Annual Report – FY2017

Research Activity for the period

July 1, 2016 to June 30, 2017

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2017 Annual Report to the Vice President for Research

i. Executive Summary

Major Accomplishments (overarching):

Climate change is a major security issue for our country and the world and a defining element for the 21st century. It impacts human and ecosystem health, the economy, causes geopolitical stress, and increases the likelihood of storms, floods, droughts, wildfires and other extreme events. The Climate Change Institute has a legacy of transformational contributions to the understanding of the physical, chemical, biological and social complexity of climate change and the application of these findings at local to international scales. One of the several transformational contributions made by the Climate Change Institute is the understanding that the wind systems that deliver moisture, heat and pollutants and that impact surface ocean currents and sea surface temperature throughout the planet can shift in a matter of a few months to years with dramatic and sustained changes in water availability, storms and health at local to regional scales. The Institute uses this perspective to understand and aid in prediction of future hemispheric scale weather impacts, notably extreme events, with the most recent being abrupt warming of the Arctic with consequences for Northern Hemisphere climate and the strengthening and poleward migration of winds around Antarctica resulting in massive changes in water availability and sea surface temperatures throughout the Southern Hemisphere. To address the likelihood of continued abrupt changes and extreme events in climate the Institute continues to conduct field research, laboratory analyses, and to develop software to aid in the understanding of non-linear climate responses for use in climate adaptation and sustainability planning.

In 2014 the Institute launched a framework for developing climate change adaptation and sustainability planning that includes continually enhanced, publicly available software to understand past, present and future changes in climate and vulnerability to climate change through the formulation of plausible scenarios for the prediction of annual to multi-decadal scale climate change. This framework now forms a primary initiative for CCI entitled Climate Futures (http://www.climatefutures.net/) (Appendix i). Within Climate Futures CCI is undertaking plausible scenario climate planning for: West Africa, the Southern Hemisphere continents, Central Asia and Maine. In addition, CCI is in the process of developing an Arctic Futures Institute with the UM Law School and the World Ocean Observatory as an offshoot of the Arctic Council meetings in Portalnd last Fall. This activity is intended to provide a mechanism for a Maine-wide focus on physical, chemical, biological and social science, busness, policy and law in the Arctic.

CCI and SPIA continue to share a highly successful NSF IGERT that is the first of its type in the nation – A2C2 (Adaptation to Abrupt Climate Change) - a building block for graduate-faculty involvement in Climate Futures.

The Institute continues to maintain its high level of research funding, return on indirect, publications, outreach and its role as the focal point for the UM's climate change research excellence.

Selected examples (youngest to oldest based on report) of additional highlights of major accomplishments follow (selection derived from the CCI News and Events section of our website, for more details concerning each item listed below go to: http://climatechange.umaine.edu/:

- Climate change directory created to connect public with experts, information - Spaulding

- John Mahon named 2017 Distinguished Maine Professor
- Portland Press cites researchers about March of Science
- The 'war on science' doesn't just hurt scientists. It hurts everyone. - Washington Post - J. Gill
- Jankowski, Kilroy, St. Amand awarded graduate research fellowships
- Elias' essay on importance of science results in meeting with Congress
- Mayewski teams with LumenARRT! for large-scale video project
- Emerging climate change research focus of Hal Borns Symposium
- UMaine Printing Services recognized by national group for digital production of CCI booklet
- BDN quotes Mayewski in article on climate change skeptic group's mailing campaign
- CBS News quotes Mayewski in report on dwindling Arctic sea ice
- UMaine names 2017 Presidential Award winners - M. Sorg, D. Sandweiss
- 'Mammoths in Maine' focus of Phi Beta Kappa talk- Borns, Hoyle
- Eos features Bohleber's Kilimanjaro findings
- Robinson's artifacts from the Amazon on display in Hudson Museum exhibit
- Biogeochemical links across Greenland key to understanding Arctic - J. Saros
- Mayewski cites role of international agreements in fighting climate change, Smithsonian reports
- Press Herald publishes feature on Hall, glacier research
- Media cite Climate Reanalyzer in stories on rising temperatures in Arctic, Australia
- AP quotes Kelley in report on disappearing salt marshes
- Statistics compiled by Sorg show record Maine drug deaths in 2016, media report
- Hudson Museum exhibit explores ancient cities & student discovery – G. Zaro
- Ph.D. candidate's article earns International Award for Excellence - K. Tanaka
- Gill examines plants encased in tar pits to reconstruct ice age ecosystem
- Ph.D. candidate named new executive director of Herring Gut Learning Center - S. Belknap
- Hamilton among notable Mainers, scientists lost in 2016, media report
- Mayewski cited in Christian Science Monitor story on Maine's Arctic shipping potential
- Mayewski quoted in CBS News climate transformation article
- Pelto's glacier painting graces cover of Mainebiz/Yale Climate Connections
- Radio Ecoshock Show interviews Gill about abrupt climate shifts, extinction
- D. Groff raised research funds via crowdfunding, Utah Public Radio reports
- Gill tells Business Insider NASA data critical to climate change research
- Mayewski discusses latest climate change research on Maine Public's 'Maine Calling'
- AP cites Olsen in report on saltmarsh sparrow research
- Birkel, Climate Reanalyzer cited in Science World on record-breaking Arctic temperatures
- Ice core and climate reanalysis analogs to predict Antarctic and Southern Hemisphere climate changes - Elsevier - Quaternary Science Reviews - Mayewski et al.
- Meltwater can influence ocean circulation, climate in Greenland fjords - E. Enderlin
- Renowned archaeologist Brian Robinson passes away
- Leading UMaine researcher, Gordon Hamilton, perishes in accident in Antarctica
- Putnam's expedition featured in Pacific Standard Magazine, Warm Regards Podcast
- Understanding the ebb and flow of Peru's glacial past - G. Bromley
- 41st Climate Diagnostics Workshop hosted at UMaine - B. Lyon
- CCI director speaks about abrupt Arctic climate change at Maine-Arctic Forum
- UMaine PhD Candidate to Develop Climate Resilience Policy – K. Miner
- Climate-Driven Change in Ice-Free Areas of Greenland – R. Northington

- STEM education in the ice age – H. Borns
- UMaine Extension 4-H connects students with researcher in Antarctica - L. Kaluzienski
- Lyon cited in National Geographic article on climate change, food crisis in Africa
- UMaine researchers refining Arctic climate history through diatoms
- Mayewski to discuss ice melt, adaptation at Maine-Arctic Forum
- Hudson Museum exhibit explores how thriftiness conserves Earth's resources - Isenhour
- Sandweiss comments on oldest indigo-dyed fabric in Science News article
- For Allen, fossils yield data to understand ocean circulation, climate
- President Obama's Mandela Washington Fellowship at UMaine
- Olsen's saltmarsh sparrow research cited in blog of PBS show 'Nature'
- The environmental legacy of acid rain - S. Norton et al.
- Sandweiss elected vice president of Phi Kappa Phi National Honor Society
- Gill, climate change research focus of New York Times blog post
- Putnam pursues climate clues in Mongolia ice fields.
- Climate scientists: Australian uranium mining pollutes Antarctic – M. Potocki

I. Overview

A. Overview

The Climate Change Institute (CCI) (http://climatechange.umaine.edu), is one of the oldest climate research organizations in the world and likely the first with a multi- and inter-disciplinary focus. CCI is a global leader in research and in combination with its UM academic unit partners it offers a robust array of graduate and undergraduate research opportunities. CCI integrates transformational field, laboratory and modeling activities to understand the physical, chemical, biological and socio-cultural components of the climate system of the past and present, to better predict future changes in climate and their impacts here in Maine and across the globe. Institute investigations span the last 2 million years to the present - a time of multi-millennial to centennial scale climate changes punctuated by abrupt (annual to decadal) shifts in climate. CCI investigations inform predictions for future climate change based upon an understanding of the full dynamic range of the natural climate system and the evolving dramatic influence of human activity. CCI has a legacy of major scientific contributions to understanding the timing, causes, and mechanisms of natural and human-forced climate change, and on the effects of physical and chemical climate changes on the biological, economic, social, and political conditions of humans and the ecosystem.

B. Mission

CCI's mission is vitally linked to the widely accepted realization that an understanding of climate change (natural and human-forced) and its implications is absolutely critical to the future of society, ecosystems, the economy, and governance. As a consequence, CCI continues to experience ever-broadening interaction with other disciplines, with other University of Maine researchers, academic and outreach units, and with local, national and international partners. Because climate change underpins the fabric of our society CCI faces rapidly emerging opportunities for application of its findings and expertise to critical issues including: climate change-induced hazards (e.g., severe storms, floods, sea level rise, coastal erosion, drought, heat waves), health threats (e.g., heat stress, drought/flood, disease, air pollution, storms), other economic and social challenges (e.g., water availability and quality, energy, food security, military security, civil unrest, agriculture, recreation, urbanization), and climate change-based decision-making by individuals, NGOs and governmental units.

C. Vision

The Climate Change Institute's vision for the future is summarized in the following statements:

1. Maintain and expand CCI's role as a national and international leader in the "exploration and discovery" of the integrated physical, chemical, biological and social components of climate change research, education and outreach.
2. Continue to enhance the quality and expand the scope of the Institute's eight primary themes (see Section VIII) and continually evaluating the potential and necessity for change and additional themes in the world's most rapidly evolving security issue – climate change.
3. Expand upon the Institute's 40+ year, highly successful, role model status of shared faculty partnerships with academic units to build a fully coupled, world-class undergraduate and graduate climate change research and education program at the University of Maine.
4. Develop a point of coordination and an identifiable framework for UM climate change research, education and outreach that includes CCI and non-CCI partners so that the University of Maine's full climate change potential and value can be realized.

D. Status of Strategic Plan

CCI routinely develops 5-year plans. The last was developed early in 2015. In concert with this CCI was selected as one of the University's Signature Research Programs and through this process our latest 5-year plan has been distilled into the Signature Research Area Vision Statement (Appendix ii).

E. Administration and Staffing Structure (CCI Organizational Chart attached – Appendix A)

II. Pathway 1: Serving Maine

A. Community Engagement

1. Numerous public lectures by all CCI faculty and many graduate students to NGOs, public schools, government.
2. Five-year update of *Maine's Climate Future* that provides a basis for Maine's (public, private, government) understanding of climate change and impacts.
3. Monitoring past and present state of Maine's lakes, forests, soils and coast to prepare Maine's people and their way of life for the future.
4. Making climate data accessible to the scientific community and public through CCI-produced innovative, highly transparent software and cyberinfrastructure that allows Mainers and the world to make informed decisions related to environmental change (eg., 10green^{TM}, Climate Reanalyzer^{TM}, p301, CLAS layers).
5. Informing Maine and the nation of health implications of their changing air quality.
6. Monitoring ice sheet and glacier volume changes to assess current and future sea level rise for coastal Maine's coastal societies and ecosystems.
7. Developing local to global scale climate model predictions to evaluate threats to Maine including: in-migration of biological agents such as Lyme tick and frequency of heat waves.
8. Establishing the intersection of climate and policy for Maine's natural resource industries, notably: lobster, forestry, agriculture and tourism.
9. Examining past and present Native community interactions with Maine's environment.
10. Developing climate and environmental outreach projects for K-12 students and teachers, the public and tourists through lectures, pamphlets, curricula and maps (eg., ECM, ITEST, Maine's Ice Age Trail).
11. Working with the Maine Office of Chief Medical Examiner and Department of Public Safety in death investigation, disaster response, and related policy analysis.
12. Inquiry into sustainability policy including analysis of efforts to balance social, ecological and economic sustainabilities.

B. Economic Development

1. CCI brings research funding into the State that supports students, technicians including analytical equipment, and fabrication of equipment by local contractors.
2. CCI's CLAS platform, Maine's Climate Future, and Climate Futures all provide potential drivers for economic planning at community to State levels.

C. Workforce Development

CCI employs technicians, contractors and students to conduct its research mission.

D. Collaborations with UMaine System Campuses

University of Maine – Presque Isle
Maine School of Law
University of Southern Maine – Muskie Center, Osher Center and others

E. Collaborations with Other Outside Institutes/Organizations Related to Maine

1. ***Within the University of Maine*** - The Schools of Biology and Ecology, Computing and Information Sciences, Earth and Climate Sciences (more than half of SECS faculty are also CCI faculty and SECS offers undergraduate and graduate degrees in climate sciences), Marine Sciences, Forest Resources, Food and Agriculture, Policy and International Affairs (CCI and SPIA share an NSF IGERT that has supported 25 PhD graduate students– first ever to address abrupt climate change), Department of Anthropology (half of the Anthropology faculty are associated with CCI and they offer undergraduate and graduate degrees associated with climate science), the Honors College, LASST, the Department of Chemistry, the Department of Physics and Astronomy, the Hudson Museum, the Center for Research in STEM Education (RISE Center), the Foster Innovation Center.
2. ***Emerging Associations Within the University of Maine*** – examples include: climate and health (One Health) with the School of Biology and Ecology and the National Center for Geographical Information and Analysis (NCGIA), environmental sensor development and data transmission with NCGIA and LAAST, innovations in past, present and future climate visualization with VEMI (Virtual Environment and Multimodal Interaction), Abrupt Climate Change, Business and Policy course with the Business School and the School for Policy and International Affairs, and a joint Climate Change Institute, School of Earth and Climate Sciences, School of Biology & Ecology and Department of Anthropology Graduate Certificate in Interdisciplinary Climate Studies.
3. ***Within Maine*** - Bangor, Lewiston-Auburn and Portland Water Districts, the Department of Water Resources, the Maine Department of the Environmental Protection, the Maine Department of Transportation, the Maine Centers for Disease Control, the Maine Geological Survey, the Maine State Museum, the Lobsterman's Association, the Gulf of Maine Research Institute, The Island Institute, The Nature Conservancy, Audubon, Manomet Observatory, Conservation Law Foundation, Maine Natural Resources Council, Maine Physical Sciences Partnerships, Schoodic Education and Research Center, Acadia National Park, Unity College, College of the Atlantic, Maine Lakes Environmental Association, Kezar Lake Watershed Association, Acadia National Park, Big Reed Forest Reserve, Maine Natural History Observatory, Toothacher Pond Association, Maine Coastal Island Wildlife Reserve, Penobscot Bay Teacher's Collaborative, Preti Flaherty Law, MicMac Environmental Monitoring Laboratory, Maine Lung Association, Eastern Maine Medical Center, Maine Estuarine Research Institute.

F. Collaborations with Other Outside Institutes/Organizations Outside of Maine

1. ***Federal examples including*** - Acadia National Park, US Department of Agriculture, US Forest Service, US Geological Survey, Oak Ridge Laboratory, National Center for Atmospheric Research, University Corporation for Atmospheric Research, National Weather Center, US Fish and Wildlife, Homeland Security.
2. ***US institution examples including*** - Dartmouth College, Harvard University, Lamont-Doherty Earth Observatory, Princeton University, University of Washington, University of Nebraska, University of Oklahoma, Appalachian State University, University of Cincinnati, Texas Tech University, Kansas State University, University of Wisconsin, Brown University, University of Wyoming, Harvard Forest, University of Minnesota Natural Resources Institute, Minnesota Pollution Control Agency, Washington State University, Washington Central University, Konza Prairie Long-Term Ecological Research Station, McMurdo (Antarctica) Long-Term Ecological Research Station, American Museum of Natural History, Boston Museum of Science, University of California – Santa Cruz, Berkeley, Santa Barbara, Brigham Young University, Michigan Technical University, Woods Hole Oceanographic Institute, Appalachian State University, Central Washington University, Pennsylvania State University.
3. ***International examples including*** - Academic, governmental and non-governmental organizations in Australia, New Zealand, Canada, Brazil, Chile, Colombia, Argentina, Peru, India, Nepal, Czech Republic, Ecuador, China, South Korea, Tajikistan, Kazakhstan, England, Scotland, Ireland, Denmark, Switzerland, Germany, France, Italy, Spain, Sweden, Norway, Greenland, Iceland and most recently: association with the University of the Arctic consortium and the South Atlantic Environmental Research Institute (Falkland Islands).

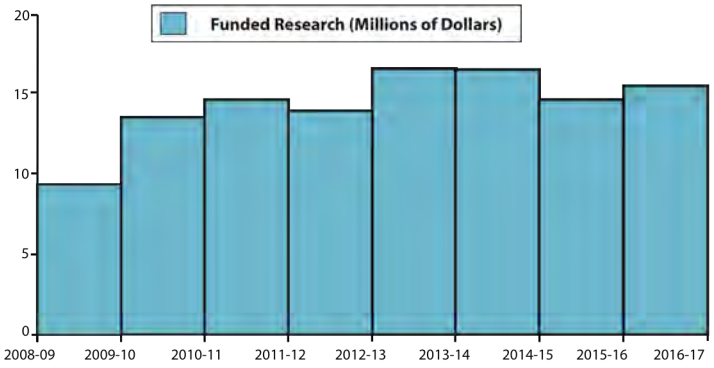
III. Pathway 2: Financial Sustainability

A. E&G Support: Salary & Operating Support
E&G Funding for CCI Salaries* (minus fringe): $675,380

B. MEIF Support
MEIF Funding for CCI Salaries* (minus fringe): $635,148
MEIF Funding for CCI Operating (Mayewski): $27,600
MEIF Funding for CCI Operating: $12,780
*almost exclusively tenure track faculty with joint appointments in academic units

C. Research Funding: Submitted & Awarded, Trends (Appendix B)

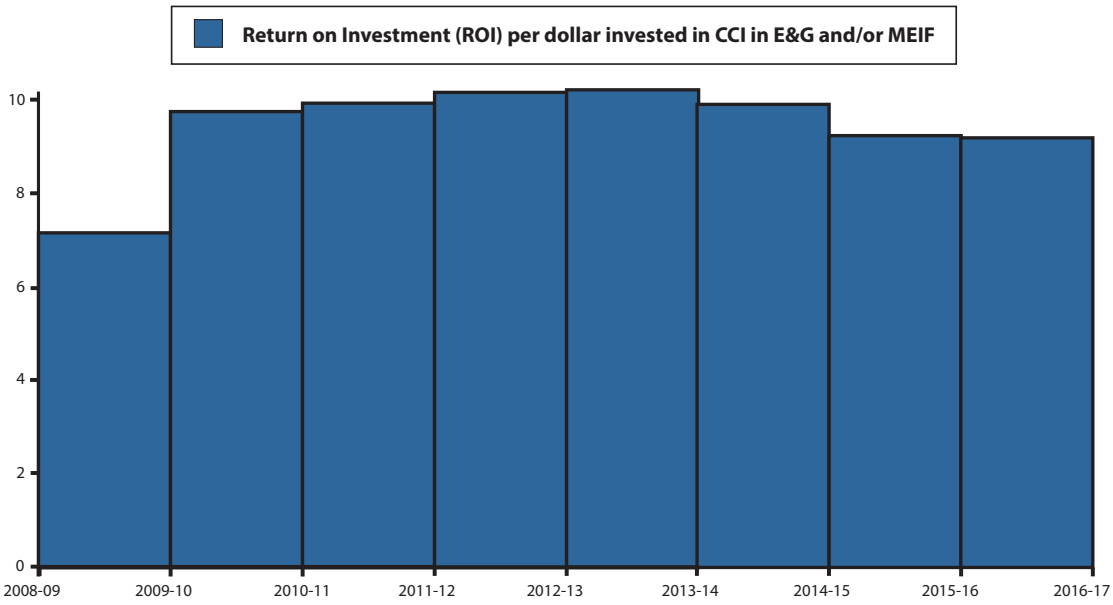
Proposal driven funds (in millions of dollars per year) raised by CCI members.



D. Brief Overview of Each Major New Award (Appendix C)

E. Return on Investment

FY 2017 ROI is $8.524 down from FY2016 ROI at $8.637 dollars per $1 invested in CCI MEIF and CCI E&G.



% SUCCESS RATE (based on ALL FY2017 submissions + continuation grants from BPL listing of current awards)

73 new grants/88 (73 [new, continuation, and supplemental awards] + 15 grants declined)
New = 30, Continuation = 43, Supplemental = 0

SUCCESS RATE: 82.95%

F. Revenue Center

NA

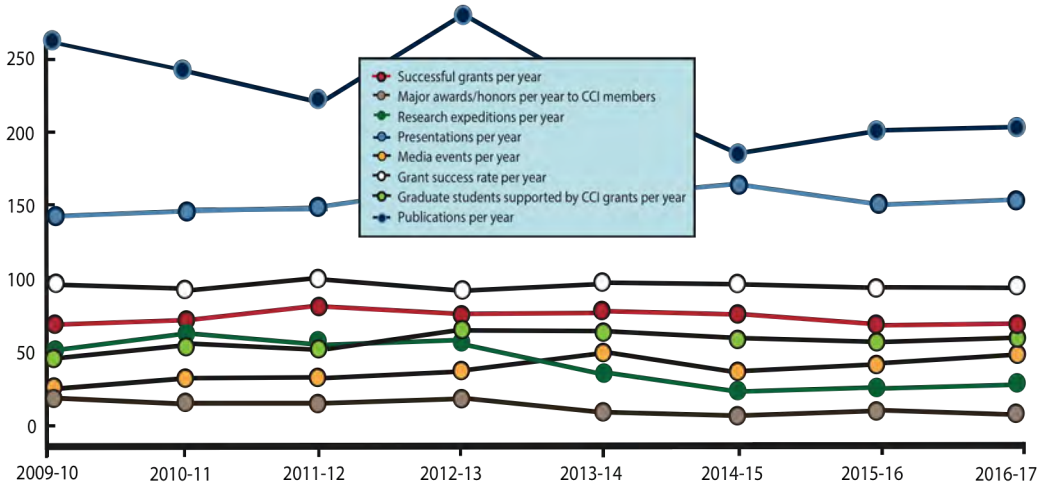
G. Private Giving/Alumni Cultivation

Dan & Betty Churchill Fund
The William Bingham Foundation
Muharram & Barbara Gokcen Fund
Plus several private donors

H. Initiatives to Increase Efficiency

CCI has discontinued base phone service for all CCI graduate students; toll calls related to research are debited to grants.

II. Pathway 3: Culture of Excellence



A. Faculty Achievements (e.g. awards, recognitions, prestigious appointments etc.)

Special Recognitions/Awards/Honors Received for Research, Scholarship, Creativity	
Mahon, John	2017 Distinguished Maine Professor, University of Maine
Sandweiss, Dan	2017 Presidential Award – University of Maine
Sorg, Marcella	2017 Presidential Award – University of Maine
Sandweiss, Dan	Elected Vice President of Phi Kappa Phi National Honor Society

B. Research and Scholarship Summary (e.g., publications, presentations, editorships, exhibits, etc.) (Data not available until after 30 June when faculty annual reports are due.)

C. Curricular Innovations/Integration with the UMaine Education Mission

CCI Graduate certificate in interdisciplinary climate studies approved by the Graduate School 2014, course credit goes to academic units

D. Program Integration (N/A)

V. Pathway 4: Student Engagement, Student Success

A. Undergraduate Student Research, Scholarship or Creative Activities*

Undergraduate Student Research – Field Expeditions			
# Undergraduate Students	**Advisor**	**Date**	**Description**
			Data not available until after 30 June when faculty annual reports are due.

Note – All CCI graduate students participate in at least one and in many cases several field programs with CCI faculty.

B. Undergraduate Student Awards
NA

C. Graduate Student Research, Scholarship or Creative Activities
See Borns Symposium appendix of mini-papers – (Appendix E)

D. Graduate Student Awards
The Churchill Award for Outstanding Exploration (2017) – Carl Tugend, Anne St. Amand
Harold W. Borns Symposium – Best Presentation Award (2017) – 1st Place: Nicholas Richmond; 2nd Place: Susan Elias; 3rd Place: Kathryn Warner
Harold W. Borns Symposium – Best Poster Award (2017) – 1st Place: Jill Pelto, Mario Williams
CCI Student Outstanding Service Award (2017) – Kimberley Miner
UGR, Maine Space Grant Consortium - Undergraduate Fellowship Winner (2017) - A. Nolan
UMaine Student Symposium (2017) – Laura Hartman – Physical Sciences Graduate Presentation Winner
National Science Foundation Graduate Research Fellowship (2017) - Anne St. Amand
International Award for Excellence – Vol. 8 – The International Journal of Climate Change: Impacts and Responses (2017) – K. Tanaka

E. Retention and Graduation Numbers, Initiatives - n/a since CCI supports graduate students but they get degrees in associated academic units.

F. Degrees Granted - n/a since CCI supports graduate students but they get degrees in associated academic units.

G. Highlighted Student Profile: Susan Elias & Catherine Hamley (Appendix F)

VI. Pathway 5: Preserving-Restoring Infrastructure

A. Renovation /Construction Projects Initiated/Completed
Considerable renovation to Sawyer 2nd floor (refurbishing for the new Sawyer Water Research Lab (SWRL)) under the direction of J. Saros and parts of first floor. Details available on request.

B. Renovation/Construction Projects Planned for Coming Year (i.e., vetted with Facilities Management)

VII. Summary of Anticipated Challenges

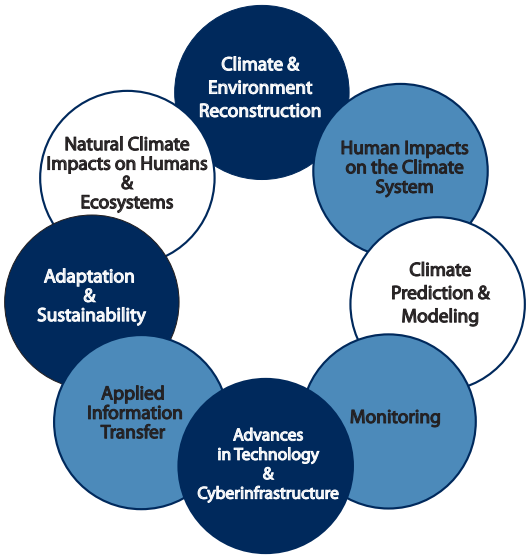
For climate change and the Climate Change Institute at the University of Maine to continue to function at the cutting edge of climate change and continue to thrive and lead in the nation and the world requires the following:

- Continued growth in tenure track faculty positions shared between CCI and its legacy academic partners (School of Earth and Climate Sciences, Department of Anthropology, School of Biology and Ecology) and continued collaboration between CCI and cooperating faculty in several academic and research units such as: School of Computing and Information Sciences, the Department of Chemistry, School of Marine Sciences, School of Forest Resources, School of Business.
- Addition to CCI of research faculty supported at least partially by E&G and/or MEIF with compensation for teaching.

- Expansion and/or addition of transformative new directions for CCI and climate change at the University of Maine including cyberinfrastructure with an emphasis on data integration, analysis and visualization.
- Resources to enhance outreach via CCI and CCI partners to address the increasing demand for climate information, mitigation support, and adaptation and sustainability strategies.

VIII. Summary of New Initiatives

1. Climate change led by CCI is a UM Signature Research program.
2. The Institute has eight major themes that together describe its breadth of contributions and linkages across the University of Maine and at state, national and international levels, and expectations for the future of CCI and climate change at the University of Maine. These eight themes represent the current evolution of the Institute's approach to the rapidly emerging understanding of climate change and the implications of change.

