Framework for an Arctic Population Risk Assessment

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Abstract: The Arctic is warming nearly two times the global average rate meaning the ecosystems and human populations are being impacted by climate change at faster rates. We provide a framework for policy makers, stakeholders, and scientists showing Arctic nation and indigenous community risks associated with future climate change.

Arctic temperature observations are warming faster than anticipated, showing rates exceeding the "worst-case" scenario (Auger et al., in review [a]). As the Arctic warms, environmental changes, such as permafrost thaw and sea-ice melt, will likely enhance the warming rate. These environmental changes will impact human populations; however, these impacts will not be felt at the same magnitude. We provide a framework for an Arctic Population Risk Assessment (APRA) for nine nations and three indigenous communities displaying risk in the context of future climate.

The APRA model is adapted from the Intergovernmental Panel on Climate Change report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC SREX, 2012), the three levels being: climate hazard (CH), ecosystem exposure (EX), and population vulnerability (PV). Representative Concentration Pathway (RCP) 8.5 projections from seven models of the Fifth Coupled Model Intercomparison Project (CMIP5) family are used as indicators for CH (temperature change) and EX (precipitation change and soil temperature) in combination with seven indicators for PV (population density and change, life expectancy, proportion of youth and elderly, education, and economy).

Figure 1 (found in Auger et al., in review [b]) shows the results of the risk assessment for the 2090–2099 period. It is evident that the Inuit (northern Canada) and Nenets (northern-central Russia) are the populations most at risk due to future projected change and their increased vulnerabilities. For nations, Alaska and Russia show the highest risk. These populations should expect future climate following at least the RCP 8.5 solutions as the likelihood of enhanced Arctic warming is high during the twenty-first century. Auger et al. (in review [b]) also propose two plausible scenarios (involving methane) that will likely enhance Arctic warming, impacting these populations earlier than the RCP 8.5 2090–2099 projection.

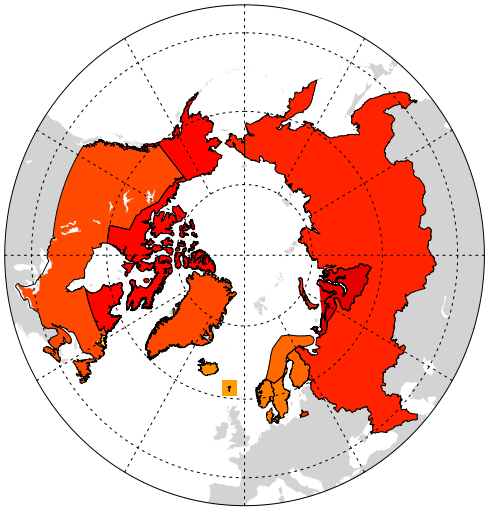

Fig. 1. APRA results for 2090–2099. Light to dark red shows level of risk (dark being highest).

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A Volcanic Linkage to the Atlantic Multidecadal Oscillation

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Abstract: Recent modeling suggests that the Atlantic Multi-decadal Oscillation (AMO) develops from volcanic forcing and associated changes in large-scale atmospheric circulation across the North Atlantic. Here, we find support for this hypothesis in an examination of historical SST, atmospheric reanalysis, and stratospheric aerosol optical depth data.

The AMO is a 60–70 year pattern of sea-surface temperature (SST) variability in the North Atlantic commonly ascribed to internal ocean dynamics and changes in northward heat transport. However, recent modeling studies suggest that SSTs fluctuate in response to explosive volcanic eruptions and changes in atmospheric circulation (Booth et al., 2012).

In examining historical SST, atmospheric reanalysis, and stratospheric aerosol optical depth data we find that cool intervals across the North Atlantic coincide with two distinct episodes of explosive volcanic activity (1880s–1920s and 1960s–1990s). Cool SST patterns develop in association with an increased prevalence of North Atlantic Oscillation (NAO)+ atmospheric patterns caused by stratospheric aerosol loading and steepened poleward temperature gradients.

NAO+ patterns promote wind-driven advection, evaporative cooling, and increased albedo from enhanced Saharan dust transport and anthropogenic aerosols. SSTs across the subpolar gyre are regulated by strength of low pressure near Iceland and the associated wind-driven advection of cold surface water from the Labrador Sea. This is contrary to an interpretation that subpolar SSTs are driven by changes in ocean overturning circulation. We also find that North Pacific and global mean SST declines can be readily associated with the same volcanic triggers that affect the North Atlantic. Thus, external forcing from volcanic aerosols appears to underpin multi-decade SST variability observed in the historical record.

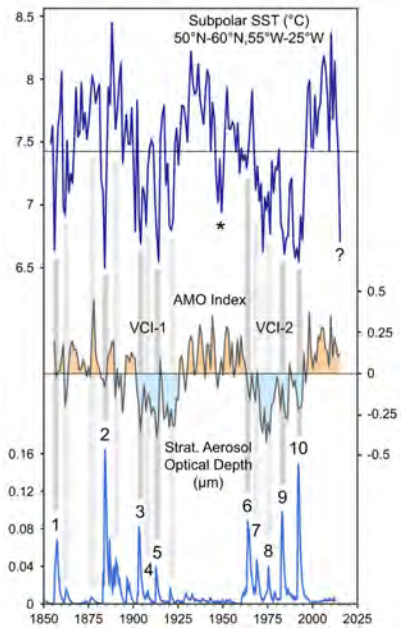

Fig. 1. Subpolar SST (top), AMO index (middle), and stratospheric aerosol optical depth (bottom). Modified from Birkel et al., 2018.

Acknowledgements: Climate Change Institute, NSF Award 1417640 (Birkel), International Center for Tropical Agriculture (Birkel and Mayewski).

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Not all Endotherms are Homeotherms: The Importance of High-Quality, Accurate Thermoregulatory Datasets

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Abstract: The ability to produce heat (endothermy) does not necessarily mean animals continuously defend high body temperatures. In actuality, many animals fluctuate their body temperatures with ambient temperature and abandon high body temperatures in order to save energy. It is thought that, because tropical mammals live in environments with relatively low seasonality and little temperature fluctuation, they have undergone stabilizing selection for body temperature regulation and have a narrow range of temperatures at which they can survive (thermolability). We are testing the hypothesis that the range of temperatures tropical mammals live within is smaller than other temperate mammals, thus making them more vulnerable to negative effects of climate change. We will be testing our hypothesis by assembling an accurate and high-quality database containing thermoregulatory data for hundreds of mammals for which studies exist, which can then be used to test predictions of different species' reactions to climate change.

Endotherms produce their own heat and are able to maintain elevated body temperature However, because of the high energetic cost of defending high body temperatures, many endotherms vary their body temperature in response to changes in ambient temperature in order to save energy (heterothermy).

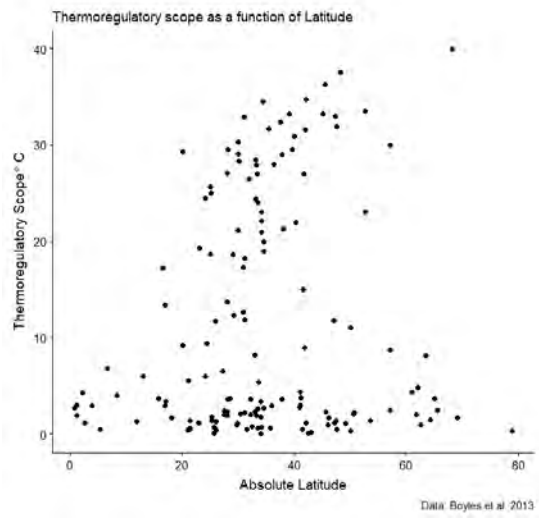

Fig. 1. Thermoregulatory Scope (°C) of different species as a function of absolute latitude using data from Boyles *et al.* 2013.

We aim to create a dataset with accurate, well-tested measurements of species' upper and lower critical ambient temperatures at which they survive as well as their basal and maximum metabolic rates. We expect the thermoregulatory scope, (the difference between a species' mean body temperature and the coldest body temperature from which the animal is able to rewarm), should be lowest in equatorial species due to the limited range of temperatures in the tropics. Temperatures are increasing globally and disproportionately at higher latitudes. Although temperatures are changing less rapidly near the equator, tropical animals may be more at risk because of their limited range of temperatures at which they are able to survive. Having a high-quality dataset quantifying thermolability will allow us to make comparisons across species and latitudes. We will use our thermoregulation dataset to access the vulnerability of species to threats such as habitat loss and climate change.

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Virtual Reconstruction of the Ostra Collecting Site, Peru: Phase 1

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Abstract: Virtual reality (VR) provides a powerful platform to disseminate and preserve archaeological research. VR can immerse the user in the simulated environment, allow them to walk around, pick up and move objects, and experience the stratigraphy of a site as a whole rather than as individually excavated units. As part of an ongoing project, a phase one initiative was carried out to collect data from the field in northern Peru in the form of aerial and ground-level images. These data, along with radiocarbon and OSL dating techniques and paleogeographic reconstruction, will be used to create a 3D simulated virtually reconstructed environment of the mid-Holocene Ostra Collecting Site when it was in use. This VR simulation will help answer questions about site logistics and possibly military tactics.

Background:

Understanding the context of an archaeological site (who was there, what they were doing, when they were there, how the site was constructed etc.) is of vital importance to the overall interpretation of a site and its occupants. In order to gain these insights, manual excavation has been the traditional mechanism, however, supplementing excavation with new technologies has the ability to enhance archaeological interpretations. The process of excavation translates 3D data into 2D data in the form of level sheets, photographs, and fieldnotes. These data are difficult to visualize partly due to the massive amount of data collected and partly due to humans' cognitive limitations with spatial transformation. Archaeologists take extensive notes in an attempt to combat this issue of data visualization by measuring depths, plotting artifacts, recording stratigraphy, and noting the color and texture of every object, but this information remains as 2D datasets spatially confined within each excavated unit. To address this, I developed a methodology to take these 2D datasets and transform them into a 3D virtually reconstructed immersive environment that is representative of the Ostra Collecting Site.

Methodology:

A drone was used to capture aerial images of the site and to create a 3D model that will serve as the base layer for the virtual reconstruction. Drone images can also be used to create heightmaps and identify features on the landscape, such as the ancient shoreline present on the site (Figure 1). A 20x20 meter grid was established across the site; six ground level photographs were taken at each grid point to form 360-degree views. These photographs are used to accurately texture the surface of the 3D base model. Excavation of a 1x1 meter unit in the northeast corner of a stone structure displayed clear stratigraphic levels, and the identification of several molluscan species within the midden matrix provides insight for the time of occupation. Two lines of slingstone piles are present on the site and are currently being dated using OSL techniques. If the results prove to be congruent with available radiocarbon dates, this site may represent the earliest evidence of warfare in South America.

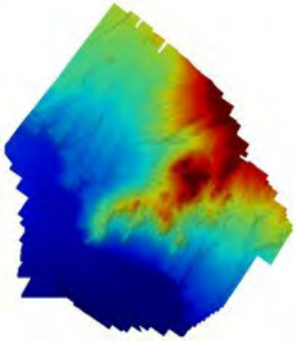

Fig. 1: An example of an elevation map created from the drone data, the eastern (right) edge of the dark blue indicates the location of the ancient shoreline.

Acknowledgements:

Field Team Members: Dan Sandweiss, Cecilia Mauricio, Paul Roscoe, Alice Kelley, Gloria Lopez, and James Munch.
Funding: Churchill Exploration Fund
Graduate Assistantship: Dr. Nicholas Giudice, Director of the VEMI Lab at UMaine.

A Preliminary Relative Sea-Level Curve for the Pine Island Bay Region, Antarctica

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Abstract: Accelerated ice shelf retreat in recent decades for Thwaites and Pine Island glaciers of the West Antarctic Ice Sheet has raised fears of a run-away collapse of these glacial systems and the potential for them to significantly contribute to global sea-level rise. For this study, we collected samples from raised marine deposits on five islands and will date these samples to construct the first relative sea-level curve for Pine Island Bay. A history of relative sea-level change in the region will provide long-term glacial isostatic uplift rates which are important parameters for ice sheet models that, ultimately, will be used to predict how quickly and how much ice will be lost in the future from these glaciers.

Project Summary:

The goal of this project is to construct a relative sea-level (RSL) curve for Pine Island Bay (PIB) that will afford insight into late-Holocene (past several thousand years) thinning of ice in the region. RSL variations represent perceived changes in local sea level due to the depression of land masses caused by the immense weight of advancing ice and subsequent rise of that land once ice thins and retreats. During this scenario, marine sediments, commonly in the form of beaches, are deposited along coastal areas. It is these beaches at different elevations that we target for sampling to collect material suitable for radiocarbon dating to create a history of RSL.

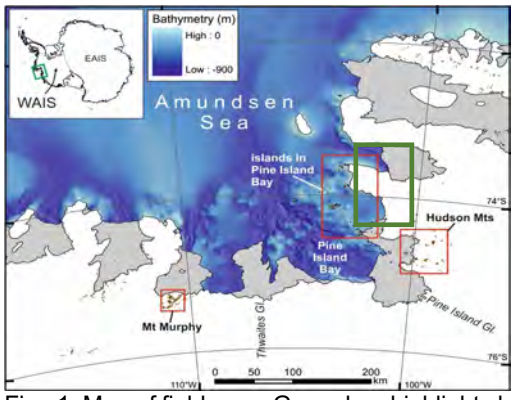

Fig. 1. Map of field area. Green box highlights location of sampled islands. Red boxes highlight areas of interest for studies to date past ice fluctuations.

Past studies(1) suggest that one of two scenarios must be true for Thwaites and Pine Island glaciers. Either their ice thickness has remained stable for the past 3,000-6,000 years or these glaciers were smaller than at present and have advanced to their current positions since that time. If evidence supports the latter scenario, then glaciers in this region were able to stabilize and readvance under climate conditions very similar to those of today and run-away collapse associated with the present ice thinning is not inevitable. An understanding of RSL variations during this period can afford critical information on former maximum ice thickness, timing of deglaciation and subsequent changes in ice thickness. Additionally, data of past ice history are critical for any forward modeling efforts that simulate behavior of the West Antarctic Ice Sheet under different future warming scenarios.

To construct a RSL curve for PIB, we collected ~300 samples of organic material for dating from five individual islands located in three distinct island chains (see Fig. 1) in February and March, 2019. Radiocarbon dating the material collected from the beaches will afford an approximate age of their formation which can then be plotted against their elevations to create a RSL curve. Samples will be processed during the summer of 2019 and results published in the subsequent year.

Acknowledgements: NSF award:PLR-1738989

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Lake Characteristics that Determine Ecological Sensitivity to Atmospheric Nutrient Deposition in Alpine Regions

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Abstract: In mountain regions of the world, high rates of atmospheric nitrogen (N) deposition result from fossil fuel and agricultural emissions. Although N deposition can significantly alter alpine lake ecology, not all lakes respond equally. Here, we evaluate the factors that determine whether or not a lake exhibits strong ecological responses to atmospheric N deposition.

