Quantifying Bias in Our Abundance Estimates of Migrating Birds to Predict Responses Due to Changing Weather and Climate

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Abstract: Migratory birds are sensitive to changing climatic and weather conditions but we currently have limited ways to estimates these effects. Using new hierarchical modeling methods we analyzed bird migration banding station data to determine the probability of detecting Black-throated Blue Warblers during migratory stopover. We found that daily changes in weather influenced the detection probability of this songbird and that this model was needed for accurate estimates of migratory population size.

A Mismatch of Life History and Modeling

Bird migration is sensitive to changes in climate and weather at the wintering grounds, over migration and at the breeding grounds.[1] Birds develop new migratory strategies and routes over time in apparent response to these changes.[2] As much of our current and historical data on bird migration comes from bird banding stations designed to monitor migration, we need to understand the biases of these monitoring techniques in order to use them to accurately predict their response to a changing climate.

This study uses a new kind of hierarchical modeling framework to estimate the size of the migratory stopover population of Black-throated Blue Warblers for the first time. Dail-Madsen models relax the assumptions of population closure among sampling intervals, which allows for the estimation of daily population size at migration monitoring stations.[3] Using sub-daily weather data (e.g., wind speed, atmospheric pressure, etc.) from nearby Miami International Airport and 10 years of bird migration banding data from Cape Florida Bird Observatory at the Bill Baggs Cape Florida State Park we determined how weather affected Black-throated Blue Warbler stopover population size.

The model simultaneously estimates four parameters at the daily scale: (1) initial population size, (2) immigration to the site, (3) emigration from the site and (4) probability of detection. We found that detection probability was affected by a variety of weather covariates during the capture period including wind speed, wind direction, temperature, and rainfall once we controlled for netting effort. Weather conditions that create migratory fallouts during the early morning also influence detectability. This led to a mismatch between naïve estimates of relative abundance and the detection-corrected estimates (Fig. 1).

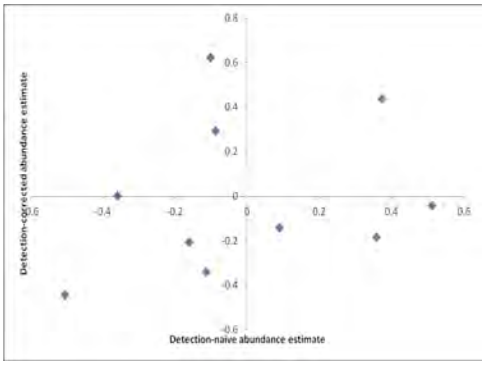

Fig.1. Correlation between normalized detection-naïve and detection-corrected estimates of annual abundance ($r<0.1$).

This effort highlights the importance of estimating detectability in surveys of bird migration and using hierarchical models to deal with surveys of animals with complicated life histories. Models such as these will be useful for making accurate regional-scale predictions for how bird respond to climate change.

Acknowledgements: The authors thank Bill Baggs Cape Florida State Park and the Biodiversity Research Institute for support.

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[1]Jenni *et al.,* "Timing of autumn bird migration under climate change," 1467-1471.

[2]Bearhop *et al.*, "A mechanism for rapid evolution of a migratory divide," 502-504.

[3]Dail and Madsen, "Estimating abundance of an open metapopulation," 577-587.

Mobile Applications with RESTful Web Interfaces*

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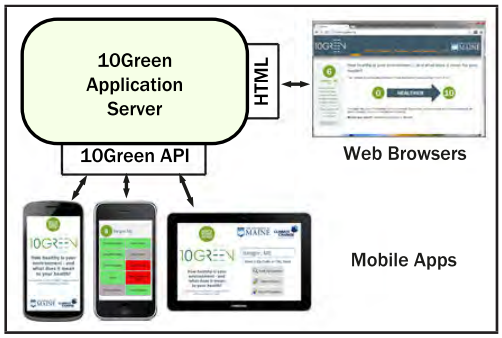
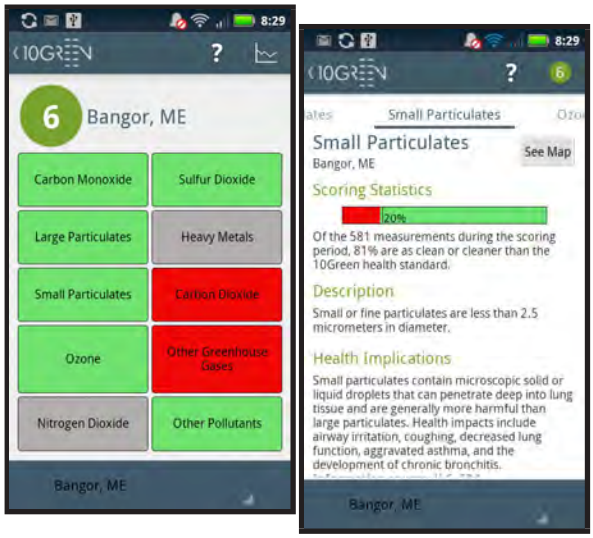
The 10Green Web application (10Green.org) integrates air quality data from diverse sources and provides an intuitive interface that summarizes this information in a manner accessible to scientists and non-scientists alike. The 10Green application programming interface (API) is an extension to the underlying server architecture to support the development of mobile applications for phones, tablets, and other handheld devices. The increasing popularity of these devices makes them powerful tools for the dissemination of climate data.



The 10Green mobile applications provide convenient access to the 10Green data using interfaces that are specially designed for mobile devices. Each mobile application uses the interface features and conventions that are native to the target platform (such as Android or iOS), as well as a format for display that is tailored for the often small screens of these devices.



In order to support mobile devices in an efficient and scalable manner, the 10Green application server implements a RESTful application programming interface.[1] REST (Representational State Transfer) is a client-server software architecture for distributed applications that improves scalability and enforces a structured and uniform interface. In order to request climate data from the server, a mobile client interacts with one of the available *resources* that are published by the server using a set of global identifiers (HTTP URIs). For example, the client may retrieve information about a parameter (one of the air quality measures) by sending an HTTP GET request to the parameters resource using the URI `http://10green.org/api/parameters/co`, which identifies the parameter with identification code "co" (carbon monoxide). Information about the complete set of parameters may be retrieved in a single transaction using `http://10green.org/api/parameters/all`.

The 10Green API transfers the requested resource data in a structure that is optimized for programmatic access, permitting convenient parsing with low overheads. The two representations currently supported are JSON (JavaScript Object Notation) and XML (Extensible Markup Language). The client specifies its preferred format using an HTTP Accept header. In our carbon monoxide example, a client requesting the information using XML encoding receives the following in response:

```
<parameter code="co" id="2">
  <uri>www.10green.org/api/parameters/co</uri>
  <name>Carbon Monoxide</name>
  <stdunit code="7">
    <desc>Parts per million</desc>
    <htmldesc>ppm</htmldesc>
  </stdunit>
  <standard>5.0</standard>
  <tengreen>1</tengreen>
</parameter>
```

Additional meta-information, such as expiration and caching requirements, is specified in the HTTP response headers. Using a sequence of such transactons, mobile clients (and other applications) can request information required by the user (parameters, 10Green scores, map properties, etc.) and display it using any appropriate method, allowing for flexible and creative uses of the 10Green data.

*Work supported in part by U.S. National Science Foundation grant EAR-1027960, the University of Maine, and the Heinz Endowments. The work of the *10Green* team are gratefully acknowledged.

[1] Erik Albert and Sudarshan S. Chawathe, 'A REST Framework for Dynamic Client Environments', in: Erik Wilde and Cesare Pautasso, editors, *REST: From Research to Practice*, (Springer, August 2011). – chapter 10.

Maya Obsidian of the Three Rivers Region, Belize

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Abstract: A sample of obsidian artifacts housed at the Programme for Belize Archaeological Project's (PfBAP) field laboratory situated in the Rio Bravo Conservation and Management Area (RBCMA), Belize, was geochemically analyzed using portable x-ray fluorescence spectrometry (PXRF).

This paper presents preliminary data concerning an obsidian provenance study conducted over the 2012 summer field season. This project is largely exploratory in nature in terms of obsidian source studies and the application of field portable x-ray fluorescence spectrometry technology (pXRF) in the Three Rivers Region of northwestern Belize. Furthermore it aims to contribute to and build upon the ongoing multidisciplinary research goals for which the various projects within the Programme for Belize Archaeological project (PfBAP) are known. The research goals of this project were designed to address the following questions: (a) how is obsidian distributed throughout the sites of the Three Rivers Region, (b) how do these patterns vary temporally and contextually, and (c) how do they compare to other sites/areas in the Maya Lowlands? The answers to these questions will undoubtably allow for further insight into the regions political and economic integration within Maya society as a while. As a largely explorative methodology, it also seeks to further assess the reliability and value of pXRF obsidian studies in Maya lowland
Research.

The Three Rivers region is a geographically defined area lying across the transition between the eastern Peten karst plateau and the Belize coastal plain occupying areas in northwestern Belize, northern Guatemala and Quintana Roo, Mexico. The area is dominated by three imposing limestone escarpments and rivers which provide the regions namesake (Dunning et al 2003). Culturally, the area lies along the eastern margin of the central Maya lowlands which was home to some of the largest Classic Maya centers such as Tikal and El Mirador (Zaro & Houk 2012).

Obsidian, a widely used material by the ancient Maya for thousands of years in the production of a variety of utilitarian stone tools and ritual items, was imported in great quantity from distant sources in highland Guatemala and Central Mexico.

PXRF analysis was performed at the PfBAP's field laboratory in May - June of 2012. Obsidian artifacts were drawn from the available assemblage curated at the field laboratory. In total 1738 chemical analyses were made on over 1700 individual obsidian artifacts.

Patterns of distribution in source material identified through pXRF analysis have provided clues into the regions integration in ancient Maya exchange networks and highlight the validity and potential for future pXRF analysis in the Maya Lowlands.

Acknowledgments: Dr. Bruse Kaiser, Bruker-AXS, The Dan & Betty Churchill Exploration Fund, Programme for Belize Archaeological Project, Graduate Student Government. Dr. Gregory Zaro & Kurt Rademaker, Climate Change Institute & Department of Anthropology, University of Maine. Dr. Brett Houk, Texas Tech University. Dr. Fred Valdez Jr., University of Texas Austin.

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Zaro, G., B. A. Houk 2012. The Growth and Decline of the Ancient Maya City of La Milpa, Belize: New Data and New Perspectives from the Southern Plazas. *Ancient Mesoamerica* 23: 143–159.

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Triple Junction, Bubble, and Grain Boundary Influences on Impurity Concentrations in Polar Ice

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Abstract: The W. M. Keck Laser Ice Facility LA-ICP-MS is capable of collecting a sample every 10 micrometers, a resolution on the scale of ice crystal triple junctions, bubbles, and grain boundaries in ice cores. Recent publications suggest that these features amplify impurity concentration, and allow migration through veins potentially obscuring the climate signals preserved in ice. LA-ICP-MS data reveal that such features do not significantly modify these signals.

The Laser Ablation Inductively Coupled Plasma Mass Spectrometer (LA-ICP-MS) is a newly developed instrument at the Climate Change Institute that is capable of sampling ice cores at 250,000 samples per meter, a resolution that could allow researchers to see storm signals in low snow accumulation areas, and in highly compacted areas, such as the base of ice cores. Recent publications, such as Barletta et al. (2012), suggest that grain boundaries and veins, which are connected triple junctions (Figure 1), within the ice concentrate impurities up to 10^5 times above the bulk composition. This would obscure the climate signal preserved, and make the sampling resolution of the LA-ICP-MS system ambiguous.

Fig. 1. The laser ablation trench (moving from the right) just before it sublimates the triple junction circled in the image. The triple junction can be recognized by the three surface groves (grain boundaries) meeting.

If climate signals were not preserved intragranularly as they are intergranularly, grain size would dictate the maximum sampling resolution (millimeter scale). This is not observed in the laser ablation data presented in Figure 2.

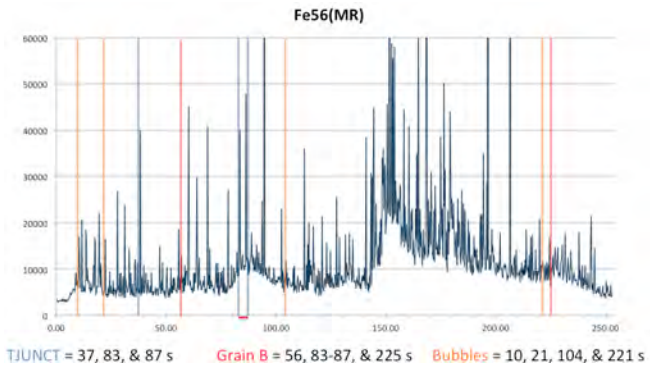

Fig. 2. Counts per second of iron (Y axis) vs. time in seconds (X axis) of laser sublimation. This data was collected over 2 centimeters of ice (1000 samples) that contained multiple triple junctions, bubbles, and grain boundaries.

This preliminary investigation demonstrates that features such as triple junctions, bubbles, and grain boundaries can concentrate impurities, but not above the magnitude of the surrounding climate signal peaks that are detected intra-granularly. Moreover, peaks in impurity concentration found in such features account for less than 5% of total peaks observed. Thus, climate signals are preserved, at least to the micrometer scale, making the detection of storm signals in ice cores at depth possible.

Acknowledgements: W. M. Keck Foundation, National Science Foundation

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The Impact of Abrupt Changes to the Gulf of Maine on Lobster Harvesters

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Abstract: Abrupt changes in the climate threaten the Gulf of Maine (GoM) and its ecosystems. Changes to these systems will directly affect lobster (*Homarus americanus*) harvesters and the communities they support. The summer and fall of 2012 provide a clear example. A boom in lobster populations nearly led to a shutdown of the industry. This points to need for a better understanding of the potential outcomes of abrupt changes in climate and their impact on the GoM, lobster harvesters and policy makers.

Water temperature in the GoM during the winter of 2011 and 2012 were 1.4-1.7°C warmer (NERACOOS) than the previous 8 years[1]. The result was an abundance of lobsters entering the market before the onset of Maine's summer tourist season, driving the price per pound down sharply (Fig.1). The average price per pound for soft shell lobsters dropped by $1.07 from the 8-year average[1]. This reduction in price caused economic and social impacts on lobstermen and fishing communities.

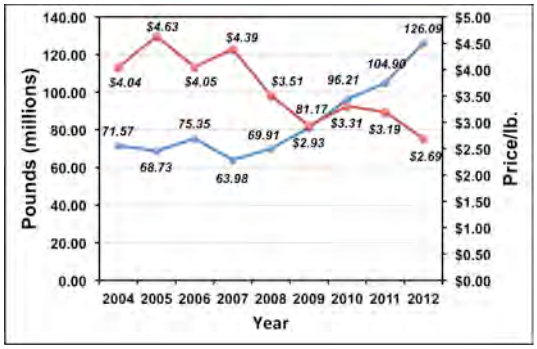

Figure 1. Lobster landings and prices for 2004-2012.

The lobster industry represents 65% of the value and commercial fishing in the state (Fig. 2). Abrupt changes to the GoM can destabilize a large portion of Maine's economy. The state has no policy measures in place to deal with abrupt changes in the GoM threatening the state's marine resources.

My research as an anthropologist is aimed at modeling potential abrupt changes to the GoM, and their impact on the lobster industry. The data gained from anthropological research will be combined with the models of abrupt climate change threats to help determine stakeholder driven, "best practices" for the lobster industry. These recommendations will be available to policy makers at the state level, providing valuable information concerning the threats of abrupt climate changes to our marine resources.

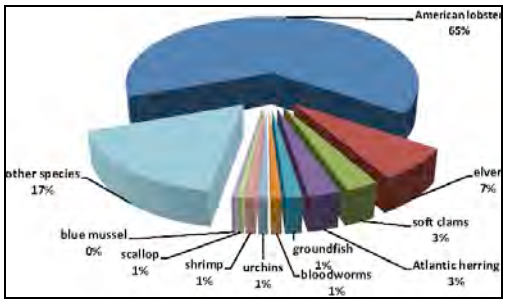

Figure 2. Percent of value of commercial marine species (Source DMR).

Goals

A key goal of this research is to understand how information is transferred from policy makers to fishermen and from fishermen to policy makers. We hope to suggest reforms that will enhance communication, the quality of policies in place, and the support these policies receive.

Acknowledgements: I would like to thank the NSF IGERT program for their funding support as well as the support of the University of Maine Climate Change Institute and Department of Anthropology

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201.3 NERCOOS: Northeastern Regional Association of Coastal Ocean Observing Systems http://neracoos.org/datatools/historical/graphing_download.

[1] Numbers represent changes from 2004-2011 average

Anticipating Surprises: Hyrdroclimatology of Lake Ice-Breakup in Maine

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For decades, the possibility of predicting regional lake ice phonology has fascinated lake limnologists and hydrologists. This paper examines the spatio-temporal pattern of early ice breakups in Maine lakes from 1950-2010 using data from 8 lakes and 5 USHCN stations and attempts to improve their prediction by establishing a relationship between these events, winter weather-climate variability and ENSO, the most well understood tropical atmospheric/oceanic pattern with predictive inter-seasonal to inter-decadal characteristics. Analyzing the magnitude of accumulated freezing and melting degree days (AFDD and AMDD) during winters of the 15 earliest and latest ice out events of the eight lakes reveals that there are 'threshold' magnitudes in the seasonal AFDD and AMDD which if exceeded result in ice cover conditions that favor early or late ice thawing events. The identification of these threshold winter temperature characteristics is significant in that it can be used to assess how changes in the duration and magnitude of extreme temperature episodes and not just changes in seasonal average temperatures during winter can enhance the occurrence of early or late ice out events in Maine lakes.

In Maine, it was found that during extreme phases of negative Tropical Northern Hemisphere (TNH; TNH<0.47) and positive North Atlantic Oscillation (NAO; NAO>0.2) teleconnection patterns, there is an increased probability in the magnitude of accumulated freezing and melting degree days towards 'milder' winters that advance the occurrence of early ice out events. However for lakes in different climate regions, significant shift towards earlier ice dates was observed only during strong negative phases of TNH. The magnitude of negative TNH is sensitive to strong El Nino episodes and this relationship suggests the potential applicability of seasonal to decadal El Nino predictions to regional event-based forecasts of early ice out events in Maine.

