Past Versus Present Climate in the North Atlantic and Arctic

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Abstract: In the last decade, the Arctic has warmed at an enhanced rate with respect to the global average. Here, we give an example of how we will investigate how much North Atlantic and Arctic climate has changed over the last two millennia comparing previous rates of change to the current abrupt climate change.

In order to understand the significance of the current abrupt climate change in the Arctic (Mayewski et al., 2013), we must have a better understanding of how Arctic climate has evolved in the past. To do this, we are building a climate proxy network in the North Atlantic and Arctic. The data to be used in this study provide calibrated proxies for summer temperature, precipitation, and atmospheric circulation. Four types of proxy records in this domain correlate to one of the climate variables: ice cores (16), varved lake sediments (15), speleothems (2), and ocean sediments (3). The records were required to be at least 500 years long and have average temporal resolutions of less than 5 years. Ideally, the records overlap the observational record, the last ~150 years, for correlation analysis.

As one example, an Icelandic Low (IL) proxy, sea salt sodium (ssNa) from the Greenland Ice Sheet Project 2 (GISP2; Meeker and Mayewski, 2002) ice core, is plotted and correlated against the DJF mean sea level pressure output from 20th Century Reanalysis (20CR; Compo et al., 2011), a model using MSLP observations as the only input/constraint and extends back to 1851. This correlation -0.31 is similar to the correlation found in Meeker and Mayewski (2002; -0.32) where they correlated against a gridded observational dataset.

Using this proxy record and reanalysis model, we find that the standard deviations of the records increase after 1850 when compared to before to 1850. This shows that the strength of the IL has become more variable since the Industrial Revolution, thus storminess has increased. Future work will compare temperature and precipitation proxy records to reanalysis models and observations to relate modern climate to past climate evolution.

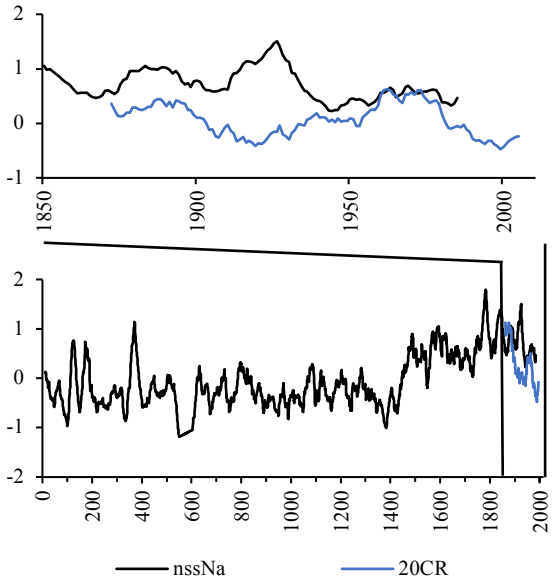

Fig. 1. The Icelandic Low proxy sea salt sodium (ssNa) from GISP2 is compared to the 20th Century Reanalysis output. Records are standardized and smoothed to a 20-year mean. The y-axes are z-scores.

Acknowledgements: This is a contribution to the Arctic Futures Institute.

Bibliography: Compo, G.P., and Coauthors, 2011: The Twentieth Century Reanalysis Project. Quart. J. Roy. Meteorol. Soc., 137, 1-28.

Meeker, L.D., and Mayewski, P.A., 2002: A 1400-Year High-Resolution Record of Atmospheric Circulation Over the North Atlantic and Asia. The Holocene, 12, 3, 257–266.

Mayewski, P.A., and Coauthors, 2013: Holocene Warming Marked by Abrupt Onset of Longer Summers and Reduced Storm Frequency Around Greenland. J. Quart. Sci., DOI: 10.1002/jqs.2684.

A Glacial Perspective on North Atlantic Climate During Heinrich Stadials

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Abstract: We use >30 ^{10}Be ages on moraine and erratic boulders to reconstruct the retreat of the former British Ice Sheet in northwest Scotland. Our work will elucidate the role of the North Atlantic region—heralded as the source of abrupt global climate change—in triggering abrupt climate events during the last deglaciation. Specifically, we address an apparent paradox in the North Atlantic, in which periods of glacier retreat during the last termination appear to have coincided with distinct cold conditions known as Heinrich stadials. Preliminary results suggest that widespread deglaciation of the British Ice Sheet occurred during ostensibly cool stadials in response to relatively warm summer temperatures.

The Heinrich Stadial Paradox

Heinrich Stadials (e.g., HS1: 18.3-14.7 ka and HS0: 12.9-11.6 ka) were abrupt millennial-scale cooling events that punctuated the last global deglaciation (~18-11 ka). Their most striking features are cold sea-surface temperatures in the North Atlantic, depressed air temperatures over Greenland, and pronounced southward shifts of the intertropical convergence zone [1]. Canonically, stadials were cold; however, glacier chronologies in New Zealand, South America, and even the European Alps show deglaciation during those times [2]. Further, recent marine data suggest that Europe's ice sheets were retreating during HS1 [3]. This paradox highlights a crucial gap in our understanding of global climate change during Heinrich Stadials, and suggests that HS1 may have been a period of high "seasonality," in which winter temperatures were cold, but summer temperatures were relatively warm.

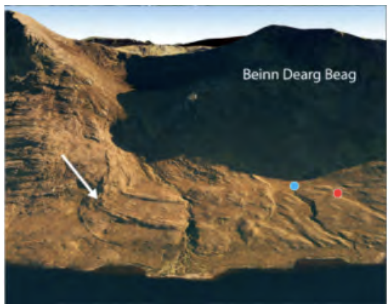

Fig. 1. Cirques in Scotland host suites of moraines documenting glacial configuration during the most recent Heinrich stadial events.

Testing the Seasonality Model

Ice sheets and glaciers are iconic indicators of climate, as they wax and wane primarily in response to summer air temperature. We test the seasonality model using geomorphic mapping and >30 ^{10}Be ages on moraine and erratic boulders to reconstruct former British Ice Sheet retreat in northwest Scotland, offering a terrestrial complement to existing marine data. Our study site in northwest Scotland is ideal for testing model, as it is downwind (climatically-influenced by) the North Atlantic and hosts arguably the best preserved geologic record of ice sheet behavior during termination in this region [4]. Our initial results suggest that widespread deglaciation occurred in Scotland during Heinrich Stadials and therefore indicate relatively warm summer temperatures in the North Atlantic during those periods.

Acknowledgements: This project was funded by National Geographic and the Churchill Exploration Fund. Further, we would like to thank Dr. Aaron Putnam, Dr. Stephen Barker, and Holly Thomas for their contributions to this project.

Bibliography:

[1]Denton, G., et al., *Science*, 328, 2010.
[2]Schaefer, J., et al., *Science*, 299, 2006.
[3]Toucanne, S., et al. (2009) *Quaternary Science Reviews* 28, 1238-1256.
[4]Bromley, G.R.M., et al. (2014) *Proceedings of the National Academy of Sciences* 111, 6215–6219.

Seasonal Analysis of Three Middle Woodland Archaeological Sites in Eastern Maine using Modern and Excavated Marine Bivalve Mollusks, *Mya arenaria*

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Abstract: Three archaeological sites in Eastern Maine will be analyzed using oxygen isotopic signals to determine the season of occupation at each site. Determining the season of occupation of a site provides contextual information about foodways and behavior that took place at the site. It has been hypothesized that Holmes Point West and Holmes Point East in Machiasport, Maine, were occupied during the summer months, while, Jones Cove in West Gouldsboro, Maine, was occupied during the winter months. Modern monthly shell samples were collected from mudflats nearby each site to form a baseline to compare the archaeological shell samples; the results will be used as proxies for determining season of occupation for each site.

Background

A shell midden is a collection of discarded materials that were no longer utilized or no longer served a purpose to the Native Americans occupying the area. The calcium carbonate present within clam shells neutralizes Maine's acidic soils, acting to preserve organic artifacts in shell middens along the coast of Maine. Three such middens, Holmes Point West and East in Machiasport and Jones Cove in Gouldsboro, have not been analyzed for seasonality using the excavated shell. These sites are hypothesized to represent summer occupation (Holmes Points) and winter occupation (Jones Cove). Determining the season of use of these sites will provide data to help evaluate the inland vs coastal occupation hypotheses.

Methods

The oxygen isotopes within a shell reflect the temperature and salinity values of their growth environment. These two values vary throughout the year in Maine due to seasonal differences. Sampling the edge of the chondrophore and the outer edge of the shell provides isotopic signals that can be measured and used to indicate when the clam was harvested. To compliment these shell samples, water samples were collected to account for changes in water salinity during the clam's life. This ensures that the signal seen for the oxygen isotope ratio is for the ^{16}O / ^{18}O ratio and not for the salt content of the water.

Results

Month	Range	Holmes Point West Archaeological Sample ID																			
		36	37	38	39	40	41	42	43	44	45	47	48	49	50	51	52	53	63	64	65	66	67
JAN	1.33 to 1.72																						
FEB	0.26 to 0.61												X				X			X			
MAR	no data - bad mass spec run																						
APR	0.33 to 0.77				X			X					X				X		X	X			X
MAY	1.12 to 1.61						X		X														
JUNE	1.12 to 1.54								X														
JULY	0.33 to 0.86			X	X			X					X						X	X			X
AUG	-0.04 to 0.35													X		X		X			X	X	
SEPT	-0.023 to 0.37													X		X		X			X	X	
OCT	no data collected - red tide																						
NOV	0.13 to 0.45													X		X	X	X					
DEC	1.76 to 2.18																						

Table 1: This table represents the excavated samples from Holmes Point West and where their isotopic signal falls with respect to the values from the modern shells.

From the comparison of the archaeological shells to the modern shells, the data suggest a summer occupation at this site; similar values are apparent for Holmes Point East. The values outlined in bold indicate shells that overlapped within the range of warm and cold signals. Jones Cove shells (results not shown) indicate a strong winter signal with no archaeological shell isotopic signals falling in warm months. Further data are currently being processed to confirm these results.

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Advisors/Committee: †Dr. Brian S. Robinson, Dr. Daniel H. Sandweiss, Dr. Alan Wanamaker Jr., Dr. Bonnie Newsom, Kendra Bird, and Sky Heller.

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

The Ecological Effects of High Nutrient Concentrations and Turbidity in Glacially Fed Greenland Lakes

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Abstract: Here we demonstrated that lakes fed by Greenland Ice Sheet meltwater have high concentrations of phosphorus (P) and nitrogen (N), which are important nutrients for aquatic organisms. The glacially fed lakes were also turbid from glacial solutes. Our findings suggest that these environmental conditions were important determinants of the unique algal communities and high algal biomass in glacially fed lakes, compared to nearby non-glacial lakes.

Greenland Ice sheet meltwater contains high concentrations of the nutrients N, P, iron and silica (Hawkings et al 2015). In North America, glacially fed lake ecosystems with elevated N have reduced algal species biodiversity and increased algal biomass compared to non-glacially fed lakes (Slemmons and Saros 2012). Greenland Ice Sheet meltwater feeds numerous lake, stream, and fjord ecosystems along the Ice Sheet margin, yet the biological effects of its elevated nutrient concentrations remain unknown. To assess these effects, we evaluated the water chemistry, sediment chemistry, and algal communities of four glacially fed lakes, and compared them to four nearby non-glacially fed lakes of similar size.

N (measured as bioavailable dissolved inorganic N, DIN) and total P (TP) were higher in glacially fed lake water, but the difference in DIN was not significant between lake types (Figure 1). Turbidity, caused by suspended glacial flour, was also higher in glacially fed lakes. Non-glacially fed lakes had higher dissolved organic carbon (DOC). Sediment chemistry suggested that most P from glacially fed lakes was in recalcitrant mineral form, and associated with aluminum. Microbes in glacially fed lakes had higher biological demand for P, as measured by microbial extracellular enzyme activity (EEA).

We did not find any difference in algal species biodiversity between lake types, but algal biomass (chlorophyll *a* concentration) was higher in glacially fed lakes. Canonical correspondence analysis clearly separated diatom algae communities of glacially and non-glacially fed lakes along turbidity and TP gradients. Two diatom species considered indicators of N availability, *Discostella stelligera* and *Fragilaria tenera*, were abundant in glacially fed lakes, suggesting N-enrichment.

We found that glacially fed lakes along the Greenland Ice Sheet exhibited distinct environmental and ecological characteristics. Aluminum controls P availability via sequestration (Kopáček et al 2005), and the high amounts found in glacially fed lake sediments, together with high microbial P demand, call into question the bioavailability of the glacial lake TP pool. Rather, the moderately high concentrations of DIN may be responsible for greater algal biomass in glacially fed lakes. This study adds to the rapidly growing body of literature characterizing the ecological effects of glacial meltwater on lake ecosystems.

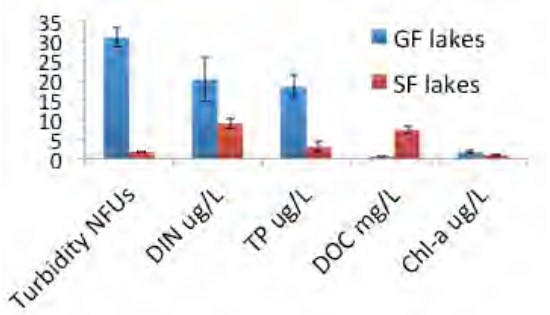

Figure 1. Turbidity, nutrients and algal biomass (chl-a) compared across glacially fed (GF) and non-glacial, snow and groundwater fed (SF) lakes. Error bars are standard error.

Acknowledgements: The US National Science Foundation (Grants no. 1203434 & 1144423) funded this research.

Bibliography:

Hawkings, JR et al. *Geochemical Perspectives Letters* 1 (2015): 94-104.

Kopáček, J et al. *Environmental Science & Technology*, 39 (2005): 8784-8789.

Slemmons, KEH, and JE Saros. *Limnology and Oceanography* 57 (2012): 1651-1663.

A Low-Overhead Scalable Data-Collection Service

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Abstract: We study the large-scale soft-realtime distributed collection, analysis, and reporting of data, emphasizing low-cost, low-overhead, and scaling over several orders of magnitude.

Consider the task of collecting and analyzing data from geographically distributed sources, and of similarly conveying results and instructions back to the sources, with soft real-time (few seconds) constraints, when the number of such sources is unpredictable and liable to vary rapidly over time and space.The term sources (of data) is used broadly, and includes for instance fully automated networked sensors as well as devices operated by humans entering observational data.The central question addressed here is: Can such a data-management system be designed at low cost with the ability to scale (both up and down) gracefully as the number of data sources varies by several orders of magnitude? As an example, consider a citizen-science initiative to collect geographically widely distributed observations (by humans) of weather or wildlife using a smartphone. It is often difficult to predict the number of people participating in such an endeavor. Further, that number may change drastically if, for instance, the initiative receives significant media attention.

A simple method of addressing this uncertainty in usage is designing the system for the highest reasonably anticipated load.There are two problems with this method: First, it all but guarantees that the system will be greatly underutilized, implying a high overhead in cost. Second, in the event of unexpected popularity and usage exceeding expectations, the system is likely to fail. (Wild success entails spectacular failure.) The problem as stated so far is very general and so it is not surprising that it has received considerable attention in both research and commercial settings. For example, techniques such as automatic scaling of virtual servers (in number and capacity) over an underlying shared hardware infrastructure provide ways to scale the size and cost of the deployed system in response to load over time.

Prior work on the 10green project has used such techniques to implement a Web site and associated smartphone app with low overhead and dynamically scaled virtual server resources. Similar solutions are applicable to many Web services. The conjunction of two features distinguishes our endeavor from such prior work: First, the focus is on a large number of transactions, each with only a small amount of data (few tens to hundreds of bytes), and in particular on transactions that submit new data or modify existing data. Second, the solution is required to scale rapidly (within seconds), from zero transactions and zero financial cost to millions of transactions per day at a low per-transaction cost. There are several existing solutions to one or the other of the above, but their conjunction is not adequately addressed. For example, financial transaction-processing systems satisfy the first but not the second; content-delivery networks partly satisfy the second but not the first.

Some recent technological developments, and concomitant product offerings, provide opportunities for a different approach to the problem. Chief among these is the rise of distributed computing platforms that adopt an event-driven serverless model. Here, serverless means that no server is provisioned on an ongoing basis, not even a virtual one. Rather, computing and other resources are allocated dynamically in response to certain events, such as the arrival of a request over the network. Although these new technologies and offerings come with very desirable cost and scaling characteristics, using them for implementing a data service is much more challenging than in the conventional model, primarily because they require working at a lower level of abstraction.

We describe the design and implementation of a prototype system for widely distributed data collection service based on these ideas.

Holocene Variability in the Southern Hemisphere Westerly Wind System Inferred From A South Pole Ice Core Dust Record

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Abstract: The Southern Hemisphere westerlies constitute the world's most powerful wind system on Earth and are suggested to have played a key role in natural climate variability throughout the Holocene (~11,700yrs ago to present). Establishing the role of the westerlies in global climate is crucial for interpreting industrial-age warming set against the background of natural variability. Ice cores contain high-resolution proxies and are powerful tools for understanding Southern Hemisphere wind system dynamics. We use sub-annually resolved micron-sized dust particles recovered from the South Pole Ice Core (SPICEcore) to interpret variations in the Southern Hemisphere westerlies from interannual to orbital timescales, affording insights into climate variability.

Dust, (i.e., find-grained mineral particles) found in ice cores is a proxy for coupled ocean-atmosphere dynamics. Dust fluxes 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 dust being transported to the Antarctic interior. Latitudinal wind shifts are hypothesized to play a driving role in natural climate variability of the pre-industrial Holocene. A better understanding of the activity of the southern westerlies will afford insight into how the wind system will behave under ongoing global warming. Here we present a record of dust flux from the South Pole Ice Core (SPICEcore) to garner greater insight into Southern Hemispheric atmospheric changes 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) have 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 flux provides a new 10kyr high-resolution record for paleoclimate. We use the Lomb-Scargle Periodogram to understand different periodicities within the SPICEcore flux (Fig. 1) to gain insight the behavior of the southern wind system during the Holocene.

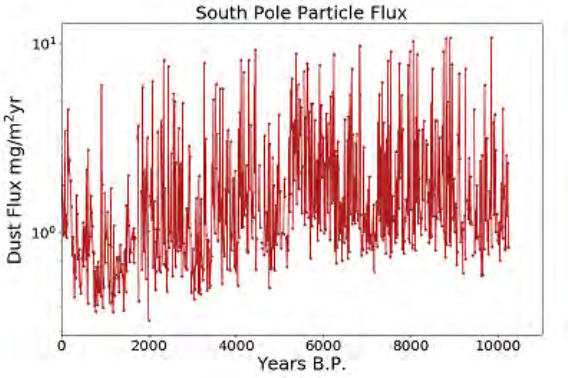

Figure 1. Holocene 15yr resampled dust flux record from the South Pole.

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Using Ice Penetrating Radar to Identify Holocene Age Ice in the St. Elias Mountains, Canada

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Abstract: The spatial and temporal character of Holocene climate events provide important context for understanding industrial age climate variability. Ice cores recovered in alpine regions can used to address this problem, however locating continuous, stratigraphically coherent, and temporally relevant (i.e., interannual resolution) ice covering the entire Holocene is a challenge. Here we present recent ice penetrating radar and ice flow modeling results from several sites in the St. Elias Mountains, including data collected in 2017 as part of a Churchill Exploration Fund project, and identify at least on location for recovery of a complete Holocene record.

During the late Holocene there have been at least four (i.e., Little Ice Age, Medieval Warm Period, Dark Ages cool interval, and the Roman Warm Period) events identified in paleoclimate data. Several hypotheses, including solar and volcanic forcing, and North Atlantic, Southern Hemisphere, and tropical-ocean atmosphere variability, have been put forth to explain these observations. A key limitation to evaluating each of these ideas is the relative scarcity of high resolution (i.e., interannual to decadal scale) records from key locations. We focus here on an expanding array of ice core records from mountain ranges influenced by North Pacific Climate. Recent advancements in low and high frequency ice penetrating radar allow for detailed exploration of surface, internal, and basal glacier characteristics. Using these data in conjunction with simple and 3D ice flow modeling, we can accurately assess the potential of an alpine glacier site for Holocene-length ice core recovery.

In 2016 and 2017, we collected detailed geophysical (radar, GPS) and shallow snow/ice core data at several locations in the St. Elias Mountains, including two sites where deep ice cores had been recovered in 2002 (Eclipse Icefield and King Col). We find that the Eclipse Icefield contains deep (in a high elevation alpine context) ice (~700 meters), an ice divide with simple internal stratigraphy vertical ice flow, and high annual snow accumulation rate (1.5 m.w.e. per year). Using these parameters in a simple Dansgaard-Johnson ice flow model implies a Holocene-age ice profile, with annual layer recognition throughout most of the column possible. In contrast, ice at King Col shows much more complicated internal stratigraphy and flow dynamics, and much shallower ice (~250 meters). We conclude that a Holocene-length is not possible at King Col.

Figure 1. Collecting GPR data at King Col (Mt. Logan, CAN).

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A 2000-Year Long European Alps Ice Core Reveals New Climate Proxies

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Abstract: The 2013 Colle Gnifetti (CG) ice core record reveals climate proxies related to Saharan dust, Atlantic moisture, and anthropogenic inputs that can extend our understanding of air mass sources transported to the European Alps region over the last ~2000 years.