Alpine lakes are generally ecologically sensitive to atmospheric deposition due to their high elevation, slow weathering bedrock, poorly developed catchment soils, sparse catchment vegetation cover, and low-nutrient water. Ecological effects of N enrichment due to atmospheric deposition include increased primary productivity and phytoplankton biomass, decreased lake clarity, and algal community changes caused by increased dominance by high-nutrient species. However, some alpine lakes do not exhibit responses to high rates of atmospheric N deposition in their sediment diatom records (e.g. Saros et al 2010; Spaulding 2015). Here, we assess the factors that determine lake ecosystem sensitivity to atmospheric N inputs.

To assess features that control lake ecological sensitivity to atmospheric N deposition, we are currently conducting a large statistical analysis across alpine lakes (n = 295) from 8 countries of North America and Europe. Data were sourced from 17 collaborating scientists. Sample lakes range between 1000-3950 m elevation and were sampled from 1981-2017 during summer and autumn. Response variables (indicators of lake ecological sensitivity) included phytoplankton biomass, dissolved inorganic nitrogen (DIN) concentration, and the magnitude of change in these variables over time. Control factors included N deposition rates, DIN and phosphorus concentrations, lake depth, catchment land cover, slope steepness, bedrock geology, and elevation. Exploratory statistical analyses performed include ordinary least squares regression (OLSR), redundancy analysis (RDA), classification and regression tree (CART) analysis, and random forest analysis.

OLSR and RDA indicated that lake algal biomass was strongly controlled by phosphorus concentration ($R = 0.42$, $p < 0.01$), and DIN concentration was related to N deposition rates ($R = 0.41$, $p < 0.01$). CART and random forest analysis confirmed that N deposition rates were important in determining changes in DIN since 2005, as was lake elevation. N deposition rates, lake elevation, and P concentrations were important in determining algal biomass changes since 2005 (Figure 1).

Together, these analyses suggest that lake responses to N deposition will be modulated by individual lake characteristics. Atmospheric deposition is increasing across mountainous regions; thus, our study may be an important precursor to future lake management practices.

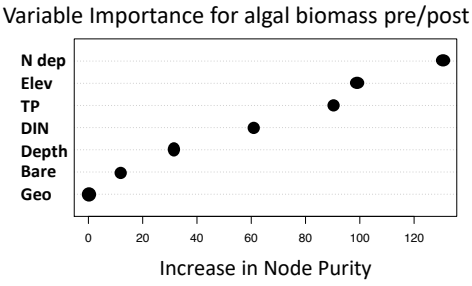

Figure 1. Importance of algal biomass controls determined by random forest analysis. N dep = N deposition rates; Elev = lake elevation; TP = total phosphorus concentration; DIN = dissolved inorganic N; Depth = max lake depth; Bare = % unvegetated catchment; Geo = lake bedrock geology.

Acknowledgements: The US National Science Foundation (Grants no. 1144423) funded this research.

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Computational Analysis of Climate-Change Discourse in News and Social Media

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Abstract: The study of topics that frame the discourse of climate change in news and social media is useful for understanding media and public perceptions of the field and its recent developments. Computational methods for topic modeling, syntactic analysis, and guided data exploration may be applied to readily available big-data streams to extract topics and related information in near-real time.

The success of plans for adapting to climate change often depends critically on the cooperation of diverse segments of the population. Such cooperation, in turn, depends on how well the plans fit with the priorities of the affected populations. While there are several methods for eliciting these priorities and other related information, the focus of this work is the use of text data streams from news and social media.

These data streams contain a wealth of information that is easily appreciated by a human reader. However, constraints on human time and effort make it virtually impossible to continually extract such information from a large number of data streams with so-called big-data characteristics: high volume, velocity, and variety. Therefore, it is useful to investigate the computational analysis of such textual data streams

An attractive class of methods for understanding a large corpus of text documents is that based on topic modeling. Such methods aim to discover latent semantic relationships and structure within the corpus by using statistical methods. Within this class, methods based on Latent Dirichlet Allocation (LDA) are among the most widely used. Here, one assumes a generative statistical model based on groups (topics) as underlying the document corpus and determines the parameters (topic descriptors) of this model using Bayesian inference.

Applications of LDA and related methods often suffer from three related practical shortcomings: First is the difficulty in determining the number of topics, i.e., groups in the underlying generative model. Second is the difficulty in interpreting the topics, identified by LDA, which are presented as a lists of weighted keywords. Third is the difficulty in evaluating the quality of the topics thus identified.

An interesting option in this context is the use of topic-related metadata that is available in some text data streams. For example, some sources of newspaper articles provide subject keywords. While the availability of such metadata is helpful, it does not remove the need for topic modeling, for two reasons: First, not all data streams include such metadata. In particular, high-velocity streams such as those from social media do not come with such metadata. Second, and more important, the corpus may include latent topics that are not reflected in the metadata tags. Nevertheless, such metadata may be used to bootstrap topic modeling and evaluation.

Top-5 subject keywords for New York Times articles containing the phrase ``climate change'', by month: (Not all matching articles are tagged with the climate-change keyword. The numbers in parentheses are article counts by keyword.)

- 2018-10: Climate change (79); Emissions (19); Greenhouse effect (15); Political parties (13); Politics (12)
- 2018-11: Climate change (56); Emissions (16); Forest & brush fires (16); Political parties (16); Presidents (16)
- 2018-12: Climate change (56); Emissions (22); Environmental policy (15); Fossil fuels (10); Carbon (9)
- 2019-01: Climate change (38); Presidents (16); Political parties (15); Social networks (15); Emissions (9)
- 2019-02: Climate change (57); Presidents (27); Social networks (21); Political parties (17); Emissions (15)
- 2019-03: Climate change (58); Social networks (24); Presidential elections (18); Emissions (17); Political parties (16)

Investigating Holocene Southern Hemisphere Westerly Wind System Variability Using a Sub-Annually Resolved South Pole Ice Core (SPICEcore) Dust Record

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The Southern Hemisphere westerlies play a key role in heat, moisture, aerosol, and greenhouse gas dynamics, and may have varied in strength and latitudinal position throughout the Holocene (~11,700yrs ago to present). We use sub-annually resolved micron-sized dust particles recovered from the South Pole Ice Core (SPICEcore) to interpret variations in the Southern Hemisphere atmospheric climate variability throughout the 20th century and the Holocene.

The concentration and size distribution of dust (i.e., find-grained mineral particles) deposited on glacier and ice sheet surfaces is an established proxy for coupled ocean-atmosphere dynamics. Dust particle-size-distributions (PSD) in Antarctic ice are especially sensitive to the configuration of the Southern Hemisphere windfield. Subtle changes to the strength or position of the windfield can change the amount of coarser or finer dust being transported to the Antarctic interior. Here we present a record of dust PSD from the South Pole Ice Core (SPICEcore) to garner greater insight into Southern Hemispheric atmospheric variability on multiple timescales during the Holocene.

The SPICEcore was drilled between the years 2014 and 2016, attaining a depth of 1751m (equating to ~54kyr of ice). The top 849m (~10kyr) has been melted at the Dartmouth College continuous flow analysis laboratory to measure dust-particle-sizes from 1.0 to 12µm. Dust-particle-sizes were measured with a Markus Klotz Abakus K particle counter yielding 5,713,320 individual particle counts at sub-annual resolution. The SPICEcore chronology for the top 734m is annually resolved on the basis of Na, Mg, dust particles (1.0 and 2.4µm), and SO_4 concentrations.

The SPICEcore dust PSD provides a new 10kyr high-resolution record of Southern Hemisphere climate. Initial results, through calibration our record with modern NCEP/NCAR reanalysis and other proxy records, reveal shifts in the PSD correlate with coastal Southern Ocean upwelling records and Southern Hemisphere atmospheric, glacial, and oceanic records. We observe abrupt centennial-scale windfield shifts throughout the Holocene. During the Early Holocene (~10-6kya), we also observe an equatorward windfield displacement.

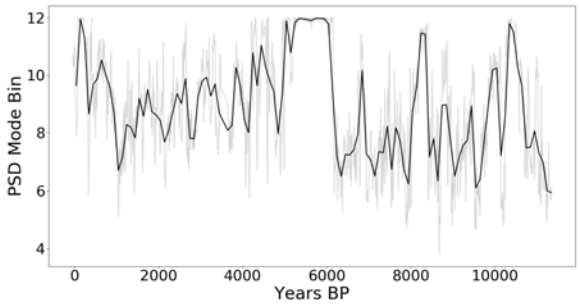

Figure 1. Holocene resampled decadal (10yr) and century (100yr) scale PSD.

Acknowledgements: Support provided by the NSF award PLR-1443397.

Connections Between Iceberg Melt Rates and Glacier Dynamics on the Antarctic Peninsula

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Abstract: Variations in iceberg freshwater fluxes exert an important control on local to regional ocean stratification and circulation, yet the influx of freshwater into the Southern Ocean due to melting icebergs has not yet been quantified on a broad spatial scale. Here we map patterns in iceberg melt around Antarctica through the differencing of high-resolution digital elevation models (DEMs), and explore connections between these melt rates and nearby glacier dynamics.

Warming ocean temperatures are an important driver of glacier retreat through submarine melt, with wide implications to bodies of marine terminating ice. However, freshwater contributions from submarine melt rates have not been quantified on robust temporal or spatial scales for tidewater glaciers around Antarctica. Glacier retreat and mass loss on the Antarctic Peninsula strongly corresponds to mid-depth ocean temperatures, suggesting ocean warming has led to ice shelf collapse and grounding line retreat (Cook, 2014). Our research produces submarine melt rate estimates for icebergs in this region and investigates connections between these melt rates and nearby glacier changes.

We use repeat stereo image-derived DEMs to estimate submarine melting of icebergs from 2013 to 2018 at 14 study sites located around Antarctica, including seven sites located on the Antarctic Peninsula (Figure 1). We find spatial connections between iceberg melt rates and regional variations in ocean temperature (e.g. Moffat and Meredith, 2018), where we see higher melt rates for icebergs located in regions where water masses are relatively warm and lower melt rates for icebergs located in regions where colder water masses are on the continental shelf. This is the case for the embayments of the Edgeworth and Seller Glaciers, which fed the former Larsen A and B ice shelves.

To assess whether variations in iceberg melting can be used to infer spatio-temporal variations in ocean forcing at glacier grounding lines and/or beneath ice shelves, we compare patterns in frontal ablation with our iceberg melt rates. Frontal ablation rates are calculated from velocity and terminus position timeseries for nearby glaciers.
We find that spatial patterns in iceberg melt rates generally follow local variations in glacier frontal ablation, with some notable deviations. This analysis suggests that submarine melt is important to overall glacier dynamics. However, the magnitude of submarine melt is small from 2014 to 2018, which makes sense given that most of the glaciers we analyzed appear to be stable or advancing.

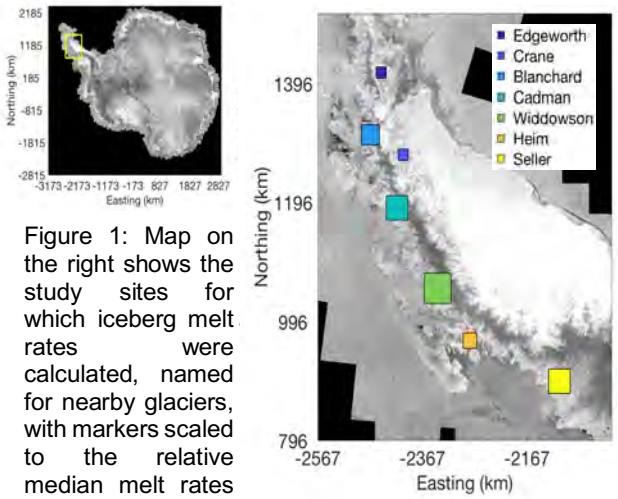

Figure 1: Map on the right shows the study sites for which iceberg melt rates were calculated, named for nearby glaciers, with markers scaled to the relative median melt rates of each location.

Acknowledgements:
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Deer Ticks Helped Along by Warming Climate and Deer

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4. *Anderson Environmental Health.*

Abstract: Winter temperatures, degree-day accumulation, relative humidity, and white-tailed deer jointly explained statewide patterns in nymphal deer tick abundance. Increased tick abundance in the northern tier is expected with continued climate warming, more so if deer are managed from the current 5/mi^2 to a future 10/mi^2.

Project Goal: Explain recent(1990-2012) and predict future nymphal deer tick abundance patterns on the basis of climatology and deer.

How Climate Change Favors Deer Ticks: Deer ticks (*Ixodes scapularis*) have been invading Maine from south to north since the late 1980s. Deer ticks transmit the agents of Lyme disease, anaplasmosis, babesiosis, Powassan encephalitis in humans. In the southern tier odeer ticks are established and the northern tier still

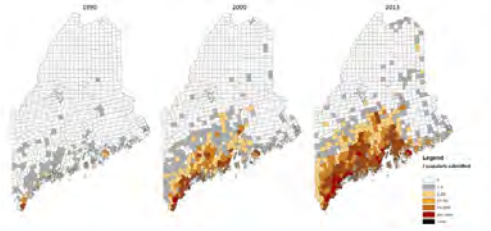

Figure 1. Range expansion of the deer tick.

emergent (Fig. 1). Climate change has brought warmer, compressed winters to the state, allowing ticks to quest for bloodmeals later into fall and earlier in spring. Earlier degree-day attainment allows more female ticks to lay batches of thousands of eggs, and for those eggs to hatch (about ~1,240 degree days >6°C are needed for hatch[1]). Attainment of this threshold by the end of August is moving northward (Fig. 2). Also, most adult ticks obtain blood meals from white-tailed deer.

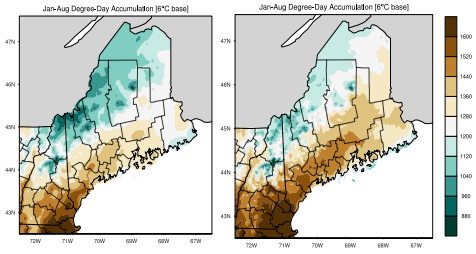

Figure 2. Increasing degree-day accumulation[2]

Results: A generalized additive mixed model using Maine's Wildlife Management Districts as the sampling unit indicated higher nymphal tick abundance was jointly explained by:

- passage of time, plus
- increasing relative humidity
- warmer winter average low temperatures
- greater accumulation of degree days,
- increasing deer abundance up to 13/mi^2. This "saturating" relationship was predicted by earlier studies that suggested ticks could be lowered enough to reduce Lyme but only if deer were lowered below 13/mi^2.

Prediction: A 1.2-fold increase in nymphal tick abundance in the northern tier may be expected with 1°C warming but a 5-fold increase if in addition deer are managed from the current 5/mi^2 to 10/mi^2.

