.*

Abstract: Maine public officials and citizens—particularly in off-shore island communities—want to lower risk of exposure to deer ticks, the vector tick of Lyme disease. Climate change has favored northward range expansion of vector ticks and exacerbated biotic conditions that favor ticks, namely overabundance of deer, mice, invasive shrubs, as well as policies that promote these conditions. A survey of island residents indicated an understanding of conditions favoring ticks, but vector ecologists must better communicate the roles of invasive shrubs, and climate change.

Project goal

Our purpose is to help unbridged Maine island communities mitigate the threat of tick-borne disease in an era of abrupt climate change.

Lyme on the Rise

Maine public officials and citizens—particularly in off-shore island communities—are grappling with how to lower risk of exposure to deer ticks, the vector tick of Lyme and other tick-borne diseases. Incidence of Lyme disease in Maine has increased five-fold over the past decade, and is among the highest of all US states at 88 cases/100,000 people[1]. At six times the state average[2], the burden of Lyme on Maine's offshore islands is even higher.

One Health

Climate change has promoted northward range expansion of vector ticks[3] and exacerbated a mosaic of biotic conditions that favor ticks, particularly: 1) focal overabundance of white-tailed deer, the blood-meal host of female ticks; 2) relative overabundance of white-footed mice, which harbor the Lyme bacteria; and 3) invasion of non-native shrubs that harbor ticks. Policies that promote these conditions increase risk of tick bite to humans, pets, and livestock. The One Health[4] concept stipulates that human and veterinary health is tied to the health of the environment. A landscape that fosters disease transmission is a "pathogenic landscape".

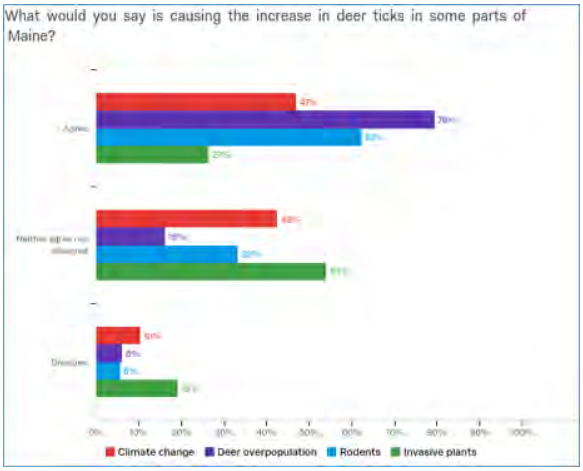
[1]https://www.cdc.gov/lyme/stats/
[2]https://data.mainepublichealth.gov/tracking/
[3] Parham et al. 2014 Theme issue: Climate change and vector-borne diseases of humans. Phil Trans Royal Society B 370(1665)
[4] www.onehealthinitiative.com

Island Tick Survey

To better understand islanders' views on deer ticks, we opened the Island Tick Survey in May 2016. A key question was "What would you say is causing the increase in deer ticks in some parts of Maine?"

Initial Results

Among 772 responses, deer overpopulation was the most frequently cited cause of increased deer ticks (79% agreeing), followed by rodents (62%), followed by climate change (47%), and finally, invasive plants (27%). Vector ecologists will need to better convey a One Health message to improve understanding of the roles of climate change and invasive plants. We will continue a tradition of providing tick control guidance to islands.



Acknowledgements: This research is supported by the US National Science Foundation Adaptation to Abrupt Climate Change IGERT program grant DGE-1144423. Any opinions, findings, conclusions or recommendations expressed are those of the authors.

Understanding the Continued Demise of Columbia Glacier, Alaska, Using High-Resolution Satellite Remotely-Sensed Observations

Ellyn M. Enderlin[1], Shad O'Neel[2], Timothy Bartholomaus[3], Gordon S. Hamilton[1]

1. *Climate Change Institute & School of Earth and Climate Sciences, University of Maine.*
2. *US Geological Survey, Alaska Science Center.*
3. *Department of Geological Sciences, University of Idaho.*

Abstract: Columbia Glacier, Alaska, has served as the archetype for the retreat phase of the tidewater glacier cycle for the past three decades. Since the mid-1980s, the terminus has retreated ~22 kilometers and the two major tributaries have thinned by >400 m. Since the separation of the two primary tributaries in the mid-2000s, the glaciers have exhibited strikingly different seasonal variations in terminus position change, ice flow, and mass loss. Here these patterns are investigated using a suite of high-resolution satellite observations acquired from 2012-2016.

Glacier mass varies over time as a function of changes in surface mass balance (snow accumulation minus ablation) and ice dynamics. Ice dynamics involves the flow of ice towards the marine margin, where mass loss occurs via iceberg calving. Changes in dynamics can be triggered by a variety of processes, including internal feedbacks that are largely independent of climate. Importantly, if a glacier overlies a retrograde bed slope, then it has the potential to rapidly increase dynamic mass loss through the positive feedback between water depth at the glacier grounded terminus and retreat rate[1].

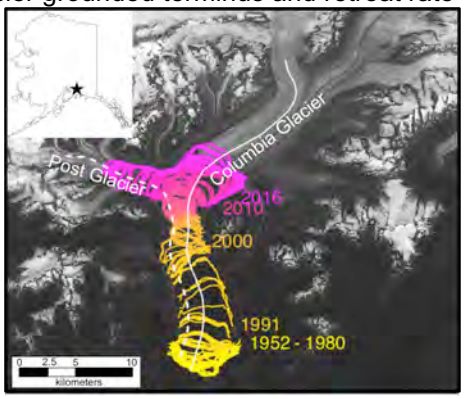


Fig. 1: Terminus change time series (colored lines) for Columbia and Post glaciers, Alaska.

Columbia Glacier, located in Alaska's Chugach Mountains, is a fast-flowing marine-terminating glacier that has long been considered the archetype of a retreating tidewater glacier. The terminus of Columbia Glacier retreated from a relatively stable position on a shallow marine shoal in the 1980s, marking the onset of a ~30-year period of dynamic acceleration, thinning, and retreat that continues today (Figure 1). In the late 2000s, the sustained retreat and thinning led to separation of a major tributary, Post Glacier, from the larger Columbia Glacier. Although these glaciers were subject to the same internally-driven changes in ice dynamics prior to separation, satellite observations acquired from 2012-2016 show that the continued response of these glaciers to long-term changes in dynamics are strikingly different. Figure 2 shows the change in ice flux from the glacier due to terminus position change (top panel) and changes in speed and thickness (bottom panel), illustrating the variations in dynamic change for the former tributary glaciers.

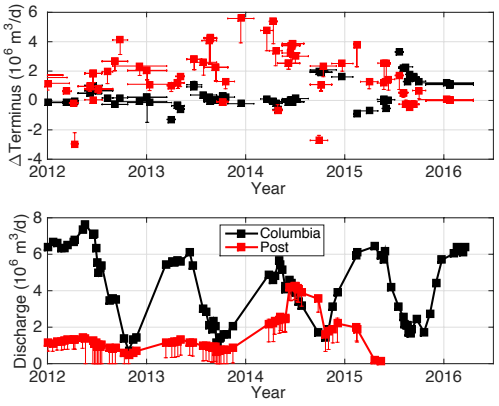


Fig. 2: Volume loss rates due to terminus (top) and ice flow (bottom) changes.

Acknowledgements: This project is funded by NASA award NNX14AH83G to E. M. Enderlin.

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Carbon Dioxide Glaciers on Mars

James L. Fastook[1], James W. Head[2]

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

Abstract: An ice sheet model adapted for Mars and a solid CO2 rheology provides insight into an explanation of High Latitude Glacier features formed during low-obliquity.

Introduction:

The presence of carbon dioxide glaciers on Mars is one possible explanation for high-latitude glacier (HLG) features such as those shown in Figure 1 [1]. These loop-like features consist of small ridges. Several have been described by [2,3] and are difficult to explain if they consist of regular water ice. Their overlap suggests multiple episodes of advance to each stillstand where the glacier could convey surface debris to build the moraine. All evidence points to the fact that the HLG features were formed by a material with a weaker rheology than water ice, and [1] suggests CO_2 as a possibility.

Results:

We consider an ice sheet forming on a uniform flat bed, prescribing a spatially symmetric mass balance with an accumulation area with a peak accumulation rate of 1 cm/yr, declining in either direction to zero and then on into ablation regions. Thickness increases with accumulation area, but even for our widest accumulation area of 2500 km producing an ice sheet over 4000 km wide, dome thickness barely exceeds 450 m. CO_2 ice is soft, even at the low temperatures encountered during low-obliquity atmospheric collapse.

Having determined the maximum thicknesses we might achieve with CO_2 glaciers of various extents, we then looked at how such ice sheets might behave on a sloping topography. Representative profiles with their companion sloping beds (flat, 0.05, and 0.1°) are shown in Figure 2.

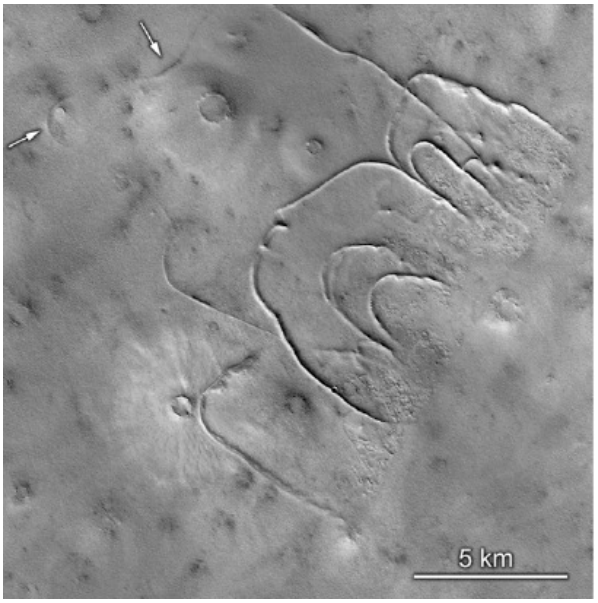

Figure 1: High-latitude glacier (HLG) deposits at 74°N96°E. from CTX image P16_007357_2541 [1, Figure 1].

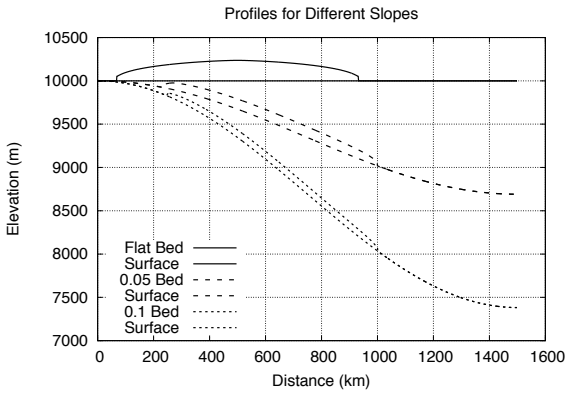

Figure 2: Profiles showing bed and surface for flat, 0.05°, and 0.1°.

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Experimental Assessment of Possible Mechanisms for Shifting DOC Concentration and Quality in Freshwater Lakes of Southwest Greenland

Rachel A. Fowler[1, 2*], Jasmine E. Saros[1, 2], and Christopher L. Osburn[2]

1. *Climate Change Institute, University of Maine.*
2. *School of Biology & Ecology, University of Maine.*
3. *Department of Marine, Earth, & Atmospheric Sciences, North Carolina State University.*

Abstract: Recent declines in dissolved organic carbon (DOC) concentration of southwest Greenland lakes have important implications for lake ecosystem function. We performed experiments to explore the effects of sunlight exposure and bacterial processing on DOC concentration and quality of natural lake water. These experiments advanced our understanding of the characterization of DOC in this region and how it can fluctuate in response to light exposure and bacterial activity, which can be influenced by climate-mediated changes.

We experimentally assessed possible mechanisms leading to alterations in DOC concentration in Arctic lakes of southwest Greenland. We focused on this region because a coherent decline in lake water DOC concentrations by 14-55% was observed here from 2001 to 2013. Experiments in surface waters of the Alaskan Arctic indicate that photodegradation influences DOC changes in that area (Cory et al. 2014). To examine whether the effects of photodegradation are a primary mechanism of DOC change in southwest Greenland lakes, we conducted sunlight exposure experiments using natural lake water from three lakes in this region. Effects of sunlight exposure were tested alone and in conjunction with bacterial activity.

In our experiments, DOC concentration showed no clear trend in response to sunlight exposure or bacterial activity. However, there were effects on DOC quality. Our results suggest that in these Greenland lakes, photobleaching is a stronger driver of DOC compositional shifts than of DOC concentration decline.

While the tested mechanisms did not explain the decline in DOC concentration observed in recent years, they did yield new information about how light exposure and bacterial activity can influence DOC quality in lakes of the Kangerlussuaq region. This study demonstrates how multiple mechanisms can control lake water DOC composition, and that these mechanisms may work in opposite directions and at different magnitudes depending on lake properties and initial characterization of DOC in the lakes. These patterns allow us to begin to describe the variability across these Arctic lakes, furthering our understanding of how future climate-mediated changes may influence DOC concentration and quality in lakes of the Kangerlussuaq region.

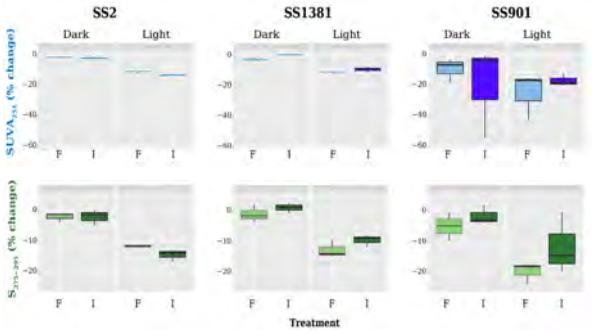

Figure 1. Results of SS2, SS1381, and SS901 lake water exposure to sunlight and bacterial activity on $SUVA_{254}$ and $S_{275\text{-}295}$, two key DOC quality metrics, represented by percent change (n = 3). F = filtered treatments, I = inoculated treatments.

Acknowledgements: This research was supported by the US National Science Foundation Adaptation to Abrupt Climate Change IGERT program grant DGE-1144423.

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Are Novel Plant Communities Also Novel Ecosystems? Plant Traits Link Pattern and Processes Over 21,000 Years of Global Change

Jacquelyn L. Gill[1, 2], Alejandro Ordoñez[3]

1. *Climate Change Institute, University of Maine.*
2. *School of Biology and Ecology, University of Maine.*
3. *Queens University, Belfast, Ireland.*

Abstract: Plant associations that lack a modern analog are a feature of both past and present ecosystems during periods of global change. Are these novel communities also novel ecosystems, or do we see functional replacement despite compositional turnover? This study takes a trait-based approach to address this question, using the late-glacial no-analog plant associations of North America as a case study in ecological novelty.

Introduction: Novel communities emerge as a result of individualistic shifts in species' ranges and abundances in response to changing climates, biotic interactions, species introductions, disturbance regimes, or other global changes (1). Such assemblages pose a management challenge, because it is unclear to what extent novel associations will maintain ecosystem function relative to a baseline of interest (typically modern). Because they are "no-analog," forecasting such communities makes is difficult when relying on contemporary observations alone, but the well-documented no-analog plant associations in North American paleorecords provide a promising model system. These late-assemblages were geographically widespread, persisted for over a millennium, and were composed of associations of boreal and temperate taxa which are likely to coexist in the future. This study is an investigation of whether late-glacial no-analog plant associations occupied novel trait space from present communities.

Methods: For this study, we reconstructed plant community dissimilarity, climate dissimilarity, and community trait dissimilarity from present throughout the last 21,000 years at 1000-year intervals. Vegetation data was calculated using pollen sites in the Neotoma database, and climate dissimilarity from present was calculated using the downscaled CCSM3 climate simulations (2). To estimate functional trait strategies, we calculated the community trait dissimilarity using community-weighted mean values of specific leaf area, maximum height, and seed weight. These axes represent different strategic trade-offs, and correlate with many ecological functions of interest (3). Values were taken from the contemporary literature and are assumed to have been conservative through time, which is a reasonable assumption for plants. To calculate dissimilarity from present, we used both a local (within-site) and regional (across all sites) baseline.

Results: For both local and regional comparisons, climate dissimilarity and community dissimilarity were correlated; both decreased through time towards the present. However, despite the linkage between climatic and plant community dissimilarity, community-weighted trait dissimilarity remained low throughout the last 21,000 years. Thus, compositional turnover represented a functional replacement, and that there is considerable functional redundancy in the regional species pool of North America. This suggests that there may be optimal plant strategies that were established early in the evolutionary or climatic history of this region, and so novel communities of species from within the regional species pool are unlikely to result in novel ecosystems.

Acknowledgements: We are grateful to Steve Jackson, Jack Williams, and Brian McGill for helpful discussion about this study.

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Occurrence Patterns of Wintering Red-Throated Loons (*Gavia Stellata*) in Relation to Proposed Offshore Wind Energy Areas in the Mid-Atlantic U.S.