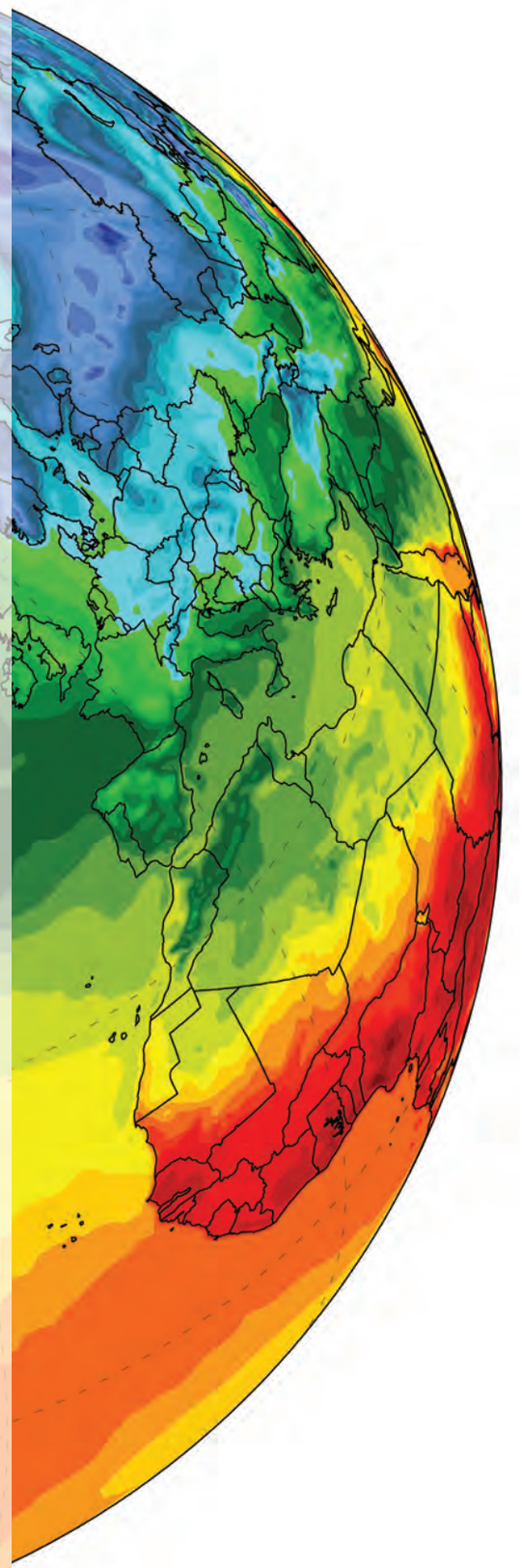


3. Climate Futures initiative emanating from the CCI themes and NSF IGERT A2C2 (Adaptation to Abrupt Climate Change).
4. The Arctic Futures Institute (AFI) is a joint initiative of the Center for Oceans & Coastal Law of the University of Maine School of Law, the Climate Change Institute of the University of Maine and the World Ocean Observatory. The three founding AFI institutions are a unique combination of science, law, policy and outreach based in Maine. The Climate Change Institute has forty years of Arctic science experience, the Center for Oceans & Coastal Law is engaged in advanced Arctic law and policy research and the World Ocean Observatory reaches a global community of "Citizens of the Oceans" through web-based content and communication. In January 2015, a White House executive order established the Arctic Steering Committee to sharpen coordination of the 22 federal agencies working on U.S. priorities in the region. U.S. Senators Lisa Murkowski (R-AK) and Angus King (I-ME) launched the Senate Arctic Caucus to promote congressional awareness of the gravity of the challenges in the northern latitudes. Under the chair of the United States the Arctic Council met in Maine in October 2017. The AFI will build on the energy and interest stimulated by that meeting and will invite participation State-wide of academic/research institutions, government and non-government entities, and businesses - many of which served on the Arctic Council Maine Host Committee. Now is the time to establish a national Arctic center of excellence in Maine that can: (1) Nurture and leverage an international network in the northern latitudes to advance State objectives including research, education and commerce. (2) Contribute to the global effort to balance science and commerce, helping to assure the long-term preservation of the Arctic. and (3) Promote understanding of Arctic issues through web-based and other communications to build broad public awareness of Arctic issues and the Institute in Maine, the United States, and throughout the global Arctic community.

Climate Change Institute

The University of Maine's Climate Change Institute has a legacy of major contributions to the understanding of the physical, chemical, biological and social complexity of climate change and the application of these findings at local to international scales. Perhaps most notable is the Institute's role in the discovery and interpretation of abrupt climate change (ACC) – dramatic changes in temperature, precipitation and storm patterns that can occur in a matter of years and last decades to centuries. ACC events occur in the naturally forced climate system, but today human activity is accelerating and magnifying the role of these controls leading to modern day ACC events such as the fast decay of Arctic summer sea ice and the Antarctic ozone hole with consequences such as increased frequency and magnitude of extreme weather events.

CCI's unique perspective combines first-hand understanding of robust archives of past climate and the environment (e.g., ice cores, lake sediments, and human artifacts calibrated with instrumentally recorded data); a diverse array of environmental monitoring systems (e.g., weather, sea level rise, glacier dynamics, lake chemistry, coastal erosion); and in-house generated understanding of weather- to climate-scale descriptions of past, current and future conditions. This climate understanding coupled with local- to global-scale understanding of climate change impacts, vulnerabilities, assets and potential for innovative solutions and opportunities, significantly enhances the potential success of climate change driven planning outcomes, including guidance in climate adaptation, mitigation, sustainability, and resilience planning.



Framework Building: The Climate Futures Team

Key elements of the basic software for the Climate Futures Framework are already operational. In particular Climate Reanalyzer™ and 10green™ attract significant attention and use (>1000 hits/day, several peer reviewed scientific and public media publications by CCI and many other researchers).

CCI and its University of Maine partner the School of Policy and International Affairs are completing a National Science Foundation Integrative Graduate Education and Research Traineeship (IGERT) grant, the first of its kind, entitled: Adaptation to Abrupt Climate Change (A2C2). It is a doctoral training program for students in earth sciences, ecology, anthropology, archaeology, international affairs, and economics. A2C2 is designed to train the next generation of natural and social scientists to meet the critical societal challenge of human adaptation to abrupt climate change (ACC). A2C2 IGERT graduate fellows are trained by IGERT faculty to be experts and leaders on the issue of climate and abrupt climate change in their disciplinary field; to understand the dynamics of coupled natural and human systems in response to abrupt climate change; to conduct collaborative, interdisciplinary research across natural and social sciences; to develop innovative policy and management solutions from their research to foster resilience and adaptation; and to develop an international perspective on adaptation to abrupt climate change including national and international experiences.

Climate Futures will build a team based upon the interdisciplinary faculty interactions and graduate student training model successes learned and developed from A2C2 IGERT. The Climate Futures team will include:

(1) Climate Futures Team Oversight
Paul Mayewski (Director, Professor, CCI)

(2) CCI Generated Software Unit
Lead developer and enhancements leader, Sean Birkel (Research Asst. Professor, CCI) and post-doctoral fellow (TBD)

(3) Climate Futures Inputs Unit
Vulnerabilities, impacts and assets: CCI ecosystem and social science faculty team and graduate student (TBD)

Rates of change, magnitude, timing: CCI physical sciences faculty team and graduate student (TBD)

(4) Climate Futures Products Unit
Plausible scenario and applications: CCI business and economics faculty team and graduate student (TBD)

CLIMATE CHANGE INSTITUTE

For more information on how you can contribute contact:

Dr. Paul Andrew Mayewski, Director, Climate Change Institute
207.581.3019, paul.mayewski@maine.edu

1865 THE UNIVERSITY OF MAINE

Climate Futures

A Pathway

CLIMATE CHANGE INSTITUTE

climatechange.umaine.edu

Introduction

Climate change defines the 21st century in ways that we are only beginning to understand.

How can we plan for the future without understanding climate change impacts on human and ecosystem health, food systems, energy production, the economy, geopolitics, and the future of storms, floods, droughts, wildfires and other extreme events?

Climate Change

Climate and its building block, weather, extend from the uppermost reaches of Earth's atmosphere into the oceans, lakes, streams, soils, fields, forests, rocks and into our homes. Climate and weather have been molding the Earth's surface through long-term variations and catastrophic changes ever since Earth gained an atmosphere. Climate and weather have been feared and revered ever since humans emerged, and plants, animals and humans migrated, thrived, adapted, and ceased to exist in some cases in response to climate change. Climate change influences where we live, our health, our economy, our art and music, and our overall quality of life.

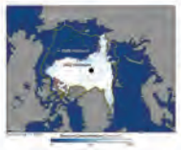
Over the last two decades, science has clearly demonstrated the realities of a changing climate and the highly significant role of human activity in these changes. With this realization, the White House, the Pentagon, and governments around the world understand that climate change is amongst the most serious and ever-present issues on the planet.

Climate Change is a Security Issue

Health (human and ecosystem)
Warming (heat stress, vector borne diseases)
Pollutants (respiratory, neurological, cancer)
Extreme events (drought, flooding, storms, heat stress)

Economy
Energy (consumption, renewable energy)
Technological advances
Redistribution of supply sources and mechanisms
Innovation opportunities
Globalization and regionalization

Catastrophes
Extreme events (drought, flooding, heat stress)
Food supply (physical and chemical impacts)
Climate change refugees
Response capability



Geopolitics
Ice free Arctic Ocean
Climate refugees from drought and storms
Water tower politics
Developed-developing country blame
Shifting agricultural resources

Climate Futures Requirements

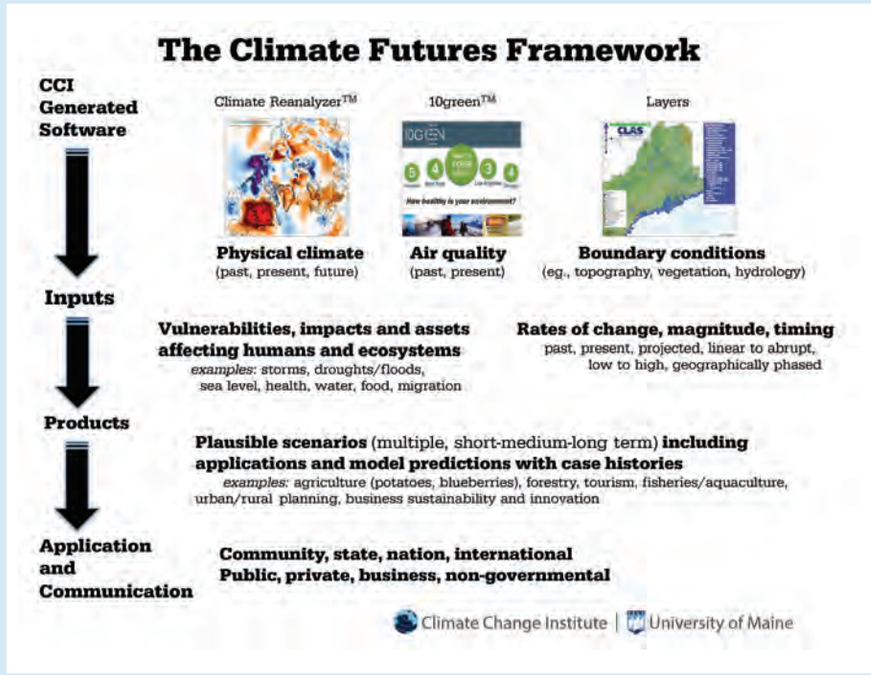
A transparent framework is needed for assessing impacts and addressing vulnerability in a changing climate where intended goals are: mitigation, adaptation, sustainability, resilience, opportunity, and entrepreneurship.

Thinking Outside the Box

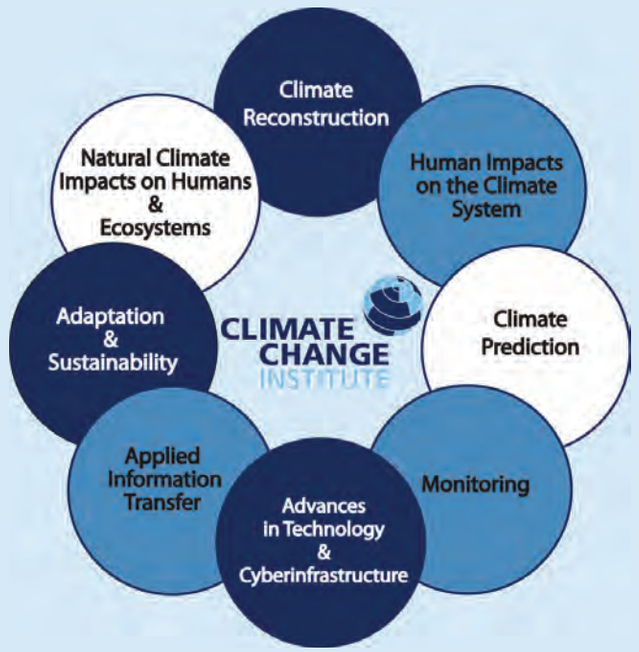
Climate prediction models are an essential element in planning for the impacts of climate change. However, existing climate models based on classic IPCC (Intergovernmental Panel on Climate Change) while essential stepping blocks, do not capture the full local- to regional-scale climate change known to exist in the past; nor do they capture the realities of non-linearities such as abrupt climate change (ACC) in the past and currently emerging climate system, or the full health consequences of changes in the chemistry of the atmosphere, and as a consequence the full range of plausible scenarios for future climate.

The Climate Futures Framework

The Climate Futures Framework offers a transformative mechanism and a platform for assessing and quantifying climate change, vulnerability, impacts, and opportunities based on classic IPCC and past climate analog change predictions, presented in the form of locale-specific plausible scenarios, that go beyond standard linear climate predictions.



Major themes that describe the breadth of CCI's contributions and abilities.



APPENDIX ii

Academic Affairs Signature Area Vision for the Future
Fall 2014 – COVER SHEET – White Papers

I. Designation/Name of Area (Select one):

X Signature; Area name: Climate Change and the Climate Change Institute

II. Submitter information:

Lead Faculty:

Name: **Paul Andrew Mayewski** – Director, Climate Change Institute; Professor, School of Earth and Climate Sciences, School of Policy and International Affairs
Phone: 1-3019 E-mail: paul.mayewski@maine.edu

Name: **Jasmine Saros** – Associate Director, Climate Change Institute; Professor, School of Biology and Ecology; Director, A2C2 IGERT
Phone: 1- 2112 E-mail: jasmine.saros@maine.edu

Name: **Ivan J. Fernandez** – Professor, School of Forest Resources, Climate Change Institute, School of Food and Agriculture
Phone: 1-2932 E-mail: ivanjf@maine.edu

Name: **Gregory Zaro** - Chair of Anthropology, Associate Professor Department of Anthropology, Climate Change Institute
Phone: 1-1857 E-mail: gregory.zaro@maine.edu

Vision

What is climate change? We (humans, animals, plants) are all connected to, affected by and integrally involved in the climate system. Climate and its building block, weather, extend from the uppermost reaches of Earth's atmosphere into the oceans, lakes, streams, soil, fields, forests, rocks and into our dwellings. Climate and weather have been molding the Earth's surface through long-term variations and catastrophic changes ever since Earth gained an atmosphere some 4.5 billion years ago. Climate and weather have been feared and revered ever since humans emerged and plants, animals and human groups migrated, thrived, adapted and ceased to exist in response to climate change. It influences where we can live, our health, our economy, our art and music, and our overall quality of life. Controls on climate and weather, underlying mechanisms of change, human and ecological impacts and their implications cannot be defined by a simple disciplinary description. Rather, climate change calls for (if not demands) multi- and inter-disciplinary approaches that include physical, chemical, biological and social dimensions and feedbacks.

The climate and environment of Maine has changed dramatically in the last several thousand years. Melting ice sheets have forced the evolution of sea level, lakes and rivers; forests and animals have migrated into and out of the region; agriculture and industry have emerged; population distribution has changed; cultural patterns and socio-economic complexity have changed; energy and transportation needs have increased; air and water quality has changed; and Maine's interaction with national and global economies and the changing dynamics of security has intensified dramatically. Woven within all of the foregoing is climate change and the realization by the scientific community, the White House, the Pentagon, and govern-ments around the world that climate change is amongst the most serious and ever-present security issues on the planet (Figure 1). Assessing Maine's place in this security web is essential to planning Maine's future.

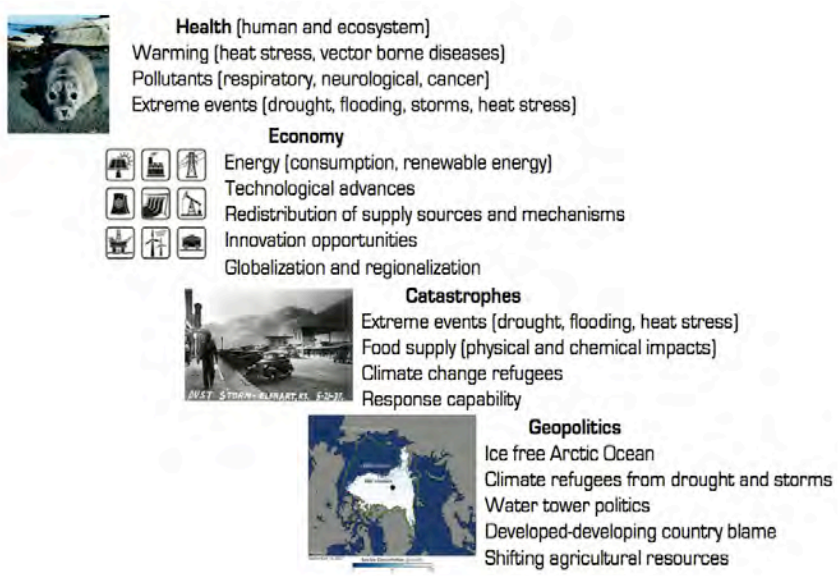


Figure 1. Climate change is a security issue.

Climate change defines the 21st century in ways we are only beginning to understand. How can Maine plan for the future without understanding its changing climate and environment and without understanding climate change impacts on human and ecosystem health, the economy, geopolitics, and the future of storms, floods, droughts, wildfires and other extreme events? The Climate Change Institute has a legacy of major contributions to the understanding of the physical, chemical, biological and social complexity of climate change and the application of these findings at local to international scales. Climate change has already impacted our lives dramatically and it will only continue to do so.

What is climate change at the University of Maine? Climate change is one of the primary signature research strengths of the University of Maine. It includes integrated undergraduate and graduate education and research opportunities and service products that are dedicated to improving the well being of the University, Maine, the nation and the world.

The Climate Change Institute's role as "nucleus" and "framework" for the University of Maine's climate change strength. The breadth of climate change cannot be captured within a single discipline or unit. That said a significant portion of the momentum for the growing reputation of the University of Maine in climate change has been leveraged from the international reputation of the research strengths of the Climate Change Institute. The Institute's historical and ongoing contributions have grown to be an integrating framework across many disciplines and units on Maine's flagship campus and beyond, encompassing undergraduate and graduate education, a broad array of research, and outreach to stakeholders and governments. The Climate Change Institute has emerged as the focal point for climate change at the University of Maine.

"Exploration and Discovery" is the Institute's slogan following the example of its Honorary Member, the great explorer Thor Heyerdahl, and the 40+ years of exploration and discovery by Institute members. The Institute fosters exploration, learning and discovery through excellence in faculty and graduate student research, addresses local through global needs through basic and applied research, and contributes research-based knowledge. The Institute is dedicated to improving the quality of life for people in Maine and around the world, and to promoting responsible stewardship of human, natural and financial resources, now and in the future.

The Institute has eight major themes (Figure 2) that together describe its breadth of contributions and linkages across the University of Maine and at state, national and international levels. These eight themes represent the current evolution of the Institute's approach to the rapidly emerging understanding of climate change and the implications of change.

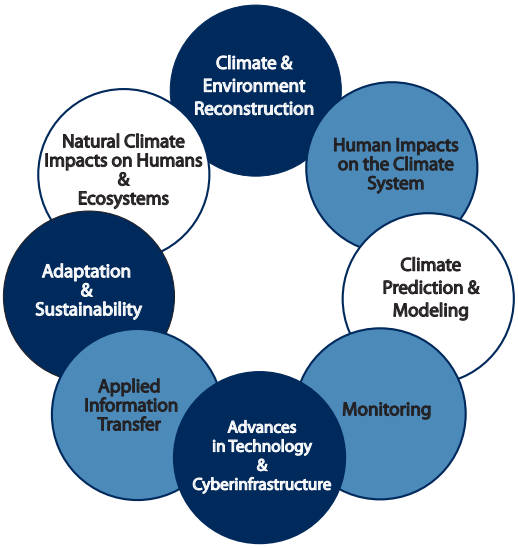


Figure 2. CCI themes.

Vision Summary for the Next Level of Excellence. The Climate Change Institute's vision for the future is summarized in the following statements:

1. Maintain and expand the Institute's role as a national and international leader in the "exploration and discovery" of the integrated physical, chemical, biological and social components of climate change research, education and outreach.
2. Continue to enhance the quality and expand the scope of the Institute's eight primary themes (Figure 2), while continually evaluating the potential for improving this approach by incorporating additional and revisiting existing themes for one of the world's most rapidly evolving security issues – climate change.
3. Expand upon the Institute's 40+ year, highly successful, role model status of shared faculty partnerships with academic units to build a fully coupled, world-class undergraduate and graduate climate change research and education program at the University of Maine.
4. Develop a point of coordination and an identifiable framework for University of Maine climate change research, education and outreach that includes Institute and non-Institute University of Maine partners so that the University of Maine's full climate change potential and value can be realized.

Needs and Justification to Achieve the Next Level of Excellence

1. *Graduate Fellowships and Post-doctoral Associates:* Following a long line of successful grant-funded support for graduate students by the Institute, the creation of prestigious Signature Graduate Fellowships will further sustain our ability to attract excellent graduate students who are vital to our research success. Funding for an Institute Post-doctoral Associate will also grow our program, as our grant-funded post-docs have often remained in the Institute and become Research Assistant Professors, expanding the breadth of our expertise.

2. *Increased Investment in Research:* Research programs in the Climate Change Institute are world renowned, and additional investment in infrastructure and personnel (eg., technicians) will grow our capacity. Institute researchers have worked hard to attract millions

of dollars of equipment from federal and private foundation support including technical expertise. However, we still have aging facilities and equipment that slows research progress, and lack the resources to nimbly invest in equipment as new methods and collaborations emerge.

3. *Return of Indirect Costs (IDC):* Widely recognized for many years is the advantage to the research mission for reinvestments through the return of indirect costs. This has been proposed in several University strategic plans, and other proposals such as the faculty incentive plan. A long-term guaranteed return of 40% IDC to 'soft-money' positions affiliated with the Climate Change Institute would be a significant incentive to build research expertise in this signature area. This is one of only a handful of areas at the university that has the critical mass and momentum to provide a high return on investment with this type of policy. The full 40% would be available only to research faculty who are not paid by University base funding, until such time that a broader university policy of indirect cost returns can be implemented.

4. *Shared Faculty Positions:* The Climate Change Institute has already established a remarkable record of success in additional shared faculty positions with academic units (notably Schools of Earth and Climate Sciences, Biology and Ecology, and Department of Anthropology). This has benefited programs in all participating units, and made the Institute a fertile framework for interdisciplinary initiatives that brings disparate units on campus together, and enhanced climate change science through academic units and institutes across campus. Using this model, the university should invest in 7-10 tenure-track, CCI shared faculty positions over the next five-year period. As with current shared positions, these should be positions providing linkages with other units heavily invested in the consequences of a changing climate for their students and stakeholders (e.g., Anthropology, Earth and Climate Sciences, Economics, Business, Computing and Information Sciences, Biology and Ecology, Food and Agriculture, Forest Resources, Marine Sciences, Policy and International Affairs, College of Engineering). CCI is currently in the process of developing its latest five-year plan including proposed shared positions. Once complete in early 2015 linkages will non-Institute University partners will be pursued.

5. *E3RB – The Extreme Environment Education and Research Building:* This facility is currently in final planning stages with expected construction Spring 2015. It will provide much needed space for staging of the Institute's ~40 expeditions per year and space and facilities for students to design innovative equipment for research in extreme environments. In addition E3RB will provide a space for the public to observe extreme environment research planning and facilities in a venue where student involvement can be highlighted.

6. *Climate Coordination and a Climate Coordination Office:* The University needs a point of departure on climate change that works to connect interested students, stakeholders, and the public to resources at the University that meet their needs on this subject, and a point of coordination for University planning on this issue, from curriculum development to large, multidisciplinary research initiatives. Such an entity would not be a required clearinghouse, but an advocate for new initiatives where it could be helpful. This could be built on and in coordination with the existing State Climatologist Office, and could include a broad range of outreach such as Maine Climate News, an ongoing Dashboard of environmental indicators for Maine, an information listing of climate change mitigation and adaptation efforts in Maine, and facilitate the university linkages to state agencies, industry, and municipalities on this subject. This office could also coordinate with the university point of contact for the USDA Northeast Climate HUB, housed in the Maine Agricultural and Forest Experiment Station. The office would require a full-time professional position (new hire) to carry out office day-to-day functions under the direction of a faculty supervisor.

7. *State Climatologist Office:* The University of Maine has been the home for the State Climatologist largely through in-kind support from the Climate Change Institute. Dr. George Jacobson contributed his time over six years through summer 2014, following several years of unpaid involvement by Dr. Greg Zielinski, and this fall Dr. Sean Birkel, a Research Assistant Professor without base funding, will assume the role of Maine State Climatologist. This position and associated travel throughout Maine should be funded from State and University base funding as outreach in the areas of Maine climate research and teaching, thereby stabilizing this critically important office in a fashion similar to other states. Dr. Birkel has been responsible for transformative climate change software that is used by researchers, the public and in many courses on this and other entities worldwide. The State Climatologist Office also offers Maine Climate News in partnership with Sea Grant and Cooperative Extension, which would continue and be integrated with the Climate Coordination Office.

8. *University-wide Climate Gen Ed Class*: As the signature programs develop, we would expect the evolution of various curricula across campus to build on these growing areas of strength and interest among our students. One component of this evolution could be to establish a general education course aimed at lower class levels (100-200) on Climate, Ecosystems and Society that provides core concepts, terminology, and an awareness of current events. We envision that this course will be developed in cooperation and administered through existing units represented within CCI. With appropriate resources, this could be developed into an on-line UMS, national and international-wide course offering. Graduate student support requested.

8.a (alternative or added to 8. above): *Establishing a Climate Gen Ed Category* in the form of Climate, Ecosystems, and Society that would broaden the existing Population and the Environment category, and could be fulfilled by any number of courses that would explicitly include these core concepts. Much like other Gen Ed categories, students would have a variety of options to fulfill this requirement, but not necessarily from a single course. The option, then, would be to have a number of courses that address these concepts in the context of a variety of curricular matters (8a), or a single course that tackles these core concepts specifically (8). Graduate student support requested.

9. *Graduate Study Certificates:* The Climate Change Institute recently initiated with approval by the Graduate School, a certificate program in Interdisciplinary Climate Studies. The Institute has the potential to pioneer additional certificate programs. Courses are and would be offered for credit through University academic units with impetus and oversight by the Institute.

Estimated Budget in addition to current E&G and MEIF support to CCI

Need	New MEIF/ year	Private Giving/ year	State	Federal/ year	UMS	E&G/ year	MEIF
1. Signature graduate & post-doc fellowships	250K	250K		>500K Note (1)			
2. Equipment and technical	150K			>500K Note (2)			
3, 40% return res. faculty Indirect						40% Note (3)	
4. shared tenure track Faculty (7-10)	450K					450K	
5. E3RB facility			500K Note (4)				
6. Climate coordination office	40K					40K	
7. State Climatologist	50K					50K	
8./8a University-wide Gen Ed						60K	
9. Graduate Study certificates						50K	

Note (1) based on federal funds currently raised by CCI in support of graduate students and post-docs.
Note (2) based on federal and private foundation funds currently raised for equipment.
Note (3) could result in considerable revenue to the University. 60% of something is better than 0% without Research Faculty.
Note (4) 500K already allocated for E3RB so this is not a new request. The building is planned for construction in Spring 2015.