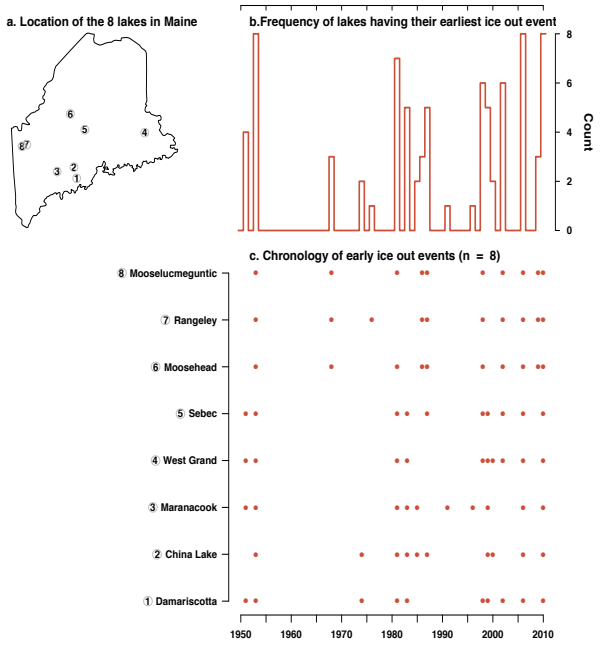

Fig. 1. This plot shows the ten earliest ice-out years of the eight Maine lakes selected. During these years, the ice breakup date deviated from as low as 8 days to as high as 30 days from the median ice-off date of each lake. In general, coastal lakes (Damariscotta, Maranacook and China lake) display stronger shifts during these years than that of northern lakes (Mooselucmeguntic and Rangeley lake)

Acknowledgments

This work is supported by National Science Foundation EPSCoR award #EPS-0904155 to Maine EPSCoR at the University of Maine.

The Climate Reanalyzer™

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Abstract: The Climate Reanalyzer™ is a new web utility through which users of different knowledge backgrounds can access and visualize a spectrum of reanalysis, general circulation, and weather models, as well as global station data.

Information about the climate system can be readily obtained from vast online archives of station data and models. However, few people except climate scientists and meteorologists know how to access these resources. In an effort to make climate data readily accessible to everyone – scientists, educators, students, and the general public – the Climate Change Institute is developing a web utility called the Climate Reanalyzer™ (cci-reanalyzer.org). The program incorporates state-of-the-art monthly and hourly climate reanalysis (e.g., ECMWF ERA-Interim, NCEP CFSR), general circulation (CCSM4), and weather forecast models (GFS, NAM), and a global archive of daily station data (GHCN). Climate Reanalyzer™ also has daily-updated summaries for near surface temperature, temperature anomaly (relative to 1979-2000 baseline), and sea ice. Users can produce maps, timeseries plots, and run linear correlations. Visualization options include PNG, JPG, PDF, Google Earth™ KMZ, ASCII text (for timeseries), and animation (current 7-day weather forecasts, and long-term mean seasonal cycle).

We acknowledge several existing web programs that afford functionality similar to Climate Reanalyzer™, e.g., Climate Explorer (climexp.knmi.nl), IRI/LDEO Climate Data Library (iridl.ldeo.columbia.edu), and the widely used NCEP/NCAR plotting pages operated by Earth System Research Laboratory (www.esrl.noaa.gov/psd/data/composites/day). In comparison, key strengths of Climate Reanalyzer™ are a simple, intuitive layout, and detailed vector-based graphics (Fig. 1). Climate Reanalyzer is expanding in hopes of capturing a significant user base.

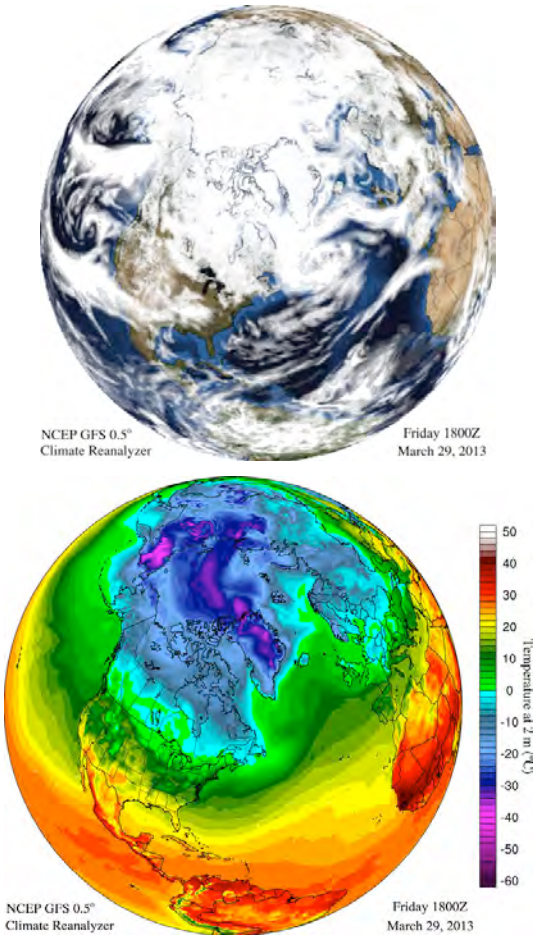

Fig.1. GFS model weather forecast for March 29, 2013 visualized using Climate Reanalyzer™. Top: Earth cloud cover, sea ice, and snow; Bottom: 2-meter air temperature. Base satellite imagery for the Earth image courtesy of NASA Blue Marble (earthobservatory.nasa.gov/Features/BlueMarble).

Acknowledgements: Funding provided by CCI (postdoc to Birkel), and the Heinz Endowments.

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All data sources referenced here can be found online at cci-reanalyzer.org/About/CR_data.php.

Evaluating the Effect of Changing Wind Strength on Thermocline Depth in Maine's Great Ponds

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Abstract: In response to declining wind speeds over terrestrial habits, it is important to understand the impact this will have on the thermal structure of lakes due to the key role of wind in its establishment. To investigate this, we will incorporate both modern lake sampling and sediment records to reconstruct how thermocline depth has changed over time and evaluate the role of wind in this change.

Changes in wind strength, specifically declining speed, have been observed over the last few decades in terrestrial habitats (Pryor *et al. 2009*). We examine how this change may affect the thermal structure (temperature profile) of lakes. This is important because wind is the main driver influencing the mixing depth of larges lakes with a surface area greater than 500 ha (Fig. 1) (Fee *et al.* 1996). As a result, we will look at how changes in wind strength impact lake thermocline depth (location in the water column where the temperature change is most drastic), utilizing sediment records to reconstruct past thermal structures of lakes. This feature of lakes plays a key role in determining the phytoplankton community (Pannard *et al.* 2007). This is because phytoplankton growth rate is determined by nutrient and light availability, which in turn is controlled by the thermal structure of the lake.

The objective of this study is to evaluate how thermocline depths have changed over time in large lakes in Maine, and how wind strength correlates with these changes. To do this, we will examine the changing relative abundances of *Discotella* and *Aulacoseira* species due to the differences in their preferred lake environments.

This study will include both paleolimnology and a modern in-lake component to attempt to answer these questions. Sediment cores will be taken from three lakes across Maine: Sebago, Tunk, and Lobster. The cores will be sectioned into 0.5 cm increments to evaluate changes in phytoplankton species over time. Preliminary findings show an increase in the number of *Discotella stelligera* and a decrease in the number of *Aulacoseira subartica* indicating shallower thermocline depth over time. For the modern in-lake component water samples will be collected from each of the three lakes during the period immediately after ice-out, during late summer stratification, and following fall turnover. The samples will be collected from the epilimnion, thermocline, and hypolminion. Nutrient analyses will be conducted for P, N, Si, and phytoplankton will be counted to determine the dominant phytoplankton species in each portion of the water column during the three collection periods.

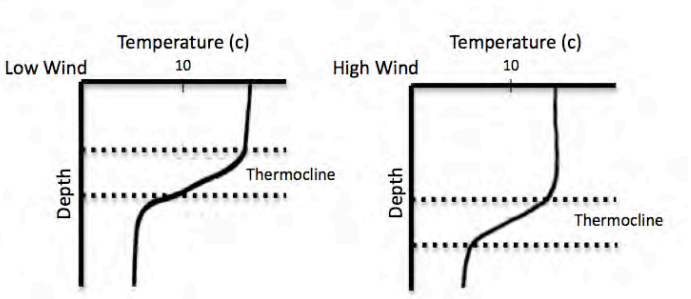

Fig. 1: Effect of wind on thermocline depth.

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Pryor, S. C., R. J. Barthelmie, D. T. Young, E. S. Takle, R. W. Arritt, D. Flory, W. J. Gutowski Jr., A. Nunes, and J. Roads. 2009. Wind speed trends over the contiguous United States. J. of Geophys. Res. 114.

John Kimball DeLaski, M.D. (1814–1874): Pioneer Glacial Geologist and Early Advocate for a Continental Ice Sheet over New England and New Brunswick

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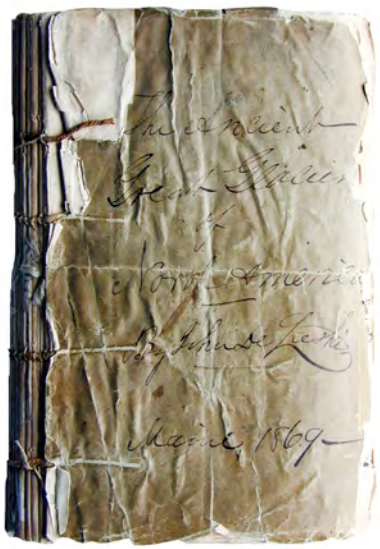
Abstract: John Kimball DeLaski, a member of the Portland Natural History Society, spent the better part of the decade of the 1860s carefully observing the Maine landscape. From a summary of these observations recorded in an as yet unpublished manuscript it is apparent that DeLaski was one of the first to recognize the immensity of the ice sheet that once covered much of North America. In the preface of his book he wrote "In presenting the following pages to the public, I am actuated by the conviction that the views hitherto had of the ancient great Glacier of North America, by scientific men as well as by geological readers generally, have not come up to the magnitude of the mass, nor to the gigantic work which it has performed upon the floor of our continent."

John K. DeLaski, M.D. practiced medicine in the Penobscot Bay region of Maine and, in addition, he was a naturalist with keen powers of observation. His study of the landscape led him to conclude that a thick glacier had overtopped the highest hills, flooded all of Penobscot Bay, extended far to the east and west and probably was part of a greater continental glacier. He published these very critical field observations and inferences in numerous articles in local newspapers and magazines, and in the American Journal of Science in 1864. His work put him on the "team" of Benjamin Silliman, James Dwight Dana and Louis Agassiz as an advocate for glaciation as the regional land-shaping force opposed to that of the Biblical Deluge, a major scientific conflict of the day both in North America and Europe. He remained a shadowy player, in the background, but clearly contributed critical observations to the argument through personal interactions with Dana, James Geikie, Agassiz and other prominent naturalists. They incorporated DeLaski's observations into their own work, sometimes without giving him credit. A synthesis of John DeLaski's work is recorded in a 400 page handwritten manuscript dated 1869 entitled "Foot Steps of the Ancient Great Glacier of North America". DeLaski died in 1874 and the book has yet to be published.



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Using Ground-Penetrating Radar to Estimate Accumulation Rate Variability and Mass Balance Estimates of the Juneau Icefield, Alaska

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

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Abstract: 200 km of 400 MHz ground-penetrating radar (GPR) centerline profiles were collected across the Juneau Icefield, Alaska, linking stratigraphic features in snow pits through GPR. Results suggest that mass balance programs in Alaska, coupled with GPR data, can significantly improve estimations of spatial accumulation rate variability and winter mass balance estimates.

In July, 2012, 200 km of 400 MHz ground-penetrating radar (GPR) profiles were collected across the Juneau Icefield, Alaska. The goal was to determine if linking stratigraphic features from annually-excavated snow pits through GPR could improve estimations of spatial accumulation rate variability and mass balance estimates. Limited mass balance measurements exist within Alaska (Juneau Icefield, Gulkana, Wolverine, McCall, Kahiltna, and Traleika Glaciers) that have a record longer than 20 years (e.g. March and O'Neel, 2011; Nolan et al., 2005). Methods to develop these records include point mass balance measurements from extracted snow pits and ablation stakes on an annual to intermittent basis. Uncertainties in these records are attributed to spatially extrapolating point measurements and trends of glacier recession which adjusts' the area that a single mass balance measurement may represent. Radar data, in conjunction with current methods, can aid in eliminating some of these uncertainties.

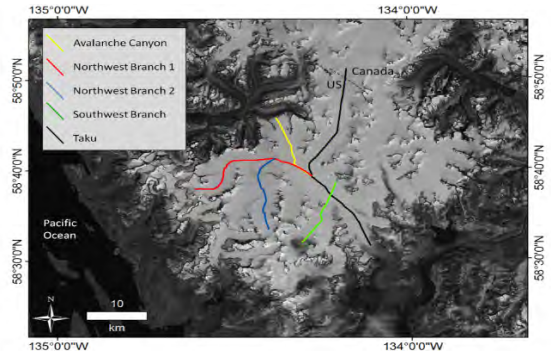

Figure 1. Map with LandSAT satellite image showing GPR centerline profile locations on the Juneau Icefield.

Profiles were collected along the centerline of the main, Northwest, and Southwest Branches of the Taku Glacier as well as the Matthes, Llewellyn, and Demorest Glaciers (Fig. 1). Over 650 km^2 and 1000 m of elevation range were covered during this pilot project linking sixteen snow pits with GPR data across the ice field.

Signal penetration reached ≤25 m with maximum depth penetration at higher elevations on the icefield and minimal depth in wetter regions at lower elevations. Ice lenses and the annual layer, recorded from mass balance snow pits, correlated well with continuous stratigraphy imaged in GPR profiles. Results suggest that lenses are relatively uninterrupted across the icefield and that GPR may be an appropriate tool for extrapolating point mass balance pit depths in this part of Alaska. The Northwest and Southwest Branches of the Taku Glacier show a strong stratigraphic thinning gradient, west to east; the main trunk of the Taku Glacier which originates from the Matthes-Llewellyn ice divide showed a similar thinning from the divide to the ELA. The thinning displayed by all three glacier systems matches a typical gradient from accumulation zone to ELA. However, it is also likely that a local influx of accumulation at the higher elevations of the Southwest and Northwest Branches result from their close proximity of the ocean.

Acknowledgements:
Steve Arcone (CRREL)
Juneau Icefield Research Program

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Algal Community Response to Increases in Dissolved Organic Carbon in Maine Lakes: Implications for Drinking Water Utilities

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Abstract: An increase in dissolved organic carbon (DOC) concentration has been documented in many lakes across Maine and has the potential to shift the biological and physical structures of the lakes. We are comparing fossilized algal remains of diatoms and chrysophytes in the sediment record from pairs of lakes with differing trends in DOC documented by a 30-year geochemical dataset to investigate how the lakes' algal communities have responded.

As a result of climate change and a reduction in air pollution, many lakes across northeastern North America and northern Europe are experiencing an increase in dissolved organic carbon (DOC) (Monteith et al. 2007). DOC encompasses a broad group of molecules and high concentrations impart a brown color to the water. This property makes DOC an important regulator in the physical and biological structures of lakes. Because it absorbs light, DOC is an important factor controlling the penetration of light through the water column and can be the primary regulator of thermal mixing in small lakes (Fee et al. 1996). Both light availability and mixing depth have implications for the algal communities living within the lake.

The Regionalized Long Term Monitoring (RLTM) program was established to monitor lake water chemistry trends and contains nearly 30 years of geochemical data. Of the 16 RLTM lakes located in Maine, seven have experienced an increase in DOC concentration since 1985, while the other nine have remained unchanged.

To augment the geochemical dataset, we will collect additional biological parameters (nutrients, chlorophyll-a, phytoplankton, and zooplankton) as well as light and temperature profiles during the spring, summer, and fall.

Since diatom and chrysophyte algae leave fossils in the lake sediment, their remains can be used to reconstruct past lake environments. Using a sub-set of the RLTM lakes, we will investigate whether algal communities have changed in three lakes with and three lakes without DOC changes (Fig. 1 shows one pair).

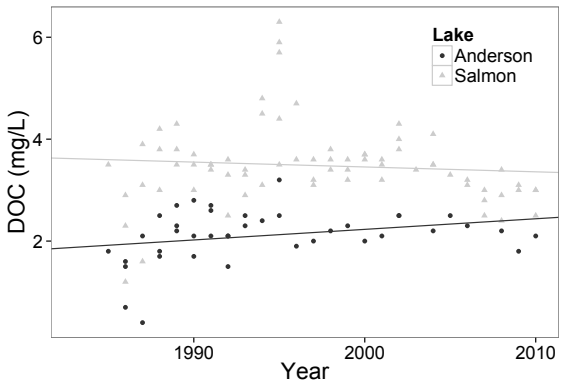

Fig. 1. Changes in two lakes with different trends in dissolved organic carbon (DOC) concentrations through time, with Anderson increasing in DOC and Salmon with no change.

Certain species of chrysophyte algae are of particular interest, since their blooms are known to cause odor and taste problems. With over 40 surface waters used for drinking water in Maine, these algal blooms are a concern for drinking water utilities.

Acknowledgements: This project is funded by the Water Resources Research Institute. The long-term databases used in this project have been collected by numerous dedicated people over the past three decades, funded by US EPA-ORD and EPA-CAMD.

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The Roles of Habitat Patch Size, Shape, and Connectivity in the Stability of Atlantic Coast Tidal Marsh Bird Communities

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3. Maine Department of Inland Fisheries and Wildlife.
4. Adaptation to Abrupt Climate Change IGERT Fellowship Program

Abstract: Tidal marshes are vulnerable to habitat loss due to impacts of climate change, particularly sea-level rise and and increase in frequency of extreme storm events. Spatial characteristics of tidal marshes such as habitat patch size, shape, and connectivity likely play a role both in the assemblage of bird communities in these marshes and the stability of these communities over time.

Tidal marshes are one of the world's most productive and dynamic habitat types. Impacts of climate change such as sea level rise and increase in extreme storm events are an emerging threat to tidal marshes because of their placement on the terrestrial-marine interface. Marshes face risk of abrupt and rapid change in spatial characteristics due to repeated flooding and overwash from storm surges. Tidal marsh breeders such as the Saltmarsh Sparrow (*Ammodramus caudacutus*), Nelson's Sparrow (*A. nelsoni*), and Willet (*Tringa semipalmata*), are especially at risk to these changes, however birds that utilize marshes for foraging or stopover habitat may also be highly affected by this change.