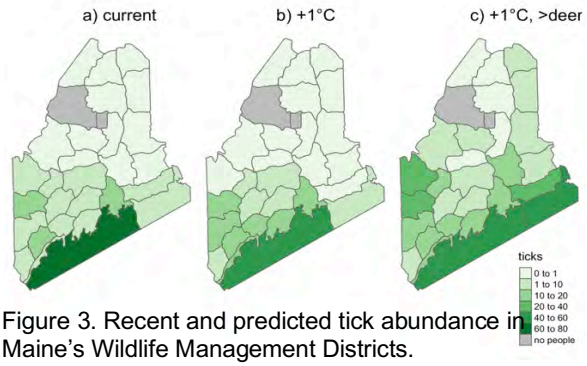

Figure 3. Recent and predicted tick abundance in Maine's Wildlife Management Districts.

[1]Rand et al. J Vector Ecol 2004;29:164-176.
[2]Birkel, S.; PRISM data, Oregon State University

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.

A Paleolimnological Comparison of Ecological Responses to Reduced Acid Deposition in a Clear Versus a Brown Lake in Acadia National Park

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Abstract: We reconstructed fossil diatom and algal pigment records from a clear versus a brown lake in Acadia National Park to compare ecological responses to reduced acid deposition in recent decades in the context of a 140-year record. With reductions in atmospheric sulfate deposition, both lakes showed signs of recovery toward pre-acidification conditions, but these changes were subtler in the clear lake, suggesting greater sensitivity to acid deposition and other external drivers such as effects of climate change.

The Paleoecological Investigation of Recent Lake Acidification (PIRLA) project of the 1980s demonstrated that lakes across eastern North America experienced widespread effects of anthropogenic atmospheric acid deposition (Charles et al. 1990). After the 1990s, reductions in atmospheric sulfate deposition likely resulted in synchronous increases in dissolved organic carbon (DOC) concentration and decreases in water clarity across lakes in Acadia National Park (ANP), ME. In northeast North America, clear and brown lakes have exhibited different ecological responses to long-term browning (Williamson et al. 2015).

We reconstructed fossil diatom and algal pigment records from a clear lake (Jordan Pond) vs. a brown lake (Seal Cove Pond) in ANP to compare ecological responses to acid deposition in recent decades in the context of a 140-year record, during which time multiple external drivers influenced both lakes (Figure 1). In Jordan Pond, diatom community structure changed continually from the beginning of the record, while it was more static in Seal Cove Pond over time, with the period of greatest change occurring after 1990. Concentrations of algal pigments were low in Jordan Pond until 1940, then increased during the 1940 to 1990 period, after which they slightly declined. The opposite pattern occurred in Seal Cove Pond—algal pigments were high until 1940, decreased in the period from 1940 to 1990, and increased after 1990.

While light availability was likely a primary control of algal responses in Jordan Pond, nutrient subsidies from allochthonous DOC may have been more important in Seal Cove Pond. Both lakes showed signs of recovery toward pre-acidification conditions, with stronger recovery occurring in Seal Cove Pond, indicating that Jordan Pond may be more sensitive to acid deposition and climate change effects.

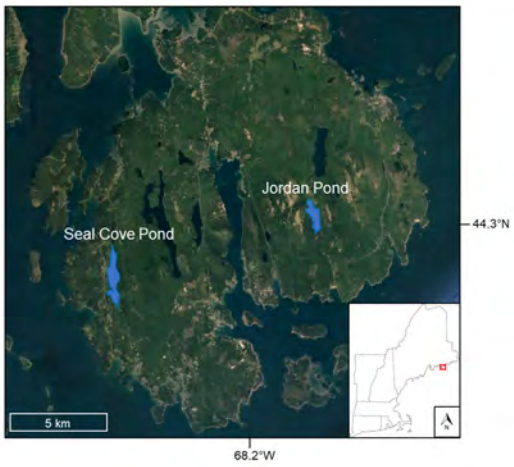

Figure. 1. Map of study sites.

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

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Vegetation Change at the La Brea Tar Pits from 50,000 to 30,000 Years BP

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Abstract: Identification and abundance estimates of plants and small mammals at the Rancho La Brea (RLB) Tar Pits in Los Angeles, California help reconstruct ecosystem structure prior to the last ice age. Plant pollen and macrofossils inform vegetation modeling of plant abundances, and net primary productivity estimates. Preliminary identifications and radiocarbon dates suggest that vegetation reorganization episodes occurred on multimillennial timescales that were likely linked to hydroclimatic shifts.

The La Brea Food Webs Project:

The La Brea Food Webs project is an NSF-funded effort to better understand Rancho La Brea ecosystems prior to the last glacial period. Radiocarbon dating, excavation, pollen analysis, and modelling are employed to better understand past vegetation structure and feeding relationships in Southern California from 50,000 to 30,000 years BP (50 – 30 ka). Past landscape and ecosystem response to climate perturbations can inform how we assess ecosystem resilience and best conservation practices today.

Materials and Methods:

RLB excavation since 2006 has focused on discrete tree boxes of fossiliferous asphaltic deposits. All excavated thus far pre-date the Last Glacial Maximum (~26 – 19 ka), and each is constrained to a few millennia. Small mammals, fossil pollen, and plant macrofossils are extracted and identified by other team investigators. The botanical data, and paleoclimate datasets of past temperature and atmospheric CO_2, inform simulations in vegetation model LPJ-GUESS to estimate the net primary productivity and abundance derived from the plant community. Distribution analysis was conducted on over 400 radiocarbon dates from the collection to investigate entrapment timing since ~45 ka.

Preliminary Results:

Pollen and macrofossil identification to date spans three boxes, and the assemblages vary between each to suggest different vegetation structure and climate. Box 1 taxa demonstrate high plant diversity and disturbance. Meanwhile, Box 14 pollen taxa are more drought-tolerant, and preliminary identifications from Box 13 and 7B suggest a wetter environment.

Charcoal has been identified from three boxes so far, and initial radiocarbon dates are coeval with MIS 3 charcoal peaks from the San Bernardino Mountains towards the east. Continued charcoal dating will test if these represent wildfire events that impacted the greater Southern California region.

Model results are based upon University of Bristol HadCM3 paleoclimate model runs from 60 – 0 ka. Initial LPJ-GUESS results show that about one-third of primary productivity in the Los Angeles Basin was derived from C3 grasses early in MIS 3, with net primary productivity totals and contribution from broad-leaved evergreen trees increasing until the Last Glacial Maximum. Future downscaling and modeling at species level will refine these results.

Project Updates:

The broader impacts of this project focus heavily on outreach, education, and communicating science to the public. Ongoing updates are maintained online at:

- Twitter: @labreawebs
- Blog: labreawebs.wordpress.com
- Specimens: http://www.inaturalist.org/projects/la-brea-webs

Acknowledgements: Funding for this research provided by NSF EAR-1623840 to PIs Jacquelyn Gill (Univ Maine), Jessica Blois (UC Merced) and Justin Yaekel (UC Merced).

Holocene Fluctuations of Ventisquero Marinelli, Cordillera Darwin

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Abstract: Glacial records afford important insight into the pattern, severity, mechanisms, and timing of natural variability necessary for predictions of climate change. Here, we present a new reconstruction of Holocene fluctuations of Ventisquero Marinelli, which drains the Cordillera Darwin icefield of southern South America. Our data show early Holocene ice recession to near-modern position, followed by roughly periodic fluctuations. However, for much of the Holocene, the glacier was smaller than at present. Our data have implications for the pattern and cause of both long-term and millennial climate change in the southern mid-latitudes.

Background:

Holocene environmental variability affords important context for future climate change. However, the cause of both long-term and millennial-scale climate change over the past ~10,000 years is not well understood, particularly in the Southern Hemisphere. For example, rapid fluctuations of climate on ~1000-yr timescales have been attributed to a variety of possible forcing mechanisms, including solar variability, ocean thermohaline circulation, and volcanic activity.

Mountain glaciers are important recorders of atmospheric temperature; from their deposits we can reconstruct past climate variations useful for testing hypotheses of the mechanisms behind climate change. Here, we examine the Holocene behavior of Ventisquero Marinelli, an outlet that drains Cordillera Darwin in southernmost South America.

Results:

Sixty-nine radiocarbon dates of trees, peat, and shells incorporated into till afford constraints on the history of Ventisquero Marinelli. Dates indicate early Holocene recession, perhaps to within the present-day glacier limit. Relatively minor advances occurred throughout the Holocene at ~6000 and ~3800 yr BP (and perhaps at other times), but in general, the glacier was smaller than at present for much of the Holocene. The largest advances of the Holocene occurred at ~1300 and ~400 yr BP.

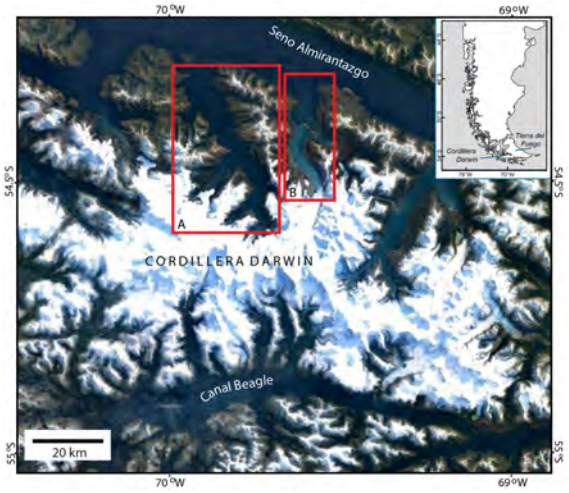

Fig. 1. Location of Cordillera Darwin and field areas at Brooks (A) and Marinelli (B) fjords.

Overall, our reconstruction of Marinelli strongly resembles glacier records from the European Alps, suggesting the possibility of a Holocene global climate signal. However, our data differ in significant ways from similar records from New Zealand, leading us to continue to search for a mechanism that can explain global patterns in alpine glacier records.

Acknowledgements: This research was funded by the Comer Family Foundation and the National Science Foundation. The late Charlie Porter was instrumental in this work.

Fire, Foxes and Bones: Evidence of the First Prehistoric Human Occupation in the Falkland Islands

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Abstract: This study utilizes a combined paleoecologocial and archaeological approach to assess the initial timing of human arrival to the Falkland Islands. Multiple lines of evidence support the hypothesis that humans had arrived in the Falklands prior to European arrival.

It has long been assumed that because there were no human inhabitants in the Falkland Islands when Europeans first arrived, that humans likely had never reached the shores of the remote south Atlantic archipelago. Initial human colonization of islands can be difficult to detect through the material archaeological record; however, even small numbers of colonizing humans can leave behind large indirect environmental signals of their habitation. The presence of a single terrestrial mammal *Dusicyon australis*, a predatory fox, at the time of European arrival is suggestive of a pre-European human presence in the Falklands.

Using a combined paleoecological and archaeological approach, we established that there is a significant shift in fire regime at New Island that is synchronous with the depositional timing of several bone piles on the island at 550 cal BP. Comparison with paleoclimate proxies suggests the increased fire activity on New Island is the result of anthropogenic burning, which is supported by the coeval timing of the largest magnitude charcoal peak in the record with the start of European utilization of New Island.

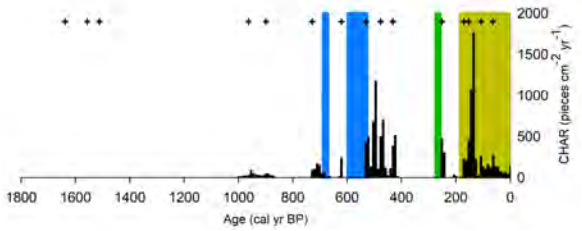

Fig. 1. New Island record with associated known historic utilization events (green and yellow) and bone pile ages (blue).

Archaeological investigation into the origins of both the bone piles, while not conclusive, is suggestive of anthropogenic deposition. Analysis into the diet of *D. australis* is further suggestive of a potential human presence in the islands.

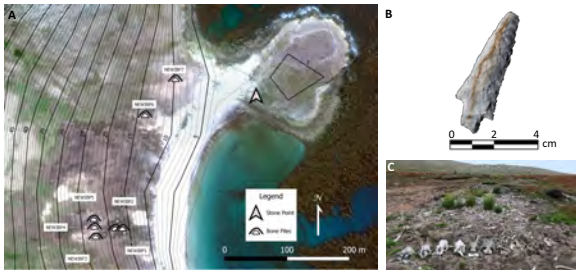

Fig. 2. (A) New island site map depicting bone piles and stone point locations. (B) A 3-D model of the New Island surface found lithic point. (C) Image of NEWIBP6 bone pile prior to excavation demonstrating the extent of surface erosion and downslope scatter.

Numerous lines of both direct and indirect evidence, indicate that humans, likely originating from South America, had reached the Falkland Islands several centuries prior to European exploration of this region of the south Atlantic Ocean.

Acknowledgements: We would like to thank Rolex and the Explorer's Club for supporting this field expedition and research and the New Island Conservation Trust and the South Atlantic Environmental Research Institute for their support.

Is There Life Under Ice? Investigating Plankton Dynamics in Ice-Covered Arctic Lakes

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Abstract: As the climate warms, ice-covered period of lakes in the Northern Hemisphere is shortening. To grasp the consequences of these changes on lake ecosystems, it is important to better understand processes happening under-ice. At present, we lack detailed information about species composition of winter plankton and its succession during the ice-covered period. Here, we show the results from our pilot study that demonstrate substantial variability of environmental conditions under ice that support a variety of planktonic microorganisms.

Project Goals:

Lake ice phenology is changing across the Northern Hemisphere along with changing climate. Shorter ice cover duration with later ice-on and earlier ice-out has been recorded in many lakes—some are even predicted to lose their annual ice cover completely during winter (Sharma et al., 2019). While lake ice is on a decline, limnologists and ecologist are just starting to gain appreciation for the importance of processes happening in lakes during winter, a season that has been historically neglected.

The establishment of ice isolates the water body from its contact with the atmosphere and the surrounding landscape cutting off gas exchange and any allochthonous input, ultimately creating a new set of conditions for organisms that persist in the lake over the winter (Hampton et al., 2017). However, at present, we know relatively little about the planktonic communities and their succession during ice-covered conditions despite their importance for food webs and biogeochemical cycling within the lake.

Our goal is to investigate succession and dynamics of planktic communities in 4 lakes in Kangerlussuaq region, a well-studied area in West Greenland that is currently experiencing one of the highest rates of warming, consequently affecting lake ice-cover phenology. During 2019 sampling season, we will deploy *in-situ* sensors to continuously measure physical variables. We will also collect phytoplankton, zooplankton and samples for chemical, pigment, and metagenomic analyses on a weekly basis. These data will allow us to precisely describe temporal succession of planktic community and identify drivers of structural shifts.

Initial Results:

During a pilot study in 2018, in-situ sensors and sediment traps were deployed under ice in 2 lakes (SS2 - inland, SS901 – closer to the ice sheet). Temperature profiles (Fig.1A, B) show variability of temperature under ice and formation of inverse stratification. Based on the content of sediment traps, both lakes have substantial primary production with a large proportion of mixotrophic algae.