APPENDIX A: ADMINISTRATION & STAFFING STRUCTURE

CLIMATE CHANGE INSTITUTE

ORGANIZATIONAL CHART

DIRECTOR
P. MAYEWSKI

ASSOCIATE DIRECTOR
J. SAROS

ASSISTANT DIRECTOR
B. LEE

POLICY ADVISORY COMMITTEE
D. SANDWEISS (CHAIR, FY17)
D. BELKNAP (FY18)
G. DENTON (FY17)
I. FERNANDEZ (FY18)
K. MAASCH (FY18)

PEER REVIEW COMMITTEE
J. Kelley (CHAIR, FY17)
B. HALL (FY18)
J. SAROS (FY18)
D. SANDWEISS (FY19)

GRADUATE COMMITTEE
K. KREUTZ (GRADUATE COORDINATOR, FY18)
B. HALL (FY18)
B. OLSEN (FY18)
G. ZARO (FY17)

ADMINISTRATION & OUTREACH
R. ADDESSI
M. SCHAUFFLER
M. SAROS (A2C2 IGERT PROGRAM COORDINATOR)
S. BIRKEL (*MAINE STATE CLIMATOLOGIST*)

ANALYTICAL LABORATORY STAFF

S. SNEED D. INTRONE M. HANDLEY	IC, LA-ICP-MS STABLE ISOTOPE LABORATORY ICP-MS ARCHAEOLOGY LABORATORY

REVISED
5/8/2017

RESEARCH THEMES

Physical & Chemical Climate Reconstruction
K. ALLEN
D. BELKNAP
S. BIRKEL
P. BOHLEBER
D. DIXON
I. FERNANDEZ
J. GILL
B. GRIGHOLM
J. KELLEY
K. KREUTZ
A. KURBATOV
P. MAYEWSKI
K. MAASCH
A. NURSE
W. SAYRE
J. SCHAEFER
A. SEIMON
J. SIMOES
N. SPAULDING

Glacial Geology & Climate Reconstruction
H. BORNS, JR.
G. BROMLEY
G. DENTON
B. HALL
R. HOOKE
A. KELLEY
A. PUTNAM
J. SCHAEFER

Paleoecology & Environmental Reconstruction
R. DAVIS
J. GILL
B. GRIGHOLM
G. JACOBSON
A. KELLEY
J. KELLEY
K. KREUTZ
A. KURBATOV
P. MAYEWSKI
S. NORTON
R. NORTHINGTON
A. NURSE
B. OLSEN
D. SANDWEISS
M. SCHAUFFLER
J. SAROS
K. SOBOLIK
C. STAGER

Anthropology & Archaeology
D. BELKNAP
H. BORNS, JR.
J. GILL
C. ISENHOUR
R. KATES
D. KEEFER
A. KELLEY
J. KELLEY
A. KURBATOV
P. MAYEWSKI
M. NISBET
L. RICKARD
P. ROSCOE
D. SANDWEISS
D. SANGER
K. SOBOLIK
M. SORG
A. STRONG
G. ZARO

Glaciology
S. BIRKEL
P. BOHLEBER
H. BORNS, JR.
E. ENDERLIN
J. FASTOOK
B. HALL
R. HOOKE
T. HUGHES
P. KOONS
K. KREUTZ
A. KURBATOV
P. MAYEWSKI
G. OSWALD
J. SCHAEFER
N. SPAULDING
W. SNEED

Marine Geology
K. ALLEN
D. BELKNAP
A. KELLEY
J. KELLEY

Ecosystems & Environmental Change
B. CLINE
I. FERNANDEZ
J. GILL
R. HOOKE
S. JAIN
J. KELLEY
D. LEVESQUE
J. MAHON
B. MCGILL
L. McNALLY
P. MAYEWSKI
S. NORTON
R. NORTHINGTON
B. OLSEN
A. PERSHING
D. SANDWEISS
J. SAROS
M. SCHAUFFLER
A. SEIMON
A. STRONG
K. SOBOLIK
M. SORG
A. THOMAS
G. ZARO

Renewable Energy & Environmental Monitoring
I. FERNANDEZ
P. KOONS
B. LYON
J. MAHON
P. MAYEWSKI
L. McNALLY
A. STRONG
J. THALER
A. THOMAS

Cyberinfrastructure
S. BIRKEL
S. CHAWATHE
J. FASTOOK
P. KOONS
A. KURBATOV
P. MAYEWSKI

Climate Prediction & Modeling
S. BIRKEL
F. CHAI
J. FASTOOK
S. JAIN
P. KOONS
B. LYON
K. MAASCH
P. MAYEWSKI
A. PERSHING
A. SEIMON

Climate Change Impacts, Policy & Sustainability
S. BIRKEL
S. CHAWATHE
D. Dixon
I. FERNANDEZ
J. GILL
C. ISENHOUR
G. JACOBSON
S. JAIN
R. KATES
A. KELLEY
J. KELLEY
D. LEVESQUE
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J. THALER
G. ZARO

APPENDIX B. RESEARCH FUNDING - SUBMITTED & AWARDED GRANTS - CLIMATE CHANGE INSTITUTE - FY 2017
LISTING INCLUDES ALL ACTIVE CCI GRANT AWARDS ADDED IN AS CONTINUATION GRANTS.

Person	Title	Role	Unit	RESP	Sponsor	Status	Request	Cost Share	Type
Allen, Katherine	Acquisition of LA-ICP-QQQ-MS equipment for in situ trace element and isotopic research and training at the University of Maine	Co-PI (Cruz-Uribe)	Climate Change Institute	10.00%	National Science Foundation	Pending	$298,269	$0	New
Allen, Katherine	Coll. Res.: Pacific Ocean stratification since the last ice age	PI		100.00%	National Science Foundation	Funded	$283,274		New
Birkel, Sean	USDA Climate Hub - UMaine Cooperative Agreement Yr 2	Co-PI (Servello)	Maine Agriculture and Forestry Experiment Station	25.00%	US Dept of Agriculture	FundedC	$23,000	$11,272	Continuation
Birkel, Sean	Glaciological and Mass Balance Modeling of Walker Basin, Nevada	PI	Climate Change Instiutte	100.00%	US Dept. of Interior	FundedC	$21,066		Continuation
Birkel, Sean	Coll. Res.: Testing the Orbital Theory of Ice Ages	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$21,450		Continuation
Birkel, Sean	GreenTRACS: A Greenland Traverse for Accumulation & Climate Studies	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$169,567		Continuation
Bromley, Gordon	Resolving the Impact of So-Called "Heinrich Stadial 1" on the Terrestrial Cryosphere of the North Atlantic Region	PI	Climate Change Institute	100.00%	Comer Science and Educational Foundation	Funded	$25,000	$11,000	New
Bromley, Gordon	Collaborative Research: Fire and Ice: Potential magmatic and glacial-geomorphic constraints on the role of deglaciation in magma evolution	PI	Climate Change Institute	100.00%	National Science Foundation	Pending	$169,472	$0	New
Bromley, Gordon	Collaborative Research: A tropical multi-proxy approach to testing the role of CO2 in the last glacial termination	PI	Climate Change Institute	100.00%	National Science Foundation	Declined	$235,669	$0	New
Bromley, Gordon	REU Supplement for NSF Grant 1443321	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$5,789		Continuation
Bromley, Gordon	Blowing Hot or Cold? Resolving the terrestrial impact of North Atlantic stadials	PI	Climate Change Institute	100.00%	National Geographic Society	Funded	$12,455		New
Bromley, Gordon	Coll. Res.: Potential direct geologic constraints on ice sheet thickness	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$291,563		Continuation
Chai, Fei	Impacts of Population Growth on the San Francisco Bay and Delta Ecosystem Yr 3	PI	School of Marine Sciences	50.00%	National Aeronautics & Space	FundedC	$142,200	$0	Continuation
Chai, Fei	The Effect of Ocean Acidification on Fe Availability to Phytoplankton in coastal and oceanic waters of the eastern North Pacific	Co-PI (Wells)	School of Marine Sciences	20.00%	National Science Foundation	Pending	$819,880	$0	New
Chai, Fei	Improving Tide-Estuary Representation in MPAS-Ocean	PI		100.00%	US Dept. of Energy	Funded	$72,624		New
Chai, Fei	Inundation Modeling for Saco, Maine	PI		100.00%	US Dept. of Energy	Funded	$62,370		New
Denton, George H.	What forced the last termination in southern middle latitudes?	PI	Climate Change Institute	50.00%	National Science Foundation	Declined	$395,135	$0	New
Denton, George H.	Heinrich Summers	PI	Climate Change Institute	100.00%	Comer Science & Educational Foundation	Funded	$40,000		New
Denton, George H.	Quesada Fund: Furthering Gary Comer's Work	PI	Climate Change Institute	100.00%	Quesada Funds	FundedC	$250,000		Continuation
Denton, George H.	The Last Glacial Termination in the MacKenzie Valley	PI	Climate Change Institute	100.00%	Comer Science & Educational Foundation	FundedC	$56,763		Continuation
Dixon, Daniel	2017 Mandela Washington Fellowship Institute - University of Maine	Co-PI (Kim (admin))	Lead PI's Department	40.00%	International Research & Exchanges Board	Pending	$145,000	$134,424	New
Dixon, Daniel	2016 Mandela Washington Fellowship Institute - Umaine			100.00%	International Research & Exchanges Board	FundedC	$150,000		Continuation
Enderlin, Ellyn	Workshop on Communicating Science for Polar Scientists	PI	Climate Change Institute	100.00%	National Aeronautics & Space	Funded	$2,235	$0	New
Enderlin, Ellyn	Glaciological analysis in support of the J2F-4 search in Southeast Greenland	PI	Climate Change Institute	100.00%	US Dept of Defense	Funded	$25,000	$5,639	New
Enderlin, Ellyn	Remote Sensing of Icebergs in Greenland's Fjords and Coastal Waters Yr 2 (J. Scheick Fellowship)	PI	Climate Change Institute	100.00%	National Aeronautics & Space Administration	FundedC	$35,000	$13,587	Continuation
Enderlin, Ellyn	Linking Ice Melange Characteristics to Glacier Terminus Evolution (Lynn Kaluzienski)	PI	Climate Change Institute	100.00%	National Aeronautics & Space	Pending	$108,813	$43,819	New
Enderlin, Ellyn	Collaborative Research: What controls calving? A Greenland-wide test of terminus change mechanisms	PI	Climate Change Institute	100.00%	National Science Foundation	Pending	$233,514	$0	New
Enderlin, Ellyn	Collaborative Research: Greenland Seasonal Ice Discharge, Freshwater Flux Distribution, and Impacts on Ocean Circulation	PI	Climate Change Institute	100.00%	National Science Foundation	Pending	$408,135	$0	New
Enderlin, Ellyn	Critical Glacier Observations from Crevassed Regions using Lidar Measurements and High-Resolution Optical Imagery	PI	Climate Change Institute	100.00%	National Aeronautics & Space Administration	Pending	$420,762	$0	New
Enderlin, Ellyn	Quantifying Greenland Iceberg Melts	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$172,372		Continuation
Enderlin, Ellyn	Intra-annual Force Balance Analysis of Tidewater Glaciers	PI	Climate Change Institute	100.00%	NASA	FundedC	$204,596		Continuation
Enderlin, Ellyn	Intra-annual Force Balance Analysis of Tidewater Glaciers - Ext.	PI	Climate Change Institute	100.00%	NASA	FundedC	$59,307		Continuation
Enderlin, Ellyn	Antarctic Submarine Melt Variability from Remote Sensing	PI	Climate Change Institute	100.00%	NSF	Funded	$368,535		New
Fernandez, Ivan J.	(Seed Grant) Maine's Changing Winter: focus on natural resources, ecology, and the economy	Co-PI (Nelson)	School of Forest Resources	20.00%	US Dept of the Interior	Pending	$5,000	$12,248	New
Fernandez, Ivan J.	Controls on Phosphorus Export from Agricultural Fields to the Aroostook River, Maine	PI	School of Forest Resources	40.00%	ME Dept of Environmental Protection	Funded	$9,842	$1,774	New
Fernandez, Ivan J.	The Climate Adaptation Fellowship: A Collaborative Curriculum Design Project	PI	School of Forest Resources	30.00%	US Dept of Agriculture	Pending	$45,709	$0	New
Fernandez, Ivan J.	Controls on Phosphorus Export from Agricultural Fields to the Aroostook River, Maine - Phase II	PI	School of Forest Resources	100.00%	US Environmental Protection Agency	Pending	$130,000	$23,442	New
Fernandez, Ivan J.	EAGER: THE PATH OF RECOVERY FROM EXPERIMENTAL AND AMBIENT ACIDIFICATION AT THE BEAR BROOK WATERSHED IN MAINE (BBWM)	PI	School of Forest Resources	70.00%	National Science Foundation	Declined	$298,269	$0	New

Fernandez, Ivan J.	Nitrogen controls on detrital organic matter dynamics in the Northern Forest: Evidence from a 26-year nitrogen addition experiment at the Bear Brook W		School of Forest Resources		US Dept. of Agriculture	Funded	$79,957	$34,221	New
Fernandez, Ivan J.	Controls on Phosphorus Export from Agricultural Fields to the Aroostook River, Maine		School of Forest Resources		ME Dept of Environmental Protection	Funded	$9,842	$1,774	New
Fernandez, Ivan J.	RAPID: Experimental Recovery at the Bear Brook Watershed in Maine		School of Forest Resources		National Science Foundation	Funded	$49,720		New
Gill, Jacquelyn	NSF DDIG Dulcinea Groff - Falklands paleoecology	PI	Climate Change Institute	100.00%	National Science Foundation	Declined	$18,711	$0	New
Gill, Jacquelyn	Surviving a mass extinction: Lessons from the post K-Pg fern spike	PI	Climate Change Institute	100.00%	National Aeronautics & Space	Pending	$241,844	$63,796	New
Gill, Jacquelyn	Collaborative research: A mouse's eye view of Rancho La Brea: Assessing millennial-scale community stability using highly-resolved mammal and vegetation food webs	PI	Climate Change Institute	100.00%	National Science Foundation	Funded	$296,534		New
Gill, Jacquelyn	PACE Workshop: Integrating Paleo and Community Ecology	PI	Climate Change Institute	100.00%	National Science Foundation	Funded	$49,426		New
Hall, Brenda L.	The Last Glacial Maximum and Termination in the South Atlantic Region, derived from Mountain-Glacier records in the Falkland Islands	PI	Climate Change Institute	100.00%	National Science Foundation	Declined	$239,294	$0	New
Hall, Brenda L.	Southern Context for the WAIS Divide Ice Core	PI	Climate Change Institute	50.00%	National Science Foundation	Declined	$399,296	$0	New
Hall, Brenda L.	NSFPLR-NERC: Geological History Constraints on the Magnitude of Grounding Line Retreat in the Thwaites Glacier System	PI	Climate Change Institute	80.00%	National Science Foundation	Pending	$490,259	$0	New
Hall, Brenda L.	Collaborative Research: High-resolution reconstruction of Holocene deglaciation in the southern Ross Embayment	PI	Climate Change Institute	100.00%	National Science Foundation	Funded	$165,146		New
Hall, Brenda L.	Signature of the Last Termination in Maine	PI	Climate Change Institute	100.00%	Comer Science & Education Foundation	FundedC	$30,000		Continuation
Hall, Brenda L.	Coll. Res.: Exploring the Vulnerability of Southern Ocean Pinnipeds to Climate	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$269,584		Continuation
Hall, Brenda L.	Coll. Res.: Assessing the Antarctic Contribution to Sea-Level Change (Hatherton)	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$200,803		Continuation
Hall, Brenda L.	Coll. Res.: Constraints on the Antarctic Ice Sheet from Bryd Glacier	PI	Climate Change Institute	100.00%	National Science Foundation	Pending	$268,219		New
Isenhour, Cynthia	Understanding Climate Resilient Development and Discourse in the Peruvian Highlands	PI	Lead PI's Department	34.00%	National Science Foundation	Declined	$24,380	$0	New
Isenhour, Cynthia	Maine's Community Waste Toolbox: Resources for Healthier People and Communities	Co-PI (Hart)	Senator George J. Mitchell Center	40.00%	Elmina B. Sewall Foundation	Pending	$84,385	$24,791	New
Isenhour, Cynthia	Community solar decision-making and demand charges for deep decarbonization	Co-PI (Klein)	Lead PI's Department	15.00%	US Environmental Protection Agency	Pending	$899,059	$0	New
Jain, Shaleen	Investigating the role of watersheds in regulating nutrient and carbon loading into Maine's drinking water lakes	Co-PI (Northington)	Senator George J. Mitchell Center	20.00%	US Dept of the Interior	Pending	$30,936	$62,482	New
Jain, Shaleen	Improved delineation of natural infrastructure and capital as improved strategies for flood attenuation in support of State's "Clean Water for Maine"	PI	Lead PI's Department	100.00%	US Dept of the Interior	Pending	$33,258	$63,418	New
Kelley, Alice	Lost to Sea: Maine's Ancient Coastal Heritage Yr2	PI	Sea Grant Program	100.00%	US Dept of Commerce	FundedC	$74,743	$60,891	Continuation
Koons, Peter O.	Collaborative Research: Flow and Fracture Dynamics in an Ice Shelf Lateral Margin: Observations and modeling of the McMurdo Shear Zone Yr 4	PI	Climate Change Institute	1.00%	National Science Foundation	FundedC	$357,356	$0	Continuation
Koons, Peter O.	Coll. Res.: Influence of Natural Ice Microstructure on Rheology in General Shear/Alaska Range	PI	Climate Change Institute		National Science Foundation	Funded	$420,937		New
Koons, Peter O.	Integration EarthCube Proposal: Coll. Res. A Syntaxis of Solid Earth Data Systems	PI	Climate Change Institute		National Science Foundation	Pending	$1,181,974		New
Koons, Peter O.	NSFPLR-NERC: Thwaites Glacier sensitivity to rheological feedbacks on lateral and englacial shear	PI	Climate Change Institute	34.00%	National Science Foundation	Pending	$3,800,000	$0	New
Kreutz, Karl J.	North Pacific hydroclimate during the Holocene using the Denali ice core archive	PI	Climate Change Institute	70.00%	National Science Foundation	Pending	$397,178	$0	New
Kreutz, Karl J.	IUSE/PFE:RED Founding the Frontiers of Sustainability Computing	Co-PI (Haddad)	Lead PI's Department	14.00%	National Science Foundation	Pending	$1,934,845	$0	New
Kreutz, Karl J.	SPICE Core Chronology & Climate Records Using Chemical & Microparticle	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$389,306		Continuation
Kreutz, Karl J.	Geophysical Reconnaissance to Expand ice Core Hydroclimate Reconst. (St. Elias)	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$214,890		Continuation
Kurbatov, A.	Coll. Res.: Developing an Antarctic Tephra Database (AntT)	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$365,095		FundedC
Kurbatov, A.	Coll. Res.: Tephrochronology of a South Pole Ice Core (SPICE TEPHRA)	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$205,000		FundedC
Kurbatov, A.	Collaborative research: Expanding, and implementing geochemical fingerprinting toolbox	PI	Climate Change Institute	100.00%	National Science Foundation	Pending	$76,845		New
Kurbatov, A.	Collaborative research: Paleo Ice Project (PIP)	PI	Climate Change Institute	100.00%	National Science Foundation	Pending	$1,161,575		New
Lyon, Bradfield	Enhancing Seasonal Drought Prediction Capabilities for the US and the Globe Using the NMME	PI	Climate Change Institute	100.00%	US Dept of Commerce	Funded	$21,707	$0	New
Lyon, Bradfield	Collaborative Research: Evaluating long-term climate variability, extremes, and change in Central Asia	PI	Climate Change Institute	100.00%	National Science Foundation	Pending	$54,511	$0	New
Lyon, Bradfield	INFEWS/T3: Crop per Drop per Joule as a Measure of Food Energy Water System Efficiency	PI	Climate Change Institute	100.00%	National Science Foundation	Pending	$140,016	$0	New
Lyon, Bradfield	Crop per Drop per Watt in the Food-Energy-Water System	PI	Climate Change Institute	100.00%	National Science Foundation	Pending	$187,179	$0	New
Lyon, Bradfield	U.S. Summer Drought Intensification and Amelioration on Sub-seasonal to Seasonal Timescales	PI	Climate Change Institute	60.00%	US Dept of Commerce	Declined	$495,996	$0	New
Lyon, Bradfield	Coupled Model Biases in the SST Distribution of the Global Tropics and Their Influence on Climate Change Projections	PI	Climate Change Institute	100.00%	National Science Foundation	Funded	$738,757	$0	New
Lyon, Bradfield	Leveraging CMIP5 and NASA/GMAO Coupled Modeling Capacity for SERVIR East Africa	PI	Climate Change Institute	100.00%	NASA	FundedC	$46,441		Continuation
Lyon, Bradfield	Diagnostics, Trends and Climate Model Projections of U.S. Summer Heat Waves	PI	Climate Change Institute	100.00%	US Dept of Commerce	FundedC	$113,998		Continuation
Lyon, Bradfield	Drying Versus Wettening of the East African Climate	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$120,655		Continuation

Maasch, Kirk A.	Mitigation of Climatic and Non-Climatic Stressors Causing Tick-borne Illness in Maine Coastal Communities	PI	Climate Change Institute	90.00%	US Dept of Commerce	Pending	$237,804	$0	New
Mayewski, Paul	Arcadia Ice Core Proposal - Initiatives on the Science of the Human Past (Harvard University) - Amendment #3	PI	Climate Change Institute	100.00%	Arcadia Fund	FundedC	$353,662		Continuation
Mayewski, Paul	An Unprecedented 3500 years of European History and Environmental Change Arcadia Reference AC3450	PI	Climate Change Institute	100.00%	Arcadia Fund	Funded	$249,250	$108,900	New
Mayewski, Paul	Coll. Res.: Ultra-High-Resolution Investigation of High Andean Snow and Ice Chemistry …	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$725,107		Continuation
Mayewski, Paul	Coll. Res.: Pleistocene/Holocene Climate Reconstruction form a Pamir High Resolution Ice	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$590,831		Continuation
Mayewski, Paul	Coll. Res: Investigating Geochemical Signatures in Greenland ice of a Possible Extraterrestrial	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$33,585		Continuation
Mayewski, Paul	Coll. Res.: Window into the World with 40,000-year Glacial Cycles	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$151,529		Continuation
Mayewski, Paul	Coll. Res.: Snapshots of Early and Mid-Pleistocene Climate & Atmospheric Composition	Pi	Climate Change Institute	100.00%	National Science Foundation	Pending	$654,176		New
McGill, Brian	iDiv contract for Measurment of BIodiversity	PI	Senator George J. Mitchell Center	100.00%	Martin Luther University Halle-Wittenberg	Pending	$52,500	$23,100	New
McGill, Brian	Space-beats-time events: leveraging spatio-temporal statistical components to characterize and detect abrupt change events in natural and socio-economic systems	Co-PI (Parmentier)	Senator George J. Mitchell Center	4.20%	National Science Foundation	Pending	$193,235	$0	New
McGill, Brian	Collaborative Research: ABI Development: Creating a generic workflow for scaling up the production of species ranges	PI		100.00%	National Science Foundation	Funded	$89,963		New
Norton, Stephen A.	Evaluating and Predicting Vulnerability for Water Quality Decline in Maine Lakes	Co-PI	Cooperative Extension	50.00%	US Environmental Protection Agency	Funded	$12,304	$990	New
Norton, Stephen A.	EAGER: Evaluating potential for lake water quality decline by partnering with citizen scientists	Co-PI	Lead PI's Department	40.00%	National Science Foundation	Pending	$98,620	$0	New
Olsen, Brian	Collaborative Research: Expanding a National Network for Automated Analysis of Constructed Response Assessments to Reveal Student Thinking in STEM	Co-PI (Smith)	Lead PI's Department	5.00%	National Science Foundation	FundedC	$38,824	$0	Continuation
Olsen, Brian	Animal use of rockweed habitats in coastal Maine	PI	Lead PI's Department	50.00%	ME Dept of Inland Fisheries & Wildlife	Pending	$108,053	$30,686	New
Olsen, Brian	Tidal wetlands after Hurricane Sandy: Baseline Restoration Assessment …	PI		100.00%	US Dept of Interior	FundedC	$291,092		Continuation
Olsen, Brian	Resilence of Tidal Marsh Bird Community to Hurrican Sandy (SANDY 2)	PI		100.00%	US Dept of Interior	FundedC	$1,409,127		Continuation
Olsen, Brian	Determining bird and invertebrate food-web connections and use of rockweed in light of commercial harvesting	Co-PI (Klemmer)		100.00%	ME Dept of Inland Fisheries & Wildlife	Funded	$17,883		New
Olsen, Brian	Collaborative Research: Expanding a National Network for Automated Analysis of Constructed Response Assessments to Reveal Student Thinking in STEM	Co-PI (Smith)		100.00%	National Science Foundation	FundedC	$38,824		Continuation
Putnam, Aaron	What forced the last termination in southern middle latitudes?	Co-PI (Denton)	Climate Change Institute	50.00%	National Science Foundation	Declined	$395,135	$0	New
Putnam, Aaron	CAREER: The Last Glacial Termination in Interior Asia	PI		100.00%	National Science Foundation	FundedC	$591,098		Continuation
Putnam, Aaron	The Last Glacial Termination at the Heart of Asia in the Mongolian Altai	PI		100.00%	Comer Science & Education Foundation	FundedC	$83,300		Continuation
Rickard, Laura	Communicating Climate Change – Messaging to impact behavior	Co-PI (Noblet)	Lead PI's Department	30.00%	US Dept of the Interior	Pending	$19,970	$8,787	New
Rickard, Laura	Collaborative research: Bridging the gap: Illuminating the influence of psychological distance on climate change engagement with visual communication	PI	Lead PI's Department	75.00%	National Science Foundation	Declined	$213,447	$0	New
Rickard, Laura	Collaborative research: Bridging the gap: Illuminating the influence of psychological distance on climate change engagement with visual communication	PI	Climate Change Institute	100.00%	National Science Foundation	Pending	$255,236	$0	New
Rickard, Laura	NRT-INFEWS: Innovations in Transdisciplinary Training: A Model for Translating Research into Economic Development (T3)	Co-PI (Bolton)	Aquaculture Research Institute	0.50%	National Science Foundation	Pending	$2,975,134	$0	New
Rickard, Laura	Sensing Storm Surge: A citizen science approach to measuring storm-estuarine interaction	Co-PI (Huguenard)			National Science Foundation	Funded	$99,994		New
Saros, Jasmine	Collaborative Research: MSB-FRA Nonlinear interactions and abrupt ecological changes in response to climate change across sub-continental North Americ	PI	Climate Change Institute	100.00%	National Science Foundation	Declined	$74,608	$0	New
Saros, Jasmine	COLLABORATIVE RESEARCH: PREDICTING THE RESPONSE OF BOREAL LAKES TO CLIMATE CHANGE: IN-LAKE AND WATERSHED PROCESSES	PI	Climate Change Institute	100.00%	National Science Foundation	Declined	$277,753	$0	New
Saros, Jasmine	Polar (DCL-16-119): Fostering Interdisciplinarity through Theme-Based Encounters: The Artic Coupled Systems (ArCS) Theme	PI	Climate Change Institute	50.00%	National Science Foundation	Declined	$299,641	$0	New
Saros, Jasmine	Collaborative Proposal: MSB-FRA: Alpine aquatic metabolism in the mountain west: emergent impacts of a changing cryosphere	PI	Climate Change Institute	100.00%	National Science Foundation	Declined	$326,411	$0	New
Saros, Jasmine	Collaborative Research: Quantifying the role of lakes in the Arctic terrestrial C cycle	PI	Climate Change Institute	40.00%	National Science Foundation	Pending	$482,242	$0	New
Saros, Jasmine	Deciphering the Ecology of Key Diatom Taxa (W. Greenland)	Pi	Climate Change Institute	100.00%	National Science Foundation	FundedC	$353,980		Continuation
Saros, Jasmine	IGERT: Adaptation to Abrupt Climate Change	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$2,929,087		Continuation
Saros, Jasmine	Jordan Pond Buoy Project	PI	Climate Change Institute	100.00%	Friends of Acadia	FundedC	$44,959		Continuation
Saros, Jasmine	Assessing the Vulnerability of Maine's Drinking Water Resources (WRRI 2016)	PI	Climate Change Institute	100.00%	US Dept. of Interior	FundedC	$27,277		Continuation
Saros, Jasmine	EPA IAG for Clean Air Act trends research, 2017-2018 (Determining the effectiveness of the Clean Air Act	PI	Climate Change Institute	100.00%	US EPA	Funded	$80,918		New

Schauffler, Molly	Charting a course to oean data literacy: designing concept-linked, interactive data actvities to engage students in ocean sciene learning	Co-PI (Lindsay)	School of Marine Sciences	20.00%	National Science Foundation	Declined	$299,956	$0	New
Sneed, Sharon	Ultra-high resolution investigation of Eemian climate	PI	Climate Change Institute	30.00%	National Science Foundation	Pending	$588,502	$0	New
Sorg, Marcella H.	Maine-Vermont Violent Death Reporting System Yr 3+$	PI	Margaret Chase Smith Center	100.00%	US Dept of Health & Human Services	Pending	$43,067	$0	Supplement
Sorg, Marcella H.	New Hampshire Fentanyl Hot Spot Expansion Study	PI	Margaret Chase Smith Center	80.00%	US Dept of Health & Human Services	Funded	$49,505	$0	New
Sorg, Marcella H.	Maine-Vermont Violent Death Reporting System Yr 3	PI	Margaret Chase Smith Center	100.00%	US Dept of Health & Human Services	FundedC	$153,733	$0	Continuation
Sorg, Marcella H.	State Surveillance of Opioid Morbidity and Mortality	PI		100.00%	US Dept of Health & Human Services	Funded	$91,179		New
Sorg, Marcella H.	New Hampshire Fentanyl Hot Spot Expansion Study	PI		100.00%	US Dept of Health & Human Services	Funded	$49,996		New
		PI							
Spaulding, Nicole	Coll. Res.: Allan Hills Englacial Site (ACHILLES) Selection	PI	Climate Change Institute	100.00%	National Science Foundation	FundedC	$35,594		Continuation
Strong, Aaron	Linking Remote Sensing to Ocean and Coastal Acidification Monitoring Networks in Maine	PI	Lead PI's Department	100.00%	National Aeronautics & Space Administration	Pending	$97,136	$37,774	New
Strong, Aaron	Resource recovery and reuse (R3) - a sustainable foundation for societies of the future	PI	School of Marine Sciences	100.00%	National Science Foundation	Pending	$218,364	$0	New
Strong, Aaron	Low pH in the coastal waters of the Gulf of Maine: What are the sources and vulnerabilities to coastal communities?	Co-PI (Townsend)	School of Marine Sciences	25.00%	US Dept of Commerce	Pending	$699,993	$0	New
Strong, Aaron	PIRE:MACROSEA^2: North Atlantic Partnership Towards Improved Coastal Sustainability through Development of Macroalgae-based Marine Bioeconomy	Co-PI (Evans)	Lead PI's Department	14.00%	National Science Foundation	Pending	$1,466,584	$0	New
Thomas, Andrew C.	MaricultureMap - Development of a GIS tool to inform mariculture development in Alaska	PI	School of Marine Sciences	100.00%	US Dept of Commerce	Pending	$56,825	$26,957	New
Thomas, Andrew C.	Linking exchange processes with hypoxia and biological hot-spots in Alaskan Fjords.	Co-PI (Ross)	Cooperative Extension	25.00%	US Dept of Commerce	Pending	$394,362	$0	New
Thomas, Andrew C.	NERACOOS_2016_2021_Buoys_CODAR_Glider_Nutrients_Satellite_Surveys			100.00%	US Dept of Commerce	Funded	$792,011		New
Thomas, Andrew C.	Multi- and hyperspectral bio-optical identification and tracking of Gulf of Maine water masses and harmful algal bloom habitat			100.00%	National Aeronautics & Space Administration	Funded	$266,383		New

TOTAL SUBMISSIONS INCLUDES FUNDED, PENDING, CONTINUATION, DECLINED & WITHDRAWN GRANTS	COUNT = 133	$42,777,041

APPENDIX C: BRIEF OVERVIEW OF EACH MAJOR NEW AWARD

(This listing includes only the listing of new grant awards for FY2017. A listing of continuing awards through FY2017 are included in the supplemental listing at the end of this document).