Collaborators with the Saltmarsh Habitat and Avian Research Program (SHARP) donated data from 1992-present to compile a large historical database (n=3020 points visited) of point count surveys assessing the abundance and distribution of tidal marsh birds in the northeast, spanning from the Chesapeake Bay in Virginia to the Canada/Maine border. To compliment this dataset, SHARP then conducted avian and vegetation surveys (n=1707) in the summers of 2011 and 2012. Many of the surveyed points (roughly 20% of total points surveyed) were surveyed during past efforts, and are comparable to the compiled historical dataset on a point-by-point basis. We hope to explore and describe change in the assemblage of birds in discrete patches of tidal marsh over time to assess the stability of these communities. Spatial characteristics of tidal marshes such as habitat patch size, shape, and connectivity likely play a role both in the assemblage of bird communities in these

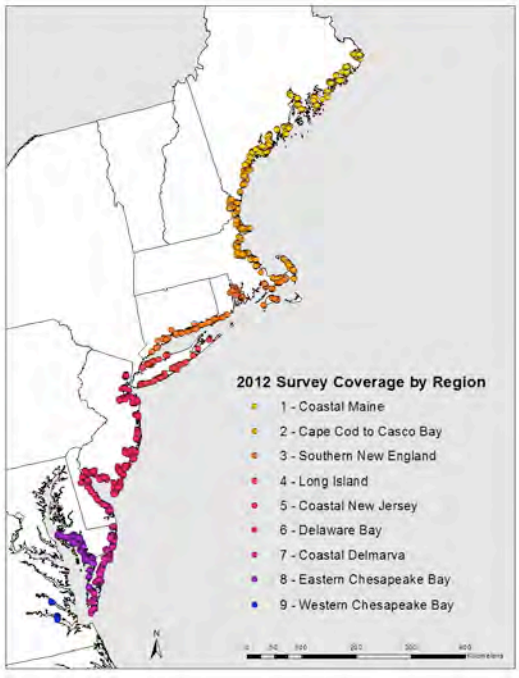

Figure 1. Points visited during the 2011 – 2012 survey effort (n=1707)

Marshes (Benoit, 2002) and the stability of these communities over time.

Acknowledgements: Thank you to SWG, MDIFW, and NSF IGERT for funding and my field crew for an excellent data collection effort over the past 2 years.

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Towards a Multi-Proxy Reconstruction of Southern Hemisphere Climate

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Abstract: Previous work has shown that West Antarctic sodium (Na) concentrations are related to the strength of the Amundsen Sea Low pressure system (1, 2). However, other work has shown a correlation between West Antarctic Na concentrations and Antarctic sea ice extent (3, 4). Are West Antarctic Na concentrations a reliable indicator of sea ice extent or is the association between Na and sea ice a consequence of the connection between atmospheric circulation and sea ice?

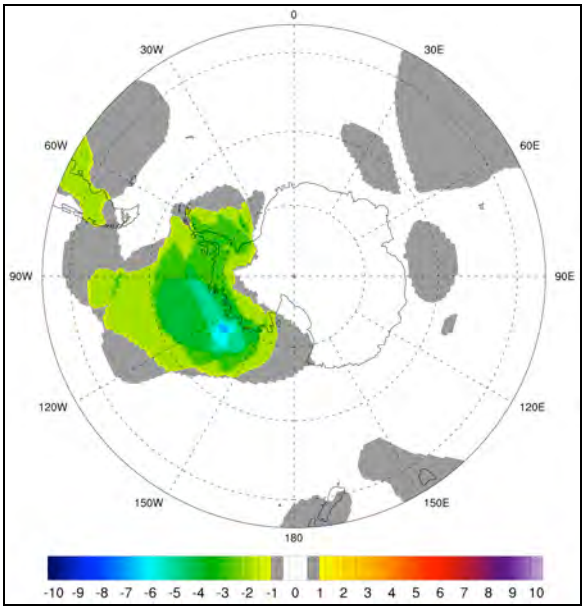

Figure 1. Ice core Na vs. ERA-Interim SON MSLP. Color scale indicates the number of correlations at >90% significance.

We use the CCI Climate Reanalyzer software to perform correlations between twelve West Antarctic ice cores and seasonal Southern Hemisphere mean sea-level pressure (MSLP) from the ECMWF ERA-Interim Reanalysis. Correlations are also performed between the twelve ice cores and ERA-Interim seasonal sea ice concentrations. For ERA-Interim seasonal periods we use March-April-May (MAM), June-July-August (JJA), September-October-November (SON), and December-January-February (DJF). We use the Na and mean annual accumulation time series from each ice core.

The ERA-Interim reanalysis data begin in 1979 and continue up to the present. However, the ice core time series cover various time periods giving us different lengths of overlap between the reanalysis and ice core data. The various data overlap periods result in various different correlation coefficient values for a given level of significance. To be conservative, we use a two-tailed test to calculate the critical significance values for each correlation. To simplify the results we plot a significance map for each core for each correlation. We combine the significance maps for each group of correlations to show the spatial distribution of correlations at the following levels of significance: 90%, 95%, 99%, and 99.9%.

We find that for negative correlations between Na vs. MSLP and Na vs. sea ice, SON is the most correlated season. However, for MSLP the maximum number of correlations occurs in the Amundsen-Bellingshausen sector (Figure 1) and for sea ice the maximum number of correlations occurs in the Weddell sector. For positive correlations between Na vs. MSLP, SON is also the most correlated season but the maximum number of correlations occurs in the sub-tropics east of New Zealand. Na vs. sea ice positive correlations exhibit similar numbers in all seasons, but over different areas from season to season.

Acknowledgements: This research is supported by US National Science Foundation (NSF) Office of Polar Programs grants to P.M.

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Surface Albedo and Glacier Mass Balance in the Central Alaska Range

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

Abstract: Surface albedo plays a vital role in the global climate system. We will measure in situ surface albedo during our field campaign this spring to Denali National Park, AK. Comparison to satellite imagery will enable us to deduce surface albedo values within the Central Alaska Range. Our final objective is to examine and quantify the relationship between surface albedo and glacier mass balance.

Introduction:

The global energy balance is highly dependent on the optical and physical properties of Earth's surfaces. Of importance are the sur-faces with high reflectance values within the cryosphere such as seasonal snowpack, glacial snow and ice, and sea ice. Surface albedo is the ratio of the reflected energy to incident energy at the surface, while the surface absorbs energy that is not reflected (Coakley, 2003). Changes in reflectance may induce feedbacks resulting in fluctuations of glacier mass balance. Quantifying the influence of albedo on mass balance will provide insight into the vulnerability of mountain-ous glaciers to climate change, and their contri-bution to global sea level. Additionally, the results may offer valuable information for the enhancement of mass balance and energy balance models.

Goal/ Objectives:

The goal of this project is to quantify the relation-ship between surface albedo to glacier mass balance in mountainous terrain. We wish to:

1) Measure and monitor spatial and temporal albedo variations across Kahiltna Glacier, AK;
2) Establish short-term (<35 yrs) record for past albedo with satellite imagery;
3) Compare in situ albedo measurements to satellite-derived albedo in the Central Alaska Range (see Fig. 1);
4) Examine correlation between surface albedo and glacier mass balance.

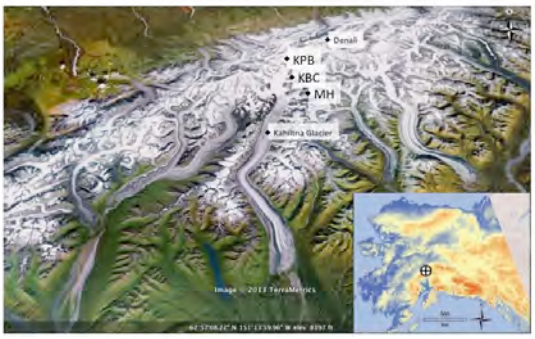

Fig. 1. Google Earth image of study locations: Kahiltna Base Camp (KBC), Kahiltna Pass Basin (KPB), and Mount Hunter (MH). Kahiltna Glacier and Mount McKinley (Denali) also noted. Insert map (from Campbell et al., 2012) shows the Central Alaska Range (circle-plus symbol) on a DEM of Alaska (red is high elevation).

Methods:

We plan to collect in situ reflectance measure-ments this spring across the Kahiltna Glacier. We will use the in situ measurements to validate the Landsat and MODIS imagery, and establish a relationship between albedo and glacier mass balance.

Acknowledgements: We thank funding from US National Science Foundation- Office of Polar Programs award 1203838 to K. Kreutz.

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20th Century Trends in Anthropogenic Pollutants over Central Asia derived from Asian Ice Core Array.

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Abstract: Concentration trends and enrichment/excess calculations from Asian Ice Core Array suggest 20th century increases in anthropogenic nitrate, sulfate, lead, and cadmium.

High-resolution records from the Asian Ice Core Array (AICA) have provided detailed 20th century glaciochemical time-series. Ice core records covering the past ~100 years allow for the investigation and assessment of anthropogenic pollutant evolution at remote high-elevation sites across central Asia. Major soluble ions and trace element analysis suggest that rises in the anthropogenic inputs of nitrate (NO_3^-), sulfate (SO_4^{2-}), lead (Pb), and cadmium (Cd) began to rise around the mid-20th century in regions of central Asia. This time period corresponds to large rapid increases in local and regional agriculture, industry, and population. Chemical concentrations, EOF analyses, crustal enrichment, and excess calculations were used to identify potential anthropogenic inputs. Northern AICA sites (Belukha and Inilchek) reveal similar rises in nitrate and sulfate, while the southern AICA sites display nitrate and sulfate trends that suggest dominant natural sources.

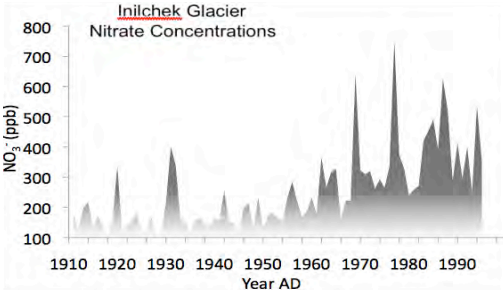

Fig. 1 Inilchek nitrate record.

Lead enrichment time-series from AICA sites (Inilchek and Geladaindong) reveal similar trends to available lead records in central Asia and the North Pacific (i.e. Mt. Logan [1]), displaying increases throughout the late 20th century corresponding to local and regional increases in Asian industrial emissions.

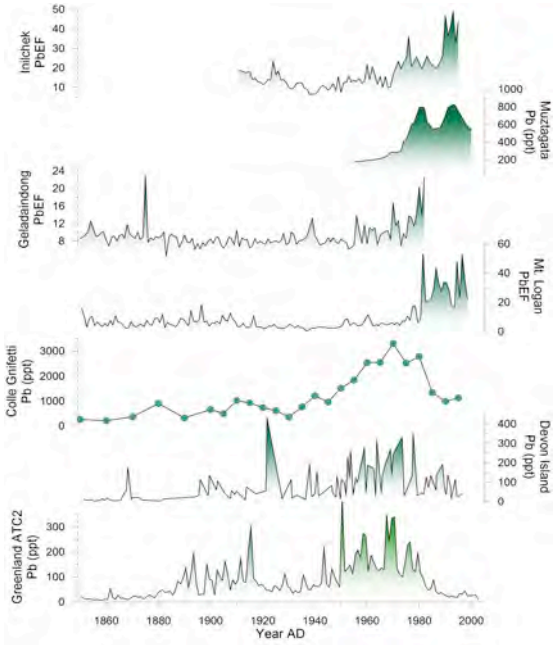

Fig. 2 Lead records from Asia, North America, Europe, and Greenland.

Comparisons to lead records from Greenland, Devon Island, and the European Alps reveal inverse trends since the early 1970s most likely resulting from North American and European air quality policies that have only recently been adopted in Asia [2,3,4].

Acknowledgements:
National Science Foundation (ATM-0754644)

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How Does the Timing of the Breeding Season Shape Fall Migration of a Neo-tropical Songbird, Black-throated Blue Warblers (*Setophaga caerulescens*).

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Abstract: Migration is an important part of the annual cycle of many animals that is influenced by many factors. Timing is one such factor and is critical to birds' success within their annual cycle. How events and phenology during the breeding season carry over to affect the timing of autumn migration is relatively unknown and more research of timing trends in the face of climate change is needed, specifically data connecting stationary periods in the life cycle to stopover sites.

Timing is critical to birds' success. A delay in one stage can cause individuals to experience less than optimal conditions, such as poor home range quality in following stages. There is a large body of evidence highlighting the importance of winter habitat to timing and breeding success in migratory songbirds. For example, migratory birds begin their breeding seasons earlier in response to increasing spring temperatures in temperate regions. The opposing phase of their annual cycle connecting the breeding and non-breeding periods, however, is less understood.

There is a timing tradeoff between producing as many young as possible during the breeding season and successful arrival to a good winter home range. Warmer fall temperatures could allow birds to extend their breeding season. Late season breeding and double brooding (in the case of birds) can increase productivity but also increase costs to survival or future productivity. Delayed arrival on non-breeding areas may limit availability of high quality winter territories and productivity in following years.

Since birds are time constrained by their breeding biology (set lengths for laying, incubating, etc), variation in the timing of these events should create variation in the timing of migration events, affecting the length, distribution, and mean migratory passage of songbirds. Broadly, the timing of avian autumnal migration is regulated endogenously by photoperiod. At a smaller scale, however, migration timing varies from year to year, suggesting a more plastic fine-scale mechanism. These fine-scale events should link stochastic changes in the breeding season to migration phenology. Questions regarding post-breeding movement and the mechanistic linkages between breeding decisions and migration, however, remain important but largely unexamined. Understanding the degree to which events carry over across annual stages can inform predictions of how populations may respond to climate change and other events that impact the annual cycle of birds (Webster and Marra 2005).

We will create regional precipitation and temperature indices that predict the timing of regional fledging and resource abundance, using Hubbard Brook's long term breeding monitoring database as a local reference. These indices will then be used to predict five metrics of fall capture of black-throated blue warblers from three long-term banding stations (Long Point Bird Observatory, Powdermill Nature Reserve, and Manomet Center for Conservation Sciences): median capture dates, first and last capture dates, time between capture quantiles, and the distribution of captures.

Acknowledgements: Thanks to Scott Sillett, Stu Mackenzie, Luke DeGroote, and Trevor Lloyd-Evans for access to their long term monitoring databases. Also, thanks to the National Park Service and the University of Maine for funding my research.

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Chasing ^{15}N through Watersheds to Study N Dynamics and Whole Ecosystem N Enrichment

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Abstract: The Bear Brook Watershed in Maine began in 1987 and includes over two decades of whole watershed experimental N-enrichment in one of two paired forested watersheds. Recently a watershed-scale ^{15}N pulse-chase experiment has been established to follow the movement of N and compare the transformation rates of the ^{15}N tracer between N-enriched and reference watersheds.

Background:

There exist few long-term experimental sites across the world devoted to studying the response of forest ecosystems to experimental anthropogenic manipulations. Since 1987, the Bear Brook Watershed in Maine has been a paired-watershed research program designed to study the biogeochemical response of forested ecosystems to experimental acidification and nitrogen (N) enrichment. The treated West Bear (WB) watershed is compared to the reference East Bear (EB) watershed. Beginning in 1989, the WB watershed has been continuously treated bimonthly by helicopter with $(NH_4)_2SO_4$ at a rate of 25.2 kg N ha^{-1} yr^{-1}. In June 2012, a watershed-scale ^{15}N pulse-chase experiment was initiated using 98 atom-% enriched $(^{15}NH_4)_2SO_4$ fertilizer as a tracer to study N dynamics in both watersheds (Fig. 1).

Fig. 1. Application of the ^{15}N tracer at the Bear Brook Watershed in Maine (21 ha) using backpack sprayers.

Results and Discussion:

Due to abiotic (leaching/adsorption) and biotic (microbial utilization) processes, the distribution of the applied ^{15}N changes within and among ecosystem components with time. The forest floor is a key site of N retention and transformation. As shown in Figure 2, there was a threefold increase in forest floor $\delta^{15}N$ values compared to natural abundance levels one month after application.

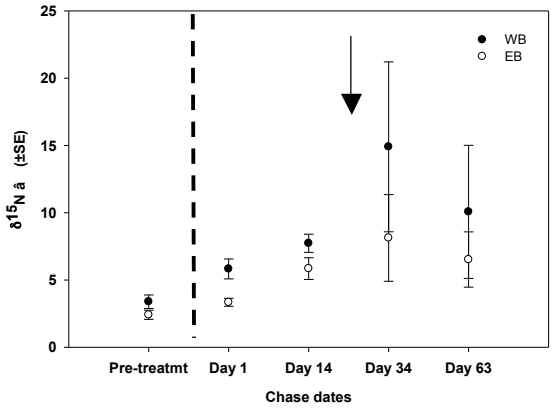

Fig. 2. $\delta^{15}N$ in the forest floor at WB and EB during the 2012 growing season. The dashed line and the arrow indicate the time of the ^{15}N tracer application and a major rain event, respectively.

Significantly higher forest floor $\delta^{15}N$ values were found in WB compared to EB for two weeks after tracer application, reflecting higher N mineralization and nitrification rates in the forest floor of WB compared to EB. A major rain event occurred on 6/26/2012 (peak stream discharge = 57 L s^{-1}), which may have contributed to larger variation in the $\delta^{15}N$ values thereafter (Fig. 2). Further analyses are underway to follow the fate of the ^{15}N tracer throughout ecosystem components and through time.

Acknowledgements: This research is funded through the National Science Foundation (DEB 1056692), the NSF LTREB Program (DEB 1119708) and the University of Maine.

Are Greenland Crevasses Migrating Inland?

Gordon S. Hamilton[1,2]

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

Abstract: The surface of the Greenland Ice Sheet experienced unprecedented melting during the 2012 summer, capping a decade of summers with above average melt extent and duration. Reports of surface cracks appearing at hitherto crevasse-free locations on the ice sheet have coincided with the intensified melt. The cracks pose a hazard to surface traversing and aircraft operations, as well as potentially leading to initiating self-reinforcing feedbacks leading to further expansion of cracks. This project seeks to understand the processes governing crack formation and predict the evolution of crevassing on interior portions of the Greenland Ice Sheet.