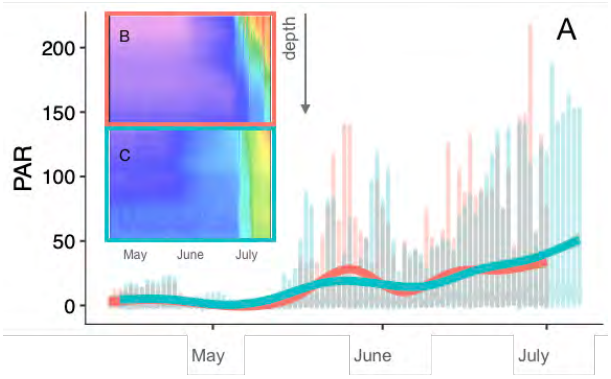

Fig. 1: Light intensity is progressively increasing throughout the season and is comparable at both sites (coral – SS2, teal – SS901). Temperature profiles show that SS2 (B) was colder than SS901 (C) when covered with ice. After ice-out (mid-/late June), SS2 warmed up and stratified quickly.

Acknowledgements: NSF grant DGE-1144423

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Spatial and Temporal Reconstruction of Past Fire and Vegetation Change in the Northwestern Amazon

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Abstract: Pre-Colombian peoples of Amazonia likely played a large role in shaping the modern forest composition. To assess past human influence, we reconstructed spatial and temporal patterns of past fire and vegetation change to determine the timings of the most recent fires, the extent of past vegetation change within the forest plot, and whether the observed vegetation changes in the forest plot resulted from past human activity.

Background:

There are an estimated 16,000 tree species in Amazonia, but 50% of the individual trees are composed of only 227 of these species, termed hyperdominants. These hyperdominant species play a disproportionately large role in the carbon sequestration. Little is known whether the same suite of species that are hyperdominant today have remained so over long time scales (1000s of years).

A recent hypothesis is that the pre-Columbian peoples played a large role in shaping the modern species composition. Forest plots used to assess Amazonian biodiversity and carbon dynamics are disproportionately located in areas with high densities of archeological sites.

Project Description:

We collected 12 soil cores in the Amacayacu Forest Dynamics Plot (S3°48', W70°16') and analyzed those for charcoal (fire history) and phytoliths (vegetation history). We dated all charcoal fragments > 10 mg. To asses the effects of past fires on modern vegetation, we compared total charcoal abundances per core with the percentages of palm, hyperdominant, and useful species found in a 15 m radius around the core site using a Spearman Rank Correlation test.

Preliminary Data:

Dated charcoal fragments indicate fires from 1650- 1850 cal yr BP, and ca, 2450 cal yr BP (Figure 1). No evidence of cultivars is present in the phytolith record. Grass phytoliths are only found in very low numbers in the surface samples.

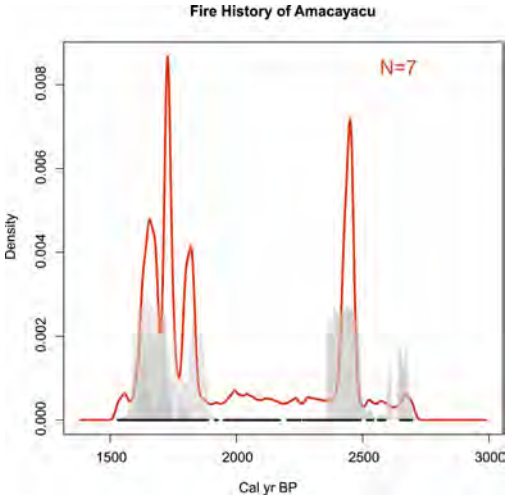

Figure 1. Fire History of Amacayacu. The x-axis shows age in calibrated years B.P. Y-axis shows the likelihood-density of the calibrated age. Seven charcoal fragments were dated.

Acknowledgments: This project was funded by the CTFS–ForestGEO 341243.

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McMichael, C. N. H., Matthews-Bird, F., Farfan-Rios, W., & Feeley, K. J. (2017). Ancient human disturbances may be skewing our understanding of Amazonian forests. Proceedings of the National Academy of Sciences, 114(3), 522–527.

Crevasse Initiation and History Within the McMurdo Shear Zone, Antarctica

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Abstract: We investigate the kinematic drivers of crevasse initiation in the McMurdo Shear Zone, Antarctica. We delineated crevasses from high-frequency ground penetrating radar (GPR) data and compared their location with kinematic outputs derived from remotely-sensed ice surface velocities to develop a statistical method to estimate crevasse initiation threshold values. Our analysis suggests that crevasse initiation in the McMurdo Shear Zone occurs when the shear strain rate exceeds a value of 0.0114 a^{-1}.

Understanding crevasse initiation may best be achieved with small-scale observations in which crevasses can be directly observed. We combine crevasse observations from high frequency ground penetrating radar (GPR) surveys and kinematic outputs derived from remotely-sensed ice surface velocities of the McMurdo Shear Zone (MSZ), Antarctica, to develop a statistical method to estimate crevasse initiation threshold values.

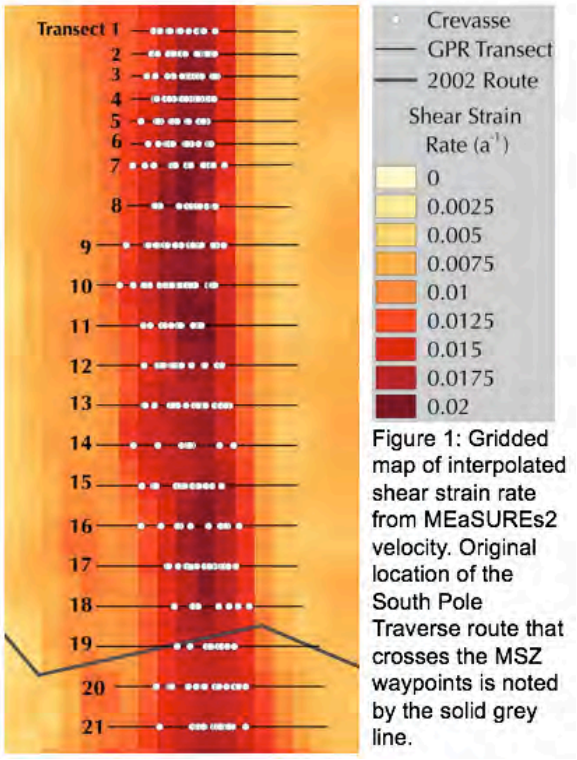

Figure 1: Gridded map of interpolated shear strain rate from MEaSUREs2 velocity. Original location of the South Pole Traverse route that crosses the MSZ waypoints is noted by the solid grey line.

We analyzed ~95 km of 400 MHz ground penetrating radar (GPR) data collected within the MSZ in October of 2017 and identified 420 crevasse features. Shear strain rate, dilatation, and vorticity were derived from MEaSUREs2 ice flow velocities. We estimated the relative frequency distribution of crevasses with respect to the kinematic data outputs. Shear strain rates proved best for predicting crevasse location.

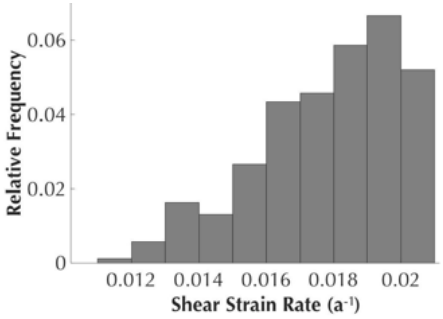

Figure 2: Plot of the relative frequency of crevasses with respect to shear strain rate

Our analysis suggests that flow in the MSZ is dominated by simple shear and that crevasse initiation typically occurs when the shear strain rate exceeds a value of 0.0114 a^{-1}.

Crevasse initiation depends on several factors including temperature, crystallography, and ice history. Therefore, the threshold values derived for the MSZ cannot be directly applied to other glacial environments. However, the method provided here can be repeated to find other kinematic threshold criteria for more complex shear margins, to study shear margin evolution, and to assess localized damage processes in locations where *in situ* data are available.

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

Glacial Lake Filling, Draining, and Hazards at Donjek Glacier and River, Yukon, Canada

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Abstract: Donjek Glacier is a surge-type glacier which has advanced during a surge-event every 10-12 years since at least the 1930s. When the glacier advances, it can partially dam the Donjek River, forming ice dammed lakes. These lakes pose a potential hazard to downstream infrastructure, including the Alaska Highway.

Introduction:

Donjek Glacier (61°11'N, 139°31'W) is a surge-type glacier located in the St. Elias Mountains, Yukon, Canada. The glacier has undergone cyclical surge events approximately every 10-12 years since at least the 1930s, where the glacier velocity increases, and mass is moved towards the terminus. These surge events have caused the terminus to advance and interact with the Donjek River, leading to damming and lake formation (Fig. 1).

Fig. 1. Donjek Lakes, Glacier, and River, August 14, 2014. Southern lake (bottom left) and northern lake (top right) are both shown.

Work by Clarke and Mathews (1981) highlight the dangers posed by paleo-Lake Donjek, which would have impounded ~0.234 km^3 of water. However, a lake of this size, formed by a complete blockage of the river, has not occurred since ~1810.

Methods and Results:

We analyzed air photographs and satellite images since 1937 to identify lake fill/drain times and quantify lake area. We find lake formation to be complex, as terminus retreat and advance due to surging has changed the lake location and timing. We find two lakes to be particularly persistent after a surge event.

The southern lake forms such that the Donjek River typically runs through the lake and is blocked on one side by the terminus of Donjek Glacier, which forms an ice cliff (Fig. 1). This lake frequently has icebergs and/or bergy bits in it. The northern lake is isolated from the river and is blocked by morainal material and/or bedrock and Donjek Glacier.

The lakes appear to drain in less than a few days, although little is known about the increase in Donjek River discharge after lake drainage begins due to a lack of monitoring. We hypothesize that the lakes drain beneath the glacier when melt water from upstream is able to open a subglacial channel. This is supported by an ice canyon, which occasionally forms and is visible cutting through the glacier after some drainage events.

Acknowledgements: This material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. DGE-1144205.

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Hot Squirrels: Temperature, Energetics and the Distribution of Flying Squirrels in Eastern North America

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Abstract: The relationship between climate and species range limits has particular relevance to Maine where a colder northern climate abruptly meets a warmer climate zone in the southern interior. The natural laboratory provided by the existing climate divisions within Maine allows for the study of species both at the northernmost and the southernmost distribution of their ranges. Our research examines rising ambient temperatures as a potential driver of the observed shifts in small mammals by determining the effects of high summer temperatures on flying squirrels.

Increasing global temperatures have the potential to rapidly alter species' range distributions and subsequent interactions. In eastern North America, two species of flying squirrel (*Glaucomys volans* and *G. sabrinus*) have undergone significant northward range shifts over the past few decades (Bowman et al 2005, Wood et al 2016). Previous studies posited that warmer winters allowed the southern species (*G. volans*) to move north where they, through competition and a parasite they carry, caused the northern species (*G. sabrinus*) to move north. As flying squirrels are nocturnal, and rest during the daytime in tree hollows with little opportunity for behavioural thermoregulation, we hypothesized that rising temperatures in the summer may also play a role in the changing range dynamics of these two species.

Project Description:
We measured resting metabolic rates over a range of ambient temperatures to model energy and water use and assess the relationship between environmental temperatures and energetics in flying squirrels. Using temperature sensitive data-loggers, we also recorded the body temperature of free-ranging southern flying squirrels as a proxy for energy use in the field. We also trapped at various locations throughout the state to determine the range boundaries of each species.

Results and Discussion:
Respirometry and body temperature data collected from Southern flying squirrels indicated that energy and water expenditure during rest are impacted by ambient temperatures. Therefore that heat stress may play a role in current range shifts. All flying squirrels caught near Orono were Southern indicated a continued northward range expansion of this species. Northern flying squirrels were found in Presque Isle and will be the focus of future data collection starting May 2019.

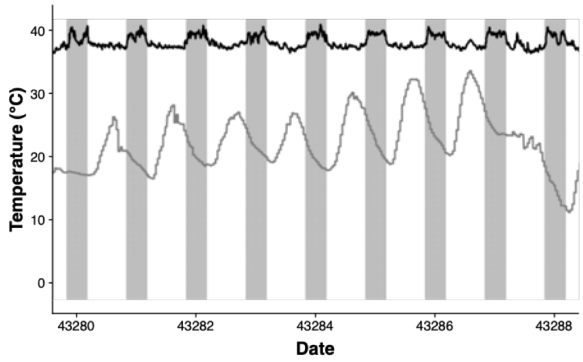

Fig. 1. A body temperature trace of *G. volans* male (black line, n =1) and ambient forest temperature (grey line). White bars indicate daylight hours and grey bars nighttime hours.

Acknowledgements: USDA NIFA, Hatch project number 21623 (MAFES) and the University of Maine Graduate Student Government Grants.

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Investigating Changes to Greenland's Peripheral Marine-Terminating Glaciers Through Automated Analysis of Satellite Imagery

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Abstract: We are adapting a program used for delineating mouse chromosome territories in fluorescence microscopy images using the multi-scale 2D Wavelet Transform Modulus Maxima (WTMM) segmentation method to automatically map glacier termini in satellite images. Using this adapted method, we will quantify terminus position changes over 30+ years for over 600 marine-terminating glaciers around Greenland's periphery.

Meltwater from Greenland's glaciers and ice sheet contributes to nearly half of contemporary global sea level rise sourced from glacier and ice sheet melt [1], which impacts human coastal settlements, marine ecosystems, and atmospheric and oceanic circulation patterns. While changes to the Greenland Ice Sheet and its major outlet glaciers have been studied extensively, we need more data on the remote glaciers around Greenland's periphery. These glaciers contribute up to 20% to Greenland's total glacier mass loss [1].

We will investigate the terminus position changes for 641 of Greenland's peripheral glaciers by developing an automated method for delineating glacier termini in satellite images. We are adapting the 2D Wavelet Transform Modulus Maxima (WTMM) segmentation method [2], previously used in biomedical image analyses, to objectively detect glacier terminus positions.

The 2D WTMM identifies regions in satellite images with the greatest change in intensity at various size scales. It places lines along regions with intensity contrasts around an image, such as the contrast between glacier ice and open water or glacier ice and sea ice. Its multi-scale analysis adapts to delineate glacier termini with variable sizes, geometries, and environmental conditions (i.e. sea ice conditions), leading to more accurate and efficient mapping than possible from manual mapping techniques. Its multi-scale capability also allows it to see through noise, a small-scale phenomenon, which makes it well-suited to analyze images over glaciers with complicated terminus conditions (Fig. 1).