Project Title: Collaborative Research: Pacific Ocean Stratification since the Last Ice Age: New Constraints from Benthic Foraminifera
National Science Foundation
$283,274
PI: Katherine Allen

Project Summary

Overview: Ice age cycles involve rapid reorganizations of the ocean and atmosphere system (e.g., Broecker and Denton, 1990), and changes in seawater density and circulation may play a key role in the repeated flips between glacial and interglacial modes of operation in the past (Adkins et al., 2002; Adkins, 2013; Ferrari et al., 2014). However, available data are not sufficient to characterize the glacial ocean density structure or to resolve rapid temperature and salinity changes during the last glacial termination. The work we propose here will fill a key data gap by establishing profiles of physical and chemical seawater properties in the Pacific Ocean, where paleo-oceanographic data bearing on density and mixing are particularly sparse. Using a regional suite of cores that spans 1 – 3 km depth, we will: 1) Assess the regional Mg/Ca temperature sensitivity using a suite of core-top samples from New Zealand, 2) Reconstruct past seawater temperature using Mg/Ca of benthic foraminiferal calcite, and 3) Estimate δ18O of seawater by combining temperature data with δ18O of benthic calcite. These records will span the past 30 thousand years and have high enough temporal resolution to provide insight into millennial-scale events. Temperature data will provide direct constraints on seawater density and will also be used to calculate δ18O of seawater. Seawater δ18O is a conservative property and thus can provide insight into mixing of water masses in the ocean interior (Lynch-Stieglitz, 2006). It may also provide insight into conditions in deep and intermediate water formation regions, including salinity. These data would represent a major step towards quantifying past density changes. Intellectual merit of the proposed activity: This work will improve our understanding of how the glacial ocean operated and also shed new light on the changes that heralded a return to our present, warmer climate mode. The proposed work is novel in several ways. First, the selected sediment cores have unusually robust chronologies based on several volcanic ashes (Shane et al., 2006). This age-model foundation eliminates any uncertainty associated with the standard methods of radiocarbon dating and alignment of δ18O records, thus these cores are uniquely poised to provide robust constraints on the timing of past ocean change. Second, a relatively novel temperature proxy will be applied: the Mg/Ca of Uvigerina calcite. To establish the pattern and timing of warming in the Pacific Ocean interior, much work is needed to fill gaps in space and time, to build upon the few pioneering studies on deep Pacific temperatures (e.g., Elderfield et al., 2010; Lear et al., 2002, 2005; Adkins et al., 2002; Nelson et al., 1993). Third, unlike some previous studies that were based on a single core, we will apply these methods to a wide depth transect of stratigraphically linked cores that span 1 to 3 km depth. This approach enables robust comparison of the relative timing of changes at different depths and provides insight into the position and extent of different water masses. Fourth, the data can shed new light on previous work in this region (e.g., on δ13C and δ18O studies), by enabling the temperature component of these signals to be quantified.

Broader impacts of the proposed activity: The project will provide support for two undergraduate students and one graduate student, all of whom will receive personal training in laboratory techniques and participate in interpretation and public presentation of results under the guidance of a team of two principal investigators, one at each collaborating institution. This work will shed light on the role of ocean stratification in late Pleistocene climate change and also may identify potential instabilities of the ocean-climate system, with implications for Earth's modern heat budget and carbon cycle. The paleo temperature data can also provide valuable input, e.g.,

constraints on the depths of key isotherms, for assessing current models of glacial ocean circulation. As part of this work, we will provide new core-top Mg/Ca data from multi-cores and establish a local, modern proxy calibration that can be used by other paleoceanographers working in this region to more accurately reconstruct past ocean temperatures.

Project Title: Blowing Hot or Cold? Resolving the Terrestrial Impact of North Atlantic Stadials
National Geographic Society
$14,045
PI: Gordon Bromley

Project Summary
What drives abrupt climate change? With continued population growth, increasing pressure on natural resources, and rising CO_2 concentrations, understanding the causes and effects of abrupt climate change poses one of the greatest challenges to modern human civilization. Thus, developing our knowledge of past perturbations is key to minimizing the risk of future "climate shock." We propose to resolve the terrestrial expression of past abrupt climate change in the North Atlantic region, widely held as a central player – if not the driver – of abrupt change, to help identify the mechanisms driving these severe, potentially catastrophic swings in temperature and precipitation. Specifically, we will use cutting-edge geochronology to reconstruct ice-sheet behavior in northern Scotland during Heinrich Stadial 1 (18,300–14,700 yrs ago), arguably the most significant abrupt climate event of the last glacial cycle. Such constraint is important because of conflicting models of how such events impact terrestrial environments and a recent hypothesis attributing this disparity to enhanced seasonality in the circum-North Atlantic. With the growing focus on future climate impacts, developing the available record of glaciation in Scotland is a logical next step towards understanding the causes and mechanisms of abrupt change.

Project Title: Resolving the Impact of So-Called "Heinrich Stadial 1" on the Terrestrial Cryosphere of the North Atlantic Region
Comer Science and Educational Foundation
$25,000
PI: Gordon Bromley

Project Summary
The last glacial termination represents the highest-magnitude climate-change event of the last ~100 kyr. The transition from glacial-to-interglacial conditions was not smooth, but occurred in a series of abrupt jumps between short-lived cold "stadial" and warm "interstadial" states. These millennial-scale oscillations are evident in climate proxies from both polar hemispheres but are most striking in records of North Atlantic air and sea-surface temperature (SST) and atmospheric circulation, prompting particular focus on the circum-North Atlantic as the type area for abrupt climate change. After the culmination of the last glacial maximum (LGM), the North Atlantic region experienced a prolonged period of stadial conditions between 18.3 and 14.7 kyr, during the so-called "Heinrich Stadial 1" (HS1). This event is associated with rapid southward shifts of the polar front, weakening of meridional overturning circulation, and spread of winter sea ice, processes that together drove a severe reduction in mean-annual temperature in the North Atlantic region. For example, alkenone data from a marine sediment core near the Iberian Margin indicate SSTs were lower during HS1 than at the LGM, a pattern also evident in Greenland air temperatures. Beyond the North Atlantic, HS1 has been correlated with cooler conditions throughout the Northern Hemisphere, weakening of the Asian monsoon, shifts in tropical ocean circulation, and displacement of tropical rain belts. In contrast, cold stadial conditions in the Northern Hemisphere seem to have coincided with periods of warming and extensive deglaciation in southern mid latitudes, possibly due to the bipolar seesaw and/or southward shifts of the thermal equator.

The wealth of data for the termination is tantalizing yet fundamentally incomplete. A persistent gap in our knowledge is the full expression of Heinrich stadials across the circum-North Atlantic, particularly the impact of HS1 on the terrestrial cryosphere. The proposed research will resolve the terrestrial expression of past abrupt climate change in the North Atlantic region, widely held as a central player – if not the driver –

of abrupt change, to help identify the mechanisms driving these potentially catastrophic phenomena. Specifically, we will use cutting-edge ^{10}Be geochronology to reconstruct ice-sheet behaviour in northern Scotland during HS1 and the late-glacial readvance. Such constraint is important because of currently conflicting models of how such events impact terrestrial environments and a recent hypotheses attributing this disparity to enhanced seasonality in the North Atlantic basin. With the growing focus on the true nature of stadial events, developing the available record of glaciation in Scotland is a logical next step towards understanding the causes and mechanisms of abrupt climate change.

Project Title: Inundation Modeling for Saco, Maine
US Dept. of Energy
$62,370
PI: Fei Chai

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19 January 2016

Dr. Malcolm Spaulding
Northeastern Regional Association of Coastal and Ocean Observing Systems
195 New Hampshire Avenue, Suite 240
Portsmouth, NH 03801

RE: NOAA-NOS-OCM-2015-2004324

Dear Dr. Spaulding,
The University of Maine Ocean Modeling Group (OMG) (Profs. Xue and Chai) will participate in the proposed project "High Resolution Coastal Inundation Modeling and Advancement of Green Infrastructure and Living Shoreline Approaches in the Northeast" if it is funded. This letter summarizes UMaine OMG's responsibilities.

A high-resolution coastal ocean model of Saco-Casco Bays has been developed as a part of NOAA Cooperative Institute for the North Atlantic Region (CINAR) storm forecast project. Sensitivities to water depth and bottom drag have been tested. The model has been used to simulate storm surges in response to 6 storms during the 2014-2015 winter season and the results have been compared with tide gauge and buoy observations. For the proposed northeast regional coastal resilience project, we will continue to develop the Saco-Casco inundation model by coupling the ocean model with SWAVE and our main tasks are as follows.

1. Carry out coupled simulations of currents and waves to calculate wave run-up in the Saco region.
2. Meet with key users to identify their principal needs and requirements for accessing model predictions and distributing and displaying the results.
3. Provide forecasting products to facilitate the development of region wide, web based tools and apps of coastal inundation maps for use in emergency response as well as 100 yr return period water levels with sea level rise in support of coastal planning (see STORMTOOLS http://www.beachsamp.org/resources/stormtools/ for an example).

Sincerely,

Profs. Huijie Xue and Fei Chai

Project Title: <u>Improving tide-estuary representation in MPAS-Ocean</u>
US Dept. of Energy
$72,624
PI: Fei Chai

Project Summary
The past decade has witnessed the development and maturing of large-scale ocean circulation models based on either structured or unstructured grids, and MPAS-Ocean ('MPAS' hereafter), developed by DOE is a prominent example from the latter category, as it possesses several desirable numerical properties suitable for long-term, global-scale applications and offers advantages over traditional models based on structured grids because of its superior capability of local refinement. Although well validated for large-scale oceanic applications, MPAS has been rarely tested in shallow-water environment (SWE). The latter presents new challenges and opportunities for model improvement. In particular, the inherent need for higher resolution and stronger forcing in SWE (due to tides, bathymetry, rivers etc.) set a high bar for model's robustness and stability (Zhang et al. 2015, 2016).

We have been developing state-of-the-art estuarine and nearshore models for the past 15 years, and have accumulated a lot of experience for SWE systems. Our experience demonstrates that for a model to do well in SWE, it has to strike a delicate balance between accuracy, efficiency, robustness and flexibility. The latest generation of modeling system we are developing, SCHISM, is a culmination of multi-year effort funded by several government agencies. At the moment, SCHISM as an open-source community driven model has 180+ registered user groups world-wide, and has 70+ related peer-reviewed publications (see ccrm.vims.edu/schism/ for a list) that cover a wide range of topics from general circulation, wave-current interaction, tsunami and hurricane storm surge inundation, hydrology, sediment transport, water quality, biogeochemistry, and oil spill. We propose improving the tide-estuary representation in the global MPAS model by sharing our experiences in both model development and validation in SWE. Due to the technical nature of this research, we'll remain flexible in the collaboration with MPAS group and with on-going ACME project. We'll start with testing MPAS' ability in SWE using the tests shown in (v) below. Depending on the test results, potential research tasks to improve the model include incorporating a biogeochemical model into SCHISM.

Located at the intersection between land and ocean, estuaries play an important role in global carbon and biogeochemical cycles (Fong et al. 2015), and yet represent the greatest uncertainties as a source or sink (Bauer et al. 2013). Adding a good representation of tide-estuary system into an existing credible global model is therefore a major step forward and closes a critical knowledge gap in water cycle. The proposed research also complements and extends on-going ACME project, as the latter seeks in the long-term to include components required to simulate impacts of sea-level change and storm surge on coastal regions, including wave models and focusing resolution in coastal and storm-track regions, as an important component of the Cryosphere-ocean system.

Project Title: Heinrich Summers
Comer Science and Educational Foundation
$40,000
PI: George Denton

Project Summary
Using the history of former glacier systems in New Zealand's Southern Alps and in the Altai Mountains of western Mongolia, we propose to examine north-south climate connections in middle latitudes of the two polar hemispheres through the last glacial maximum and the last termination, with a concentration on the time of Heinrich Stadial 1. We have chosen glacier systems of comparable size and elevation in each hemisphere. The Altai Mountains are near the center of the earth's largest continent and the Southern Alps are in the midst of the earth's largest ocean. We anticipate that the results of this exercise will compare summer climate oscillations in the two polar hemispheres. Such an approach will complement the usual north-south comparison between the winter-centric Greenland and the Antarctic ice-core records, which does not take northern summers into consideration. The Mongolian project is funded and underway. Here we request funds to complete the New Zealand leg of the proposed inter-hemispheric comparison.

Project Title: Glaciological analysis in support of the J2F-4 search in Southeast Greenland
US Dept. of Defense
$25,000
PI: Ellyn Enderlin

Overview: In November 1942, a United States Coast Guard (USCG) Grumman J2F-4 "Duck" aircraft crashed in Southeast Greenland with three personnel on board. Recent efforts to locate the wreckage and remains have been unsuccessful, in large part because of uncertainties in the actual crash location and the trajectory of the debris in the > 70 years since the crash. Here we propose a comprehensive analysis of ice flow in the region of crash site in order to accurately model the potential debris trajectories. The work will be based on automated feature-tracking applied to sequential very high-resolution (0.5 m ground resolution) satellite images. Once the surface flow field is derived, we will model 70-year trajectories from multiple starting points corresponding to possible crash locations to yield the present-day positions of wreckage. The major outcome of this work will be an assessment of the likelihood that wreckage is still recoverable and, if so, where search efforts should be concentrated.

Project Title: Antarctic Submarine Melt Variability from Remote Sensing of Icebergs
National Science Foundation
$368,535 (YR1, YR2, YR3)
PI: Ellyn Enderlin
Co-PI: Gordon Hamilton

Overview: Nearly three-quarters of the Antarctic ice sheet's grounding line adjoins to floating ice shelves fed by outlet glaciers or ice streams. These ice shelves play an important role in modulating the dynamics of glaciers flowing into them by imparting a back stress on the upstream grounded ice. A reduction in the amount of back stress, for example due to ice shelf thinning or complete disintegration, will lead to an increase in ice flux across the grounding line. Given the importance of ice shelves in modulating Antarctica's ice flux to the ocean, and thus changes in sea level, the conditions governing ice shelf mass balance need to be properly understood.

Oceanic forcing is an important control of the ice sheet's mass balance because it brings heat into contact with marine-terminating ice. Recent studies point to an increase in heat transport across the Antarctic continental shelf towards the ice sheet, which is consistent with the timing of recent grounding line retreat and increasingly negative mass imbalances for Antarctica's marine-terminating glaciers and ice shelves. While the aforementioned observations paint a convincing picture for an oceanic driver for the accelerated thinning along portions of the ice sheet's marine margin, direct evidence for a mechanistic link is still at a

rudimentary level because of sparse spatial and temporal sampling of ocean conditions on the continental shelf.

Here, we propose a new approach for mapping spatial and temporal patterns in ocean properties around the coast of Antarctica using iceberg submarine melt estimates from very high-resolution stereo satellite images. Our method has been applied to icebergs located around the Greenland ice sheet's periphery and has been successfully tested on icebergs adjacent to the Antarctic Peninsula. The method is robust, precise and has a well-constrained error budget. By applying the technique to the available stereo image archive(2011 onwards) and new images acquired as part of this project, we will produce a unique dataset of submarine melt rates for multiple regions around the Antarctic coast at seasonal (and potentially shorter) time-scales.

Project Title: Workshop on Communicating Science for Polar Scientists
National Aeronautics & Space Administration
$2,235
PI: Ellyn Enderlin

Abstract
This proposal requests support for a science communication skills workshop specifically aimed at polar researchers (both Arctic and Antarctic), many of whom are conducting NASA-Funded research. Recently, related to both increased public interest in polar and climate science as well as the significant investment in polar science during the International Polar Year (2007-2009), the number of polar researchers has grown significantly. These researchers need to build interdisciplinary science communication skills as they develop their scientific and analytical capabilities. By promulgating effective communication techniques through workshops such as the one proposed, scientific information itself is enhanced because it is more clearly articulated to the people who will use it for social benefit (e.g., Bodmer et al., 1985; Provencher, 2011).

Here we propose to hold a three-day workshop that will train 32 polar researchers (20 of which will be early career) in scientific communication. The workshop will be organized by the US National Committee of the Association of Polar Early Career Scientists (USAPECS) and will immediately precede the International Glaciological Society (IGS) Symposium on Polar Ice, Polar Climate, Polar change in Boulder, Colorado, on August 14-19, 2017. Workshop participants will learn and practice strategies for enhancing oral and written science communication and will be expected to hone skills through post-workshop activities. The workshop will integrate training in communication strategies with examples of effective (and ineffective) polar science communication. Activities will include improvisational exercises, reflective writing, interactive presentations, and the development of communication materials that can be used by each participant after the workshop. By the end of the workshop, participants will have observed, evaluated, and collected a portfolio of innovative communication approaches and materials that can be adopted and adapted to their needs. The workshop will encourage participants to continue to hone their science communication skills through post-workshop activities, continued peer discussion, and skill-sharing with their home communities.

Research Assistant Professor Dr. Ellyn Enderlin will act as institutional PI on the subaward to the University of Maine from the University of Colorado Boulder.

Project Title: Nitrogen controls on detrital organic matter dynamics in the Northern Forest: Evidence from a 26-year nitrogen addition experiment at the Bear Brook Watershed
US Dept of Agriculture
$79,957
PI: Ivan Fernandez
Co-PI: Marie-Cécile Gruselle

Abstract
Temperate forests are increasingly expected to simultaneously fulfill multiple ecosystem services, an important one being to limit greenhouse gas concentrations in the atmosphere. Forests can store carbon (C) in biomass and soil organic matter (SOM). Woody detritus, as part of SOM, plays an important role in the forest C cycle; however, little is known regarding the factors that control its persistence in forested settings. Previous studies in New England suggest that nitrogen (N) additions to forested plots slow SOM decomposition, which has resulted in an increase in C in the forest floor. It is not currently known if elevated N also slows woody detritus decomposition. In this study, our goal is to investigate the influence of site quality, particularly site N status, on storage of C and N in woody detritus at the Bear Brook Watershed in Maine, a long-term paired watershed experiment with one watershed receiving experimentally elevated N inputs for over 25 years. The watersheds are composed of red spruce and mixed northern hardwood forests. Our research objectives are: (1) Determine the C and N concentrations, stocks, and ^{15}N composition of woody detritus along a decomposition gradient at two sites differing in N status, (2) Compare C and N dynamics in standard sugar maple and red spruce wood stakes between sites differing in N status in a field decomposition experiment, and (3) Evaluate the influence of environmental parameters and decay stake initial chemistry on C and N dynamics of woody detritus after 12 months in the field. This research will (1) increase our understanding of the role of elevated N in controlling woody detritus decomposition and thus C cycling and, (2) produce empirical relationships between woody detritus C and N contents across a range of tree species and decay classes common in the Northern Forest. Our results will be relevant to researchers, modelers, and practitioners, particularly for forecasting future C dynamics for the dominant tree species of the Northern Forest. This is increasingly important as interest grows in forest C modeling, given the limitations of common C models (such as the Forest Vegetation Simulator) as decision-support tools for current and emerging C markets.

Project Title: Controls on Phosphorus Export from Agricultural Fields to the Aroostook River, Maine
ME Dept. of Environmental Protection
$9,842
PI: Ivan Fernandez

Abstract
This contract is between The University of Maine and Maine Department of Environmental Protection for work to be performed in 2017 and 2018. This work is part of a larger project ("Controls on Phosphorus Export from Agricultural Fields to the Aroostook River, Maine") and follows on an initial contract designed to purchase groundwater wells in 2016 and install them in early 2017 in preparation for Phase II, as described here.

Several small streams with perennial flow draining to the Aroostook River, Maine, are chemically and biologically impaired, based on data from the Maine Department of Environmental Protection (K. Hoppe, unpublished). Preliminary data from surface waters found high pH in several streams, oscillating above and below 8.0, with high alkalinity (>1,000 ueq/L), and orthophosphate-phosphorus (SRP) and total P ranging 10-30 and 20-60 µg P/L, respectively. The concentrations of P are not substantially different in moderate flow (May-June) and base flow (July-August). Orthophosphate P and total P concentrations in groundwater from drilled bedrock wells within the watershed range from 1-2 µg/L. These observations suggest that the origin of the P is from surficial and subsurface (shallow groundwater) transport, and likely dominated by agricultural field sources. Both phases of this project have the combined goal of understanding the mechanisms by which agriculturally-derived excess P moves from fields to streams, fueling the

productivity of streams. This knowledge will assist the State in developing best-management-practices to mediate the high P in Aroostook County streams.

This contract is specifically for the characterization over time of stream, groundwater, and domestic well P and related chemistries that provide insight on P source-sink relationships in a representative agriculture watershed along Amsden Brook in Washington County, Maine. In addition, a transect of soils and selected stream sediments will be intensively characterized for surface chemistry and operationally defined P fractions at multiple depths in soils. Details of the research design are in the full proposal.

Project Title: RAPID: Experimental Recovery at the Bear Brook Watershed in Maine
National Science Foundation
$49,720
PI: Ivan Fernandez
Co-PI: Steve Norton

PROJECT OVERVIEW
This proposal describes a unique, time-sensitive opportunity to study mechanisms of ecosystem recovery from multi-decadal, chronic experimental whole-watershed acidification and nitrogen (N) enrichment following the cessation of 27 years of bi-monthly treatments with ammonium sulfate by helicopter in October 2016. Past research has documented changes in the biogeochemistry of biota, soils, and solutions, linking the treatment and climate to altered ecological function on short-term and decadal time scales. The proposed research will study ongoing long-term recovery in the reference watershed (East Bear) from declining ambient atmospheric deposition of N and S, and will capture the stream chemical signature from the initial year of hypothesized rapid biogeochemical response to the cessation of treatments in West Bear.

INTELLECTUAL MERIT
This research builds on three decades of science at the BBWM that has studied the mass balance of water and elements in response to declining ambient S and N deposition, long-term experimental acidification and N enrichment, and decadal trends of warming and increased precipitation that, combined, have uncertain consequences for ecosystem function and resilience in the future. In October 2016, long-term experimental treatments of S and N ceased. This immediately began a critical period of initial recovery to a nearly 80% reduction in S and N deposition in West Bear with minimal influence of other complex long-term changes in ecosystem biogeochemical function. This RAPID proposal tests hypotheses about the rate at which sudden shifts in atmospheric deposition may alter the composition, quality, and flux of DOM in the absence of confounding drivers (e.g. climate, forest type, precipitation).This RAPID proposal also tests mechanisms of recovery driven by declining sulfate export from soils, and the unknown sequence of altered base cation and aluminum response to recovery in soils and streams.

BROADER IMPACTS
The proposed research will include training for undergraduate and graduate students already part of the BBWM program. The BBWM program has a substantial history of field and laboratory training of undergraduate and graduate students, as well as postdocs, producing numerous theses and publications. During the past five years, K-12 teachers and students have increasingly participated in our program, providing unique research opportunities and examples for their classrooms which will continue. In the 2016-2017 school year, one of those schools is establishing their own watershed study (Old Town High School) inspired by BBWM and with ongoing input from the PIs. Students working and studying at BBWM have been relatively evenly represented by gender. BBWM will also continue to provide a platform for collaborative research with visiting international and domestic scientists, and for scientific collaborations with other research sites. Finally, this research addresses mechanisms of ecosystem response to important vectors of change in air quality and the climate system that are critical to maintain the ecosystem services provided by forests and their associated surface waters on which society depends. Findings from BBWM have and will continue to contribute to policy assessments at the state and national level.

Project Title: Collaborative research: A mouse's eye view of Rancho La Brea: Assessing millennial-scale community stability using highly-resolved mammal and vegetation food webs
National Science Foundation
$296,534 (YR1, YR2, YR3)
PI: Jacquelyn Gill

Overview: The composition and structure of present-day communities are changing in many ways: local populations are lost to human land use or climate change, the increasing rarity of the earth's largest species is leading to a "trophic downgrading" of the planet's biodiversity, and novel communities and ecosystems are forming as species arrive, depart, or go extinct. Yet understanding the drivers and responses of in-progress biodiversity changes, and disentangling signal from ecological complexity is difficult without adequate baselines. Here, the small mammal and vegetation components of the Rancho La Brea (RLB) tar pits are systematically identified, then integrated into multi-trophic paleo food webs. Terrestrial community and species stability to natural climate variability is assessed and used to predict and validate outcomes of the myriad environmental changes that occurred globally over the past 50,000 years. These analyses will not only permit exploration of paleo food web structure and dynamics, but will allow verification of the dynamical predictions against known future extinctions in the ecosystem.