Carrie E. Gray[1], Brian Olsen[1, 2], Andrew Gilbert[3]

1. *School of Biology and Ecology, University of Maine.*
2. *Climate Change Institute, University of Maine.*
3. *Biodiversity Research Institute, Portland, Maine.*

Abstract: Wind energy offers a clean and abundant source of electricity; however, it may have multiple adverse direct and indirect effects on seabirds in the offshore environment. We used satellite tracking methods to determine patterns of use of Red-throated Loons while on their wintering grounds offshore of the mid-Atlantic U.S. Results of this study can be used by regulators during the permitting and planning phases of offshore WEA development to minimize siting effects on sensitive seabird species.

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Project Goals and Background:

The goal of this study is to determine occurrence patterns of Red-throated Loons (RTLO) (*Gavia stellata*) in the mid-Atlantic U.S. during migration and winter, using platform terminal transmitter satellite tracking tags (PTTs). Results will be used to evaluate the potential for interactions with proposed wind energy areas (WEAs) offshore of the U.S. Middle Atlantic coastline and to inform regulators during the permitting and planning phases of development. Zero-emissions wind energy is associated with fewer environmental degradation issues compared to fossil fuels; however, European studies indicate sensitive seabird species, such as the RTLOs avoid WEAs, resulting in displacement from key foraging areas and migration and feeding flight pathways (Furness et al. 2013).

Satellite tracking data from 88 RTLOs deployed with PTTs during the winters of 2012 – 2015 were incorporated into a dynamic Brownian bridge movement model (dBBM) to estimate the winter utilization distribution (UD) (Kranstauber et al. 2012). The UD is the two—dimensional relative frequency distribution of an animal's occurrence in space and time. The home range and core use areas encompass 95% and 50% of the volume of the UD, respectively.

Initial Results:

Core use areas of RTLO winter UDs did not overlap proposed WEAs in the region; however, small areas of overlap existed between the 95% home range and several WEAs (Fig. 1). While UDs of RTLOs during the winter period did not overlap substantially with proposed offshore WEAs, preliminary results suggest that use of the offshore environment by RTLOs is more prevalent during the spring and fall migration periods and necessitate further analysis.

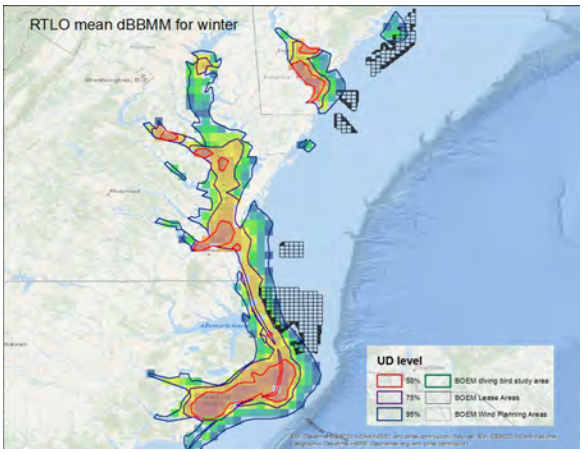

Fig. 1. Number of abstracts submitted per year.

Acknowledgments: This work was supported primarily by the Bureau of Ocean Energy Management, along with additional funding from the Department of Energy.

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Identifying Pollen of Native Grasses from the Falkland Islands to Build a Reference Collection

Kayla Greenawalt[1,3], Dulcinea V. Groff[1,2,3], Frin Ross[4], Jacquelyn L. Gill[1, 2]

1. *Climate Change Institute, University of Maine.*
2. *School of Biology and Ecology, University of Maine.*
3. *Ecology and Environmental Sciences Program, University of Maine*
4. *Falklands Conservation*

Abstract: Grasslands of the Falkland Islands are the dominant vegetation and serve an important role by preventing erosion, providing food for livestock, sheltering animals from the persistent winds, and are critical breeding habitat for seabirds. This project contributes to ongoing research of the response of grasslands to environmental change using fossil pollen records. We investigated morphological variation of pollen for eight native grass species.

Research Description:

Grass pollens are particularly difficult to distinguish in paleo sediments. The pollen features are not distinct enough to be set apart from one another without further analysis. By measuring a pollen grain's polar axis, equatorial axis, and pore diameter as well as analyzing the texture of these grains, modern pollen grains can show how a particular species has responded to changes in climate by comparing them to past sediment records (Schüler and Behling, 2011). We compared the pollen of native grasses in the Falkland Islands to the Falklands most vital grass species, *Poa flabellata* (Fig 1.). Using plant samples collected by Falklands Conservation, a reference collection of pollen (known species identity) was created. The pollen was concentrated using chemical processing followed by imaging pollen grains using scanning electron microscopy and light microscopy. Afterwards, the pollen grains were analyzed for morphological differences.

Detecting differences in grass pollen is important to understand how the grasslands that make up important breeding habitat of marine fauna may have responded to climate change, and fluctuations in the abundance of their populations.

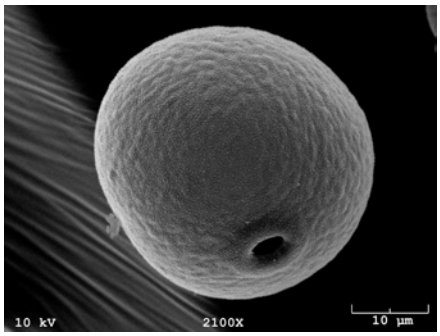

Fig. 1. *Poa flabellata* pollen grain

Acknowledgements: I would like to thank the Center for Undergraduate Research for the opportunity and funding for this research, Falkland Conservation for growing the native grasses , and Kelly Edwards from the University of Maine Electron Microscopy Lab.

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The Interaction of Climate and a Marine-Terrestrial Linkage in the Falkland Islands?

Dulcinea V. Groff[1,2,3], Catherine Hamley[1,3], Jacquelyn L. Gill[1, 2]

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

Abstract: Guano-derived nutrients from seabirds and marine mammals may be essential to maintain biodiversity on low productivity islands. Globally, seabirds are especially valuable proxies for environmental and climate change studies. The reconstruction seeks to identify the interaction of the climate system with marine-terrestrial ecosystems using paleoenvironmental proxies and establish a baseline for ecologists and conservation biologists to contextualize the sensitivity of seabirds and their habitats to global change.

Research Description:

Marine food webs are linked to primary production of isolated terrestrial environments by way of nutrient transfers. Guano from seabirds and marine mammals is an important source of nutrient input and may be essential to maintain biodiversity on low productivity islands (Mulder et al. 2011). Globally, seabirds are especially valuable proxies for environmental and climate change studies. ***Our work reconstructs the dynamic interaction of the climate system with marine and terrestrial ecosystems using paleoenvironmental reconstructions.***

This study addressed three main questions: *1) How have seabirds and marine mammals responded to abrupt shifts in the climate system during the Holocene?* 2) *How has terrestrial vegetation responded to fluctuations in seabird nutrient inputs?* 3) *Did seabirds, marine mammals, and vegetation respond to changes in the latitudinal position and intensity of the Southern Hemisphere westerly wind belt?*

Using multi-proxy analyses of sedimentary records found in tussac grass peatlands in the Falkland Islands, we evaluated proxies for marine-derived nutrients from guano (bioelements), plant species assemblages (pollen analysis), and fire frequency (charcoal) and natural abundance of $\delta^{15}N$ to identify shifts in the trophic position of marine top predators breeding on the Falkland Islands.

Analyses of tussac grass (*Poa flabellata*) peat cores were used to reconstruct Holocene environmental changes to test the sensitivity of this terrestrial-marine linkage and its impacts on island plant and animal communities.

Results indicate that a decline in the relative abundance of seabird and marine mammal populations occurred in sync with changes in island plant communities that provide important breeding habitat, and that fire is a frequent component of tussac grasslands. These results improve our understanding of how the climate system and specifically changes in the position and strength of the southwesterly winds influenced tussac grasslands and nutrient input through fluctuations in populations of marine fauna. Furthermore, these records establish a baseline that will provide ecologists and conservation biologists with a reference to contextualize the status of seabirds and their habitats, and the sensitivity of both to global change.

Acknowledgements: I gratefully thank the NSF A2C2 IGERT Fellowship, the Falkland Islands Department of Agriculture, Geological Society of America, Sawyer Water Environmental Research Laboratory, Falklands Conservation, and the South Atlantic Environmental Research Institute.

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Humans and the Falkland Islands Warrah: Investigating the Oorigins of an Extinct Endemic Canid

Kit Hamley[1,2], Dan Sandweiss[1,4], Brenda Hall[1,5], Jacquelyn Gill[1,3]

1. *Climate Change Institute, University of Maine.*
2. *Department of Ecology and Environmental Science, University of Maine.*
3. *School of Ecology and Biology, University of Maine.*
4. *Department of Anthropology, University of Maine.*
5. *School of Earth and Climate Sciences, University of Maine.*

Abstract: This study utilizes the sedimentary charcoal record from several sites in the Falkland Islands to assess potential pre-colonial human impacts on the islands, and whether humans may have introduced *D. australis* from South America. In the absence of known archaeological evidence, charcoal from peat cores is an indirect proxy for identifying human presence, as background charcoal levels typically increase by an order of magnitude following human arrival on islands.[1]

This study examines the charcoal records of three sites within the Falklands; New Island (NI), Bleaker Island (BI) and Mount Usborne (MU). The data show that NI exhibited a different fire history than that of BI or MU (Figs. 1 and 2). NI shows a significant increase in background charcoal, peak magnitude, and fire frequency beginning at 550 y BP (Fig. 2). Similar trends were not observed in the records from BI and MU. The divergence of the NI fire record from the other two cores suggest that there was a strong influence on the NI fire regime that was not controlled by regional climate trends, which would have affected the three locations similarly. The NI loss-on-ignition record, which is indicative of fuel availability, suggests that changes in fuel load or other environmental factors also were not responsible for fluctuation in fire frequency and intensity. Therefore, the paleoecological record from NI is strongly suggestive of a pre-European human presence at this location beginning around 550 y BP.

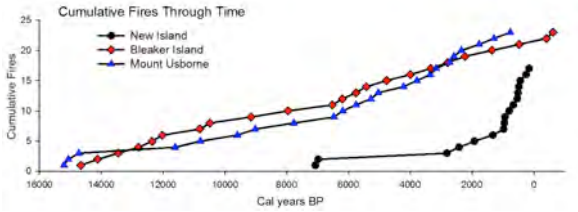

Fig. 1. Cumulative fires through time for study sites.

Further evidence that is suggestive of a human presence at NI is our discovery of six large bone piles. The bone assemblages consisted of Southern Sea Lion, Fur Seal and penguin bones and can likely be attributed to human activity.

Radiocarbon dating of several bones samples from these piles yielded ages of 550 years BP, which is coeval with the orders of magnitude increase in charcoal flux at NI. Further dating is needed to verify this date. Two stone points have been found by landowners in close proximity to the bone piles, which further suggests pre-European human activity in this area.

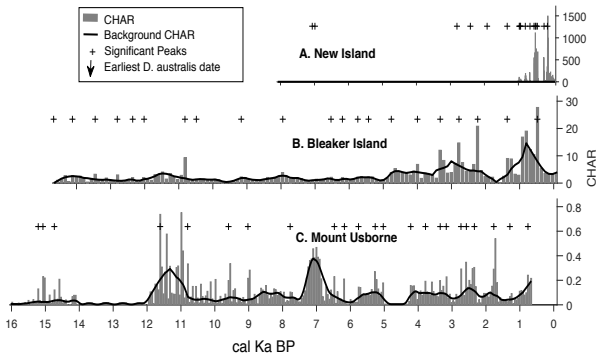

Fig. 2. Charcoal data for study sites addressed in text.

Acknowledgements: We would like to thank Dan and Betty Churchill, the Geological Society of America, the donors who supported our experiment.com crowdfunding campaign and the many Falklands landowners for their cooperation and support.

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Improving Geochemical Fingerprinting of Ultra Fine Tephra Particles

Laura H. Hartman[1], Andrei V. Kurbatov[1,2], Michael J. Mengason[3], Martin Yates[2].

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Microscopy and Microanalysis, National Institute of Standards and Technology.*

Abstract: Accurately determining the geochemical composition of volcanic particles extracted from ice cores is crucial for establishing the source and climatic impact of the volcanic eruption. The development and application of a new quantification procedure using the NIST DTSA II software to SEM / EDS analyses is at the forefront of this current research. Once this is complete, we can refine possible volcanic source(s) responsible for tephra layer(s) at a specific interval in a given ice core.

Paleoclimate reconstructions from ice cores rely on an accurately developed time scale. The best ice core dating method available is based on annual layer counting, which can often be verified by radiometric dating and volcanic-based time markers. Small volcanic glass particles, called tephra, that get injected into the atmosphere and eventually deposit on polar ice sheets can serve as chronostratigraphic markers in ice cores (e.g. Zielinski 2000). If we can chemically match the tephra to historic volcanic eruptions, we can provide better time constraints on a given section of an ice core that contains tephra. However, particle size can be a challenge. Recent advancements have refined the methods to capture and mount very fine (<10 µm in size) volcanic particles, called cryptotephra, from ice core samples (Iverson et al., 2016). The present study utilizes these methodological developments to build a better analytical regime for examining cryptotephra extracted from polar ice cores using the NIST DTSA II software.

The DTSA II method works by using standard and reference spectra files and compares them to an unknown spectra file. The standard spectra tell the software the relative intensity of each of the elemental peaks in the file, which it will then use in quantifying your unknown. Therefore, the standard should be a well-known material that closely matches the unknown. The reference spectra guide the software to establish an individual element peak for each element in the standard/unknown, which prevents peak overlap. Peak overlap occurs when one of the characteristic x-ray lines of one element lies close to, or sometimes directly under, another characteristic x-ray line of a different element; thus affecting the results of the first element. The best reference files to use are simplest material possible like pure iron or titanium.

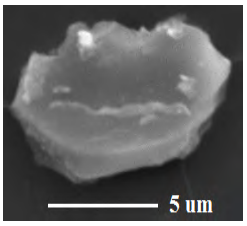

Figure 1: SE image of a tephra particle captured from the SPICE ice core. This particle is ~10 um in size.

To date, this study has focused on examining the South Pole Ice Core (SPICE) for tephra layers. Several depth intervals in this core have been found to contain tephra (figure 1). The raw chemistry of <19 tephra particles of 3-15 um size examined in this ice interval containing the particle shown in figure 1 point to a source outside of Antarctica. This layer will be the test interval for the DTSA II program. With the standardized files, we can then refine a possible volcanic source responsible for the tephra and sulfate peak found at this depth interval. Once the methodology is finalized, it will improve the quantification procedure for ultra-fine tephra extracted from polar ice cores.

Acknowledgments: NSF grants PLR–1543361 and 1142007. Sarah Wheatley for laboratory, software, and data assistance. SPICE ice core research and logistical support team.

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Mapping Adaptation Imaginaries: An Ecology of Practice for Climate Development

Jamie Haverkamp [1,2]

1. *Climate Change Institute, University of Maine.*
2. *Anthropology and Environmental Policy, University of Maine*

Abstract: Despite the most aggressive mitigation actions taken today, ongoing and future climate impacts will require socio-political adaptation efforts. However, not all adaptation responses are good ones, and some may even produce or reproduce the vulnerabilities they aim to redress. This research presents a novel methodology for working through the politics of difference that often hinder sustainable and equitable adaptation outcomes.

The mantra that "not all adaptation responses will be good ones"[1] is unfortunately an understatement for the social groups who are not best positioned to capitalize on the benefits of adaptation projects – paradoxically, the poor, marginalized and vulnerable. Although climate adaptation efforts are recognized to have emancipatory and transformative potential, they are equally capable of producing and worsening social inequalities that factor negatively into equations of resilience and sustainability.

This legitimacy crisis for adaptation interventions, grounded in empirical evidence of outcomes of produced and reproduced local vulnerabilities, is perhaps novel within climate change studies, but is only part and parcel of wider ongoing crises of 'projects of care' in late liberalism. The received wisdom underpinning projects of care, that, *something is better than nothing*, is increasingly debated as these social projects are often not so much replacing "nothing" but replacing another, already existing, "something"[2]. In the case of climate solutions, adaptation works must be careful not to erode local cultural knowledges and practices that often poses their own forms of resilience.

This paper offers an alternative approach to centralized and technocratic adaptation interventions through an ecology of practice, striving to empower marginalized voices within the adaptation process.

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[2] Besky, S. *The Darjeeling distinction: Labor and justice on fair-trade tea plantations in India*. Univ of California Press, 2013.

Methodology & Preliminary Results

This methodology gathers a shared sense of what constitutes a resilient socio-ecological system (SES) to rapid glacier retreat in the Peruvian Cordillera Blanca, across a diverse and conflicting set of stakeholder imaginaries. This qualitative study is centered upon a participatory action research (PAR) approach and employs qualitative methods including interviews, observation, questionnaires and workshops in order to co-produce indicators of socio-ecological resilience across four cognitive domains: government, NGOs, experts, and Campesinos.