Ice core archives provide the most direct and detailed evidence of past climate and atmospheric conditions, however, traditional ice core sampling (~1cm resolution, Fig 1**B.**) does not provide significant environmental detail in low accumulation and compressed ice core sites. Using the Climate Change Institute's W.M.Keck Laser Ice Facility ultra-high-resolution (120-µm) continuously sampled laser ablation-inductively coupled plasma-mass spectrometer (LA-ICP-MS) (Fig 1**C**.) data from the CG ice core we are able to resolve proxies for both climatological and meteorological scale events.

To calibrate the large datasets generated by our ultra high-resolution sampling, we compare our data with traditionally sampled discrete ICP-MS measurements. We are able to capture variability on a meteorological scale using the continuous LA-ICP-MS record based on dust (^{56}Fe, ^{44}Ca, ^{27}Al, ^{25}Mg), marine (^{23}Na) and anthropogenic inputs (^{208}Pb and ^{63}Cu). Major air mass sources to the CG region are establsihed using proxies captured by variance differentiation of associated elements using a principal component analysis (PCA): 1) Saharan dust (57% - Ca, Fe, Mg, Al), 2) marine (10% - Na, Cl, K), 3) anthropogenic (9% - Pb, Cu, Bi), and 4) volcanic (6% - Bi).

The Saharan dust proxy (PCA 1 in Fig 1**A,B)** reveals a significant increase during the 900-1000 C.E. interval. This increase period (Fig 1**B**) is distinguished as a cluster of dust events, using our LA-ICP-MS ^{56}Fe record (Fig 1**C**). The increase period is consistent with the warmest period of the Medieval Warming Period (MWP) during the 900s inferred from tree ring temperature reconstructions[4].

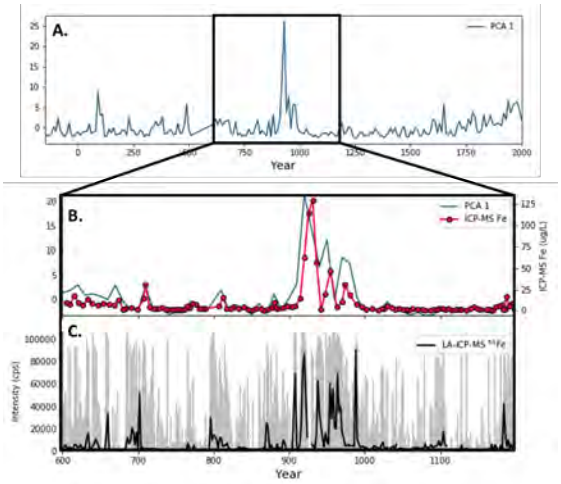

Fig 1. **A**. PCA 1 (Saharan dust proxy) in blue for full record, **B.** PCA 1 in blue, ICP-MS Fe (ug/L) in red, and **C**. LA-ICP-MS ^{56}Fe in grey with 100pt smooth in black for the time interval 600-1200 C.E.

Future work will involve comparison of developed climatological and meteorological proxies with historical observations

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Bibliography:

1 Sneed, Sharon B., et al. "New LA-ICP-MS cryocell and calibration technique for sub-millimeter analysis of ice cores." *Journal of glaciology* 61, no. 226 (2015): 233-242.\

2 Spaulding, Nicole E., et al. "A New Multielement Method for LA-ICP-MS Data Acquisition from Glacier Ice Cores." *Environmental science & technology* 51, no. 22 (2017): 13282-13287.

3 Bohleber, Pascal, et al. "Temperature and mineral dust variability recorded in two low-accumulation Alpine ice cores over the last millennium." *Climate of the Past* 14, no. 1 (2018): 21.

4 Esper, Jan, et al. Schweingruber. "Low-frequency signals in long tree-ring chronologies for reconstructing past temperature variability." *science* 295, no. 5563 (2002): 2250-2253.

Assessing Rifting on the Western Lateral Boundary of Ross Ice Shelf, Antarctica

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Abstract: Destabilization of the Ross Ice Shelf (RIS) through propagation of rifts would reduce backstress and increase flow of grounded ice on the West Antarctic Ice Sheet toward the ocean, which directly contributes to sea level rise. At its northwestern extent, an edge effect around exposed bedrock allows full thickness rifting. We hypothesize that basal crevasses form as glacier ice streams cross the grounding line into RIS and define the material strength distribution throughout RIS as ice flows across the shelf to the ocean/ice margin. We are evaluating the role of rift propagation on RIS stability through application of three dimensional numerical models.

Ice shelves exist along 75% of Antarctica's coastline, and span more than 1.5 million square kilometers (Rignot et al. 2013). There have been notable ice shelf collapse events on the Antarctic Peninsula (AP) in recent decades, which have been linked to the buildup of surficial meltwater to cause rift propagation (Scambos et al. 2000; Vieli et al. 2007). The Ross Ice Shelf (RIS) is the largest in Antarctica, spanning 472,960km^2 and reaching thicknesses of several hundred meters. The West Antarctic Ice Sheet depends on RIS as a buttressing force on its flow.

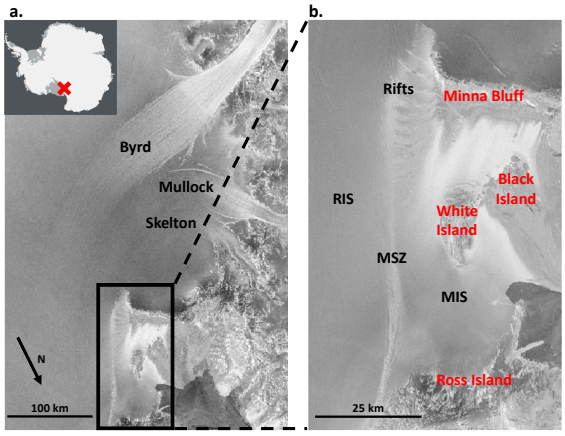

Fig.1. Rift development on RIS. (a) Byrd, Mullock, and Skelton ice streams flow northward onto RIS. (b) Full thickness rifting occurs along Minna Bluff. McMurdo Shear Zone (MSZ) is between RIS and slower moving McMurdo Ice Shelf (MIS). 1997 RADARSAT-1 images accessed using the Norwegian Polar Institute's Quantarctica Package.

The study site is at the northwest lateral margin of RIS and is primarily fed by three ice streams (Figure 1). As these ice streams flow across the grounding line, buoyancy causes flexure initiating a vertical instability that can produce wide basal crevassing (Bassis and Ma 2015). Basal crevasses advect downstream and persist as zones of weakness throughout RIS. Ice comes in contact with Minna Bluff, and drag along the edge allows full thickness rifting.

Unlike at the AP, the atmosphere of RIS has not significantly warmed to produce surface melt pooling. Instead, we suggest that rifts have an inherent periodicity defined by weak zones originating as basal crevasses at the grounding line, further modified by sub-ice circulation. I plan to explore this system of advecting instabilities using 3D finite element analysis of the coupled ice-ocean system.

Acknowledgements: Thanks to Peter Koons for mentorship. This project is made possible by the NSF- Grant Number: PLR-1246400

Bibliography:

Bassis, J.N., and Y. Ma. 2015. "Evolution of Basal Crevasses Links Ice Shelf Stability to Ocean Forcing." Earth and Planetary Science Letters 409 (January): 203–11.

Rignot, E., S. Jacobs, J. Mouginot, and B. Scheuchl. 2013. "Ice-Shelf Melting Around Antarctica." Science 341 (6143): 266–70.

Scambos, Ted A., Christina Hulbe, Mark Fahnestock, and Jennifer Bohlander. 2000. "The Link between Climate Warming and Break-up of Ice Shelves in the Antarctic Peninsula." Journal of Glaciology 46 (154): 516–530.

Vieli, A., A.J. Payne, A. Shepherd, and Z. Du. 2007. "Causes of Pre-Collapse Changes of the Larsen B Ice Shelf: Numerical Modelling and Assimilation of Satellite Observations." Earth and Planetary Science Letters 259 (3–4): 297–306.

Scalability Analysis of Structured Embedded Grids and Unstructured Meshes in Large Scale Ice Sheet Modeling

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Abstract: This research compares the scalability profile of *embedded,* structured grids and unstructured meshes in the simulation of large-scale ice sheets at multiple levels of resolution.

Background

Currently, there are two approaches to implementing large-scale ice sheet simulations. One approach, which is based on the use of an evenly-spaced structured grid, is to simulate the entire ice sheet at the highest resolution required. The other approach is to model the ice sheet at different levels of resolution using unstructured meshes. Structured grids lend themselves quite well to partitioning on multi-core, distributed memory parallel computers, leading to good computational efficiency, load-balancing and reduced communication costs. However, simulating a continent-level ice sheet at high resolution requires tremendous computational resources. Unstructured meshes can reduce such costs by allocating computational resources to regions of the mesh based on the required resolution. However, unstructured meshes are difficult to effectively decompose on distributed memory parallel computers, and can experience poor cache utilization, significant load imbalance, high communication costs, and significant synchronization times.

Approach

We are developing a different approach, termed ELSM (Embedded simulation for Large Scale ice sheet Modeling), which is based on the Parallel Ice Sheet Model (PISM). To provide multi-resolution capabilities within PISM, we embed high-resolution models of areas undergoing rapid change into a lower-resolution, whole ice sheet model. We compared ELSM with the Ice Sheet System Model (ISSM), which is based on unstructured meshes, using a low-resolution Greenland whole ice sheet model with 500-meter resolution data of the Jakobshavn outlet glacier. Because unstructured meshes can provide the same quality of resolution as a structured grid using significantly fewer degrees of freedom, we did not attempt to directly compare their performance. Rather, we created a range of problem sizes for each approach that, we believe, can be considered together in a meaningful way.

Results

The figures below show the *strong scaling efficiency* of each approach, which represents the percentage of linear speedup obtained when the problem size remains fixed and the number of processors is increased. We conclude that ELSM scales quite well with increasing problem sizes and core counts. ISSM scales well for smaller problems and core counts (128-256), but scales poorly at large core counts and for large problem sizes.

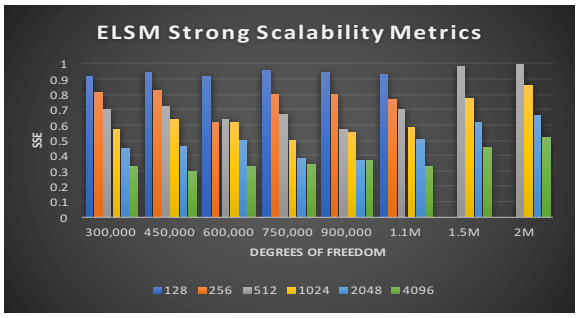

Figure 1. Strong scaling efficiency of ELSM

Figure 2. Strong scaling efficiency of ISSM

Understanding Ocean Forcing of Polar Glacier Change Using Remotely-Sensed Iceberg Melt Data

Mariama C. Dryak[1, 2], Ellyn M. Enderlin[1, 2]

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Abstract: Over the last several decades, warming atmosphere and ocean temperatures have led to the retreat and acceleration of glaciers throughout the Antarctic. Along the Antarctic Peninsula, glacier acceleration has been preceded by the collapse of the floating ice shelves that buttress ice flow from the glaciers to the oceans. The observed patterns of glacier retreat, acceleration and associated increases in iceberg discharge from this region were likely triggered by both increased surface and submarine melting, but we lack direct observations of air and ocean temperatures needed to tease-out their relative importance. Here we attempt to resolve spatial and temporal variations in ocean forcing using remotely-sensed estimates of iceberg melting around the Antarctic Peninsula from 2011 to 2018. Patterns in iceberg submarine melting will be used to infer changes in ocean forcing at glacial margins, improving our understanding of ice-ocean interactions and their role in triggering ice shelf collapse and glacier mass loss.

Submarine melting (i.e., melting below the waterline) is responsible for 55±10% of ablation for Antarctic ice shelves greater than 100km^2 in size (Rignot *et al.*, 2013). Along the Antarctic Peninsula, glacier retreat and accelerated mass loss strongly corresponds to increases in mid-depth ocean temperatures, suggesting ocean warming has led to increased submarine melt rates in this region (Cook, 2014). Although submarine melting is a critical control on the ice sheet mass balance and stability of the ice sheet's marine margins, submarine melt rates have not been quantified on robust temporal or spatial scales around Antarctica.

We aim to use near-field iceberg submarine melt estimates and far-field ocean temperature measurements to quantify submarine melt of ice bodies around the Antarctic Peninsula. Project objectives include: 1) quantification of submarine meltwater fluxes and area-averaged melt rates from 2011 to 2018 by differencing digital elevation models (DEMs) in time (Figure 1); 2) inferences of local ocean temperatures from submarine melt rates; 3) measurement of glacier change (from iceberg sources); 4) investigation of links between source glacier fluctuations and inferred ocean temperature patterns.

We expect to see spatial variation in submarine melt rates, with higher melt on the western Antarctic Peninsula than on the east due to known exposure to warmer ocean temperatures to the west. We anticipate that iceberg melt rate time series will reveal changes in ocean forcing that correlate well with glacier terminus fluctuations. We also predict that distal ocean temperature measurements and regional models will differ from the local, near glacier/ice shelf patterns inferred from the iceberg melt rates due to modification of water masses over the large distances between observations and local complexities in submarine topography.

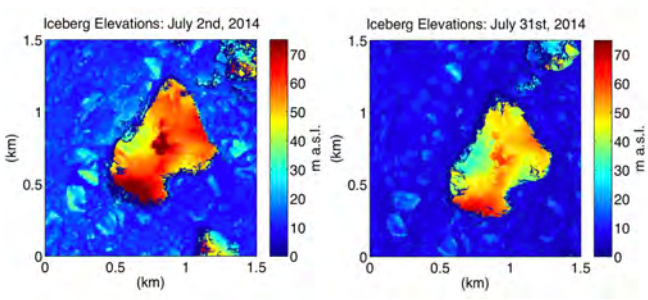

Figure 1: Example iceberg elevations from DEMs for icebergs near Helheim, Greenland in 2014 using the same methods. Elevations from time 2 (July 31st) are subtracted from time 1 (July 2nd) elevations and are used to produce submarine iceberg melt rates.

Acknowledgements:
National Science Foundation

Bibliography:

Cook, A. "Spatial and Temporal Changes in Marine-terminating Glaciers on the Antarctic Peninsula since the 1940s." PhD diss. Swansea University, 2014.

Rignot, E., Jacobs, S., Mouginot, J. and Scheuchl, B. "Ice-shelf melting around Antarctica." *Science*, 341, no. 6143 (2013): 266-270.

Deer Tick Phenology and Warming Climate in Maine, USA

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Abstract: Tick-borne illness has coincided with the Maine's range expansion of deer ticks (*Ixodes scapularis)*. Multiweek advances in peak tick activity across the past several decades may be linked to recent warming, especially in the northern climate division of the state.

Project Goal

Determine whether deer tick abundance and advances in tick phenology are associated with earlier degree-day accumulation and warmer winters in Maine.

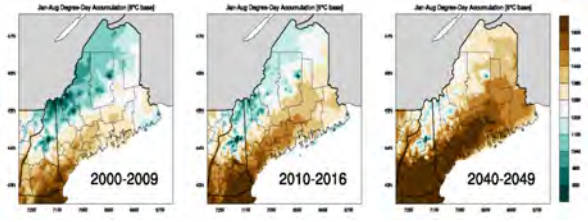
Maine: A Unique Study Area

Maine spans several climate zones, including the southern climate division where ticks are established and the northern climate division, where ticks are still emergent. Deer ticks are sensitive to temperature and humidity, thus advances in tick phenology (earlier weeks of peak abundance) in Maine may be at partly associated with climate change. Phenological advances imply subsequent higher tick survival and abundance[1].

For deer tick females to lay eggs, and for those eggs to hatch, about ~1,240 degree days (DD) >6°C (21°F) must accumulate from January 1[2]. If this threshold is not attained by the end of August, most tick eggs will not hatch, or will hatch too late for larvae to find blood meals[2].

Initial Results

1. Degree days >6°C attained by the end of August were calculated from daily spatial temperature[3] for the decades 2000-09, 2010-16, and 2040-49. Before ~2010, 1,240 DD >6°C has not been attained in Maine's northern tier, but attainment of this threshold has moved northwards (Figure). By 2040-49, DD accumulation will be sufficient for tick egg hatch in all but the highest elevations.
2. Climatological data for Maine's three climate divisions were obtained[4] and monthly and seasonal averages calculated. Northern average winters (Dec-Jan-Feb) are now climbing above -6°C, a threshold significant to tick survival[5].



3. Tick burdens on southern Maine songbirds, 1990-2017: Peak nymphal burdens shifted from early July to early June. Larval ticks also advanced by 3 weeks.
4. Statewide tick identification program, 1990-2013[6]: In the southern tier, nymphs found on people and pets advanced from late to early June peaks. In the northern tier, nearly all nymphs were found during 2000-2012, peaking in early July. Adult ticks advanced by one week.
5. Correlations[1]: a) Earlier peaks in nymphs on birds were weakly associated with earlier DD accumulation; b) Larvae burdens were weakly associated with warmer winters (Dec-Jan-Feb); c) Spring and fall cohorts of adult ticks were moderately associated with warmer winters in the northern tier.

[1]Levi et al. Phil Trans RSoc B 2015;370:20130556.
[2]Rand et al. J Vector Ecol 2004;29:164-176.
[3]PRISM Climate Group, Oregon State University
[4]NOAA: GHCN-M
[5]Bruner et al. J Med Ent 2012;49:981-7
[6]Rand et al. J Med Ent 2007;44:1118-1129

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.

[1] Spearman rank correlations: weak=0.30-0.49, moderate=0.5.

High-resolution Satellite Observations of Columbia Glacier, Alaska, Reveal Shifting Controls on Mass Loss During Retreat

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Abstract: Columbia Glacier in southcentral Alaska has been rapidly shrinking since the glacier's terminus retreated from a shallow marine shoal in the early 1980s. Although the glacier's multi-decadal acceleration and increase in iceberg production has been driven by its long-term retreat, detailed satellite observations from 2012-2016 reveal that retreat and acceleration are not necessarily linked over short time scales. Instead, we find that seasonal changes in mass loss are strongly controlled by changes in the hydrologic network that underlies the glacier system. Terminus retreat only acts as the primary control on ice flow acceleration when it leads to a marked loss in frictional resistance generated at the glacier base.

Columbia Glacier (64.17°N, -146.97°E) is one of Alaska's largest and fastest-flowing marine-terminating glaciers. In the early 1980s, the glacier's terminus retreated from a shallow shoal near the mouth of Columbia Bay, initiating a >30 year-long period of mass loss. As the terminus retreated into deeper water, ice flow resistance decreased and the glacier accelerated (O'Neel et al., 2005). A "domino effect" ensued wherein terminus retreat led to acceleration, which caused the ice near the terminus to stretch-out until it could no longer buoyancy effects, more retreat occurred, and so on and so forth.

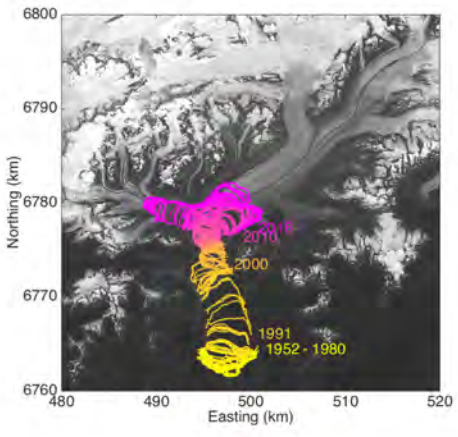

Fig. 1. Long-term retreat of Columbia Glacier from McNabb and Hock (2015) and Landsat images.

The positive feedback loop between glacier retreat and acceleration is primarily controlled by the glacier's geometry. As such, it has been hypothesized that glacier mass loss during retreat is insensitive to changes in climate. Here we use approximately monthly, 150 m-resolution satellite observations of glacier terminus position, speed, and thickness from 2012-2016 to construct time series of glacier mass loss and the force balance that governs flow for Columbia Glacier. Using these datasets, we find that although the glacier's multi-decadal retreat has driven acceleration, terminus position and speed change are not necessarily linked over seasonal time scales. Seasonal variations in glacier speed are instead driven by the meltwater-driven reorganization of the hydrologic network that underlies the glacier. Additionally, we find that controls on seasonal variations in glacier length vary with the geometry of the glacier terminus. When the terminus lies in shallow water, seasonal retreat is coincident with surface melting. As the water depth increases, the terminus position becomes more sensitive to changes in the flux of ice from the interior.

These observations suggest that the sensitivity of marine-terminating glaciers to climate change varies strongly with glacier geometry. Thus, accurate predictions glacier mass loss in future decades require detailed knowledge of both climate change and glacier geometry.

Acknowledgements: Funding was provided by NASA award NNX14AH83G.

Bibliography:

O'Neel, S., Pfeffer, W.T., Krimmel, R., and Meier, M. (2005). Evolving force balance of Columbia Glacier, Alaska, during its rapid retreat. J. Geophys. Res. Earth Surf. 110, doi:10.1029/2005JF000292.

Glaciation on Mercury: Flow of Ice in Permanently Shadowed Circum-Polar Craters

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Abstract: Earth-based radar observations have revealed the presence of radar-bright materials near the poles of Mercury shown in Figure 1 [1]. Analysis of the radar data suggests that these highly reflective materials are composed of nearly pure water ice, with less than ~5% volume fraction of silicates. Extensive data from MESSENGER provides evidence that these water-ice deposits are distributed within the permanently shadowed terrains near the poles of Mercury [2].