Intellectual Merit: This project adds value to the extensive existing records of megacarnivores and megaherbivores at one of the most significant paleontological sites in the world by providing a better understanding of the full biodiversity in the region around RLB during the late Quaternary and generating useful datasets that can be mobilized to put ongoing single-species research in a broader ecological context. Second, the Bayesian framework developed for this proposal can be applied to both paleo and modern food webs to facilitate integration of multiple proxies that better characterize areas of certainty and uncertainty in understanding past ecological interactions. Third, by exploring the structure and stability of food webs through time, this proposal will determine cross-trophic linkages in a system that has previously focused extensively on the upper trophic levels of communities. Finally, by predicting the likely responses of species to global changes, then testing these predictions using the known megafaunal extinction events across the Pleistocene-Holocene transition, this proposal will improve understanding of the importance of intact ecological networks for the vulnerability and/or resilience of taxa in a trophically downgraded Anthropocene. The first three contributions alone will significantly advance understanding of both paleontological methods as well as provide insight into the paleoecological structure of a site of international importance. The final contribution will connect the findings from the fossil record with understanding of how present-day ecosystems may change given current and future global change.

Broader Impacts: The broader impacts of our proposal will take four main themes: 1) Contribute to the past and future intellectual legacy of RLB. Generating small mammal and vegetation data for RLB will be useful to ongoing and future research pursuits at RLB, as well as outreach and education efforts. All data will be publicly available, ensuring access to the data by other researchers and the public alike. This project will also focus on 2) Secondary education, teacher training, and citizen science. A postdoctoral researcher trained in paleontology and/or biological education will be mentored at the Tar Pits Museum to oversee the development of a student-based citizen science initiative, which will bring the primary research at RLB to the students and general public. This project will also 3) Inform development of products that focus on public outreach and education, through blog posts, exhibit renovation, and the development of a children's book, all taking a "mouse's eye view" of RLB. Finally, this project will 4) Contribute to interdisciplinary training in ecology and earth science by cross-training postdocs, grad student, and undergraduates in paleontological research methods, state-of-the art food web modeling, and science education.

Project Title: PACE Workshop: Integrating Paleo and Community Ecology
National Science Foundation
$49,426
PI: Jacquelyn Gill
Co-PI Brian McGill

Paleoecology and population and community ecology (PCE) are naturally allied subdisciplines of ecology, linked by their shared interest in understanding the fundamental processes governing the distribution, abundance, and interactions among species in biological systems. In the rapidly changing world of the Anthropocene, ecological research is increasingly focused on studying systems in transition, and on understanding how community dynamics are governed by the joint effects of environmental change, abrupt events, biotic interactions, and historical legacies. The on-going informatics revolution is making it increasingly possible to synthesize multiple kinds of ecological data across spatial, temporal, and taxonomic scales, including species traits, past and present distributions, ancient and contemporary genetics, environmental covariates, and phylogenetic history.

However, while there are clear opportunities for synergy between paleoecology and PCE, various structural challenges hinder integration between the two sub-fields. Paleoecology and PCE emerged from different traditions and disciplines. Community ecology emerged from population biology and natural history, and tends to focus on ecological phenomena and processes that are readily observable today, e.g. species interactions, physiological traits, environmental controls, and disturbance. Historical legacies and environmental variability are well-understood to be important, yet many classic modeling frameworks in population and community ecology implicitly or explicitly assume a stable environment or that environmental variables are modified only by the organisms themselves. In contrast, paleoecology has roots in ecology, earth and climate science, and physical geography, with practitioners dispersed across these disciplines. Paleoecologists tend to view species assemblages in a strong Gleasonian sense: transient, individualistic, often influenced by historical contingency or stochastic processes, and largely controlled by environmental variables. As a result, paleoecologists spend substantial effort on documenting the complex temporal and spatial variations in environmental factors that can produce correspondingly complex responses in, species, and communities. Many processes that are foundational to community ecology, such as species interactions, often are invisible in the paleoecological archive or can only be studied indirectly REFS, albeit with notable exceptions such the recent wave of interest studying the consequences of the Pleistocene megafaunal extinctions REFS. Paleoecologists must study and understand the taphonomic processes that affect the representation of ecological processes in geological archives, a topic of remote interest to most community ecologists.

Both the natural alliance and divide between paleoecology and PCE are structurally persistent features; neither is likely to disappear anytime soon. Many authors have called for a closer synthesis of paleoecological and community ecology REFS, particularly in light of conservation biology or global change and many individual researchers have productively worked at this intersection. **In our opinion, little will be accomplished by another paper calling for closer integration between these disciplines. Rather, the critical need is to actively build the community, encourage a mixture of formal and informal conversations, and facilitate the growth of a new interdisciplinary network. We propose to do this by hosting a workshop of 20 paleoecologists, biogeographers, and population and community ecologists.** We have carefully selected the invitees with multiple criteria in mind: people already working at the interface between paleoecology and PCE and people primed to start working at this intersection, established leaders in the field and pre-tenure scientists, with close attention to maximizing diversity of genders and backgrounds. We have also thought carefully about how to structure this workshop to both gain the advantages of a small informal conversation while also using multiple social media avenues to open the conversation and make it maximally inclusive.

Project Title: <u>Collaborative Research: High-resolution reconstruction of Holocene deglaciation in the southern Ross Embayment</u>
National Science Foundation
$165,146
PI: Brenda Hall

Overview: Reconstructing past fluctuations of the Antarctic Ice Sheet (AIS) is critical for understanding the sensitivity of ice volume to sea-level and climatic change. Constraints on past behavior help put ongoing changes into context and provide a basis for predicting future sea-level rise. In order to constrain recession of the AIS during the last deglaciation, we will reconstruct and date past ice-surface elevations at

nunataks along the coast of the southern Ross Embayment. High-resolution dating will come from numerous ^{10}Be surface exposure ages of erratics collected along elevational transects, as well as from ^{14}C dates of algae within shorelines from ice-dammed ponds. Our sites have been chosen specifically to allow close comparison of these two dating methods, which will afford constraints on Antarctic ^{10}Be production rates. Determination of this production rate has important implications for the calculation and interpretation of all Antarctic surface exposure ages. Moreover, these dates will allow us to distinguish between models of ice retreat, which have important implications for former ice configuration and dynamics, and to constrain the contribution from Ross Sea deglaciation to global sea level through the late Holocene.

Project Title: Coll. Res.: Influence of Natural Ice Microstructure on Rheology in General Shear/Alaska Range
National Science Foundation
$420,937
PI: Peter Koons

Project Summary

Glacier and ice sheet mass balance is one of the highest impact components of climate change, due in large part to its affect on sea level. Both Greenland and Antarctica, as well as alpine glaciers, discharge primarily though streaming flow, so the dynamics of that flow is central to the overall mass balance of the cyrosphere. In glaciers and ice streams, the rheological conditions at the bed are of course important, but so also is the strength of the lateral margins, which in many locations support >75% of the resisting stress. From experimental deformation studies, numerical models, and observations of surface velocities, we can bracket the rheological parameters affecting lateral margin strength, but the uncertainty is extremely high. Variations in the intensity and orientation of the crystallographic fabric can result in up to a ten-fold difference in flow strength. Ice is also highly thermally sensitive. Yet in-situ observational studies of the thermal and rheological structure of streaming flow margins number in the low single digits. Most microstructural and in-situ rheological studies come from ice divides, near sites of paleoclimate coring. We propose a plan to measure the temperature and microstructural parameters in a profile across a lateral strain gradient on Jarvis Glacier, in the eastern Alaska Range. More specifically, we will determine whether a correlation exists among microstructure, strain, temperature, and the constitutive laws necessary to numerically reproduce the observed kinematics. This will be the first study of which we are aware to document both temperature and microstructure and relate those to the modeled and observed 3D strain state and surface velocity. Expected outcomes include (1) testing numerical models of microstructure development against a natural system, (2) testing 3D numerical models of the velocity structure, using various forms of the constitutive laws, against the observed 3D velocity structure, and (3) identifying the operative deformation mechanisms in a polythermal glacier. Although the field effort focuses on a polythermal glacier, many rheological interpretations will scale to continental ice streams and other glacier types.

For this proposed project to identify the relationship between microstructure and strain in a natural lateral shear setting, we must select a glacier with the following characteristics: (a) a well characterized 3D geometry, (b) sufficiently shallow to obtain multiple surface-to-bed cores in a single field season, (c) wet-based so that much of the resisting force is carried by the lateral margins, and (d) with achievable logistics to maintain sufficiently low sample temperatures and prevent annealing. Based on our preliminary data, Jarvis Glacier meets those criteria.

Broader Impacts. The main focus of the project has direct societal relevance in that the results will contribute immediately to climatic predictions. In addition to the main scientific focus, we will collect snow pit samples that will add to our understanding of atmospheric circulation patterns and use numerical modeling to complement efforts elsewhere in Alaska predicting the geomorphic and geodynamic effects of glacial erosion. We will continue our long history of involving undergraduates in cutting-edge research and will use many aspects of the data and models in undergraduate courses. This project provides an opportunity to improve U.S. standing in this field. Currently, the majority of glacial rheological and microstructural work occurs in Europe and the western Pacific countries; the U.S. has few active research projects in this field. The project will strengthen collaboration between universities and federal institutions and contribute to training the next generation of geoscientists.

Project Title: Coupled Model Biases in the SST Distribution of the Global Tropics and Their Influence on Climate Change Projections
National Science Foundation
$738,757 (YR1, YR2, YR3)
PI: Bradfield Lyon

Overview: Spatial variations in tropical sea surface temperatures (SSTs) play a central role in shaping regional climate patterns across substantial areas of the globe. Many coupled climate model simulations (and projections), however, generate SST fields that are considerably more zonally symmetric than observations, suggesting the models are more sensitive to thermodynamic forcing than ocean dynamics. A fundamental question, having substantial implications for future climate change, is to what extent ocean dynamics will offset, or otherwise alter, the thermodynamic influence of increased anthropogenic forcing in determining projected changes in regional climate. The climate models contained in the Coupled Model Intercomparison Project Phase 5 (CMIP5), while showing some improvements over earlier versions, still struggle to capture important aspects of the tropical SST distribution, confounding attempts to use them to answer this question directly. The proposed study first identifies systematic biases in CMIP5 simulations of tropical SSTs and assesses their impact on regional climates around the globe. Similarities between CMIP5 projected changes in regional climate and the responses to simulated SST errors will then be evaluated using two atmospheric models. Finally, the atmosphere model component of a state-of-the-art CMIP5 model will be coupled to an ocean mixed layer model and used to generate a set of climate change projections. In addition to using increasing greenhouse gas (GHG) concentrations, varying heat flux adjustments will be used in this hybrid coupled model configuration to mimic changes in the strength of ocean dynamics and their influence on zonal asymmetries in tropical SSTs. ***The overall goal of the project is to evaluate the influence of coupled model tropical SST biases on regional climate and climate change projections around the globe.*** The approach will utilize observationally based data sets as well as climate model output in the analysis. The main objectives of the study are to:

1. Utilize archived CMIP5 coupled, and atmosphere model (AMIP), runs and two atmosphere general circulation models (AGCMs) to systematically examine regional and global climate responses to identified biases in tropical SSTs in CMIP5 simulations.
2. Compare the results of objective 1 with runs of the two AGCMs forced with CMIP5 projected SSTs, examining the extent to which regional climate responses to SST biases in simulations become amplified when using projected SSTs.
3. Couple the atmosphere model component (CAM5) of the Community Earth System Model (CESM1) to an ocean mixed layer model (OML). Use varying heat flux adjustments to mimic changes in the strength of ocean dynamics on SST and include increasing GHGs to generate climate projections. Compare with objective 2 results.

Project Title: Enhancing Seasonal Drought Prediction Capabilities for the US and the Globe Using the NMME
US Dept. of Commerce
$21,707
PI: Bradfield Lyon

This grant will support a project initiated by the PI while at Columbia University. In the current performance period the work will focus on two activities. The first activity will be to oversee the development of web-based tools for the analysis and prediction of drought in the US and the globe. The second work activity will be to examine the behavior of the NMME during the three strong El Nino events of 1982-83, 1997-98 and 2015-16. The results from this latter effort will be reported in a manuscript to be submitted to a peer-reviewed journal.

Project Title: <u>An Unprecedented 3500 years of European History and Environmental Change Arcadia Reference AC3450</u>
Arcadia Fund
$249,250 (YR1, YR2, YR3)
PI: Paul Mayewski

Overview: The Black Death (1346-53), the outbreak of a pandemic now conclusively identified as Yersinia pestis, killed 40-60% of the population of Europe, representing the greatest per capita mortality crisis in the history of western Eurasia. On the basis of two and a half years work with support from Arcadia, we present the first unambiguous and drastic environmental impact of that plague in the form of a new ice core record of atmospheric Pb pollution deposited at Colle Gnifetti, Switzerland (hereafter "CG"; 4450m.a.s.l.). We show (fig. 1) that atmospheric levels of Pb deposition stemming from European silver and lead mining and smelting dropped in 1348 to levels unparalleled in the new 3500-year record of high-altitude atmospheric pollution. This delivers the first accurate glimpse of how low atmospheric lead pollution must have been prior to the introduction of metallurgy, of how high such pollution levels have in fact been for the last 3500 years, and shows that the pandemic mortality must have brought western European metal production to a near total halt, providing a new measure of the economic impact of pandemic disease at the dawn of the modern era and of the deep history of heavy metal pollution in the atmosphere of western Eurasia. This example gives a small sample of what we have already discovered with Arcadia's support and will be publishing soon, even as it indicates the extraordinary potential that remains to be developed. We respectfully request the extension of the present award to allow the exceptional team that has pioneered these new methods, new questions, new data, and new results to remain together in order to pursue the unexpectedly massive, unexpectedly high quality, and unexpectedly ancient data we have discovered in the first period of Arcadia support. This project will, through case studies such as this, define the new paradigm in integrated historical, scientific and archaeological investigation of ancient environments and economies.

Our team has recovered and is now deep into the measurement, analysis,and interpretation of the endangered natural archive captured in that European glacier. This archive offers a robust source for understanding the intersection of environment (climate) and culture (history of the economy, political stability, pollution, disease) with significant lessons for predicting future climate change and human response. The powerful new cutting-edge apparatus, high quality of the ice retrieved, and technical excellence of the team members have resulted in an unprecedented quantity and quality of data, allowing us to target climate signals not previously seen in past records, using the most careful and searching analysis. It is possible that we might already have recovered more data in this project than any other ice core including those from the polar regions that are more than tenfold deeper. The SoHP-CCI team will complete all benchmark measurements, publications, and data availability goals outlined for the present Year 3 of the project.

But our success at recovering data has outstripped our most optimistic expectations: the second millennium of our era (1000-2000 A.D.) is fully covered by the core, as expected, despite previous attempts (at the same site) that were only able to identify records extending back in time 200-400 years.We had hoped that the first millennium(1-1000 A.D.) would be covered as well. Those hopes have been met and exceeded: we are wrestling with data, for instance on ancient and medieval metal pollution that surpass anything anyone has ever seen by its volume, its precision, and its quality (see Fig. 2).

We would not have dared to believe that we would recover signals reaching into the Bronze Age (ca. 3200-600 B.C. in Europe) but we now have a preliminary record of laser sampled Calcium signals that take us approximately to 1500 B.C., and we may be able to extend this back in time several hundred more years. The quality is very good for all of this segment of the ice core. We have moreover discovered tephra—microscopic volcanic particles in the core—where specialists outside of our team were sure they could not be found. This may hold special promise for absolute dating of segments of the core and for directly comparing the climate impacts of volcanic activity to written records, since the chemistry of the tephra can be attributed to specific volcanoes, and even to specific eruptions of a particular volcano, using technology available within our team.

In sum, we have been successful beyond our wildest dreams. We have developed an extraordinary team with expertise unique on the globe in the instrument, in this glacier, in the historical and archaeological records and in the challenges of analyzing massive quantities of new data that were not even within reach prior to our new technology and our interdisciplinary team of humanists and scientists. Our preliminary findings have already attracted the attention of academic and popular publications, and have highlighted the generous support of the Arcadia Fund in our ongoing efforts to study the history of climate change and human response to it.

We request an extension of this project for three years in order to keep this team together and at work: we are certain that what we have found, what we have already produced, and what we can yet produce will constitute a landmark in the integrated discovery, analysis, and open access of new scientific data on the ancient environment, economy, and civilizations of Europe. What is more, the collaboration that has emerged through our combined glaciological–climatological–historical–archaeological team of post-doctoral fellows, senior scientists and student sets a new standard in these fields, opens new avenues of understanding and is preparing a new generation of researchers whose success seems guaranteed, judging by recent appointments.

Project Title: Collaborative Research: ABI Development: Creating a generic workflow for scaling up the production of species ranges
National Science Foundation
$89,963
PI: Brian McGill

A species geographic region n is a fundamental unit of analysis in ecology and evolution. Species ranges are increasingly playing a vital role in conservation, both singly (e.g. IUCN criteria for listing a species includes range size) and in ensemble (e.g. species richness across space is often analyzed by overlaying geographic ranges). On recent application is the identification of biodiversity hotspots (regions with disproportionately high specie richness and high endemism). Ensemble sets of species ranges covering a majority of the 60,000 vertebrate species are available from websites such as NatureServe and IUCN. However ensemble sets of species ranges from the other 95+% of species on the planet are rarely available. Isolated collections such as trees and shrubs of North America (600 species) or palms of the Amazon (1000 species) are available but systematic collections spanning plants and invertebrates are not available. The time is ripe to change this. Electronic biological inventories like GBIF mean that adequate observational data is available, but computational effort is needed.

We propose to develop and make freely available a generic pipeline capable of going from biodiversity occurrence data to species ranges. Perform such work on for one or a few species is now trivial (indeed a few lines of code in R package dismo). However scaling these computations to 1000s or 100,000s of species remains prohibitive. A lack of appropriate tools and a failure to combine tools into an integrated pipeline prevent such scaling. Key challenges include: 1) Appropriately scrubbing data, 2) identifying clear best practice methods for range modelling applicable across diverse species, 3) innovating range modelling methods that integrate diverse data such as presence only museum collections and abundance-based plot data 4) scaling computationally-intensive range modelling in an HPC environment, and 5) integrating with phylogenies.

We propose to develop such a pipeline using the previous work on the BIEN project which has assembled a database of 20,000,000 observations 100,000+ species of plants and the new world. The BIEN project provides a pre-existing user community spanning museum directors, plot ecologists, and biodiversity scientists. The BIEN project also contains enough data to demonstrate scalability.

We will also produce paleo and projected future species ranges using GCM models of climates at different times. Intellectual merit: Biologically, we will enable the production of species ranges of plants and invertebrates that will allow study of even such basic questions as how herbaceous and invertebrate species richness varies across space (a topic studied almost exclusively in vertebrates and trees). We will also

examine whether biodiversity hotspots are constant through time (an important question for conservation not substantially addressed to date).

Computationally, we will take core questions about data scrubbing, niche modelling practices, novel niche modelling methods, and mega-phylogeny analysis methods. Broader impacts: Four major broader impacts will emerge: 1) the production of a pipeline usable by any group of scientists interested in scalable generation of species ranges across an ensemble of species; 2) the production of species ranges for all plant species (bryophytes to angiosperms) in the New World; 3) The production of paleo ranges (using paleoclimate data) and future species ranges (using climate models) for 100,000+ plant species. 4) The tying together of plant species ranges with a phylogeny allowing for questions of phylogenetic diversity and niche conservatism. These will all be shared via internet.

Project Title: Evaluating and Predicting Vulnerability for Water Quality Decline in Maine Lakes
US Environmental Protection Agency
$12,304
PI: Steve Norton

Impairments to Maine lakes (algal blooms and loss of deep-water oxygen) are caused by excessive concentrations of the nutrient phosphorus (P). In most Maine lakes, the amount of algae is proportional to the concentration of P in the lake. A naturally occurring element in the earth's crust, P is ubiquitous. In undisturbed lake watersheds, very little P is exported from the land to the lake. In contrast, storm-water flowing off developed watersheds is often 'enriched' with P that is transported from eroding sites to lakes. This project will conduct a focused study on approximately 15 Maine lakes to fill gaps in the dataset currently being analyzed to create a lake Vulnerability Index. A graduate student will be funded to conduct the gap analysis, begin model development and collect additional samples from approximately 15 lakes in Maine with the assistance of volunteers in the VLMP. The student will combine these results with the current dataset (150 lakes) and analyze these data along with physical attributes such as geographic location, bedrock, soil characteristics, land-use measures, morphometry, and temperature to produce a draft lake Vulnerability Index. This Index will then be tested against a similar dataset compiled for 50 previously sampled DEP lakes.

Project Title: Determining bird and invertebrate food-web connections and use of rockweed in light of commercial harvesting
ME Dept. of Inland Fisheries & Wildlife
$17,883
PI: Brian Olsen
Project Coordinator: Dr. Amanda J. Klemmer

Overview: This project will provide critical information on the structure of rockweed food webs in the context of commercial rockweed harvesting. These data are needed by IFW, Maine Department of Marine Resources (DMR), and the US Fish and Wildlife Service (USFWS) for the management of natural resources. Currently, there is little information on how rockweed is used by animals along the Maine coast. Such information is critical for understanding the effects of rockweed harvest on hunted stocks, such as Common Eider, or species of conservation concern, such as Purple Sandpipers or the state threatened Harlequin Duck. Rockweed supports a vibrant commercial harvest, but the evolving state-wide rockweed fishery management plan may put limits on harvest due to concern for vertebrate use of the resource without the information necessary to make informed management decisions. Information is urgently needed both to protect high value habitats for bird species and to prevent undue restrictions on a growing commercial interest.

Project Title: Sensing storm surge: A citizen science approach to measuring storm surge-estuarine interaction in three Maine communities
National Science Foundation
$99,994
PI: Laura Rickard

Overview
Facing escalating costs to infrastructure and the local economy, U.S. coastal communities are increasingly exploring protection measures to reduce storm surge risk. To date, researchers have relied on models to represent idealized scenarios of storm surge behavior; however, without observations to capture how storm surge behaves inside an estuary, actual effects remain a mystery. To explore this question, this project pursues three interconnected objectives: (1) to develop an improved understanding of storm surge behavior in three Maine estuaries with varying physical properties; (2) to use a quasi-experimental design to engage local residents in data gathering, involving varying training; and (3) to evaluate the citizen science component by establishing the reliability of the physical data and by measuring citizen scientists' engagement in climate change-related issues. The first objective will be achieved by deploying a network of pressure sensors maintained by local citizen scientists. Statistical analyses will quantify storm surge amplitude and phase propagation properties as it interacts with varying channel geometries, geomorphology, river discharge, and estuary alignments. To achieve the second objective, individuals will be assigned to one of four groups that vary by contributory or co-created approach to citizen science -- specifically, whether in-person training is provided, and whether a co-designed, dialogue-based activity occurs. The third objective will be achieved in two parts, by first evaluating the outcomes of citizen science participation, and second, by assessing the reliability of physical data. A pre- and post- project survey, in addition to in-depth interviews, will evaluate cognitive, affective, and behavioral indicators of engagement. Data reliability will be quantified using cross correlation between citizen science data and duplicate station data maintained by an expert scientist. Between-group comparisons will allow for testing of whether differences in citizen science approaches are associated with data accuracy.

Intellectual Merit
Generally, storm surge has been shown to amplify over a mildly sloping continental shelf, attenuate over long stretches of wetlands, and amplify in funnel (converging) shaped estuaries; however, relying on model-based scenarios has left the specific influence of channel geometry, geographic orientation, and geomorphologic interaction unknown. Indeed, understanding where storm surge accelerates or amplifies is critical to designing climate change adaptation measures to reduce damage to waterfront infrastructure. Since an expansive network of pressure sensors would be time intensive for a scientist to maintain, a citizen science approach presents an opportunity for an increased data footprint. Following questions of reliability, however, data collected by citizens has come under recent scrutiny. In answer, emerging studies have suggested that aspects of the citizen science approach - including the provision of information and in-person training - can boost data reliability. We seek to understand if adjusting the co-created nature of the experience - such as through a guided dialogue activity -influences cognitive, affective, and behavioral outcomes, such as citizens' likelihood to engage in climate change-related discussion. This experiment is novel and unique, in that no known citizen science study has involved collecting storm surge data.

Broader Impacts
The proposed research will empower citizen scientists to remain an integral voice in the discussion of climate change adaptation in their communities. The project also supports participation of underrepresented groups in STEM fields, achieved by including a network of Maine high school students in the training of citizen scientists. Additionally, the research will provide the local communities adjacent to each of the three study areas with a map of storm surge intensity in their region. Understanding climate change and storm surge impacts are a current priority for many towns and management agencies in coastal Maine, as well as for federal agencies with local interests, such as the National Park Service.

Project Title: EPA IAG for Clean Air Act trends research, 2017-2018 (Determining the effectiveness of the Clean Air Act and Amendments on the recovery of surface water
US Environmental Protection Agency
$80,918
PI: J. Saros & S. Nelson

Project Objectives: This research is part of EPA CAMD programs that are verifying the effectiveness of emission controls at reducing acidification of surface waters. Our approach is to collect long-term high-quality data that characterize the trends and patterns of response in low ionic-strength surface waters that are classified as sensitive to acidic deposition and a sample of lakes across the Northeast in varying landscape settings.

Overall Scope of work and timelines for FY 2017 and 2018: The EPA has an interagency agreement with the USGS. The University of New Hampshire and the University of Maine have an agreement with the USGS (Agreement # G14AP00132) under that interagency agreement to determine the effectiveness of the Clean Air Act and Amendments on the recovery of surface waters in the northeastern US. The third year of this project will begin on July 1, 2016 and encompasses the majority of the 2016 field season. Sample collection and analysis for TIME, LTM and BBWM sites in 2016 will proceed as it has in previous years. In 2016, a limited set of HELM lakes will be sampled with participation by J. Daly. TIME, BBWM and HELM sampling will not occur in 2017 unless additional funds are provided. Only the first round of spring sampling of LTM lakes will occur in 2017. The 2016 data QA and reporting will occur as it has in previous years, but the data from the one round of LTM sampling collected in 2017 will only be available in raw form after laboratory analyses are conducted.

Scope of work for Sarah Nelson, University of Maine:
This subcontract covers activities that are relevant to detecting chemical and biological recovery of aquatic systems in the northeast following controls on acid deposition following passage of the Clean Air Act Amendments (CAAA). The main activity is to continue on-going long-term water chemistry trends monitoring designed to detect (a) the response of northeast lakes to the CAAA and (b) chemical responses to the long-term acidification experiment at Bear Brook Watershed in Maine. We will provide logistics and organizational support, field sampling assistance for sample collection, laboratory analyses for East Bear Brook, data management, quality assurance reports, and collaborate in data analysis, interpretation, and publication. Nelson will also work with partners at EPA and UNH to streamline data reporting and discuss potential sample site or frequency changes. Nelson will work with the project team in preparing final reports, databases, and peer-reviewed publications as the result of these activities. Nelson will supervise an MS student working toward publishing project data.

Project Title: State Surveillance of Opioid Morbidity and Mortality
US Dept. of Health & Human Services
$91,179
PI: Marcella Sorg

The University of Maine, Margaret Chase Smith Policy Center, is named as a contractor for a project proposal to be submitted by the Maine DHHS/Center for Disease Control, in response to an FOA released by the U.S. Centers for Disease Control, National Center for Injury Prevention and Control, CDC-RFA-CE16-1608: "Enhanced State Surveillance of Opioid-Involved Morbidity and Mortality."

The Maine Office of Attorney General would contract with the Margaret Chase Smith Policy Center for a co-PI and Project Director for a project to enhance state and federal surveillance of unintentional fatal and nonfatal opioid overdoses, in close partnership with the Maine CDC and the Office of Chief Medical Examiner (OCME). The project would be funded by the U.S. Centers for Disease Control, National Center for Injury Prevention and Control, in the form of a cooperative agreement with the Maine Department of Health and Human Services.

Marcella H. Sorg, Research Professor, rank effective September 1, 2016, Margaret Chase Smith Policy Center, would be the PI of this contract at the University; she is named in the State's proposal as the co-PI of the State's project. Jamie A. Wren, Research Associate, Margaret Chase Smith Policy Center is named as co-PI/PD of the contract at the University; he is named as the PD of the State project. Sorg and Wren will lead the implementation of enhanced surveillance-related data collection, analysis, and results dissemination related to fatal and nonfatal opioid overdoses, in collaboration with PI Sara Robinson at the Maine CDC.