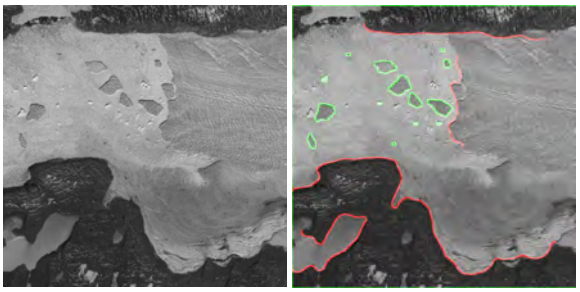

Fig. 1. Landsat image over Jakobshavn Glacier in Western Greenland (left). The bright sea ice and icebergs in front of the terminus make this a difficult image to analyze. However, the 2D WTMM is able to resolve subtle changes in intensity around the image and delineate icebergs as well as the terminus (right).

Here we present results from our method run on a representative sample of 10 glaciers and compare the accuracy of these automated delineations to manual delineations. Once we expand this analysis to all 641 glaciers, we will explore the spatial and temporal variations in glacier terminus changes and the environmental variables that drive them.

Acknowledgements: This research is funded by the National Aeronautics and Space Administration (NASA) ROSES Cryospheric Science Grant 80NSSC18K1228.

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Developing a Long-Term Perspective on the Sensitivity of Lake Trophic State Changes in Maine

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Abstract: Paleolimnological records spanning the past 400 years will be used to determine the sensitivity of lakes to changes in land use and climate. This will be used to develop a long-term perspective on trophic states and algal abundances that vary across biophysical regions in Maine. Background information will be gathered on land use history and fisheries. Diatoms and algal pigment profiles will be generated for each lake core. Data will be compared across lakes and the biophysical regions to assess lake sensitivity to land use and climate changes.

Project Goals

The goal of this project is to determine patterns of algal production over the past 400 years in lakes that vary across key features. The past 400 years captures a period of major land use changes in the state as well as climate changes. This research will be used to improve our understanding of the sensitivity of Maine's lakes to changes in land use and climate by developing a long-term perspective on trophic states and algal abundances in lakes that vary across features. There are two main questions being posed: has land clearance affected lakes similarly across different biophysical regions of Maine? Does fossil evidence suggest similar nutrient disturbance as a consequence of land clearance? The biophysical regions of Maine were developed to relate patterns of woody plant species to climate, topography, bedrock and surficial geology, and soils. There are fifteen classified in the state of Maine.[1] We focus on regions 9 (Southwest Interior) and 10 (Central Interior) because of land use history as well as proximity to the coast. In region 10, an additional parameter of interest is whether lakes lie on the marine clay layer, which affects phosphorus loading to lakes. Six lakes across the two regions have been selected for this study (Table 1). Additional background information will be collected on land use history, fish community, and water clarity.

Water Body	Surface Area (hectares)	Max Depth (m)	TP (µg/L)	Marine Layer	Bioregion
Long Lake	2142.8	18	4	No	Southwest Interior
Pleasant Lake	539	18.9	5	No	Southwest Interior
Highland Lake	539.9	15.2	5.9	No	Southwest Interior
Unity Pond	1039.6	12.5	21	Yes	Central Interior
Webber Pond	499	12.5	18	Yes	Central Interior
Sebasticook Lake	1836.1	15.2	24	No	Central Interior

Table 1: Lakes chosen for study.

Methods

Sedimentary diatom and algal pigment profiles will be generated for each lake after dating lake cores. The strength of algal response to land use changes over time will be compared across lakes and bioregions.

Acknowledgements

This project is funded by the MAFES program. Thanks to the Saros Lab, Andrea Nurse, and committee members: Jacquelyn Gill and Amanda Klemmer.

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Little Mountains, Big Implications: Alpine Mircorefugia in the Northeastern United States

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Abstract: Alpine and subalpine plant communities in the northeastern United States are scattered across relatively low elevation peaks and ridges. These mountain habitats have long histories as conservation land, but their alpine and subalpine plants — culturally and ecologically important resources — often comprise small, disjunct populations at the southern edge of their circumboreal or circumarctic distributions. Northeast alpine and subalpine assemblages have been interpreted as post-glacial tundra relicts, however paleoecological records above treeline are sparse and this assumption remains untested. If these mountains have supported persistent alpine and subalpine plant taxa throughout the Holocene, perhaps these microrefugia are more resilient to climate change than previously thought. New pollen and macrofossil analyses from montane ponds in Maine, combined with recent plant population studies on decadal timescales will uncover vegetation dynamics at these alpine and subalpine sites and give managers and conservation practitioners new insights into the response of plant communities to past warming events.

Project Goals:

The goal of this project is to bring a long temporal perspective to alpine and subalpine plant community dynamics in the northeastern United States through new conservation paleobiology fieldwork. Documenting the prevalence and spatial distribution of persistent tundra microrefugia in the northeast will provide critical context about the vulnerability of these iconic plant communities and allow conservation practitioners to focus management actions and refine extinction risk estimates for alpine and subalpine plants.

Initial Results:

While the northeast is warming faster than the contiguous United States, high elevations and coastal islands may be buffered from regional warming by cloud cover (Karmalker and Bradley 2017, Seidel et al 2009). On coastal mountains in Acadia National Park, Maine there is evidence that local microclimate gradients are decoupled from elevation gradients (McDonough MacKenzie et al 2019). This kind of local-scale heterogeneity in microclimates has been associated with reduced extinction risk from climate change (Suggitt et al 2018).

We conducted new fieldwork at two of the most iconic landscapes above treeline in the northeast: Acadia National Park's Sargent ridge and Baxter State Park's Chimney Pond in the bowl behind Katahdin (Norton et al 2011, Urban et al 2017). We recovered 409.5 cm of sediment from Sargent Mountain Pond in Acadia and 196.5 cm of sediment from Chimney Pond in Baxter; we're currently analyzing 103 Sargent pollen samples, 49 Chimney pollen samples and sorting and identifying macrofossils at 0.5 cm increments from both stratigraphies. We're also compiling records of floristic change over the last century at both sites. Together, these neo- and paleoecological studies will help managers refine climate change vulnerability assessments.

Acknowledgements: David H. Smith conservation biology postdoctoral fellowship.

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Investigating Dog Burials for Insights on Human-Canine Interactions in the Maine/Maritime Region: An Archaeological Case Study

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Abstract: Archaeological dog remains in burial contexts contain evidence of past diet, behavior, and human agency. Using canines to infer past diet is a well-established method, especially when human remains are unavailable.[1,2] Aside from insights about resource use, temporal and cultural trends derived from burials are indicators of past human behavior. Burials reflect the complex role of dogs in past human societies[3], which change in response to community needs and choices. This proposed study examines two dog burials in order to better understand human-canine interactions in the Maine/Maritime region during the Middle Ceramic Period (ca. 2150 – 950 BP).

Project Objectives

This proposed study examines human-canine interactions by analyzing two dog burials from the Holmes Point West site in Machiasport, Maine. This project has several intersecting objectives: 1) to identify the socio-cultural context of dog burials at the Holmes Point West Site; 2) to develop a pathology and health profile of dog remains; 3) to analyze stable isotopes $\delta^{13}C$ and $\delta^{15}N$ for canine dietary data; and 4) to situate results within regionally comparative datasets. Community stakeholder engagement is planned to enhance research processes and outcomes.

Site Overview

Holmes Point West (62-8) is a shell midden site occupied from the early Ceramic Period (ca. 3050 BP) until historic times.[4] Shell middens offer ideal alkaline preservation conditions for bone remains due to their high concentration of CaCO3. Site 62-8 is the subject of recent studies highlighting differential choice of animal remains for ritual purposes[4] and increased site vulnerability due to climate change.[5]

Available Data and Future Work

This study focuses on existing dog remains recovered during the 1973 excavations at site 62-8. The skeletons were oriented in mirror image, less than one meter apart.[4] Burial of whole and unmodified organisms is indicative of non-subsistence behavior and suggests they were valued by pre-contact peoples. Ingram's (2011) faunal study identified four fragmentary canines in the assemblage (Fig. 1).[4] Analyses of subsistence bone recovered since 2011 may yield additional canid remains. Fieldwork is planned for 2019 to recover additional data. Analysis of the entire canid sample will commence subsequently and will include a pathology and health profile and a dietary reconstruction. Results will be compared to existing canid data from the region.

Fig. 1. Right mandible of dog from site 62-8.

Acknowledgements: Funded through the Maine Academic Prominence Initiative (MAPI) Grant. Thanks to Dr. Bonnie Newsom, Dr. Daniel Sandweiss, Dr. Eric Guiry, Sky Heller, Matthew James, and Kendra Bird**.** Graduate Assistantship: TRIO Student Support Services.

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Impacts of Glacier Surface Melt on Isotope Signal Preservation in Arctic Ice Cores

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Abstract: Ice core-based paleoclimate reconstructions are useful in preparing for regional climate change as the Arctic continues to warm. Here we identify factors driving glacier surface melt at Arctic ice coring sites, and examine the associated reductions in stable isotope signal preservation.

Motivation and Background

The Arctic is warming rapidly in comparison to the rest of the globe, making climate change adaptation increasingly necessary for Arctic communities. To predict and prepare for changes in temperature, precipitation amounts, storminess, and resource availability, it is important to understand how regional hydroclimate has behaved in the past.

Ice core proxy records provide a useful method for reconstructing past hydroclimate variability. Temperature reconstructions are based on the well-established linear relationship between stable isotope ratios in ice and air temperature at the time of initial snow deposition (Dansgaard 1964).

However, meltwater percolation through the snowpack can degrade the original isotope signal, making paleotemperature reconstruction more challenging. In the St. Elias Mountains (Yukon, Canada), we see melt-related signal loss at Icefield Divide despite high signal preservation at nearby Eclipse Icefield (Fig. 1). Eclipse is 100 m higher and 30 km away from Divide.

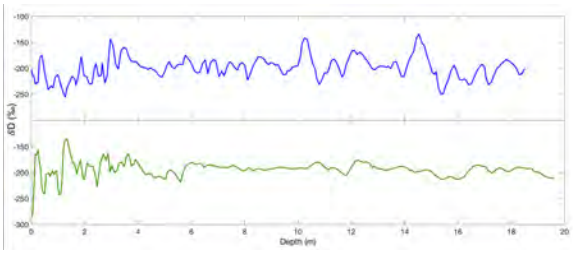

Fig. 1. Hydrogen isotope signal measured in ice cores drilled at Eclipse Icefield in 2017 (top), and at Icefield Divide in 2018 (bottom). Low signal amplitude in the Divide record indicates wash-out due to surface melt at the coring site.

In this project, we aim to examine the hydroclimate characteristics (temperature, accumulation rate, and melt amount) of Arctic ice coring sites in order to identify a critical threshold for isotope signal preservation. For this analysis, we use ice core and instrumental records collected by our group in the St. Elias Mountains as well as published results from other Arctic sites.

Initial Results

In our case study of Eclipse and Divide, we found that a small (1-2 °C) temperature difference between these two sites plays a major role in the observed difference in isotope signal preservation. We compare these results to observations at other Arctic sites such as Mt. Hunter in S.E. Alaska, where a 1.9 °C increase in air temperature is associated with a 60x increase in melt (Winski et al. 2018) but no isotope signal alteration. We will discuss site characteristics that may be useful for determining the critical threshold between melt and isotope preservation.

These results have important implications for ice core paleoclimate reconstruction during the early Holocene and for isotope signal preservation in the future as the Arctic continues to warm.

Acknowledgements: CCI, NSF, Maine Space Grant Consortium, Churchill Exploration Fund; Bradfield Lyon, Luke Copland, Christian Zdanowicz, Douglas Introne, Will Kochtitzky.

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Multi-Level Governance of Climate Change Adaptation: Exploring Synergies and Barriers to Adaptation Implementation in Samoa

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Abstract: International finance for climate change adaptation projects implemented in developing countries is on the rise. Multilateral organizations, such as the World Bank, have pledged to double adaptation funding over the next five years. These projects inherently present a multi-level governance challenge. They are usually developed at the national level, funded at the international level, and ultimately implemented at the local level. This paper examines a case study of two country-wide adaptation projects in Samoa to understand the dynamics between multi-level governance and effective adaptation efforts.

Background:
The Independent State of Samoa is a Small Island Developing State (SID) located in the South Pacific. This research focuses on Samoa's two main islands, Upolu and Savai'i. Samoa, and its counterparts in the Pacific, are at the forefront of climate change adaptation and are some of the main drivers behind obtaining climate adaptation financing from the international community. Samoa's national government has made climate change central to its overall development agenda and a broad national priority.

Case Study:
The Samoan government is currently engaged in two country-wide adaptation projects funded by the Adaptation Fund and the World Bank's Pilot Program for Climate Resilience, respectively. These partner initiatives have three main elements: updating district level Community Integrated Management (CIM) Plan, supporting community adaptation through a small grants program, and implementing large infrastructure projects. We use a multi-level governance (MLG) framework to understand the dynamics at play in these adaptation projects. MLG suggests that when all governance levels are intentionally interacting to build a support structure for the other levels, they all function more effectively in policy planning and implementation.

Results:
Interviews with project stakeholders and site observations of adaptation projects on Upolu and Savai'i suggest that, in some respects, MLG accelerates adaptation efforts while in other areas MLG itself was less apparent, often resulting in less effective elements of the project. The CIM Plan update process is an example of MLG facilitating adaptation. Namely, through adopting a new, "pragmatic approach," the national government supported mainstreaming of adaptation planning at the village level as well as across most national government agencies. However, the tourism ministry has yet to fully embrace adaptation planning and is more focused on growing the country's tourism industry in the next five years. As a result, MLG breaks down when unresolved, conflicting development agendas are simultaneously pursued by the national government. This example highlights that management of trade-offs may be an essential element of effective MLG.

Acknowledgements: This project is supported by the National Science Foundation Graduate Research Fellowship DGE-1144205, the SPIA Richardson-Churchill Fellowship, the Churchill Exploration Fund, the Phi Kappa Phi Love of Learning Grant, the Schwartz Legacy Fund, and Graduate Student Government grants.

Chronicles from the Mammoth Steppe: A Multi-Proxy Reconstruction of Beringia's Paleoecology

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Abstract: The extinction of late Quaternary megafauna consisted of multiple extinction events taking place globally towards the end of Pleistocene. Various hypotheses have been proposed to explain the causes of these extinctions, however not much attention has been put on how ecosystems responded to them. Arctic megafauna existence was linked to that of a productive grassland ecosystem called "Mammoth Steppe". Its disappearance has traditionally been interpreted as the cause of arctic megafaunal extinction. However, large herbivores are known to influence arctic vegetation structure by affecting nutrient cycling and plant interspecific interactions. Therefore, the disappearance of the Mammoth Steppe might be also interpreted as a consequence of megafaunal extinctions. The goal of this project is to use a high-resolution, multiproxy approach to investigate the timing and nature of megafaunal extinctions and environmental changes in the Beringia region, once part of the Mammoth Steppe biome.

