THE UNIVERSITY OF MAINE

CLIMATE CHANGE INSTITUTE

FY2022 Annual Report

Research Activity for the period
July 1, 2021 - June 30, 2022

I. CLIMATE CHANGE INSTITUTE – MISSION & GOALS

In 2022 the Climate Change Institute will celebrate its 50th anniversary making it one of the world's oldest multi-disciplinary climate research units. When CCI started (as the Institute for Quaternary Studies) climate was assumed to operate slowly, over hundreds of years, and therefore to have relatively little immediate effect on humans and ecosystems. Through the pioneering efforts of CCI researchers we now know that climate can change abruptly, in 2-5 years; that the cause for modern climate change is primarily driven by human activity; and that it has dramatically affected human and ecosystem health. Today 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 frequency and magnitude of storms, floods, droughts, wildfires and other extreme events. CCI is recognized as an international leader in climate science and is a Signature Research area in the University of Maine. It has a legacy of transformational contributions to the understanding of the physical, chemical, biological and social aspects of climate change and the application of these findings at local to international scales. CCI continues to maintain its high level of interdisciplinary climate science program leadership, research funding, return on indirect, scientific and popular press publications, state, national/international leadership, and its role as the focal point for the University of Maine's climate change research excellence. Examples for the current reporting year follow. CCI researchers are involved in 187 currently active research grants and contracts for a total of $65,671,990. CCI return on investment for FY2022 remains high at 20.22 factored using the Research Information Management Tool and based on activity by all CCI affiliated researchers. CCI provides a climate change framework for several academic units at the university (e.g., Schools of Earth and Climate Sciences, Marine Sciences, Biology and Ecology, Business, Department of Anthropology) and for the University of Maine Law School and other UMS institutions (e.g., University of Southern Maine, University of Maine at Fort Kent). CCI interacts with: State of Maine agencies (e.g., Department of Environmental Protection, Department of Conservation, Forestry and Agriculture, Department of Transportation, Maine Geological Survey, Maine Inland Fisheries and Wildlife, Maine Center for Disease Control, Department of Licensing and Regulatory Services) including a prominent role in Gov. Mills' Maine Climate Council; federal agencies (e.g., National Science Foundation, Environmental Protection Agency, Department of the Interior, National Park Service, US Department of Agriculture, US Forest Service, Natural Resource Conservation Service, US Department of Commerce, National Oceanic and Atmospheric Administration]; Maine-based non-governmental organizations (e.g., Blue Hill Heritage Trust, Friends of Acadia, Maine Lakes Society, Maine Audubon); and both national (e.g., Harvard, Princeton, Dartmouth, Columbia, University of Washington, University of Colorado) and international research organizations (eg., Scientific Committee for Antarctic Research, University of the Arctic, United Nations, Victoria University (New Zealand), Universidade Federal do Rio Grande do Sul (Brazil), Magallanes University (Chile), Australian National University, Nottingham University (UK) and University of Venice (Italy)). CCI has a long tradition of outreach through numerous media venues, public talks, popular articles, and web-based software with the most prominent example being Climate Reanalyzer (2000-3000 hits/day). CCI, with a pause during the COVID-19 pandemic, continues to maintain its legacy of field expeditions throughout Maine and the world and offers the more than 54 graduate students associated with CCI the opportunity to experience on the ground research and career changing experiences. CCI's eleven research laboratories continue to produce high quality data and hands on opportunities for students - all leading to transformational scientific discoveries.

II. CCI DIVERSITY, EQUITY AND INCLUSION EFFORTS

The CCI Diversity, Equity and Inclusion Committee prepared (2021-2022) and distributed (Spring 2022) an inaugural DEI Survey to CCI faculty, staff and graduate students. The goals of the survey were threefold. First, to obtain a baseline understanding of the diversity that currently exists within CCI. Second, to solicit information about the experiences of respondents re CCI related to equity and inclusion. Third, to obtain perspectives from respondents on current and potential future DEI initiatives. The survey results will be reviewed and compiled into a CCI DEI Survey Summary Report. In addition, CCI has a legacy of experiential learning including cultural diversity for its students based on CCI's worldwide expeditionary activities.

III. KEY PERFORMANCE INDICATORS

Research Funding – Tables below use the Research Information Management Tool using the FY2022 CCI filter.

CCI Award & Submission History – FY2022 – FY2020
Totals include grants/submissions by all CCI Affiliated Researchers

FY 2022	FY 2021	FY2020
CCI Award History Total # Awards: 46 Total All Projects: $11,833,176 ROI: 20.22	**CCI Award History** Total # Awards: 41 Total All Projects: $16,088,154 ROI: 26.93	**CCI Award History** Total # Awards: 48 Total All Projects: $20,170,478 ROI: 29.1
CCI Grant Submission History Total # Submissions: 68 Total All Submissions: $52,171,767	**CCI Grant Submission History** Total # Submissions: 56 Total All Submissions: $29,744,699	**CCI Grant Submission History** Total # Submissions: 66 Total All Submissions: $29,587,395
CCI Award History (Active in Range*) *includes all currently active grant awards Total # Awards: 187 Total All Projects: $65,671,990	**CCI Award History (Active in Range*)** *includes all currently active grant awards Total # Awards: 165 Total All Projects: $58,152,700	**CCI Award History (Active in Range*)** *includes all currently active grant awards Total # Awards: 155 Total All Projects: $63,871,303

CCI Faculty Listing – Joint, Associate, External and Research (Appendix A).