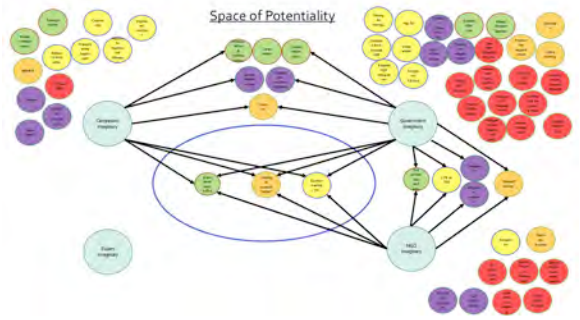

Fig. 1. Network display of resilience indicators across four imaginaries.

While research is ongoing, Fig. 1 illustrates the beginning stages of a mapping tool for identifying the most synergetic indicators of resilience across group level imaginaries.

Acknowledgments: National Science Foundation Adaptation to Abrupt Climate Change IGERT program grant DEG-1144423. Dissertation advisors Drs. Ranco and Isenhour, and committee members.

Sealing the Deal: Genetic Analysis of Archaeological Phocid Bone from the Holmes Point West (62-8) Site Near Machias, ME

A. Sky Heller[1, 2], Kristina M. Cammen[3]

1. *Anthropology Department, University of Maine.*
2. *Climate Change Institute, University of Maine.*
3. *School of Marine Sciences, University of Maine.*

Abstract: This paper presents brief results from an interdisciplinary project using DNA from archaeological bone to explore 1) the use of morphological features to identify phocid temporal elements to species, and 2) the impacts of population bottlenecks on genetic diversity of modern seal populations.

DNA test of morphological identification:

The first goal of this project was to follow up on research completed by Rob Ingraham for his Master's Thesis with Dr. Brian S. Robinson on faunal remains from the UMaine Archaeological Field School site Holmes Point East (900-250 cal BP) located near Machias, ME. In his analysis Ingraham (2015) found evidence for differential retention of skeletal elements between two phocid species, gray seal (*Halichoreus grypus*) and harbor seal (*Phoca vitulina*). The temporal portion of the skull – including the distinctive auditory bulla – was the most frequently recovered element for both species. Ingraham (2011; 2015) put considerable effort into identifying morphological indicators with which to differentiate between the two species in this element. He found that while differences in harbor seal right and left temporal element counts were not statistically significant, the gray seal assemblage was dominated by left bulla (Table 1).

	Left	Right	Total	Chi-squared *p*
Gray Seal	11	2	13	**0.013**
Harbor Seal	6	11	17	0.225

Table 1 - Phocid temporal elements by side and species (from Ingraham et al. 2015).

Genetic analysis of a wider sample of phocid temporal elements from the site verified the morphological species indicators. Thirty-eight temporal elements identified using Ingraham's morphological methods underwent genetic

analysis. Of these, seal DNA (mitochondrial control region) was successfully amplified from 27, *all* of which were found to match the morphological identification.

Genetic diversity:

The second goal of this project was to compare genetic diversity of the archaeological sample to modern seal populations to better understand how population bottlenecks resulting from 19th- and 20th-century bounty hunting campaigns have impacted modern population genetics.

Analysis of the mitochondrial control region found significantly greater genetic diversity in the archaeological samples than the modern samples. Each of the eight archaeological gray seal samples successfully sequenced had a unique haplotype, seven of which were not observed in the modern samples (N=385). In harbor seals (N=20), half of the archaeological haplotypes were not found in modern samples (N=94) (Cammen et al., in preparation).

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Extended Product Lifetimes as Climate Mitigation Policy

Cindy Isenhour,[1] Brieanne Berry[2]

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

Abstract: More than 42% of greenhouse gas emissions in the United States are linked to the products consumers buy (EPA 2009). Yet only a small fraction of these products is still in use six months after purchase. Recognizing this, policies designed to extend product lifetimes are rapidly emerging. To inform policy, we examine the social, economic, and environmental benefits of reuse.

ResourcefulME:

Life cycle analyses of energy use and associated emissions suggest that, in the clear majority of product categories, it is advantageous to extend product lifetimes rather than to produce new goods. Despite this, the proliferation of disposable and low cost goods has led to accelerating rates of product replacement and unsustainable global waste streams.

With increased recognition of the environmental and climate impacts of consumption, policies designed to address climate change by extending product lifetimes have begun to emerge on multiple scales. The State of Oregon, for example, has recently released a strategic plan on reuse. The United Nations ten-year framework on Sustainable Consumption and Production targets “Encouraging…the promotion of repair and maintenance work as an alternative to new products” (United Nations 2012).

This trend is even more pronounced at the local level (Cooper and Timmer 2015). Austin, Seattle, Chicago, Philadelphia, New York and Detroit are only a handful of the cities that have set up programs to facilitate and support reuse through community swaps, repair events, industrial symbiosis projects, and materials exchanges. Indeed, in an era of climate change, uneven development, resource depletion and growing waste streams, reuse is being promoted as a key strategy for long-term economic, environmental, and social adaptation on multiple scales. Despite these emerging policies, reuse economies are significantly understudied and empirical research is scarce.

Fig. 1. Maine flea markets provide a venue for reuse

Our research project "Resourceful ME" tracks the development of reuse policies for climate mitigation and uses Maine's reuse economy to develop a robust methodology for measuring the potential for reuse economies to contribute to climate mitigation. The design includes:

- Spatial analysis of county-by-county repair, resale, rental and reuse activity.
- Derived datasets to estimate aggregate economic and environmental impacts of reuse activities.
- Net impact analyses of second hand vs new product consumption.
- Social scientific analysis of decision criteria for and barriers to participation.

Acknowledgements: College of Liberal Arts and Sciences Faculty Fellowship, University of Maine.

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Lateral Shearing of the McMurdo Shear Zone, Antarctica: Implications on Ice Shelf Stability

Lynn Kaluzienski[1,2]

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

Abstract: Lateral resistance arising from the shearing motion of the fast-moving Ross Ice Shelf (RIS) and the slow moving McMurdo Ice Shelf (MIS) likely plays a role in the stability of the western portion of the RIS. In this study we performed seismic, GPS, and high-resolution GPR surveys of the McMurdo Shear Zone (MSZ) as well as finite-element numerical modeling in order to investigate the stability of the current flow regime of the RIS and its susceptibility to future breakup events, the importance of lateral boundary conditions, and the role ice rheology (crevassing and marine ice) plays in ice dynamics in the MSZ.

Understanding the controls on ice-shelf stability is critical to predicting the future evolution of the Antarctic Ice Sheet. For the RIS, an important region of lateral resistance is MSZ, a 5-10 km wide strip of heavily crevassed ice. In situ seismic, GPR, and GPS surveys were conducted to determine crevasse extent, surface kinematics, and material properties of the ice column. GPS surveys spanned a 12 x 12 km grid with 29 poles surveyed over 2 consecutive field seasons. A 5 x 10 km array of 4.5 Hz geophones recorded ground-motion from crevasse remediation blasting in the MSZ performed by South Pole Traverse (SPOT) personnel. In addition, GPR surveys utilized a lightweight remote-controlled robot to tow a 200 MHz antenna within a 5 x 5.7 km grid.

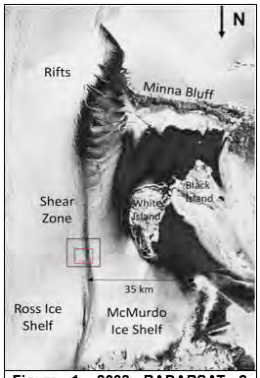

Figure 1. 2008 RADARSAT 2 image of the SZM. Outlines indicate the extent of GPS (black) and GPR (red) surveys

Analysis of the GPS data indicates a sharp velocity gradient across the shear zone. Strain rates range between 0 and 0.016 yr^{-1} with crevasse initiation occurring at ~0.01 yr^{-1} which falls within the published estimates required for crevasse initiation[1]. The strongest shear strain occurs where longitudinal velocity gradient shifts from compression to stretching. GPR analysis reveals parabolic diffractions indicative of both surface and basal crevasses. Firn crevasse strike angles range from 35–40° to transect direction and basal crevasse strike angles range from 27–50°. Spatial correspondence between near-surface and basal crevasse signatures suggests coeval fracturing.

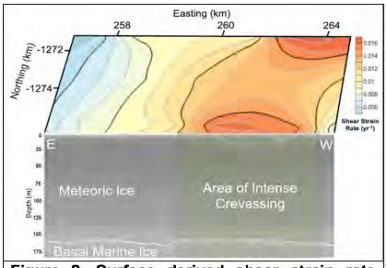

Figure 2. Surface derived shear strain rate contours with a compressed 200 MHz radar image of one 5.7 km transect below. The green portion of the GPR transect highlights an area of intense crevassing observed in both the upper firn and basal marine ice boundary layers.

Further investigation of temporal changes in crevasse extent and orientation may reveal a weakening of the RIS lateral margin. Efforts to quantify this weakening and incorporate observations within an ice-sheet numerical modeling framework is currently underway.

Acknowledgements: Gratitude for the support of Dr. Gordon Hamilton, Dr. Peter Koons, and Dr. Ellyn Enderlin with funding from the National Science Foundation grant ANT-1246400 and the Churchill Exploration Fund.

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Radiocarbon Chronology of Ice Extent in the Transantarctic Mountains from the Hatherton Glacier Region

Courtney King[1,2], Brenda Hall[1,2]

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

Abstract: Outlet glaciers drain the East Antarctic Ice Sheet through the Transantarctic Mountains, into the Ross Embayment. Ice-free regions adjacent to Hatherton Glacier outlet system provide an ideal setting for determining past ice thickness and extent during the local Last Glacial Maximum. Here, we present 89 radiocarbon ages of ancient algae that grew in former ice-dammed ponds from two regions adjacent to Hatherton. These algae represent past elevations of a thicker Hatherton Glacier and, therefore, help us understand better the timing and extent of ice within the Transantarctic Mountain valleys from the local Last Glacial Maximum to present.

If the entire Antarctic Ice Sheet (AIS) melted, it would contribute to nearly 60 m global sea-level rise (SLR), a cause for concern over its future stability under the present-day warming. With this study, we hope to understand the mechanisms driving ice-sheet behavior and, in particular, assess how the AIS responded during past periods of atmospheric warming. This information will help us address the AIS potential future contribution to SLR.

Outlet glaciers flow from the polar plateau of East Antarctica, through the Transantarctic Mountains and into the Ross Sea. Present-day ice-free valleys adjacent to these outlet-glacier systems contain evidence of past, thicker ice extent in the form of widespread glacial deposits. These sediments are associated with glaciolacustrine deposits from former ice-dammed ponds that contain ancient algae. These algae afford insight into elevation and timing of past ice extent (Bockheim et al., 1989).

Here, we construct the timing of maximum extent and rate of subsequent thinning of Hatherton Glacier from 89 radiocarbon ages of ancient algae that grew in former ice-dammed ponds. Our results indicate Hatherton Glacier reached its maximum position subsequent to the global last glacial period and began thinning at a steady and gradual rate ~9500 yr BP in the Lake Wellman valley and <9000 yr BP in Dubris Valley region.

Our thinning history contrasts with hypotheses that suggest rapid ice loss in the Antarctic during deglaciation. Geophysical models input with far-field sea-level proxy datasets suggest that the AIS contributed up to 20 m of global SLR in a few centuries approximately ~14,600 yr BP (Clark et al., 2002; Deschamps et al., 2012). In contrast, our data demonstrate that the AIS thickened during the global deglaciation, likely due to increased accumulation over the ice sheet from warming atmospheric temperatures (Hall et al., 2015). We postulate that prior to ~9500 yr BP, a marine mechanism – such as SLR or warmer ocean temperatures – propagated up flowline, reaching the Lake Wellman valley ~9500 yr BP and Dubris Valley <9000 yr BP. This marine mechanism overcame the accumulation effect, leading to ice-sheet retreat. Based on these interpretations, the ice sheet's potential future contribution to SLR is still cause for concern.

Acknowledgements: NSF grant #1246170, 1443248; GSG & GSA grants

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Distribution Patterns of Planktonic Diatoms in Lake Superior in Response to Climate

Amy Kireta[1, 2], Jasmine Saros[1, 2]

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

Abstract: This study investigates relationships between environmental variables and 4 diatoms in Lake Superior related to climate-driven physical changes in other lakes. Three diatoms were related to climate-driven changes, with two supporting previous relationships with light availability. All diatoms were related to various water chemistry and nutrient variables, supporting the importance of multiple drivers and species-specific responses.

Introduction:

Major physical, biological, and chemical changes are occurring in Lake Superior. Changes in microscopic diatom algae remain a mystery, although there have been suggested links to climate change [1]. Diatoms are ideal for studying biological response to climate change since they are an important component of the Lake Superior flora and respond quickly to environmental change. We are investigating the ecology of key diatom species in small lakes that have been used as climate indicators of epilimnion depth, the upper warm layer of lakes that forms in the summer months and affects the availability of light [2]. We hypothesize similar relationships with light availability in Lake Superior: *Discostella stelligera* will be associated with high light; *Lindavia comensis* will be associated with intermediate light; and *Lindavia bodanica* and *Lindavia ocellata* with lower light.

Objective:

This study will help identify the drivers of modern diatom changes in Lake Superior and clarify the role of climate in these changes.

Method:

We used multiple linear regressions on 10 years of EPA monitoring data, investigating thermal structure (thermocline) and other environmental variables to identify potential drivers of diatom change.

Results and Conclusion:

Models explained between 12-60% of variation in diatom abundances. Two diatoms were related to high (*D. stelligera*) and moderate (*L. comensis*) light availability, consistent with previous research (Table 1). *L. ocellata* was related to decreasing temperature.

Table 1. Positive and negative relationships of diatoms to environmental variables. Bold text indicates significant relationships, while red boxes indicate climate-driven physical change (solid line) or proxy for light (dashed line).

	D. stelligera	*L. comensis*	*L. ocellata*	*L. bodanica*
Consistency with previous findings	*	*		
Conductivity	+	+	+	
Nitrate+Nitrite		-		-
Silica	+	-	+	
Phosphorus				+
Temperature			-	
Thermocline		-		
Turbidity	-	+		
Adjusted R^2	*0.12*	*0.6*	*0.18*	*0.23*

While climate change is related to three of the four tested species, relationships with environmental variables are species specific and varied.

Acknowledgements: This project is funded by the National Science Foundation Adaptation to Abrupt Climate Change IGERT program grant DGE-1144423.

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Understanding Surge Dynamics of Donjek Glacier, Yukon, Canada

William Kochtitzky[1, 2], Karl Kreutz[1, 2], Ellyn Enderlin[1, 2], and Seth Campbell[1, 2]

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

Abstract: Even though surging glaciers make up approximately 1% of the total number of glaciers around the world, they exhibit dramatic changes in ice flow over multi-year time scales that must be understood in order to accurately predict future mass loss from glaciers and ice sheets. Alaska-type surge glaciers in particular have lost more mass than any other group of glaciers on the planet, making them an important contributor to global sea level rise. Here we propose to analyze surging at Donjek Glacier in the St. Elias Range, Yukon, Canada, because ice core records from the study site provide a means to reproduce past climate during surge events that can be paired with ice stratigraphy and thickness data acquired during a 2017 summer field campaign.

Donjek Glacier

Donjek Glacier is a known surge-type glacier in Yukon, Canada (figure 1). The glacier covers approximately 450 km^2 and is 55 km long from the glacier terminus to the Eclipse Ice Field (figure 1). Donjek was observed to surge in 1935, 1961, 1969, 1978, 1989, 2001, and 2013 (Abe et al, 2016). No known thickness measurements exist of Donjek Glacier, however, radar work on the Eclipse Ice Field suggests that the ice is over 700 m thick at the glacier head.

During a May 2017 field campaign, we will use ground-penetrating radar to estimate thickness along the proposed transect (figure 1). These measurements will be combined with a satellite image-derived velocity map to extrapolate thickness measurements across the entire glacier using a flux-gate model. These thickness estimates will play a key role in understanding how Donjek Glacier transfers mass from the reservoir to the ablation area.

Donjek Glacier is typical of many Alaska-type surging glaciers because it has a relatively short repeat cycle (12 years) and is temperate. The ice cores previously collected at the Eclipse Ice Field at the head of Donjek Glacier provide a unique record of accumulation. By combining annual accumulation history from the ice core with known surge dates, we hope to better understand whether temporal variations in snow accumulation influence surge dynamics at Donjek Glacier.

This project ultimately aims to compare the surge dynamics of Alaska and Svalbard type surge glaciers. Similar datasets acquired at Donjek and a Svalbard surge-type glacier will enable a inter-regional comparison of surge dynamics with respect to climate, which will be beneficial for estimating future mass loss from glaciers and ice sheets.

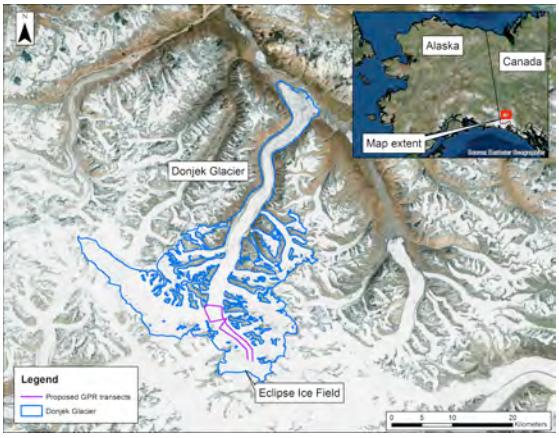

Figure 1. Study area of Donjek Glacier including the glacier outline (blue) and proposed radar transects (purple).