Thermal models suggest that water ice is stable within the permanently shadowed terrains on Mercury on geologic timescales **[3]**. Mercury provides a unique environment for ice accumulation due to lack of an appreciable atmosphere to trap heat and the planet's low obliquity of 0.034° **[4]**. A detailed energy-balance model of the surface temperatures around and within polar craters **[5]** suggests an annual mean temperature near 110 K in permanent shadow, and surface temperatures close to 400 K in sunlit regions.

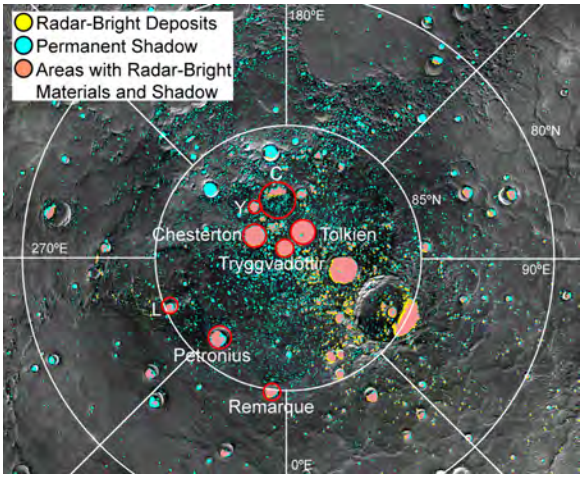

Fig. 1. Radar-bright deposits in shadowed craters.

As an end-member for the maximum extent of glaciation in permanently shadowed regions, we treat the extreme case where ice deposits fill the crater to the shadow line. We found that temperatures are sufficiently cold that flow velocities were vanishingly small (10^{-8} to 10^{-11} m/yr). Including lateral conduction from surrounding hot sunlit terrain increases potential velocities to 10^{-3} m/yr for the 55 km craters and to potentially 1 m/yr for 10 km craters, certainly enough to produce observable deformation. Results for various geothermal heat fluxes are summarized in Table 1. Note, these are for the extreme case of thick ice (>1000 m even in the 10 km craters). Given current estimates of the timing of ice deposits (<50 million years old **[6]**) and thickness of the ice (between several m **[7]** and ~50 m **[8]**, this suggests that the ice on Mercury today was deposited and likely has not advanced at all.

Heat Flux	20 mW/m²			30 mW/m²			50 mW/m²		
Uniform Heat Flux									
Max Warming from surface	55 km	89.5°	13.6 K	55 km	89.5°	20.5 K	55 km	89.5°	34.5 K
Max Velocity	55 km	85.5°	4.1X10^{-11} m/yr	55 km	86.0°	8.4X10^{-10} m/yr	55 km	87.0°	4.1X10^{-8} m/yr
Min Velocity	10 km	89.5°	2.1X10^{-12} m/yr	10 km	89.5°	1.5X10^{-11} m/yr	10 km	89.5°	6.7X10^{-11} m/yr
Lateral Heat Transport									
Highest Velocity	10 km	87.0°	0.88 m/yr	10 km	87.0°	1.6 m/yr	10 km	87.0°	5.3 m/yr
Max Warming due to Transport	10 km	89.5°	115 K	10 km	89.5°	117 K	10 km	89.5°	121 K
Min Warming	55 km	85.0°	33.6 K	55 km	85.0°	33.8 K	55 km	85.0°	34.1 K
Speedup for Min Warming	5.21 (orders)	4.6X10^{-11} to 6.5X10^{-4} m/yr		4.67 (orders)	3.9X10^{-10} to 2.9X10^{-1} m/yr		4.31 (orders)	2.6X10^{-08} to 5.2X10^{-2} m/yr	
Speedup at Uniform Max	5.32 (orders)	4.1X10^{-11} to 6.5X10^{-4} m/yr		5.06 (orders)	4.4X10^{-10} to 5.0X10^{-2} m/yr		4.60 (orders)	4.1X10^{-09} to 1.6X10^{-2} m/yr	
Max Speedup	10 km	89.5°	12.4 (orders)	10 km	89.5°	11.8 (orders)	10 km	89.5°	10.8 (orders)
	2.1X10^{-12} to 5.6X10^{-05} m/yr			1.6X10^{-11} to 0.12 m/yr			6.7X10^{-11} to 0.52 m/yr		

Table 1. Summary of results

Acknowledgements: Support for J Head came from the NASA NNA14AB01A; A Deutsch was supported by NASA under grant NNX16AT19H

Bibliography. 1 Harmon et al. (2011) *Icarus*, 211, 37. **2** Deutsch et al. (2016) *Icarus*, 280, 158. **3** Paige et al. (2013) *Science*, 339, 300. **4** Margot et al. (2012) *JGR Planets*, 117 E00L09. **5** Vasavada et al. (1999) *Icarus*, 141, 179. **6** Crider and Killen (2005) *GRL*, 32, L12201. **7** Black et al. (2010) *Icarus*, 209, 224. **8** Deutsch et al. (2018) *Icarus*, 305, 139

Science and Scientists in Ongoing Support of the U.S. Clean Air Act

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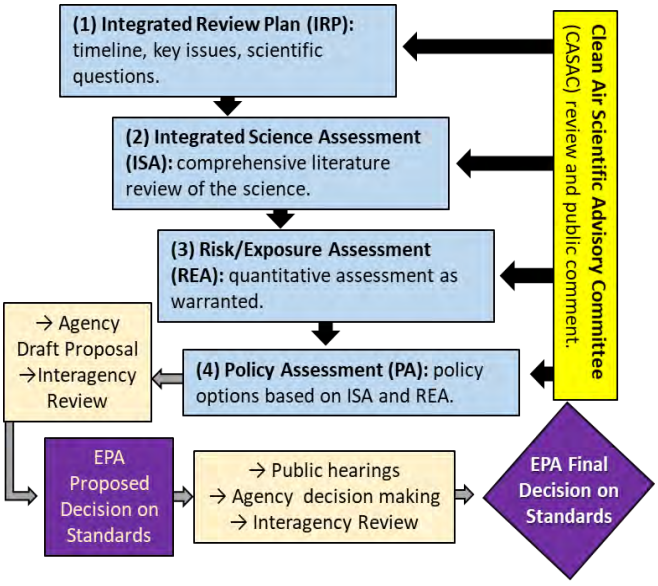
Abstract: The U.S. has a strong track record to date of using research and environmental monitoring to drive the development of policy that promotes environmental quality. The U.S. Clean Air Act is one of the most successful and influential pieces of environmental legislation in the world. However, these laws are not static, requiring ongoing evaluation based on the best available science. Currently, this process is underway for secondary standards of oxides of sulfur and nitrogen as well as particulate matter and demonstrates the importance of environmental monitoring, research, and scientists working at the interface of science and policy.

The Clean Air Act has been an influential environmental law in the U.S. responsible for major improvements in air quality. The CAA has had several major amendments since it was first passed into law (1970, 1977, 1990). The law established a regulatory program known as the National Ambient Air Quality Standards (NAAQS) for six criteria air pollutants (CO, Pb, O_3, NO_x, SO_x, PM). This required the establishment of primary (human health) and secondary (welfare, which includes visibility and ecological effects to crops, forests, animals, surface water and structures) standards. Beginning in 1980, and periodically thereafter, the U.S. Environmental Protection Agency (EPA) Administrator is charged with completing a thorough review of current air quality criteria based on the best available science at the time.

In 2016, the most recent review of the secondary standards began (1). The review will take several years, and proceeds through four phases shown in Table 1 that include the development of a/an 1. Integrated Review Plan (IRP), 2. Integrated Science Assessment (ISA), 3. Risk/Exposure Assessment (REA), and 4. Policy Assessment (PA). This is an intensive process involving EPA scientists and scientists from the public and private sectors spanning several years.

The EPA requests advice and review of the process from the EPA Science Advisory Board's (SAB) Clean Air Scientific Advisory Committee (CASAC). The culmination of the process is a recommendation to the EPA Administrator. The final decision on whether to modify the existing standards rests with the EPA Administrator who considers a wide range of factors. However, through the SAB, external scientists are responsible for evaluating the EPA efforts. Thus, research scientists are fundamental in not only doing the original research, but translating the importance and relevance of the research to policy-makers through this ongoing process.

Table 1. Generalized overview of the U.S. EPA's process for reviewing NAAQS (1).



(1) U.S. EPA. 2017. Integrated Review Plan for the Secondary National Ambient Air Quality Standards for Ecological Effects of Oxides of Nitrogen, Oxides of Sulfur and Particulate Matter. EPA-452/R-17-002.

How do Climatic Factors Influence Shifts in Dissolved Organic Carbon and Depth of Light Attenuation in Lakes in West Greenland?

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Abstract: Lakes exhibit strong responses to climate forcing, so the coherence (i.e. shared variance between time series) of lake metrics across a region can provide information about effects of climate on ecological processes within lakes. We examined the coherence of dissolved organic carbon (DOC), absorbance at 380 nm (a_{380}), and depth of 1% photosynthetically active radiation (PAR) in two regions near Kangerlussuaq, Greenland and found that coherence between the regions is influenced by local mean monthly precipitation and spring air temperature.

Comparing data from June of each year from 2013-2017, we assessed the level of coherence of several lake metrics (1% PAR; DOC concentration; and a_{380}, a DOC quality metric that strongly controls 1% PAR) within and between two distinct regions near Kangerlussuaq ("Kellyville" and "Ice sheet", approximately 40 km apart). The lake metric with the strongest coherence was 1% PAR, which is a key predictor of thermal structure in a suite of southwest Greenland lakes (Saros et al. 2016, *Limnol. Oceanogr.*), with implications for primary production, algal community structure, and rate of carbon cycling.

The strong between-region coherence of 1% PAR deteriorated in 2015 (Figure 1). We determined that 1% PAR is negatively correlated with average monthly precipitation in Kellyville lakes, while it is positively correlated with average spring air temperature in the ice sheet region.

In 2015, average monthly precipitation in Kellyville was >60% below the long-term mean, while average spring air temperature was ~3°C below the long-term mean at the ice sheet lakes. These regional differences in weather variables likely explain the breakdown in 1% PAR coherence between Kellyville and ice sheet lakes in 2015. Deciphering such connections between climatic signals and key ecological lake metrics allows us to better understand and predict responses of Arctic lakes to global climate change.

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

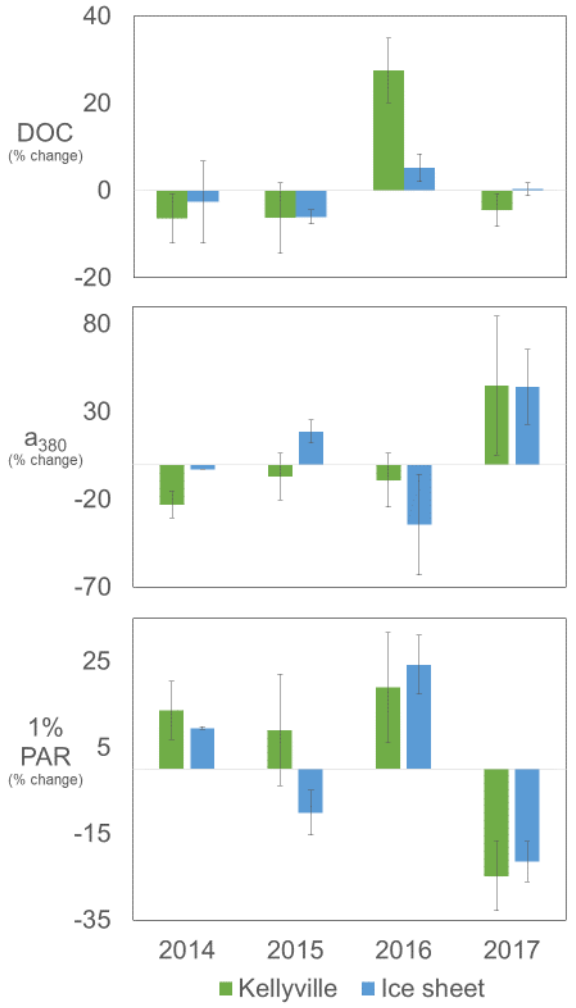

Figure 1. Shifts in lake water quality metrics in lakes near Kellyville and the Greenland ice sheet measured in percent change from previous year (n = 5 lakes per region).

Temporal Ecology for Communities in a Dynamic World

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Abstract: Temporal ecology is the study of ecological processes and patterns in time, integrating across long-term ecological monitoring and experimental networks, historical ecology, Quaternary paleoecology, and deep-time paleobiology. Temporal dynamics are often central to how ecologists construct theory, but timescales are often poorly defined, and most studies have a temporal grain or extent that is insufficient to provide a meaningful test. In the dynamic world of the Anthropocene, ecosystems are rapidly changing in space and time, demanding new research priorities and conservation strategies. This talk will summarize the findings of the PACE workshop (2017), an interdisciplinary exploration of temporal scaling and community dynamics.

Background: There have been significant advancements in understanding how ecological processes play out across spatial scales, but we have lagged in developing a framework for understanding the temporal dynamics of communities. A century of paleoecological research has shed light on how species and their assemblages change through time, but theories of community assembly or other ecological processes often derive from short-term studies. In the era of global change, ecologists are increasingly studying species assemblages in transition. We accept that communities are dynamic, but lack a theoretical framework to make predictions about the timescales at which community processes of interest play out, which underscores the need to understand the drivers of community dynamics across timescales.

Results: From historical legacies to disequilibrium dynamics, to understand the "where" and "how" of communities, we must also understand the "when." The recent fossil record provides insights into communities as temporal phenomena: 1) The temporal grain and extent of sampling has implications for our inferences. 2) The post-glacial fossil record for animals and plants reveals the transient nature of many communities, including non-analog assemblages as an emergent property of species' individualistic response to environmental change. 3) By linking demographic processes with observations of range dynamics in long-lived species like trees, we may better predict how communities emerge as the result of processes that play out across timescales. *Fig 1:*

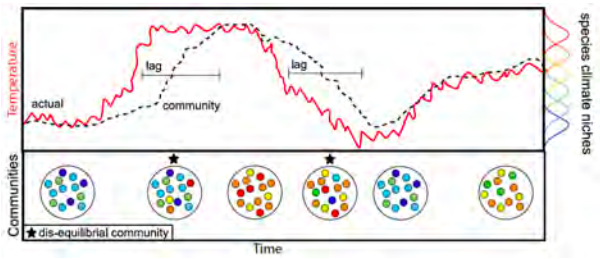

Fig. 1. Lags and disequilibrial dynamics are more likely in times of rapid change and for organisms with longer life-spans or limited dispersal.

4) Disequilibrium dynamics, critical transitions, and threshold responses are difficult to predict, but long-term datasets and insights from climatology offer promising ways forward. 5) Community response to environmental change is a process that plays out across temporal scales; mid-Holocene and contemporary species losses may shed light on nested temporal responses to disturbance, from sub-annual to millennial timescales. 6) Historical legacies at a range of temporal scales may be just as important as modern processes in explaining communities.

Conclusion: These examples highlight the need for an improved conceptual framework to understand communities not only as dynamic entities, but as byproducts of processes across timescales.

Vegetation Cover and Climate at the Rancho La Brea Tar Pits, Southern California during Marine Isotope Stage 3 (57 – 29 ka[i])

Katherine C. Glover[1]

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

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. Pollen and macrofossils inform vegetation modeling of plant abundances, and net primary productivity estimates. Preliminary data support an open woodland in the Los Angeles Basin during late MIS 3 (~33-30 ka), and entrapment coeval with long-term drought conditions.

Objective

Earth's biodiversity is under threat at a global scale, due to development and climate change. Understanding the structure, interactions, and extinctions of past communities can inform anticipated ecosystem change scenarios. The La Brea Food Webs project employs a paleoceological approach to understanding past community structure and interactions in the Los Angeles Basin during Marine Isotope Stage 3 (MIS 3, 57 – 29 ka), using the extensive La Brea Tar Pits Museum collection.

This project focuses on small mammals and fossil plants, currently understudied in the collection. The RLB collection and collaborators also afford the opportunity to investigate the following question: were asphaltic deposits, and entrapment events, most active at certain times across the last ice age?

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

Late MIS 3 (~33-30 ka) material includes abundant *Juniperus* spp., *Quercus* spp., and Poacese (grass). This is consistent with low-density woodland, and cool-wet conditions in Southern California. Radiocarbon date clustering has led to a new hypothesis that entrapment events during late MIS 3 were climatically-driven. High distributions are coeval with regional drought conditions, and the rapid North Atlantic heating of Dansgaard-Oeschger events 4 and 3. This provides a framework to test clustering of additional dates as they are generated in the course of this project, and other concurrent research at RLB. It also supports recent records from Southern California and the Southwest that show a very dynamic paleohydrologic history for the region in the lead-up to the Last Glacial Maximum.

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: https://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)

[i] "ka" refers to "thousands of years before present."

Modern Calibration of Tussac Grass (*Poa flabellata*) as a New Paleoclimate Proxy

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Abstract: The variations of $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios of carbon and oxygen in plant leaf cellulose reveal differences between winter and summer conditions. A link between cellulose oxygen isotopes and precipitation is not clear, and the effects of temperature and humidity and/or soil moisture are proposed to account for these differences.

Monospecific stands of Tussac grasses (*Poa flabellata*) are a peat forming community found along coastal fringes of the Falkland Islands, and other sub-Antarctic islands in the South Atlantic region. Vegetation in peatlands record variation in regional precipitation and temperature in the cellulose of leaf plant tissues. A modern proof-of-concept study has determined how modern living *P. flabellata* records temperature, relative humidity, and precipitation using carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) stable isotopes of leaves.

At four locations in the Falkland Islands, *P. flabellata* plants were collected monthly, and temperature (°C) and relative humidity (%) were measured continuously between Sep. 1, 2015 to Sep. 1, 2016. Monthly composite precipitation at each location was used to construct a local meteoric water line using $\delta^{2}H$ and $\delta^{18}O$. Measurements of $\delta^{18}O$ in precipitation and leaf cellulose indicate a weak negative correlation. Measurements of $\delta^{13}C$ in leaf cellulose positively correlated with monthly average temperature (Pearson's r=0.82) and negatively correlated with relative humidity (Pearson's r = -0.76) across all sites. Across all sites, the mean summer $\delta^{13}C$ of leaf cellulose (-24.28‰) was significantly greater than winter (-26.80‰; t=8.91, df=73, p<0.001), and mean seasonal temperatures range from 9.32°C to 3.68°C for summer and winter, respectively. A positive correlation between $\delta^{13}C$ and $\delta^{18}O$ indicates that *P. flabellata* tracks temperature and humidity and/or soil moisture, similar to other studies[1].

The $\delta^{13}C$ and $\delta^{18}O$ isotope composition in leaf cellulose, along with the abundance of macrofossil *P. flabellata* leaves in peat deposits spanning the Holocene, supports the use of coastal grasslands formed by *P. flabellata* in the Falkland Islands as a paleoclimate proxy in the South Atlantic region.

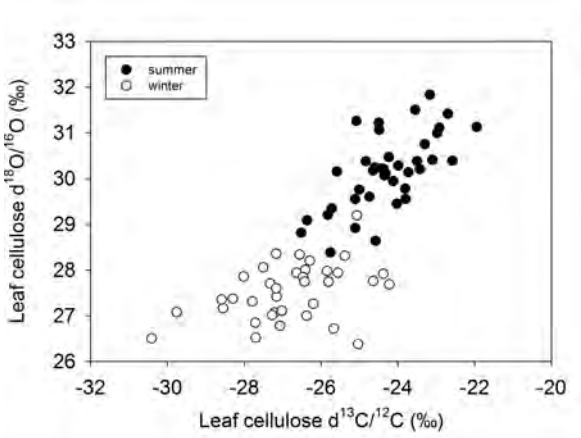

Fig. 1. Carbon and oxygen stable isotope ratios of leaf cellulose in summer and winter.

Acknowledgements: Without the citizen science work from Ben Bernsten, Nikki & Mike Summers, Mike & Phyl Rendell, Robert & Elaine Short, Kicki & Thies Matzen. We gratefully thank the support from Paul Mayewski, Matthew Amesbury, Kayla Greenawalt, Kit Hamley, Megan Tierney at the South Atlantic Environmental Research Institute, & Craig Cook at the University of Wyoming Stable Isotope Facility. This research was supported by the US National Science Foundation Adaptation to Abrupt Climate Change IGERT program grant DGE-1144423 and NSF award #1137336, Inter-university Training in Continental-scale Ecology.

Bibliography:

1. Saurer, M. K. Aellen & Siegwolf. 1997. Correlating Saurer M., Aellen K. & Siegwolf R. (1997) Correlating δ13C and δ18O in cellulose of trees. Plant, Cell & Environment 20, 1543-1550.

Glacial Geochronology of the Northern Peruvian Andes: ^{10}Be Exposure Ages from the Cordillera Blanca, Peru

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Abstract: The northern Peruvian Andes contains a rich record of glaciation and currently hosts the largest volume of modern glaciers in the tropics. This is the first study to report numerical ages from moraines on the east side of the Cordillera Blanca range. Preliminary data resolves the position of ice during the Little Ice Age, mid and early Holocene, Antarctic Cold Reversal, and an older advance (MIS 6).

Introduction

The northwest-southeast trending Cordillera Blanca (CB) of northern Peru (~8-10°S), is an important tropical location for studying past, present, and future climate change as this high relief landscape contains the second highest peak in the Andes, experiences a precipitation gradient across the range, and preserves a rich record of glaciation back to at least MIS 10.