Research and Scholarship Summary - Publications, Presentations, Research Expeditions, Workshops & Conferences, Tours

Research & Scholarship Summary	FY2022	FY2021	FY2020	FY2019	FY2018
Peer Reviewed Publications	**103**	**153**	**183**		
Total Peer & Regular Publications	**273**	**221**	**254**	**206**	**214**
Presentations	**124**	**119**	**132**	**130**	**176**
Research Expeditions	**26**	**14**	**24**		**31**
Workshop & Conferences	**39**	**53**	**70**	**4**	
Tours	**5**	**2**	**16**	**24**	

Special Events:

- Saros led graduate/undergraduate students in an NSF funded Arctic Systems Science field effort in south Greenland.
- Campbell leads Juneau Icefield Research Program for undergraduate and graduate students in Alaska.

Major Outreach Efforts:

- CCI plays a major role in the Maine Climate council and follow-on activities.
- Birkel's *ClimateReanalyzer* software has 2000-3000 hits per day from researchers, public, media.
- CCI spearheads the *Climate Challenge Consortium* survey designed to assess UMS capacity.
- Veazey (Maine Portland Gateway), Mayewski and Norchi (Law School) are organizing a new UM initiative – Complex Problem Solving – intended to intensify UM/UMS transcdiscipl;inary apprpocahes to major challenges faced by dociety

Invention Disclosures:

- CCI enhances *ClimateReanalyzer* and 10Green software to increase public awareness and provide researchers access to physical and chemical climate data.

Gifts/Donations:

- Dan ('63 UMaine) & Betty Churchill – Annual Gift; Joan Netland & Family Gift; Bob & Judy Sturgis Gift, Russell Grinnell Gift, and several other donors.

Other Revenue:

- Ice Age Trail Map Sales

IV. STRATEGIC VISION & VALUES

A. Fostering Learner Success

1. Undergraduate Experiential Learning Initiatives – while CCI is a graduate program it still offers opportunities for undergraduates
   - UMaine Early College offers new Climate Change Pathway to high school students.
   - Juneau Icefield Research Program – 75th Anniversary – S. Campbell.
   - Sea to Sky Experience (ERS 410) – K. Kreutz.
   - School of Performing Arts 'Terra Nova' play with input by P. Mayewski.
   - Research Learning Experience Course Offerings (Fall 2021) - A. Kurbatov & K. Kreutz.
2. Graduate Studies Impact Examples (**Appendix B – CCI Mini-Papers/Harold W. Borns Symposium**)
   - Climate Change Institute Ice-Age Breaker
   - MercoPress reports on Hamley and Gill ESA award.
   - Human-induced climate change impacts highest reaches of the planet – Mount Everest – M. Potocki, P. Mayewski, et al.paper ranked 327th of 391,820 out of tracked articles.
   - UMaine-led research in northern Peru unearths oldest adobe architecture in the Americas – A. Mauricio, D. Sandweiss, A. Kelley.
   - UMaine-led research discovers evidence of prehistoric human activity in Falkland Islands – K. Hamley, J. Gill, D. Groff et al.
   - Winter in Maine gets off to slow start – Portland Press Herald – P. Mayewski & H. Tubbs.
   - UM students debate international climate action in UN negotiation simulation – N. Micinski.
3. Workforce Development Activities Examples
   - Maine Climate Council (S. Birkel, I. Fernandez, B. Lyons, D. Dixon, et al.).
   - Agriculture Maine Weather Forecasting (S. Birkel).
   - Bangor Daily News cites UMaine climate change report in story about Maine in 2100.
   - P. Mayewski & I. Fernandez discuss UN climate report with WAGM.
   - I. Fernandez discusses state climate action plan on 'Maine Calling'.
   - BDN talks with Mallory, Birkel re Maine's extended growing season.
   - BDN cites UMaine climate report re rising sea level in 'City of Ships' – S. Birkel.
   - I. Fernandez, et al. in Maine Public re threats climate change poses to Christmas trees.
   - $1 million for Maine Climate Science Information Exchange project – I. Fernandez
   - UMaine and Maine Med Center - Lyme disease-causing ticks increase in Maine – S. Elias.
   - Newsom awarded $50,000 grant from Telling the Full History Preservation Fund.

- Birkel featured in Maine Public report about climate change and snowmobiles.
- 'Maine Question' asks how changing Arctic affects Maine – K. Kreutz & K. Schild.
- State of Maine Legislature's Joint Resolution commends UMaine R1 designation.
- Acadia National Park lakes show recovery from acidification – R. Fowler, J. Saros, K. Warner et al.
- Maine Science Festival 2022 – K. Allen, J. Gill, S. Campbell.
- Shell midden research receives Maine Historical Preservation Commission grant – A. Kelley et al.
- UMaine cited for sustainability efforts on campus – D. Dixon.
- Maine International Trade Center interviews P. Mayewski re UM role in climate science.