Project Goals

The main study objective is to understand the relationship between the disappearance of the Mammoth Steppe and the megafaunal populations that inhabited it. Beringia has been chosen as study location because it was part of the Mammoth Steppe biome and has a rich history of paleoenvironmenal reconstructions. Until the onset of Holocene it was completely emerged and unglaciated (Figure 1), connecting western North America and eastern Asia and acting at the same time as a corridor and refugium for many species. Current knowledge suggests that the Mammoth Steppe was a productive grassland with a diverse vegetation able to sustain large population of cold adapted mammals. However, there are still gaps in our understanding of Beringian past ecology, hydrology and biogeography. We also still lack information on how megafauna-vegetation interaction might have shaped the plant community. Our project will allow to address these topics by reconstructing Beringia paleoenvironment using a multiproxy approach. We will collect four sediment cores from different locations all over Beringia and analyze them to compare trends of pollen (proxy for vegetation), dung fungi spores (proxy for megafauna abundance) and charcoal (proxy for fire regimes) abundance to build an accurate chronology of the events in the region. We will analyze fossil dung from the region to reconstruct past interactions between animal and plants to understand how they might have shaped Mammoth Steppe's vegetation. We will perform modern vegetation experiments in the Arctic to assess the effect of herbivores on arctic vegetation, simulating temperature increase to assess if herbivore disappearance might have affected vegetation resilience to past climate change.

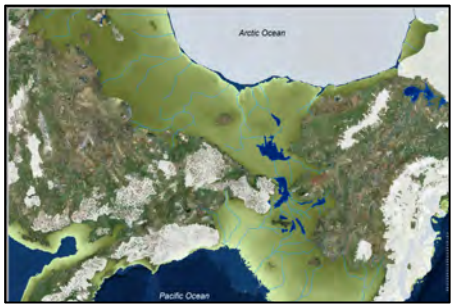

Figure 1. Reconstruction of Beringia during the Last Glacial Maximum[1]

Acknowledgments: This project is possible thanks to an NSF CAREER grant earned by Dr. Jacquelyn Gill, and thanks to her mentoring and guidance.

[1] Bond, J.D., 2019. Paleodrainage map of Beringia. *Yukon Geological Survey, Open File 2019-2*

Interactions Between Local Land-Terminating Glaciers and Ross Sea Ice at and Since the Last Glacial Maximum in the Royal Society Range, Antarctica

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Abstract: The behavior of the Antarctic Ice Sheet (AIS) since the Last Glacial Maximum (LGM) is still under debate. The purpose of this study is to examine the past interactions of the land-terminating Walcott and Howchin Glaciers and the marine Ross Sea ice sheet in the Royal Society Range of the Transantarctic Mountains. Here, we combine a glacial-geomorphic map with radiocarbon ages to reconstruct a chronology of the past extent of ice. By reconstructing its past behavior, we hope to predict how this system will respond to future warming.

The future contribution of the Antarctic Ice Sheet (AIS) to global sea-level rise is a high-priority question. Insight into its future contribution can be sought from its past behavior. We examine the history of the AIS since the LGM in the Royal Society Range of the Ross Sea sector. Grounding of ice in the Ross Sea at the LGM led to expansion of an ice sheet to the continental shelf edge, fed by both East and West Antarctic ice[1]. This ice sheet deposited a distinct drift along the headlands of the Royal Society Range adjacent to the western Ross Sea.

Fig. 1. Map of the field area with location inset

There are at least two competing hypotheses on the driving mechanisms of this ice sheet. The first is that increased accumulation caused thickening of East Antarctic Ice Sheet outlet glaciers which caused the expansion of the grounded ice sheet. The second hypothesis is that the initial advance was caused by lower sea level and reduced melting along the grounding line.

Our preliminary radiocarbon ages show that Ross Sea ice was depositing the headland moraine and nearing its maximum extent by 18,400 years before present, which corresponds well with other dates along the coast[2]. Cross-cutting relationships between Ross Sea drift and alpine moraines indicate that local glaciers did not advance and contribute to the Ross Sea ice sheet during the LGM. This suggests that the Ross Sea ice was controlled by a different mechanism than the land-terminating glaciers. The extent of Walcott and Howchin glaciers appears to be controlled by accumulation, while the Ross Sea grounding was the driven by marine mechanisms.

Further work includes the processing of additional radiocarbon and surface exposure-age samples and the drafting of a detailed geomorphological map.

Acknowledgements:
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Tess Walther, Laura Mattas, Tyler Pollock, and Allie Balter.

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Quantifying the Volume of a Diatom

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Abstract: A method for quantifying the volume of microscopic fossils is devised. Using computer aided design software (CAD), a 3D model of a diatom is constructed. This method enables the amount of material in a diatom's outer cell wall to be calculated. A discussion of the various research and teaching applications of this new method is provided.

The Diatom Frustule:
Diatoms construct complex outer cell walls made of silica dioxide (frustules). Each species creates a frustule with a unique architecture. Construction of each unique architecture requires different amounts of silica dioxide (SiO_2); thus, each species has different silica dioxide requirements (Julius and Theriot 2010). Herein we utilize an exceptionally well-preserved assemblage of diatoms from sediment recovered from Herd Lake, ID USA. Specifically we present *Stephanodiscus niagarae* Ehrenberg 1845: 80 as a model organism in creating a CAD model.

3D Modeling Method:
Advancements in CAD allow for the precise calculations of physical parameters of shapes with complex architecture. Creating CAD models of the diatom frustule reveals the volume of SiO_2 contained in a frustule.

Each species has a unique set and distribution of components that describe the shape of the frustule. *S. niagarae* exhibits spines, fascicles, areolae, and variable thickness. Each of these components is correlated to the diameter of the individual.

Considering the variable diameter of *S. niagarae* individuals and the corresponding number of components per diameter, a size diminution series of 3D models is created (Figure 1). The volume of each model in the size series represents the volume of the average individual for each diameter. This allows for interpolation of intermediary sized individuals.

Applications:
Research applications derived from this method will allow ecologists to quantify silica requirements for each species of diatom.

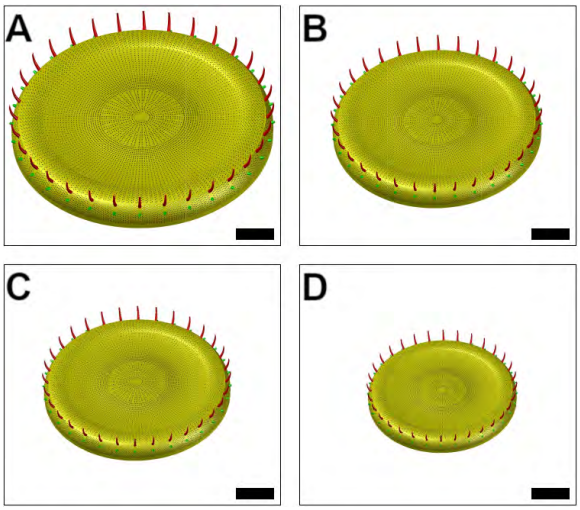

Figure 1. Size diminution series of 3D models of *S. niagarae.* Scale bars are 10 µm.

Paleontological investigations will be informed of changing available silica as related to past changes in precipitation from climate shifts. These models have improved pedagogy in diatom taxonomy classes at Indiana State University and SUNY at Fredonia.

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Rethinking Ceramic Tempers in Maine: New Insights from the Holmes Point West Site (68-2)

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1. *Anthropology Department, University of Maine.*

Abstract: Past analyses of pre-contact ceramics from the Maine/Maritime region point to crushed rock and shell as common tempers used by Indigenous potters. Other sources of temper such as plants, bone, and fur are common in ceramic production around the world but have not been identified in pre-contact ceramics in the region. A recent analysis of ceramics from the Holmes Point West site in eastern Maine revealed conifer needle imprints within ceramic fabrics spanning roughly 1700 years during the late Holocene. Here, we present these findings and reflect on their ecological and archaeological implications.

Introduction:
Recent analyses of ceramics from the Holmes Point West site in Machiasport, Maine suggest that Indigenous potters used conifer needles in ceramic manufacturing. Conifer needle imprints are evident in multiple ceramic vessels dating to roughly 2150-420 B.P. These findings indicate a broader suite of tempering materials than what has been reported previously for the Maine/Maritimes region. This paper presents these findings and reflects on their environmental and archaeological implications.

Archaeological Context:
The Holmes Point West site (62-8) is a shell midden in eastern Maine. It is part of a cultural landscape that includes multiple archaeological sites and Indigenous petroglyphs--most of which date to the Ceramic Period (3050-250 B.P.) Archaeological research at the site produced evidence of both pre- and post-contact occupations (Bird 2017).

Findings and Imprint Characteristics:
In 2017, we initiated analyses of ceramics from the Holmes Point West site in preparation for continued research at the site. During analysis, James observed elongated imprints within the fabrics of ceramic sherds representing multiple temporal units. Comparative analyses with contemporary conifer needles and consultation with UMaine plant specialists indicate that the imprints represent conifer needle inclusions in the ceramic pastes. These imprints occur on the inner and outer surfaces of the vessels and within vessel walls. They are elongated voids measuring 1-2mm wide and up to 20mm long. They exhibit a centerline ridge along the long axis and blunt-to-pointed ends (Figure 1).

Figure 1. Left: Image showing location of conifer needle imprint. Right: Magnified image of conifer needle imprint (~1mm wide).

Significance: Paleoenvironmental research in the Maine/Maritime region relies on multiple lines of evidence to reconstruct past environments. These findings add another dataset to aid in those reconstructions. This study also calls for expanded methods for regional ceramic analysis and provides new avenues of research into potters' choices in the pre-contact period.

Acknowledgements: Maine Academic Prominence Initiative Grant (MAPI); UMaine Work-Study Program; Dr. Aram Calhoun and Andrea Nurse, M.S. for plant ID support; the Indigenous peoples of Maine for sharing their archaeological heritage.

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Understanding the Ecology of Key Diatom Taxa in the *Aulacoseira* Genus in Relation to Climate

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Abstract: *Aulacoseira distans and A. alpigena* are associated with changes in the water column stability of lakes, but there are gaps in our understanding of their ecology. Observations about the effects of key resources such as light and nutrients showed contrasting responses among the species.

Aulacoseira has been suggested as an indicator of unstable water column, given the denser trait of their frustule. Turbulence is a mechanism for the location of the genus in the water column (Carrick et al., 1993; Stone et al., 2011)

It is presumed that the Nordic-alpine species *A. distans and A. alpigena* reflect thermal changes in lakes, so they can be used as proxies to track the deviation in the mixing of lakes. However, it is unknown if only the turbulence or the interaction with light and nutrients determine the occurrence of the species (Gibson et al., 2003).

This research studied the ecological response of the target species to light, nutrients and the distribution along the water column in alpine lakes in the Greater Yellowstone area.

The distribution of the species throughout the water column in the surveyed lakes suggests that the target species respond to the variation established by light access. Thus it originated different responses of the species across lakes. In Kersey Lake the highest density was observed between the epilimnion and metalimnion, in Beauty it was found between the metalimninon and hypolimnion and for Beartooth it was in metalimnion. The main correlations are between the density and the amount of light available in the epi, meta, and hypolimnion. No significant correlations are between density and ion concentration or nutrient availability.

The nutrient experiments showed that the density and growth of *Aulacoseira* spp do not exhibit a particular response to an increase in N, P or N+P. However, it was found that the location in the water column and its interaction with nutrients affect the growth rate.

For the light experiments, the species had a different response, but the trend suggested that light influences the growth rate. The result of light experiments indicates that light is a determinant factor in the distribution of *Aulacoseira* spp. Light in conjunction with the thermal gradient explains the differences in response among the species. The current work is focused on the full identification of the Aulacoseira specimens found in the lakes (Fig 1).

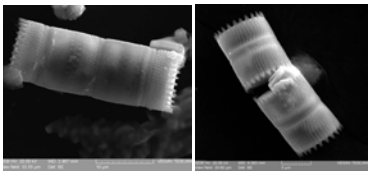

Fig. 1. Aulacoseira key taxa in Beauty Kersey and Beartooth lakes during the survey on July of 2017 (Pictures by Joe Mohan).

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

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Cosmogenic ^{10}Be Surface Exposure Dating Moraine Chronology of Late-Holocene Climate Fluctuations, Hooker Glacier, Southern Alps, New Zealand

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Abstract: Cosmogenic ^{10}Be surface-exposure dating from the moraines of Hooker Glacier in New Zealand's Southern Alps indicates that natural variability of New Zealand's climate during the past ~1500 years has been independent of European climate variations. Glacial retreat within the last century has been synchronous with the global signal of anthropogenic warming.

Introduction:

Late-Holocene climate fluctuations such as the Little Ice Age (LIA; ~1150 CE to ~1850 CE) and Medieval Warm Period (MWP; ~900 CE to ~1150 CE) are well documented in the Northern Hemisphere but are poorly recorded in the Southern Hemisphere. Without high-quality Southern records, it is not clear whether these climate variations were regional or global in extent. The cosmogenic ^{10}Be surface-exposure chronology of moraines constructed by the Hooker Glacier in this study shows that climate variations in New Zealand's Southern Alps over the past ~1500 years have not matched those in Europe during the same period.

The Hooker Glacier flows down from Aoraki/Mt. Cook in New Zealand's Southern Alps. The glacier's small size, steep incline, and large mass-balance gradient make it exceptionally sensitive to temperature change (Mackintosh, et al., 2017). This sensitivity to temperature makes the preserved moraines in the Hooker valley useful as records of natural climate variability. Previous ^{10}Be surface-exposure ages indicate that the outermost moraines in Hooker valley are ~1500 years old (Putnam et al., 2012), meaning that the features are of appropriate ages to test hypotheses regarding the MWP and LIA.

Results:

During January and February of 2018, we collected samples from boulders embedded in moraines of the Hooker Glacier. We completed laboratory analyses of thirty-one samples for cosmogenic ^{10}Be surface exposure dating at Lamont-Doherty Earth Observatory during the summer of 2019. Based on the dates obtained from those samples, moraines were constructed at 952±83 yr, 815±41 yr, 762±13 yr, ~697 yr, 618±83 yr, 582±101 yr, 456±30 yr, 253±20 yr, and 231±58 yr ago. This chronology indicates that the Hooker Glacier was stable or advancing during periods of both warm and cool temperatures as recorded in Europe, namely the MWP and LIA. The Hooker Glacier has retreated rapidly within the past century.

Discussion:

Moraine construction at the Hooker Glacier other New Zealand glaciers during periods of both warm and cool European conditions suggests that the Late-Holocene climates of Europe and New Zealand's Southern Alps varied independently. Rapid retreat in both locations during the past century is indicative of the global influence of anthropogenic warming.

Acknowledgements:

Funds from the National Geographic Society, Comer Family Foundation, and the Churchill Exploration Fund have supported this research.

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Annual Variability in a 1,600 Year Ice Core Record from Central Asia

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Abstract: An ice core chemical record from Kyrgyzstan is among the oldest records obtained in Asia. It preserves annual signals measured by laser ablation inductively-coupled plasma mass spectrometry (LAICPMS) to an age of >1,600 years. Intra- and inter-annual patterns vary across major climate periods, suggesting major shifts in atmospheric circulation.