Geologic and Geographic Setting

The ~200km long Cordillera Blanca Detachment Fault, bounding the western side of the range, offsets early Holocene (and older) moraines as this fault accommodates the uplift of the CB batholith. Characteristic of the western CB are wide U-shape valleys carved into granitic bedrock filled with ~15-20m of sediment. In contrast, the eastern side of the CB is underlain by granitic and metasedimentary bedrock, is not bound by an active tectonic structure, and is more typically characterized by V-shaped valleys also containing sediment. The degree of preservation of glacial features is greater on the more accessible western side as compared to the constricted valleys of the eastern CB, thus, glacial chronologies exist the southwestern part of the range, where multiple sets of cross-cutting moraines are preserved (e.g. Farber et al., 2005; Smith and Rodbell, 2010). To date, no numerical ages have been reported from the eastern side of the CB and very few from the central and northern sections of the western CB.

Objectives, Methods, and Initial Results

We mapped and sampled moraines along three east-west transects in the northern, central, and southern parts of the range to look at the distribution of paleoglaciers across precipitation gradients and tectonic/lithologic boundaries. Together with field and remote mapping, we use ^{10}Be surface exposure dating of moraine crest boulders to identify the timing of ice retreat associated with the Little Ice Age (LIA) and older glaciations. To date, we have 16 exposure ages from moraines associated with advances during the LIA (216-292 years), mid-Holocene (4.5-5.9ka), early Holocene (9.1ka), Antarctic Cold Reversal (12.4-14.3ka), and ~MIS 6 (141-180ka) all with external errors of ~10%. With ~29 additional ages, we will have more complete view of the paleoglaciers of the CB.

Acknowledgements: This work has been funded by the Anne T. and Robert M. Bass Earth Systems and Geosciences Fund[1] and internal funds from McGill University and Newcastle University.

Bibliography:

Farber, D.L, Hancock, G.S., Finkel, R.C., Rodbell, D.T., 2005. "The age and extent of tropical alpine glaciation in the Cordillera Blanca, Peru." *Journal of Quaternary Science* 20 (7-8) 759-776.

Smith, J. A., and Rodbell, D.T., 2010. "Cross-cutting moraines reveal evidence for North Atlantic influence on glaciers in the tropical Andes." *Journal of Quaternary Science* 25: 243-248.

Using Paleoecology and Archaeology to Re-write the Human History of the Falkland Islands

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Abstract: We excavated several bone piles on New Island to determine if they were anthropological in origin. We determined that the assemblages primarily consist of southern sea lion *(Otaria byroni*) and rockhopper penguin bones (*Eudyptes chrysocome*); this mix of species is unlikely to be the result of natural processes.

At the time of European arrival to the Falkland Islands in the mid eighteenth century, the only native terrestrial mammal was the warrah, a fox-like canine also known as the Falkland Islands Wolf (*Dusicyon australis*). By 1876, local ranchers had hunted the warrah to extinction, making it the first canid to go extinct in the historic record. No humans were present on the islands at the time of European arrival. The lack of definitive evidence of a pre-European human presence in the Falklands, coupled with the expansive channel separating the islands from mainland South America, raises a question: were pre-European humans responsible for the transport and introduction of *D. australis* to the Falklands.

We investigated the sedimentary charcoal record for evidence of pre-European humans in the Falklands as a first step in assessing human impacts on the islands, and potential human introduction of *D. australis* from South America. In the absence of known archaeological evidence, charcoal is a useful indirect proxy for identifying a human presence: background charcoal levels typically increase by an order of magnitude following human arrival on islands[1]. There was a significant increase in background charcoal and peak magnitude at New Island beginning 1000 years BP, with an orders of magnitude increase occurring at 550 years BP, which is strongly suggestive of a pre-European human presence in this location.

Further evidence that suggests a human presence at New Island is our discovery and excavation of several large bone piles that pre-date European arrival to the region by several centuries. After careful excavation of two of the bone piles during our 2018 field season, we determined that the assemblages primarily consist of southern sea lion (*Otaria byroni*) and rockhopper penguin bones (*Eudyptes chrysocome*); this mix of species is unlikely to result naturally. Preliminary radiocarbon dating of several bones samples from these piles yielded ages of 550 years BP, which is coeval with the orders of magnitude increase in charcoal flux at New Island. Two stone points, made of locally sourced material, have been found by landowners on the surface near the bone piles, which further suggests human activity in the area. I also submitted three *D. australis* bones for radiocarbon dating. One yielded the oldest date thus reported: 4270 Cal BP, a minimum arrival date.

While this work does not directly answer the question of the origins of *D. australis*, it strengthens the possibility of prehistoric human transport of the canid to the Falklands. This study is the first of its kind in the Falkland Islands and fills a critical gap in our understanding of the human history of the Falklands and prehistoric travel and exploration in 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.

Bibliography: Burney, D.A., Burney, L.P., MacPhee, R.D., 1994. Holocene charcoal stratigraphy from Laguna Tortuguero, Puerto Rico, and the timing of human arrival on the island. Journal of archaeological science 21, 273-281.

Microanalysis of Tephra from the Colle Gnifetti Ice Core

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Abstract: Several intervals were selected from the Colle Gnifetti ice core to determine if volcanic material was present. One interval, from 57.67- 57.88 meters, had two (5-8 µm) rhyolitic tephra particles. We used SEM/EDS to analyze all materials and processed the data using the NIST DTSA-II software to obtain a fully quantitative major element geochemical fingerprint of tephra.

New sampling methodology allows us to capture and quantitatively analyze fine (<10 um) insoluble particulate matter from ice samples. Three intervals from the Colle Gnifetti ice core were sampled to determine if volcanic material was present in meltwater samples. Intervals were selected based on established glaciochemical signatures for volcanic products in the Colle Gnifetti ice core; bismuth, sulfur, and sulfate[1]. These intervals are: 57.67-57.88 m (485 C.E.), 68.2-68.4 m (1940 B.C.E.), and 69.26-69.46 m (2107 B.C.E.).

The shallowest section, 57.68-57.88 m contained two rhyolitic tephra particles (5-8µm). These particles were analyzed at the University of Maine using SEM/EDS and quantified using the NIST DTSA-II software. Several eruptions were evaluated as a possible source based on timing of tephra deposits. These include: 536 C.E. unknown[3,9,11], Hekla 3 (~1000 B.C.E.)[4], White River Ash (843 C.E.)[5], Ilopango (200 C.E.)[6], and El Chichon (540 C.E.)[7]. The 536 C.E. unknown, ice-core based volcanic event was selected as the most likely source candidate because the timing of the rapid cooling associated with the this event is captured in the glaciochemical signatures of the Colle Gnifetti ice core at the time of tephra deposition[1,3]. In addition, previous studies from several Northeastern European lakes (dated as 776-887 C.E.)[12] and peat bogs (dated 400-700 C.E.)[9,11] established tephra geochemical signatures whose trends are similar with the Colle Gnifetti particle geochemistry (Fig. 1). Several volcanic glass shards found in a Greenland ice core at the 536 C.E. interval also have geochemical trends consistent with Colle Gnifetti tephra[3]. Overall, volcanic ash geochemical trends suggest an Icelandic source (Fig. 6).

The new Colle Gnifetti tephra is the second example of an Icelandic volcanic product transported to the Colle Gnifetti ice core site[10]. Based on the timing of the event and tephra geochemistry in Colle Gnifetti, Greenland ice cores, and European lakes and peat bogs, we suggest this tephra is affiliated with the 536 C.E. unknown event and has an Icelandic source.

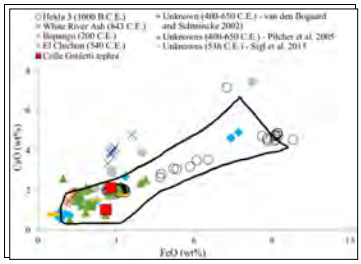

Figure 1. Geochemical correlations for Colle Gnifetti tephra deposits. Outlined field defines a composition of eruptive products from Iceland[2]

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Bibliography:

1. Bohleber et al. (2018). Temperature and mineral dust variability recorded in two low-accumulation Alpine ice cores over the last millennium. *Climate of the Past* 14(1): 21.
2. Bourne et al. (2016). Underestimated risks of recurrent long-range ash dispersal from northern Pacific Arc volcanoes. *Scientific reports* 6: 29837.
3. Sigl et al. (2015). Timing and climate forcing of volcanic eruptions for the past 2,500 years. *Nature* 523 (7562): 543.
4. Óladóttir et al. (2011). Holocene volcanic activity at Grímsvötn, Bárdarbunga and Kverkfjöll subglacial centres beneath Vatnajökull, Iceland. *Bulletin of Volcanology* 73 (9): 1187-1208.
5. Richter et al. (1995). Mount Churchill, Alaska: source of the late Holocene White River Ash." *Canadian Journal of Earth Sciences* 32 (6): 741-748.
6. Garrison et al. (2012). Dacite formation at Ilopango Caldera, El Salvador: U-series disequilibrium and implications for petrogenetic processes and magma storage time. *Geochemistry, Geophysics, Geosystems* 13 (6).
7. Nooren et al. (2017). Explosive eruption of El Chichón volcano (Mexico) disrupted 6th century Maya civilization and contributed to global cooling. *Geology* 45(2): 175-178.
8. Esper et al. (2014). Northern European summer temperature variations over the Common Era from integrated tree-ring density records. *Journal of Quaternary Science* 29(5): 487-494.
9. Pilcher et al. (2005). A Holocene tephra record from the Lofoten Islands, arctic Norway. *Boreas* 34 (2): 136-156.
10. Luongo et al. (2017). Possible Icelandic Tephra Found in European Colle Gnifetti Glacier. *Geochemistry, Geophysics, Geosystems* 18 (11): 3904-3909.
11. van den Bogaard, Christel and Hans-Ulrich Schmincke (2002). Linking the North Atlantic to central Europe: a high-resolution Holocene tephrochronological record from northern Germany. *Journal of Quaternary Science* 17 (1) 3-20.
12. Lawson et al. (2012). The spatial distribution of Holocene cryptotephras in north-west Europe since 7 ka: implications for understanding ash fall events from Icelandic eruptions. *Quaternary Science Reviews* 41: 57-66.

Squirrels on the Move: The Response of North American Flying Squirrels (*Glaucomys Volans* And *G. Sabrinus*) to Rising Ambient Temperatures

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Abstract: Both species of flying squirrel present in the state of Maine have undergone significant northward range shifts over the past 25 years, yet the driving forces are largely unknown (Wood et al., 2016). Our research examines rising temperature as a potential driver of the observed shifts by determining the effects of high summer temperatures on northern (*Glaucomys sabrinus*) and southern flying squirrels (*G. volans*) within the state.

Background

Over the past few decades, two of the three species of flying squirrels present in North America have shown significant northward range shifts (Garroway et al. 2011; Wood et al., 2016). One explanation for these shifting populations is increasing temperatures resulting from global climate change (Garroway et al., 2011; Bowman et al., 2005).

Our research aims to test the hypothesis that high summer temperatures are contributing to the observed range shifts of North American flying squirrels by examining the effects of high ambient temperature on metabolic rate and body temperature, as well as monitoring summer activity patterns and local climate variation.

Project Description

Building on a previous field season, we will continue to trap for southern flying squirrels (*Glaucomys volans*) in Old Town/Orono, ME and search for a population of northern flying squirrels (*G. sabrinus*) in Presque Isle, ME.

We will use flow-through respirometry to measure metabolic rate and evaporative water loss of individual squirrels over a range of ambient temperatures. Additionally, we will implant a subset of squirrels with temperature-sensitive data loggers to collect core body temperature of free-ranging individuals and attach radio collars for monitoring activity patterns. We will collect local climate data from each trapping site and identified nest locations to better understand the microclimate conditions flying squirrels experience during a Maine summer.

Preliminary Data

During our preliminary field season (2017), we only located populations of southern flying squirrels. We collected resting metabolic rate data across 5 ambient temperatures (n=12). We also collected the first and only body temperature trace of a free-ranging flying squirrel (Figure 1).

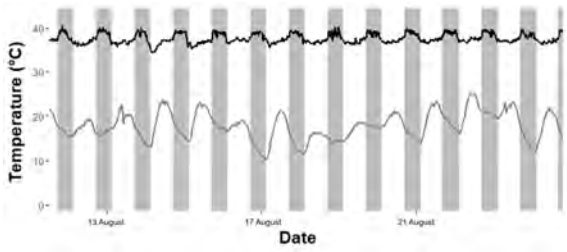

Fig. 1. Full body temperature trace of *G. volans* male (black line, n =1) and ambient forest temperature (grey line) from 12 Aug. – 24 Aug. 2017. White bars indicate daylight hours and grey bars nighttime hours.

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

Bibliography: Bowman, Jeff, *et al*. 2005. "Northern Range Boundary Dynamics of Southern Flying Squirrels: Evidence of an Energetic Bottleneck." Canadian Journal of Zoology 83 (11): 1486–94.

Garroway, Colin J., *et al*. 2011. "The Genetic Signature of Rapid Range Expansion by Flying Squirrels in Response to Contemporary Climate Warming: Genetics of Rapid Expansion." Global Change Biology 17 (5): 1760–69.

Wood, Connor M., Jack W. Witham, and Malcolm L. Hunter. 2016. "Climate-Driven Range Shifts Are Stochastic Processes at a Local Level: Two Flying Squirrel Species in Maine." Edited by D. P. C. Peters. Ecosphere 7 (2).

Shifting Accounts and Shifted Emissions: Emissions Accounting, Trade and the Reproduction of International Advantage in Climate Change Negotiations

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Abstract: Our research traces the emergence and adoption of proposals to modify the territorial accounting methods used in international climate negotiations. Despite evidence that alternative methodologies provide more accurate and equitable means for the determination of mitigation responsibility, we find strong evidence to suggest that these proposals have been marginalized. We argue that the incorporation of methods able to account for trade-embedded emissions can increase mitigation ambition and the chances of achieving the goals of the Paris Agreement.

Background

The territorial or "production-based" emissions (PBE) accounting methodologies utilized in international climate negotiations do not adequately account for the emissions embodied in international trade and therefore create a skewed picture of mitigation responsibility. Several scholars note that PBE methods favor post-industrial states that benefit from carbon trade imbalances. Alternative accounting methods exist and are increasingly advocated by a wide range of actors (Afionis 2017).

Methods

We trace the diffusion of proposals to modify accounting methodologies and the critical junctures that maintained the current accounting system, constructed entirely on territorial-emissions. We integrate six lines of evidence: 1) UNFCCC official decisions and supporting documents between 1992 and 2017; 2) side events between Durban (2011) and Marrakesh (2016); 3) Intended Nationally Determined Contribution (INDC) documents; 4) media coverage with relevance to emissions accounting; 5) observations at six meetings between Copenhagen (2009) and Bonn (2017); and 6) interviews with participants at 3 meetings.

Findings

We found that despite growing advocacy by a wide range of actors including scientists, civil society organizations and several state parties including India, China and the Marshall Islands,

Fig. 1. A meeting room at COP23 in Bonn, Germany.

proposals for alternative accounting systems have been marginalized in official UNFCCC process. While other scholars have attributed the exclusion of these approaches to a “range of technological and policy-related uncertainties” (Afionis et al 2017:2), we found considerable evidence to suggest that resistance is also deeply political and tied to efforts, both explicit and implicit, to reproduce existing relations of power in a highly unequal global economy. We conclude that the incorporation of trade embedded emissions can increase mitigation ambition and thus the chances of achieving the goals of the Paris Agreement.

Acknowledgements:
National Science Foundation, Dan & Betty Churchill Fund, Bangor Saving & LoRusso Faculty Development Fund.

Bibliography:
Afionis et al. 2017. Consumption-based carbon accounting. https://doi.org/10.1002/wcc.

Lateral Shearing of the McMurdo Shear Zone, Antarctica: Crevasse Observations

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Abstract: Lateral resistance arising from the shearing motion of the fast-moving Ross Ice Shelf (RIS) and the slow moving McMurdo Ice Shelf (MIS) plays a role in the stability of the western portion of the RIS. In this study we couple GPR surveys of the McMurdo Shear Zone (MSZ) with remote sensing datasets to determine critical kinematic threshold values for crevasse initiation.

For the Ross Ice Shelf (RIS), an important region of lateral resistance is the McMurdo Shear Zone (MSZ) located just downstream of the rock outcrop Minna Bluff. Here, the fast-moving Ross Ice Shelf (~450 m/yr) shears past the slower-moving McMurdo Ice Shelf (MIS;~200 m/yr), creating a 5-10 km wide zone of intense crevassing. A weakening of this lateral margin might destabilize the RIS and recent modeling work by *Reese et al.* (2017) found that moderate thinning in this region can have far-reaching effects, including an immediate acceleration ice streams located more than 900 km away. This region is also of great logistical importance to the United States Antarctic Program (USAP). On a yearly basis USAP mitigates crevasse hazards along the South Pole Traverse (SPoT) route that crosses the MSZ.

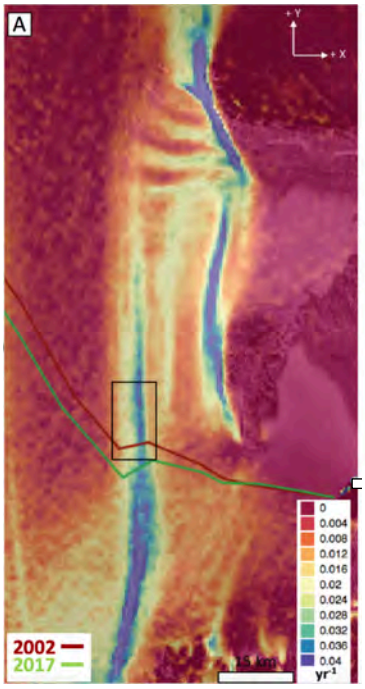

Figure 1 A) Shear strain rate interpolated from MEaSUREs velocity data with initial SPoT route and its new location in 2017 **B)** Shear strain rates in study area. Purple lines indicate 2017 crevassed regions and yellow dots indicate 2014 crevasse detections.

Various *in situ* datasets have been collected in the MSZ during field seasons in 2014-2017 including 400MHz frequency ground penetrating radar (GPR) surveys. We examine interpolated kinematic outputs including shear strain rate, dilatation, and vorticity from remotely sensed velocity datasets (*Gardner et al.*, 2018) and compare with crevasse location, depth, and maximum width. Preliminary analysis of the data suggests that crevasse initiation typically occurs at a minimum strain rate of ~0.019 yr^{-1} (**Fig 1 and 2**).

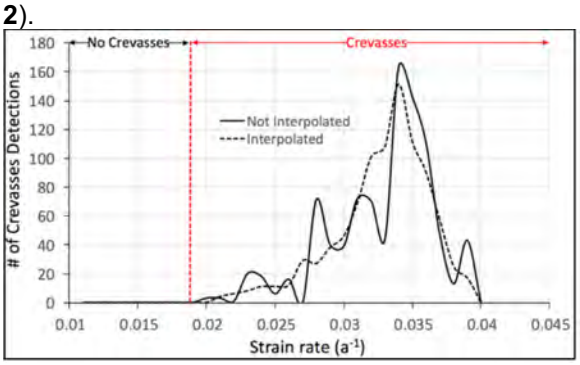

Figure 2). Histogram of 2014 crevasse detections and shear strain rate. 2017 data not yet included in threshold analysis.

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

Bibliography:

Gardner, A. S.," Increased West Antarctic and unchanged East Antarctic ice discharge over the last 7 years", *The Cryosphere* 12 (2018): , 521-547.

Reese, Ronja, et al. "The far reach of ice-shelf thinning in Antarctica." *Nature Climate Change* 8.1 (2018): 53.

What Causes Glaciers to Become Unstable? An Exploration of Controls on the Surging Behavior of Donjek Glacier, Yukon Territories, Canada

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Abstract: Surging glaciers offer an analogue to predict future ice sheet mass loss. Alaskan surge-type glaciers in particular are important due to their significant contribution to recent sea level rise. Using air photography, satellite remote sensing, ground penetrating radar, and ice cores on Donjek Glacier, Yukon Territories, Canada, we show that accumulation is a control surging.

Ice streams draining Greenland and Antarctica are known to become unstable (i.e., surge) on centennial time scales, leading to rapid sea level rise. Smaller mountain glaciers also surge, except on decadal time scales, and provide an analogue to understand these ice instabilities. Specifically, we can test hypotheses about glacier instabilities by observing multiple surges of the same glacier. To this end, we are combining the first in situ and satellite derived record of mass accumulation on a surge-type glacier to test the hypothesis that accumulation controls surging. Accumulation has long been considered an important driver of surging (Meir and Post, 1969), yet no one has made in situ observations of accumulation between surge events.

Using five ice cores, field observations, and satellite remote sensing data from Donjek Glacier in the Yukon Territories, Canada, we are testing the role of accumulation on glacier surges. We employ an archive of six ice cores collected since 1996 to measure accumulation and use ground-penetrating radar to quantify the spatial variation of precipitation across the site. We additionally employ satellite observations to measure glacier thickness change and velocity change during a surge. We find that the glacier has surged 3 times in the last 30 years, in 2013, 2001, and 1989. From 1989 to 2001 and 2001 to 2013 we measured 16.0 and 15.6 meters of snow water equivalent accumulation (Figure 1), respectively, in the 2016 ice core. These remarkably similar amounts imply that accumulation exerts a strong control on surging.