The surface of the Greenland Ice Sheet experienced unprecedented melting during the 2012 summer, capping a decade of summers with above average melt extent and duration. Melting covered ~97% of the ice sheet during its 2012 peak and lasted almost two months longer than the 1979-2011 average. This sustained intensified melt has led to down-wasting of the surface, and has also played a role in accelerated ice flow by supplying runoff to enhance subglacial sliding.

One of the consequences of a speed-up in the ablation zone is an increase in strain rate and a possible inland expansion of crevasses. An increase in crevasse extent might initiate a positive feedback because new crevasses act as nascent pathways for the delivery of surface meltwater deep into the ice sheet or the bed where it enhances cryo-hydrologic warming and basal sliding. A subsequent speed-up propagates extensional strain rates farther inland and allows additional fractures to be be created.

During the peak of the 2012 melt event, a series of cracks appeared on and around the groomed runway at Raven (DYE-2) (Figure 1), the main training site for ski-equipped aircraft in Greenland. New cracks also appeared on the route used by the Greenland Inland Traverse (GrIT) in northwest Greenland, at locations previously known to be crevasse free. These fractures are a hazard to safe logistic operations, and may severely impact to the long-term viability of ski-equipped aircraft training and surface traversing in Greenland. Informed planning for future logistic activities in Greenland requires an understanding of the processes responsible for the appearance of new surface cracks and an assessment of the likelihood that their distribution will increase with time.

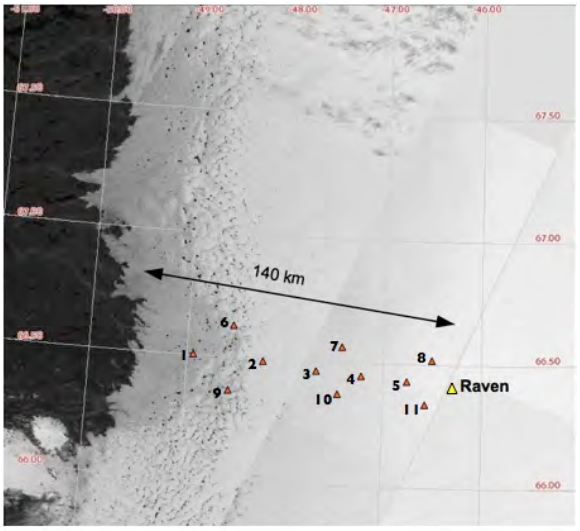

Fig. 1. Strain grid through the ablation zone of central West Greenland.

We are testing several hypotheses for the formation of the Raven fractures by conducting an analysis of surface strain rates using GPS methods. These results will allow us to test if 1) the cracks are due to vertical subsidence as the result of surface collapse into a void created by drainage of a firn aquifer, or 2) the cracks are true crevasses arising from an increase in strain rate due to meltwater-enhanced speed-up of downstream ice.

Acknowledgements: Supported by Department of the Army award W913E5-13-C-0003.

A Look Into Abrupt Climate Events Using High Resolution Analysis of an Ice Core from Roosevelt Island, Antarctica

Skylar Haines[1]

1. Climate Change Institute, University of Maine.

The ice core at Roosevelt Island is situated ideally to capture past changes in climate impacting the Ross Ice Shelf, and the West Antarctic Ice Sheet. The Roosevelt Island Climate Evolution Project, or RICE, seeks to determine the stability of the Ross Ice Shelf in a warming world. As a core processor for the 2012-2013 RICE field season and a student at the Climate Change Institute, I will be analyzing the parts of the RICE ice core that contain large fluctuations in element concentrations. I will be using the Climate Change Institute's Keck Laser Ice Facility LA-ICP-MS, or Laser Ablation Inductively Coupled Plasma Mass Spectrometer, in order to detect and analyze significant climate events throughout the history of Antarctica and the Southern Hemisphere.

The ice core at Roosevelt Island is situated ideally to capture past changes in climate impacting the Ross Ice Shelf, and the West Antarctic Ice Sheet. Weather systems such as the Amundsen Sea Low frequently affect the Ross Ice Shelf region and West Antarctica. Sea ice has exhibited dramatic changes over the recent years on unprecedented levels. The West Antarctic Ice Sheet has changed substantially over the last several thousand years. All of these climate changes can be documented in the archives of the ice core that were extracted through the Roosevelt Island Climate Evolution project, or RICE.

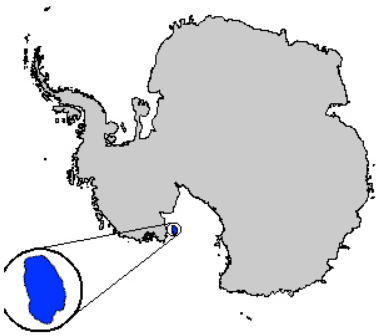

Figure 1. Map of Antarctica showing the location of Roosevelt Island.

As a core processor for the 2012-2013 RICE field season and a student at the Climate Change Institute, I will be analyzing the parts of the RICE ice core that contain large fluctuations in element concentrations. I will be using the Climate Change Institute's Keck Laser Ice Facility LA-ICP-MS, or Laser Ablation Inductively Coupled Plasma Mass Spectrometer, in order to conduct my analysis.

This new instrument allows the analysis of ice cores with sampling resolutions as low as 4 micrometers, where all other ice core analysis methods have sampling resolutions no lower than one centimeter. Using the Keck Laser Ice Facility LA-ICP-MS, I will be able to detect and analyze significant climate events throughout the history of Antarctica and the Southern Hemisphere, as preserved in the Roosevelt Island ice core. Climate events of particular interest are Meltwater Pulse-1A, the Antarctic Cold Reversal, as well as other abrupt climate change events that may be detected.

Are there precursors in the climate system at the scale of weather events that signal the onset of abrupt climate change? My findings, in collaboration with that of others, will perhaps shed light on the finer analysis of these abrupt climate events in the Earth's past, and may allow us to further predict what we may see in the future. Our findings may one day serve as an avenue for the scientific community to predict regional to global scale climate evolution.

Acknowledgements:

National Science Foundation grant to P. Mayewski

RICE Colleagues

MSc committee

Are Drumlins a Product of a Thermo-mechanical Instability?

Roger LeB. Hooke[1,2], Aaron Medford[1,2]

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2. School of Earth & Climate Sciences, University of Maine.

Abstract: Subglacial patches of frozen ground surrounded by thawed till likely provide the seeds for drumlin formation. Sliding ceases over such frozen patches, so ice flowing over adjacent till at the pressure melting temperature converges in their lee, dragging till with it. The energy balance is such that this till will freeze, increasing the amplitude of the perturbation.

Model

Of numerous theories of drumlin genesis, none has been widely accepted. It seems evident, however, that some form of positive feedback process is involved. Under certain circumstances perturbations are amplified. Herein we suggest that patchy areas of frozen bed provide the initial perturbation. Such frozen patches may occur in local areas underlain by material of lower thermal conductivity or on slight topographic highs. Drag exerted by the frozen patch deflects ice flow into its lee, resulting in a herringbone pattern in till fabric analyses (Fig. 1), and dragging with it mobile till eroded from the thawed area. The energy balance is such that this till likely refreezes (Fig. 2), either producing a topographic perturbation or amplifying an existing one. The resulting topography then deflects more of the geothermal heat away from the developing hill and into the adjacent trough, resulting in a positive feedback. Once the thermal perturbation exceeds a critical (though as yet undefined) level, melting may decouple the ice from the bed, preventing further entrainment of till from thawed areas, and thus limiting the height and length of the drumlin.

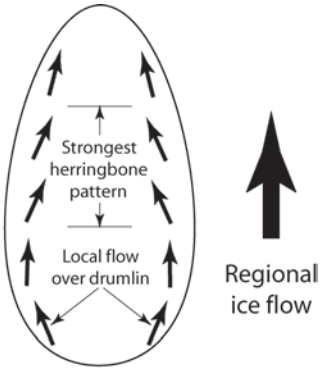

Figure 1. Pattern of ice flow around a frozen patch in a glacier bed.

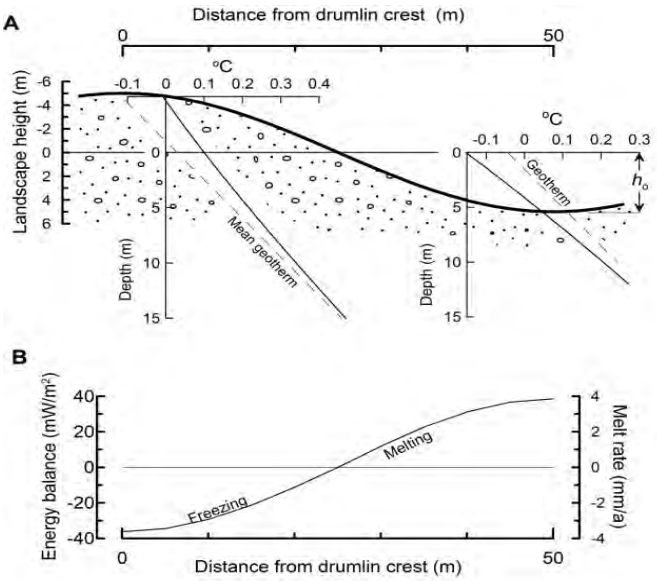

Figure 2. **A**. Calculated temperature profiles in a 5-m amplitude perturbation in a glacier bed. Under the hill the temperature gradient, dT/dz, in the substrate is lower than the mean geotherm, so less geothermal heat is conducted to this area. Under the trough, the reverse is true. **B.** The energy balance at the ice-till interface is such that freezing occurs over the hill and melting throughout the trough.

Acknowledgements: This research was supported by the School of Earth and Climate Sciences at the University of Maine.

Reference: Hooke. R. LeB., and Medford, A., 2013. Are drumlins a result of a thermo-mechanical instability? *Quaternary Research Available online 8 February 2013.*

The Putative Irish Landbridge

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2. School of Earth & Climate Sciences, University of Maine.

Abstract: We are working on year 3 of a project to evaluate the sea-level lowstand in the Irish Sea. The preliminary data suggest a "shallow" lowstand and no chance of a Holocene land bridge. This contradicts a National Geographic Society map of the Irish Sea that was published this year.

The National Geographic Magazine recently published a full-page map (Fig. 1) depicting the Irish Sea with land bridges connecting England and Scotland with Ireland and a large river down the axis of the Irish Sea shortly after deglaciation. It is a striking illustration that, sadly, is based on no data and likely wrong in almost all regards.

The question of an Irish land bridge has been posed for more than a century. It has been used to explain both the peopling of Ireland and the supposed presence of amphibians and other animal and some plant species there. We have been working for three years on a National Environmental Research Council (NERC) project with colleagues from the UK, Canada and the Republic of Ireland to address this question. During year 1 we collected geophysical data (seismic reflection, multibeam bathymetry) around Ireland, focusing on Bantry Bay and Waterford, to the south, Cardigan Bay (Wales) and the Isle of Man to the east, Dundrum Bay and the mouth of the River Boyne to the west and Belfast Lough to the north. We found evidence of a lowstand to about -80 m in the southern part of the study area, but nowhere else. In the North, where people first settled Ireland and where a land bridge is alleged to have facilitated their migration, the low stand was around -30 m, leaving a deep strait between Northern Ireland and Scotland.

In 2012, we collected more than 140 vibracores from targets located on the seismic lines. Our goal, to penetrate transgressive unconformities, was reached in numerous locations. Many of the cores also contained fossil shells that are being radiocarbon dated at the present time. By early summer, we hope to begin to publish the first observational data regarding the presence, or likely lack of a Holocene land bridge connecting the UK with Ireland. Although we hope that our publications will have a large impact on the question of an Irish landbridge, the impact of the National Geographic illustration, based on no observational data, will be difficult to surpass.

Figure 1. Hypothetical map of Irish Sea (NGS, 2012).

National Geographic Society, 2012, Doggerland-The Europe that was.

http://education.nationalgeographic.com/education/maps/doggerland/?ar_a=1

Evaluating Possible Sources of Dust to West Antarctica

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2. School of Earth & Climate Sciences, University of Maine.
3. Lamont-Doherty Earth Observatory of Columbia University.
4. Cornell University.

Abstract: Atmospheric transport modeling studies suggest that Australia is the dominant dust source for West Antarctica. However, particle size distributions of dust deposited in central West Antarctica during the late Holocene have a mode size of 5-8 µm, indicating a significant contribution from local (Antarctic) sources. We use geochemical data generated by particle-induced x-ray emissions (PIXE) analysis to evaluate possible dust sources to this region.

Biological production in large regions of the world's oceans is limited by lack of the nutrient iron (Fe; Turner and Hunter, 2001; Moore et al., 2009). Atmospheric dust deposited in surface waters is an important source of Fe; its addition can stimulate both photosynthesis and nitrogen fixation, thus impacting the global carbon and nitrogen cycles (Boyd et al., 2007; Moore et al., 2009). Fe content and solubility vary depending upon the source of dust, with orders-of-magnitude differences between fresh, mechanically weathered glacial flours and chemically weathered desert soils (Sedwick et al., 2007; Schroth et al., 2009). The biological availability of aerosol Fe may be more influential in stimulating primary production than total dust aerosol loading. Therefore, precise knowledge of dust source is germane to understanding links between dust, bioavailable Fe, atmospheric CO_2 and climate variability in the Antarctic region.

Mineral aerosol (dust) particles can be used to trace atmospheric transport from source regions because particulate mineral, chemical, and isotopic compositions reflect that of the parent material. We use major element chemistry generated by particle-induced x-ray emissions (PIXE) analysis of mineral dust from the WAIS Divide ice core to explore potential dust sources for modern-day West Antarctica. We discuss possible reasons for changing dust sources through time, and argue that New Zealand may have been an important source of dust to West Antarctica in past climates, such as during the Last Glacial Maximum.

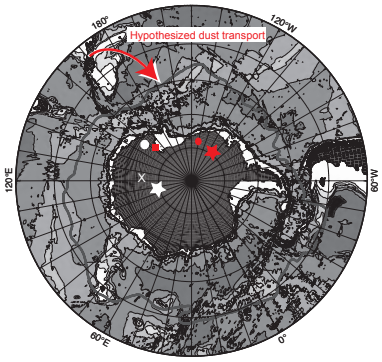

Figure 1. Polar projection map of Antarctica and the Southern Ocean showing hypothesized NZ LGM dust transport (red arrow) and ice core sites where previous dust provenance work has been done.

Acknowledgements: This work was supported by NSF ANT – 0636740.

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Final Pulse of the Last Glacial Termination in New Zealand was Coeval with the Younger Dryas Stadial in the Northern Hemisphere

Tobias N. B. Koffman[1,2], Aaron E. Putnam[3], Joerg M. Schaefer[3,4], George H. Denton[1,2], David J. A. Barrell[5], Roseanne Schwartz[3], Robert C. Finkel[6]

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5. GNS Science, Dunedin, New Zealand.
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Abstract: We present a new Beryllium-10 moraine chronology for the Rakaia Glacier during the latter half of the last glacial termination. This glacier held its ground during the Antarctic Cold Reversal, but receded coevally with the Younger Dryas stadial in the northern hemisphere.

The last glacial termination is a critical interval for understanding the cause of ice-age climate cycles. A globally well-distributed suite of precise climate records would offer one way to distinguish between plausible mechanisms that may have driven the termination. This period of rapid global warming was marked by millennial-scale climate oscillations that are antiphased between Greenland and Antarctic ice cores. However, the geographic breadth of this bi-polar seesaw remains uncertain, as does its cause and possible impact on Earth's climate. For instance, did the Antarctic pattern extend into the southern hemisphere's mid-latitudes? How quickly did abrupt deglacial climate changes propagate from pole to pole, and what does this tell us about their cause?

Here, we focus on the response of the Rakaia Glacier to late-glacial punctuations of the rapid global warming during the termination. We use beryllium-10 surface-exposure dating to build a chronology of moraines preserved on bedrock knobs that protrude above the valley floor. After a collapse during Heinrich Stadial 1 (Putnam *et al.* in prep), the Rakaia glacier readvanced during the Antarctic Cold Reversal, constructing moraines at 14.0 and 13.2 ka. These ages agree within error with those of moraines elsewhere in New Zealand (Putnam *et al.* 2010). Moraines farther up-valley record glacier retreat during the Younger Dryas (YD) stadial in the northern hemisphere. The next moraine up-valley formed at 12.2 ka and represents an ice-surface lowering of at least 200 m in ~1,000 years.

A recessional moraine formed at 11.7 ka marks an ice surface ~50 m lower than that at 12.2 ka. A modeled temperature increase of ~1° C in the Rakaia Valley during the YD (Rowan *et al.* 2012) is consistent with the warming estimated from reconstructed snowlines of the Irishman Stream cirque glacier, located 100 km to the southwest (Kaplan *et al.* 2010). The onset of YD warming in New Zealand coincided with the sudden inception of YD stadial conditions in the northern hemisphere, suggesting a fast-acting mechanism, such as a southward shift of global zonal wind belts, may have been at work.

Acknowledgements: This work is supported by the National Science Foundation, the Comer Science and Education Foundation, and the Quesada Family Foundation. We thank Tim and Anna Hutchinson of Double Hill Station for their hospitality and for excellent helicopter transport. We thank the Department of Conservation, Te Papa Atawhai and Te Rünanga o Ngäi Tahu for permission to access and to sample the moraines of the upper Rakaia Valley.

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Evidence of Hemispheric- and Local-scale Atmospheric Pollution in a South Pole Ice Core

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Abstract: As, Ba, Fe, Cu and Pb have been measured in a South Pole ice core covering the period 1541 to 1999 A.D. Our results show significant enrichment of these elements during the recent decades most likely due to anthropogenic activities.

Human activities now have a major impact on the global atmospheric cycles of many trace elements.[1,2] Here we present a ~450-year record of atmospheric Ba, Cu, Fe, Pb and As concentrations as recorded in a South Pole ice core. The ice core was collected during the US International Trans-Antarctic Expedition traverse in 2002 (site US ITASE-02-6) at 89.93°S, 144.39°W at en elevation of 2808 m a.s.l. The top 59.4 meters of the core were melted using the Climate Change Institute continuous melting system[3] at a temporal sample resolution of ~9.4 samples per year. Collected samples were analyzed for major and trace element content using the inductively-coupled plasma sector field mass spectrometry. The analyzed section covers the period 1541 to 1999 A.D.