The system will utilize the already-existing infrastructure of the National Violent Death Reporting System at the U.S. CDC, of which Maine is a funded, participating state, and which Sorg and Wren also administer via contract with the Maine Attorney General. The new project would collect data about opioid-involved deaths and non-fatal overdoses in an effort to enhance understanding of these events and help design methods to prevent them. Data sources will include a Mortality Component and a Morbidity Component: (1) medical examiner records of fatal opioid overdoses and (2) de-identified EMS records combined with hospital emergency room discharge records. The project will take place primarily at the Maine Center for Disease Control and the Maine Office of Chief Medical Examiner (part of the Maine Office of Attorney General).

While the fiscal agent for the federal grant would be the Maine DHHS/Maine CDC, the project will be a joint endeavor between Maine CDC and Maine OCME, partnering with the University of Maine. The PI of the federal grant at the Maine CDC is Sara Robinson. Kirsten L.C. Figueroa (Kirsten.figueroa@maine.gov), Administrative Services Division Chief at the Maine Office of Attorney General, 207-626-8593, 6 State House Station, 109 Sewall St., Augusta ME 04333-0006 will be the fiscal point of contact for the University contract.

Project Title: New Hampshire Fentanyl Hot Spot Expansion Study
US Dept. of Health & Human Services
$49,996
PI: Marcella Sorg

ABSTRACT: As a result of our initial fentanyl mortality data analysis of New Hampshire medical examiner data, several data gaps were identified and recommendations were made to bridge them. This proposal addresses those recommendations, focusing on outcomes that can be accomplished by December, 2016.

During the period September 1, 2016 through December 31, 2016, the University of Maine, Margaret Chase Smith Policy Center, will conduct a brief, expanded analysis of decedent toxicology focused on overdoses associated with fentanyl and fentanyl analogs in New Hampshire during the period January 1, 2015 through September 30, 2016. University of Maine staff will work collaboratively with staff at the New Hampshire Office of Chief Medical Examiner to send biological samples to AFMES for laboratory testing, to analyze the results and to conduct an examination of medical examiner files on the identified decedents.

Goal 1: Expand testing of postmortem biological specimens from OCME.

Problem and Need: Due to budget limitations associated with the Office of Chief Medical Examiner, toxicology testing has been limited to a relatively comprehensive panel of drugs. Specifically, a minority of cases have been tested by the State Laboratory for illicit drugs only, and the majority of cases have been tested by National Medical Labs for their "expanded panel," which screens for acetyl fentanyl and some additional analogs (has changed over time). Further testing of retained urine specimens, available for autopsied cases, would potentially reveal a more comprehensive picture of all of the illicitly produced fentanyl products and associated other psychoactive, "designer," and synthetic drugs amongst the autopsied cases.

Objective 1A: Work collaboratively with the New Hampshire Office of Chief Medical Examiner to send specimens of all recently retained urine samples from suspected overdoses (January, 2015 to September 30, 2016) to AFMES for comprehensive toxicology testing (screening, with quantification if available), maintaining routine chain of custody protocols. This would involve approximately 160 samples.

Objective 1B: Analyze postmortem toxicology results, including:

(a) Frequency distribution by substance and by substance combinations with key co-intoxicants (e.g., heroin, synthetic opioids)
(b) Analysis of patterns associated with age category, sex, race, and county
(c) Frequency distribution by quarters (2015 (1Q, 2Q, 3Q, 4Q) and 2016 (1Q, 2Q, 3Q)
(d) Assessment of value of expanded testing compared to testing done previously for the OCME. How does testing expansion improve the following:
    - Cause and manner of death determination
    - Understanding drug trafficking patterns

Objective 1C: Produce a report of the analysis by December 31, 2016

Goal 2. Expand the understanding of fentanyl/fentanyl analog-associated deaths, including decedents' medical history, social circumstances, and the associated cause and manner of death.

Problem and Need: Although medical records are collected on most autopsy cases, these are used by the OCME only to determine cause and manner of death, as required by State statute, but not for more expanded epidemiological purposes. Staffing and time limitations prohibit the OCME from an expanded effort.

Objective 2A: Work collaboratively with the OCME to collect epidemiological data on 160 autopsied cases of suspected overdoses, targeting fentanyl-involved deaths, including those for which urine specimens were available, as well as an age and sex-matched sample of non-autopsied fentanyl deaths in 2016. Data sources will include autopsy records, death investigation documentation, and medical records when available.

Objective 2B: Produce by December 31, 2016, a descriptive analysis of fentanyl and fentanyl analog-involved deaths, including pre-existing diagnoses and medical interventions, social circumstances, demographic characteristics, and the associated cause and manner of death.

Project Title: NERACOOS 2016 2021 Buoys CODAR Glider Nutrients Satellite Surveys
US Dept. of Commerce
$792,011
PI: Aaron Thomas

The Physical Oceanography Group at the University of Maine, directed by Neal R Pettigrew, has designed, fabricated, and operated the University of Maine Ocean Observing System (UMOOS) in the Gulf of Maine (G0M) since 2001. In 2009 UMOOS joined the Northeast R egion Associate of Coastal Observing Systems (NERACOOS). This proposal is for the next five years of this program.

Observing subsystem Data Buoy Array– NERACOOS has operated a regional observing system by building on assets and experience based on earlier programs. Multipurpose UMOOS data buoys in the GoM, measuring surface and subsurface properties, form the system's backbone. These are cost-effective platforms (less than half the operational cost of a 24/7 glider line) capable of carrying large sensor payloads and able to resolve temporal scales of variability. The return on investment for moorings is arguably higher than any other platform and their information is used by all ocean use sectors from harbor pilots to ecosystem scientists and managers.

In the GoM, seven UMOOS moorings are currently deployed (Pettigrew et al., 2010). They support the meteorological sensors carried by standard National Data Buoy Center (NDBC) buoys and additional sensors for atmospheric visibility, surface currents, water-column current profiles, temperature and conductvity, fluorescence (for "chlorophyll a" estimation), and several optical sensors include dissolved oxygen. Additional separately funded sensors, such as fish tracking devices (NMFS) and bat sensors (Stantec) have been added to most buoys. Two deep water buoys are located in the Northeast Channel and Jordan Basin and five coastal buoys are widely spaced down the Maine and Massachusetts coasts. The mooring within Massachusetts Bay, supported with contributions from MWRA, addresses water quality concerns in the densely populated region of the GoM around Boston, MA includes additional sensors including dissolved oxygen. In addition, the USGS has recently begun funding the addition of near-bottom instrument packages on four coastal GoM buoys for understanding near bottom sediment resuspension.

PhOG will handle all data processing, QA/QC, archival, and metadata in a manner consistent with IOOS-DMAC requirements, and posts the data and metadata on the web. Data will be updated from the buoys twice per hour in order to provide the most recent data. PhOG will continue to send the real-time data to NOAA/NDBC for all UMOOS buoys.

Surface currents from HFR– UMaine will continue operation and maintenance of High Frequency RADAR (CODAR) sites at Grand Manan, NB, Cape St. Mary, NS, and Greens Island, ME. A fourth HFR site will be tested at Schoodic Point, ME. If the Schoodic Point location improved coverage and accuracy the Cape St. Mary system will be moved to the new location. The operations include site inspection , routine servicing, trouble shooting, antenna pattern surveys, QA/QC data processing, posting the results on the web (http://gyre.umeoce.maine.edu), passing data on to the national HFR network, and analyzing of the surface currents. As part of the national surface current measurement program, UMOOS operates a HFR network at three locations in the eastern GoM. These data are shared openly and available to the environmental data server used by the US Coast Guard (USCG) search and rescue program.

Glider Seasonal Spatial Surveys –While the broad utility and high value of ocean observing data buoys is very clear, their worth is greatly magnified with spatial surveys between the buoy locations. Although oceanographic ships can measure both surface and subsurface spatial gradients, they are quite costly. In contrast, autonomous glider surveys can provide a spatial context for subsurface temporal buoy data for a small fraction of ship costs. The glider cruises leverage the IOOS investment in the GoM buoy array and provide significant variations in three directional spatial scales that are small relative to the distance between the data buoys. The gliders will measure and report temperature, salinity, dissolved oxygen and will carry optical sensors measuring chlorophyll and turbidity. Surface currents and depth-averaged ocean currents will be calculated using glider positioning and internal diagnostics. The glider spatial surveys will provide a valuable complement to the buoy time series, elucidating the seasonal and inter annual spatial structure of the Eastern and Western GoM coastal currents (EMCC and WMCC), and the Jordan Basin gyre.

Satellite Remote Sensing – High-resolution (1km) satellite data provides the only complete coverage of the entire NERACOOS region for any ocean variable, is an operational, ongoing, consistently processed, unbroken time series extending back over 30 and 17 years (for SST and color respectively). UMaine) will continue this time-series providing daily, 8-day and monthly SST and ocean color images, as well as derived anomaly products. Customized products and new products derived from the daily data will be created upon request for specific user groups and using field data as ground-truth from other NERACOOS groups.

Nutrient sensors on the buoy array–The Integrate Nutrient Observatory project, SUNA nitrate sensors will be deployed and maintained on four of the UMOOS moorings (E & I [at 50m], N & M [3-6 depths]). Nutrient measurement at these offshore buoys are critical to understanding already documented inter annual and longer-term variability in nutrient fluxes to the GoM and its coastal waters, and the effects on plankton production. Autonomous measurements of phytoplankton biomass and community structure with multichannel fluorometers on GoM moorings (A, B, E, I, N) by provided by Bowdoin College will provide

direct observations of the changing phenology of the base of the oceanic food web in response to hydrographic and nutrient variability.

Ship surveys–Discrete water samples for both nutrient and phytoplankton community structure will help validate the autonomous measurements and provide essential data for sentinel ecosystem monitoring. In addition to the above autonomous observations a ship based effort will directly support ISMN goals through additional biological observations that are currently hard or not possible with autonomous platforms. Plankton and other water column properties will be collected monthly at the Wilkinson Basin Time Series Station (WBTS) by UMaine.

Project Title: Multi- and hyperspectral bio-optical identification and tracking of Gulf of Maine water masses and harmful algal bloom habitat
National Aeronautics & Space Administration
$266,383
PI: Andrew Thomas, Professor, School of Marine Sciences, University of Maine, Orono,
CO-PIs: William Balch, Bigelow Laboratory for Ocean Sciences,
Tora Johnson, GIS Service Center & Laboratory, University of Maine, Machias
Alison Sirois, Maine Department of Marine Resources
David Townsend, School of Marine Sciences, University of Maine
Huijie Xue, School of Maine Sciences, University of Maine

Project Summary
Each summer, extensive areas of Maine coastline are closed to shellfish harvesting due to Alexandrium, a toxic dinoflagellate, costing millions of dollars in lost commercial revenue and monitoring efforts. Unlike the harmful algal blooms of other coastal waters, Alexandrium is dangerous even as just a minor part of the phytoplankton community, at concentrations too low to be detectable with current remote sensing technology. However, extensive previous research has shown that these organisms are widespread, have strong spatial and temporal patchiness, are associated with specific temperature and nutrient regimes, and are transported by local physical processes. The waters of the Gulf of Maine, especially those close to shore, are optically complex due to varying amounts, sources and characteristics of colored dissolved matter, suspended sediment, and varying concentrations and diversity of phytoplankton. A systematic investigation of the capability of multispectral satellite data to isolate and monitor the oceanic habitat of Alexandrium has not been carried out. In this proposal, we use NASA multispectral and SST data and new hyperspectral field data to bio-optically classify different Gulf of Maine surface water masses, identify those water masses that are preferred Alexandrium habitat, track these water masses and map their interaction with, and impact on, coastal shellfish harvesting sites. We bring a multi-institution and multi-disciplinary team to address this problem.

The global ocean color community is poised to transition to the next generation of space-borne ocean color data from hyperspectral optical sensors. NASA's focus in this effort is the PACE mission, expected to launch in the next 5-6 years. Maine's ocean scientists and environmental resource managers need to transition to this level of data complexity to remain competitive and fully reap the benefits of these data for Maine applications and priorities. This proposal builds both instrument and intellectual infrastructure with hyperspectral data, while addressing a Maine technology priority and interfacing with a critical marine resource sector.

Our overarching goal is to use NASA's satellite-based measurements of coastal ocean bio-optical and hydrographic characteristics to define, isolate and track those water masses most closely associated with Alexandrium and coastal shellfish toxicity. The research involves a combined retrospective and real-time analysis of existing field observations and multispectral satellite data and 3 years of new fieldwork that leverages an existing, separately funded project, and introduces a project-purchased hyperspectral instrument. This instrument will be deployed on a ship and will emulate PACE, allowing unprecedented spectral resolution of Gulf of Maine surface waters to better discriminate optical water types. Both efforts are supported by numerical modeling of circulation to view inter annual and spatial variability in flow

trajectories and the forcing that drives 2 these, and GIS modeling to map and model the interaction between these parcels and DMR sampling sites, coastal shellfish beds and both state and municipal stakeholders.

The project leverages existing infrastructure, data sets and research projects in Maine and Canada, while impacting Maine scientific personnel across many stages of career. The proposal transitions a group of established ocean scientists to a new technology necessary for future NASA ocean color research. The proposal entrains a young scientist who has not had prior NASA funding and a Post Doc. We request funding for two graduate students whose research will straddle satellite data analysis directly applicable to NASA and coastal applications directly applicable to Maine resource management. Lastly, we build in undergraduate research opportunities for 12 students at two Maine campuses using satellite data and GIS as STEM teaching tools.

CONTINUING GRANT AWARDS – FY2017

Project Title: USDA Climate Hub – UMaine Coooperative Agreement
US Dept. of Agriculture
$23,000
PI: Sean Birkel

Project Title: Glaciological and Mass Balance Modeling of Walker Basin, Nevada
U.S. Department of Interior
$21,066
PI: Sean Birkel

Project Title: Collaborative Research: A Test of the Orbital Theory of Ice Ages
National Science Foundation
$21,450 (YR1, YR2, YR3)
PI: Sean Birkel

Project Title: Collaborative Research: GreenTrACS: A Greenland Traverse for Accumulation and Climate Studies
National Science Foundation
$169,567 (YR1, YR2, YR3)
PI: Sean Birkel

Project Title: REU Supplement for NSF Grant 1443321
National Science Foundation
$5,789
PI: Gordon Bromley

Project Title: Coll. Res.: Potential Direct Geologic Constraints on Ice Sheet Thickness
National Science Foundation
$291,563
PI: Gordon Bromley

Project Title: Impacts of Population Growth on the San Francisco Bay and Delta Ecosystem
National Aeronautics & Space Administration
$142,200
PI: Fei Chai

Project Title: Quesada Fund: Furthering Gary Comer's Work
Quesada Fund
$250,000 (Multiple Years)
PI: George Denton

Project Title: The Last Glacial Termination in Southern Middle Latitudes
National Science Foundation
$393,844 (YR1, YR2, YR3)
PI: George Denton

Project Title: 2016 Mandela Washington Fellowship Institute – UMaine
International Research & Exchanges Board
$150,000
PI: Daniel Dixon

Project Title: Remote Sensing of Icebergs in Greenland's Fjords and Coastal Waters (J. Scheick NASA Fellowship)
National Aeronautics & Space Administration
$35,000
PI: Ellyn Enderlin

Project Title: Quantifying Greenland Iceberg Melt Rates
National Science Foundation
$172,086 (YR1, YR2, YR3)
PI: Ellyn Enderlin

Project Title: Intra-annual Force Balance Analysis of Tidewater Glaciers
National Aeronautics & Space Administration
$270,355 (YR1, YR2, YR3)
PI: Ellyn Enderlin

Project Title: Signature of the Last Termination in Maine
Comer Science & Education Foundation
$30,000
PI: Brenda Hall

Project Title: Collaborative Research: Exploring the Vulnerability of Southern Ocean Pinnipeds
National Science Foundation
$269,584 (YR1, YR2, YR3)
PI: Brenda Hall

Project Title: Collaborative Research: Assessing the Antarctic Contribution to Sea-level Change
National Science Foundation
$200,803 (YR1, YR2, YR3)
PI: Brenda Hall

Project Title: Lost to Sea: Maine's Ancient Coastal Heritage Yr2
US Dept. of Commerce
$74,743
PI: Alice Kelley

Project Title: Collaborative Research: Flow and Fracture Dynamics in an Ice Shelf Lateral
National Science Foundation
$357,356 (YR1, YR2, YR3)
PI: Peter Koons

Project Title: SPICE Core chronology and Climate Records Using Chemical and Microparticle Measurements
National Science Foundation
$389,306 (YR1, YR2, YR3)
PI: Karl Kreutz

Project Title: Geophysical Reconnaissance to Expand Ice Core Hydroclimate Reconstructions in the Northeast Pacific
National Science Foundation
$214,890 (YR1, YR2, YR3)
PI: Karl Kreutz

Project Title: Collaborative Research: Developing an Antarctic Tephra Database for Interdisciplinary Paleoclimate Research (AntT)
National Science Foundation
$365,095 (YR1, YR2, YR3)
PI: Andrei Kurbatov

Project Title: Tephrochronology of a South Pole Ice Core (SPICE TEPHRA)
National Science Foundation
$205,000 (YR1, YR2, YR3)
PI: Andrei Kurbatov

Project Title: Leveraging CMIP5 and NASA/GMAO Coupled Modeling Capacity for SERVIR East Africa
National Aeronautics & Space Administration
$46,441
PI: Bradfield Lyon

Project Title: Diagnostics, Trends and Climate Model Projections of U.S. Summer Heat Waves
US Dept. of Commerce
$113,998
PI: Bradfield Lyon

Project Title: Drying Versus Wetting of the East African Climate
National Science Foundation
$120,655
PI: Bradfield Lyon

Project Title: Arcadia Ice Core Proposal - Initiatives on the Science of the Human Past (Harvard University)
Arcadia Fund (Harvard University)
$358,897 (YR1, YR2, YR3)
PI: Paul Mayewski

Project Title: Coll. Res.: Ultra-High-Resolution Investigation of High Andean Snow and Ice Chemistry
National Science Foundation
$725,107
PI: Paul Mayewski

Project Title: Coll. Res.: Pleistocene/Holocene Climate Reconstruction from a Pamir High Resolution Ice Core
National Science Foundation
$590,831
PI: Paul Mayewski

Project Title: Coll. Res.: Investigating Geochemical Signatures in Greenland Ice
National Science Foundation
$33,585
PI: Paul Mayewski

Project Title: Window into the World with 40,000-year Glacial Cycles
National Science Foundation
$151,529
PI: Paul Mayewski

Project Title: Coll. Res.: Expanding a National Network for Automated Analysis of Constructed Response Assessments to Reveal Student Thinking in STEM
National Science Foundation
$38,824
PI: Brian Olsen

Project Title: Tidal Wetlands after Hurricane Sandy: Baseline Restoration Assessment and Future Conservation Planning
U.S. Department of the Interior
$291,092
PI: Brian Olsen

Project Title: Resilience of the Tidal Marsh Bird Community to Hurricane Sandy
U.S. Dept of Interior
$1,409,127 (YR1, YR2, YR3)
PI: Brian Olsen

Project Title: CAREER: The Last Glacial Termination in Interior Asia
National Science Foundation
$591,098
PI: Aaron Putnam

Project Title: The Last Glacial Termination at the Heart of Asia in the Mongolian Altai
Comer Science & Education Foundation
$83,300
PI: Aaron Putnam

Project Title: Deciphering the Ecology of Key Diatom Taxa to Understand Climate-Induced Changes in West Greenland Lakes
National Science Foundation
$353,980 (YR1, YR2, YR3)
PI: Jasmine Saros

Project Title: IGERT: Adaptation to Abrupt Climate Change
National Science Foundation
$2,929,087 (YR1, YR2, YR3, YR4, YR5)
PI: Jasmine Saros

Project Title: Jordan Pond Buoy Project
Friends of Acadia
$44,959
PI: Jasmine Saros

Project Title: Assessing the Vulnerability of Maine's Drinking Water Resources (WRRI 2016)
US Dept. of Interior
$27,277
PI: Jasmine Saros

Project Title: Maine-Vermont Violent Death Reporting System – YR2
US Dept. of Health & Human Services
$153,733
PI: Marcella Sorg

Project Title: Allan Hills Englacial Site (ACHILLES) Selection
National Science Foundation
$35,594
PI: Nicole Spaulding

Implications for Southwest Greenland from a Warming Arctic

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

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

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

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

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

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

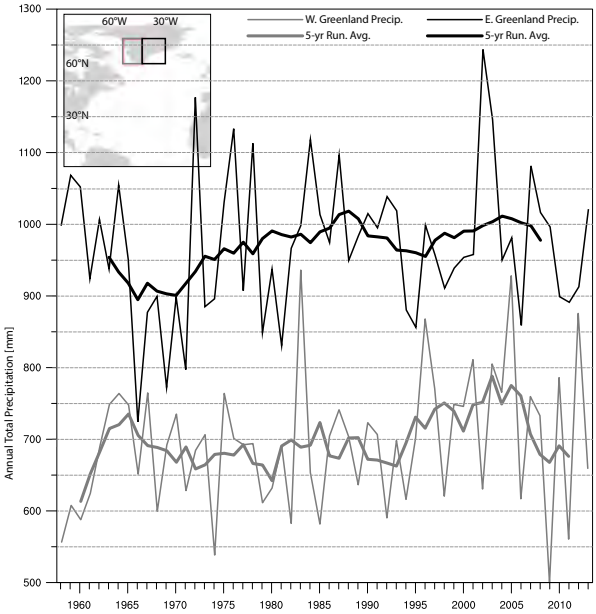

Fig. 1 Precipitation in southwest (gray) and southeast (black) Greenland from JRA-55.

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

Bibliography:

J. D. Auger, S. D. Birkel, K. A. Maasch, P. A. Mayewski, and K. C. Schuenemann, "Examination of precipitation variability in South Greenland," Journal of Geophysical Research (in review).

J. A. Francis and S. J. Vavrus, "Evidence for a wavier jet stream in response to rapid Arctic warming," Environmental Research Letters 10 (2015).

M. C. Serreze, A. P. Barrett, J. C. Stroeve, D. N. Kindig, and M. M. Holland, "The emergence of surface-based Arctic amplification," The Cryosphere 3 (2009): 11-19.

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

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

Project goals

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

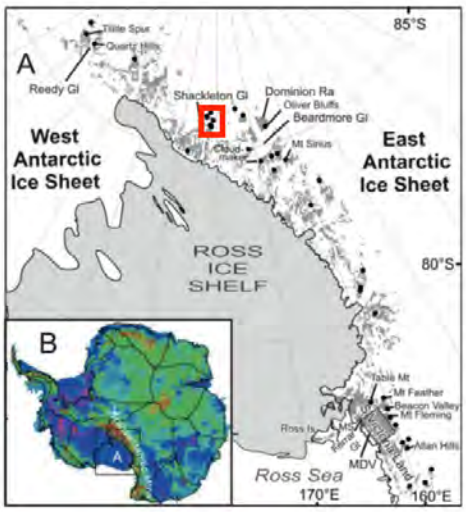

Figure 1: A) Location of Roberts Massif (red box) at the head of Shackleton Glacier. B) Map of Antarctica.

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

Methods and Preliminary Results

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

Acknowledgements

National Science Foundation grant #144332.

References

[1]Chandler, M., Rind, D., Thompson, R., 1994. "Joint investigations of the middle Pliocene climate II" Glob. Planet. Change 9, 197–219.

[2]Scherer, R.P., DeConto, R.M., Pollard, D., Alley, R.B., 2016. Windblown Pliocene diatoms and East Antarctic Ice Sheet retreat. Nat. Commun. 7, 1–9.

[3]Winnick, M.J., Caves, J.K., 2015. Oxygen isotope mass-balance constraints on Pliocene sea level and East Antarctic Ice Sheet stability. Geology 43, 879–882.

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

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

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

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

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

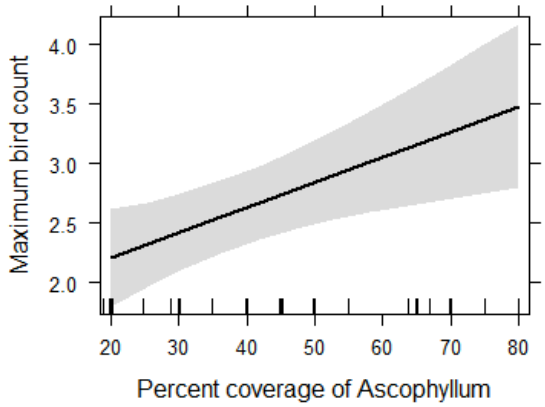

Fig. 1. Higher coverage of Ascophyllum positively affects bird abundance.

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

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

**p*-value based on interaction terms

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

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

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

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

SST and Volcanic Aerosols

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

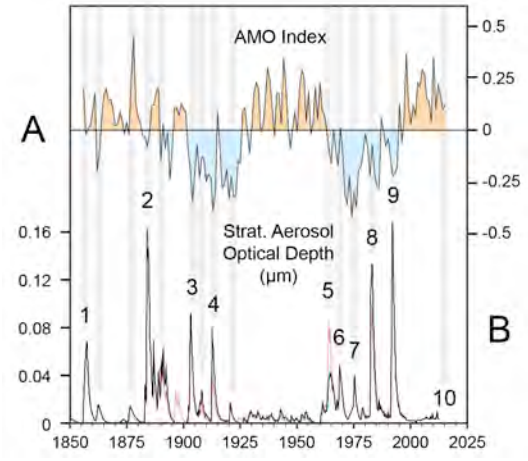

Fig. 1. (A) AMO index and (B) stratospheric aerosol optical depths (Sato et al., 1993; NASA GISS).

Atmospheric Circulation

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

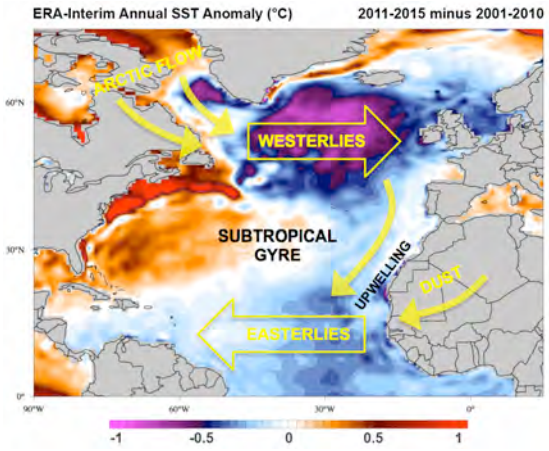

Fig. 2. Schematic relationship between atmospheric forcing and SST anomalies over the North Atlantic.

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

Bibliography: Bourassa, A.E. et al., "Largest volcanic aerosol load in the stratosphere linked to Asian monsoon transport." Science 337, 78-81.

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

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

Background:

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

Objective:

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

Methods:

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

Acknowledgements:

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

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

Bibliography:

Mette, Madelyn et al., (2015) *"Linking large-scale climate variability with Arctica islandic shell growth and geochemistry in northern Norway." ASLO,* 1-17.

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

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

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

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

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

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

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

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

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

Bibliography:

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

Hanna, E et al. *Journal of Climate* 21 (2008): 331-341.

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

Functional-Programming with Generic Mapping Tools (fGMT)

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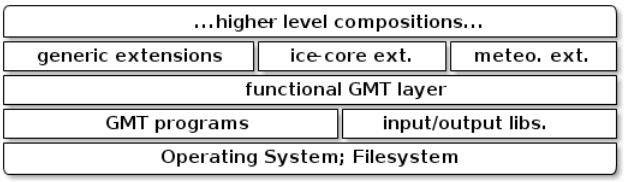
Abstract: We describe *fGMT*, a *functional-programming* interface to the very popular GMT collection of mapping and plotting tools. Our implementation uses *scsh Scheme* and is designed to permit incremental building of higher-level interfaces that incorporate domain-specific knowledge.