B. Discovering & Innovating

1. Research & Scholarship Summary
   a. Publications, presentations, editorship, exhibits (Section III)
   b. Major projects and outcomes
      CCI continues its legacy of major scientific contributions to the physical, biological, chemical, and social aspects of climate and environmental science through a broad array of projects in Maine and worldwide. See examples in previous text, **Appendix C** and https://climatechange.umaine.edu/ based on news items submitted by CCI researchers and posted on our website.
2. Student Research, Scholarship, or Creative Activities Examples
   - 2022 UMaine Student Symposium Virtual Presentation Graduate Awards to Avery Lamb, Hannah Brooks, Emma Erwin, Jonathan Maurer, Mikala Manello and Scott Braddock.
   - UMaine research on Falkland Island warrah translated to kid-friendly format – K. Hamley.
   - Mereghetti ice age coprolites research highlighted in BDN.
   - Graduate students host BioBlitz to count species on campus – M. Landrum et al.
   - Hazukova examines whether West Greenland lakes emit or capture carbon.
   - Charles A. and June R.P. Ross Research Grant Award – GSA – Alessandro Mereghetti.
   - Landazuri helps translate the first recorded accounts of El Nino.
   - Phys.org reports on H. Clifford's study on water quality around Everest.
3. Faculty & Staff Mentoring and Professional Development
   - Climate Change Workshop – A Virtual Event for Educators Professional Development – K. Glover.
4. Faculty & Staff Achievements (Awards, Recognition, Appointments) Examples
   - Mayewski ranked among top Earth scientists in the world by Research.com.
   - UM awarded observer status at UN Framework Convention on Climate Change – Isenhour, Micinski.
   - UMaine Arts Initiative Maine Economic Development Arts Program grants– B. Newsom.
   - Hamley & Gill recognized by ESA for Falkland Islands Research.
   - UMaine names 2022 Presidential Award winners – K. Kreutz.
   - Sandweiss named 2022 Distinguished Maine Professor.
   - Sandweiss named president-elect of the Society for American Archaeology.
   - Ranked in the top .034% of all research outputs tracked by Altimetric – npj Climate and Atmospheric Sciences articles: Mt. Everest's highest glacier is a sentinel for accelerating ice loss – Potocki, Mayewski et al.
   - Kreutz selected as UArctic Chair in Arctic Ice, Climate and Environmental History in University of the Arctic (UArctic).
   - CCI researcher participating in Comic Con panel as STEAM Superstar – K. Miner.
   - UMaine glaciologist, Juneau Icefield Research Program profiled in new book – S. Campbell.
   - Everest expedition led by Mayewski plus 5 other CCI scientists sets 3 world records.
   - CCI researchers among internationally recognized scientists leading new $25M Center for Oldest Ice Exploration –A. Kurbatov and P. Mayewski.
   - Rickard recipient of the 2022 CLAS Research and Creative Activity Award.
   - McGill named ISI Highly Cited Researcher in 2021 (in addition to 2019, 2022).
   - Hall named Fellow, Geological Society of America (2020).
   - Fernandez received Natural Resources Council of Maine 2021 Conservation Leadership Award.
   - Juneau Icefield Research Program nominated for the Nye Award & Lecture within the American Geophysical Union Cryosphere community (Campbell).

C. Growing & Expanding Partnerships

1. Collaborations: External and with System Campuses
   - CCI is UMaine contact for University Center for Atmospheric Research and University of the Arctic.
   - Campbell directs the glaciology field program – Juneau Icefield Research Project.
   - CCI led Climate Challenge Consortium and Complex Problem-Solving Initiative designed to align and enhance UMS research and education
2. Research Commercialization & Economic Development
   - CCI provides climate change science advice to the public, farmers, planners, governments, and NGOs.

V. INFRASTRUCTURE/FACILITIES/EQUIPMENT PROJECT COMPLETED OR PLANNED FOR COMING

- Bryand Room 300 converted into the Borns Polar Facility to house the Virtual Polar Center and NSF NRT activities.

VI. SUMMARY OF ANTICIPATED CHALLENGES - none foreseen

VII. SUMMARY OF NEW INITIATIVES, OPPORTUNITIES, MAJOR ACCOMPLISHMENTS AND HIGHLIGHTS

- Climate Futures initiative continues to evolve through software innovations and applications worldwide.
- CCI joined A. Abeedi and team in an AI approach to predicting future weather/climate patterns.
- CCI working with O. Apul and team to bring a PFAS facility to UM plus microplastics capability.
- CCI led Climate Challenge Consortium and Complex Problem-Solving Initiative designed to align and enhance UMS research and education.

VIII. CARNEGIE R1 CLASSIFICATION

1. R&D Expenditures in Science & Engineering and in non-Science & Engineering (see III: Key Performance Indicators above)
2. R&D Staff with Doctoral Degrees (**Appendix D**)
3. Doctoral degrees awarded in STEM, Humanities, Social Sciences, and other fields (**Appendix D**)