Central Asia (CA) is among the driest places on Earth, with water resources for both natural and engineered systems derived primarily from warm season (JJAS) melt of snow and ice that accumulates in glacierized high-elevation regions during the cold/wet season (primarily MAM) (Kaser, et al., 2010). Changes in the atmospheric circulation patterns that deliver this moisture to the region, as well as seasonal changes in storm behavior and temperature have and will continue to affect annual water availability in the region.

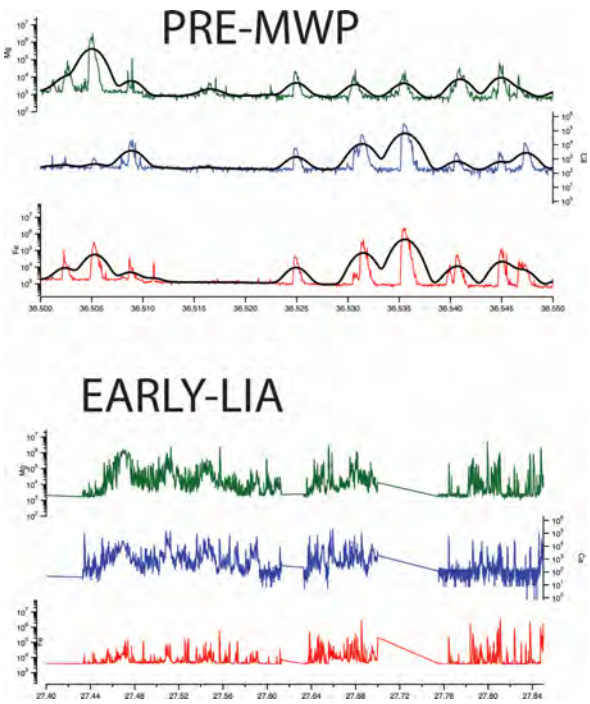

Fig. 1. LAICPMS measures from before the Medieval Warm Period (~1700 years ago) and during the Little Ice Age (~475 years ago). Magnesium (green), Calcium (blue), and Iron (red) measures appear to show a single dusty season in the early period, separated by low-input periods, and more continuous delivery in variably-stormy years during the LIA.

In 2016, a ca. 37 meter ice core was drilled (to bedrock) in the Pamir mountains of Kyrgyzstan, CA. Ultrahigh resolution (>500 measurements per cm) LAICPMS analysis of the chemical record in this core allows us to build on earlier work (Rodda, et al, 2017, 2018). Dust and atmospheric chemicals dissolved in snow that fell on the glacier are preserved in annual layers that can be measured to greater ages than have previously been attained in Asian ice core records. Relatively low concentrations of atmospheric chemistry, delivered in a single annual pulse are characteristic of the warm/wet/calm conditions that prevailed prior to and during the MWP. During the cold/windy conditions that prevailed throughout the LIA in CA and upwind areas, annual delivery of higher concentrations of atmospheric chemistry occurred throughout the year, in storms that formed and tracked across dustier regions.

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

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Ice core Dating Integration in the Climate Data Workbench

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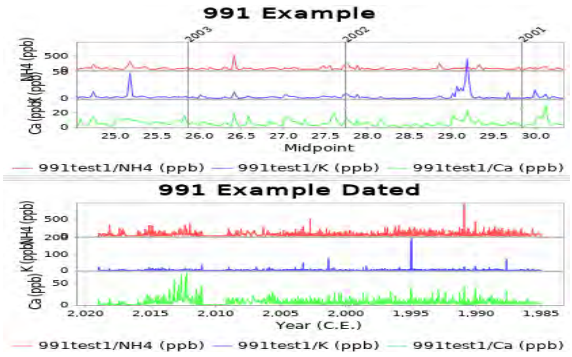
Abstract: We present the software integration of ice core dating tools to the Climate Data Workbench (P301 system). The implementation allows researchers to use different annual indicators in ice core time series in order to develop and apply time scales. During the creation of the time scale, an interpolated, dated version of the actively investigated core is presented to the researcher in real-time.

Ice core records are among the best geological archives for investigating past climate conditions. The snowfall that accumulates on glaciers captures various types of atmospheric aerosols and particulates. When ice cores are collected and analyzed, each sample depth is used to identify measured concentrations. The concentrations of soluble and insoluble impurities e.g., volcanic ash particles, gas bubbles, and other properties are analyzed. Certain types of chemical compounds, such as sulfate, hydrogen peroxide or sodium, are often utilized to determine seasonal markers in the ice core.

We developed ice core dating software that assists scientists with assigning the date for each depth interval. First, the collected ice core concentrations are plotted by depth. Next, known year markers are inserted into the plot. The result is that a year becomes associated with a unique depth value. The time scale developed by counting the number of annual layers from the top of the core (accounting for possible core breaks or other issues) and the depth for the marker is directly obtained from the domain axis of the plotted concentrations.

The association of depth and year for every sample is calculated by the interpolation algorithm. Two common interpolation approaches are linear and spline (cubic). Often, the method of linear interpolation is used to convert measured concentration amounts from the depth into a time domain for every sample.

The following figure contains a screenshot example of an active dating session. The top graph contains raw depth, and the bottom graph contains the dated components.



We build on ideas from previous versions of Ice Core Dating software developed at the University of Maine. In these previous versions, the raw ice core data is imported, and then annual markers are added. In the new version of the software, the dating is integrated into the Climate Data Workbench. Because of this integration, the features of the Climate Data Workbench are accessible to researchers of the system. The data set is presented on the cloud to share with other researchers, and the toolset from the Climate Data Workbench is immediately available to the researcher.

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The Role of Circulation Changes in the North Atlantic in Increasing Summer Precipitation in the Northeastern U.S.

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Abstract: This study aims to examine the role of changing circulation patterns in the North Atlantic on the recent precipitation increase in the northeastern United States.

Since the early 2000s, annual precipitation in the Northeast has drastically increased compared to previous decades (Fig. 1). The increase is primarily attributed to the occurrence of more frequent extreme precipitation events in summer, rather than an increase in the intensity of individual storms (e.g. Frei et al., 2015). Recent decades have also seen an increase in Greenland blocking events (Fig. 2) and a wavier polar jet stream, which promotes persistent atmospheric patterns and increases the chance of extreme events (Francis and Vavrus, 2015).

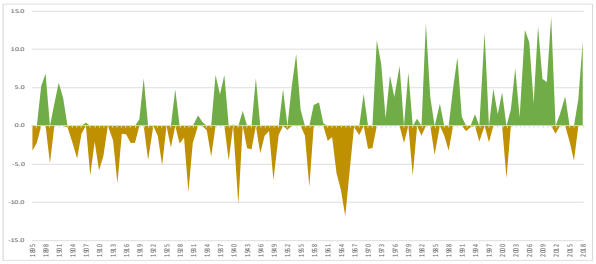

Fig. 1. Summer precipitation anomaly for the Northeast.

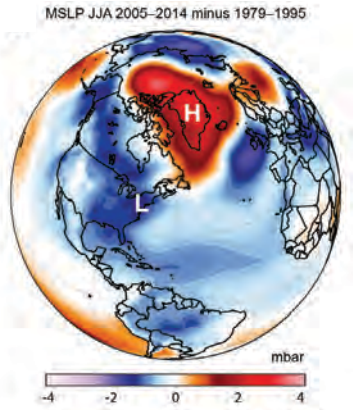

Fig. 2 Summer mean sea level pressure difference map (from Birkel and Mayewski, 2018).

The purpose of this study is to examine the role of circulation changes in the North Atlantic on the increased precipitation of the last decade. Associating trends in Northeast precipitation with large scale atmospheric circulation changes could be pertinent in assessing the performance of climate models, both in replicating historic conditions and producing projections.

Acknowledgements: This project is funded by a UMaine Signature and Emerging Area of Excellence Graduate Fellowship to the Climate Change Institute.

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Millennial-Scale Cycles of the Southern Hemisphere Westerlies through Paleoclimatic Reconstruction of the Falkland Islands

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Abstract: The Southern Hemisphere Westerly Winds (SHW) have a tremendous impact on the climate and ocean currents of the mid-latitudes in the Southern Hemisphere. Paleorecords suggest that the SHW have changed in average position and intensity since the Last Ice Age and may be a potential driver of abrupt climate change. This research will reconstruct the paleoclimatic history of the Falkland Islands, situated within the modern belt of the SHW, since the Last Ice Age to identify shifts in the location and/or intensity of the SHW, along with its effect on regional climate. These results will afford a new record at this latitude with which to test hypotheses of abrupt climate change and will broaden the data set needed to create better models of future change.

Project Goals

The goal of this project is to provide constraints on the meridional location and/or intensity of the Southern Hemisphere Westerlies (SHW) since the Last Ice Age to assess the influence of the SHW on Holocene millennial-scale climate change and to improve models predicting the movement and impacts of this system on future climate.

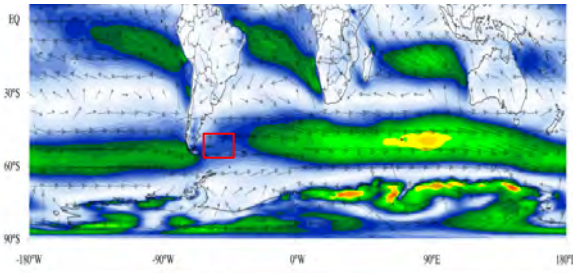

Figure 1 The modern location and intensity of the Southern Hemisphere Westerly Winds. The SHW are centered over 50°S on average. This belt shifts poleward (equatorially) in austral summers (winters). The map shows arrows for wind direction and warm colors for increased wind speed. The Falkland Islands are boxed in red within the SHW belt. (Climate Reanalyzer, 2018).

The Falkland Islands currently have a relatively warm, wet climate within the SHW belt. Episodes of cooler, drier climate are expected to coincide with northward shifts in the SHW. Thus, I hypothesize that changes in the position of the SHW will be expressed in the Falkland Islands through variations in temperature, precipitation, and wind intensity. My work consists of reconstructing paleoenvironmental change reflective of the SHW in the Falkland Islands. I am using a multiproxy approach on lake Sediments from high-elevation tarns on Mt. Usborne. In addition to the usual physical core parameters (i.e. grain size, magnetic susceptibility, etc…), I will examine pollen and leaf wax isotopes (∂D and ∂^{13}C) to provide paleotemperatures and precipitation information.

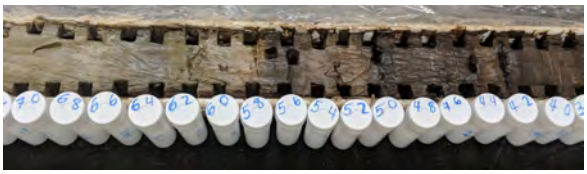

Image 1 Sampling of a 2018 core with lithographic facies present.

Initial Results

Analysis of the physical properties of cores collected in 2018 is nearly complete and shows dynamic environmental changes over the past 10,000 years consistent with shifts in the position of the SHW.

Reconnaissance work for pollen and leaf wax analysis has been promising, with shifting assemblages appearing to correlate with lithographic changes. Pollen assemblages will be processed in-house, while leaf wax analysis will be carried out at the University of Cincinnati in Summer 2019.

Acknowledgements: Churchill Exploration Fund support, University of Maine Graduate School Grant, 2018 Falkland field crew, University of Cincinnati- especially Dr. Tom Lowell and Dr. Aaron Diefendorf.

Bibliography: Climate Reanalyzer 2018.

Contributions from the Archaeological Record: Molluscan Climate Proxies and El Niño-Southern Oscillation (ENSO)

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Abstract: ENSO activity and intensity have varied in the past, and abrupt shifts during the mid- to late-Holocene are associated with cultural changes on the North Coast of Peru.[1] Mollusks from archaeological sites are ENSO proxies because they record fluctuations in stable isotopes associated with sea surface temperature (SST) anomalies and marine upwelling, enabling estimates of ENSO variability over time.[2] Despite their utility in paleoclimate research, the reliability of certain species and their application in ENSO reconstructions is hotly debated.[2,3] This research assesses the accuracy of δ18O-derived SST reconstructions of modern mollusk species.

Research Background and Objectives:
ENSO is a complex phenomenon that has shaped environments and human behavior in Peru for millennia.[1] Today, El Niño (EN) events occur every 3-8 years and are associated with heavy rains, erosion, and an interruption of marine upwelling that disrupts productive fisheries.[1] Improving our understanding of data that we use in reconstructions is key to better understanding past EN patterns and impacts.

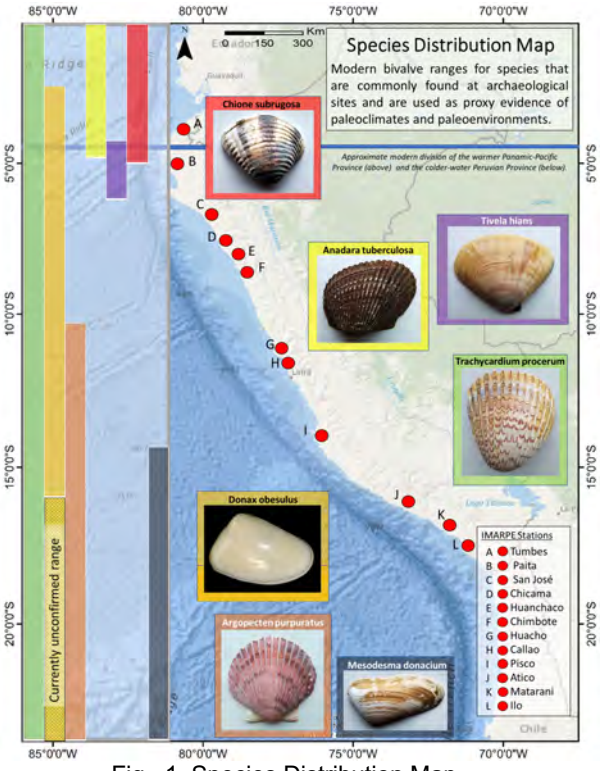

Fig. 1. Species Distribution Map.

Proposed Methods:
Mollusks common in archaeological contexts will be collected from harbors with Instituto del Mar del Perú (IMARPE) stations (see Fig. 1: locations A, B, H, I, and L). Specimens that survived the 2015-16 and 2017 ENs will be selected based on size. Acetate peel and microscopy of growth rings will determine drilling protocols based on ontogeny.[2,3] $CaCO_3$ powder will be collected from growth rings for δ18O analysis. Molluscan δ18O-derived SST reconstructions will be compared to IMARPE records to assess agreement between δ18O and SST. Biomineralization patterns will be used to independently constrain EN events. Results will enable researchers to appropriately select mollusks from archaeological sites for long-term studies on behavior and cultural impacts of ENSO, increase utility of archaeological materials in climate research, and increase the accuracy of paleoenvironmental reconstructions.

Acknowledgements: NSF GRFP and the Dan and Betty Churchill Exploration Fund.