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

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

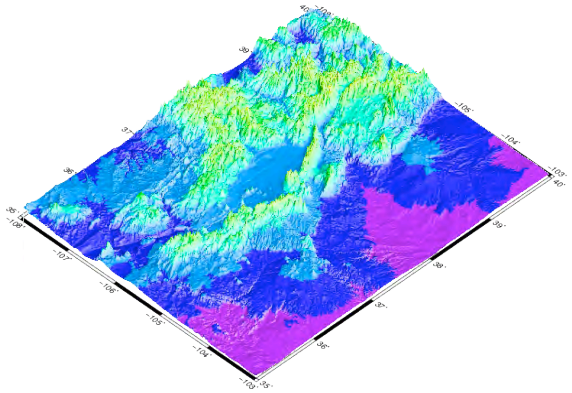
Design. Our design of *fGMT*, a functional (in the sense of *functional programming*) interface to GMT aims to address the above drawbacks. The hypothesis is that a functional interface to these tools not only makes them easier to compose into larger, perhaps specialized, tools but also makes them easier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



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

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

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



Dust and Trace Metal Analysis from SPICE Core, Antarctica

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

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

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

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

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

Figure 1. Dust deposition on ice.

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

Bibliography:

Martin, J. H. 1990. "Glacial-Interglacial CO2 Change: The Iron Hypothesis." *Paleoceanography* 5 (1):1-13. doi: 10.1029/PA005i001p00001.

Investigating Ultra-High Resolution Glaciochemical Records within Ancient Ice

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

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

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

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

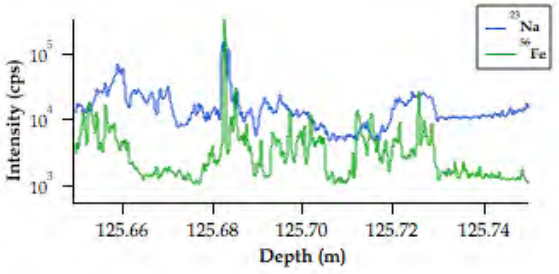

Fig. 1 LA-ICP-MS ultra-high resolution intensity measurements shown by ^{23}Na and ^{56}Fe (100pt smooth) data from Allan Hills site BIT-58 ice core.

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

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

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

Bibliography:

[1]Legrand, Michel, and Paul Mayewski. "Glaciochemistry of polar ice cores: a review." Reviews of geophysics 35, no. 3 (1997): 219-243.

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

[3]Spaulding, Nicole E., et al. "Ice motion and mass balance at the Allan Hills blue-ice area, Antarctica, with implications for paleoclimate reconstructions." Journal of Glaciology 58, no. 208 (2012): 399-406.

[4]Higgins, John A., et al. "Atmospheric composition 1 million years ago from blue ice in the Allan Hills, Antarctica." Proceeding of the National Academy of Sciences 112, no. 22(2015): 6887-6891.

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

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

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

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

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

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

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

Bibliography: Hutchinson G.E. 1957. *Quant Biol* 22:415–427. Schluter D. 2000. *Oxford University Press*. Van Valen, L. 1965. *Am. Nat*. 99:377–389.

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

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

Project Goals:

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

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

Fig. 1. Fishers in Estaquilla ready their boats.

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

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

Bibliography:

[1]J. Castilla and S. Gelcich. "Management of the loco as a driver of self-governance…", *Case Studies in Fisheries Self-governance.* (2008): 441-451.

[2]A. Moreno and C. Revenga, "The System of Territorial Use Rights in Chile," *The Nature Conservancy* (2014), 1-88.

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

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

Project goal

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

Lyme on the Rise

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

One Health

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

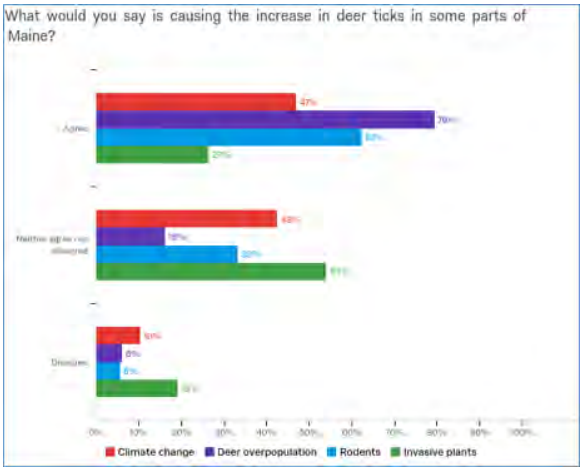
[1]https://www.cdc.gov/lyme/stats/
[2]https://data.mainepublichealth.gov/tracking/
[3] Parham et al. 2014 Theme issue: Climate change and vector-borne diseases of humans. Phil Trans Royal Society B 370(1665)
[4] www.onehealthinitiative.com

Island Tick Survey

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

Initial Results

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



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

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

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

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

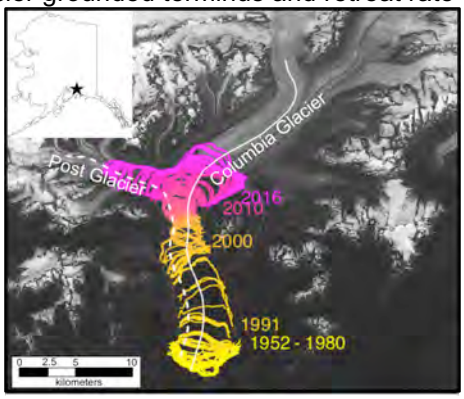

Fig. 1: Terminus change time series (colored lines) for Columbia and Post glaciers, Alaska.

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

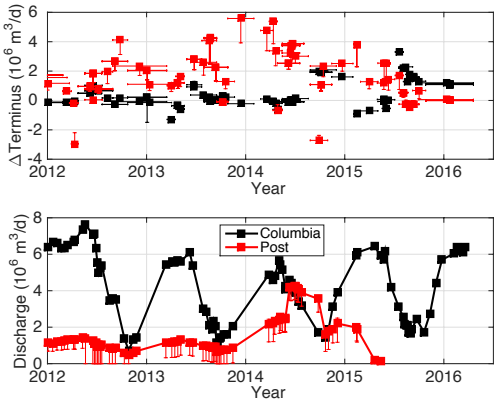

Fig. 2: Volume loss rates due to terminus (top) and ice flow (bottom) changes.

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

Bibliography:

1) Meier, M. and A. Post (1987). Fast tidewater glaciers. J. Geophys. Res. 92, 9051-9058.

Carbon Dioxide Glaciers on Mars

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

Introduction:

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

Results:

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

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

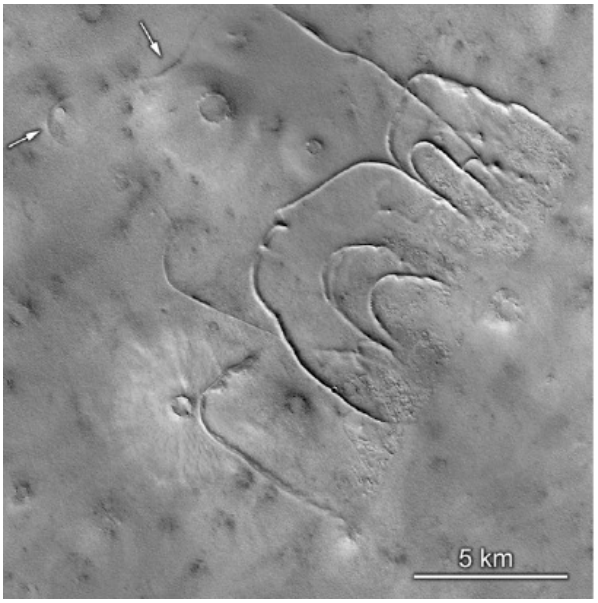

Figure 1: High-latitude glacier (HLG) deposits at 74°N96°E. from CTX image P16_007357_2541 [1, Figure 1].

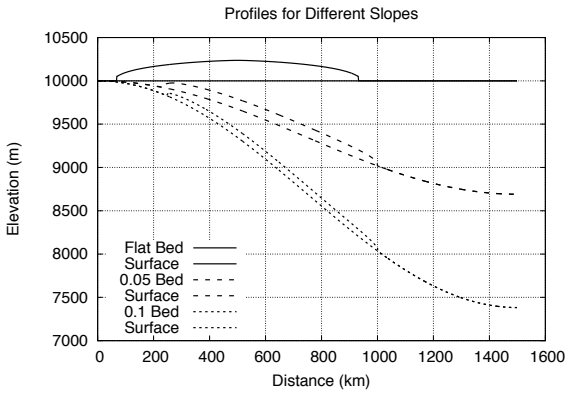

Figure 2: Profiles showing bed and surface for flat, 0.05°, and 0.1°.

Bibliography:

[1] Kreslavsky and Head. *Icarus,* 216:111, 2011; [2] Garvin et al. *Meteorit. Planet. Sci.* 41, 1659, 2006; [3] Kreslavsky and Head. *LPS38,* #1576, 2007.

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

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

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

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

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

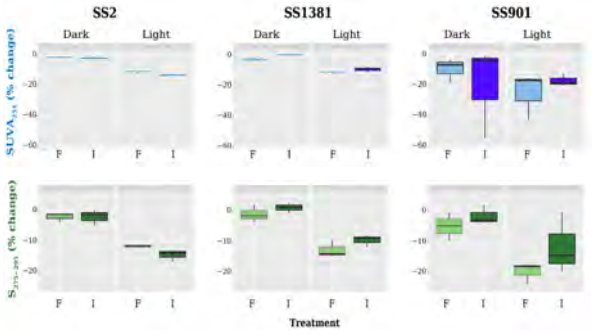

Figure 1. Results of SS2, SS1381, and SS901 lake water exposure to sunlight and bacterial activity on $SUVA_{254}$ and $S_{275\text{-}295}$, two key DOC quality metrics, represented by percent change (n = 3). F = filtered treatments, I = inoculated treatments.

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

Bibliography:

Cory, R. M. et al. 2014. Sunlight controls water column processing of carbon in arctic fresh waters. *Science*, 345(6199): 925-928.

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

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

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

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

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

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

Bibliography: (1) Williams & Jackson, 2007. Novel climates, no-analog communities, and ecological surprises. Front. in Eco. & Env. 5: 475-482. (2) Liu, Z. et al. Transient simulation of last deglaciation with a mechanism for Bølling-Allerød. Science 325:310-314. (3) Wright et al., 2004. The worldwide leaf economic spectrum. Nature 428: 921-827.

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

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3. *Biodiversity Research Institute, Portland, Maine.*

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

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Project Goals and Background:

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

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

Initial Results:

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

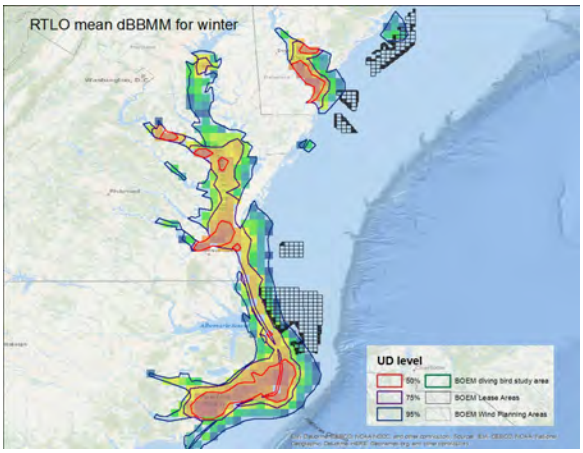

Fig. 1. Number of abstracts submitted per year.

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Bibliography:

Furness, R. W., Wade, H. M., and Masden, E. A. "Assessing vulnerability of marine bird populations to offshore wind farms". Journal of Environmental Management 119 (2013): 56-66.

Kranstauber, B, R. Kays, S.D. LaPoint, M. Wikelski, and K. Safi. "A dynamic Brownian bridge movement model to estimate utilization distributions for heterogeneous movement. Journal of Animal Ecology 81 (2012): 738 – 746.

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

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3. *Ecology and Environmental Sciences Program, University of Maine*
4. *Falklands Conservation*

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

Research Description:

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

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

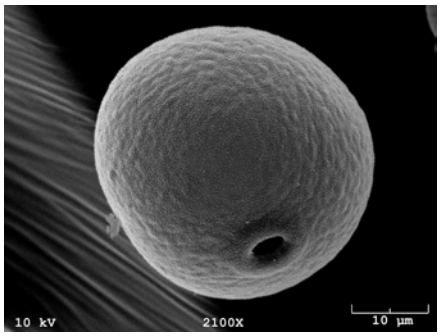

Fig. 1. *Poa flabellata* pollen grain

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

Bibliography: Schüler, L., & Behling, H. (2011). Poaceae pollen grain size as a tool to distinguish past grasslands in South America: a new methodological approach. *Vegetation History and Archaeobotany*, *20*(2), 83-96.

Radaeski, J. N., Bauermann, S. G., & Pereira, A. B. (2016). Poaceae Pollen from Southern Brazil: Distinguishing Grasslands (Campos) from Forests by Analyzing a Diverse Range of Poaceae Species. *Frontiers in Plant Science*, *7*.

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

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

Research Description:

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

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

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

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

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

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

Bibliography: Mulder, C.P.H., Jones, H.P., Kameda, K., Palmborg, C., Schmidt, S., 2011. Impacts of seabirds on plant and soil properties. In C.P.H. Mulder, et al. (eds) Seabird islands: ecology, invasion and restoration. Oxford University Press, 492 p.

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

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

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

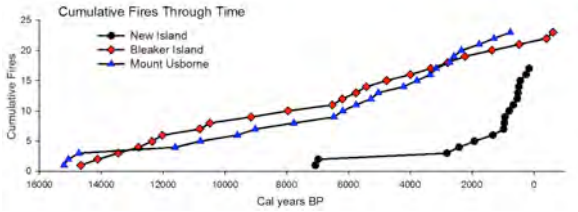

Fig. 1. Cumulative fires through time for study sites.

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

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

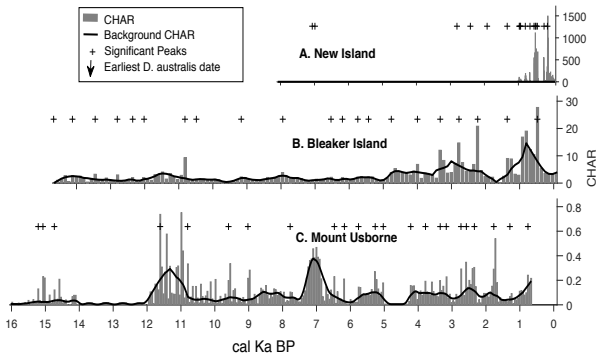

Fig. 2. Charcoal data for study sites addressed in text.

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

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

Improving Geochemical Fingerprinting of Ultra Fine Tephra Particles

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

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

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

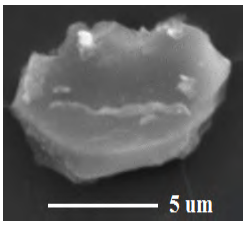

Figure 1: SE image of a tephra particle captured from the SPICE ice core. This particle is ~10 um in size.

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

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

Bibliography:

Iverson, N. A., D. Kalteyer, N. W. Dunbar, A. V. Kurbatov, and M. Yates. 2016. “Advancements and Best Practices for Analysis and Correlation of Tephra and Cryptotephra in Ice.” Quat. Geochron: 1–11.

Zielinski, G. A. 2000. “Use of paleo-records in determining variability within the volcanism-climate system.” Quat. Sci. Rev.: 417–438.

Mapping Adaptation Imaginaries: An Ecology of Practice for Climate Development

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

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

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

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

[1] Eriksen, S.H., A. J. Nightingale, & H. Eakin. "Reframing adaptation: the political nature of climate change adaptation." *Global Environmental Change* 35 (2015): 523-533.
[2] Besky, S. *The Darjeeling distinction: Labor and justice on fair-trade tea plantations in India*. Univ of California Press, 2013.

Methodology & Preliminary Results

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

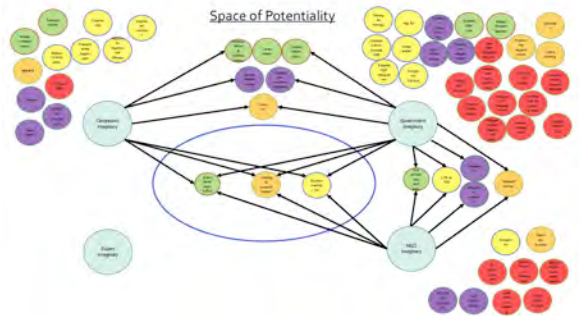

Fig. 1. Network display of resilience indicators across four imaginaries.

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

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

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

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

DNA test of morphological identification:

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

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

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

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

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

Genetic diversity:

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

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

Bibliography

Cammen, KM, S Vincze, AS Heller, BA McLeod, SA Wood, WD Bowen, MO Hammill, WB Puryear, J Runstadler, FW Wenzel, M Kinnison, and TR Frasier. In preparation. "Genetic Diversity from Pre-Bottleneck to Recovery in Two Sympatric Pinniped Species in the Northwest Atlantic."

Ingraham, RC. 2011. "Specialized Taphonomies from an Eastern Maine Shell Midden: Faunal Analysis from Site 62-8, Holmes Point West, Machias, Maine." University of Maine.

Ingraham, RC, BS Robinson, KD Sobolik, and AS Heller. 2015. "'Left for the Tide to Take Back': Specialized Processing of Seals on Machias Bay, Maine." *The Journal of Island and Coastal Archaeology* 4894 (October): 1–18.

Extended Product Lifetimes as Climate Mitigation Policy

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2. *Department of Anthropology, University of Maine*

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

ResourcefulME:

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

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

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

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

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

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

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

Bibliography:

UN. 2012. A 10-Year Framework of Programmes on Sustainable Consumption and Production. New York, United Nations.

Cooper, R. & V.Timmer. 2015. Governments and the Sharing Economy. Vancouver, One Earth.

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

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

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

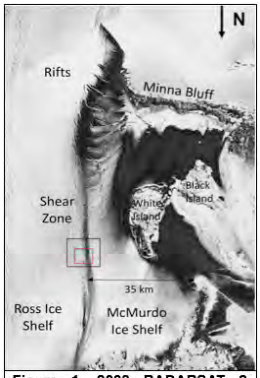

Figure 1. 2008 RADARSAT 2 image of the SZM. Outlines indicate the extent of GPS (black) and GPR (red) surveys

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

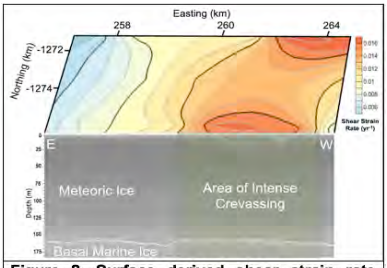

Figure 2. Surface derived shear strain rate contours with a compressed 200 MHz radar image of one 5.7 km transect below. The green portion of the GPR transect highlights an area of intense crevassing observed in both the upper firn and basal marine ice boundary layers.

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

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

Bibliography:

1. Vaughan, D. G.," Relating the occurrence of crevasses to surface strain rates", *Journal of Glaciology* 39 (1993): 255-266.

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

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

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

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

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

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

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

Bibliography:

Bockheim, J.G., Wilson, S.C., Denton, G.H., Andersen, B.G., Stuiver, M., 1989. Late Quaternary ice-surface fluctuations of Hatherton Glacier, Transantarctic Mountains. Quat. Res. 31, 229–254.

Clark, P.U., Mitrovica, J.X., Milne, G.A., Tamisiea, M.E., 2002. Sea-level fingerprinting as a direct test for the source of global meltwater pulse IA. Science 295, 2438–2441.

Deschamps, P., Durand, N., Bard, E., Hamelin, B., Camoin, G.F., Thomas, A.L., Henderson, G.M., Okuno, J., Yokoyama, Y., 2012. Ice-sheet collapse and sea-level rise at the Bølling warming 14,600 years ago.Nature 483, 559–64.

Hall, B.L., Denton, G.H., Heath, S.L., Jackson, M.S., Koffman, T.N.B., 2015. Accumulation and marine forcing of ice dynamics in the western Ross Sea during the last deglaciation. Nat. Geosci.1–5.

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

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

Introduction:

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

Objective:

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

Method:

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

Results and Conclusion:

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

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

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

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

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

Bibliography:

1. Reavie, E. D., & Allinger, L. E. (2011). What have diatoms revealed about the ecological history of Lake Superior?. *Aquatic Ecosystem Health & Management*, *14*(4), 396-402.

2. Saros, J. E., Stone, J. R., Pederson, G. T., Slemmons, K. E., Spanbauer, T., Schliep, A., & Engstrom, D. R. (2012). Climate-induced changes in lake ecosystem structure inferred from coupled neo- and paleoecological approaches. *Ecology*, *93*(10), 2155-2164.

Understanding Surge Dynamics of Donjek Glacier, Yukon, Canada

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

Donjek Glacier

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

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

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

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

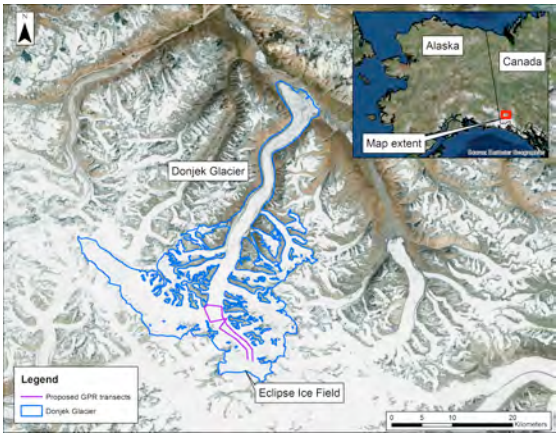

Figure 1. Study area of Donjek Glacier including the glacier outline (blue) and proposed radar transects (purple).

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Bibliography:

Abe, Takahiro, Masato Furuya, and Daiki Sakakibara. "Brief Communication: Twelve-year cyclic surging episodes at Donjek Glacier in Yukon, Canada." The Cryosphere 10, no. 4 (2016): 1427-1432.

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

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

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

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

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

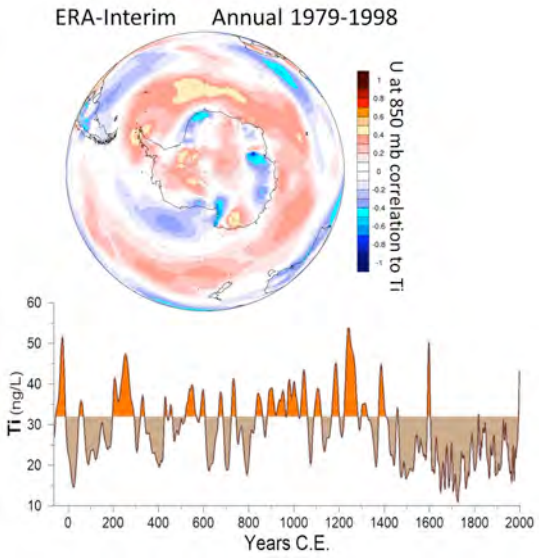

Fig. 1. South Pole Ti concentrations, and Ti correlation to U at 850 mb (http://cci-reanalyzer.org).

Acknowledgements: NSF OPP

Bibliography:

Li, Y., J. Cole-Dai, and L. Zhou (2009), Glaciochemical evidence in an East Antarctica ice core of a recent (AD 1450-1850) neoglacial episode, J. Geophys. Res. Atmos., 114(8), 1–11.

Meyer, I., and S. Wagner (2009), Past Climate Variability in South America and Surrounding Regions, Paleoenviron. Res., 14, 113–128, doi:10.1007/978-90-481-2672-9.

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

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

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

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

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

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

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

Bibliography:

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

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

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

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

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

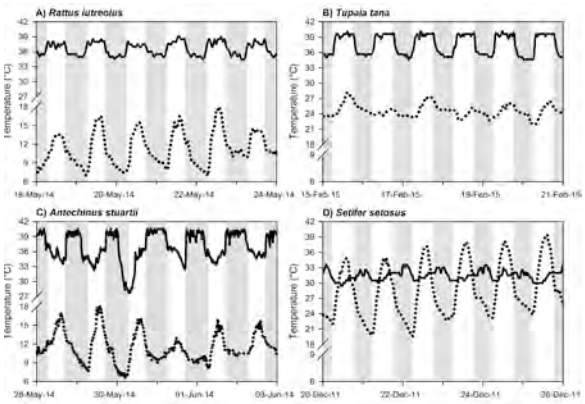

Fig. 1. Body temperature (solid lines) for four different small mammal species showing varying degrees of torpor (a controlled decrease in metabolism). Solid lines indicate body temperature, dashed ambient temperature and the grey bars are nighttime. From Levesque *et al.* 2016.

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

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

Bibliography:

Huey RB, *et al.* (2012) Predicting organismal vulnerability to climate warming: roles of behaviour, physiology and adaptation. Philos Trans R Soc Lond B Biol Sci 367 (1596):1665-1679.

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

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

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

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

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

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

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

Bibliography:

[1]MARENA (2010). Programme Proposal. *Adaptation Fund.*

[2]Adaptation Fund (2015). Projects and Programmes. *Adaptation Fund.* https://www.adaptation-fund.org.

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

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

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

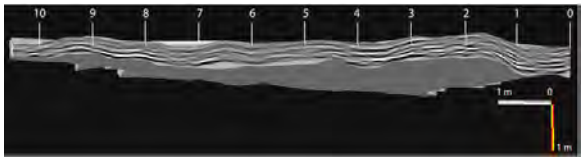

Fig. 1. The 3D representation of a shell midden with a GPR record superimposed on one face.

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

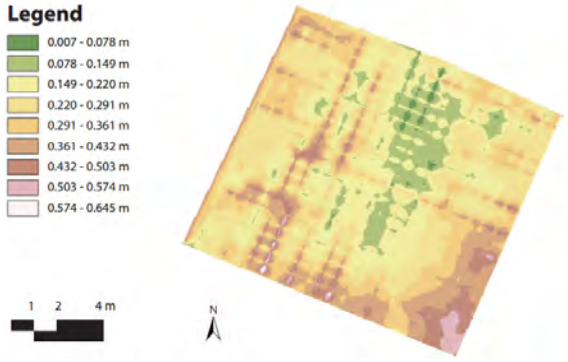

Fig. 2. Thickness of a midden in meters.

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

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

Microscopic Controls on Ice Flow, Jarvis Glacier, Alaska

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

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

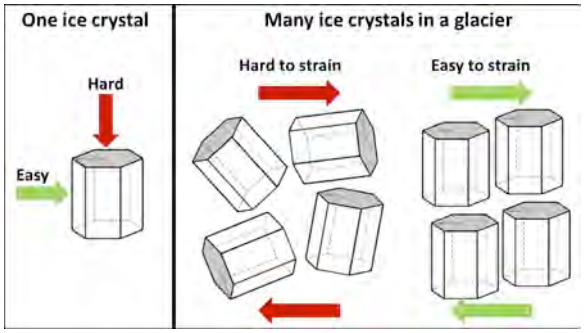

Figure 1. Each ice crystal has an easy-flow and hard-flow direction. If all crystals are aligned in the easy-flow direction, the ice can flow faster. At a glacier margin, shearing should cause all crystals to align.

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

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

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

A Model for Screening Persistent Organic Pollution Risk from Glacial Meltwater

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

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

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

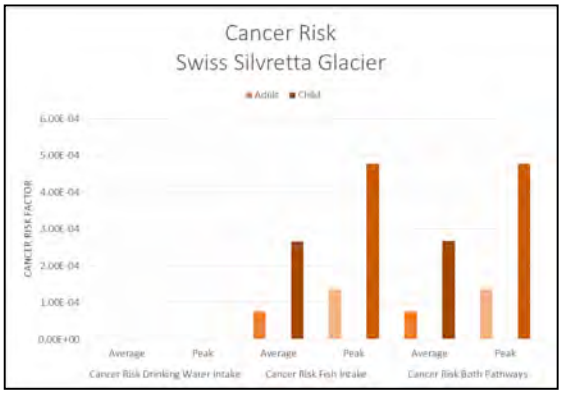

Figure 1. Output of cancer risk model from Silvretta glacier in Switzerland

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

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

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

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

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

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

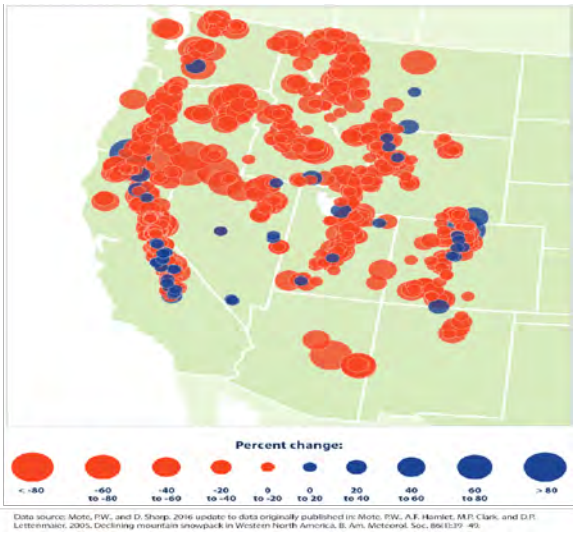

Fig. 1. Trends in April Snowpack in the Western United States 1955-2016 (US EPA 2016).