Acknowledgements: This material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. DGE-1144205. Any opinion, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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A ~2050-Year Atmospheric Dust Record from a South Pole Ice Core

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

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

Abstract: Here we present a high-resolution continuous records of dust variability developed from a South Pole ice core. A significant decrease in dust elements concentrations occurs ~1400 CE. The timing of the shift coincides with the beginning of the Little Ice Age (LIA), and is most likely attributed to the weakening of the Southern Hemisphere Westerlies (SHWs) and a decrease in precipitation in the dust source area.

Antarctic ice core records are an important source for reconstructing past dust variability in the Southern Hemisphere. Most of the dust deposited in Antarctica originates from South America and Australia; with the southern South America dust source being more significant for the South Pole region.

Here we present records of atmospheric dust deposition obtained from a South Pole ice core record. A suite of major and trace elements was measured using ICP-SFMS (Inductively Coupled Plasma Sector Field Mass Spectrometry) analysis using the upper 200-meters of the South Pole ice core at a temporal sample resolution of ~9 samples per year. Crustal enrichment factor calculations and empirical orthogonal function analysis indicate that crustal dust is a significant source for La, Ce, Pr, Al, Ti, V, Fe and U in the South Pole record. Elevated concentrations of dust elements are observed from 60 BCE to 1400 CE, followed by a significant decrease around 1400 CE (Fig. 1). Comparison between dust element time series and ERA-Interim climate reanalysis data indicates that dust deposition at South Pole is influenced by the strength of the SHWs (Fig. 1). Our records suggest a significant weakening of the SHWs after 1400 CE, which coincides with the onset of the LIA. Decrease in dust deposition could also be influenced by changes in precipitation in the dust source area. Our findings are consistent with previous paleoclimate reconstructions and modeling studies, that showed weakening of the SHWs and increased precipitation in southern South America during the LIA (Li et al., 2009, Meyer and Wagner, 2009).

Most dust element concentrations remain relatively low until present time, except for V, Ba and Fe, that show an increase in concentrations during the 20th century. Elevated concentrations of these elements are most likely not related to changes in atmospheric circulation, but instead are related to anthropogenic activities in the Southern Hemisphere.

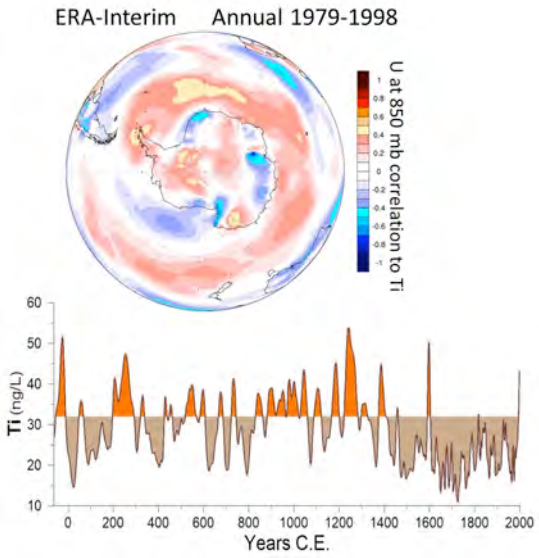

Fig. 1. South Pole Ti concentrations, and Ti correlation to U at 850 mb (http://cci-reanalyzer.org).

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The Link Between Climate Change, Harmful Algal Blooms, and Algal Toxins on the Development of Neurological Diseases

Matthew Kruger[1, 2], Roger B. Sher [3]

1. *Climate Change Institute, University of Maine.*
2. *Graduate School of Biomedical Science and Engineering, University of Maine*
3. *Department of Neurobiology and Behavior, Stony Brook University.*

Abstract: Climate change is resulting in increased temperatures across the planet and will likely lead to an abrupt increase in temperature sensitive blue-green algae and their associated toxins. Moreover, algae release toxins in the form of harmful algal blooms (HABs) as a defense mechanism against organisms that feed on them. Unfortunately, chronic exposure to one HAB toxin in particular, BMAA, has been associated with the development of sporadic Amyotrophic Lateral sclerosis (ALS). Studying the effects of environmentally relevant concentrations of BMAA in public freshwater bodies in New England using zebrafish will provide insight into how increased exposure to the toxin could affect human health. Additionally, this work may lead to the development of new therapeutic medications for ALS. Results of this project will be made available to policymakers and the general public.

Abrupt Climate Change is leading to an increase in the average global temperature of our planet. Unfortunately, with this increase in temperature comes an increase in harmful algal bloom (HABs) consisting of temperature sensitive blue-green algae. These HABs release toxins that can affect human health. One such toxin, BMAA, has been repeatedly associated with an increase in the prevalence of the neurological disease, Amyotrophic Lateral Sclerosis (ALS; Banack et al. 2015; Holtcamp, 2012). Therefore, my project's primary focus is on measuring environmentally relevant concentrations of fresh water HAB toxins and determining their effects on zebrafish neuromuscular fitness, a model system for Amyotrophic Lateral Sclerosis.

Researching how abrupt climate change will affect the concentrations of BMAA in New England drinking water sources will enable us to strengthen the link between the toxin and ALS. This will aid in determining the mechanism of how increased chronic exposure to BMAA increases people's risk of developing ALS.

Zebrafish are a useful tool for studying the effects of a toxin, such as BMAA, on animal health. Overall, studying the effects of BMAA on zebrafish neuromuscular fitness may lead to novel drug therapies to prevent or reduce the symptoms associated with environmentally-induced ALS.

Through working with Maine's DEP and CDC, the results of the project will be disseminated around the local communities via seminars, posters, pamphlets, news articles, or a website, to inform the general public about their potential health risks associated with climate change. BMAA, and ALS. The project results will also enable policy makers to develop or modify policies to improve or reduce the prevalence of BMAA in local drinking water sources.

Acknowledgements: This research was supported by the US National Science Foundation Adaptation to Abrupt Climate Change IGERT program grant DGE-1144423.

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Thermoregulatory Physiology as a Tool for Predicting the Vulnerability of Small Mammals to Climate Change

Danielle L. Levesque[1,2]

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

Abstract: Thermoregulatory characteristics, such as rigidity or flexibility in metabolism and body temperature regulation, affects the energetics of a species. Knowledge of the thermoregulatory physiology of a species is vital for the development of realistic, predictive, models assessing the vulnerability of species to climate change. Using small mammals as model organisms, my research seeks to address gaps in our fundamental understanding of mammalian energetics using a combination of laboratory and field-based projects aimed at elucidating the effects of activity, humidity and high ambient temperature on the performance (and ultimately the distribution) of mammals.

The relationship between animals and their thermal environment has been gaining prominence in the fields of ecology and physiology with the increasing concern over climate change (Huey et al. 2012; Levesque et al. 2016). Physiological data are vital for the development of realistic, predictive, models assessing the vulnerability of species to climate change. The data obtained through studying thermoregulation and energetics can have multiple applications. By understanding the dynamics of the relationship between an animal and its thermal environment, we can better predict energy budgets and responses to changes in climate and resource availability.

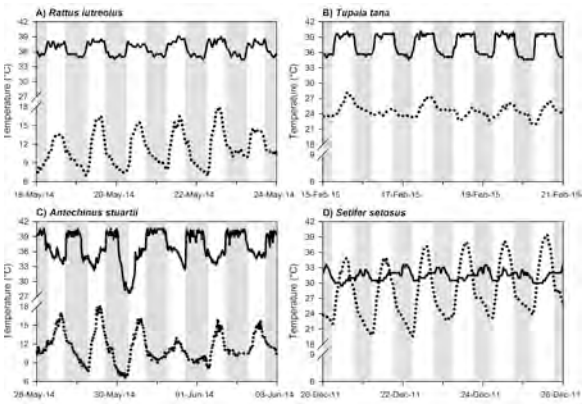

Fig. 1. Body temperature (solid lines) for four different small mammal species showing varying degrees of torpor (a controlled decrease in metabolism). Solid lines indicate body temperature, dashed ambient temperature and the grey bars are nighttime. From Levesque *et al.* 2016.

The ultimate aim of research in the Levesque Lab is to obtain physiological data that are essential for the formulation of climate change mechanistic predictive models. We use thermoregulation and energetics to access the vulnerability of species to threats such as habitat loss and climate change. The natural laboratory provided by the existing climate divisions within Maine allows for the study different species both at their northernmost and southernmost range distribution. Comparing heat tolerance, between closely related species from either side of the climate divide (such as Northern and Southern flying squirrels) will allow me to elucidate mechanisms that allow some species to tolerate high temperatures, and constrain others. A combined field and laboratory approach will contribute to mechanistic physiological models for use in predicting potential range shifts under various climate change scenarios.

Acknowledgements: This research is supported by Hatch project number 21623 through the Maine Agricultural & Forest Experiment Station.

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Effectiveness of a UNFCCC Adaptation Fund Project in Enhancing Resilience to Climate Change in Northwestern Nicaragua

Anna McGinn[1, 2], Cindy Isenhour[1, 3], Aaron L. Strong[1, 4]

1. *Climate Change Institute, University of Maine.*
2. *School of Policy and International Affairs, University of Maine.*
3. *Department of Anthropology, University of Maine.*
4. *School of Marine Sciences, University of Maine.*

Abstract: The United Nations Framework Convention on Climate Change's (UNFCCC) Adaptation Fund (AF) project in northwest Nicaragua has four objectives: to install infrastructure for water capture and storage; to increase agroforestry; to facilitate climate resilient management plans; and to sustain monitoring and analysis of climate change in the region[1]. AF projects have been deployed around the world, yet there is little published work on what is taking place on the ground. This research explores the case study of northwest Nicaragua to understand the extent to which resilience to climate change is enhanced by the objectives of the AF project.

Human, ecosystem, and infrastructural adaptation to climate change are necessitated by the continuing rise of global atmospheric greenhouse gas concentrations. One mechanism developed by the UNFCCC to support adaptation projects is the Adaptation Fund (AF). The AF's charge, to fund concrete adaptation projects in developing countries vulnerable to climate change, situates the fund at the nexus of climate change and sustainable development policies. There is a unique opportunity to enhance resilience through these projects, which I explore through a case study of a project in Nicaragua: *Reduction of risk and vulnerability based on flooding and drought in the Estero Real River Watershed*.

About 60% of the population living in the Estero Real River Watershed relies on agriculture for their livelihoods. The region, which also has a high level of extreme rural poverty, has been the subject of many development attempts including government efforts in the 1970s to transition the region's agriculture to monoculture and agrochemical farming techniques. In 1998, Hurricane Mitch hit the region destroying most of the infrastructure that did exist setting development back significantly. In more recent years, Nicaragua has initiated a renewed effort to set priorities on agriculture and water management with a focus on local water committees and agro-forestry. In this context, implementation of this AF project began in 2011 focused on four goals: to install infrastructure for water capture and storage; to increase agroforestry; to facilitate climate resilient management plans; and to sustain monitoring and analysis of climate change in the region[1].

This research project aims to understand, from the perspective of the community, if the AF project has enhanced regional resilience. It will explore the project's potential co-benefits, such as increased job security and greater levels of social equality as well as potential negative externalities including livelihood loss and conflict. Finally, it seeks to understand the additionally of adaptation and development funds.

Acknowledgements: This project is supported by the National Science Foundation Graduate Research Fellowship DGE-1144205, the SPIA Richardson-Churchill Graduate Fellowship, and the Churchill Exploration Fund.

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Ground Penetrating Radar and Archaeological Site Delineation: Quantifying Rapidly Eroding Shell Middens Along the Coast of Maine

Jacquelynn F. Miller[2], Alice R. Kelley[1,2], Joseph T. Kelley[1,2], Daniel Belknap[1,2], Arthur Spiess[3]

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

Abstract: Approximately 2000 aboriginal shell middens along the coast of Maine archive a unique record of cultural and climatic change, but these archaeological sites are continually lost to the sea through climate-driven coastal erosion and sea-level rise. Traditional methods of midden delineation employ destructive and labor intensive archaeological investigation. This research seeks to circumvent these issues and demonstrate the utility of ground penetrating radar (GPR) survey as a precise and cost-effective means of characterizing archaeological shell midden extent and stratigraphy.

Coastal middens are the result of pre-European aboriginal accumulation of centimeters to meters of clam and/or oyster shells, with associated artifacts and faunal remains, and are records of 5,000 years of Gulf of Maine coastal lifeways and environmental conditions. Currently, Maine lacks a statewide plan of shell midden site monitoring and rescue because characterization has focused on expensive and destructive archaeological excavation. This project employs ground penetrating radar (GPR) to obtain high-resolution site extent and stratigraphic data using an efficient, cost-effective, and nondestructive survey method (see Fig. 1).

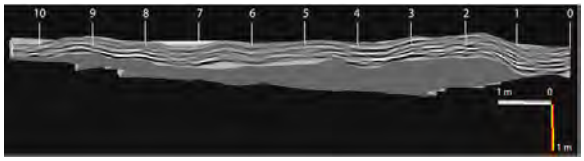

Fig. 1. The 3D representation of a shell midden with a GPR record superimposed on one face.

GPR profiles record below surface stratigraphy by noting differences in the electrical properties of the material that reflect variations in layer composition, compaction, grain size, or water content. This data is used to evaluate midden thickness (see Fig. 2), presence or absence of disturbance, and may be able to resolve the remains of dwellings. A traditional geographic information system (GIS) comparison of aerial photography time-series was undertaken as part of this study, but results indicate a need for improved techniques to understand rates and processes of midden loss. This work creates a baseline understanding for applicable monitoring, preservation, and rescue strategies.

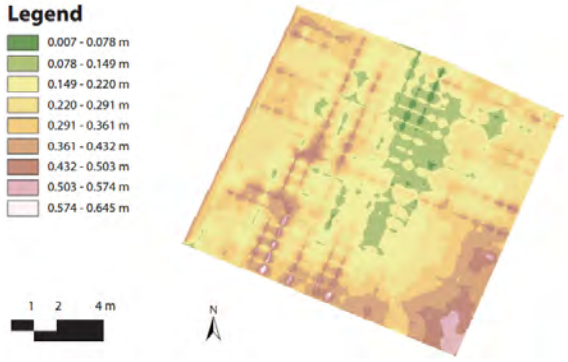

Fig. 2. Thickness of a midden in meters.

The goal of this research is the creation of a monitoring, preservation, and rescue plan for coastal shell middens in the state of Maine. As sea level continues to rise, and sites and the information they hold are currently disappearing, the need for the application of GPR and shoreline change studies of coastal shell midden sites in Maine is critical.

Acknowledgements: This project is made possible by funding from Maine Sea Grant.

Microscopic Controls on Ice Flow, Jarvis Glacier, Alaska

Stephanie Mills[1], Christopher Gerbi[1]
1. *School of Earth and Climate Sciences, University of Maine.*

Abstract: This project's primary question is: how do microscopic properties affect the flow of glacial ice? Ice streams and glaciers are primary means of ice mass loss; shear zones at their margins are likely to have different microstructural and flow properties. We will be collecting the following data on a glacier with simple geometry in order to correlate ice flow with microstructure: radar, seismic, surface and down-borehole velocity, borehole temperature, core stratigraphy, and crystallographic orientation and grain size of ice cores. All of this data will be analyzed in a numerical model, testing whether the real microstructure has a significant effect on the flow.

Ice streams and glaciers are the primary means of ice mass loss in ice sheets. The margins of ice streams and glaciers commonly account for over half of the resistance to flow, and much shearing takes place at the margin. Theoretically, shearing should cause all the ice crystals to rotate in the same direction, though to date, very little work has been done to verify this in a real glacier. Each ice crystal has an easy-flow and hard-flow direction, so if all the crystals are lined up in the easy-flow direction, the ice can flow faster (figure 1). Ours will be the first study to measure crystallographic orientation of deep ice cores (50-120 meters) at a glacier margin and relate it to glacial flow.

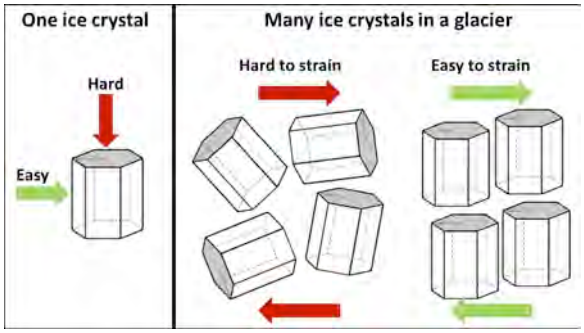

Figure 1. Each ice crystal has an easy-flow and hard-flow direction. If all crystals are aligned in the easy-flow direction, the ice can flow faster. At a glacier margin, shearing should cause all crystals to align.