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

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4. *GNS Science.*
5. *Environmental Science and Sustainability, University of Maine at Presque Isle.*
6. *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), the Altai Mountains of western Mongolia (49°N, 88°E), and the Eastern Tibetal Plateau, China (30°N, 99°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 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.

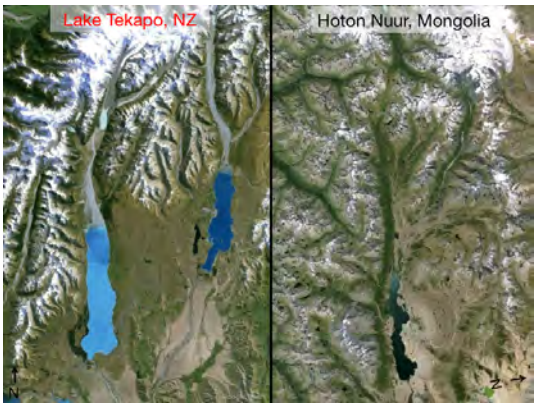

Figure 1. Comparison the Lake Tekapo basin, New Zealand and Hoton Nuur valley, Mongolia

In the Eastern Tibetan Plateau, sample processing is underway, with no ages yet to report.

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.

Coupled Model Biases in Sea Surface Temperature (SST) Distribution and their Impacts on Tropical Cyclone Characteristics

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Abstract: Changes in sea surface temperature (SST) distribution can significantly alter regional climate patterns. Of Particular interest are the tropics, where SST variability is closely linked to regional climate conditions, such as occurs during El Niño Southern Oscillation (ENSO) events. Most CMIP5 models are currently unable to properly simulate all observed features of the climatological SST distribution, particularly in upwelling regions. The inability to properly simulate current SST distributions has implications for simulating regional climate. Of particular interest here are the potential impacts on tropical cyclone genesis, which is found to be sensitive to biases in the climatological SST distribution.

Project Goal:

The overall goal of this research project is to better understand the influence of SST biases in coupled climate models to simulations of regional climate. Emphasis here is on tropical cyclone (TC) development given the importance of TC impacts around the world resulting from strong winds, storm surge, and heavy rainfall.

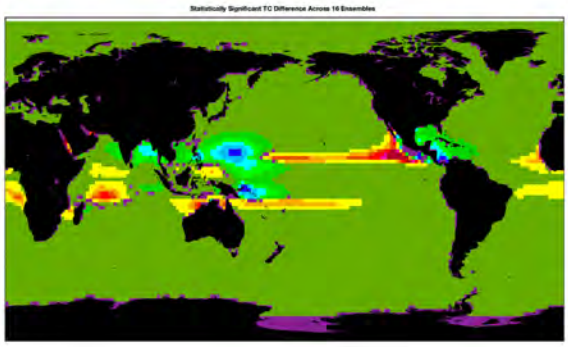

Figure 1: Statistically significant (P < 0.05) differences in total TCs based on ECHAM5 SST bias and control runs for 1979-2004. Reds and oranges depict regions where ECHAM5 is overestimating total number of tropical cyclones whereas blues and light greens signify an underestimation.

To test the sensitivity of TCs to CMIP5 SST biases, climate model experiments are undertaken where an atmospheric model is forced with observed SST and climatological SST obtained from 31 coupled climate models. The model outputs are then analyzed, which includes calculating a tropical cyclone genesis index (TCGI), which is a measurement of total number of tropical cyclones that a particular environment could support. The input variables for the TCGI include the SST (degrees Celsius), vertical wind shear between 850 hpa and 200 hpa (m/s), 600 hpa relative humidity (%), and 850 hpa absolute vorticity (1/s). Additional calculations will be performed to calculate such things as the potential intensity (PI) of TCs, which will be a focus for future work.

Initial Results:

Preliminary results show the SST biases result in an underestimation of TC number in the western Pacific east of the Philippines and southwestern Gulf of Mexico, with an overestimation in the eastern Pacific **(Figure 1)**. The relative number of TCs is also enhanced in the western Indian Ocean. Thus, both directly (through changes in SST) and indirectly (through changes in circulation), coupled model SST biases can substantially influence the environment for TC formation.

Acknowledgements:

This work is supported by a grant from the National Science Foundation (NSF) Division of Atmospheric and Geospace Sciences Award #1650037.

Reconstruction of Koettlitz Glacier, Southern McMurdo Sound, Antarctica During the Last Glacial Maximum and Termination

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Abstract: The Antarctic Ice Sheet plays a vital role in global sea level and climate. An understanding of how the ice sheet has responded to variations in climate in the past gives insight into how it will react to future warming. At issue are competing hypotheses of whether expansion in the Ross Sea region at the last glacial maximum (LGM) was due to interior ice-sheet thickening and expansion of outlet and local glaciers, or if the expansion was due only to local grounding of ice in the Ross Sea tied to sea-level change. These hypotheses predict very different responses of the East Antarctic Ice Sheet to climate change. Koettlitz Glacier (Fig. 1), a local glacier that flows into the Ross Sea, is ideal to address this question because its past behavior, although poorly known, has been cited by supporters of both hypotheses.

Project Summary:

The Antarctic Ice Sheet contains the world's largest reservoir of fresh water. Accurate reconstructions of its changes in thickness and extent are important for evaluating past and present sea-level change and for validating numerical models necessary to make realistic predictions of future climate.

During the LGM, ice grounded in the Ross Sea reached close to the continental shelf edge. There are currently two hypotheses to explain this grounding. The first is that expansion was caused by interior ice-sheet thickening and expansion of outlet and local glaciers. The second is that the expansion was due only to local grounding of ice in the Ross Sea tied to sea-level change.

Koettlitz Glacier, a local glacier adjacent to the Ross Sea, is ideal to test these hypotheses. One hypothesis (1) is that Koettlitz Glacier expanded significantly during the LGM to fill McMurdo Sound before retreating during the Holocene. An alternative hypothesis (2) is that Ross Sea ice flowed into McMurdo Sound and buttressed a smaller than present Koettlitz Glacier, which then advanced in the Holocene. These hypotheses have strongly different implications for the behavior of local glaciers and the Antarctic Ice Sheet.

To delineate the extent of Koettlitz Glacier, we collected ~100 samples of boulders from ice-free areas adjacent to Koettlitz for cosmogenic surface-exposure dating. These dates will be paired with radiocarbon dates from algae deposits from a proglacial lake dammed by Koettlitz.

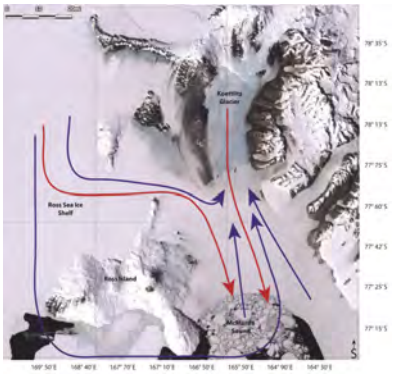

Figure 1: Presentation of competing hypotheses for grounded ice in the western Ross Sea Region. The arrows denote ice-flow reconstructions for southern McMurdo Sound during the LGM. Blue arrows denote ice flow consistent with the hypothesis that grounded ice resulted from lowering of sea level. Red arrows denote ice flow consistent with the hypotheses that local glaciers (Koettlitz) expanded and advanced during the LGM.

Acknowledgements: NSF award: 1643248

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Differences in the Effects of Storms on Dissolved Organic Carbon (DOC) in Boreal Lakes During an Early Summer Storm and an Autumn Storm

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Abstract: Increased precipitation events have been linked to increased concentrations of dissolved organic carbon (DOC) in boreal lakes, however the effects of seasonal differences on DOC and how this may impact storm response remain unclear. The goal of this study is to investigate relationships between the quantity and quality of lakewater DOC and the seasonal timing of precipitation events in an early summer storm and an autumn storm in Acadia National Park.

In boreal lakes, dissolved organic carbon (DOC) is an important regulator of ecosystem structure and function. Recent research suggests that precipitation events contribute to short-term abrupt changes in DOC quantity and quality (Warner & Saros 2019), however less is known about how DOC responds to precipitation events at different times of the year. Precipitation events have increased by 70% since the 1950's, and in the northeastern United States specifically, precipitation has increased by more than 15% in the autumn and by about 3% in the spring since 1901 (Easterling et al. 2017). Therefore, understanding how DOC response differs during different times of year is important.

The goal of this research is to better understand differences in seasonal storm response. We evaluated DOC concentration and a set of DOC quality metrics during an early summer storm and an autumn storm on a suite of 6 lakes in Acadia National Park in Maine. Our results revealed differences in the response of DOC quality metrics to the two storms. In the early summer storm, the response of DOC quality metrics suggests that photobleaching was the primary process contributing to change in deep lakes with long residence times. In the autumn storm, the response of DOC quality metrics suggests that more allochthonous inputs and bacterial processing were the primary processes contributing to observed changes in lakes with large watershed area to lake area ratios.

This research will allow for better understanding of key differences in lakewater DOC response to an early summer versus autumn storm and will be useful in informing management plans for lakes in Acadia National Park.

Fig. 1. The the six 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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A Holocene Multi-Proxy Lake Sediment Record of Environmental and Human Changes in Jamaica, West Indies

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Abstract: Jamaica has diverse ecological communities that are threatened by climate change and human activities. Lake sediments record millennial-scale environmental variability, which provides temporal and spatial context for modern conservation planning. We generated an ~5,800-year record of vegetation, climate, fire and human changes in Jamaica using lake sediments. This novel paleoecological information documents the impacts of successive human colonization events as well as abrupt climate variation. These data expand knowledge about long-term human-environment dynamics in the Caribbean and aid local biodiversity management efforts.

Proxy data

We assessed the timing of variations in pollen (vegetation), dung fungal spore (grazing activity) and charcoal (fire activity) abundances, and ostracod $\delta^{18}O$ and $\delta^{13}C$ (climate) in a lake sediment core, to develop an integrated paleoecological framework for understanding Holocene environmental and human changes in Jamaica. For example, ecological zone WP-4 (433 cal yr BP-114 cal yr BP) (Figure 1) was marked by a gradual decline in arboreal and shrub taxa, persistence of herbaceous disturbance taxa (e.g. *Amaranthaceae* and *Asteraceae*), an increase in *Poaceae*, the appearance of cultivated exotic species (e.g. *Haematoxylum campechianum* and *Saccharum officinarum*), and the continuous presence of dung fungal spores (*Sporormiella*, *Cercophora*, and *Sordaria*). These sedimentary proxy data indicate an open landscape under the influence of anthropogenic pressures, including land clearance, and crop and pastoral activities. The age of zone WP-4 is coeval with European colonization of Jamaica and corroborates historical accounts of agricultural intensification under a plantation economic system.

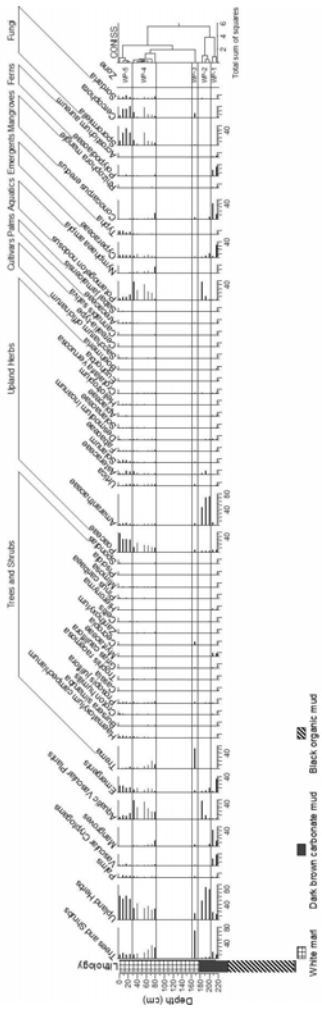

Figure 1. Pollen diagram for lake sediments collected from Wallywash Pond, Jamaica, W.I.

Acknowledgements

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Mid-Holocene Climate Change Inferred from a South Pole Ice Core

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Abstract: The rapid cooling seen in global paleoclimate records near 6000 BP is not well understood despite its occurrence near the onset of the Neoglacial period. Here we present annually resolved glaciochemical data from the South Pole ice core as an archive of Southern Hemisphere climate variations during the Holocene. We show that sea salt concentrations at the South Pole increased throughout most of the Holocene with the exception of an abrupt decline at 6000 BP. Based on instrumental back trajectory and correlation analyses of modern records, we hypothesize that the rapid sea salt decline at 6000 BP represents a decrease in Southern Ocean sea ice extent, particularly in the South Atlantic sector near the Prime Meridian.

The Holocene epoch is marked by a series of cold events when temperatures, especially in the North Atlantic region, rapidly dropped for a period of centuries before recovering (Mayewski et al. 2004). The climate anomaly at 6000 BP is not as well studied or as well expressed as many of the other Holocene events, yet it is clearly present in global syntheses of Holocene paleoproxy records (Steig 1999). During this event, most areas worldwide grew cooler and drier relative to prior Holocene conditions.

Here we present the record of sodium flux in the South Pole ice core (hereafter SPICEcore) spanning the entire Holocene, with particular emphasis on the 6-5 ka event. We hypothesize that the sodium record from SPICEcore reflects conditions in the Southern Ocean, providing a high-resolution compliment to studies observing rapid Holocene climate change in the North Atlantic (e.g. Bond et al. 1997).

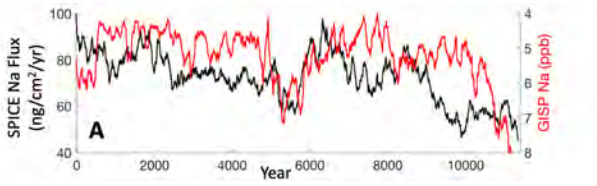

Figure 1: Comparison between GISP2 and SPICEcore sodium records with frequencies higher than 64 years removed (black: SPICEcore, red: GISP2, inverted (Mayewski et al. 1994)), each showing similar structure during the mid-Holocene.

Back trajectory analysis, meteorological data, correlations to reanalysis output, and resemblance to the Holocene Dronning Maud Land sodium flux record (Fischer et al. 2007) support the interpretation that much of the SPICEcore sodium originates from the southeast Atlantic sector of the Southern Ocean. Correlation with ERA-Interim reanalysis also supports this hypothesis and shows that South Pole sea salt sodium may be related to sea ice concentrations near the Prime Meridian. Like other Antarctic records (e.g. Kreutz et al. 1997), levels of sea salt have increased over the course of the Holocene. However, SPICEcore and Dronning Maud Land show a significant decrease in sodium at 6000 BP that we hypothesize is related to a rapid reduction in Southern Ocean sea ice extent.

Sodium concentrations at GISP2 (Mayewski et al. 1994) show an inverse relationship to SPICEcore and EDML sodium flux during the mid-Holocene, potentially indicating an antiphase relationship in sea ice extent between the North and South Atlantic. This pattern is consistent with a slowdown of AMOC and potentially a shift in atmospheric circulation toward more SAM+, La-Niña-like conditions.

Acknowledgements: This work was supported by the National Science Foundation.

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