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

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

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

Bibliography

Lidsey, R. 2001. “Influence of El Niño and La Niña on Southwest Rainfall.” NOAA Climate.gov. https://www.climate.gov/news-features/event-tracker/influence-el-ni%C3%B1o-and-la-ni%C3%B1a-southwest-rainfall.

Trujillo, Ernesto, and Noah P Molotch. 2014. “Snowpack Regimes of the Western United States.” Water Resources Research 50 (7): 5611–23. doi:0.1002/ 2013WR014753.

US EPA, OA. 2016. “Climate Change Indicators: Snowpack.” Reports and Assessments. Climate Change Indicators. December 17. https://www.epa.gov/climate-indicators/climate-change-indicators-snowpack.

Holocene Deglaciation at Amundsen Glacier, Antarctica

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3. *Department of Earth and Space Sciences, University of Washington.*

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

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

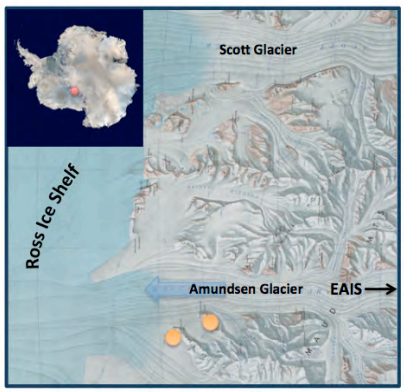

Fig.1. Location of Amundsen Glacier inset; Orange points mark the two nunataks where sampling was conducted; Note south is up.

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

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

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

Acknowledgements:
National Science Foundation.

Bibliography:

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

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

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

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

Excavations at Tranquility Farm: A Seasonality Analysis Using Mollusk Remains

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

Background:

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

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

Figure 1. Abbe Museum Field School 2012

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

Purpose:

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

Methodologies:

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

Acknowledgements:

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

Bibliography:

Spiess, Arthur E. and Robert, Lewis A. "The Turner Farm Fauna: 5000 Years of Hunting and Fishing in Penobscot Bay, Maine." *American Antiquity* 69, no. 1 (2004): 185.

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

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

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

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

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

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

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

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

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

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

Bibliography:

[1] D. Bolius, et al., Ann. Glaciol. **43**: 14–22 (2006).
[2] P. Ginot, et al., Clim. Past **2**: 21–30, (2006).
[3] G. Casassa, et al., A contribution to the International Hydrological Programme (IHP) and the Global Environment Monitoring System (GEMS). UNESCO, Paris (1998).
[4] R. Garreaud, Adv. Geosci., **22**: 3–11 (2009).
[5] D.R. Hardy, The Wilson Journal of Ornithology (2008).
[6] S.B. Sneed, at al., Journal of Glaciology, **61**: 233-242 (2015).

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

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

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

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

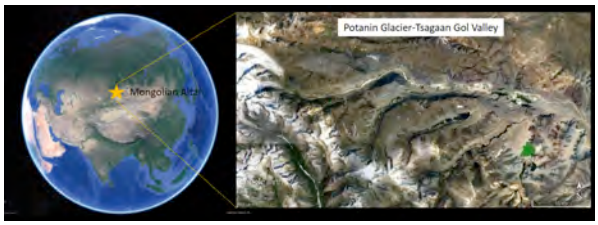

Fig. 1. Google Earth imagery of study area.

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

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

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

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

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

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

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4. *U.S. Geological Survey, Maine Cooperative Fish and Wildlife Research Unit.*

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

Spying on Salmon

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

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

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

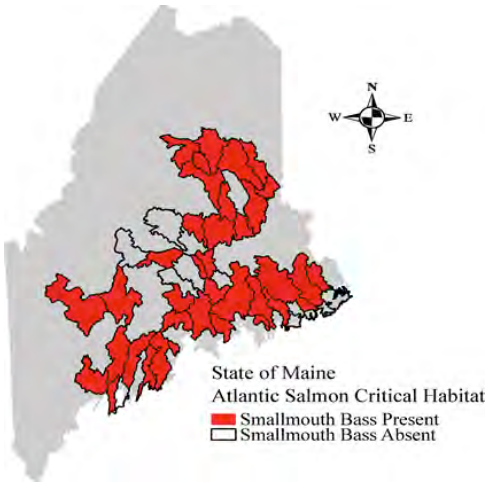

Figure 1. Presence of smallmouth bass within watersheds deemed Atlantic salmon critical habitat, identified by the US Fish and Wildlife Service and made available through ESRI ArcMap Online. Location of smallmouth bass compiled from the Maine Department of IFW Recreational Fishing Guides.

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

[1] IPCC. 2014. Climate change 2014: synthesis report. Contribution of working groups I, II, and III to the fifth assessment report of the intergovernmental panel on climate change {core writing team, R.K. Pachauri and L.A. Meyer (eds)}. IPCC, Geneva, Switzerland, 151 pp.

Declining Dissolved Oxygen in the Central California Current Region

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

Introduction:

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

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

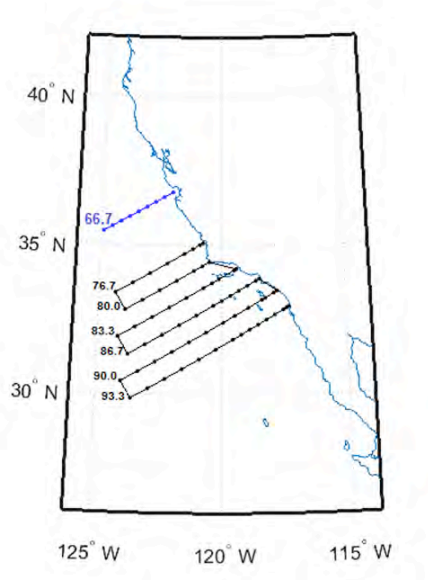

Fig. 1. Map of the location of CalCOFI Line 67, stations 50 to 90 (blue), and the standard CalCOFI sampling lines (black).

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

Results:

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

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

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

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

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

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

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

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

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

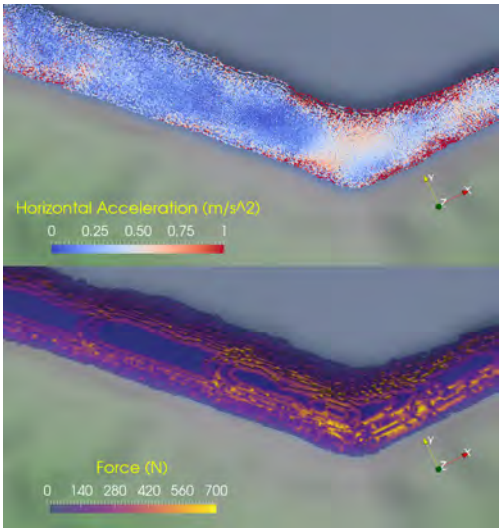

Fig. 1. The 3D fluid motion calculated using SPH reveals that simple changes in geometry can greatly increase the normal forces, such as in the above bend in a bedrock channel (plan view, flow is left to right). These normal forces have tremendous erosive potential and were previously inaccessible by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

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

Bibliography:

Crespo, A.J.C., J.M. Domínguez, B.D. Rogers, M. Gómez-Gesteira, S. Longshaw, R. Canelas, R. Vacondio, A. Barreiro, and O. García-Feal. 2015. "DualSPHysics: Open-Source Parallel CFD Solver Based on Smoothed Particle Hydrodynamics (SPH)." *Computer Physics Communications* 187. Elsevier B.V.: 204–16. doi:10.1016/j.cpc.2014.10.004.

A 2,000-Year Climate History of Central Asia

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

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

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

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

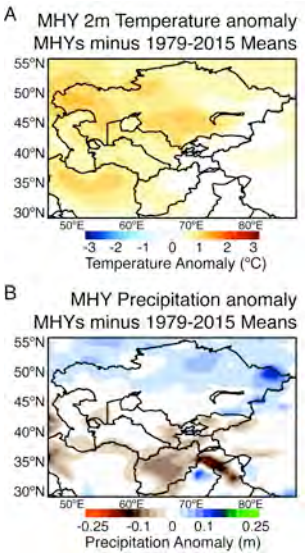

Fig.1. MHY analogs for a warming climate; panel A shows 2 meter temperature differences and B shows precipitation differences, relative to 1979-2015 means

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

Bibliography:

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

Narisma, G.T., Foley, J.A., Licker, R., Ramankutty, N., 2007. Abrupt changes in rainfall during the twentieth century. Geophysical Research Letters 34, 1–5.

Annotating Unit Functions in the Climate Data Workbench

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

Introduction

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

Java Unit Support

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

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

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

Example

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

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

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

Distinguishing Between Clouds and Icebergs Along Greenland's Marine Margins

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

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

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

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

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

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

Bibliography: van den Broeke, MR, *et al.* (2016). "On the recent contribution of the Greenland ice sheet to sea level change." *The Cryosphere* 10(5): 1933-1946.

Enderlin, EM *et al.* (2014). "An improved mass budget for the Greenland ice sheet." *Geophysical Research Letters* 41: 1-7.

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

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

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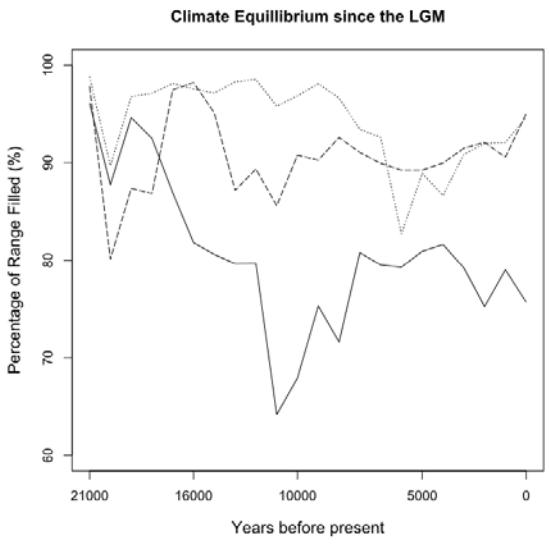
Abstract: The ability for species to keep up with projected climate change remains a critical unknown for quantifying of future biodiversity loss. I present an analysis which reveals when past climate change events outpaced species' ability to keep up. Doing so allows for better estimates on how rapidly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

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

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

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

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



Bibliography:

1. Marcott, Shaun A., et al. "A reconstruction of regional and global temperature for the past 11,300 years." *science* 339, no. 6124 (2013): 1198-1201.
2. Loarie, Scott R, et al. "The velocity of climate change." *Nature* 462, no. 7276 (2009): 1052-1055.
3. Svenning, Jens-Christian, and Flemming Skov. "Limited filling of the potential range in European tree species." *Ecology Letters* 7, no. 7 (2004): 565-573.

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

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

Project Goals

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

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

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

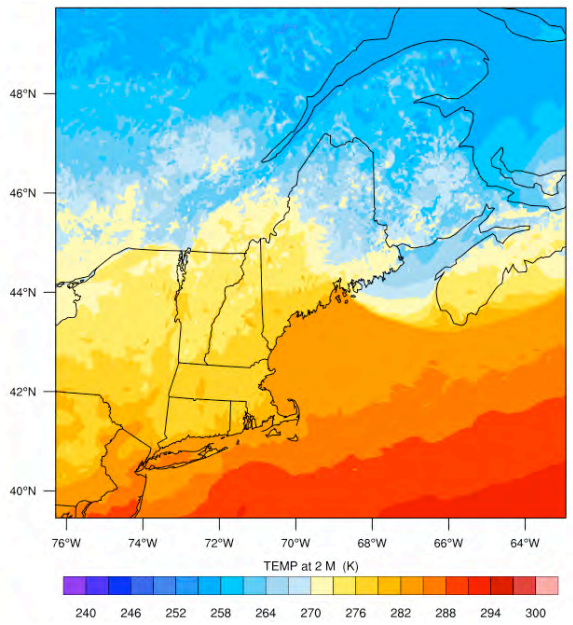

Fig. 1. Model output of 2 meter air temperature for December 23, 2013 at 12Z.

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

Bibliography:

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

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

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

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

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

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

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

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

[1] Sandweiss, Maasch, Andrus, Reitz, Riedinger-Whitmore, Richardson III, & Rollins. (2007). Chapter 2: Mid-Holocene climate and culture change in coastal Peru. Climate change and cultural dynamics: A global perspective on Mid-Holocene transitions, 25-50. **[2]** Sandweiss, Kelley, Belknap, Kelley, Rademaker, & Reid (2010). GPR identification of an early monument at Los Morteros in the Peruvian coastal desert. Quaternary Research, 73(3), 439-448.

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

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

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

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

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

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

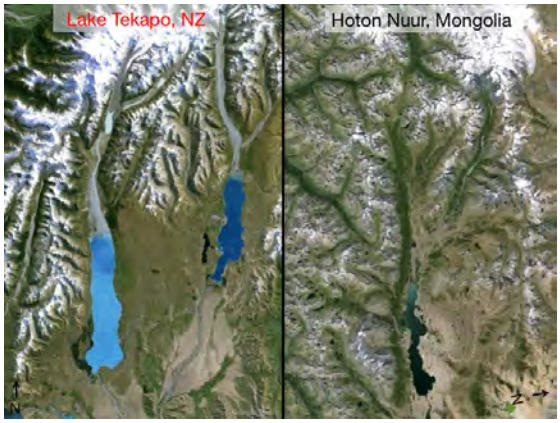

Figure 1. Comparison the Lake Tekapo basin, New Zealand and Hoton Nuur valley, Mongolia

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

The Oceans in International Climate Policy: Oceans Governance After Paris

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

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

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

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

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

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

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

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

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

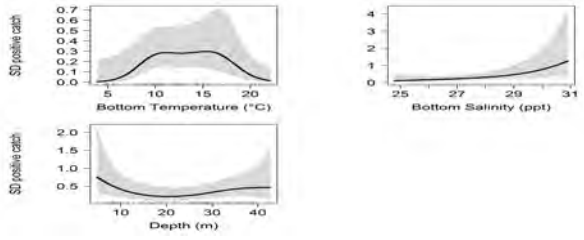

Figure 1. Smoothing curves for significant univariate explanatory variables.

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

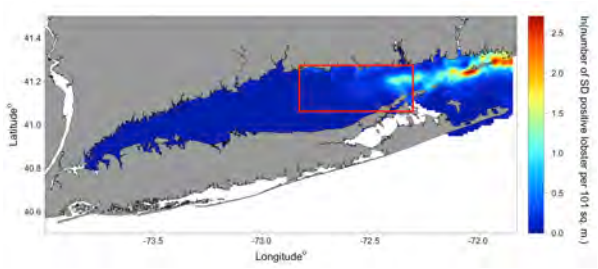

Figure 2. Predicted shell disease prevalence in Long Island Sound (2000-2013).

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

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

Bibliography:

Tanaka, Kisei R., Samuel L. Belknap, Jared J. Homola, and Yong Chen. 2017. "A Statistical Model for Monitoring Shell Disease in Inshore Lobster Fisheries: A Case Study in Long Island Sound." *Plos One* 12 (2): e0172123. doi:10.1371/journal.pone.0172123.

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

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

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

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

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

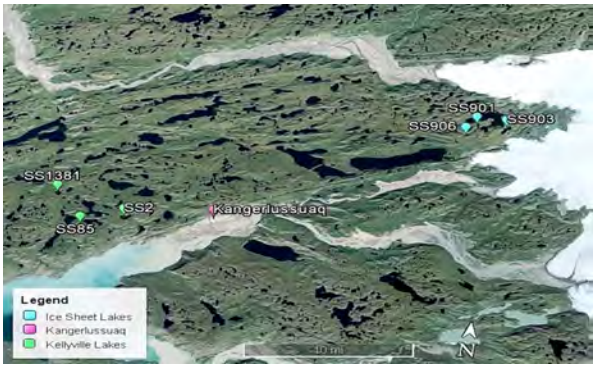

Fig. 1. Map of the 6 study lakes

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

Bibliography:

Ghislain et al. (2010) "Impact of Geese on the Limnology of Lakes and Ponds from Bylot Island (Nunavut, Canada)." International Review of Hydrobiology 95.2: 105-29.

Jefferies RL (1998) Pattern and process in arctic coastal vegetation in response to foraging by lesser snow geese. In: Plant Form and Vegetation Structure, Adaptation, Plasticity and Relationship to Herbivory pp. 281–300. SPB Academic Publ., The Hague.

Manseau et al. "Effects of summer grazing by caribou on composition and productivity of vegetation: community and landscape level." *Journal of Ecology* (1996): 503-513.

Walker et al. (2003) The dynamics of nitrogen movement in an Arctic salt marsh in response to goose herbivory: a parameterized model with alternate stable states. Journal of Ecology, 91, 637–650.

Implications of Extreme Precipitation Events on Lakes in Acadia National Park

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

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

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

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

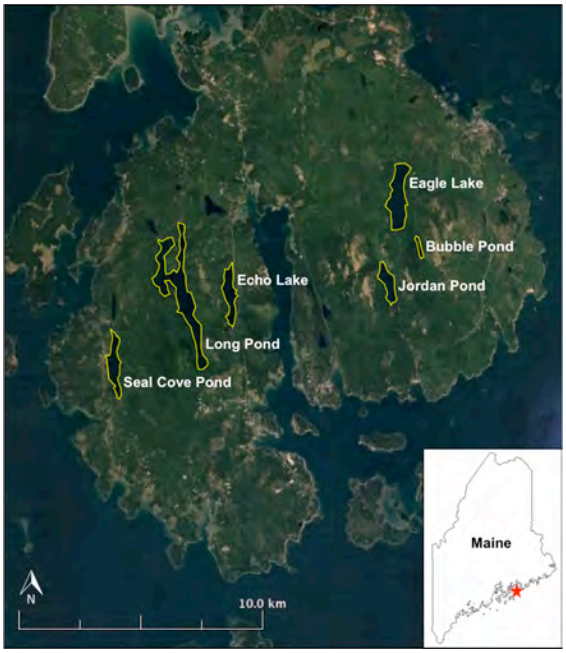

Fig. 1. The the 6 study lakes in Acadia National Park

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

Bibliography: Madsen T. and N. Wilcox. 2012. When It Rains, It pours: Global Warming and the Increase in Extreme Precipitation from 1948-2011. Environment America Policy Center, 43p.

Strock K.E. et al. 2016. Extreme weather years drive episodic changes in lake chemistry: implications for recovery from sulfate deposition and long-term trends in dissolved organic carbon. Biogeochemistry. 127:353-365.

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

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

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

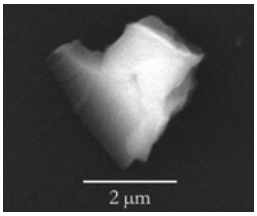

Fig. 1 Tephra particle captured from WDC-06A-01 (depth of 16.325-16.415 m) using the new mounting method. The particle is ~3 µm in diameter.

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

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

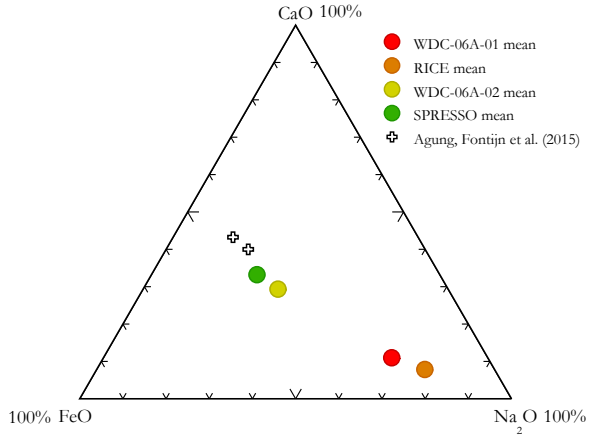

Fig. 2 Geochemical fingerprinting diagram for major elements with a composition >2%. The open crosses represent the published composition for the 1963 Mt. Agung eruption. The closed circles represent the ice core tephra. All samples were adjusted using the EDAX Genesis PhiRhoZ Quantification procedure.

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Bibliography:

Fontijn, K, F Costa, I Sutawidjaja, C G Newhall, and Jason S Herrin. 2015. “A 5000-Year Record of Multiple Highly Explosive Mafic Eruptions From Gunung Agung (Bali, Indonesia): Implications for Eruption Frequency and Volcanic Hazards.” Bull. Volc. 77 (7): 1–15.

Hammer, C U. 1980. “Acidity of Polar Ice Cores in Relation to Absolute Dating, Past Volcanism, and Radio-Echoes.” J. of Glaciology 25: 359–72.

Iverson, N A, D Kalteyer, N W Dunbar, A V Kurbatov, and M Yates. 2016. “Advancements and Best Practices for Analysis and Correlation of Tephra and Cryptotephra in Ice.” Quat. Geochron: 1–11.

Zielinski, G A, P A Mayewski, L D Meeker, K Grönvold, M S Germani, S Whitlow, M S Twickler, and K C Taylor. 1997. “Volcanic Aerosol Records and Tephrochronology of the Summit, Greenland, Ice Cores.” J. of Geophys. Res. 102 (C12): 266.

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

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

Project Goals

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

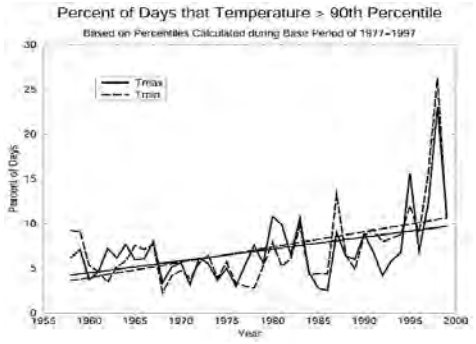


Figure 1. The number of extreme warm days in the Caribbean has increased over the past decades.[1]

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

Broader Impacts

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

Acknowledgements

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

[1] Peterson et al. 2002. Recent changes in climate extremes in the Caribbean region. *J. Geophys. Res. Atmos.* 107(D21).

"We need to be thinking ahead when we're managing our yards, our communities, our state. As our climate changes, we need to be thinking about how to reduce our risk of infectious disease, especially tick-borne disease."

Susan Elias, Ph.D. student, School of Earth & Climate Sciences & Climate Change Institute
National Science Foundation A2C2 IGERT Fellow

Deer ticks *(Ixodes scapularis)* in the US vector (transmit) at least five human diseases that can seriously affect people: Lyme, anaplasmosis, babesiosis, Powassan virus encephalitis, and tick-borne relapsing fever.

Susan Elias thinks climate change is one major driver of the range expansion of the deer tick in Maine. "What we're experiencing in Maine now is compression of winter, so that means adult deer ticks can quest for a blood meal later in fall and earlier in spring. Once a female tick is fed, she will lay up to 2,000 eggs."

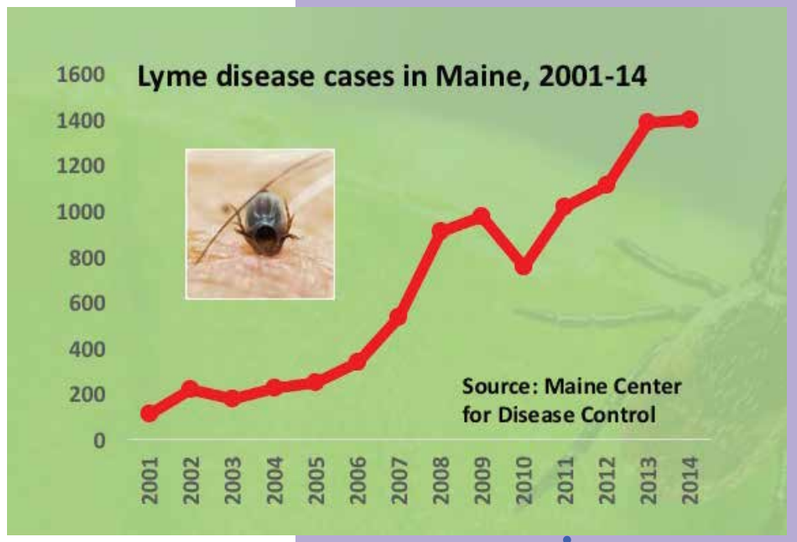
"Climate is one piece of the puzzle," Elias says, citing other drivers. "Where the landscape is out of balance, overabundant white-tailed deer and high densities of white-footed mice provide abundant tick blood meals, and the mice amplify disease agents. Also, Japanese barberry -- an escaped ornamental shrub with bright red berries and fierce thorns -- has completely taken over the understory in some forests and provides perfect tick habitat."

UMaine climate scientists and Elias are creating models that better integrate the drivers of tick range expansion. "But what matters the most is helping communities plan their tick control strategies. We already know enough to act. We know that natural resource management policies need to protect the health of the landscape if we are to protect human and animal health and adapt to climate change. That's the One Health concept."

Photo courtesy University of Maine

Susan Elias, a vector ecologist and Ph.D. student with the University of Maine Climate Change Institute, conducts research on the eco-epidemiology of tick- and mosquito-borne disease in an era of abrupt climate change.

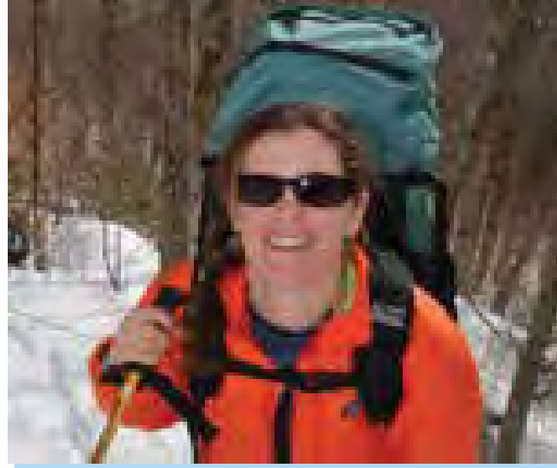
Questing Tick by Erik Karits



Lyme Disease research

"Being a scientist is about more than advancing the knowledge of the scientific community, it comes with the responsibility of reaching out to the community at large, inspiring kids to pursue higher education, and teaching future generations about the importance of scientific research."

Kit Hamley, Ph.D. candidate, Ecology & Environmental Science;
National Science Foundation Research Fellow, Climate Change Institute



Kit Hamley's primary research is in the Falkland Islands where she is working to determine whether humans had reached the islands prior to European arrival in the mid seventeenth century. When Europeans arrived in the islands they were greeted by a large fox, locally known as the warrah, which was the only terrestrial mammal native to the Falkland Islands, but there were no human inhabitants. The lack of definitive evidence of a pre-European human presence, coupled with the expansive channel separating the Falklands from mainland South America, raises questions about how and when the now extinct, endemic warrah arrived in the islands.

The goal of her research is to determine if there was a human presence in the Falkland Islands prior to European arrival in the eighteenth century and to assess the potential link between humans and the arrival of the Warrah to the islands.

Over the past several years, Kit has been active in the development and implementation of a new outreach program called Follow A Research, which connects K-12 students with graduate researchers. This program has reached thousands of students in Maine and around the country and has allowed them to virtually accompany scientists to the highland glaciers of Peru, the remote Falkland Islands and the vast expanses of ice making up Antarctica.

To Kit, being a scientist comes with the responsibility of reaching out to the community at large, inspiring kids who may never have envisioned themselves pursing higher education, and teaching future generations about the importance of scientific research, all the while, showing them that it can also be an amazing adventure.

I am an National Science Foundation Graduate Research Fellow at the Climate Change Institute at the University of Maine. I have a broad array of academic interests that are all fueled by an underlying desire to understand how humans have interacted with and altered the environment through time. I am passionate about sharing my experiences with others through personal outreach, video documentaries and photography.

Falkland Islands

research & outreach