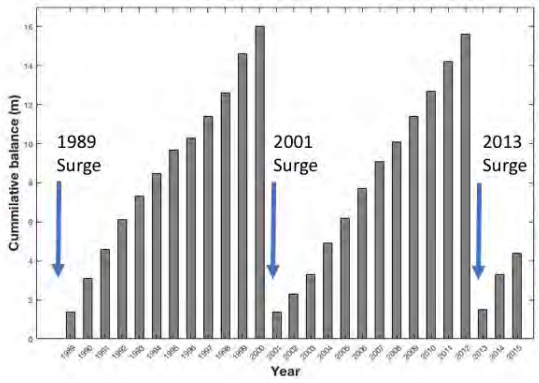

Fig. 1. Cumulative mass accumulation at Eclipse Ice Field from the 2016 ice core.

In order to gain sufficient potential energy to surge, snow had to accumulate for 12 years at high elevation, leading to a steepening of the glacier surface slope. These findings have strong implications for the role of mass balance on ice stream stability in Greenland and Antarctica and demonstrates the need for continued glacier mass balance monitoring around the world.

Acknowledgements: This material is based upon work supported by the NSF Graduate Research Fellowship under Grant No. DGE-1144205 and the Dan and Betty Churchill Exploration Fund and NSF AGS - 1502783.

Bibliography: Meier, M.F., and Post, A., 1969, What are glacier surges? Canadian Journal of Earth Sciences, v. 6, p. 807-817.

Developing an Ultra- High-Resolution Record of the Termination II and the Last Interglacial from the Allan Hills Blue Ice Area (BIA), Antarctica

Elena Korotkikh[1,2], Paul A. Mayewski[1,2], Andrei V. Kurbatov[1], Douglas Introne[1], Sharon Sneed[1], Michael Handley[1], Nicole Spauding[1], Heather Clifford[1,2]

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Abstract: The Climate Change Institute W.M. Keck Laser Ice Facility laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) measurements were conducted on Marine Isotope Stage (MIS) 6a and on last interglacial period (MIS 5e) samples from the Allan Hills Blue Ice Area (BIA). Our ultra-high-resolution glaciochemical record captures annual layers in highly compressed ice. Increased continental dust emissions are observed with unprecedented details during the glacial intervals.

Understanding climate of the last interglacial period is crucial since it is one of the analogs for the present interglacial. Allan Hills BIA ice core samples provide an opportunity to investigate climate conditions during the last interglacial period in a unique location: between East and West Antarctica. The new data could help in understanding how West and East Antarctic Ice Sheets interacted in the past and responded to past climate changes.

Several ice core sections from Allan Hills BIA vertical ice core S27 are being analyzed in the W.M. Keck Laser Ice Facility using LA-ICP-MS. Analyzed sections cover intervals during MIS 5e and MIS 6a, yielding environmental signals from the last glacial and interglacial. Ice core analysis by LA-ICP-MS provides ultra-high sampling resolution (~153 micrometers), which is much higher than the finest resolution traditional core processing analysis (~1cm/sample). Such ultra-high-resolution data allows identification of annual layers, calibrated using stable isotope correlation dating, in old compressed ice. Figure 1 shows that the annual signal is well preserved in Allan Hills BIA glacial ice.

Our records show increased dust (represented by Fe, Al and Mg) and marine aerosols (Na) inputs at the end of the penultimate glacial period (MIS 6a), and decreased dust and Na levels during the last interglacial (MIS 5e). LA-ICP-MS analysis will allow us to determine how fast changes in dust and marine aerosols occurred during the glacial-interglacial transition.

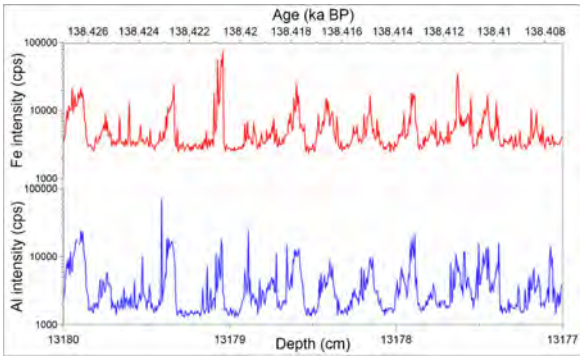

Fig. 1 Ultra-high-resolution measurements of Fe and Al in a section of ice core S27 collected from the Allan Hills BIA. 17 annual peaks are apparent in a 3 cm ice core section.

Acknowledgements:
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W. M. Keck Foundation

Bibliography:

Sneed, S. B. et al. New LA-ICP-MS cryocell and calibration technique for sub-millimeter analysis of ice cores. J. Glaciol. 61, 233–242 (2015).

Spaulding, N. E. et al. Climate archives from 90 to 250ka in horizontal and vertical ice cores from the Allan Hills blue ice area, Antarctica. Quat. Res. 80, 562–574 (2013).

Spaulding, N. E. et al. A New Multielement Method for LA-ICP-MS Data Acquisition from Glacier Ice Cores. Environ. Sci. Technol. 51, 13282–13287 (2017).

Climate Change may Increase the Prevalence of Amyotrophic Lateral Sclerosis (ALS) in Maine.

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Abstract: Temperatures in Maine are predicated to increase over the next several decades as a result of abrupt climate change. This increase in temperature will result in an increase in temperature sensitive cyanobacteria and their toxins; cyanobacteria release toxins in the form of harmful algal blooms (HABs). Unfortunately, exposure to these toxins can lead to serious health issues. One such toxin is beta-Methylamino-L-alanine (BMAA). BMAA is associated with an increase prevalence of Amyotrophic Lateral Sclerosis (ALS). By studying the BMAA genetic-environmental interaction, we hope to discover the molecular pathways for how BMAA increases the prevalence of ALS, potentially leading to novel treatments to stop the progression of this disease. Additionally, we will use our data to inform Maine policies to reduce the public's exposure to BMAA.

Temperatures in Maine are projected to increase in prevalence over the next several decades, leading to an increase in cyanobacteria and their harmful algal blooms (HABs). Therefore, studying how the HAB toxin, BMAA, will increase overtime in Maine waters is an important endeavor, as the toxin is strongly associated with an increase prevalence of Amyotrophic Lateral Sclerosis (ALS) (Banack et al. 2015; Holtcamp, 2012).

ALS is a progressive neurodegenerative disease that leads to loss of motor control and eventually death. Furthermore, there is no cure for ALS and the few treatments available only increase life expectancy by a few months. Therefore, my project aims to uncover novel mechanisms that could lead to the development of more effective drug treatments for ALS. To do this, I study the interaction between genes and environmental toxins known to be associated with the development of ALS.

To study the BMAA / gene interaction we use zebrafish, an excellent model for studying environmental toxins on living animals. To accomplish this, BMAA concentrations detected in Maine waters will be used to determine if and how developmental exposure to those concentrations effect zebrafish neurological health. Determining how BMAA affects zebrafish neurological health will facilitate uncovering novel cellular signaling mechanisms involved with environmentally-induced ALS, potentially leading to the development of more effective treatments for ALS.

In addition to studying the gene-envirmental interaction of BMAA from a molecular prospective, I will also tackle the problem from the policy side. To do this, I will work with the Maine DEP to help facilitate policy changes that will reduce people's exposure to BMAA in local water sources. Additionally, the results of my project will be disseminated around the local communities via seminars, posters, pamphlets, news articles, or a website, to inform the general public about their potential health risks associated with climate change, BMAA, and ALS.

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

Bibliography:

Banack S, Caller T, Henwwegan P, Haney J, Murby A, et al. (2015) Detection of Cyanotoxins, β-N-methylamino-l-alanine and Microcystins, from a Lake Surrounded by Cases of Amyotrophic Lateral Sclerosis. Toxins 7: 322–336.

Holtcamp W. 2012. The Emerging Science of BMAA: Do Cyanobacteria Contribute to Neurodegenerative Disease? *Environmental Health Perspectives*, 120 (3): A110-6.

Mammalian Thermoregulation in Hot Climates: Clues for Deciphering the Past and Predicting the Future

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Abstract: Despite a large body of knowledge on the thermoregulation of temperate and cold-climate endotherms, our functional knowledge of endotherms in tropical and subtropical climates remains incredibly scarce. Small endotherms (<5kg) are often assumed to live predominantly at temperatures below thermoneutrality. Tropical and subtropical mammals, however, routinely experience temperatures above the lower critical limit of the thermoneutral zone. Therefore, unlike temperate species, that must consistently generate heat to maintain elevated body temperatures, low latitude species spend more time at thermoneutrality and therefore can spend the energy elsewhere. I discuss the costs and benefits of differences in thermoregulatory flexibility in warm climates.

The evolution of endothermy, the maintenance of a high and relatively constant body temperature via biochemical and physiological processed, allowed a level of decoupling between aerobic performance and environmental temperatures in mammals and birds. Capable of maintaining muscle temperature constant over a wide range of ambient temperatures, endotherms were able to radiate into environments previously unavailable to temperature-dependent ectothermic species (Lovegrove 2012). Cold temperatures, however exert a strong selective force on thermoregulatory traits leading to marked increases in basal metabolic rates and body temperatures in higher latitude species when compared to their warm climate counterparts.

In tropical and sub-tropical environments, continuous access to external means of heat production has allowed for a wider range of thermoregulatory phenotypes for mammals. Yet, much of our understanding of the thermoregulatory physiology of endotherms has been shaped by the study of animals from temperate environments. Consequently, we currently have a better understanding of mammalian responses to cold then to heat, which impedes our ability to predict potential responses to climate change (Levesque et al 2016). A greater understanding of the thermoregulatory phenotypes of mammals from warm climates can therefore help to both understand past patterns, as endothermy evolved in tropical environments, as well as to help predict the future range shifts in a changing world.

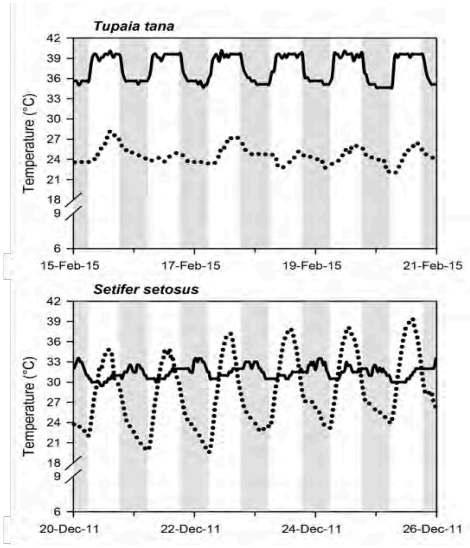

Fig. 1. Body temperature (solid lines) for two small mammal species showing different thermoregulatory phenotypes. Solid lines indicate body temperature, dashed ambient temperature and the grey bars are nighttime. Adapted from Levesque *et al.* 2016.

Acknowledgements: Thanks to collaborators at University of KwaZulu-Natal and Universiti Malaysia Sarawark, especially Barry Lovegrove and Andrew Alek Tuen.

Bibliography:

Levesque DL, Nowack J, Stawski C (2016) Modelling mammalian energetics: the heterothermy problem. Clim Ch Responses 3 (1):7

Lovegrove BG (2012) The evolution of endothermy in Cenozoic mammals: a plesiomorphic-apomorphic continuum. Biol Rev 87:128–162

Conservation Paleobiology Above Treeline in the Northeastern United States

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Abstract: Anthropogenic climate change presents new challenges to protected landscapes, especially for conservation areas that protect isolated natural communities comprising small populations at the southern edge of their ranges. The long temporal perspective from paleobiology can help managers identify vulnerable species and predict community-level responses to changes in climate. At low elevations, extensive pollen records from ponds, lakes, hollows, and bogs provide a wealth of data about the paleoecology of the northeastern United States since the last glacial retreat. Here, we review the sparse literature on pollen records at and above treeline and add cored from two new sites from Maine. Understanding the history of alpine and subalpine vegetation above treeline is deeply relevant as conservation practitioners work to protect these vulnerable communities in the face of anthropogenic climate change.

Project Goals

The goal of this project is to bring relevant paleobiology research to conservation managers working above treeline in the northeastern United States. We will review the last five decades of palynology research at high elevations in the northeastern United States. With a focus on Maine, we will collect the management positions, policies, and challenges for alpine and subalpine vegetation scattered across federal, state, and other conservation lands in the state. Finally, we will expand conservation paleobiology research in Maine across a coastal-to-inland gradient at two iconic conservation lands: Acadia National Park and Baxter State Park. We cored two high elevation ponds: Sargent Mountain Pond in Acadia and Chimney Pond in Baxter, and we will begin processing and analyzing the pollen records from these sediment cores in summer 2018.

Initial Results

While the paleobiology of New England is well documented at low elevations, only scattered records of sediment cores exist from the region's high elevation ponds. Reviews of pollen and plant macrofossil data from the Adirondack Mountains in New York (Jackson and Whitehead 1991) and the White Mountains in New Hampshire (Spear et al. 1994) reveal dynamic spatial patterns of vegetation along the elevation gradient. When Norton et al (2011) analyzed pollen in a small section of a Sargent Mountain Pond core they found dramatic changes in vegetation around the Younger Dryas. Historically, pollen records from Baxter State Park have been restricted to low elevation ponds.

In September 2017 we retrieved two 4 m sediment cores from Sargent Mountain Pond (elevation 335 m) from a cataraft anchored to shore. In March 2018 we retrieved two 2.6 m sediment cores from Chimney Pond (elevation 888 m) through 52 cm of ice. These sediments were extracted with a combination of Bolivia and Livingston piston corers. Initial core description and macrofossil sampling was carried out at the University of Minnesota's LacCore facility in late March 2018. In both Acadia and Baxter, park managers and rangers were integral to the planning and logistics of the backcountry fieldwork. We will present our paleobiological results to regional conservation managers at the Northeast Alpine Stewardship Gathering in Fall 2019.

Acknowledgements: David H. Smith conservation biology postdoctoral fellowship.

Bibliography:

Jackson, Stephen T., and Donald R. Whitehead. "Holocene vegetation patterns in the Adirondack Mountains." *Ecology* 72, no. 2 (1991): 641-653.

Spear, Ray W., Margaret B. Davis, and Linda CK Shane. "Late Quaternary History of Low-and Mid-Elevation Vegetation in the White Mountains of New Hampshire." *Ecological Monographs*64, no. 1 (1994): 85-109.

Norton, Stephen A., Randall H. Perry, Jasmine E. Saros, George L. Jacobson, Ivan J. Fernandez, Jiří Kopáček, Tiffany A. Wilson, and Michael D. SanClements. "The controls on phosphorus availability in a Boreal lake ecosystem since deglaciation." *Journal of Paleolimnology* 46, no. 1 (2011): 107-122.

Calibrating Ice Core, Weather Station, and NASA MODIS Ice Surface Temperature Records to Analyze Atmospheric Variability in the St. Elias, Yukon, Canada

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5. *Department of Earth Sciences, Uppsala University, Sweden.*

Abstract: The St. Elias region is characterized by complicated atmospheric dynamics that respond to climate forcing. This makes understanding these cycles, and how they may respond to climate change, essential to adaptation planning within communities of the North Pacific. This project aims to quantify the relationships among meteorological data, climate reanalysis models, and ice core records to reconstruct temporal hydroclimate variability in the St. Elias.

Interactions between atmospheric systems in the St. Elias cause variations in temperature, precipitation, and storminess over annual to decadal scales, which impact local populations. This study will increase our confidence in using a long record of ice cores retrieved from Eclipse Icefield (Fig. 1) in 2017, 2016, and 2002 as a proxy for atmospheric variability.

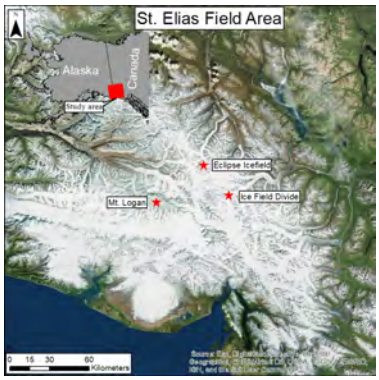

Fig. 1. Map of the St. Elias field area. Eclipse (elev. 3,017 m) and Mt. Logan (elev. 5,340 m) are ice core sites. Ice Field Divide (elev. 2,900 m) will serve as a calibration site after retrieval of a short ice core next to an automatic weather station

Paleoclimatologists commonly use stable water isotope ratios as a means of reconstructing past temperatures via ice core meltwater analysis. However, site-specific precipitation characteristics, such as moisture source region and seasonality, can interfere with the isotope signal and reduce the accuracy of isotope-based paleotemperature reconstructions. Atmospheric general circulation model analysis has justified the use of isotopes in temperature reconstruction so long as they are calibrated with observational records (Jouzel et al., 1997).

This project will involve measuring stable water isotope ($\delta^{18}O$ and δD) fluctuations in a short ice core and snow pit sampled next to an automated weather station (AWS) in order to calibrate the isotope record with observed temperature and accumulation records. NASA Moderate Resolution Imaging Spectroradiometer (MODIS) ice-surface temperature data will serve as another observational record. We can then use this calibrated isotope thermometer to interpret the longer record of ice cores from Eclipse Icefield.

Acknowledgements:
National Science Foundation (NSF), Churchill Exploration Fund, and Maine Space Grant Consortium

Bibliography:

Jouzel, J., R. B. Alley, K. M. Cuffey, W. Dansgaard, P. Grootes, G. Hoffmann, S. J. Johnsen, R. D. Koster, D. Peel, C. A. Shuman, M. Stievenard, M. Stuiver, and J. White (1997), Validity of the temperature reconstruction from water isotopes in ice cores, *Journal of Geophysical Research, 102*(C12), 26,471-26,487.

Multi-Level Governance of Climate Change Adaptation: Examining Rhetoric and Resources from the Halls of the United Nations to the Hillsides of Nicaragua

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Abstract: Looking at climate change adaptation as a multi-level governance challenge, this project explores an Adaptation Fund project in Nicaragua and the associated interactions of governance from the municipal to the international levels to understand the propellers and obstacles to adaptation implementation. At the international level, there is strong support for the Adaptation Fund underpinned by a perception that the adaptation projects are working. Consistent with the multi-level governance frame, this project will look at each jurisdictional level to identify the extent to which the Adaptation Fund model does facilitate effective adaptation project implementation.

Background

The United Nations Framework Convention on Climate Change's (UNFCCC) Adaptation Fund is one of the primary tools used by this Convention to fund adaptation in vulnerable regions of developing countries. Its structure—developing countries drawing money from the international level to fund local projects—necessitates that climate change adaptation be understood as a multi-level governance challenge. This research looks at an Adaptation Fund project in Nicaragua and explores the interactions of the levels of governance from the UNFCCC to the municipalities to identify the propellers and obstacles to adaptation implementation.

Findings at the International Level

Site observations of negotiations at the 2016 and 2017 UNFCCC Conferences of the Parties (COP) show that the rhetoric of developing countries towards the Adaptation Fund is wholly positive. Factors driving this sentiment include: (1) frustrations with other funds that are seen as inaccessible; (2) unique mechanisms including direct access and safeguards; (3) seeing the creation of the Fund as a 'developing country win' which should be sustained; and (4) the belief that the Fund actually does support meaningful adaptation efforts in their countries. During negotiating session on the Adaptation Fund, delegates reiterated inputs such as, "it goes without saying the importance of the Adaptation Fund" (Egypt on behalf of the Africa Group) and "we believe that the Adaptation Fund is a Fund that we are proud of because it has provided a lot of support to our member states (Uganda on behalf of the Least Developed Countries Group). One of the primary ways that the Adaptation Fund receives feedback from the countries is through this international process. At the COPs, the message to the Adaptation Fund is clear—keep doing what you are doing.

Next Steps

Yet, the multi-level governance perspective requires an understanding of what is taking place from the international level to the local level to fully understand if the system is working effectively. The next step of this project is to explore the other jurisdictional levels to identify the extent to which the Adaptation Fund model does facilitate effective climate change adaptation project implementation.

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

Ground-Penetrating Radar as a Rapid Cultural Resource Management Technique for Shell Midden Delineation

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

Coastal middens are the result of pre-European aboriginal accumulation of centimeters to meters of clam and/or oyster shells, with associated artifacts and faunal remains, and are records of up to 5,000 years of Gulf of Maine coastal lifeways and environmental conditions. This project employs ground penetrating radar (GPR) to obtain high-resolution site extent and stratigraphic data using an efficient, cost-effective, and nondestructive survey method (Fig. 1).

GPR profiles record below surface stratigraphy by noting differences in the electromagnetic properties of the materials that reflect variations in layer composition, compaction, grain size, salinity and/or water content. This data and archaeological profiles are used to evaluate midden thickness (Fig. 1 and 2), presence or absence of disturbance, and can resolve the remains of dwellings (Fig. 1).

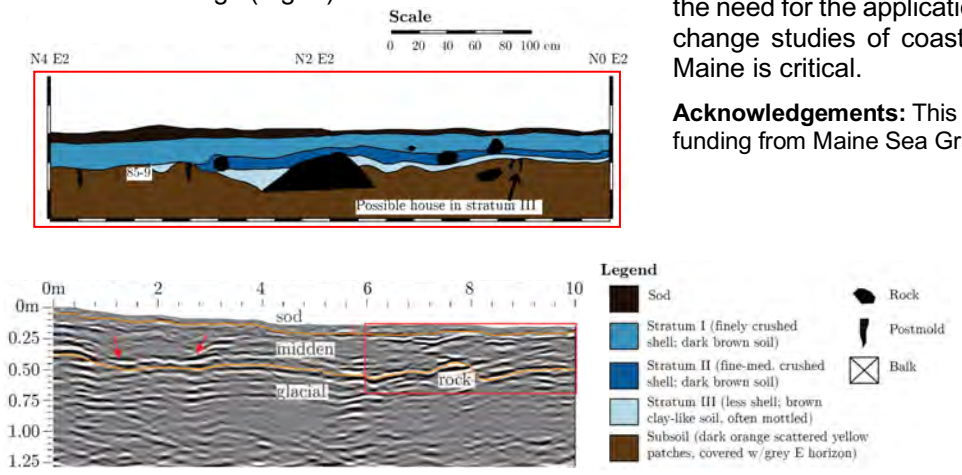

Fig. 1. Archaeological profile courtesy of Maine Historic Preservation Commission. Red box denotes profile location on GPR transect. Red arrows point to a house floor in the GPR data.