Our records show increased concentrations of Ba (by a factor of ~9), Cu (~2), As (~3), Pb (~3) and Fe (~4) during the recent decades (Fig.1). We observed increases in crustal enrichment factor (EFc) values for Ba (by a factor of ~7), As (~3), Pb (~3), Fe (~3) and Cu (~2) during the period between 1970 and 1999, suggesting input from anthropogenic sources (Fig.1). A comparison of the As, Pb, Cu and Fe data with other Antarctic glaciochemical record indicates that the increase in atmospheric concentrations of trace elements is widespread. Increase in As, Pb, Cu and Fe concentrations and their EFc values are most likely related to stationary fossil fuel and gasoline combustion, and nonferrous metal production in the Southern Hemisphere countries.[2,4-6,] Comparison with previously reported Antarctic Ba records[5,6] suggests that significant increases in Ba concentrations at South Pole during recent decades are most likely caused by local source pollution, such as diesel fuel combustion and intense aircraft activity at Amundsen-Scott South Pole Station.

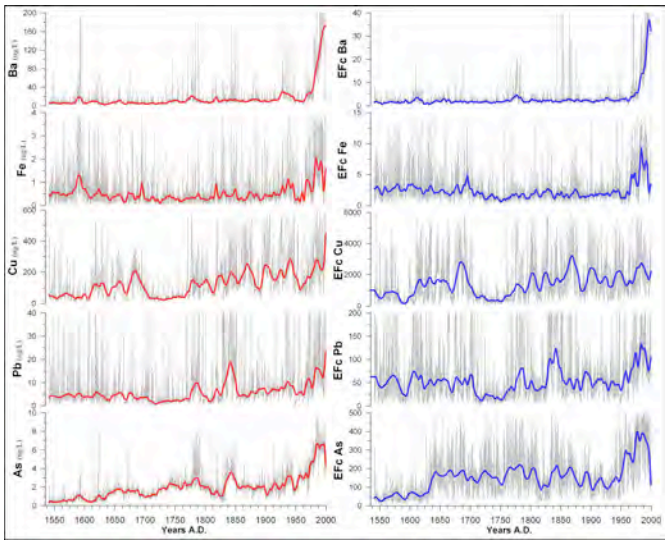

Fig. 1. US ITASE-02-6 Ba, Fe, Cu, Pb and As concentrations and crustal enrichment factor (EFc) values for the period from 1541 to 1999 A.D. The grey color lines are raw data and the red and blue color lines are background level, estimated using robust spline smoothing function.

Acknowledgements: NSF OPP

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Real-time Snow Accumulation Measurement on the Mt. Hunter Plateau, Alaska

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4. Complex Systems Research Center, University of New Hampshire.

Abstract: We describe an automatic weather station to be installed on the Mt. Hunter glacier plateau (4000 masl) in May 2013, configured to monitor local snow accumulation via two methods and relay data to UMaine via Iridium satellite.

Snow accumulation time series derived from ice core records provide a direct record of past precipitation changes, and can therefore be used to infer past spatial and temporal climate patterns. However, the relationship between local snow accumulation and regional precipitation can be complicated by local processes (e.g., snow redistribution from wind, melting/refreezing/sublimation, settling). Ideally, a continuous record of snow deposition and metamorphism at the ice core site can be collected, and used in conjunction with meteorological data to derive a quantitative relationship between local accumulation, regional precipitation, and other regional climate parameters. Developing a year-round local accumulation record is challenging at remote alpine ice core sites, where access during winter months is usually not possible.

During the 2013 field season on the Mt. Hunter glacier plateau in the Central Alaska Range, we plan to install an automatic weather station (AWS) specifically designed and configured to measure local snow accumulation continuously and year-round (Fig. 1). Along with standard meteorological sensors for temperature, pressure, wind speed and direction, the AWS will have a sonic depth sounder measuring distance to snow surface every hour. In addition, the AWS will have a digital camera pointed towards a set of four poles marked with 10-cm increments, arranged in a 0.5 m square to account for drifting. A high-resolution picture of the poles, and therefore snow height, will be taken daily. Having redundant, yet complementary (i.e., hourly vs. daily snow height measurement resolution, single spatially-integrated snow height vs. individual point measurement) data should yield a robust time-series of snow accumulation change that can be correlated with regional meteorological data easily via the Climate Reanalyzer software.

AWS meteorological data and images will be transferred weekly to UMaine via the Iridium RUDICS (Router-Based Unrestricted Digital Internetworking Connectivity Solutions) satellite data service.

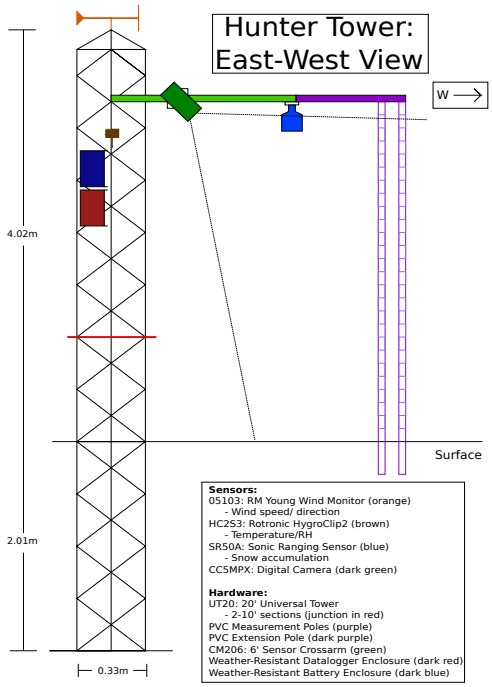

Fig. 1. AWS schematic.

Acknowledgements: Funding provided by the National Science Foundation. We thank Denali National Park, and Talkeetna Air Taxi, and CPS Polar Services for logistical support.

Improving Detection of Volcanic Products in Ice Cores

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

Abstract: Update on a new method for detecting tephra and associated soluble volcanic products (aerosol particles) in ice core records

Volcanism is one of the natural drivers of the Earth's climate system. However, precise climate-forcing mechanisms, natural threshold levels, and interactions of different types or magnitudes of volcanic events with the climate system are poorly understood for past large magnitude events. To date, only the Antarctic ice sheet provides an opportunity to reconstruct long-term history of volcanically produced sulfate and tephra particles in the stratosphere. Unfortunately, detection and geochemical fingerprinting of 1-5 micron size tephra particles from large tropical volcanic eruptions is one of the major unresolved technical problems in modern ice core research.

We are developing a new method for detecting tephra and associated soluble volcanic products (aerosol particles) in ice core records. A large suite of analytical instrumentation will be used to study in great detail the relationship between soluble and insoluble volcanic products. We also aim to improve the methodology related to geochemical fingerprinting of extracted particles, SEM image processing methods for counting the number of particles, and calculating volume and grain size distribution.

Our transformative study can lead to improving fundamental principles governing the interaction of volcanic products and human produced pollutants with ozone layer health and the impact of global volcanism on climate. The results will be of particular significance to volcanologists, climatologists, paleoclimatologists, atmospheric chemists, geochemists, climate modelers, environmental statisticians and policy makers.

Acknowledgements: This research is partially supported by NSF ANT-1142007 project.

Graphics Processing Units (GPU) Acceleration of the Weather Research and Forecasting (WRF) WSM5 Microphysics Scheme

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2. School of Earth and Climate Sciences, University of Maine.
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Abstract: The complex relationship between earth and climate environments has imposed a large and growing obstacle to computational scientific investigations. In this study, we try to use Graphics Processing Units (GPU) to create a new computation framework to better understand the dynamic connections between climate and earth systems. Initial experiments, testing various CPU/GPU configurations in the microphysics module of WRF demonstrate potential for highly efficient acceleration for the WRF WSM5 microphysics scheme. We achieve an overall speedup of 23% in case of 2 GPU as compared to the 2-processor CPU version when applied to modeling of recent Hurricane Sandy.

Introduction:

The complex dynamic system between earth and climate embraces many non-linear physical systems. We hope we can couple those systems in numerical models that will provide a framework for evaluating spatial and temporal dependences of physical and geochemical surface evolution. In recent years, Graphics Processing Units (GPU) has emerged as a low-cost, low-power and a very high performance alternative to conventional microprocessors. The proposed interactive supercomputing provides runtime what-if analysis based on high-resolution graphics to achieve enhanced understanding of past and future climate change.

Here we present our preliminary results about the computational efficiency of the WRF (Weather Research and Forecasting model) WSM5 (WRF Single Moment 5-tracer) microphysics scheme by comparing GPU and the CPU implementation models.

Results:

Testing was done on a Linux workstation with 2 x NVIDIA GTX 680 GPU coprocessors. We chose the "Hurricane Sandy" as our test case. The WRF model domain is 256 by 220 grids at a horizontal resolution of 30km and with 28 vertical levels. The experimental time is from Oct 21, 2012 to Oct 30, 2012.

Table 1 shows the computation time for WRF WSM5 microphysics scheme in both CPU and GPU versions with different processor combinations.

Processors number	CPU (min)	GPU (min)	Acceleration
2	402	311	22.60%
4	295	257	12.90%
8	174	144	17%

Table 1.Computation time on CPU and GPU.

The results are extremely promising, showing a maximum improvement of 23% for GPU version relative to the CPU version. Meteorological outputs from the CPU and GPU versions were visually indistinguishable (Figure 1).

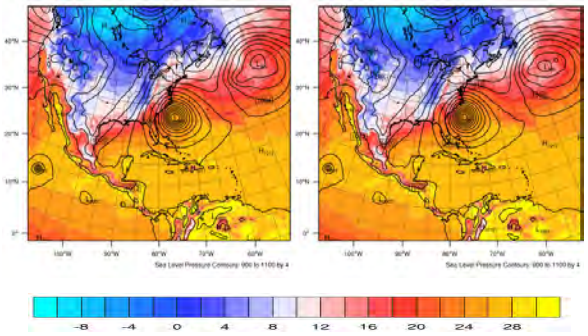

Fig.1.WSM5 2m air temperature(color, ℃) and sea level pressure(dashed line, hPa) from the CPU (left) and GPU code (right).

Acknowledgements: NSF-CDI EAR-1027809 toYifeng Zhu, Bruce E. Segee, Peter O. Koons.

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Deciphering the Mechanisms Behind Climate-Driven Changes in the Relative Abundances of the Diatom *Cyclotella*

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Abstract: While the relative abundances of the diatom *Cyclotella* have already increased in response to global warming across lakes in Arctic, alpine, and boreal regions, it remains unclear what mechanisms associated with warming are eliciting these aquatic community changes. The primary research goal of this study is to decipher the mechanisms behind the climate-driven changes in the relative abundance of *Cyclotella*

Diatoms are a group of phytoplankton commonly observed in almost every aquatic ecosystem. Recent surveys have reported a sudden increase in the relative abundance of small size diatom, *Cyclotella* and a strong correlation between cell size and temperature in Northern Hemisphere lakes due to global warming (Winder *et al*., 2008). Temperature is often considered the direct variable in climate change driving the increase in this group of diatoms. However, temperature rarely has a direct effect on phytoplankton community structure, but it can alter mixing regimes and hence, the availability of resources in lakes. Therefore, temperature-driven change in other variables like light and nutrients may be the primary factors eliciting community changes.

A study conducted by Saros *et al.* (2012) on three different *Cyclotella* species i.e. *Discotella stelligera, Cyclotella bodanica* and *Cyclotella comensis* in alpine lakes suggested that these species can be used to infer the climate driven changes in oligotrophic lakes. They found that these three species were affected by mixing depth and nutrients (Fig.1). But it still remains uncertain how the interactions between light and nutrients play the potential driving force in determining cell size and distribution of *Cyclotella* species. Therefore, the primary objective of this study is to observe the effects of light, nutrients and their interactions on small size diatom *Cyclotella* abundance, distribution and morphology.

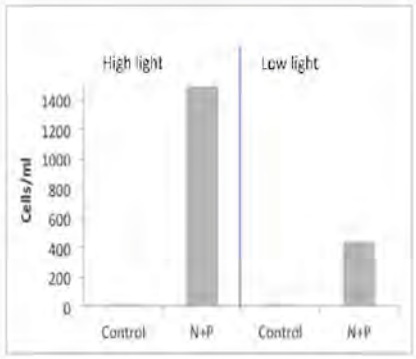

FIG. 1. Density of *D. Stelligera* cells under nutrient enrichment conditions with high and low light intensity

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Recent Increase in Wind Speed and Precipitation Over the West Coast of Southern South America: Cause and Implications

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Abstract: Recent intensification and southward migration of the austral westerlies has resulted in a 20% increase in autumn wind speed and a 20cm increase in precipitation over the west coast of South America (Fig. 1).

In recent decades, air temperatures over portions of coastal Antarctica, the Southern Ocean and the winter atmosphere over Antarctica have exhibited record warming with associated catastrophic disintegration of Antarctic ice shelves and coastal glaciers and impacts on the marine ecosystem (summarized in ACCE, 2009). Concurrently, there has been a strengthening of the austral westerlies, resulting from a steeper latitudinal (N–S) thermal gradient produced by the Antarctic ozone hole and increased tropospheric greenhouse gases (Thompson and Solomon, 2002) that has left much of interior Antarctica isolated from the full force of greenhouse gas warming and led to increases in sea ice extent surrounding much of Antarctica (Turner et al., 2009). Recent average latitudinal displacement and speed of the polar jet stream and associated westerlies has been significant, moving poleward (winter 3.38S, summer 1.88S) and intensifying (up to 6%) between 1981–1990 and 2001–2010 (Mayewski et al., 2012).

Most global and regional climate models suggest that poleward retreat of the austral westerlies will result from continued greenhouse warming during this century. Here we show examples of the recent impacts of this poleward retreat with implications for wind speed, moisture balance, ocean circulation and ecosystem migration.

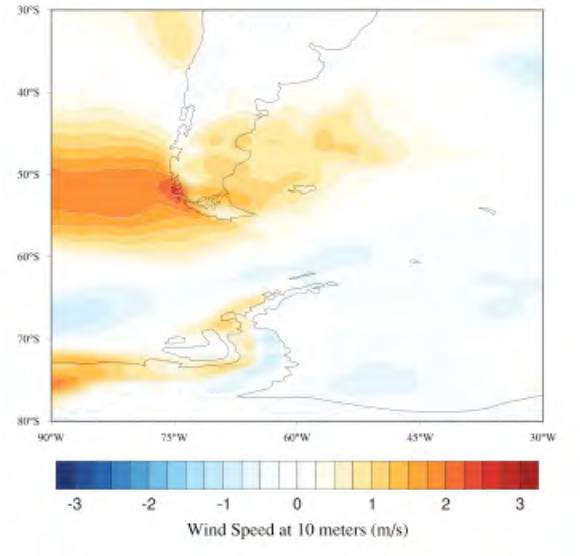

Fig.1. 2005-20011 minus 1979-2005 autumn wind speed (10m height) based on ECMWF ERA Interim Reanlysis.using the CCI Climate Reanalyzer™.

Acknowledgements: Support provided by NSF OPP and the Kuli Foundation.

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Birds In The Wind: Modeling Spatial Patterns of Bird Migration within the Gulf of Maine

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Abstract: Migration is a critical stage in many songbirds' life-cycle, and the environmental factors that influence migration will directly affect individual success and population viability across the annual cycle. One such factor is wind and its effects on flight speed, flight times, and energy expenditures, thereby affecting survival. Despite considerable research focused on wind patterns as a controlling factor in birds' migratory flight costs, the influence of local and regional wind patterns along migration are still poorly understood.

Migrant birds are influenced by environmental factors in multiple locations: breeding, wintering, and along migration. Because of the proposed effects of climate change, such as shifts in wind conditions, these birds may become more threatened with population declines. Migration routes are and will continue to be affected by climate change through alterations in the strength and direction of prevailing winds and the location and quality of stopover sites. Impacts of climate change on atmospheric and oceanic circulation patterns have been increasingly reported in recent literature, and these impacts have dramatic consequences for the patterns of regional weather systems. Understanding the current and future relationships between songbird migration and regional winds, therefore, will be invaluable for conserving North American birds in the face of climate change.

I propose to model past and future bird migration patterns within the Gulf of Maine (GOM) region. Currently I am exploring modeling options such as HYSPLIT, a single particle langtangian integrated trajectory model created by NOAA that incorporates weather reanalysis data. Unlike particles, birds a have mass, speed, and flight vector. To account for these factors I will adapt HYSPLIT to accept biological "particles". Stable isotopes have indicated that birds breeding as far northwest as Alaska migrate through the GOM. I intend to use breeding bird abundances from across Canada as input into the model. The model will run nightly to mimic birds' nocturnal migration. Once established, I will validate the model output by comparing it to the number of birds captured on the ground at thirteen migration monitoring stations operated during four fall migration seasons (2009-2012) in Acadia National Park, Maine.

With projected changes in wind patterns through climate change I expect to see changes in bird migration patterns. The International Panel on Climate Change's (IPCC) 2007 synthesis report outlines six emissions scenarios. Emission scenarios will each create varying surface temperature increases and affect wind patterns differently. Using the validated migration model I hope to model future migration patterns in the GOM region under each emission scenario. This model will allow ANP and other partners to predict areas of high concentrations of migrants as well as forecast changes in timing of migrants utilizing ANP's habitats.

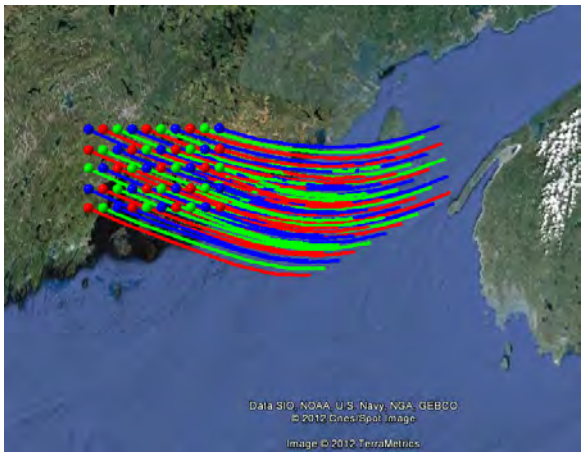

Fig 1. Example HYSPLIT output of birds floating like particles in the wind.

Acknowledgements: Thank you to Brian Mitchell and Bruce Connery of the National Park Service for their support and to Peter Koons and Sean Birkel for their continued support with this project.