APPENDIX A – FY2022 CCI Faculty Listing

FY2022 CCI Faculty Listing		
Name	**Administrative Title**	**Affiliation**
Robert Ackert	External Associate	CCI
Guleed Ali	Ford Foundation Postdoctoral Fellow	CCI
Katherine Allen	Coop. Assistant Professor	CCI/SECS
Harjharan Balasubramanian	Post-Doctoral Research Associate	CCI
Daniel Belknap	Professor Emeritus	CCI/SECS
Nancy Bertler	Adjunct Assistant Research Professor	CCI/Victoria University of Wellington
Sean Birkel	Research Assistant Professor	CCI/Cooperative Extension
Pascal Bohleber	External Associate	CCI/University of Venice
Gordon Bromley	External Associate	CCI/NUI Galway
Seth Campbell	Research Assistant Professor	CCI/SECS
Sudarshan Chawathe	Coop. Associate Professor	CCI/SCIS
Kiley Daley	Associate	CCI
Ronald Davis	Professor Emeritus	CCI/SBE
George Denton	Professor	CCI/SECS
Phillip Dickens	Associate Professor	CCI/SCIS
Daniel Dixon	Research Assistant Professor	CCI/Office of Sustainability
Alice Doughty	External Associate	
James Fastook	Coop. Professor	CCI/SCIS
Ivan Fernandez	Distinguished Maine Professor	CCI/SFR
Jennifer First	External Associate	CCI/University of Tennessee
Jacquelyn Gill	Associate Professor	CCI/SBE
Katherine Glover	Associate	CCI
Bjorn Grigholm	External Associate	CCI
Brenda Hall	Professor	CCI/SECS
Sarah Hall	Adjunct Research Professor	CCI/College of the Atlantic
Daniel Hayes	Associate Professor	CCI/SFR
Gabriel Hrynick	External Associate	CCI/University of New Brunswick, Fredericton, CA
Cindy Isenhour	Associate Professor	CCI/Anthropology Dept.
George Jacobson	Professor Emeritus	CCI/SBE
Shaleen Jain	Coop. Assistant Professor	CCI/CEE
David Keefer	External Associate	CCI
Alice Kelley	Research Associate Professor	CCI/SECS
Joseph Kelley	Professor Emeritus	CCI/SECS
Bess Koffman	External Associate	CCI/Colby College
Peter Koons	Professor Emeritus	CCI/SECS
Karl Kreutz	Professor	CCI/SECS
Andrei Kurbatov	Associate Professor	CCI/SECS
Justin Lapp	Associate	CCI/Dept. of Mechanical Eng.
Danielle Levesque	Coop. Assistant Professor	CCI/SBE
Bradfield Lyon	Research Professor	CCI/SBE
Kirk Maasch	Professor	CCI/SBE
Caitlin McDonough MacKenzie	External Associate	CCI
Paul Mayewski	Director/Distinguished Maine Professor	CCI/SECS
Brian McGill	Coop. Assistant Professor	CCI/SBE
Lou McNally	Research Assistant Professor	CCI/UMaine Machias/UMaine Augusta
Nicholas Micinski	Associate	CCI/SPIA & Political Science
Kimberley Miner	External Associate	CCI/JPL Caltech
Alexander More	Assistant Research Professor	CCI/Harvard University/ Long Island University
Peter Neil	Research Associate	CCI/World Ocean Observatory
Bonnie Newsom	Assistant Professor	CCI/Anthropology Dept.
Charles Norchi	Coop. Professor	CCI/Maine School of Law
Robert Northington	External Associate	CCI/Husson University
Stephen Norton	Professor Emeritus	CCI/SECS
Andrea Nurse	Research Associate	CCI
Brian Olsen	Associate Professor	CCI/SECS
Gordon Oswald	Research Professor	CCI
Andrew Pershing	Adjunct Professor	CCI/Gulf of Maine Research Institute
Aaron Putnam	Assistant Professor	CCI/SECS

David Reidmiller	External Associate	CCI/GMRI Climate Center
Laura Rickard	Assistant Professor	CCI/Dept. of Communication & Journalism
Paul Roscoe	Professor Emeritus	CCI/Anthropology Dept.
Katharine Ruskin	Associate	CCI/EES
Daniel Sandweiss	Professor	CCI/Anthropology Dept.
David Sanger	Professor Emeritus	CCI/Anthropology Dept.
Jasmine Saros	Professor/Associate Director	CCI/SBE
Joerg Schaefer	Adjunct Professor	CCI/Columbia University
Rachel Schattman	Associate	CCI/SFA
Molly Schauffler	Assistant Research Professor	CCI/SECS
Jessica Scheick	External Associate	
Kristin Schild	Assistant Research Professor	CCI/SECS
Anton Seimon	Adjunct Assistant Professor	CCI/Appalachian State University
Jefferson Simoes	Visiting Professor	CCI/Universidade Federal do Rio Grande do Sul
Sharon Sneed	External Associate	CCI
Kristin Sobolik	Adjunct Professor	CCI/University of Missouri-St. Louis
Marcella Sorg	Research Professor	CCI/MCSPC
J. Curt Stager	External Associate	CCI/Paul Smith's College
Jeff Thaler	Associate Faculty	CCI/Maine School of Law
Andrew Thomas	Coop. Professor	CCI/SMS
Dominic Winski	Assistant Research Professor	CCI
Manuel Woersdoerfer	Associate	CCI/SCIS
Gregory Zaro	Associate Professor	CCI/Anthropology Dept.
YongJiang Zhang	Associate	CCI/SBE

APPENDIX B – CCI Borns Symposium Mini-Papers

CCI Borns Symposium MiniPapers are located on the CCI Google Drive site at the following location:

https://drive.google.com/file/d/1yvympeTKDW-SQUaSCWI1fDoPYN8cswRA/view?usp=sharing