We will collect ice cores across a velocity gradient at the margin of Jarvis glacier, Alaska. One core will be very sheared, one will not be sheared, and we will collect a third core in-between. In each borehole, we will measure temperature and tilt. The temperature is an important controlling factor on flow, and the tilt is part of the measurement of flow. We will also collect velocity data on the surface of the glacier as another measure of flow, and use radar to generate the geometry of the glacier for the numerical model. The crystallographic orientation of the ice cores will be measured on the scanning electron microscope at UM SECS, one of two such microscopes in the world that can analyze large (bigger than 2x3 cm) samples of ice. The orientation data will be entered into a numerical model that will test whether the orientation has a significant impact on the velocity of the flow and whether it matches the measured velocity.

Because collecting ice cores is expensive, time consuming, and spacially limited, Steve Bernsen and Seth Campbell (UM SECS) will be testing how radar and seismic properties correlate with bulk crystallographic orientation. If clear correlation can be made, researchers would be able to map the bulk crystallographic orientation over large areas relatively quickly. This could be entered in numerical models to make better predictions of future glacial flow and mass loss.

Acknowledgements: This project is being completed by a large team. UM SECS: Seth Campbell, Steve Bernsen, Kimberley Miner, Karl Kreutz, Peter Koons. Dartmouth: Bob Hawley, Ian Lee, David Clemens-Sewall. We are also grateful for the support from Alaska CH2M Hill Polar Services, especially Laurel McFadden, and the Alaska Cold Regions Research and Engineering Laboratory, especially Tom Douglas. This project is funded by NSF award 1503924.

A Model for Screening Persistent Organic Pollution Risk from Glacial Meltwater

Kimberley Rain Miner[1,2] Karl Kreutz[1,2] Christopher Gerbi[2]

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

Abstract: Organochlorine compounds released into the environment by industrial nations as pesticides and industrial additives beginning in the 1950's have expanded worldwide, moving throughout ecosystems. Glaciated ecosystems are no exception, with glaciers acting as reservoirs for decommissioned chemicals. While studies have demonstrated the existence of resident pollutants within glaciated ecosystems, no one has used standard toxicological testing methods to assess the risk posed by these compounds when released in glacial outflows. This study uses existing Environmental Protection Agency models with a new application, to determine screening level risk from glacial meltwater to downstream residents.

In 1980 the United States House introduced an act to monitor and mitigate the impacts of hazardous waste on American soil. From that bill the Environmental Protection Agency developed the 'Superfund' program, to determine and lessen the impacts of hazardous sites. The framework developed for understanding and integrating human risk from pollution continues to this day to be the framework for toxicological risk management.

Utilizing the Superfund model, but adapting it to the entirely new purpose of managing legacy contaminants within glacial meltwater has provided a screening-level understanding of the long term risk these pollutants pose. We have analyzed compounds emergent from the Silvretta glacier in Switzerland, and the Lys glacier in Italy. Our model shows that high-risk glaciers within the Alps range may contain levels of persistent organic pollutants that over the long-term could have a deleterious impact on downstream human residents. Our model combines two main oral uptake pathways in the forms of fish and water consumption. These sources give us an idea of long-term risk for residents consuming products directly from, and in equilibrium with, glacial meltwater. Though initial screening has determined the concentration in glacial meltwater from two glaciers below the cancer risk level, they are above the level considered safe for a number of other diseases. This may be most important for children whose long-term uptake and small body size significantly increase risk.

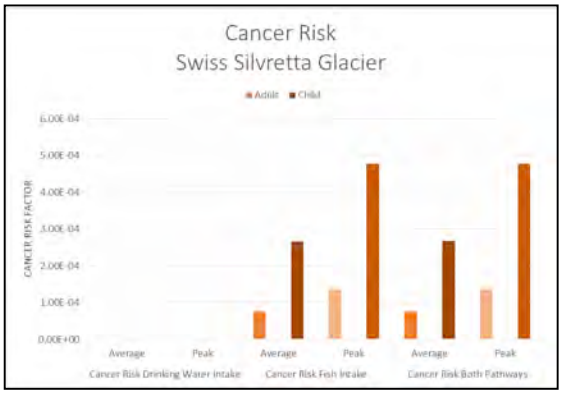

Figure 1. Output of cancer risk model from Silvretta glacier in Switzerland

Additional screening parameters and contaminants will be considered, as well as an expansion of the field sites to include North America. This model provides a versatile and replicable screening level understanding of persistent organic pollutant risk in glacial meltwater and could be used at other sites of concern throughout the world.

Acknowledgements: Gratitude for the support of Dr. Karl Kreutz, Dr. Chris Gerbi, Dr. Brian Perkins, Dr. Jules Blais, Dr. Aaron Putnam, Dr. Shaleen Jain, Dr. Christian Bogdal, Dr. Glenn Rice and Dr. Sean Birkel. Support provided by the NSF program grant DGE-1144423, NSF award PLR-1503924, Robert and Patricia Switzer Foundation, SMART program at the DOD, Fulbright program at the State Dept.

Implications of Changing Snowpack for Alpine Lakes: Response of Diatom Communities in Rocky Mountain Lakes

Edna Luz Pedraza Garzón[1, 2], Jasmine Saros[1.2]

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

Abstract: Snowpack is declining in alpine regions of the western US, with part of this pattern driven by changes in the El Niño Southern Oscillation (ENSO). The aim of the project is to understand the effects of snowpack decrease associated with ENSO events on diatom communities in alpine lakes.

Alpine lakes are sensitive ecosystems that respond rapidly to climate change. In the Rocky Mountains these lakes depend on ice cover and snow accumulation to regulate lake structure and function (Trujillo and Molotch 2014).

El Niño southern oscillation (ENSO) causes anomalous weather in the western United States, triggering warmer and wetter winters, as well as drier and warmer summers due to snowpack reduction (see Fig. 1). (Lidsey 2001). It changes the timing of ice off, water column stability, and nutrient cycling that affects biological interactions. ENSO will behave unpredictably with warmer conditions, causing unforeseen changes in lakes functioning.

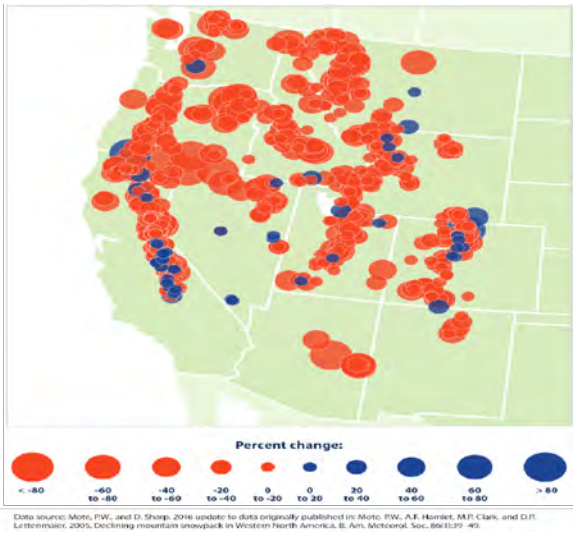

Fig. 1. Trends in April Snowpack in the Western United States 1955-2016 (US EPA 2016).

Physical and chemical shifts in alpine lakes caused by ENSO are well understood, but there is limited understanding about repercussions on biological communities. The aim of this research is to study diatom communities of alpine lakes to comprehend the effect of ENSO on primary producers and to clarify doubts about some species that are considered to be favored by early ice out and prolonged mixing, such as *Aulacoseira lirata*, *A perglabra* and *A. distans.*

To address this, lake sediments from 5 alpine lakes of the Greater Yellowstone Ecosystem will be analyzed and lake surveys will be done to test the effect of early ice-off on diatom composition, contributing to knowledge of *Aulacoseira* species ecology.

Acknowledgements: Thank you to Fulbright Program and to Churchill Exploration Funds for funding.

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Holocene Deglaciation at Amundsen Glacier, Antarctica

Jill N. Pelto[1,2], Brenda L. Hall[1,2], John O. Stone[3]

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

Abstract: In 2016-17 we carried out fieldwork near Amundsen Glacier to document glacial recession during the last termination. The results of this study will allow us to further constrain the chronology of the retreat of the Ross Sea Ice Sheet after the Last Glacial Maximum.

The Antarctic Ice Sheet (AIS) contains ~58 m of global sea-level equivalent, thus it is crucial to investigate ice-sheet behavior to predict future sea-level rise (Fretwell et al., 2013). To do so, this study examines the Last Glacial Maximum (LGM) ~26.5-18 ka, when the East (EAIS) and West Antarctic Ice Sheet (WAIS) expanded to form the marine-based Ross Sea Ice Sheet (RSIS)(Denton and Hughes, 2002). Constraining past ice-sheet fluctuations will help us to understand the controlling mechanisms of the AIS (Hall et al., 2013).

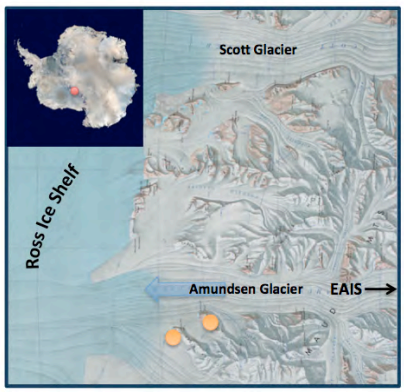

Fig.1. Location of Amundsen Glacier inset; Orange points mark the two nunataks where sampling was conducted; Note south is up.

Amundsen Glacier (~85°S, ~159°W) is sourced from the EAIS and flows through the Transantarctic Mountains to the Ross Ice Shelf (Fig. 1). The goals of the work are to map glacial deposits to determine former ice extent and elevation during the LGM and to develop a chronology for ice fluctuations. In particular, we will produce age vs. elevation transects at ice-free regions near the coast which will allow us to produce a chronology of glacier recession following the LGM.

Fieldwork consisted of mapping glacial deposits to delineate former ice margins and collecting ancient algae samples for ^{14}C dating from glacial landforms and lacustrine deposits. Just as today, in the past ice-marginal ponds were dammed by Amundsen Glacier. As the ice thinned, the ponds followed the ice margin and moved downslope. The algae from these ponds were stranded on the hillsides and thus record the position of the former ice margin as it thinned to its present location (Hall et al., 2016).

The history of Amundsen Glacier and the wider RSIS since the LGM will improve our knowledge of the sensitivity of an ice sheet grounded below sea level to various ocean and climate changes. By investigating a past marine-based ice sheet, such as that which existed in the Ross Sea, we can make predictions about the response of WAIS to sea-level rise and increasing oceanic and atmospheric temperatures.

Acknowledgements:
National Science Foundation.

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Excavations at Tranquility Farm: A Seasonality Analysis Using Mollusk Remains

Kate Pontbriand[1, 2], Dr. Daniel Sandwiess[1, 2]

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

Abstract: Tranquility Farm is a pre-Contact Native American archaeological site located on the coast of Gouldsboro, Maine. This coastal shell midden has provided a wealth of stone and bone tools, burned plant remains, and house floors dating back 1200 years. To determine the season of occupation, oxygen isotopic patterns within mollusk shells will be analyzed and seasonal indicators identified. These data, combined with a sample of faunal bones previously analyzed, will help determine the season of occupation and contribute to our understanding of what activities and seasonal patterns in which the site's occupance participated.

Background:

Tranquility Farm is a shell midden archaeological site located in Gouldsboro, Maine which has provided a wealth of knowledge to the archaeological community and served as an important outreach and education tool for the Abbe Museum of Bar Harbor, Maine.

The calcium carbonate contained in the midden's shells neutralizes the site's acidic soils allowing for the preservation of organic materials, such as faunal bones and burned plant remains. The presence of these preserved remains allows archaeologists to better recreate the environment at the time of occupation and, thus, better understand the people who lived there.

Figure 1. Abbe Museum Field School 2012

Tranquility Farm also served as a teaching site for the Abbe Museum which hosted an annual field school to educate participants about archaeology and the Wabinaki Nations. The materials from this site are used by museum educators and researchers to create exhibits, educational programs, and events for the public.

Purpose:

By looking at oxygen isotopic patterns within mollusk shells recovered from the site, I should be able to determine the season of death, i.e. when the mollusk was harvested. Determining the season of harvest will indicate if the site was a summer of winter occupation and contribute to our understanding of subsistence patterns.

Methodologies:

To analyze my thesis data for seasonality, I plan to use the methodologies of sectioning, processing, and analyzing mollusks discussed in the current literature and set forth by Dr. Daniel Sandwiess and Dr. Arthur Spiess.

Acknowledgements:

Julia Gray of the Abbe Museum and Dr. Arthur Spiess of the Maine Historic Preservation Office for giving me the opportunity to work on this site and use the data it produced, Dr. Daniel Sandwiess for advising me in this process, and Dr. Elizabeth Hufnagel for providing me with my research assistantship which allows me to attend the University of Maine.

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A New Ice Core from Osjollo Anante, Peruvian Andes - Preliminary Results

Mariusz Potocki[1, 2], Charles Rodda[1, 2], Paul A. Mayewski[1, 2], Douglas Introne[1]

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

Abstract: A 21 m ice core extracted from Osjollo Anante Glacier in 2016 offers a history of environmental change in the Southern Peruvian Andes.

Since the mid-1980s ice core research has been conducted in South America. Ice cores have been retrieved from the tropical Andes to Patagonia (Bolius et al., 2006).

Instrumental records of climate and environmental variability over the Andes are sparse and rarely extend to higher elevations or cover more than 100 years. However, ice cores from the tropics and mid-latitude glaciers can provide high-resolution records of past climate dynamics and chemistry of the atmosphere ranging from seasonal to millennia time-scales (Ginot et al., 2006) Unfortunately, as a result of recent warming, many low to mid-latitude glaciers suitable for robust reconstructions of climate and environmental change records are rapidly disappearing (Casassa et al.,1998).

Despite the recent collection effort, a large spatial data gap remains between the mid latitudes and the tropics. To help fill the gap, a 21 m ice core was recovered, in October 2016, from the Nevado Osjollo Anante glacier (5600m, 13°46'S, 71°05'W) in the Cordillera Vilcanota in Southern Peru. Peruvian glaciers are rapidly disappearing, taking with them unique paleo-environmental information stored in the ice, information that can still be retrieved by drilling ice cores. Osjollo Anante (OA) ice core climate archives are likely in peril in the near future as regional and global temperatures are predicted to continue to rise and tropical glaciers continue to ablate at continually higher elevations.

Climate along the eastern and western slopes of the Peruvian Andes is highly variable (Garreaud, 2009). At tropical and sub-tropical latitudes relatively cold and arid conditions exist along the Pacific coast and the western slopes of Andes, while warm, moist and rainy conditions prevail on the eastern slopes. There is a strong precipitation seasonality in Cordillera Vilcanota with a mean dry season (June–August) and a mean wet season (November–March) (Hardy 2008).

Preliminary glaciochemical and isotopic analyses conducted in our laboratory of OA ice indicate that the paleo-record is well preserved. Human activities including agriculture, mining, industry and large-scale land use change release heavy and trace metals in concentrations greater than natural background levels will likely be found in the OA record.

The OA ice core was recovered from an exposure revealing highly compressed ice layers from the modern surface down (Fig. 1) to the beginning of the Little Ice Age (locally AD1350-1880). Using the 120 micron sampling resolution capability of our Keck Laser Ice Facility (Sneed et al., 2015) we expect to examine sub-seasonal to storm scale changes in climate and environmental parameters.

Fig 1. Drill site for the 2016 core on Nevado Osjollo Anante

Acknowledgements: NSF grant P2C2 1401899 and the W.M. Keck Foundation.

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Chronology of the Last Termination of Tsagaan Gol-Potanin Glacier Valley, Altai Mountains, Mongolia Using ^{10}Be Surface Exposure Dating

Mariah J. Radue[1, 2], Aaron E. Putnam[1, 2], Peter D. Strand [1, 2]

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

Abstract: The mechanisms that triggered rapid warming during the termination of the last ice age are unresolved. Here, we present a ^{10}Be surface-exposure chronology in the Mongolian Altai to constrain temperature change during deglaciation. By comparing this record to climate forcers, such as CO_2, we can better understand the mechanisms that forced this major global warming event.

The Last Termination (~19-11 ka) marks the end of the last ice age and the transition to modern interglacial conditions. Increasing northern hemisphere summer insolation alone cannot account for the rapid global warming during this time. Various hypotheses posit other mechanisms that drove rising temperatures, such an increase in atmospheric CO_2, changes in ocean circulation, shifting wind belts, and water vapor. The mystery of rapid warming during the Termination is a fundamental question in earth science and impinges our understanding of the climate system.

This research investigates the Last Termination in the Mongolian Altai (49°N, 88°E), a mountain range in central Asia (Fig. 1). We will reconstruct the glacial record to constrain atmospheric temperature from the Last Glacial Maximum to the Late Holocene. Glaciers are highly sensitive to changes in atmospheric temperatures as seen by their current retreat due to modern warming. Mongolia is an ideal location to document past climate because it is isolated from oceanic influences; therefore, our climate record should be sensitive to local radiation forcing from changes in Earth's orbital configuration, greenhouse gases, and heat transfer from atmospheric circulation.