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Maine Stakeholder Questions about Climate Change and Novel Methods for Interpolating Climate Using Satellites

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Abstract: We will present two results of interest. First, a group of researchers has assembled a large group of stakeholders in Maine interested in the effects of climate change on organisms (ECCO) (i.e. forestry, agriculture, conservation, disease). We will summarize the questions of most interest to this group. Second, we will present a novel technique for interpolating weather data to provide estimate of weather between weather stations that uses satellite data to provide superior spatial accuracy.

ECCO Stakeholder Group:

The ECCO (Effects of Climate Change on Organisms) research team, has worked to assemble a group of stakeholders here in Maine who are interested in how climate change may effect non-human living organisms. This scope is broad covering forestry, agriculture, disease and conservation.

We assembled a list of over 50 potential stakeholders and invited them to participate in a one-day workshop. To our surprise there was a strong selection process on who expressed interest, namely conservation, tourism and disease sectors were interested, while we were unable to get participants from forestry or agriculture (feedback from somebody in agriculture was “farmers deal with weather all the time – climate change is no big deal to them”).

At the one day workshop we used a brainstorming and prioritization process to identify key questions. Many of the questions most highly prioritized were a strongly interdisciplinary with significant social science, ecological and climatological components.

We also asked stakeholders how they envisioned working with researchers to answer these questions. There were a strong believe that determining the questions for research should be very collaborative (equal roles), the research and interpretation should be done primarily by researchers while still involving stakeholders, and the translation of results to policy should be done primarily by stakeholders with involvement by researchers.

Fusion interpolation:

There is a strong global network of weather stations taking daily, high accuracy measures of weather. To date various interpolation methods have been used to fill in the spatial gaps. Unfortunately these weather stations are strongly biased towards areas of high human population and away from unique climates (e.g. mountains, shorelines) and can be far apart in some areas (as much as several 100 kms in the tropics).

A group of researchers funded by NASA, NCEAS, and iPlant are seeking to develop a new “fusion” method that merges satellite data with high spatial resolution with weather stations that have long temporal records and high accuracy.

We have completed a case study in Oregon and are now extending the study to Venezuela. Results show that which explanatory variables are included are fairly unimportant, that the statistical interpolation method used is fairly unimportant, but that the number of stations is very important. Further the results show that the fusion method achieves superior results at validation (held out stations) by measures such as RMSE. The spatial structure of the fusion method in between stations looks much more realistic but it is difficult to rigorously test this claim.

Acknowledgements: NASA, Maine EPSCoR.

A Map of Subglacial Water in Greenland

Gordon K. A. Oswald[1]
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Abstract: Analysis of ice-penetrating radar data gathered by the University of Kansas in 1998-2003 has been completed. Water beneath the Greenland Ice Sheet is widespread and the measurements are highly self-consistent.

Melting at the base of ice sheets

The world's major ice sheets have been subject to extensive topographical study since the 1960s, and in 1973 it was confirmed that radar measurements could detect the presence of melt lakes at the ice bed in Antarctica. More recent developments in radar technology have greatly improved the quality of radar recordings, and it has been possible to extend the analysis to determine basal thaw even where lakes as such are not found. This is the case beneath the Greenland Ice Sheet.

Findings and consistency in Greenland

Airborne radar surveys have been acquired in Greenland by Kansas University Radar and Remote Sensing Laboratory, now the Center for Remote Sensing of Ice Sheets, under NASA's Program for Arctic Regional Climate Assessment (PARCA) and recent NSF programs.

These radar records have been analyzed, covering the period 1998-2003, to determine the state of the bed over the full survey area. A total of 739,000 determinations were made. Water is found to occupy large parts of the observed bed in different regions, with an average incidence of thaw of 17.6%. A map of bed freeze (cyan) and thaw (blue) is shown in Figure 1.

In over 50% of cases, two or more determinations have been made at the same point from different survey years, flights or flight segments. In these cases, agreement is found to be over 92%. With such a large population, and with measurements made in different flight directions and geometries, this degree of consistency gives a high measure of confidence in determining the bed state.

Of six cores drilled to bedrock (Camp Century, Dye 3, GISP2, GRIP, North-GRIP, and NEEM), only one (North-GRIP) encountered water at the bed. This was towards the southern extent of the large blue area near (-50,50) in the figure. The small set of actual ground truth data are therefore in agreement with this study. The measurement at the NEEM site predicted the bed state correctly.

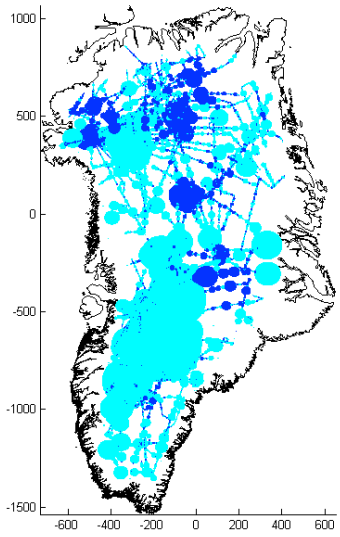

Fig. 1. Areas (blue) in which subglacial thaw has been determined beneath the Greenland Ice Sheet.

Acknowledgements: This research has been supported under NSF ARRA Grant No. 0909431

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Fluvial Deposition and El Niño at San José de Moro, Perú

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2. Graduate School, University of Maine.
3. Department of Anthropology, University of Maine.
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Abstract: We will investigate the sequence of flood deposits at San José de Moro along the Chamán River in the Jequetepeque Valley, Peru in order to illuminate past El Niño chronology and processes and its impact on prehistoric inhabitants of the region.

Background

The archaeological site of San José de Moro is located on the bank of the braided Chamán River in the northern Jequetepeque Valley approximately 5 km north of the city of Chepén, La Libertad, in the coastal desert of northern Peru. Extensive excavations have established the site as an important cemetery and ceremonial center beginning around 1,600 BP (Castillo et al. 2008). Due to its position in the floodplain of the Chamán River the depositional environment at San José de Moro is dominated by fluvial processes. The regional environment is extremely dry and receives less than two inches of rainfall in a normal year. Flooding is essentially non-existent under these conditions. During El Niño years, however, western Peru can receive significantly more rainfall, often leading to extensive flooding. Based on this phenomenon, it is presumed that the Chamán floodplain at San José de Moro is composed primarily of fluvial sediments deposited during El Niño flood events. The goal of our research is to use the sedimentary sequence at San José de Moro to develop a chronological record of El Niño events.

Research Goals and Methods

Research at San José de Moro will be focused on an effort to extract a record of El Niño magnitude and intensity from the sedimentary sequence at San José de Moro, and to use these data to understand the potential environmental effects of this major climatic event on the archaeological record in the Jequetepeque Valley. Summer 2013 field work will consist of the excavation and detailed analysis of a trench at the San José de Moro site, and will take place in conjunction with the archaeological excavations of El Proyecto Arqueológico San José de Moro led by Professor Luis Jaime Castillo Butters of Peru's Pontifical Catholic University. The stratigraphic section exposed in the trench will be carefully described, drawn, photographed and sampled, using standard techniques. Individual strata will be dated using luminescence dating of sediments, radiocarbon dating of organic materials, and/or artifact chronology as possible.

This information will be used to infer past patterns of El Niño flooding with respect to timing and magnitude. The stratigraphic information will be compared with the known prehistory of the Jequetepeque Valley in an effort to understand the impacts of El Niño flooding on occupants of the region. We expect the sequence to provide data for the time period from approximately 5,800 BP, when El Niño returned after a hiatus (Sandweiss et al. 2007), until around 1,600 BP after which the site began to be intensively occupied and flooding no longer appears to have a strong effect on the community.

The past history of El Niño is relatively poorly understood. An interpretation of floodplain deposition of the Chamán River has the potential to provide information about El Niño chronology and variation, to help understand the past environmental context of the archaeological record in the Jequetepeque Valley and to contribute to global studies of ancient El Niños.

Acknowledgements: This research is funded by NSF Award ARC-1152156 to Jeffrey Quilter (Harvard University).

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Short Term Arsenic Deposition Record from Detroit Plateau, Antarctic Peninsula

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Abstract: Arsenic was measured in a series of dated ice core samples, covering the period 1980 to 2007, collected from a remote, high snow-accumulation site in Detroit Plateau, Antarctic Peninsula.

Pronounced enhancements of elements like Arsenic (As) have been observed during the last few decades in Antarctic snow and ice. The enhancements have been attributed to the emissions of heavy metals into the atmosphere from human activities in Southern America, especially from non-ferrous metal mining and smelting (Wolff et al., 1999; Planchon et al., 2002).

Decrease in As concentration was observed in the 1990s in response to the introduction of environmental regulations enacted to reduce As emissions from the copper industry, primarily in Chile. The observed decrease suggests that governmental pollution regulations are effective in reducing air pollution at both the regional and global level (Hong et al., 2012).

We present results from high resolution (average 36 samples/year) ice core analysis of As and deposition on the Detroit Plateau (DP), northern Antarctic Peninsula, covering the period from the end of 1980 to the end of 2007. We use seasonal peaks in hydrogen peroxide (maxima represent the summer-time onset of photochemical reactions in the Antarctic atmosphere) to date the 98m-long DP ice core. Chemical analysis demonstrates that the site has a high seasonal accumulation (average of ~2.4m H20 equiv./yr) providing potentially high-resolution records of atmospheric chemistry. Our analyses also reveal that As exhibits large seasonal variability, with a distinct single annual maximum and minimum concentration.

Climate Reanalyzer (ECMWF ERA-Interim Reanalysis) and NCEP/NCAR Reanalysis indicate strong correlation between As concentration on DP and zonal winds on the East Tropical Pacific and Northern Chile (Fig 1.).

The association between zonal wind and As concentrations from the DP ice core, from 1981 to 2007, reveals a statistically significant (above 99%) correlation in excess of 0.7 in the aforementioned areas.

The primary source of anthropogenic As in the atmosphere is linked with the transport of dust emitted during cooper mining and milling operations. In the Southern Hemisphere, Chile and Peru are particularly large source regions (Barbante et al. 2001). However, these two areas both emit natural- and anthropogenic-source As.

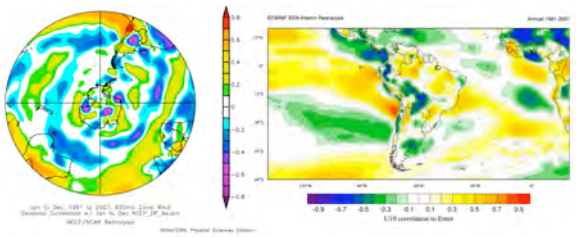

Fig 1. Seasonal correlation for (DP) As concentration and 850mb Zonal Wind over the Southern Hemisphere from 1981 to 2007 (left: NCEP/NCAR Reanalysis; right: ECMWF ERA-Interim Reanalysis).

Acknowledgements: A grant from NOAA to PM; funds to JS UFRGS; logistics support provided by INACH.

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Case Studies with the P301 System*

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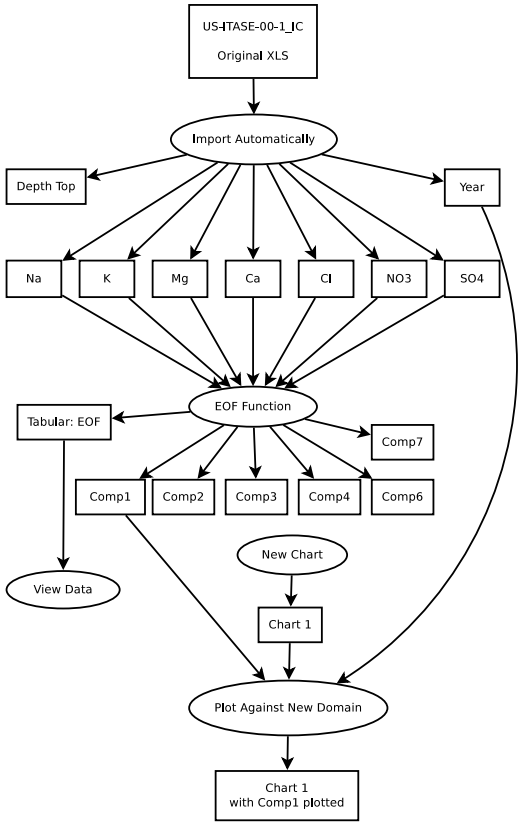
The *P301* system aids the researcher with storing, cleaning, analyzing, and visualizing data, with an overall goal of facilitating the workflow from raw data to research results. It allows researchers to share data among individuals or groups in a common repository. In addition to built-in tools for processing data, data can also be processed in external systems, such as *R* or *Octave*, and the *CCI Climate Reanalyzer*.

In a typical scenario, data collected in the field must be stored in some kind of file, spreadsheet, or database. Before it can be analyzed, the data is cleaned using interactive tools. Statistical routines operate on the data and produce derived data sets to help with analysis, visualization, and interactive exploration. Throughout this process of transforming data, the details of applied operations and provenance of the data must be maintained in order to ensure reproducibility and to facilitate similar analyses later, perhaps long after the work of the initial researcher.

As an example, consider the task of plotting the first component output based on empirical orthogonal function (EOF) analysis of the data set US-ITASE-00-1_IC. The process is outlined in the adjoining figure, in which boxes represent data sets and ovals represent operators. The data must first be imported into P301, which provides tools to assist with the tasks of determining and adding column names, units, additional row-based metadata, and data set metadata (e.g., ownership and references). The importer has the option to make the data immediately available to the rest of the research group. The EOF function is selected from the collection of available tools. The user then selects the seven ions from the just-imported data set, located in the working objects area. These ions are used as the parameters to the EOF function. Prior to execution of the function, the certificate associated with the function is verified. In general, a certificate is a set of conditions that a data set must satisfy. In the case of the EOF function, the certificate checks the data is a monotonically increasing timeline based on the year. The unit data is critical for correct evaluation. When the certificate is verified, the EOF function is applied to the data set. Since this function is an externally implemented one, the data is sent to a server containing an *Octave* instance in which runs a procedure that performs the necessary computations. The result is sent back to the originating P301 instance and is added to the working objects area in a tabular form that includes correlation statistics and component results. The correlation results are viewed by applying the *View Data* function. A new chart is created using the *New Chart* function. The first component data is plotted using the *Plot Against New Domain* function along with the original year data that was stored in the working objects area.



Another task is to resample Siple Dome 1994 data to view using the *CCI Climate Reanalyzer*. In this case, annual means must be calculated in order to meet the *Reanalyzer* input specification, which requires a specific format and the years to be meaned. The *Annual Means* function is executed with the data, January, and December as parameters. The smoothed data that results is placed in the working objects area. The smoothed data is viewed by applying the *Plot Against Years* function. From here the user can export the data from *P301* to the *Reanalyzer* for further analysis.

*Work supported in part by the U.S. National Science Foundation grant EAR-1027960 and by the Climate Change Institute. Contributions from the entire *P301* team are gratefully acknowledged.

Comparison of Fecundity Calculation Methods and Observed Nest Success Probabilities for Sharp-tailed Sparrows

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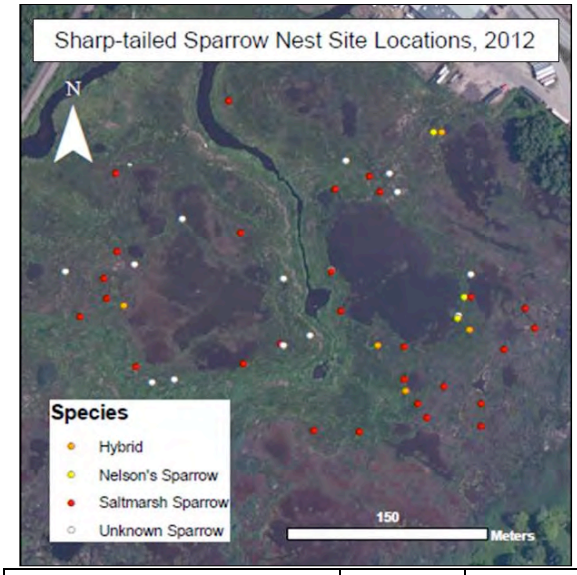
3. United States Environmental Protection Agency.

Abstract: We compared various methods for calculating nest success of Sharp-tailed Sparrow populations in southern Maine. With all methods, we found significant differences of nest success among species. Finally, we compared the nest success and failure probabilities among species, considering spatial and nest structural variables as causes for the observed differences.

Fecundity, or number of young produced successfully by an individual, is a vital rate that is essential for assessing and managing wildlife populations[1]. Despite its universal importance, many methods have been used in avian biology to estimate fecundity. Most methods have limited resolution due to constraints imposed by the breeding biology of a species or practicalities of data collection[1]. For example, most fecundity estimation methods examine only a single breeding attempt due to the difficulty of tracking adults who make multiple breeding attempts throughout the breeding season[1]. In this study we compare various methods of calculating fecundity for populations of Saltmarsh Sparrows (*Ammodramus caudacutus*), Nelson's Sparrows (*Ammodramus nelsoni*), and their apparent hybrids at a breeding site in southern Maine. At four study plots over 2011 and 2012, we found and tracked sparrow nests throughout the breeding season (May-September). We found nest success varied significantly among species. Despite very different rates of nest flooding from 2011 to 2012, in both years of study hybrids experienced the highest nest success, followed closely by Saltmarsh Sparrows. Nelson's Sparrows experienced very low relative nest success. These results, specifically the low survival of Nelson's Sparrow nests, are unexpected because previous research has suggested that the Nelson's Sparrow range has increased over time[2,3,4]. Finally, in this study we examine spatial dynamics and nest building traits as explanatory variables for the observed differences in nest success and failure probabilities among species.

Acknowledgements: U.S. Fish & Wildlife Service, Saltmarsh Habitat & Avian Research Program collaborators, my committee, particularly Matt Etterson, and the Olsen lab.



NEST SUCCESS	2011	2012
Hybrid	9%	23%
Nelson's Sparrow	3%	11%
Saltmarsh Sparrow	9%	21%

Fig. 1. Nest locations at one 10ha study plot.

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Exploring Climate-Induced Changes in West Greenland Lakes

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2. School of Biology and Ecology, University of Maine.

Abstract: Across the Arctic, lake sediment records provide some of the few key archives documenting rates of ecosystem change in this region since the last ice age. In particular, striking changes in communities of diatoms have occurred over the last 150 years. We used experiments to provide key ecological information that will enhance interpretation of several existing diatom records from southwest Greenland, and will discuss a new project that starts this summer.