APPENDIX C – Examples of additional CCI Major Projects and Outcomes

- Potocki interviewed by IFLScience about Mount Everest base camp status.
- Cover story *Global Geneva*: The Hindu Kush Himalaya - An endangered 'water tower' in a warming world, Mayewski, More, Norchi.
- Top 5% of all research outputs scored by Altmetrics: AGU journal article: The Impact of a Six-year Climate Anomaly on the 'Spanish Flu' Pandemic and WWI – More, Loveluck, Clifford, Handley, Korotkikh, Kurbatov, McCormick and Mayewski.
- UMaine scientists co-author article about Zealandia Switch for the Conversation – A. Putnam, G. Denton.
- Winski interviewed by Glove and Mail about ice core sampling on Mount Logan.
- Mayewski quoted in NYT Opinion piece about climate cooperation on Mount Everest.
- Mayewski interviewed by CNN about moving Everest base camp.
- Adirondack Explorer features UMaine Climate Reanalyzer data.
- Maine wild blueberry fields experience warming differently depending on location, season, time, UMaine study finds – J. Zhang, S. Birkel et al.
- Smithsonian features Ruskin in article about saving the saltmarsh sparrow.
- Media reports on UMaine-led study of Antarctic glaciers – S. Braddock & B. Hall.
- Present Antarctic deglaciation may be unprecedented in last 5,000 years, UMaine study finds – S. Braddock, B. Hall.
- Isenhour interviewed for Waste Dive about reusable takeout containers.
- Kurbatov co-authors volcanic event paper on Thera volcano featured in Futurity.
- Gill interviewed by AP about maintaining optimism in light of the climate crisis.
- UMaine researchers co-author Smithsonian study about Indigenous oyster consumption – B. Newsom, A. Kelley.
- New round of RRF grants support collaborations and student research learning across the state – J. Zhang, K. Schild.
- AP interviews Gill for article about climate change 'doomers'.
- World Ocean Explorer Deep Sea Exhibit opens – B. Grigholm, P. Neil.
- Mayewski research cited in ABC News Australia article about 'worst year to be alive'.
- The Independent features UMaine Climate Reanalyzer in article about Conger Ice Shelf collapsing.
- News Center Maine features UMaine climate change researchers – M. Potocki, P. Mayewski.
- USA Today features UMaine Climate Reanalyzer in article about South Pole temperature record – S. Birkel.
- ClimateReanalyzer used to reveal dramatic warming over the Arctic.
- Micinski pens article about Ukrainian refugee protection for Washington Post.
- The Maine Podcast: What happens if Mount Everest loses all of its snow and ice? – Mayewski & Potocki.
- Glaciers are shrinking fast. Scientists are rushing to figure out how fast – NPR – P. Mayewski.
- Black Point Group features Newsom and her indigenous stories research in Acadia National Park.
- Connecticut Media highlight Mayewski's Arctic lecture.
- Maine Science Podcast features Birkel in latest episode.
- Media advance study of air bubbles in Antarctic ice co-authored by A. Kurbatov.
- Mercury exposure in tidal marshes affecting breeding success of two sparrow species – K. Ruskin.
- Media report on Gov. Mills climate change conference at UMaine.
- Gill co-authors report arguing Anthropocene should be a geological event, not an epoch.
- Birkel discusses how climate change impacts severe weather on 'Maine Calling' segment, News Center.
- J. Kelley & C. Isenhour's Educational Videos: Rising Tides: Changes in Sea Level along the Maine Coast & Relationship between Climate Change & Consumption.
- Birkel comments on climate change in Maine, New England in USA Today.
- Mitchell Center presentation on secondhand economy highlighted in BDN, Sun Journal – C. Isenhour, B. Berry.
- Levesque's NSF CAREER Award supports study of small mammal thermoregulation, energy use in changing climate.
- Kelley, Bellefontaine talk with CNN about importance of understanding climate change.
- Guardian interviews Lyon about heat waves.

APPENDIX D – Carnegie R1 Classification – R&D staff with doctoral degrees & doctoral degrees awarded in STEM, Humanities, Social Sciences and other fields.

Doctoral & Master Degrees Awarded (2022 – 2017)			
Name	**Degree Awarded**	**Date Degree Awarded**	**Advisor**
Charles Rodda	PhD, Earth & Climate Sciences	2020	Paul Mayewski
Elena Korotkikh	PhD, Earth & Climate Sciences	2018	Paul Mayewski
Jeff Auger	PhD, Earth & Climate Sciences	2019	Paul Mayewski
Heather Clifford	PhD, Earth & Climate Sciences	2022	Paul Mayewski
Heather Clifford	MSc, Earth & Climate Sciences	2019	Paul Mayewski
Mariusz Potocki	PhD, Earth & Climate Sciences	2022	Paul Mayewski
Anne Marie Lausier	PhD, Civil and Environmental Engineering	2019	Shaleen Jain
Mussie Beyene	PhD, Civil and Environmental Engineering	2019	Shaleen Jain
Mary Bourque	Master of Engineering (Water & Environment Concentration), Civil and Environmental Eng.	2020	Shaleen Jain
Nuha Abdullah	PhD, Civil and Environmental Engineering	2020	Shaleen Jain
Ali Aljoda	PhD, Civil and Environmental Engineering	2021	Shaleen Jain
Rachel Coleman	PhD, Ecology and Environmental Science	2022	Shaleen Jain
Prashanta Bajracharya	PhD, Civil and Environmental Engineering	2022	Shaleen Jain
Amy Kireta	PhD, Ecology & Environmental Sciences	2017	Jasmine Saros
Susan Elias	PhD, Ecology & Environmental Sciences	2019	Kirk Maasch
Sarah Ebel	PhD, Anthrop & Environmetnal Policy	2019	Christine Beitl
Kathryn Warner	PhD, Ecology & Environmental Sciences	2019	Jasmine Saros
Nicole Ramberg-Phil	PhD, Ecology & Environmental Sciences	2020	Hamish Greg
Rachel Fowler	PhD, Ecology & Environmental Sciences	2019	Jasmine Saros
Benjamin Burpee	PhD, Ecology & Environmental Sciences	2020	Jasmine Saros
Edna Pedraza Garzon	PhD, Ecology & Environmental Sciences	2020	Jasmine Saros
Joseph Mohan	PhD, Ecology & Environmental Sciences	2022	Jasmine Saros
Carl Tugend	MS, Ecology & Environmental Sciences	2017	Jasmine Saros
Jared Homola	PhD, Ecology & Environmental Sciences	2018	Michael Kinnison
Simona Lukasik	MS, Ecology & Environmental Sciences	2020	Jasmine Saros
Matthew Farragher	MS, Ecology & Environmental Sciences	2021	Jasmine Saros
Lydia Kiffner	MS, Civil and Environmental Engineering	2017	Steve Norton
Kaci Fitzgibbon	MS, Earth & Climate Sciences	2017	Steve Norton
Gregory McDonald	MS, Civil and Environmental Engineering	2018	Steve Norton
Nicholas Messina	MS, Civil and Environmental Engineering	2019	Steve Norton
Jeremy Deeds	PhD, Ecology and Environmental Science	2022	Steve Norton
Ingalise Kindstedt	MS, Quaternary & Climate Sciences	2021	Karl Kreutz
Erin McConnell	MS, Quaternary & Climate Sciences	2019	Karl Kreutz
William Kochtitzky	MS, Earth & Climate Sciences	2019	Karl Kreutz
Kimberley Miner	PhD, Earth & Climate Sciences	2018	Karl Kreutz
Courtney King	PhD, Earth & Climate Sciences	2017	Brenda Hall & George Denton
Tessa Walther	MS, Earth & Climate Sciences	2020	Brenda Hall
Meghan Spoth	MS, Earth & Climate Sciences	2020	Brenda Hall
Jill Pelto	MS, Earth & Climate Sciences	2018	Brenda Hall
Hunter Tubbs	MS, Earth & Climate Sciences	2021	Bradfield Lyon
Anna Olsen	MA, Anthropology and Environmental Policy	2022	Gregory Zaro
Mario Williams	MS, Ecology & Environmental Sciences	2019	Jacquelyn Gill
Benjamin Seliger	PhD, Ecology & Environmental Sciences	2019	Jacquelyn Gill
Dulcinea Groff	PhD, Ecology & Environmental Sciences	2018	Jacquelyn Gill
Michael Torre	PhD, Ecology & Environmental Sciences	2019	Yong Chen
Lynn Kaluzienski	PhD, Earth & Climate Sciences	2022	Ellyn Enderlin & Peter Koons
Jessica Scheick	PhD, Ecology & Environmental Sciences	2019	Ellyn Enderlin
Julia Simonson	PhD, Earth & Climate Sciences	2020	Sean Birkel
Kisei Tanaka	PhD, Ecology & Environmental Sciences	2018	Yong Chen
Mariah Radue	MS, Quaternary & Climate Studies	2018	Aaron Putnam
Alexander Audet	MS, Earth & Climate Sciences	2021	Aaron Putnam
Allie Balter	MS, Earth & Climate Sciences	2018	Gordon Bromley
Laura Mattas	MS, Earth & Climate Sciences	2019	Aaron Putnam
Meaghan Conway	PhD, Ecology & Environmental Sciences	2019	Brian Olsen