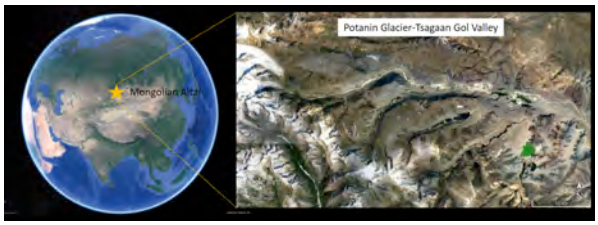

Fig. 1. Google Earth imagery of study area.

To create a climate record in the Mongolian Altai, we use ^{10}Be surface-exposure dating to determine the ages of moraines in the Tsagaan Gol-Potanin Glacier valley (Fig. 2). The depositional age of boulders on moraines give ages to former stable ice positions. From the glacier positions, we determine atmospheric temperatures through glaciological modeling.

Fig. 2. Conducting ^{10}Be surface exposure dating sampling in the Mongolian Altai, Potanin Glacier in the background (Photo: Aaron Putnam).

In addition, we are performing glacial geomorphic mapping using satellite and unmanned aerial vehicle (UAV) imagery. We use structure-from-motion software to create elevation models of our sampling areas. The use of UAV in mapping has provided high-resolution imagery and elevation models that are two orders of magnitude more accurate than currently available satellite data.

We await preliminary data that may provide insight into the climate of central Asia during the Late Quaternary and the nature of the Last Termination.

Acknowledgements: The National Science Foundation and The Comer Family Foundation provided funding and support for this research.

The Impacts of Competition on Juvenile Atlantic salmon (*Salmo salar*) Recovery in a Rapidly Changing Climate

Nicole C. Ramberg-Pihl[1,2], Hamish S. Greig[2], Stephen Coghlan[3], Joseph Zydlewski[3,4]

1. *Climate Change Institute, University of Maine.*
2. *School of Biology and Ecology, University of Maine.*
3. *Department of Wildlife, Fisheries, and Conservation Biology, University of Maine.*
4. *U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit.*

Abstract: Atlantic salmon face multiple threats stemming from climate change and invasive species. Our aim is to understand how factors such as climate change and competition with non-native species impact juvenile Atlantic salmon in Maine streams. We anticipate that our research will better inform management solutions by helping managers identify and prioritize critical salmon nursery habitat for stocking in light of climate changes that may occur rapidly in the state.

Spying on Salmon

Extreme precipitation (flooding/drought) and temperature events are expected to occur more frequently in the future[1] and could impact the recovery of Atlantic salmon (*Salmo salar*) in Maine streams by altering competition dynamics with native brook trout (*Salvelinus fontinalis*) and non-native smallmouth bass (*Micropterus doloieu*).

By using artificial stream environments in the laboratory, we simulate flooding or drought conditions by altering stream flow. Similarly, we simulate extreme temperature events by manipulating water temperature. We run trials with varying combinations of Atlantic salmon, non-native smallmouth bass, and native brook trout, to examine how the presence of native versus non-native competitors impacts salmon performance. Interestingly, little is known about the impacts of smallmouth bass competition on salmon performance despite the fact that invasive smallmouth bass have a history of prolific range expansion in Maine and are known to coexist with salmon in regions deemed as critical salmon habitat (Figure 1).

All trials are recorded using cameras fixed above each artificial stream and allow for accurate collection of performance metrics such as foraging attempts, agonistic encounters, displacement, and bioenergetic demand of swimming (i.e. tailbeats). This work could help elucidate how salmon may be outcompeted for space and resources in a rapidly changing climate and contribute to salmon recovery efforts.

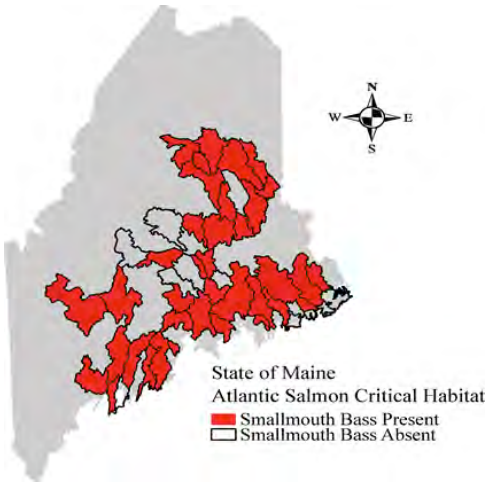

Figure 1. Presence of smallmouth bass within watersheds deemed Atlantic salmon critical habitat, identified by the US Fish and Wildlife Service and made available through ESRI ArcMap Online. Location of smallmouth bass compiled from the Maine Department of IFW Recreational Fishing Guides.

Acknowledgements: This research was supported by the US National Science Foundation Adaptation to Abrupt Climate Change IGERT Program grant DGE-1144423, Maine Sea Grant, and The Atlantic Salmon Federation Olin Fellowship.

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Declining Dissolved Oxygen in the Central California Current Region

Alice S. Ren[1, 2], Fei Chai[1, 2], Huijie Xue[2], Francisco P. Chavez[3], David M. Anderson[3]

1. *Climate Change Institute, University of Maine.*
2. *School of Marine Science, University of Maine.*
3. *Monterey Bay Aquarium Research Institute.*

Abstract: Regionally, the California Current has experienced dissolved oxygen declines since the late 1980s with observations from Oregon and the Southern California Bight. Here, we present observations of declining dissolved oxygen along CalCOFI Line 67 off of Monterey Bay, in the Central California Current region, and investigate likely mechanisms.

Introduction:

A potential consequence of climate change is a global decrease in dissolved oxygen at depth due to changes in the balance of ventilation, mixing, respiration, and photosynthesis in the oceans.

Regionally, the California Current has experienced dissolved oxygen declines since the late 1980s with observations from Oregon and the Southern California Bight. Here, we present observations of declining dissolved oxygen along CalCOFI Line 67 off of Monterey Bay, in the Central California Current region, and investigate likely mechanisms.

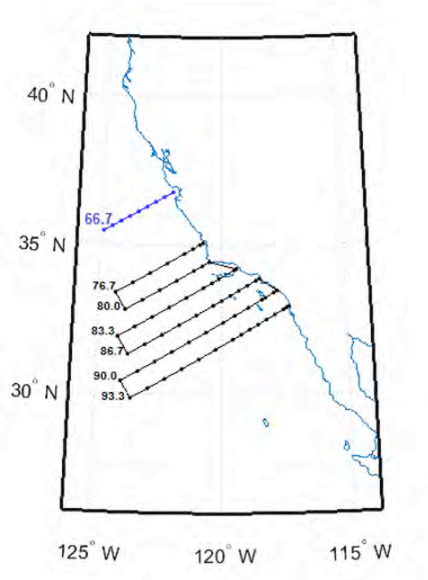

Fig. 1. Map of the location of CalCOFI Line 67, stations 50 to 90 (blue), and the standard CalCOFI sampling lines (black).

The hydrographic cruises obtained dissolved oxygen measurements 50-300 km from shore between 1998 and 2013, with quasi-seasonal sampling resolution. Data for this analysis were from CalCOFI Line 67, at stations 50, 55, 60, 65, 70, 75, 80, 85, and 90 (see Fig. 1). The Line 67 transect, as all CalCOFI lines, runs approximately normal to the coastline.

Results:

Dissolved oxygen decreased along the entire transect over the 16-year period on the σ_θ 26.6-26.8 isopycnals, corresponding to depths between 250-400 m. At two regions around 130 and 240 km from shore respectively, declines in dissolved oxygen occurred on σ_θ 25.7-26.5 as well as σ_θ 26.6-26.8.

Variations in oxygen concentration σ_θ 25.5, at approximately the bottom of the surface mixed layer, did not show similar decline, but correlated with environmental climate indices including the NPGO and the upwelling index. A box model of the region suggests that the primary mechanism at work is changing dissolved oxygen concentration of source waters feeding the Central California Current upwelling region, but that there may be multiple mechanisms.

Our work highlights the need for care in investigating dissolved oxygen in the California Current system due to the complex mechanisms at work.

Acknowledgements: This research was supported by the US National Science Foundation Adaptation to Abrupt Climate Change IGERT program grant DGE-1144423 and the David and Lucile Packard Foundation.

Hardware-Accelerated Hydrodynamic Modeling Enables Three-Dimensional Study of Bedrock Channel Evolution

Nicholas Richmond[1], Peter Koons[1, 2]

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

Abstract: Inertial forces generated by complex flows in bedrock channels may exceed the erosive potential of shear forces by a factor of two or more. Previous methods failed to capture these inertial forces, which we are now able to quantify and incorporate into a solid earth failure model.

Bedrock channels connect climate-driven surficial processes with deep Earth processes and communicate this connection at multiple frequencies across dynamic landscapes. The evolution of bedrock channels has historically relied on unphysical simplifications and phenomenological approximations which obscure the complex interactions between flowing water and the solid Earth. Chief among these simplifications is the omission of the normal forces associated with changes in channel geometry such as cascades and river bends. Recent advances in hardware-accelerated computational fluid dynamics enable high-resolution numerical simulation of the complex flows which sculpt landscapes.

Smoothed Particle Hydrodynamics (SPH) is a computational technique which approximates the physics of three-dimensional flows by solving the Navier-Stokes (N-S) equations which govern the motion of fluids. Prior to the advent of parallel processing with graphics processing units (GPUs), numerical solutions to the N-S equations were too computationally expensive to be practical for simulating three-dimensional flows. DualSPHysics (Crespo et al. 2015), a GPU-enabled SPH solver, provides detailed three-dimensional flow kinematics and enables computation of the forces imposed by flowing water on the solid Earth.

By coupling the 3D hydrodynamics with a Mohr-Coulomb failure model, we can investigate the sensitivity of bedrock channels to complex flows and rock strength heterogeneities, thereby gaining insight into how complex flow patterns influence bedrock channel incision. Forthcoming investigations will focus on the erosion dynamics associated with river bends, plunge pools, and other bedrock channel features which are sensitive to the climatic controls on discharge.

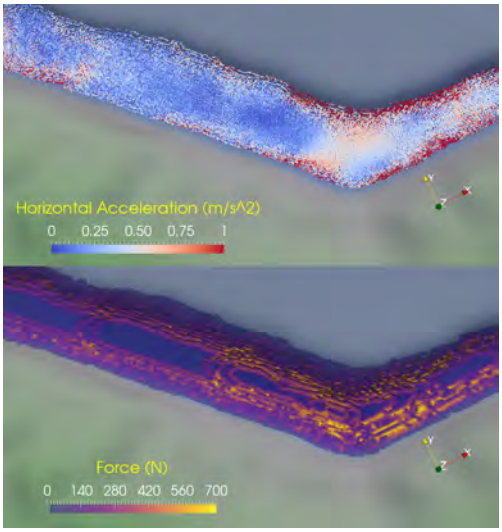

Fig. 1. The 3D fluid motion calculated using SPH reveals that simple changes in geometry can greatly increase the normal forces, such as in the above bend in a bedrock channel (plan view, flow is left to right). These normal forces have tremendous erosive potential and were previously inaccessible by traditional numerical methods.

Acknowledgements: NSF GeoPRISMS OCE-1249909 Grant to Dr. Peter Koons. Training and outreach support from Graduate Student Government. Collaboration with Dr. Sean Smith and Dr. Samuel Roy.

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A 2,000-Year Climate History of Central Asia

Charles I. Rodda[1, 2], Paul Mayewski[1, 2], Sean Birkel[1, 2]

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

Abstract: We synthesize 2,000 years of paleoclimate proxy records from Central Asia, examine weather station data from 600 Central Asian stations active since the beginning of the twentieth century, and compare climate reanalysis model outputs since 1978 to describe historical climate changes in Central Asia. We also use recent hot years as analogs to predict potential climate futures for Central Asia. This method suggests that glaciers and water resources in Central Asia will be threatened by decreased precipitation and enhanced warming in glaciated regions.

Central Asia is one of the driest regions on Earth, and is likely to be particularly ecologically sensitive to changes in rainfall, due to the potential for strong feedbacks related to aridification (Narisma, et al., 2007). Changes in annual melt water delivery are of primary concern, as ~80% of Central Asia's water flow comes from delayed snow and ice melt in the Pamir Mountains (Kaser et al., 2010).

Using data from ~600 Central Asia weather stations active since 1871, we find that that the Global Historical Climatology Network weather station record is insufficient in and of itself to make a regional assessment of atmospheric circulation and moisture delivery, due to the spatial and to a greater degree, the temporal discontinuity of the data sources. Erroneous data and discontinuous records confound regional synopses. Weather station data is useful, however, to "ground truth" a suite of reanalysis models. The ERA-Interim reanalysis model is found to be the best-correlated to weather observations within Central Asia, and should be used for climate study in this region until a better-correlated reanalysis model is discovered.

A novel method of predicting future atmospheric circulation, temperature, and precipitation in Central Asia by using modern hot years (MHY) as analogs for a warming climate is shown to be a potentially useful tool for predicting climate change and future resource availability on spatial and temporal scales not possible by using the regularly cited CCSM3 and CCSM4 models. Our approach suggests that even with regionally averaged annual mean temperature increases well below those predicted by the CCSM models, changes in the location and seasonality of shifting atmospheric circulation and moisture delivery to Central Asia is likely to be enhanced in ecologically significant areas.

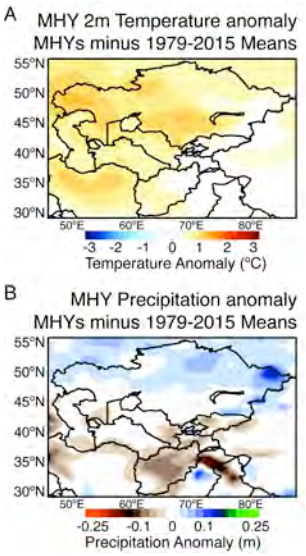

Fig.1. MHY analogs for a warming climate; panel A shows 2 meter temperature differences and B shows precipitation differences, relative to 1979-2015 means

Acknowledgements: This research is supported by NSF grant #1401899.

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Annotating Unit Functions in the Climate Data Workbench

Mark Royer[1], Sudarshan S. Chawathe[1,2], Andrei V. Kurbatov[2], Paul A. Mayewski[2,3]

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

Abstract: We describe a method for representing measurement units for the *Climate Data Workbench*, providing easier avoidance and detection of a significant source of errors in scientific code. Our method uses the *Java virtual-machine*'s class-loading extensions, and annotations with runtime retention policies, to enforce units conformance and conversion at runtime.

Introduction

It is common practice for physical quantities (such as 0.23 m/s) to be represented in programs as 0.23, with the units being implicit or separately maintained. This practice is a frequent source of errors. A notable instance is the unit conversion error that was implicated in the crash of the NASA Mars Climate Orbiter in 1998: English measurement units were not converted into the required metric types. Often, errors involving units are very difficult to detect. Such errors tend to propagate throughout the system and are not discovered until a later time when the program fails for an apparently enigmatic reason. A much worse outcome is when the system does not detectably fail, but continues to operate with inaccurate values, with potentially dangerous consequences. Our implementation of the *Climate Data Workbench* builds on prior work on unit conversion, compile-time annotations, and run-time checks to support measurement unit more robustly.

Java Unit Support

A few Java Specification Requests (*JSRs*) address unit support by modeling units in the Java type system (JSR 108, 275, and 363). Other approaches model units using annotated types (JSR 308). There are also programs for performing the conversion from one type of unit to another (GNU Units, JConvert, and units-in-java).

Our workbench uses an annotation-based approach. Methods that require parameter types with units are annotated. However, unlike JSR 308, the unit is not encoded as an annotation type. Instead, the unit is recorded as a string valued parameter of the annotation. For example, the annotation `@Unit('ppb')` indicates that the associated value is a concentration with units *ppb*. The annotation has a runtime retention policy, so that unit information will not be discarded after compilation.

At runtime, an extended class loader is used to detect unit annotations. Types found in the user *classpath* are loaded by the extended class loader, and classes found on the system *classpath* are delegated to the default loader. Bytecode manipulation and I/O operations are performed using the ASM bytecode manipulation and analysis framework. This allows the class loader to inject methods with additional bytecode for annotated methods. The supplementary code enforces unit conformance and performs unit conversion using a units database.

Example

Consider the following small illustrative code example that sums two floating point numbers and returns the result.

```
public @Unit("ppb") double sum(@Unit("ppb") double m1,
                               @Unit("ppt") double m2) {
        return m1 + m2;
}
```

The method parameters *m1* and *m2* have annotations indicating that they are concentrations (*ppb* and *ppt*). The result of the function is also a concentration (*ppb*). There are multiple errors that are exposed by augmenting the code with unit information. First, *m1* and *m2* are not the same unit, and so the summation would lead to an error. In addition, in absence of unit annotations, there is no guarantee that the runtime arguments will have the proper units. The code to verify and convert the data is automatically inserted by the class loader.

Distinguishing Between Clouds and Icebergs Along Greenland's Marine Margins

Jessica Scheick[1,2], Ellyn Enderlin[1,2], Gordon Hamilton[1,2]

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

Abstract: Recent changes in iceberg discharge from the marine margins of the Greenland ice sheet have likely resulted in changes in iceberg size distributions. Knowledge of changes in iceberg abundance and size are important for coastal navigation and quantifying distributed freshwater fluxes to the ocean. However, little work has been done to quantify these changes in iceberg size distribution. This project employs advanced computational techniques to develop a cloud-masking routine that can be applied to optical satellite images. In combination with a previously developed iceberg delineation algorithm, we will derive a time series of iceberg size distributions to quantify changes in the meltwater flux to the ocean and inform coastal maritime navigation.