In numerous lake sediment records from the high Arctic of Canada and Europe, diatom species generally associated with warmer conditions increased at unprecedented rates during the 20th century (Smol, 2005). Diatom communities in lake sediments from west Greenland are dramatically different from those in the rest of the Arctic- they are rich in these "warmer" water diatoms throughout the Holocene, not just the last century (Perren et al. 2009). This difference has raised questions about what we can use diatoms to infer in the Arctic, and suggests the need to clarify the ecological traits of key diatom taxa in order to advance our understanding of drivers of change.

In 2011, we conducted a microcosm experiment to provide key ecological information that will enhance interpretation of climate-induced ecological changes from several existing diatom records from southwest Greenland. Experiments manipulated both nutrient availability (nutrients added or not) and light (surface and deep, where 10% photosynthetically active radiation remains). Preliminary results suggest that a "warmer" diatom taxon of interest (*Cyclotella radiosa*) responds to increased light availability but has limited response to nutrient enrichment (Fig. 1).

Understanding the ecology of these species will provide important tools to decipher the extent to which direct and indirect effects of climate are contributing to rapid ecological change. Ultimately, diatom records from arctic lakes may be providing much richer signals of the response of these lake ecosystems to climate change than previously thought.

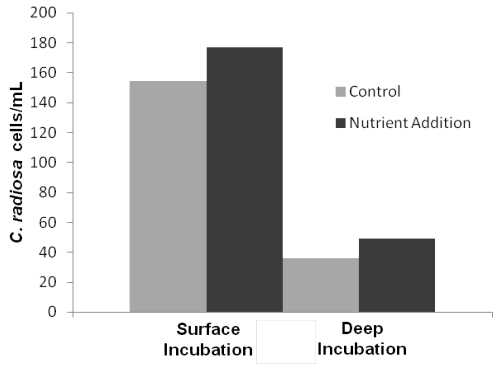

Fig. 1. *Cyclotella radiosa* experimental results

This research served as the foundation for a larger project that will begin in the summer of 2013. The new project will involve comparative lake sampling across a large region around Kangerlussuaq, and a series of small-scale experiments similar to those conducted in 2011. Using Lake SS16, we will also conduct the first whole-lake mixing experiment in an Arctic lake ecosystem. SS16 will be instrumented with an array of sensors and sediment traps to remotely monitor the response of this lake to climate-induced changes in mixing regimes.

Acknowledgements: Funding for this project was generously provided by the Dan and Betty Churchill Exploration Fund and the Gokcen Fund. Funding for the new project is from NSF Arctic 1203434.

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Using High Rate GPS Observations to Investigate two Subglacial Lakes under Byrd Glacier, Antarctica

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Abstract: Byrd Glacier is one of the largest glaciers in the world, with a catchment area encompassing 1,070,400km^2 of the East Antarctic Ice Sheet (Rignot and Thomas 2002). In 2007, two subglacial lakes drained catastrophically, releasing ~1.7km^3 of water and causing the glacier to accelerate by ~10% of mean velocity (Stearns *et al*. 2008). Whether or not lake filling and draining is a cyclic process and whether Byrd Glacier flow is perturbed repeatedly are unknown. Preliminary analysis of 25 months of GPS observations shows changes in surface elevation over the lakes on the order of a couple of meters. Further investigation will explore the relationship between changes in elevation and flow at the lake sites with changes in flow speed along the trunk of the glacier.

Byrd Glacier (Fig. 1) drains a portion of the East Antarctic Ice Sheet (EAIS) through the Transantarctic Mountains. Its catchment area of 1,070,400km^2 (Rignot and Thomas 2002) makes it one of the largest glaciers in the world. The glacier's main trunk extends ~75km and is ~20km wide.

Stearns *et al*. (2008) constructed a 48 year velocity record for Byrd Glacier. Flow speeds remained more or less constant between November 1960 and December 2005. From December 2005 to February 2007, a ~10% increase in velocity was observed along the entire trunk of the glacier (Fig. 1), concurrent with a rapid decrease in surface elevation at two locations ~200km above the grounding line. The acceleration was attributed to the draining of two subglacial lakes. After the lakes finished draining in February 2007, flow began to decelerate (Stearns *et al*. 2008).

From January 2011 through January 2013, global positioning system (GPS) receivers were placed on the Byrd Glacier lake sites (Fig. 1, UL and DL) to monitor flow and elevation variability of the glacier surface. Using surface elevation to monitor subglacial lakes is inherently complicated due to factors such as station settling and advection downstream along a steep gradient. Preliminary results from the lake sites show changes in elevation on the order of several meters. Further investigation will compare these data with GPS observations from along the trunk of the glacier to provide further insight into the mechanisms affecting the flow of Byrd Glacier.

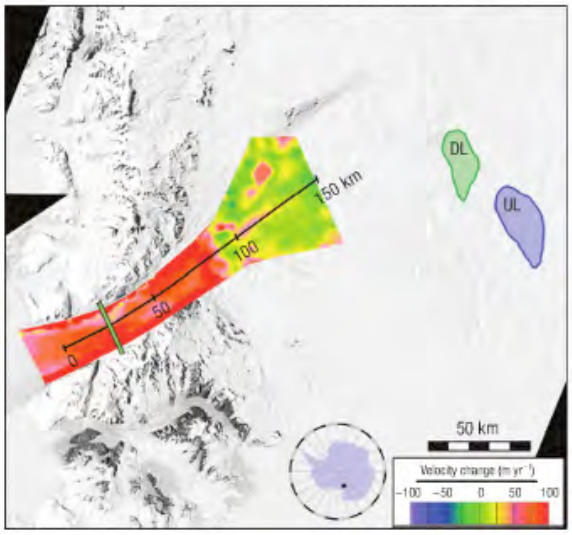

Fig. 1. Byrd Glacier, Antarctica. Location of upstream lake (UL) and downstream lake (DL). Contours are velocity change from pre-2005 average speeds to 2006-2007 peak speeds overlain on a Landsat image. From Stearns *et al*. 2008.

Acknowledgements: Field work was supported by NSF-0944087.

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Implications of Nitrogen-rich Glacial Meltwater for Phytoplankton Diversity and Productivity

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Abstract: Meltwater from alpine glaciers in the Rocky Mountains of the U.S. is enriched with dissolved inorganic nitrogen, providing subsidies to associated lake ecosystems. We investigated whether glaciers have been a chronic driver for biotic change in aquatic communities over the late Holocene in alpine lakes.

Introduction: Glacier meltwater has numerous effects on the physical, chemical and biological characteristics of aquatic communities, with the recent and rapid recession of alpine glaciers over the last 150 years having major implications for these associated systems[1,2]. The presence of glaciers on the landscape and the differential timing of glacial loss over the Holocene have created heterogeneous aquatic communities, both spatially and temporally, within alpine ecosystems.

Methods: To determine if glaciers have been a chronic driver of lake structure and function, we compared diatom species richness, community assemblages, and pigment composition over time from lake sediment cores taken from paired lake systems, one lake fed by both glacial and snowpack meltwaters (GSF), and one by snowpack alone (SF) in the central Rocky Mountains of North America to better understand the influence that nitrogen-rich glacial meltwater has on phytoplankton.

Results: The GSF lake shows greater variability in percent organic material, community composition and algal pigments with significant changes occurring post Little Ice Age compared to the SF counterpart. Species richness has declined in the GSF lake since 1850, showing an increase in dominance of diatom species such as *Cyclotella stelligera* and *Asterionella formosa,* the latter an indicator of nitrogen enrichment, within the last 150 years.

Conclusions: Our results suggest that nitrogen-rich glacial meltwater promotes key differences in structure and function of GSF compared to SF lakes and imply that GSF lakes will take a different ecological trajectory when glaciers disappear.

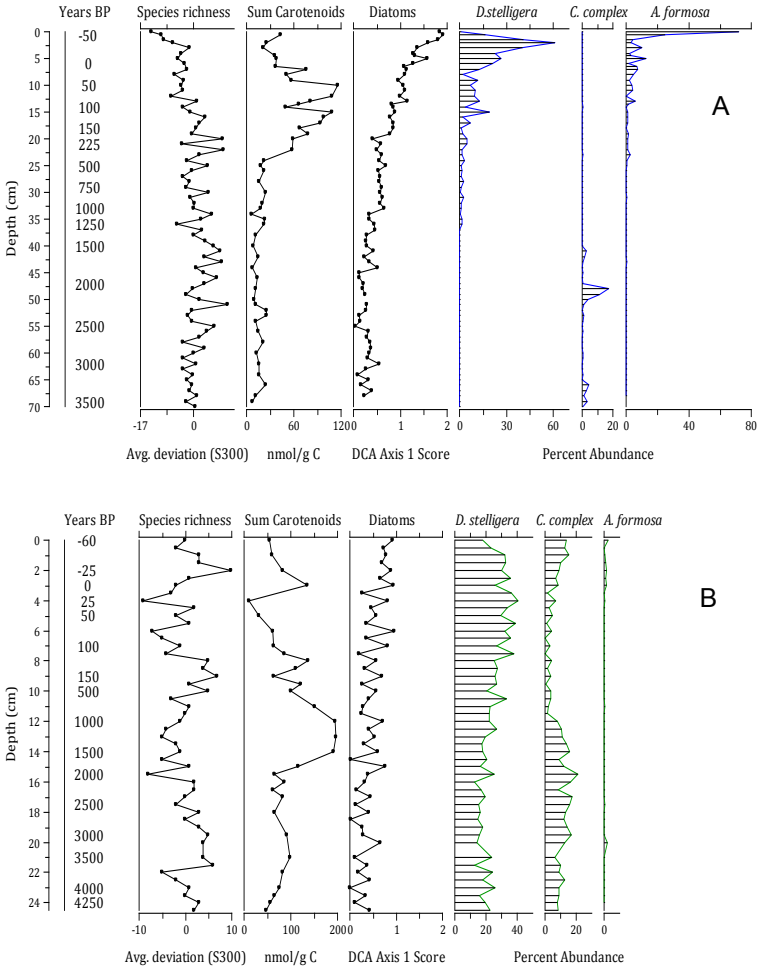

Fig. 1: Biotic profiles of diatom species richness, PCA Axis 1 score of algal pigments, DCA Axis 1 scores of diatom assemblages, and the change in three key diatom species in Jasper Lake (A), a glacially-fed lake, and Albino Lake (B), a snow fed lake in the Northern U.S. Rocky Mountains.

Acknowledgements: NPS George Melendez Wright Climate Fellowship, Dan and Betty Churchill Fund, NSF-DEB 0734277

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[2] Saros, J. E, et al. 2010. *Environ. Sci. Technol.* **44**: 4891-4896.

Norske Øer Ice Barrier

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Abstract: The Norske Øer Ice Barrier (NØIB) is a large, landfast and sea ice structure located at about 79° North and 17° West. It is so named because of its proximity to Norske Øer (Island) and the major role it plays in the annual generation of the Northeast Water (NEW) polynya to the north of the ice barrier. The ice barrier has long been considered a semi-permanent structure whose size varies from year to year but with the complete breakup of it a rare event.

Research Question:

The NØIB reportedly broke up sometime in the 1950s (Wadhams, 1981) and since then satellite images show that the ice barrier has broken up during the summers of 1997, 2002-2005, 2008, and 2010-2012. NØIB abuts the eastern termini of Nioghalvfjerdsfjorden (79N) and Zachariae Isstrøm glaciers, two of the three outlet glaciers of the Northeast Greenland Ice Stream; the ice stream drains ice from about 15% of the Greenland ice sheet.

What role does the ice barrier play regarding the dynamic stability of these two large outlet glaciers? What are the effects of increasing terrestrial meltwater runoff on the ice barrier? Is the breakup a purely local phenomenon or does it's increasing frequency indicate regional changes in the East Greenland Current and the Greenland Sea? What climate and weather factors are contributing to the break up?

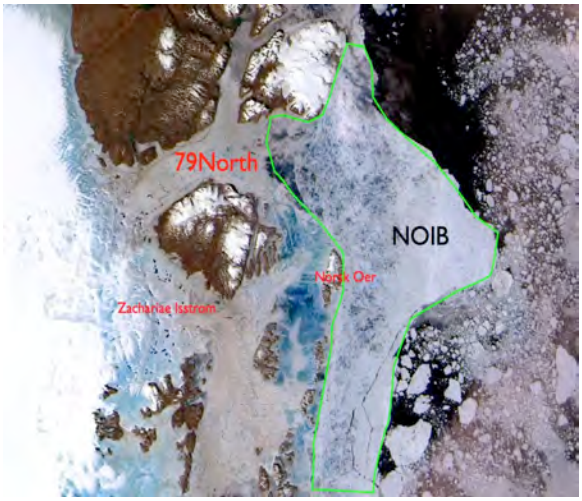

Fig. 1. Satellite image of NØIB.

Acknowledgements: Initial funding from a NASA research fellowship; current funding from the SSA.

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Climate Impacts on Decomposition in Forensic Taphonomy: A Pilot Study

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Abstract: Forensic taphonomy research utilized *Sus scrofa* cadavers as surrogates for human forensic cases in a pilot test to monitor decomposition in open and wooded environments of Maine. Decomposition patterns deviated from published models developed in Eastern Tennessee and Indiana, despite temperature controls.

Commonly used models to estimate postmortem interval in forensic cases assume a phased decomposition process including insect involvement and no scavenger modification. These models are based on datasets from warmer climates, such as eastern Tennessee, for example, where the mean temperatures are below 4°C only two months of the year. These models assume that controlling for temperature using accumulated degree days (ADD) is sufficient to address regional variation in decomposition contexts. Northern New England, in contrast, has a colder, more seasonally variable climate, a densely forested landscape, and a high level of scavenger access. In at least five months of the year mean temperatures are below 4°C, inhibiting necrophagous insects.

Using pig (*Sus scrofa)* cadavers and excluding mammalian and avian scavengers, we executed a small pilot study to explore whether climatic factors and microenvironmental site differences, such as snow cover, forest canopy, and insect absence might impact the rate and character of decomposition, and require different models.

Two pig cadavers were placed at the outdoor Maine research site on November 5, 2010, monitored via camera daily for two years, with hourly temperature and humidity data. They were placed in cages to protect them from scavengers. Temperature was analyzed as Accumulated Degree Days (ADD). Cages were approximately 30 m apart, one in an open, grassy meadow ("Field Pig"), and the other under a 75% evergreen canopy ("Woods Pig").

The Woods Pig progressed through stages of decomposition at a faster rate than the Field Pig, particularly during the bloat and early decomposition phases. The Woods Pig had higher decomposition scores at all 100-ADD benchmarks, despite lower average temperatures and a slower build-up of ADD in the woods (see Fig. 1).

Figure 1. Compares the amount of time and Accumulated Degree Days for the Field Pig (8 months; 1440 ADD) and Woods Pig (7 months; 645 ADD) cadavers to become fully skeletonized.

The Woods Pig reached full skeletonization on June 24 at 645 ADD. The Field Pig reached full skeletonization 34 days later, at 1440 ADD.

Deviations from expected decomposition progress in this pilot study suggest the need for more research to develop climate-specific decomposition models for forensic cases. Emerging climate change data should be incorporated to make the models more dynamic and regionally applicable.

Research supported by Award No. 2008-DN-BX-K177 awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice. The opinions, findings, and conclusions or recommendations expressed in this presentation are those of the authors and do not necessarily reflect those of the Department of Justice.

Periodic Episodes of Catastrophic Aeolian Sand Deposition, Shetland UK

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

Abstract: We present research showing that a large scale aeolian event that forced the abandonment of the Township of Broo, Shetlands UK during the 18th century was not an isolated occurrence, but the last in a series of similar events that have occurred for thousands of years.

Sand invasions involve the large-scale transportation of massive quantities of dune sand in a short period of time. Such invasions are very disruptive to local communities and have led to the abandonment of locales. Many researchers have focused on large-scale coastal aeolian sand movements on the northern European mainland coast, but fewer reports have examined the northern Scottish islands, and most of those have focused on ancient archeological sites. The most well documented sand invasions occurred during the Little Ice Age when hundreds of thousands of acres were affected by sand drift across Western Europe and Britain.

Fig.1. Photograph of the field site taken from helicopter. Areas with yellow vegetation indicate the area that was inundated by sand.

Previous studies of Archaeological sites in Shetland noted sand inundation across a wide range of sites from the prehistoric sites of Old Scatness (Burbidge et al., 2001) and Jarlshof (Dockrill and Bond, 2009), as well as the historic period site of Broo (Bigelow et al., 2005). Our study site, the Township of Broo in Quendale Links of the Shetland Isles, UK, was inundated by sand during the 17th and 18th centuries and subsequently abandoned. Archaeological excavations at Broo, approximately 2 km from the coast, have exposed a 17th century farmstead that was covered by up to a meter of wind-blown sand. This property was once the most productive area on the Shetland Isles prior to abandonment. Ground Penetrating Radar (GPR) was employed in conjunction with excavation and OSL dating to determine if the 17th century event that buried the township was an isolated occurrence or the last in a series of sand invasions. Initial results show that the 17th century event was not an isolated occurrence, but one of several sand invasions that occurred as early as 3700 BP, and that sand has continued to accumulate within parts of the system during the past 150 years following drastic sand movement in earlier centuries.

Acknowledgements: We would like to thank Churchill Exploration Fund, NSF, Dr. Gerald Bigelow, Matt Bampton(USM), and Marianne Okal(UNAVCO)

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Searching for Ancient Ice in the Allan Hills – A Project Synopsis

Nicole E. Spaulding[1,2], Andrei V. Kurbatov[1, 2], Paul A. Mayewski[1, 2], Michael L. Bender[3], John A. Higgins[3]

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3. Department of Geosciences, Princeton University.

Abstract: A summary of key findings regarding the age and integrity of the paleoclimate archives of the Allan Hills Blue Ice Area.

Many important insights into climate dynamics have come from deep ice cores, however their resolution and sample volume is limited, particularly in deep time. In order to better understand annual to millennial scale changes, or make multi-parameter measurements, larger samples volumes are needed. Within blue ice areas (BIAs) old ice is sheared to the surface and eroded by strong winds allowing for large volume samples of ice to be gathered directly from the surface. Using geophysical surveys and glaciochemical analysis of ice in the Allan Hills BIA we have 1) identified a flowzone (Spaulding et al., 2011) within which ice of continuous ages can be collected, 2) determined the age of the ice along that flowline (Spaulding et al., submitted) and 3) demonstrated that the ice contains an environmental signal consistent with East Antarctic climate history (Spaulding et al., in prep).