Mariama Dryak	MS, Earth & Climate Sciences	2019	Ellyn Enderlin
Jamie Haverkamp	PhD, Anthropology & Env. Policy	2019	Cynthia Isenhour
Laura Hartman	MS, Quaternary & Climate Studies	2019	Andrei Kurbatov
Ann Hill	MS, Earth & Climate Sciences	2019	Kristin Schild
Anna McGinn	MS, Quaternary & Climate Studies	2019	James Settele, Cynthia Isenhour
Abigail Mann	MS, Quaternary & Climate Studies	2021	Bonnie Newsom
Erin McConnell	MS, Quaternary & Climate Studies	2019	Karl Kreutz
Jillian Pelto	MS, Earth & Climate Studies	2018	Brenda Hall
Kate Pontbriand	MS, Quaternary & Climate Studies	2019	Daniel Sandweiss
Emily Blackwood	MS, Quaternary & Climate Studies	2019	Daniel Sandweiss
Frankie St. Amand	MS, Quaternary & Climate Studies	2019	Daniel Sandweiss
Elizabeth Leclerc	MS, Quaternary & Climate Studies	2022	Daniel Sandweiss

R&D Staff with Doctoral Degrees		
Name	**Degree Awarded**	**Date Degree Awarded**
Elena Korotkikh	PhD, Earth & Climate Sciences, University of Maine	2018
Hariharan Balasubramanian	PhD, Ocean Engineering, Florida Atlantic University	2019
Katherine Glover	PhD Geography, University of California, Los Angeles	2016

Quantifying Rapidly Changing Tidewater Glacier-Fjord Systems in S. Greenland

Sydney J.N. Baratta[1,2], Kristin M. Schild[1,2], Lee Karp-Boss[3]

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

Abstract: With accelerated mass loss in Greenland, some of the retreating tidewater glaciers in the Kujalleq municipality, South Greenland, have transitioned from marine to land-terminating. Fjords with marine-terminating glaciers are highly productive and sustain fisheries that are important to local communities, while land-terminating fjords are not. In this study, we focus on establishing the response rate of fjords to a change in glacier forcing, as glacier retreat is projected to increase under a warming climate and the resulting impact will be detrimental to local community subsistence fishing.

This multi-disciplinary project aims to provide South Greenland stakeholders with an insight on how rapidly changing tidewater glaciers impact subsistence fishing. In June 2022, we will collect in-situ fjord measurements to quantify glacier freshwater flux, subglacial sediment flux, and phytoplankton abundance. In coupling these measurements with remote sensing data, we will quantify the rate of biological change under variable glacier forcing.

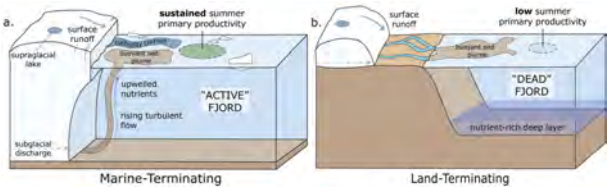

Fig. 1. Fjord dynamics of fjords with marine-terminating (a) and land-terminating (b) glaciers.