The response of the Greenland ice sheet (GIS) to recent climate changes continues to grow more pronounced. Mass balance has become increasingly negative over the past two decades as the result of increased surface meltwater runoff and iceberg discharge into surrounding ocean basins (van den Broeke *et al*. 2016). Changes in iceberg discharge due to variations in ice flow (i.e. ice dynamics) are responsible for approximately half of Greenland's annual mass loss (e.g. Enderlin *et al*. 2014). Discharged icebergs act as a distributed source of freshwater to the oceans, impacting ecosystems, fjord stratification, and circulation. Icebergs also constitute a significant navigational hazard. However, despite the importance of icebergs as a key component of the ice-ocean system, they have been the focus of relatively few studies.

Anecdotal evidence from residents of Greenland's coastal towns and a preliminary analysis of iceberg size distributions from repeat satellite images suggests the size and spatial distribution of icebergs in Greenland's coastal waterways have changed over recent decades. We aim to quantify potential changes in freshwater flux as a result of changes in iceberg size distributions through application of a computer algorithm that has been developed to automatically delineate icebergs in optical satellite images. A significant challenge to automated delineation of icebergs is the presence of clouds; thus, we have focused on the development of a cloud-masking algorithm to identify clouds in optical satellite images, allowing us to maximize the temporal resolution of our iceberg distribution time series by enabling use of the full satellite image archive.

Traditional methods of detecting clouds in optical satellite imagery employ thresholding techniques that exploit temperature and near-infrared reflectivity differences between clouds and the underlying terrain to identify and mask out clouds. However, ice/snow and clouds often have similar spectral properties, limiting the success of thresholding techniques. Recent advances in the computational fields of machine learning and feature detection and tracking make these methods more accessible for scientific application and provide an alternative, non-threshold based approach to cloud masking. Preliminary application of machine learning and open source feature detection algorithms to Landsat images of Disko Bay, west Greenland, suggests that these techniques may be used to improve differentiation between icebergs and clouds. Ongoing work aims to optimize use of these advanced computing techniques and quantify the impact of misidentifications on derived iceberg size distributions.

Acknowledgements: This work is supported by a NASA Earth and Space Science Fellowship (NESSF) awarded to Jessica Scheick.

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Have Rapid Climate Change Events Following Deglaciation Outpaced Trees' Ability to Keep Up?

Benjamin J. Seliger[1, 2], Jacquelyn L. Gill[1,2]

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

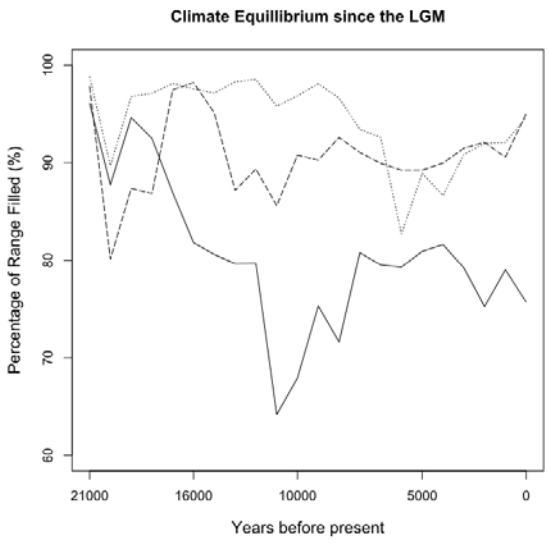
Abstract: The ability for species to keep up with projected climate change remains a critical unknown for quantifying of future biodiversity loss. I present an analysis which reveals when past climate change events outpaced species' ability to keep up. Doing so allows for better estimates on how rapidly species can disperse and how readily ranges can shift under climate change.

Global climates are predicted to warm by 2 to 4°C in the next century, a rate faster than any climatic event in the last 10,000 years (Marcott et al. 2013). As a result, species will have to move their ranges track their climatic preferences (Loarie et al. 2009), and it is unknown if anthropogenic warming will outpace species ability to keep up. One way we can examine the capacity for species to track rapid climate change is by quantifying the degree to which a species is at equilibrium with its preferred climatic conditions (also called its 'niche'). For example, if climate change outpaced a species' dispersal ability, the species fails to realize all suitable areas and would not be fully in equilibrium with climate.

Previous studies have measured species' equilibrium with modern climate (Svenning and Skov 2004), however, because range expansion is a time-transgressive process, information like how species responded to the Younger-Dryas may be lost by looking at a single time slice. Pollen analyses, which allow for studying ranges continuously through time, have been used to examine how readily species tracked moving climates, but despite their advantage in providing a long-term record, few studies have used the pollen record to track species niches in a spatially-explicit manner.

I am using a technique called 'range filling' to quantify climate equilibrium for North American trees continuously since the LGM using the pollen record. This method uses the percentage of a species' 'potential range' (that is the area a species could climatically live) that the species occupies as a measure of climate equilibrium. In doing so, this allows for us to see specifically when and where species were outpaced rapid climate climatic events.

Below I show range filling results for 3 trees, Pine (solid), Oak (dashed), and Spruce (dotted). Despite individualistic responses to climate changes, some patterns emerge. First, range filling drops at 12,000yr BP for all species, probably in response to the Younger-Dryas. Lastly, all species have lower modern filling than at the LGM, suggesting that species have yet to fully catch up to postglacial warming and could be further outpaced by future warming.



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Reconstruction and Analysis of the Most Damaging Storms in Maine over the Past 20 Years

Julia M. Simonson[1], Sean D. Birkel[1], Kirk A. Maasch[1, 2], Paul A. Mayewski[1, 2], Bradfield Lyon[1]

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

Abstract: Each year, Maine and New England experience severe weather that can negatively impact personal property, civil infrastructure, and natural systems. The purpose of this dissertation work is to catalog and produce numerical simulations of the most damaging storms to affect the region in the past two decades.

Project Goals

The overarching goal is to provide stakeholders with an online archive of sub-hourly weather maps and timeseries of previous severe storms to assist resource planning. This work will be done in collaboration with the electricity supplier Emera Maine, who will use historic storm data (e.g., temperature, wind, precipitation type) across service areas to facilitate development of a damage prediction model. This work will also evaluate historical changes in storm frequency and intensity to assess what might lie ahead for the region in a warming world.

Weather simulations are being conducted using the Weather Research and Forecasting (WRF) model (Skamarock et al. 2008). WRF is a mesoscale numerical weather prediction model designed for atmospheric research and operational forecasting using real data (observations or reanalyses) or idealized conditions. Input to WRF will be supplied by ERA-Interim Reanalysis (ERAI). Meteorological outputs will be generated at convection-permitting 3 km x 3 km gridcell resolution for 2 meter air temperature, precipitation (all types), wind speed, low-level wind shear (useful to Emera Maine and wind power utilities) and other common metrics.

Initial work includes data acquisition, and model setup and sensitivity testing. A test case for the Christmas 2013 Ice Storm (Figure 1) is being run and validated against station observations. Model sensitivity testing places particular emphasis on planetary boundary layer, radiation transfer, and cloud physics options and the performance of each in different seasonal settings. Once established, this framework will be applied to other events, including the well-known 1998 Ice Storm and Hurricane Irene.

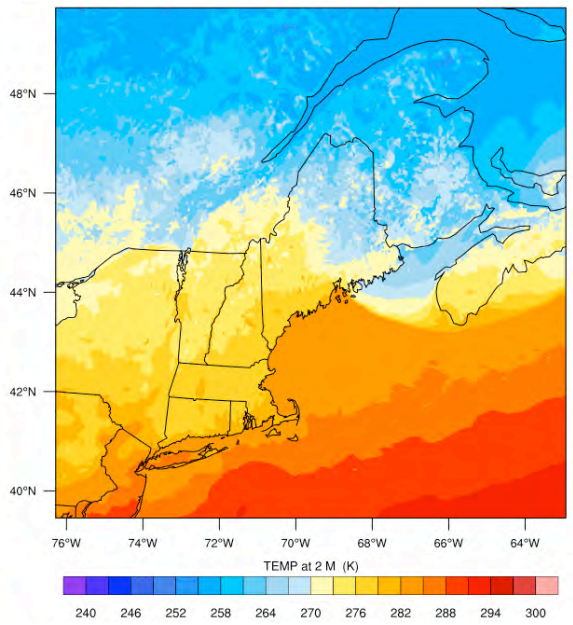

Fig. 1. Model output of 2 meter air temperature for December 23, 2013 at 12Z.

Acknowledgements: Funding for this project is provided by the Coca-Cola Fellowship and CCI.

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Spatial and Spectral Analysis of A Buried Archaeological Site on The North Coast of Peru: Implications for Climate Change and Human Adaptation

Anne St. Amand[1,2,3], Daniel H. Sandweiss[1,2,3], Alice R. Kelley[1,2,3]

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

Abstract: The cultural tradition of large monumental construction on the North Coast of Peru is temporally associated with the reappearance and subsequent intensification of the climatic phenomenon known as El Nino, ca 5800-3000. Los Morteros, a North Coast archaeological site, is composed of alternating layers of aeolian sediment and human occupations that date to this period. This research assesses the possibility of intentional sand accumulation via environmental manipulation (construction of wind barriers and funnels), which would place Los Morteros at the beginning of monumental construction on the North Coast. Geophysical and archaeological investigations assess deposition and transport patterns at the site to explore whether natural wind conditions created this mound or if human intervention was a necessary component of formation.

Project Goals:
Within the barren Salinas de Chao valley, high winds scour and deposit sediments in distinctive patterns. Barchan dune trains several km long migrate across the floor of a dry paleoembayment. Here, Los Morteros, a striking feature once thought to be a natural dune, has been shown through excavation and ground penetrating radar investigations to contain alternating layers of aeolian sediments and the remains of mid-Holocene human occupation (structures, refuse, human remains).

Figure 1: Los Morteros, Salinas de Chao, Peru.

Geophysical and archaeological investigations (ground penetrating radar, satellite data, computational fluid dynamics (CFD) modeling, and excavation) were conducted to assess whether human activity was a required component of the accumulation of this large mound. In-situ wind velocity measurements, combined with remote sensing data and elevation models, are used in CFD modeling to explore the impacts of walls, stone floors, and structures on sand accumulation over a 900-year period.

Initial Results:
Validation of CFD input is underway to ensure that the model can recreate present deposition and transport scenarios. Reconstruction of paleoclimates will be addressed by evaluating multiple scenarios (wind velocity, turbulent kinetic energy, and terrain rugosity), with geographic forcing elements (topography of surrounding mountain ranges) held constant. After validation, various scenarios will be run (using landscape topographies that exclude and include the existing mound, as well as various stages of its accumulation) to evaluate transport conditions on this spot. Could Los Morteros form from natural accumulation? Was continued human environmental manipulation required throughout mound formation for it to reach its current size?

Acknowledgements: This research is funded by: Churchill Exploration Grant, NASA-MSGC Fellowship.

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A Bi-Hemispheric Perspective on the Last Glacial Termination from the Southern Alps of New Zealand and the Altai Mountains of Western Mongolia

Peter D. Strand[1], Aaron E. Putnam[1], Joerg M. Schaefer[2], George H. Denton[1], David J.A. Barrell[3], David E. Putnam[4], Oyungerel Sambuu[5], Rosanne Schwartz[2]

1. *School of Earth and Climate Sciences, University of Maine.*
2. *Lamont-Doherty Earth Observatory.*
3. *GNS Science.*
4. *Environmental Science and Sustainability, University of Maine.*
5. *School of Geology and Mining Engineering, Mongolian University of Science and Technology.*

An understanding of the last glacial termination will help hone our understanding of the processes that drove warming to completion and of the climate system sensitivity to natural and human forcing factors, such as atmospheric CO_2. Here, we test possible drivers of the last glacial termination by comparing chronologies of mountain glacier recession in the middle latitudes of both polar hemispheres. We present ^{10}Be surface-exposure chronologies and glacial geomorphologic maps of mountain glacier recession since the Last Glacial Maximum in the Southern Alps of New Zealand (44°S, 170°E) and in the Altai Mountains of western Mongolia (49°N, 88°E).

The last glacial termination (~18,000 – 11,000 yrs ago) represents the last great global warming and the last time CO_2 rose by a substantial amount before the industrial period. In addition, a prominent version of the Milankovitch (1941) hypothesis of ice ages is that variations of Earth's ice sheets are paced by periodic changes in Earth's orbit and consequent seasonal redistribution of incoming solar radiation at 65°N latitude.

Extra-polar mountain glaciers are highly sensitive to atmospheric temperature, and glacier landforms afford insight into past climate conditions. I present ^{10}Be surface-exposure chronologies and glacial geomorphologic maps of mountain glacier recession since the Last Glacial Maximum in the Southern Alps of New Zealand (44°S, 170°E) and in the Altai Mountains of western Mongolia (49°N, 88°E) (Figure 1). I use the ^{10}Be exposure-age dating technique to determine the chronology of glacial landforms surrounding Lake Tekapo.

The moraine ridges and glacial geomorphologic deposits of the former Tekapo Glacier reveal multiple glacier advances during MIS 4, 3 and 2. This preliminary chronology also reveals that glaciers in the Southern Alps of New Zealand responded rapidly to the onset of the Last Glacial Termination (~18,000 yrs ago). Such a glacial retreat requires a powerful and rapid global climate driver, including atmospheric CO_2 or major atmospheric and oceanic reorganizations.

In the Mongolian Altai, preliminary ^{10}Be ages indicate that the last glacial termination may have been underway prior to that in New Zealand. On the basis of these two chronologies, we evaluate the relative roles of rising atmospheric CO_2, local insolation forcing, and ocean-atmosphere reorganizations in driving the warming that ended the last global ice age.

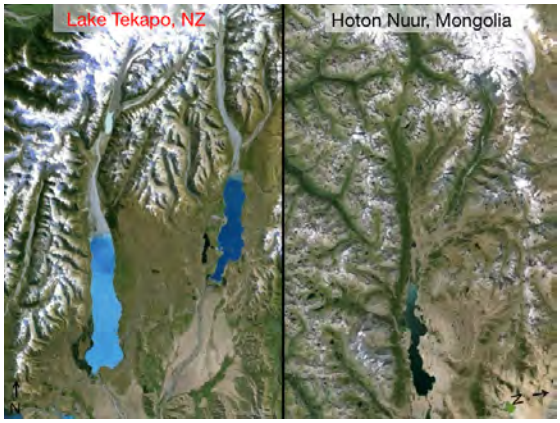

Figure 1. Comparison the Lake Tekapo basin, New Zealand and Hoton Nuur valley, Mongolia

Acknowledgements: We thank the Churchill Exploration Fund, Gary C. Comer Science and Education Foundation, the National Science Foundation, and the Quesada Family Foundation for support.

The Oceans in International Climate Policy: Oceans Governance After Paris

Aaron L. Strong[1,2]

1. *Climate Change Institute, University of Maine.*
2. *Marine Policy Program, School of Marine Sciences, University of Maine.*

Abstract: What is likely to be the evolving role of the oceans on the international climate policy stage? How will ocean carbon sinks and ocean climate impacts be considered under Paris, and how will these approaches align with and interact with new initiatives in international oceans governance under the UN Law of Sea and with efforts to implement the Sustainable Development Goal 14? In this two-minute mini-talk, I discuss what the Paris Agreement's bottom up approach to climate mitigation commitments, and what its approach to adaptation, finance and transparency, means for both ocean ecosystems and the livelihoods of people that depend on them and for climate politics.

Despite the major role that the oceans play in the global carbon cycle, and despite substantial anthropogenic disruption of the marine environment, the oceans have never figured prominently in international climate change negotiations or in the politics of multilateral climate policy. Until now. In the lead-up to COP21 in Paris, a small coalition of countries, including many island nations, issued a "Because the Oceans" declaration urging greater attention and recognition of the oceans in the Paris Outcome. And they achieved their goal. For the first time in any international climate agreement, the negotiated Text actually included the word "ocean", the IPCC will soon issue a special report on climate change and the oceans, and the next UN negotiations, hosted by Fiji in Bonn in November 2017, will prominently feature consideration of the oceans and ocean carbon cycling. This "consideration" is intended to build on international efforts to address climate change under the June 2017 UN Oceans Conference hosted by Fiji in New York. But, do these steps represent progress? If so, toward what end? This research project builds on textual analysis, dozens of semi-structured interviews with negotiators, and participant observation conducted at the COP 21 Negotiations in Paris in 2015. Based on these exploratory data, I outline a series of critical research questions in oceans/climate governance for the future:

1. What are the interactions between the UN Law of the Sea, UN Oceans Governance process, and UNFCCC Meeting?
2. How are blue carbon ecosystem services incorporated into transparency and reporting requirements and what factors shape the assumptions behind this consideration?
3. How are coalitions forming and evolving to shape the direction of the consideration of oceans science for mitigation and adaptation under the implementation of the Paris Agreement under the UNFCCC?
4. What scientific information is regarded as salient, legitimate and credible within the oceans/climate nexus, and why?