Fig. 2. Thickness of a midden in centimeters.

The goal of this research was to delineate the vertical and lateral extent of shell middens using GPR (Fig. 1 and 2), and to create a methodology applicable to shell middens anywhere. As sea level continues to rise, and sites and the information they hold are currently disappearing, the need for the application of GPR and shoreline change studies of coastal shell midden sites in Maine is critical.

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

A Screening-Level Protocol for Quantifying Risk From Organochlorine Pollutants in Glacial Meltwater: Jarvis Glacier, Alaska

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Abstract: Widespread transport of organochlorine pollutants (OCPs) has been documented throughout the North American Arctic. Some of these OCPs are entrained in glacial ice and can be released into downstream reservoirs. Though this dynamic is known, risk from glacial meltwater to communities has not been accomplished. We use a screening-level risk assessment, based on US Environmental Protection Agency (EPA) methodology, which we utilize to characterize risk in the glaciated Jarvis Creek watershed within interior Alaska. Our results indicate that even low levels of OCPs can be move through the food chain as a result of bioaccumulation and high fish consumption. This increases the risk of cancer and disease impacts above acceptable limits.

Glaciers within the Alaska Arctic have never been sampled for OCP deposition, though trace amounts have been identified within humans, oceanic fish and pelagic fish. Sampling ice cores drilled by a joint team from the University of Maine, Dartmouth and the University of Alaska, we identified the pesticides DDT, DDE and DDD along with α-HCH and Ɣ-HCH within Jarvis Glacier ice and meltwater. These toxic, legacy pesticides are being released into the watershed currently, and may impact the health of downstream populations.

Utilizing established EPA risk assessment methodology but adapting it to the entirely new purpose of managing legacy contaminants within glacial meltwater, we identify potential long-term risk these pollutants pose. Though initial screening has determined the concentration in glacial meltwater from the glacier to be below the cancer risk level for shorter term consumers, they are above the screening level for lifetime consumers. This may be most important for children whose long-term uptake and small body size significantly increase risk.

Our protocol shows that even at low levels, DDT could impact the health of downstream populations that consume large quantities of salmon species. The results indicate a need for additional study, on a community-specific or individualized level. While risk from other pollutants including mercury have been documented within Alaskan watershed, OCP chemicals released from glaciers may increase cancer and disease risks in resident populations.

Image 1. Jarvis Glacier ice core section in the cold storage room.

Overall, the need for further monitoring and assessment of increasing glacial watershed pollution is clear. Our work identifies factors of concern and can be used to prioritize sites for further research.

Acknowledgements: Gratitude for the support of Seth Campbell, Chris Gerbi and the UAF, UMaine and Dartmouth teams. Support provided by the NSF program grant DGE- 1144423, NSF award PLR-1503924, Dan and Betty Churchill, The Robert and Patricia Switzer Foundation, A2C2 IGERT, The SMART program and the Fulbright program.

How Much Silica do Diatoms Bury?

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Abstract: A novel method for estimating the volume of silica in a diatom cell is devised. Computer aided design (CAD) software is used to create a 3D model of the diatom *Stephanodiscus niagarae*. The CAD model informs a mathematical model of the silica contained within each cell. The mathematical model will allow for calculation of the total silica buried by a population of diatoms. This has implications for estimating the biotic influence upon the rock record, aquatic nutrient cycling, and diatom-driven ecosystem engineering.

Through time lakes typically become more biologically productive. As organisms die their carcasses can sink and contribute to the sediment load of a lake. In combination with terrigenous inputs, the biological sediment load will eventually fill a lake basin completely and form a bog and eventually dry land [1]. The diatoms (Bacillariophyta) are of interest in lacustrine records as they exhibit hard silica dioxide outer cells of various forms and sizes [2]. The silica cell walls fossilize readily, thus contributing to the sediment load.

The method being developed herein aims to construct a model that will quantify the volume of silica that is turned into sediment by each species of diatom. The amount of silica buried by each species represents an export of available nutrients out of the water column and into sediment. This is the primary mode of silica export in ecosystems [3].

Bibliography:

1. Likens, G. E., Brenner, M. & Escobar, J. Ontogeny of Aquatic Ecosystems. *Encycl. Inl. Waters* **1,** 456–461 (2009).

2. Julius, M. L. & Theriot, E. C. The diatoms: a primer. in *The diatoms: applications for the environmental and earth sciences* 8–22 (2010).

3. Tréguer, P., Nelson, D. M., Bennekom, A. J. Van, Demaster, D. J. & Quéguiner, B. The Silica Balance in the World Ocean : AAAS **268,** 375–379 (1995).

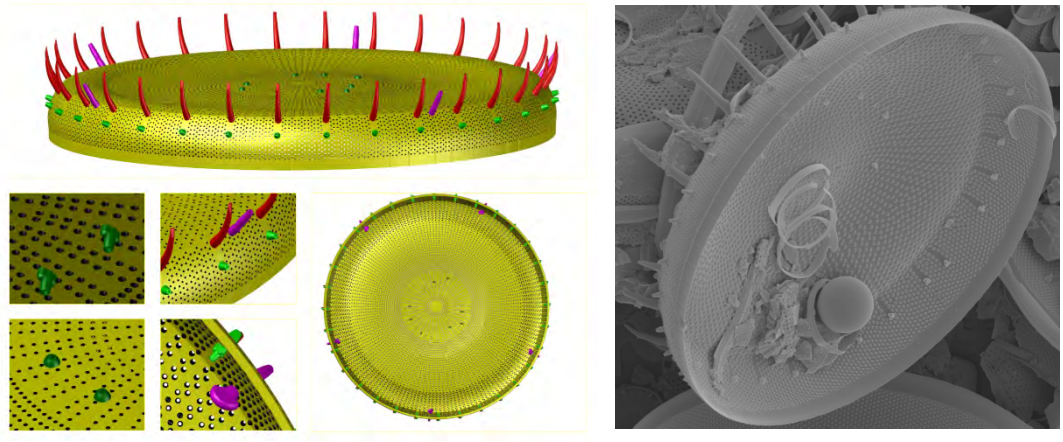

Figure 1: 3D CAD model of the diatom *S. niagarae* from multiple viewports on left. SEM image of *S. niagarae* on right.

Establishing the Timing and Characteristics of Recent Floods in the Forearc of Southern Peru

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2. *Climate Change Institute, University of Maine.*
3. *INGEMMET, Peru.*

Abstract: The Atacama Desert of the western Andean margin spans the southernmost part of Peru and Chile. We focus on the landscape of the southern Peruvian forearc, where good preservation due to hyperaridity since at least 3Ma reveals a dynamic region shaped by intimately interacting active tectonic and climatic processes. Despite the persistent hyperaridity, the Atacama is subject to climatic variability from the El Niño Southern Oscillation (ENSO). Periods of hyperaridity are punctuated by flash events of high precipitation that lead to large scale flooding that can rework the landscape significantly. These floods remain poorly understood. We analyze the morphology and stratigraphy of a set of braided channels and abandoned terraces dissected by a recent rupture of the Purgatorio fault to reconstruct the timing and characteristics of recent precipitation events that have shaped the area, and contribute to establishing a more complete record of the timing of ENSO events in the forearc.

Study Goals

The goals of this project are to establish the timing and characteristics of recent floods in the forearc, and determine what tectonophysical model new structural and climatic data from the forearc fit best.

We determine the stratigraphy of abandoned terraces, conduct geomorphic surveys of paleo and modern stream features, and conduct relative and absolute dating of organic matter, ash, and abandoned surfaces to reconstruct a recent record of flow in the forearc.

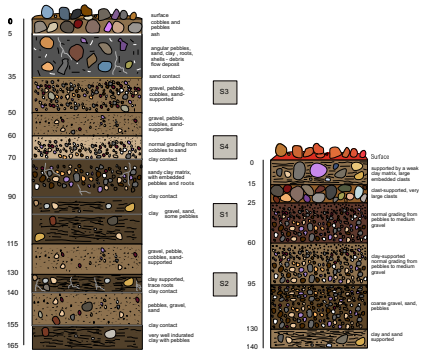

Figure 1: stratigraphy of two abandoned terraces in the Purgatorio area.

We combine these data with a multiscale analysis of the Incapuquio flower structure to propose landscape evolution in the forearc is shaped by a wedge maintenance mechanism regulated by the flower structure in which floods play an important role in lubrication that triggers landslides that control hillslope evolution.

Preliminary Results

Our data show that 1) flow in these channels occurs primarily in the form of mud-rich debris flows, 2) the oldest terrace has been protected by a right-lateral offset ridge and not experienced flow for a long time (evidenced by desert varnish), 3) the river has incised a 29.5m long and 2.3m deep, bedrock channel since the last rupture event (recorded by the youngest abandoned terrace which, if the ash layer in the pit dug in that terrace is from the Huyanaputina eruption (~1600AD) indicates this incision has occurred in under 400 years, indicating a minimum incision rate of 0.57cm/ka. These new data suggest remarkably dynamic feedbacks between seismic and climatic processes in shaping the local landscape.

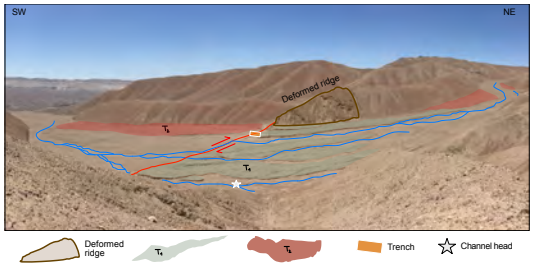

Figure 2: study site, where the Purgatorio fault dissects a set of braided channels.

Understanding the Ecology of the Diatom *Aulacoseira* in Alpine Lakes

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Abstract: Deciphering the changes in environmental factors that affect aquatic ecosystems requires the understanding of the autecology of sentinel species. *Aulacoseira* species are associated with changes in the water column stability of lakes. However, research quantifying the preferences of these species is needed.

Diatoms are widely used as tools to record changes in aquatic ecosystems and to reconstruct past climate (Reid et al., 1995). Diatom-based climate reconstructions require clear links between the shifts in the composition of diatom community and a fluctuation of environmental conditions (Catalan and Donato-R, 2016; Stevenson and Pan, 1999).

Deciphering the environment that triggers the predominance of a particular diatom demands the understanding of the autecology of the species, to ensure an accurate prediction about the driver that affects the diatom populations. Many paleolimnological studies argue the disappearance of *Aulacoseira* species from fossil records correspond to a decrease in the mixing of lakes. However, the gap in the ecology of those species, and some scarce reports about oligotrophic preferences (Potapova, 2009) for some of these species, cast doubts about the parameters that affect *Aulacoseira* populations.

The aim of this research is to understand the ecological preferences of *Aulacoseira lirata*, *A perglabra A. alpigena* and *A. distans* to improve the prediction power regarding the occurrence of these species and possible correlation with changes on water column stability in response to variation of the lacustrine thermal profile.

To address the objective, 5 alpine lakes of the Greater Yellowstone ecosystem were sampled last summer. Water samples from different depths and data from vertical profile of physical-chemical parameters were collected in order to detect the preferred depths for those species and the variables that can be associated with those zones. This paper presents partial results corresponding to the presence of *Aulacoseira alpigena* in Kersey and Beauty Lake. The occurrence of this diatom showed different trends among lakes; the density was profuse on the deepest lake with the major occurrence in zones below the epilimnion. Meanwhile, the occurrence of this diatom in Kersey lake was discrete and showed a slow increase by the end of the observations (Fig 1).

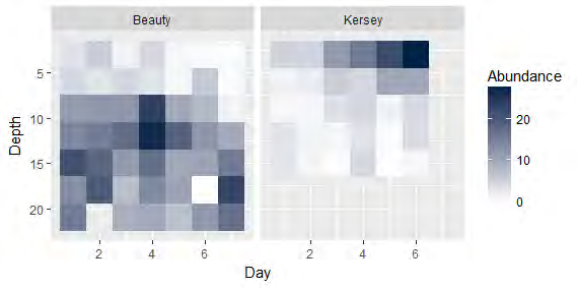

Fig. 1. Density (cells ml^{-1}) of *Aulacoseira alpigena* with depth in Beauty and Kersey lakes during July of 2017

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

Bibliography

* Catalan, J., and Donato-R, J.C. (2016). Perspectives for an integrated understanding of tropical and temperate high-mountain lakes. J. Limnol. *75*.

* Potapova, M. (2009). Aulacoseira alpigena.

Reid, M., Tibby, J., Penny, D., and Gell, P. (1995). The use of diatoms to assess past and present water quality. Austral Ecol. *20*, 57–64.

* Stevenson, R.J., and Pan, Y. (1999). Assessing environmental conditions in rivers and streams with diatoms. Diatoms Appl. Environ. Earth Sci. *1*.

Holocene Deglaciation at Amundsen and Liv Glaciers, Antarctica

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Abstract: In 2016-18 we carried out fieldwork near Amundsen and Liv Glaciers to document glacial recession during the last termination. The results of this study will allow us to further constrain the chronology of the retreat of the Antarctic Ice Sheet after the Last Glacial Maximum

The Antarctic Ice Sheet (AIS) contains ~58 m of global sea-level equivalent, thus it is crucial to investigate ice-sheet behavior to predict future sea-level rise (SLR)[1]. To do so, this study examines how the ice sheet changed in the past, specifically, how it responded to the major warming that occurred at the end of the last ice age. During the Last Glacial Maximum (LGM) ~26.5-18 ka the East (EAIS) and West Antarctic Ice Sheet (WAIS) expanded to fill the Ross Sea[2]. Constraining the subsequent retreat of the AIS will help us to understand the controlling mechanisms of the AIS[3].

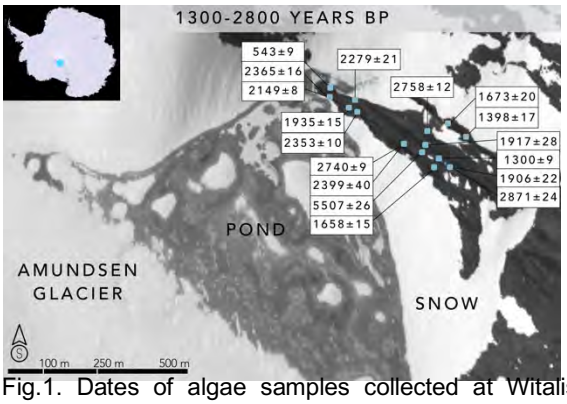

Fig.1. Dates of algae samples collected at Witalis Peak, Amundsen Glacier. Location shown in inset.

Amundsen (~85°S, ~159°W) and Liv (~84°S, ~167°W) Glaciers are sourced from the EAIS and flow through the Transantarctic Mountains to the Ross Ice Shelf. The objectives of my work are to determine former ice extent, elevation, and flow direction, and to develop a chronology for ice fluctuations and retreat. To do this I will produce age vs. elevation transects at ice-free regions near the coast, which will allow us to produce a chronology of glacier recession following the LGM.

Fieldwork, which was conducted at ice-free regions near the coast, consisted of mapping glacial deposits to delineate former ice margins and collecting ancient algae samples for ^{14}C dating from glacial landforms and lacustrine deposits (Fig. 1). Just as today, in the past ice-marginal ponds were dammed by Amundsen and Liv Glaciers. As the ice thinned, the ponds followed the ice margin and moved downslope. The algae from these ponds were stranded on the hillsides and thus record the position of the former ice margin as it thinned to its present location[4].

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

Acknowledgements:
National Science Foundation
Joel Gombiner[3], Jessica Badgeley[3]

Bibliography:

[1]Fretwell, P., Pritchard, H. D., Vaughan, D. G., Bamber, J. L., Barrand, N. E., Bell, R., . . . Zirizzotti, A., "Bedmap2: Improved ice bed, surface and thickness datasets for antarctica." *The Cryosphere, 7*(2013), 375.

[2]Denton, G.H., Hughes, T.J., "Reconstructing the Antarctic Ice Sheet at the Last Glacial Maximum" 21 (2002): 193–202.

[3]Hall, B.L., Denton, G.H., Stone, J.O., Conway, H., "History of the grounded ice sheet in the Ross Sea sector of Antarctica during the Last Glacial Maximum and the last termination." *Geol. Soc. London, Spec. Publ.* 381(2013): 167–181.

[4]Hall, B.L., Bromley, G., Stone, J., Conway, H., "Holocene ice recession at Polygon Spur, Reedy Glacier, Antarctica." *The Holocene* 27(2016): 122-129.

Excavations at Tranquility Farm: A Seasonality Analysis Using Mollusk Remains

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

Background

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

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

Figure 1: Abbe Museum Field School 2012

Purpose

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

Initial Results

By looking at the monthly average of oxygen isotopes measured from modern shells, the values from the archaeological shells were fit within the analytical uncertainty of these monthly modern averages. Due to overlapping ranges in the modern data set, in some cases, archaeological values fell into more than one monthly average range. Initial results suggest that Tranquility Farm was occupied by Native Americans during the fall, winter, and spring.

Tranquility Farm Excavated Archaeological Sample														
Month	Range	TF_10	TF_11	TF_35	TF_37	TF_43	TF_45	TF_46	TF_47	TF_48	TF_59	TF_60	TF_61	TF_62
JAN	0.603 to 0.863			X	X	X	X						X	
FEB	No data collected - iced over													
MAR	No data collected - iced over													
APR	1.610 to 1.870							X						
MAY	.215 to .475									X	X			
JUNE	-0.195 to 0.065													
JULY	-0.520 to -0.230													
AUG	-0.224 to 0.036													
SEPT	-.304 to -0.044													
OCT	No data collected - red tide													
NOV	0.730 to 0.990			X		X								X
DEC	0.520 to .780				X	X	X						X	

Table 1: Modern Monthly Averages vs. Excavated

Acknowledgments:

My collaborator Emily Blackwood; advisor Dr. Daniel Sandweiss; Dr. Alan Wanamaker, Director of the Stable Isotope Laboratory in the Department of Geological & Atmospheric Sciences at ISU; and my funders: The Abbe Museum and the University of Maine GSG.

Ice Core from Osjollo Anante, Peruvian Andes - Preliminary Results

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Abstract: The first ice core extracted from Osjollo Anante Glacier reveals well-preserved annual layers and potential for a several hundred year record of past climate and environmental change.

The study of atmospheric circulation and past climate variability from ice cores has been largely conducted in the polar regions. Recent efforts have focused on recovering more ice cores from high mountain glaciers around the globe. Still, a large spatial data gap remains between the mid latitudes and the tropics.

Tropical glaciers are rapidly disappearing, taking with them unique paleo-environmental information stored in the ice, information that can still be retrieved by drilling ice cores (Casassa et al.,1998). Instrumental records of climate and environmental variability over the Andes are sparse and rarely extend to higher elevations or cover more than 100 years. However, ice cores from the tropics and mid-latitude glaciers can provide high-resolution records of past climate dynamics and chemistry of the atmosphere ranging from seasonal to millennial time-scales (Ginot et al., 2006).

Our team collected a 21m ice-core (surface to near bedrock) from Osjollo Anante Glacier ice cliff (5600m, 13°46'S, 71°05'W). Osjollo Anante ice core climate archives are likely in peril in the near future as regional and global temperatures are predicted to continue to rise and tropical glaciers continue to ablate at continually higher elevations.

Climate along the eastern and western slopes of the Peruvian Andes is highly variable (Garreaud, 2009). At tropical and sub-tropical latitudes, relatively cold and arid conditions exist along the Pacific coast and the western slopes of Andes, while warm, moist and rainy conditions prevail on the eastern slopes. There is a distinct seasonality in snowfall in the Cordillera Vilcanota region where we collected the ice core characterized by a mean dry season (June–August) and a mean wet season (November–March) which is ultimately preserved in the ice stratigraphy. (Thompson et al. 1987, Hardy 2008).

Preliminary glaciochemical and isotopic analyses (Fig. 1) of the collected ice indicate that the climate record is well preserved. Mean annual layer thickness in the basal ice is about 4cm cm based on laser analyses of selected ice sections. Thus, the Osjollo Anante ice core record may reveal past atmospheric circulation patterns over this part of the tropical Andes. South American emissions of trace metals are increasing as a result of increasing population, agriculture, and industrial production. The primary source of heavy metals and trace elements in the atmosphere is the transport of dust emitted during surface mining and milling operations (Barbate et al. 2001).