Fjord water quality, biology, and circulation are driven by the type of glacier at the fjord head. Greenland glaciers can either terminate directly into the fjord ("marine-terminating", MTG) or on land, just prior to the fjord ("land-terminating", LTG). At MTGs, the coupling of surface runoff and subglacial discharge at depth increases turbidity, and the upwelling of entrained nutrient-rich water to the fjord surface, sustains summer primary production[1]. These glaciers can additionally lose mass through the calving of icebergs, which act as point sources for freshwater nutrient injection[2]. LTGs, however, only supply turbid water at the fjord surface, restricting nutrients at depth and decreasing primary production overall[1] (Fig. 1).

Our study focuses on three glacier-fjord systems, identified through remote sensing imagery: (1) actively retreating MTG, (2) stable LTG, and (3) stable MTG (Fig. 2). As glaciers continue to retreat, understanding the impacts on Inuit fishing and hunting grounds is of critical importance.

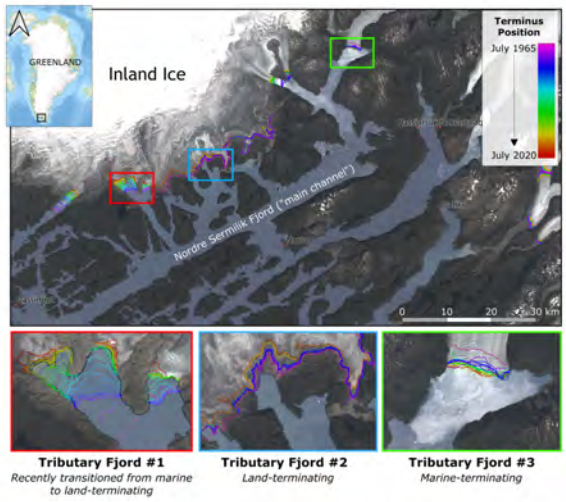

Fig. 2. Map of South Greenland fjords with annual terminus positions (colored lines) from 1965 - 2020.

Acknowledgements: This work is funded by the NSF/NRT-NNA, Award # 2021713.

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Evaluation of Reanalysis Temperature and Precipitation for the Andean Altiplano and Adjacent Cordilleras

Sean D. Birkel[1,2,3], Paul A. Mayewski[1,3], Baker Perry[4], Anton Seimon[1,4], Marcos Andrade-Flores[5]

1. *Climate Change Institute, University of Maine.*
2. *Cooperative Extension, University of Maine.*
3. *School of Earth and Climate Sciences, University of Maine.*
4. *Appalachian State University, Boone.*
5. *Lab. for Atmos. Phys., Institute for Phys. Res., Univ. Mayor de San Andres.*

Abstract: This study compares six reanalysis products for the central Andes Altiplano. Evaluations against 2-meter (2m) temperature and precipitation observations at selected sites suggest that ERA5 provides the most robust climate estimates for the domain. ERA5's high resolution and 1950–present record make it well suited for use in conjunction with ice core studies.

Introduction

Ice cores have been recovered from several glaciers in the central Andes to develop proxy records of past climate variability, offering perspective relative to modern glacier retreat and the influence atmospheric circulation. In addition to validation from local observations, interpretation of ice core climate proxy records can benefit from spatial context and the means to examine large-scale climate teleconnections afforded by reanalysis products. Reanalysis refers to numerical solutions of the state of the atmosphere through inputs of surface observations, radiosonde, and satellite data.

Methods

We evaluated the climate reproduction of six widely used reanalysis products: NCEP/NCAR Reanalysis, NCEP Climate Forecast System Reanalysis, European Reanalysis Interim and version 5 (ERA5; Hersbach et al., 2020), JMA 55-year Reanalysis, and NASA MERRA version 2. Our analysis includes a) comparisons of annual 2m temperature and precipitation trends across the central Andes for 1980–2018, b) annual and monthly time series at sites with observations with altitudes ranging 3,248m to 5,650m (including recent data from an automatic weather station on Quelccaya Ice Cap), c) El Niño Southern Oscillation (ENSO) correlation maps, and d) vertical profiles of temperature, relative humidity, and wind along a longitudinal transect of Quelccaya for major El Niño years (ERA5 only).

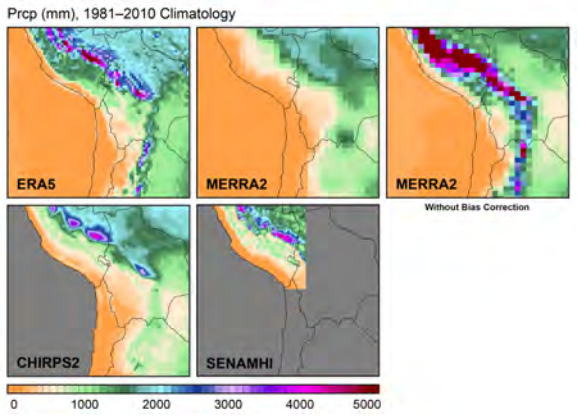

Fig. 1. ERA5 and MERRA2 annual precipitation 1981–2010 compared to gridded observations.

Results

ERA5 affords robust overall climate depiction for the central Andes. However, due to a gauge-based bias correction, MERRA2 produces lower precipitation error scores than ERA5; the uncorrected MERRA2 has poor realism (Fig. 1). ERA5 vertical profiles over Quelccaya for major El Niños suggest need for caution interpreting ENSO signatures in ice cores.

Acknowledgements: National Science Foundation (NSF) awards AGS-1600018 (Mayewski, Birkel), AGS-1566450 (Seimon, Perry), and AGS-1347179 (Perry). Computing support provided by NCAR Comp. and Inform. Sys. Lab. (CISL), sponsored by NSF.

Bibliography: Hersbach, H., et al. (2020). The ERA5 global reanalysis. *Quart. J. Roy. Meteor. Soc.*, **146**, 1–51.