High-precision GPS measurements taken with a 14 year interlude were use to determined the speed of ice flow through the BIA and also show that exposed ice has an upward vertical velocity. This is the first well-constrained support of hypothesized blue ice dynamics. In combination with future radar work, these measurements will aid in the development of a precise 3-dimensional time-scale.

Our analysis of the δD_{ice} (a common proxy for temperature), $^{40}Ar_{atm}$, and $\delta^{18}O_{atm}$ of trapped gas, suggest that the sampled ice is in good stratigraphic order and is between 80 and 250 ka. The presence of 100 m of uncollected ice above bedrock indicates that ice as old as 400 ka may be present. Measurements from off-flow ice cores suggest ice frozen to the bed is up to 1 Ma.

Beyond providing an age estimate the δD_{ice} trends demonstrated that the temperature signal near the surface had not been altered, as it followed the trends observed in other Antarctic ice cores. To further examine the integrity of the climate signal, samples corresponding to both glacial and interglacial states were selected for glaciochemical analysis. Element concentrations exhibit a high level of correlation with δD, as anticipated given the increase in transport efficiency and source strength during glacial periods. Patterns of rare earth element enrichment and soluble impurity composition exhibit changes dictated by the prominence of marine air mass incursions and changes in transport intensity.

In summary, the glaciochemistry of the AH BIA is suitable for paleoclimate reconstruction. A map of surface ages within the AH BIA is provided below (Figure 1).

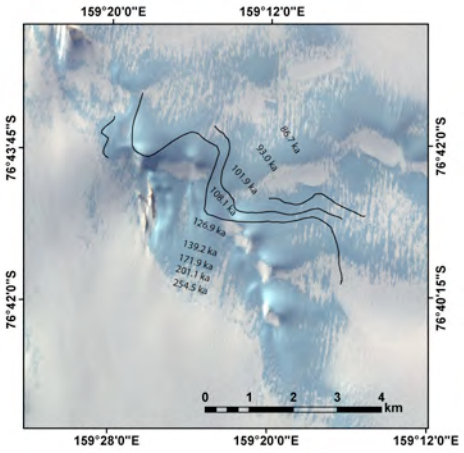

Fig. 1. Ages along the dated portion of the flowline are between 86 and 254 ka.

Acknowledgements: Funding was provided by NSF OPP grant ANT-0838843. Samples were collected with support from RPSC and Kenn Borek Air Ltd and analyzed by Sharon Sneed, Mike Handley and Douglas (Cap) Introne. We gratefully acknowledge the insight provided by V. Blue Spikes and the field and laboratory assistance of Kristin Schild, Melissa Rohde, Mike Waszkiewicz, Calum Hamilton, Daniel Lesser and Ashley Suitter.

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Exploring the Effects of Extreme Hydrologic Events in the Northeastern U.S.: Implications for Brownification and Episodic Acidification in Maine Lakes

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2. School of Biology and Ecology, University of Maine.
3. Senator George J. Mitchell Center for Environmental and Watershed Research, University of Maine.

Abstract: In the northeastern U.S., there has been a widespread decline in sulfur deposition as a result of Clean Air Act amendments. Over this same time period, extreme precipitation events increased in frequency by over 61 percent. To explore the potential interactions between reduced atmospheric deposition and changes in the frequency of extreme weather events, we paired weather data collected from watershed-scale climate models with lake geochemistry collected by US-EPA monitoring programs over the past three decades.

Increased dissolved organic carbon (DOC) concentration, or "brownification," is a phenomenon that has been observed in many regions of the Northern Hemisphere. DOC is a highly diverse pool of organic compounds that impart a brown stain to lake water. These changes have been attributed to both declining sulfur deposition and climate-mediated drivers. Long term monitoring of Maine lakes documents variable trends in DOC over the past three decades. To explore the effects of extreme weather events on DOC trends, we paired weather data collected from watershed-scale climate models with surface water geochemistry from sixteen remote Maine lakes collected by US-EPA monitoring programs over the past three decades.

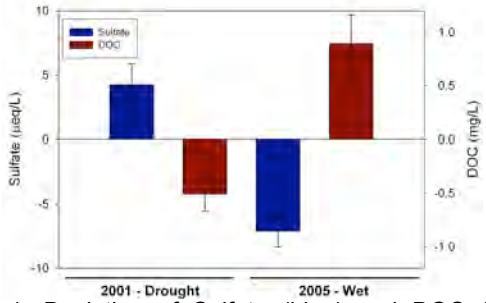

Fig. 1. Deviation of Sulfate (blue) and DOC (red) concentrations from a 30 year mean for 2001 (a marked drought year) and 2005 (a marked wet year) across 16 Maine lakes.

Sulfate increased across this subset of Maine lakes in 2001, suggesting episodic acidification during drought years (Fig. 1). This response appears to be more pronounced in catchments with greater wetland coverage. During wet years, there was an increase in DOC, or episodic brownification. A peak in sulfate has been observed at other individual research sites following a period of drought; however, the extent to which this is characteristic of a broad-scale regional response is still unclear (Kerr et al. 2012). Our findings not only suggest a state-wide chemical response to drought conditions, but also increased brownification in Maine lakes during wet years.

DOC is a pivotal regulator of aquatic ecosystems, and increased concentrations can complicate drinking water treatment. For example, increased DOC can raise the risk of bacterial contamination and produce carcinogenic by-products during the water treatment process (Alarcon Herrera et al. 1994).

Clarifying the response of DOC to extreme weather events across gradients of landscape position and atmospheric deposition is increasingly important for policy and management decisions, as the frequency of extreme rain events continues to increase in this region.

Acknowledgements: This project is funded by the Water Resources Research Institute. The lake chemistry data collection was funded by US EPA-ORD and EPA-CAMD.

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Nitrogen Subsidies in Glacial Meltwater: Implications for High Elevation Aquatic Chains

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Abstract: Alpine glacial meltwater, rich in reactive nitrogen, has profound effects on nutrient chemistry in alpine lakes and streams. Less is known about how nitrogen subsidies from melting glaciers propagate down a chain of lakes and streams. The goal of this study is to pair an understanding of how increased nitrogen can change the limiting nutrients, algal biomass and biodiversity of high elevation aquatic chains with an understanding of the influence that lakes, streams and the landscape have on each other.

Glacially-fed lakes have nitrate concentrations one to two orders of magnitude higher than lakes fed by snowmelt alone (Saros et al. 2010) In alpine systems where glacial meltwater is rich in dissolved inorganic nitrogen, it remains unclear how these nitrogen subsidies propagate down a chain of lakes and streams. We assessed the effects of these nutrient subsidies in a set of aquatic chains in the U.S. central Rocky Mountains. Nutrient limitation via nutrient enrichment experiments and algal biomass were measured in a chain of lakes and streams fed by glacial meltwater and a chain fed by snowmelt alone.

Results demonstrate that increased nitrogen in glacial meltwater drive changes in nutrient limitation patterns that propagate down the chain. In the glacial chain, lakes were primarily phosphorus-limited; the strength of this limitation signal weakened down the chain, with the lake at the bottom of the chain showing nitrogen and phosphorus co-limitation. In the snowmelt chain, lakes were co-limited with no change in strength down the chain. In lakes, algal biomass was consistently higher in those glacially-fed, whereas it varied spatially in streams. Results of stream bioassays varied and were more complex. Overall, aquatic chains fed by glacial meltwater had higher variability in nutrient limitation and were more productive.

It is important to understand the extent and magnitude of glacial meltwater influences on these interactions so we can understand how the loss of this resource subsidy will affect aquatic chains as glaciers disappear.

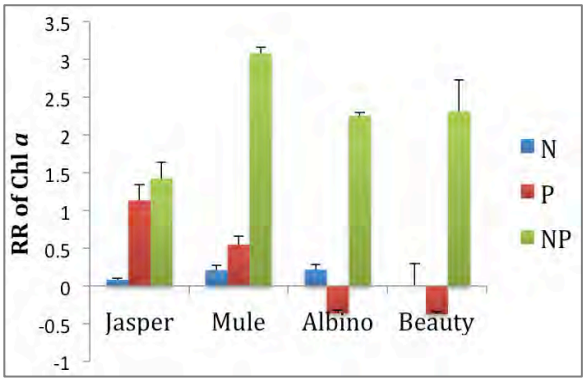

Fig 1. Relative response of chlorophyll *a* to nutrient enrichment expressed as changes in the mean concentration ± 1 SE compared to the control. Jasper and Mule are glacially-fed lakes and Albino and Beauty are snowmelt-fed lakes.

Acknowledgements: We are very grateful to The Dan and Betty Churchill Exploration Fund and The Gokcen Fund for the funding of this research.

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The Subglacial Water System of Byrd Glacier and its Impacts on Flow Dynamics

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Abstract: Drainage networks have been found beneath East Antarctica and subglacial lake drainage events have been linked to the acceleration of ice streams. In 2006, an acceleration of Byrd Glacier was observed that coincided with a subglacial lake discharge. We model the flow dynamics of Byrd Glacier with the University of Maine Ice Sheet Model (UMISM) to understand the impact of subglacial water on the ice flow.

Basal hydrology influences ice flow, meltwater transport to the ice shelves, bedrock topography development and subglacial lake environments. Beneath the East Antarctic ice sheet, the existence of many subglacial lakes provides clear evidence for the widespread presence of water, but the hydrology beneath this ice mass is poorly understood (Wingham and others, 2006). Byrd glacier has one of the largest catchment areas in Antarctica and is expected to influence the mass balance of East Antarctica and hence sea level significantly (Stearns and others, 2008).

There is no evidence for a change in flow velocity of Byrd glacier between 1960 and December 2005. Then the lowermost ~100 km accelerated about 10% until February 2007, thereafter the glacier began to decelerate again (Stearns and others, 2008). This speed-up coincided with a potential subglacial lake drainage about 200 km upstream from the grounding line.

The University of Maine Ice Sheet Model (UMISM) is used to simulate the ice dynamics of Byrd Glacier. UMISM incorporates a basal water model coupled to a sliding law.

Figure 1 shows the basal water layer distribution for the Byrd glacier catchment area. We release an additional amount of subglacial water at the overdeepening in the bedrock at ~80.4°S, 155°E to simulate the flooding event of the lakes and fit the acceleration pattern of the ice. However, releasing the full amount of lake water drained during the flood results in a higher acceleration of the glacier than was observed. The direction of subglacial water flow depends on the hydraulic pressure potential and is therefore highly sensitive to the ice surface topography. Basins in the hydraulic pressure potential allow for subglacial lakes to form. Here we find lakes listed in the inventory (Siegert and others, 2005) and possible new lake sites.

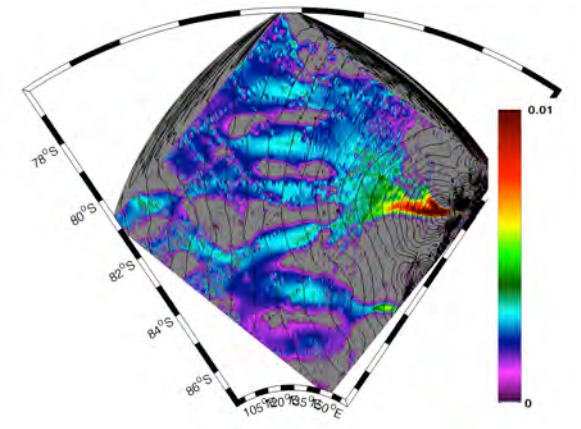

Fig. 1. Basal water distribution for Byrd glacier catchment area in (m).

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Acknowledgements: This project is supported by the National Science Foundation award NSF-0944087.

Influence of the Last Glacial Maximum on Orogenesis in the St. Elias Range, southeast Alaska

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3. GNS, New Zealand.

Abstract: Three-dimensional modeling of the kinematics and glaciation of southeast Alaska show that a LGM-sized glacial load can affect the kinematics of the region and in this case can be used to constrain the rheology.

The St. Elias orogen is an excellent location to study the effects of glacial loading and unloading on orogenesis because it maintains the highest coastal mountains on Earth, has an extensive temperate glacier network, and the region is actively deforming with convergent rates greater than 40 mm/yr. Today the coast of southeast Alaska is defined by a northern subduction boundary, a strike-slip fault (Fairweather fault) to the east, and an enigmatic, Transition fault to the southwest (figure 1). Southeast Alaska is

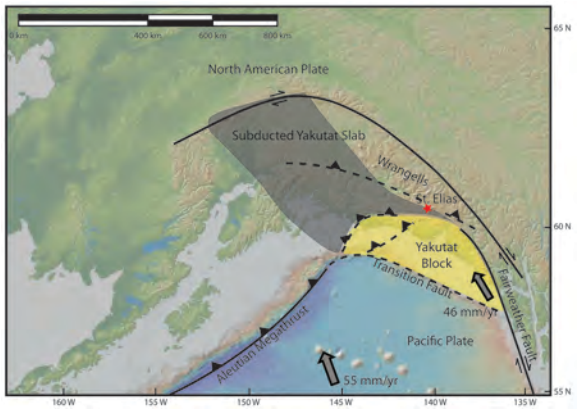

Fig. 1. Tectonic setting of Alaska (After[1]).

very well-constrained, which allows us a rare opportunity to investigate the rheology of the region and further constrain movement along the Transition fault. Using three-dimensional modeling of the kinematics and geometry of coastal Alaska and dynamic ice sheet modeling of the Last Glacial Maximum (LGM) extent (figure 2), we test the sensitivity of the Transition fault to rheological structure and glacial loading during the LGM. The Transition fault follows a well defined boundary between the Oceanic Pacific plate and the Yakutat block. The rheology of the region is constrained by the fact that the strength of oceanic lithosphere is well known and there is a large step in crustal thickness between the Pacific and Yakutat crust[2]. Based on hypocenter data we suggest that the lower 5-15 km of the Yakutat crust is weak relative to its surroundings. This weakness, when coupled with a glacial load, allows the Transition fault to accommodate strain.

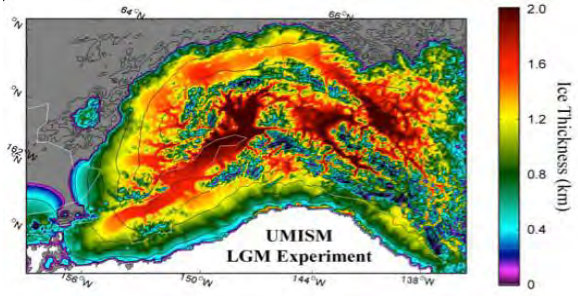

Fig. 2. University of Maine Ice Sheet Model simulation of LGM ice thickness distribution over south-central Alaska (Sean Birkel).

Model results show that when there is no weakening of the lower crust, most of the strain is accommodated along the strike-slip and subduction boundaries. With the addition of a LGM sized load some strain is partitioned into the Yakutat block but does not reach the Transition fault. Strain is only partitioned to the Transition fault when the Yakutat lower crust is weak. Results from this study suggest that the spatial and temporal distribution of glaciers influences the tectonics, seismicity, and orogenic evolution of accreting terranes and that observations of tectonic response to these loads can be used to constrain the rheology of a region.

Acknowledgements: NSF Award Abstract EAR-0409162 St. Elias Erosion/tectonics Project (STEEP).

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Landscape Position and Diatom Community Response to Drought in Northern Temperate Lakes

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Abstract: Landscape position can affect lake response to environmental change, depending on the hydrologic setting of different sites. Here, we examine biological response to drought conditions in sediment records from a highland and a lowland lake in northern Wisconsin (USA).

Landscape position affects a number of different lake features, including physical, chemical, and biological characteristics. Though lakewater chemistry is influenced by several factors, in the North Temperate Lakes – Long Term Ecological Research Site (NTL-LTER, Wisconsin, USA), changes in water chemistry are often related to groundwater sources and, hence, lake location in the regional groundwater flowpath. As groundwater is often higher in solutes than precipitation or surface inflow, lowland lakes receiving more groundwater tend to have higher concentrations of major cations than highland lakes that are less connected to groundwater sources. However, hydrologic budgets are also tightly linked with regional drought conditions, which may shift the relative importance of water sources and cause differential responses in chemistry depending on the landscape position of sites (Webster et al. 2000).

We developed a diatom calibration set to explore relationships between landscape position, lake features, and diatom community structure within the NTL-LTER region. From the calibration set, we developed transfer functions for four parameters (conductance, maximum depth, pH, and total phosphorus) and applied these to fossil diatom assemblages from two sites over the past century. Reconstructed values and diatom community structure characteristics over the past century at a lowland site and a highland site were compared to climate variables to identify differences in lake response to environmental change.

Diatom community structure and response to drought conditions differed between the lowland and highland lakes. Diatom community structure in the lowland site, Allequash Lake, did not show clear relationships with climate variables, with shifts in community structure primarily related to chemical changes in lakewater. Diatoms at the highland site, Crystal Lake, indicated little chemical change relative to drought conditions, but instead responded to physical changes in lake level. In the lowland lake, diatom response to lakewater chemistry was not clearly linked to climatic conditions, likely due to the influence of groundwater at this site. In the highland lake, diatom communities responded to drought-induced changes in lake level rather than lakewater chemistry, providing a novel biological metric to track climatic change in lake sediment records of upland systems.

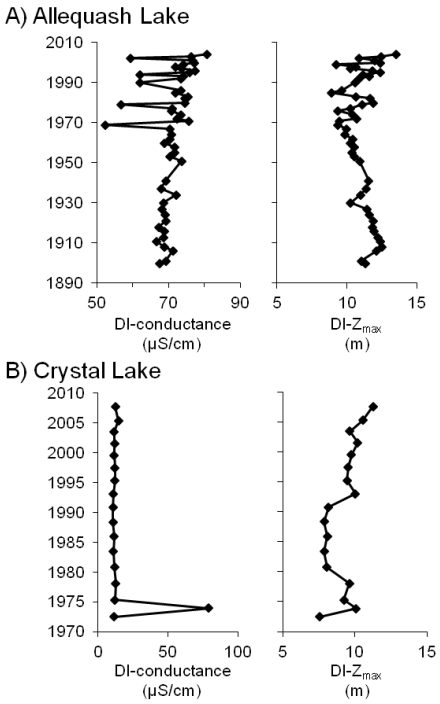

Fig. 1. Diatom-inferred (DI) reconstructions for two sites in the NTL-LTER. Note differences in scales.

Acknowledgements: This project was funded by the National Science Foundation (DEB-0751283).

Bibliography: Webster et al. 2000. Structuring features of lake districts: landscape controls on lake chemical responses to drought. *Freshw. Biol.* 43:499-515