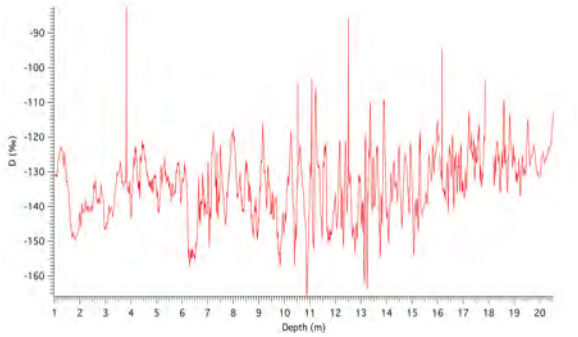

Fig 1. Raw deuterium isotope record (‰)

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

Bibliography:

[1] Casassa G., et al., A contribution to the International Hydrological Programme (IHP) and the Global Environment Monitoring System (GEMS). UNESCO, Paris (1998). (2006).
[2] Ginot P., et al., Clim. Past **2**: 21–30, (2006).
[3] Garreaud, R., Adv. Geosci., **22**, 3–11 (2009).
[4] Thompson L.G. et al., Abrupt Climate Change 99-110 (1987).
[5] Hardy D.R., White-winged Diuca Finch (Diuca speculifera) nesting on Quelccaya
Ice Cap, Perú. The Wilson Journal of Ornithology (2008).
[6] C. Barbante, et al., Environ. Sci. Technol. **35,** 4026-4030 (2001).

Late-Holocene Climate Fluctuations Recorded by the Moraines of Hooker Glacier, Southern Alps, New Zealand

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Abstract: We have collected geomorphic mapping data and samples for cosmogenic ^{10}Be surface-exposure dating from the moraines of Hooker Glacier in New Zealand's Southern Alps. A detailed moraine chronology will be used to reconstruct climate fluctuations in New Zealand during the past ~1500 years.

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. Understanding the spatial extent of such fluctuations will provide evidence with which to test hypothesized drivers of climate variability. This study will use a cosmogenic ^{10}Be surface-exposure chronology of moraines constructed by the Hooker Glacier to recreate the climate of New Zealand's Southern Alps over the past ~1500 years.

The Hooker Glacier flows down from Aoraki/Mt. Cook in New Zealnad'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 well-preserved moraines in the Hooker valley promising as records of natural climate variability. A reconnaissance set of ^{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.

2018 Field Season

During January and February of 2018, we collected seventy-one samples from boulders embedded in fourteen Hooker Glacier moraines for cosmogenic ^{10}Be surface-exposure dating. In addition to collecting samples, we used differential GPS measurements, geomorphic mapping, and a DJI Phantom 4 unmanned aerial system (UAS, or drone) to collect data for the construction of a detailed geomorphic map of the area. Photographs from UAS flights will be used in Agisoft's structure-from-motion software Photoscan to create a 3D model, orthomosaic image, and digital elevation model of the study area.

Future Work

Sample processing for ^{10}Be surface-exposure dating will take place during the spring and summer of 2018 at Lamont-Doherty Earth Observatory in Palisades, NY. Around thirty or forty samples will be processed. A second field season may be conducted in early 2019 to pursue further questions raised after processing the data from the 2018 field season.

Acknowledgements: Funds from the Comer Family Foundation and the National Science Foundation have supported this research.

Bibliography

Mackintosh, Andrew N., Brian M. Anderson, and Raymond T. Pierrehumbert. 2017.
"Reconstructing Climate from Glaciers." *Annual Review of Earth and Planetary Sciences* 45 (1): 649-680.

Putnam, Aaron E., Joerg M. Schaefer, George H. Denton, David J.A. Barrell, Robert C. Finkel, Bjørn G. Andersen, Roseanne Schwartz, Trevor J.H. Chinn, and Alice M. Doughty. 2012. "Regional Climate Control of Glaciers in New Zealand and Europe during the Pre-Industrial Holocene." *Nature Geoscience* 5 (9): 627–30.

The Last Termination Recorded in Tsagaan Gol-Potanin Glacier Valley, Altai Mountains, Mongolia

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

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

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

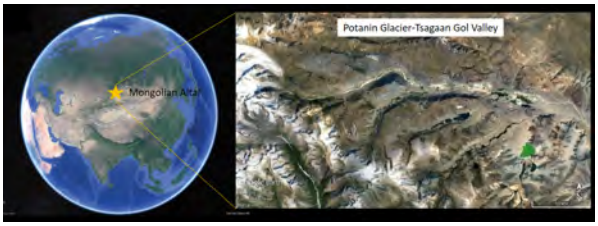

Fig. 1. Google Earth imagery of study area.

Fig. 2. Example of boulder sampled for ^{10}Be surface-exposure dating in the Mongolian Altai, Potanin Glacier in the background. Two-meter measuring tape for scale (Photo: Mariah Radue).

We used ^{10}Be surface-exposure dating to determine the ages of moraines in the Tsagaan Gol-Potanin Glacier valley (Fig. 2). The depositional age of boulders on moraines give ages to former stable ice positions. From the glacier positions, we determine atmospheric temperatures through glaciological and snowline reconstructions. In addition, we performed glacial-geomorphic mapping using drone imagery. We used structure-from-motion software to create high-resolution (~30 cm/pi) elevation models of our sampling areas that underpin our chronology and snowline reconstructions.

Constraining the glacial history of the valley may provide insight into the climate of central Asia during the last ice age and the nature of the last termination.

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

A 1,600-year Ice Core Chemical Record from Central Asia

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Abstract: We present a 1,600-yBP-to-present ice core chemical record from the Pamir Mountains in Central Asia. Core physical properties, stable water isotopes, and preliminary trace elements measurements are presented. Select portions of the record are further explored using ultrahigh resolution laser ablation-inductively coupled plasma-mass spectrometry (LAICPMS). A tentative age-depth scale is refined using multi-proxy volcanic records, and subannual LAICPMS signals.

A New Central Asian Ice Core Record

Central Asia (CA) is one of the most arid places on Earth (Kaser et al, 2010). Human and ecological systems are dependent on annual glacier meltwater delivery during the summer dry season. In 2016, a ca. 37 meter ice core was drilled (to bedrock) in the Pamir mountains of CA. Analysis of the chemical record in this core allows us to build on earlier work (Rodda, et al, 2017, 2018) in defining the abruptness of changes in atmospheric circulation that drive moisture delivery to CA and changes in the scope of water resource availability in the region.

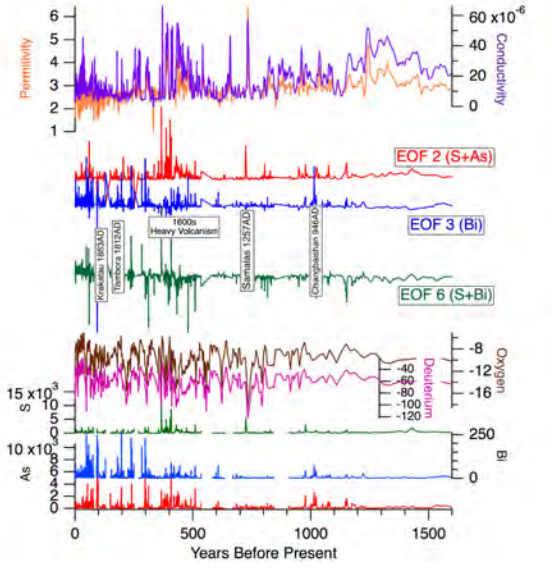

Fig. 1. 1,600 years of select core physical properties, volcanic species co-variance, stable water isotopes, and trace element data in the 2016 Pamir Ice core, with dated major eruptions noted.

Four major eruptions identified using variations in the physical properties of the core and trace element chemistry are used to refine the age-model in the Pamir core. Depth of

A nearly-continuous trace-element record has been obtained for the Pamir core, and indicates significant increases in chemical flux to the Pamir core coincident with the onset of the Little Ice Age (LIA) in CA. This is consistent with existing sediment core records from the region.

The sampling resolution of our records, and additional sampling underway should allow us to develop a characterization of the onset of the LIA that is unprecedented in detail. Laser ablation inductively coupled mass spectrometry (LAICPMS) sub-sampling underway is on sub-daily scales.

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

Bibliography:

Kaser, G., Großhauser, M., Marzeion, B., 2010. Contribution potential of glaciers to water availability in different climate regimes. Proceedings of the National Academy of Sciences of the United States of America 107, 20223–20227.

Rodda, et al., 2017. A 2,000-year climate history of Central Asia. Proceedings of the Borns Symposium. <http://cci.siteturbine.com/uploaded_files/climatechange.umaine.edu/files/2017MiniPaperscombinedreduced.pdf >

Rodda, C, Birkel, S, Mayewski, P., 2018. Future water resource availability in Central Asia based on 2,000yBP to present climate records, Quaternary Science Reviews, In Press.

A Tiny Java Library for Maintaining Model Provenance

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

Abstract: We present a lightweight Java library that simplifies maintenance of the provenance of software object models. The implementation is based on annotations that are interpreted by an extended class loader to inject the Java bytecode to enable model maintenance.

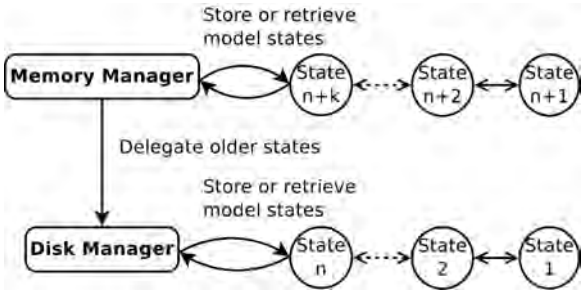
When a software program evolves to meet changing requirements, the object model used in its implementation is likely to evolve as well. Such changes are more frequent and more extensive in scientific software than in business software due to the more fluid requirements in the former. A systematic approach to managing such changes requires maintaining the history and provenance of object models as they evolve. Maintaining such histories explicitly is tedious and error prone.

We present a small Java library (50 KB) that automatically maintains the states of specified model objects. This is achieved by initializing a history manager with an object model and annotating undoable functions. An extended class loader scans annotated classes as they are loaded by the Java Virtual Machine. When an undoable function is encountered, the necessary bytecode to preserve the state of the model is injected into the loaded class file.

In order to inject bytecode, the default class loader is extended, and the **findClass** method is overridden. This allows the class file description to be intercepted, and additional bytecode to be injected at the proper location in method definitions. Only user defined classes are modified; standard Java runtime environment classes are ignored.

A history state manager object is used to preserve previous model states over the lifetime of the application. The application program must first register the object model to preserve with the manager. The model is required to be serializable so that the history manager can take advantage of the default Java serializing mechanisms. It is acceptable for the object model graph to contain cycles, since the serializable mechanism can handle them without issue.

The following figure depicts the memory managers used by the history manager.



The history manager uses a hierarchical chain of history-store objects to preserve the model. By default, one history store is created for saving previous model states on the Java heap, and another history store is created for storing states on disk. The number of states maintained by each store, along with the maximum data size of the store are specified. When a model is saved, it is first handed to the heap memory store. If the amount of heap memory would be exceeded, then the model is passed to the child store. Older states are delegated to the slower disk storage as the heap memory manager becomes full.

Acknowledgements: Valuable input from Dale Royer is gratefully acknowledged.

The Kangerlussuaq International Research Network (KAIRN)

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Abstract: An international working group formed in 2015 to assess environmental change across the Kangerlussuaq, Greenland landscape. With 28 members from 7 different countries, the group is using the Kangerlussuaq area as a model system experiencing abrupt climate change, and has analyzed recent responses in the margin of the ice sheet, rivers, glacial outwash plains, and terrestrial and lake ecosystems.

In 2015, an international working group formed to assess recent climate-driven changes across the West Greenland landscape. This group, with 28 members from 7 different countries, is focused on synthesizing biogeochemical linkages across paraglacial landscapes, and in the future will assess how these are being altered with and feeding back into environmental change. The group is using the Kangerlussuaq area as a model system, and includes data from systems such as the margin of the ice sheet, rivers, glacial outwash plains, as well as terrestrial and lake ecosystems, and incorporates the role of organisms spanning from bacteria to caribou.

During the first workshop, the group produced a publication synthesizing current biogeochemical linkages across the Kangerlussuaq landscape, and projecting future changes (Anderson et al. 2017). The second and third workshops focused on producing a manuscript assessing recent climate change and how ecosystems across the landscape are responding. Workshop activities are summarized by Northington et al. (2016).

We will discuss the results of the latter two workshops, which reveal that the region has experienced abrupt climate change since 1994. Widespread, nonlinear environmental responses have occurred with or shortly after these climate shifts, revealing surprisingly tight coupling of environmental response to climate.

Fig. 1. A sub-set of the KAIRN working group convening in Sogndal, Norway, in May 2017.

Bibliography:

Anderson, N.J., J.E. Saros, J.E. Bullard, S.M.P. Cahoon, S. McGowan, E.A. Bagshaw, C. Barry, R. Bindler, B.T. Burpee, R.A. Fowler, M. Giles, L. Hamerlik, A. Law, S.H. Mernild, R.M. Northington, C.L. Osburn, S. Pla-Rabes, E. Post, J. Telling, E. Whiteford, M. Yallop, and J.C. Yde. 2017. The Arctic in the 21st century: Changing biogeochemical linkages across a glacial landscape of Greenland. *BioScience* 67: 118-133.

Northington, R.M., J.E. Bullard, and J. Telling. 2016. Climate-driven change in ice-free areas of Greenland. *EOS* 97, doi: 10.1029/2016EO060283

Anthropogenic Trace Elements (Bi, Cd, Cr, Pb) Emissions in the West Antarctica

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Abstract: In this study, long-term Bi, Cd, Cr, Pb records in West Antarctica during the period 1882–2015 is presented based on ice-core concentration analyses from Pine Island Glacier ice divide, West Antarctica. The results show that anthropogenic activities were likely important contributors to those trace element records.

Project Goals

Atmospheric concentrations of trace elements are influenced by natural and anthropogenic processes. Most anthropogenic sources (fossil fuel combustion, smelting, industry, agriculture, and large-scale land use) have increased since the late 19th century becoming a worldwide issue for humans and the environment. Here, we present long-term Bi, Cd, Cr, and Pb records (Fig. 1) in West Antarctica during the period 1882–2015 based on ice-core concentration analyses from Pine Island Glacier ice divide.

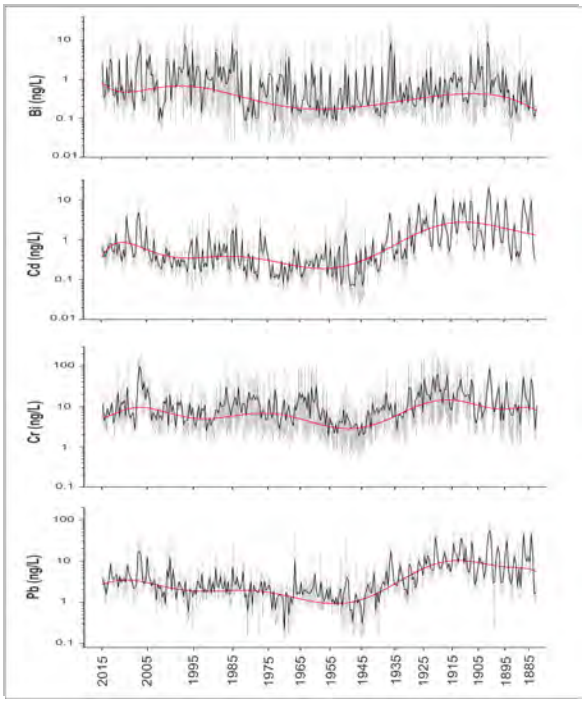

Fig. 1. Bi, Cd, Cr, and Pb records in West Antarctica during the period of 1882–2015.

Two Mount Johns ice cores (79°55'28" S, 94°23'18" W, 2100 m a.s.l) were recovered in the austral summer of 2008/2009 (91.20 m depth) and 2015 (19.12 m depth). Trace element concentrations were determined using inductively coupled plasma mass spectrometry (CCI/UMaine).

Results

The results of enrichment factor and principal component analysis revealed that anthropogenic activities were likely important contributors to those trace element records (Fig. 2).

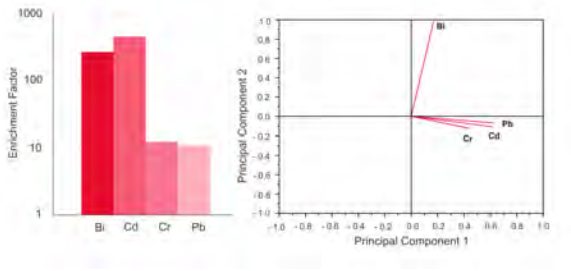

Fig. 2. Enrichment factors in relation to Earth's crust (EFc) and Principal Component Analysis.

We find that Bi, Cd, Cr, and Pb emissions increased after 1884 and remained high until the late 1920s, with a temporary low during the Great Depression (1931) and again at the end of World War II (1948). After 1960 the concentrations of these elements in the ice increase again and remain above background levels until the present.

Acknowledgements: CNPq project 407888/2013-6 and post-doc grant CAPES 88881.120030/2016-01.

North American Trees Underfill Climatic Ranges

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Abstract: The relative influence of climatic and non-climatic factors in constraining ranges has been rarely quantified, despite fundamental importance for forecasting future biodiversity loss. We tested equilibrium with potential climatic ranges and analyzed the range shapes relative to potential ranges to detect disequilibria drivers. We conclude that drivers vary with range size, and climate is a poor predictor for small ranged species, which show dispersal limitations.

Understanding species' geographic ranges and their relationship with climate is essential for forecasting future biodiversity loss. Many studies attempt to predict range shifts or contractions under future climate change; however, these methods assume species are in equilibrium with contemporary climate[1]. This assumption has been challenged by evidence of disparities between species realized and fundamental niches[2], which may be driven by dispersal and establishment lags in response to past climate change[3] or biotic interactions inhibiting population growth[4]. These insights point to the growing need to quantify the relative influences of climate and non-climatic factors in governing geographic ranges, particularly as we forecast biodiversity responses to climate change. We tested the degree to which species are in equilibrium with their potential climatic ranges against a geometric, non-ecological null model. We also analyzed the shapes of ranges relative to their potential ranges to detect the drivers of disequilibrium.

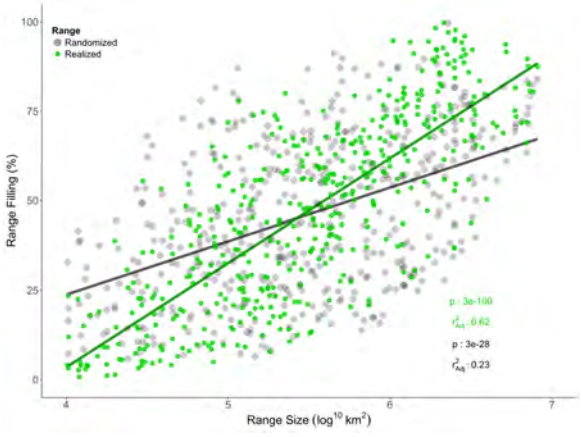

Fig.1. Positive correlation between range size & filling.

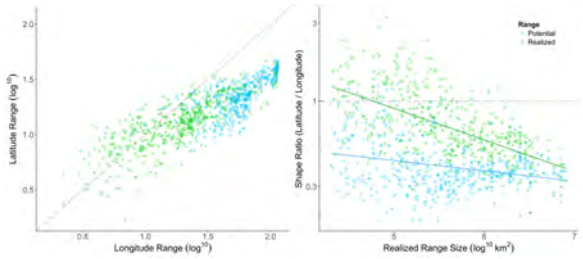

Fig.2. Small-ranged species have more circular ranges, large-ranged match potential range shapes.

We found widespread evidence that the potential climatic ranges of North American trees are largely under-filled, with mean range filling values of just under half (47.5%). Additionally, small ranged species underfill their ranges and large ranged species overfill their ranges in comparison to the geometric null ranges (Fig.1), suggesting range-filling is revealing ecological processes involving in determining range sizes. Range shape was lowest for large-ranged species and approached and was > 1 for small-ranged species. This trend was found in potential range shapes as well, with their values being lower on average than those of the realized ranges (Fig.2). This suggests that large ranged species more closely conform to physiological climate barriers, while small-range species show influence of dispersal limitations.

Acknowledgements: I would like to thank the CCI, SBE, EES, and UMaine for support.

Bibliography: 1) Pearson, Richard G., and Terence P. Dawson. *Global Ecology and Biogeography.* (2003)
2) Hargreaves, Anna L., Karen E. Samis, and Christopher G. Eckert. *The American Naturalist.* .(2013).
3) Svenning, Jens-Christian, and Brody Sandel. *American Journal of Botany*. (2013).
4) Brown, Carissa D., and Mark Vellend. *Proceedings of the Royal Society of London B: Biological Sciences.* (2014)

Evaluating Numerical Simulations of the December 2013 Ice Storm Across Maine, USA

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Abstract: Accurate numerical weather forecasts of severe storms are reliant on robust depiction of atmospheric processes, especially at subgrid scales. We tested the sensitivity of physics parameterizations for processes within the planetary boundary layer (PBL) in the WRF model. Results do not indicate a clear "best" choice, but instead highlight model deficiencies that should be improved upon.

Here we evaluate numerical simulations of the damaging December 2013 ice storm across Maine, USA using the Weather Research and Forecasting (WRF) model (Skamarock et al, 2008). An overarching goal is to improve accuracy in forecasting areas of damage to civil infrastructure from winter storms. WRF is a mesoscale numerical weather prediction model that includes a suite of physics parameterizations of subgrid-scale processes that are not explicitly resolved due to resolution limitations. Such parameterizations have a modularized design and interact indirectly through the modification of state variables. The appropriate choice of physics options is dependent on model setup and factors related to simulation domain, season, and type of weather event.