I invite members of the Climate Change Institute community, in particular those whose work explores our understanding of current and future sea-level rise from changes in ice sheet extent, to consider engaging in this nascent research effort to explore the consideration of that scientific information within the UNFCCC. The COP23 and COP24 negotiations in 2017 and 2018 present distinct opportunities to explore and understand the ways in which use-inspired climate scientific information and data-visualization and decision-support tools can inform the development of international climate policy, and in particular the development of transparency and accounting norms for monitoring and tracking adaptation and mitigation commitments.

Acknowledgements: Thanks to Michael Wara, Neil Tangri, and Chris Field support for and advice on the development of this project.

A Statistical Model for Monitoring Shell Disease in Inshore Lobster Fisheries: A Case Study in Long Island Sound

Kisei R. Tanaka[1,2]*, Samuel L. Belknap[2,3], Jared J. Homola[2,4], Yong Chen[1,2]

1. *School of Marine Sciences, University of Maine, Orono, Maine.*
2. *Climate Change Institute, University of Maine, Orono, Maine.*
3. *Department of Anthropology, University of Maine, Orono, Maine.*
4. *School of Biology and Ecology, University of Maine, Orono, Maine.*

Abstract: The objective of this study is to develop a statistical model that could enhance the existing monitoring effort of American lobster shell disease through (1) identification of potential disease-associated abiotic and biotic factors, and (2) estimation of spatial variation in disease. A delta-generalized additive modeling (GAM) approach was applied using fishery independent survey data collected from 2001–2013 in Long Island Sound. The model showed spatial distribution of shell disease was strongly influenced by the interactive effects of latitude and longitude, and projected high disease prevalence in non-surveyed locations. This study provides a modeling framework to enhance research, monitoring and management of emerging and continuing marine disease threats.

Following the major outbreak of shell disease observed in 1996, the lobster fisheries in southern New England experienced unprecedented rise and spread of shell disease. Concern over the stability of the lobster fishery has called for development of tools that can enhance the existing disease monitoring efforts.

The objectives of this study were to develop a statistical model to (1) quantify associations of lobster shell disease with abiotic and biotic factors, and (2) predict relative lobster shell disease prevalence across the entire study area to identify potential disease hotspots in Long Island Sound (LIS).

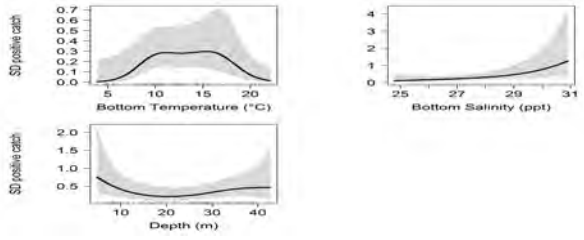

Figure 1. Smoothing curves for significant univariate explanatory variables.

A delta-generalized additive modelling (GAM) approach was applied to evaluate the relative contributions of environmental and biological factors to shell disease prevalence. The results showed bottom temperature, bottom salinity, and depth were important factors affecting the spatial variability in shell disease prevalence (Fig. 1), while the predicted shell disease prevalence in LIS showed a 'high-east: low-west' spatial pattern (Fig. 2).

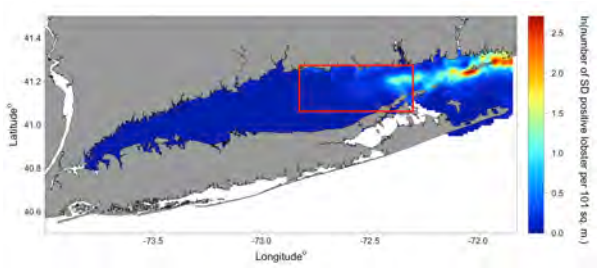

Figure 2. Predicted shell disease prevalence in Long Island Sound (2000-2013).

This study will provide policy-relevant information for effective ecosystem-based marine disease surveillance programs.

Acknowledgements: This work is being funded by the US National Science Foundation Adaptation to Abrupt Climate Change IGERT program grant DGE-1144423.

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Effects of Geese and Caribou on Nutrient and Carbon Inputs to Arctic Lakes in Southwest Greenland

Carl Tugend[1,2], Jasmine Saros[1,2]

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

Abstract: Global Goose populations have nearly doubled over the last few decades while caribou show a declining trend in population. The goose increase is mainly attributed to a lower winter mortality rate. Caribou declines however are thought to be caused by multiple factors. With few studies examining the effects of geese and caribou on freshwater systems, the impacts of these population changes on arctic lakes and watersheds are unclear. We investigated whether geese and caribou enhance nutrient and organic carbon loading rates to freshwater ecosystems in southwest Greenland.

Climate change in the Arctic generates a complex series of stressors that could change catchment hydrology, vegetation, and habitat for wildlife. It also alters wildlife distribution, expansion, and foraging behaviors. Low nutrient freshwater bodies are susceptible to changes in external inputs of nutrients and carbon, altering their biogeochemistry (Ghislain et al 2010).

Geese and caribou in particular may have a large impact on arctic freshwater systems. To date, only a few studies have been conducted on these effects on arctic lake systems. Grazing by geese have led to a 30-75% increase in nutrient loading rates in other freshwater systems. (Jefferies 1998; Walker et al. 2003). Caribou graze for a longer duration in these arctic watersheds than geese and also contribute to nutrient and carbon loading. However their declining populations may ultimately lead to less total nutrient flux (Manseau et al. 1996). Increase in geese populations will add a greater amount of nutrients over a shorter period of time compared to the long term inputs from caribou, changing the water chemistry of these freshwater systems.

The goal of this project is to understand the effects of geese and caribou on nutrient and carbon inputs to Arctic lakes of Southwest Greenland. This research will allow us to understand how changes in these populations and duration spent at these lakes will alter freshwater systems. This will give insight into what to expect in the future and possible management plans in order to address these changes.

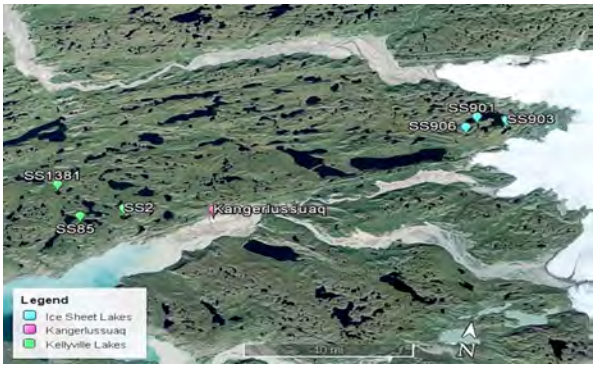

Fig. 1. Map of the 6 study lakes

Acknowledgements: We are very grateful to The Dan and Betty Churchill Exploration Fund.

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Implications of Extreme Precipitation Events on Lakes in Acadia National Park

Kate A. Warner[1,2], Rachel A. Fowler[1,2], Jasmine E. Saros[1,2]

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

Abstract: Decreases in water clarity in Acadia National Park have been linked to long-term changes in dissolved organic carbon (DOC) concentrations. Less is known about how extreme precipitation events influence short-term changes in DOC and associated biological trends, which also have implications for water clarity and quality. The goal of this research is to evaluate chemical and biological responses to extreme precipitation events in Acadia National Park.

Lakes in Acadia National Park are an integral part of the landscape and are highly valued for their aesthetics, recreational use, and provision of drinking water. Average water clarity in Acadia's lakes has been decreasing since 1995 and thus may alter these important values. This decline in water clarity corresponds to an increase in dissolved organic carbon (DOC) concentrations in the same set of lakes. While much research has investigated reasons for the long-term increase in DOC, attributing the change largely to reduced sulfate deposition, less is known about how changes in precipitation patterns may contribute to short-term changes in DOC, other water quality metrics, and associated biological changes. Extreme precipitation events have increased in frequency by 70% since the 1950's (Madsen & Wilcox 2012) and this trend of increased frequency of precipitation events is predicted to continue to rise. Additionally, research suggests a significant increase in DOC concentrations in lakes during extreme wet years (Strock et al. 2016), thus understanding the role these precipitation events play in water quality is important.

The goal of this research is to examine current chemical and physical changes from extreme precipitation events and investigate the associated biological trends. We have selected 6 Acadia lakes in which to focus our study (Fig 1). Our objectives are to evaluate changes in key water quality metrics, including DOC, algal biomass, and nutrient concentrations, as well as evaluate changes in algal community structure and species diversity.

This research will allow for better understanding of the implications of chemical and biological changes on lake water clarity and will be useful in informing management plans for lakes and ponds in Acadia National Park.

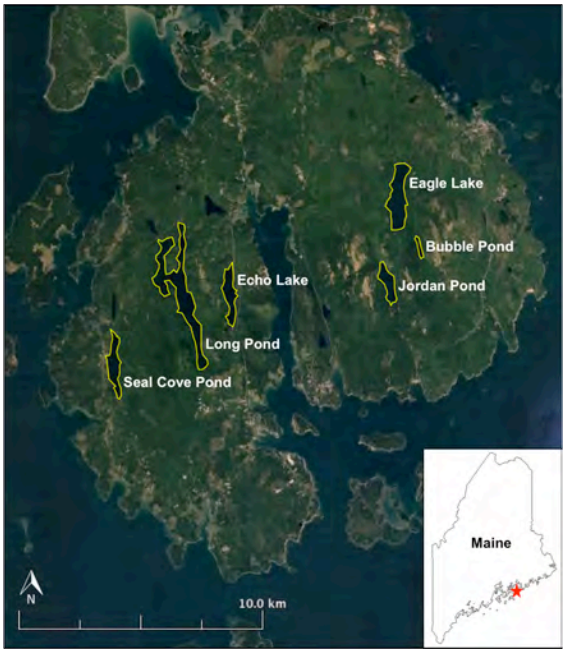

Fig. 1. The the 6 study lakes in Acadia National Park

Acknowledgements: This research was supported by the NSF Adaptation to Abrupt Climate Change IGERT program grant DGE-1144423 and a Schoodic Institute Research Fellowship.

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Potential for a Second Volcanic Source for Mt. Agung (1963 C.E.) Attributed Sulfur Spike in Antarctic Ice Cores

Sarah D. Wheatley[1], Andrei Kurbatov[1,2], Martin Yates[2]

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

Abstract: Despite the size of the 1963 C.E. eruption of Mt. Agung in Indonesia eruption, tephra from the eruption has often eluded tephrochronologists searching in ice cores. Using a new method, very small tephra particles (cryptotephra) were found from the 1963-1964 C.E. interval in the SPRESSO, RICE, and WDC-06A ice cores. The cryptotephra geochemistry revealed two distinct compositions, pointing to two potentially different eruptive sources.

When volcanic products, such as tephra or aerosols, rises into the stratosphere, sulfate layers (Hammer, 1980) often accompanied by tephra particles (e.g., Zielinski et al., 1997 and others) accumulate on polar ice sheets. These volcanic layers serve as isochrons, marking the timing of a volcanic event. However, tephra <15 µm in diameter would often go uncaptured and unidentified, leading to a record of globally significant volcanic activity based only on sulfate concentrations (Sigl et al., 2013). To more effectively capture smaller tephra particles (<15 µm), the methods (Iverson et al., 2016) were refined.

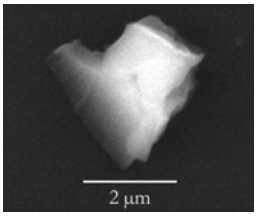

Fig. 1 Tephra particle captured from WDC-06A-01 (depth of 16.325-16.415 m) using the new mounting method. The particle is ~3 µm in diameter.

Adhesives or filters were replaced with clean, flat, inert metal surfaces (repurposed computer hard drive disks) heated to 70ºC, Kapton Single-Sided Polyimide Tape, and plastic mounting rings to create a sealed evaporation area. Sample was slowly delivered to the evaporation spot using syringe pump. This new method resulted in a greater capture of particles >2 µm in size (see Fig.) in a permanent mount. Samples from the WDC-06A, RICE, and SPRESSO cores were taken at depths corresponding to the 1963 C.E. Mt. Agung eruption and sampled for cryptotephra. Particles were analyzed using the Tescan Vega XMU Scanning Electron Microscope - Electron Dispersive Spectroscopy (SEM-EDS).

Despite ~2% errors associated with SEM-EDS analysis of unpolished tephra, the difference in the major fingerprinting oxides (see Fig. 2) between layers is difficult to resolve. Bimodal composition of the layers, shows a complexity of volcanic signals in ice cores.

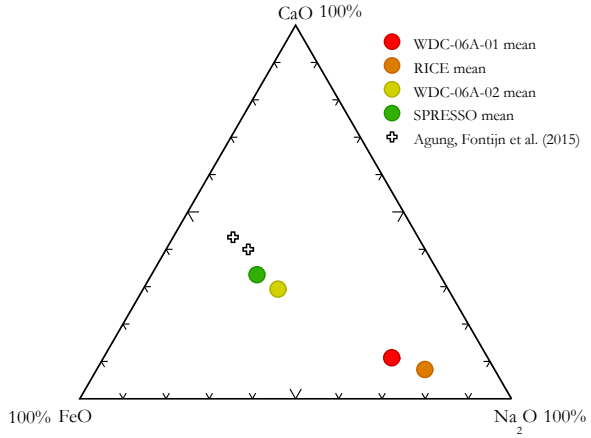

Fig. 2 Geochemical fingerprinting diagram for major elements with a composition >2%. The open crosses represent the published composition for the 1963 Mt. Agung eruption. The closed circles represent the ice core tephra. All samples were adjusted using the EDAX Genesis PhiRhoZ Quantification procedure.

Acknowledgements: NSFPLR-1142007 and PLR-1142069 grants. CCI graduate scholarship. Mark Royer, Elena Korotkikh, Laura Hartman, Donna Kalteyer, and Natasha McWalters for data, software and laboratory assistance. This work is a contribution to the Roosevelt Island Climate Evolution (RICE) Program. Support of the WAIS Divide Science Coordination Office for the collection and distribution of the WAIS Divide ice core and related tasks is acknowledged.

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A Multi-Proxy Reconstruction of Holocene Environmental and Climate Changes in Jamaica, West Indies

Mario A. Williams[1, 2], Jacquelyn L. Gill[1, 2]

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

Abstract: Jamaica is highly biodiverse, however climate and land-use changes threaten the integrity of its ecosystems. Increased knowledge about past environmental variability allows us to better contextualize the scope of current environmental changes. Lake sediments continuously record environmental conditions, and are useful for reconstructing past ecosystems and human impacts. The analysis of a lake sediment core from Jamaica will improve our understanding about the response of the island's biological communities to past natural and human disturbances. These data will provide insight into Jamaica's environmental history, and will strengthen efforts to safeguard the long-term sustainability of the island's environmental resources.

Project Goals

The study objectives are to evaluate the response of Jamaican vegetation to past natural and human disturbances, and help constrain the date of first human arrival on the island. The Caribbean attracts high conservation interest due to growing concerns about the impacts of climate change (Figure 1) and human activities on the region's rich biodiversity.

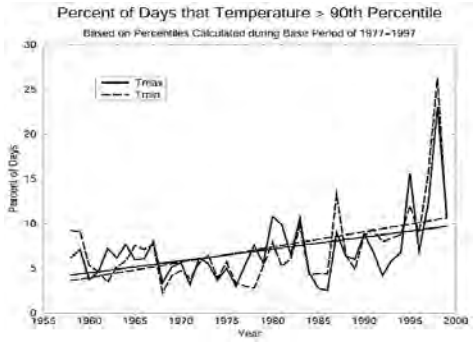

Figure 1. The number of extreme warm days in the Caribbean has increased over the past decades.[1]

Paleoecological studies provide baselines for gauging the efficacy of modern conservation initiatives. However, there is a research gap in understanding long-term ecological changes on Caribbean islands, and of these, Jamaica is one of the least studied. Also, questions remain about the date of first human settlement on the island, and the impacts of both prehistoric and European colonizers on the island's landscapes. I will collect and analyze a lake sediment core from Jamaica, and quantify proxies for vegetation (pollen), fire (charcoal), relative moisture (ostracod $\delta^{18}O$) and herbivore density (*Sporormiella*) to develop an environmental record spanning > 10 ka. Proxy data can provide critical insight into key points in human and environmental history. For example, an abrupt rise in sedimentary charcoal particles can indicate increased landscape burning due to human arrival on islands. Analysis of the timing of appearance and abundances of these proxies in a lake sediment core will elucidate past environmental changes in Jamaica.

Broader Impacts

This project will expand the information available to Jamaican resource managers, therefore providing benefits to local conservation efforts. This project will also stimulate interest in Jamaican archaeological research, if our paleorecord indicates that prehistoric settlers colonized the island earlier than is suggested by existing evidence. Furthermore, the study will promote the advancement of ecological research in Jamaica, and will provide a scientific platform for future investigations about prehistoric environmental changes on the island.

Acknowledgements

I thank the Churchill Exploration Fund for financial support, and my advisor, Jacquelyn Gill, for her continued guidance and mentorship.

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