Thus far we have focused on testing model sensitivity to changes in PBL physics. Other simulations tested the effects of grid nudging and increasing the model vertical resolution. Large-scale features such as the frontal boundary location are generally consistent with observations (Figure 1), but the performance of individual PBL schemes differ by location and variable. Biases present in all tests are related to known model deficiencies, such as overestimation of wind speeds for low wind conditions and underestimation of surface temperatures over snow cover. A publication is in preparation and will be completed pending final analyses.

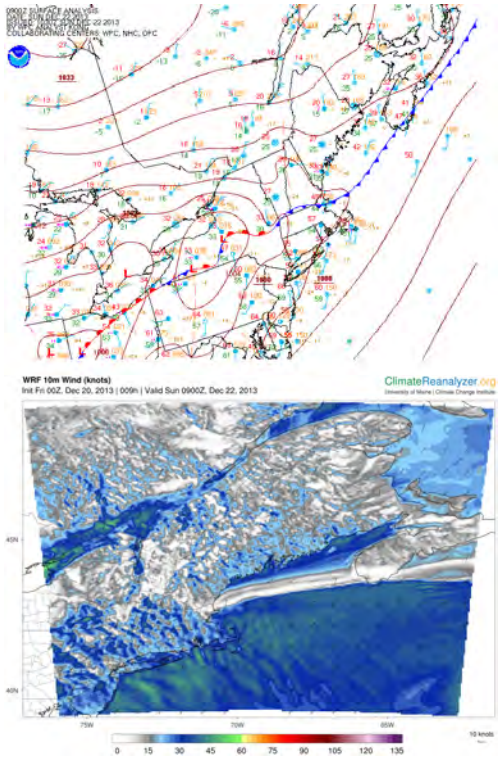

Fig. 1. Comparison of frontal boundary location for modeled 10 meter winds (bottom) to surface analysis (top).

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

Bibliography:

Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, D. M. Barker, M. G Duda, X.-Y. Huang, W. Wang, and J. G. Powers, 2008: A Description of the Advanced Research WRF Version 3. *NCAR Tech. Note NCAR/TN-475+STR,* 113 pp. doi:10.5065/D68S4MVH

Differential Retreat Rates Barnes Ice Cap, Arctic Canada: 1985-2016

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Abstract: Analysis of satellite imagery from 1985 and 2016 shows that the retreat rate of the margin of Barnes Ice Cap varies significantly with location along the periphery. Consistent with a modeling effort by Gilbert, et al. (2017), the northeast margin is retreating more slowly (9.1 m/a) than the southwest margin (mean ~12 ma^{-1}). Along the southwestern margin retreat rates vary within areas that have surged or not surge.

Introduction

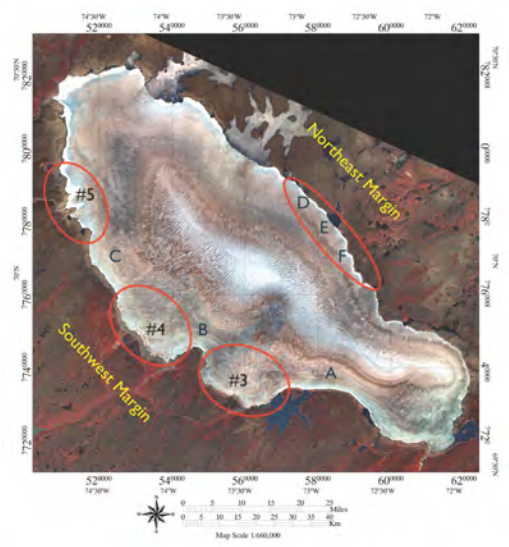
Barnes Ice Cap covers ~5750 km^2 near the center of Baffin Island in Arctic Canada. At its base is Pleistocene ice — the last remnant of the Laurentide Ice Sheet that once covered much of North America (Hooke, (1976). The August, 1985 ice margin was digitized using Landsat7 imagery with 15 m spatial resolution. The August, 2016 margin was digitized using a Landsat8 image with 30 m spatial resolution. All images are Level 1, Tier 1 with a radial root mean square error between common points of ≤12 m.

Changes

The 1985 area of the ice cap was ~5920 km^2. In 2016 the area had decreased to ~5450 km^2. The average retreat of the margin during this time period was 12.6 ma^{-1}. For comparison, Sharp, *et al.* (2011) reported the 1958 area as 5995 km^2 and the 2000 area as 5874 km^2. Combining these results, the area decrease at a rate of ~3 km^{2}a^{-1} of area from 1958 to 2000, and ~8 km^{2}a^{-1} since 2000.

Between 1985 and 2016, the mean retreat rate along 23 km of the northeastern margin was 9.1 ma^{-1} while that along the southwestern margin, including Surge Lobes 4 and 5, was 15.0 ma^{-1} (weighted mean). Gilbert (2016, p. 1530) attributed the more rapid retreat of the southwest margin to the general southwesterly slope of the bedrock; his modeling suggested that this would result in higher emergence velocities on the northeast side. However, he also acknowledged an asymmetry in mass balance due to the lower elevation of the southwestern side. Surge lobes 4 and 5 seem to be retreating slightly more rapidly than the average for the southwestern side, but the differences are small, and within the limits of uncertainty in our measurements (± ~ 1 ma^{-1}).

Additionally, the southwestern margin will receive, on average, more solar radiation due to the geographical aspect of the ice cap with its long axis in a NE-SW direction. What role, if any, this may play in the differing retreat rates is, at present, unknown.



Surge Area	Non-Surge	Retreat Rate Area, ma^{-1}
#3	—	5.2
#4	—	15.9
#5	—	16.5
—	A	8.0
—	B	10.8
—	C	14.9
—	D	8.5
—	E	8.3
—	F	9.3

Acknowledgements:

Gilbert, A. et al., 2017. The projected demise of Barnes Ice Cap: Evidence of an unusually warm 21st century Arctic Geophysical Research Letters,44, 2810-2815. Hooke, R. LeB., 1976. Pleistocene ice at the base of the Barnes Ice Cap, Baffin Island, N.W.T., Canada Journal of Glaciology, V17, N75, 49-59. Sharp, et al., 2011. Remote sensing of recent glacier changes in the Canadian Arctic. Global Land Ice Measurements for Space, Kargel, J. et al. Eds.

Climate-Driven Migration: Prioritizing Cultural Resources Threatened by Secondary Impacts of Climate Change

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Abstract: Coastal archaeological sites are at risk due to primary impacts of climate change (sea level rise (SLR), flooding, erosion). Increasingly, secondary impacts (destruction by climate-driven resettlement) threaten these resources, which represent cultural and paleoenvironmental records archiving millennia of human occupation. Assessing risk calls for the development of standard methods for prioritizing highest-risk sites that can be used by researchers, communities, and governmental officials. This study integrates decadal-to-centennial climate projections, socio-economic and demographic data, and land use and cultural resource management regulations to create a risk assessment framework. The products are multi-scalar maps at the town and parcel level in Southern Maine that identify and prioritize cultural resources threatened by secondary climate impacts. This approach can be used for risk evaluation in similar coastal regions.

Project Goals

Archaeological sites are important culturally and as paleoclimatic and environmental proxies. In the coastal zone, climatic threats to sites grow yearly, and primary impacts of SLR, erosion, and flooding are easily identified. However, little attention has been given to the secondary impacts which threaten inland cultural resources via the landward migration of coastal populations.[1] This pilot study proposes a quantitative risk assessment framework for site prioritization that will enable communities to develop informed development plans that mitigate site damage (a legal requirement when federal funds support "resettlement" and/or as required by state or local law). The products are multi-scalar spatial tools that indicate potential site destruction due to climate-driven changes in population and infrastructure density from the present to 2100.

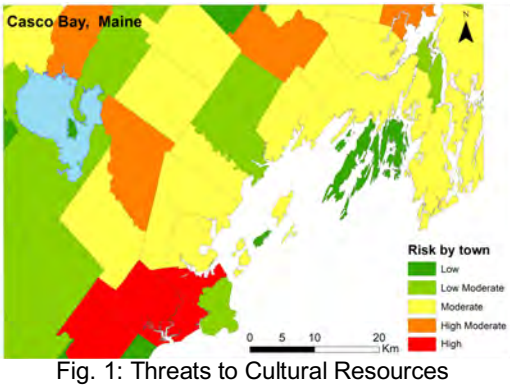

Fig. 1: Threats to Cultural Resources

Results

A summed risk matrix was developed with socio-demographic, economic, and geographic criteria (equally weighted as factors affecting overall risk to heritage). Results do not follow first order trends (Fig. 1). Three towns clustered in the southern portion of the Casco Bay region were categorized as 'High Risk'. Despite having higher than average property taxes, they met all other criteria for likely resettlement of displaced populations. 'High Moderate Risk' towns are all interior, and have seen the most rapid growth in housing unit construction in the past two decades, as well as moderate to rapid growth in population density during this time (U.S. Census growth categories).[2] This framework allows researchers, communities, and government officials to identify towns and parcels where increased population and infrastructure density are likely to occur over the remainder of this century and will affect known heritage sites.

Acknowledgements: Research funded by a CCI Graduate Research Assistantship. Archaeological data provided by the Maine Historic Preservation Commission), GIS data from MEGIS.

Bibliography: [1] Anderson et al. (2017). Sea-level rise and archaeological site destruction: An example from the southeastern United States using DINAA (Digital Index of North American Archaeology). *PloS one*, *12*(11), e0188142. [2] Christopher Mazur and Ellen Wilson, *Housing characteristics: 2010*. US Census Bureau, 2011.

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

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

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

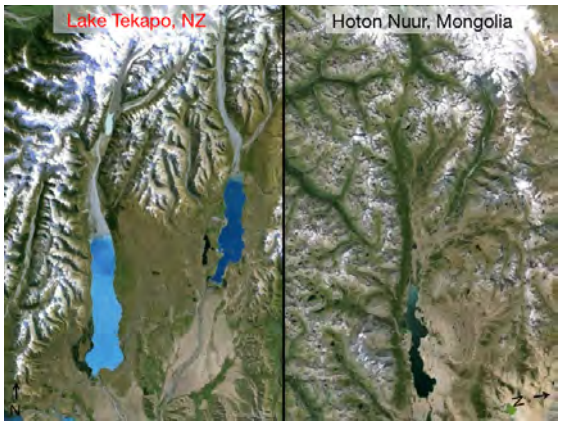

Figure 1. Comparison the Lake Tekapo basin, New Zealand and Hoton Nuur valley, Mongolia

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

A Model-Based Approach to Incorporate Environmental Variability Into Assessment of an CAmerican Lobster Fishery

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2. *School of Marine Sciences, University of Maine.*

Abstract: The climate-driven habitat suitability index was used to inform the lobster recruitment dynamics within the size-structured population dynamics model. The performance of the assessment model with an environment-explicit recruitment function is evaluated by comparing relevant assessment outputs. The environmentally-informed lobster assessment model estimated higher recruitment in the late 2000s and early 2010s.

Changes in bottom-up forcing are fundamental drivers of the fish population dynamics. Recent literature has highlighted the need to incorporate the role of dynamic environmental conditions, particularly climate variability in the assessment of the fishery stocks as a key step toward the adaptive fishery management in a changing environment.

Combining a bioclimate envelope model and a population dynamic model, we propose a model-based framework that can incorporate ecosystem products into single-species stock assessments. The proposed framework was applied to a commercially important American lobster stock in the Gulf of Maine - Georges Bank (Fig. 1).

Changes in annual median lobster recruit habitat suitability index during 1984-2013 were treated as an index of environmental variability, which was assumed to have influenced the stock recruitment dynamics during the period. The environmentally-informed lobster assessment model showed higher recruitment in the early 2010s and improved model fit. This analysis indicates that climate-driven changes in lobster habitat suitability contributed to increased lobster recruitment.

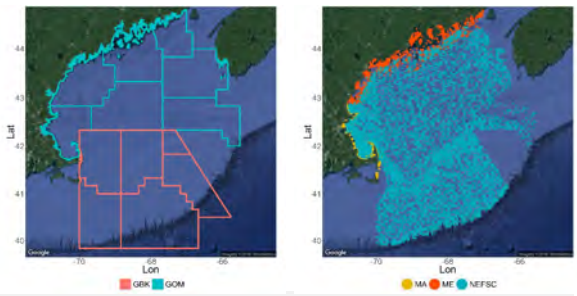

Figure. 1: Gulf of Maine/Georges Bank lobster stock management areas (left) and sampling locations from bottom trawl surveys during 1984-2013 (right).

The framework was designed to improve assessment of the U.S. American lobster stocks but extendable to other fish populations that are impacted by environmental change. The proposed model-based framework can improve our understanding of environmental-driven marine ecological processes and ability to assess the status of exploited fishery resources, which can potentially enhance our adaptive management capacity in changing environment.

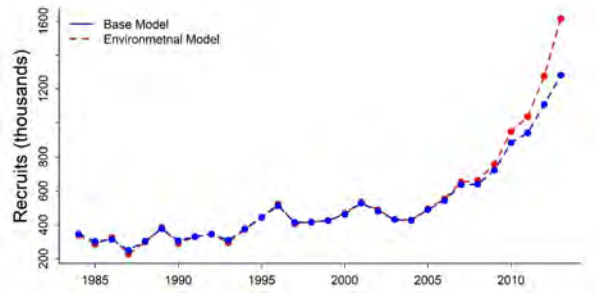

Figure 2: Comparison of stock assessment model estimates for recruitment (top) and fishing mortality (bottom) with and without environmentally informed recruitment dynamics.

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

Bibliography:

Haddon, Malcolm. Modelling and Quantitative Methods in Fisheries. Cambridge University Press, 2011.

The Paleoecology of Great Duck Island with Emphasis on Charcoal Analysis

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

Abstract: An analysis of a 2m peat core collected from Great Duck Island (GDI), a 220 acre island in the Gulf of Maine, Hancock county, reveals paleoecological events spanning thousands of years. Through incremental sediment analyses by x-ray imagery, geochemistry, charcoal abundance, pollen and Sporormiella identification, this core enables reconstruction of the paleoecological and paleoclimatological story of GDI including information on nesting seabirds, human activity, vegetation characteristics, and storm records.

Background

The Great Duck Island (GDI) core was taken in 2011 as part of a larger study involving a transect of 10 offshore island cores from Gulf of Maine locations that will ultimately identify nesting seabird activity and changes in sea surface temperatures across the Gulf. GDI hosts the Alice Eno Field Research Station, an active research site managed by College of the Atlantic (figure 1).

Figure 1. Drone imagery of GDI taken by Michael Cornish, 2016.

Methodologies

We subsampled and analyzed the core for charcoal and conducted preliminary 210Pb dating. We subsampled the first half of the core for charcoal at 2cm intervals with each centimeter represented evenly in a $1cm^3$ sample. The second half was subsampled at 1cm intervals. We bleached samples in H2O2 for 12-24 hours and then filtered them through 250µm and 125µm sieves. We counted charcoal fragments >250µm in the sieve. We washed filtrate caught in the 125µm sieve and dried it at 50°C before counting fragments.

Preliminary Results

We constrain ages for portions of the core using a combination of ^{210}Pb dating and radiocarbon dating of organic materials. Preliminary results suggest sedimentation rates on the order of ~0.1cm/yr for the upper ~20-30cm of the core. This age model suggests that the core represents the last ~1,400 years. counts of >250µm charcoal reveal three zones starting at depths of 30cm, 51cm, and 65cm that all contain more than 100 charcoal fragments. Each of these depths represent events that happened more than 150 years ago. The upper most fire event 30cm down the core overlaps with the first known family to live on the island and a second landowner clearing much of the north end of GDI for farming and grazing.

Acknowledgements

Supported by the Geological Society of Maine Walter A. Anderson fund and the Maine Space Grant Consortium.

Special thanks to Dr. John Anderson lead researcher and supervisor of College of the Atlantic's Alice Eno Field Research Station on GDI whom none this would have been possible without.

How do Changes in the Timing of Ice-Out Affect Arctic Versus Boreal Lakes?

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Abstract: In many regions of the Northern Hemisphere the timing of lake ice-out has advanced. Less is known about how changing ice-out influences lake properties and how this may vary regionally. The goal of this research is to evaluate the effects of ice-out on thermal stratification as well as biological and biogeochemical characteristics during an early and late ice-out regime in Arctic and boreal lake ecosystems.

Changes in the timing of ice-on, ice-out, and the duration of ice cover are occurring throughout the Northern Hemisphere (Magnuson et al. 2000), and the effects of this changing ice phenology varies due to regional differences. For example, ice out occurs later in the year in Arctic lakes compared to boreal lakes and the duration of the ice-free season is shorter. In Arctic and boreal regions, in addition to differences in ice-out, there are also important climate factors such as temperature, precipitation, solar insolation, and permafrost thaw that drive lake responses. We assessed how differences in ice-out influence thermal stratification and the subsequent biological implications in both Arctic and boreal lake ecosystems during an early and late ice-out regime in late spring and evaluated the role of key climate factors.

Our results suggest that there are regional differences in lake response between early and late ice-out years. During the early ice-out year, mixing depths were deeper in Arctic lakes and shallower in the boreal lake (Fig. 1). This finding supports different patterns in the influence of the timing of ice-out on the length of spring turnover. Additionally, this difference has important biological implications on specific phytoplankton taxa in the Arctic lakes.

This research demonstrates differences in Arctic and boreal lake responses between early and late ice-out years, and that important climate factors are key drivers of the observed changes. Better understanding of the links between physical and biological effects would allow for a better understanding of biological implications from changing ice out within lakes.

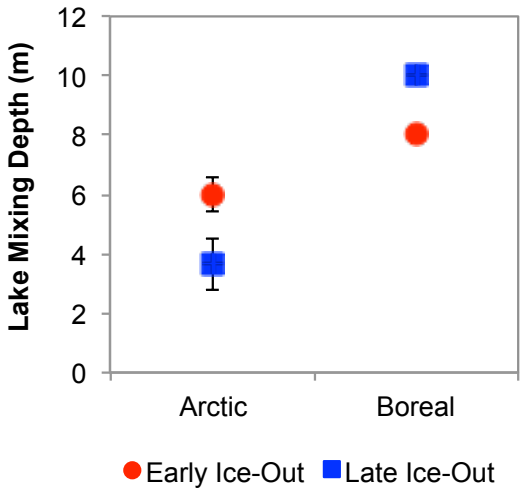

Fig. 1. Comparison of lake mixing depths for early and late ice-out conditions during the late spring in Arctic and boreal lakes. Response of three Arctic lakes are averaged (mean ± standard error) for each season.

Acknowledgements: Arctic data were funded by two grants from the US National Science Foundation (grants #1203434 and #1144423). Boreal data were funded by the Maine Agricultural and Forest Experiment Station Project ME021409.

Bibliography: Magnuson J.J. et al. 2000. Historical trends in lake and river ice cover in the Northern Hemisphere. Science. 289:1743-1746.

Holocene Climate, Vegetation, Fire and Human Impacts in Jamaica, West Indies

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Abstract: Jamaican ecosystems have significant conservation value due to high species diversity and endemism. However, the sensitivity of these ecosystems to past climate and environmental forcing is poorly understood. Multi-proxy paleoecological studies enable the reconstruction of prehistoric environmental conditions, which helps us contextualize modern rates of ecological change and set ecosystem restoration targets. We collected a new sediment core from Wallywash Pond, Jamaica in February 2018 to evaluate the response of Jamaican vegetation communities to past human and non-human stressors. The analysis of lake sediments from Jamaica will contribute to an improved understanding about climate and environmental changes in the Holocene tropics, and will provide valuable ecological data for local conservation planning efforts.

Background

Jamaican biodiversity faces increasing threats from deforestation, human encroachment, bauxite mining, and climate change, yet little is known about the response of Jamaican ecosystems to environmental variability over long timescales. To date, no studies have examined millennial-scale vegetation changes in Jamaica. We collected a new sediment core from Wallywash Pond, Jamaica to assess the response of Jamaican vegetation to past natural and anthropogenic disturbances, and to help constrain the timing of first human arrival on the island, using a multi-proxy analytical approach.

Recent Advances

8 m of sediment (see Fig. 1) were collected from Wallywash Pond (18° N, 78° W), Jamaica using a 2-inch Livingstone piston corer; several drives were taken with polycarbonate tubes using a Bolivia adapter. Wallywash Pond (area: 0.76 km^2) is the largest freshwater lake on the island.

Fig. 1. Core sections collected from Wallywash Pond, Jamaica. Images were taken at the National Lacustrine Core Facility (USA).

We also conducted a rapid vegetation survey. Upland areas adjacent to the lake were dominated by logwood (*H. campechianum*) and dense thickets of pepper rod (*C. humilis*). The lake margin was dominated by cattails (*T. domingensis*), sedges (*E. elegans*) and grasses (*P. australis*). The dominant aquatic vegetation was longleaf pondweed (*P. nodosus*).

Initial core description, high-resolution digital imaging, and core logging were conducted at the National Lacustrine Core Facility (USA). Core logging generated geophysical proxy information, including magnetic susceptibility and electrical resistivity, that will illuminate past environmental changes at Wallywash Pond.

Future Directions

Analysis of biological sedimentary proxies, such as pollen, charcoal, and *Sporormiella* will be conducted at the University of Maine. These proxy data will inform us about changes in vegetation, fire, and grazing pressure, respectively. Ostracod stable isotope ratios will inform us about climate variability. This research will provide crucial insights into the role of human and non-human drivers in shaping Jamaica's ecosystems with implications for paleoecological, archaeological and historical interpretations of the island's landscapes.

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