Virtual Reality and the Archaeological Record: Rethinking Monumentality at the Ostra Collecting Station

Emily M. Blackwood[1,2]

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

Abstract: This research explores using virtual reality (VR) technologies to simulate an archaeological site. Incorporating VR in site analyses can provide an interface where data can be tested against various hypotheses without having to be 'in the field' and can be continuously updated or modified as data becomes available and technology advances. The Ostra Collecting Station is a mid-Holocene site located on the northern coast of Peru with unique characteristics that warrant further consideration and offers an excellent opportunity for this type of technological exploration.

Background:

The Ostra Collecting Station is positioned atop an ancient sea cliff and radiocarbon dated to ~6,500 calibrated years B.P. During the time of occupation, the site was only accessible from three directions (north, east, or south) due to the presence of the ocean to its immediate west. A 9x8 meter granite stone structure is located at the western edge of the site. The size of this structure, in the context of the time, can be considered monumental. This site is also hypothesized to be the oldest site in the America's with evidence of defensive strategies. There are two lines of slingstone piles extending eastward from the ancient shoreline with the southern line extending from the structure and the northern line located ~200 meters north. The presence of pearls at its sister site (located 3km to the south) accompanied by the molluscan species and diagnostic artifacts found at both sites presents an interesting, if not perplexing, narrative for this area and its original occupants.

Methodology:

Archaeological data was recovered through excavation and a drone was flown over the site to create a DEM. Unity 3D game engine is being used to create the simulated environment.

Discussion:

In present day, the Pacific Ocean is located 5km to the west of the site, but during occupation it washed up against its western edge (Figure 1). This highlights the accessibility restrictions of this site and its defensibility. Excavation data from a 1x1 meter unit located within the stone structure consisted of midden matrix and charcoal which has been radiocarbon dated and shown to be in stratigraphic order. The size of the structure is inconsistent with other structures dating to this time, which leads us to wonder what purpose did it serve? Due to the presence of diagnostic artifacts recovered from this site and the radiocarbon dates, it can be linked to the Ostra Base Camp located 3km to its south. This linkage is important to the overall narrative for this area as there are no obvious signs of what lead to the abandonment of these sites. The presence of pearls is another unique aspect because they have not been recovered (to date) from any other site in Peru. Following this, the midden matrix consists of molluscan species no longer available at this latitude.

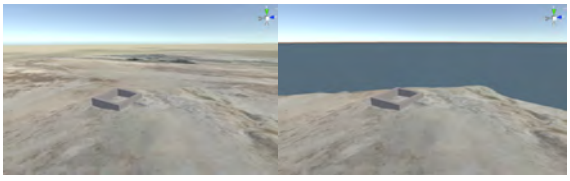

Fig. 1. Simulation of the Ostra Collecting Station with view looking towards the west. Left panel: Ostra Collecting Station in present day. Right panel: Ostra Collecting Station during occupation.

Acknowledgements:

Field Team Members: Cecilia Mauricio, Dan Sandweiss, Alice Kelley, Paul "Jim" Roscoe Gloria Lopez.

Funding: Churchill Exploration Fund (2019)

Graduate Assistantship: Dr. Nicholas Giudice, Chief Research Scientist at the VEMI Lab.

Interpreting Unconformities in Ground-Penetrating Radar Profiles Across the West Antarctic Ice Sheet

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

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

Abstract: We aim to compare observations of stratigraphy within ground-penetrating radar (GPR) datasets with existing exposure-age dates and ice-history models to provide independent evidence for Quaternary ice-surface changes of the West Antarctic Ice Sheet (WAIS). We find stratigraphic unconformities in GPR datasets at 15-30 m and 120 m below the current surface at Mount Waesche that may represent former ice surfaces. Future work will examine GPR profiles from additional sites around the WAIS for similar evidence of ice-surface lowering.

Driving Questions:

The history of the WAIS and the timing and magnitude of past ice fluctuations remain critical questions to address as sectors of the WAIS are rapidly changing and predicted to continue this trend into the future[1]. Studying smaller-than-present ice configurations in Antarctica is difficult, because much of the evidence remains buried beneath the ice sheet.

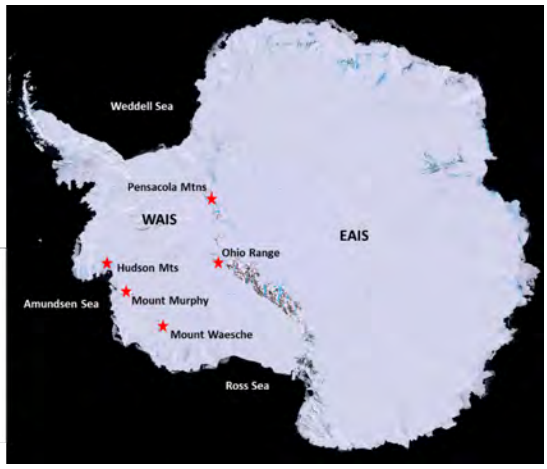

Fig. 1. Map of Antarctica with red stars denoting field sites mentioned in text.

One method to afford insight into smaller-than-present ice configuration of the WAIS is by examining ice stratigraphic features recorded in GPR profiles collected from sites adjacent to nunataks on the periphery and interior of WAIS (Fig 1). GPR data can reveal evidence of fluctuations in ice thickness and flow patterns with high spatial resolution[2]. It is possible to observe previous surface layers in radar profiles, as well as to examine the internal stratigraphy of ice at these sites to determine changes in ice-flow history. Here, I will interpret GPR profiles at four sites around the WAIS: 1) Mount Murphy, 2) Mount Waesche, 3) Pensacola Mountains, and 4) Ohio Range to determine, the spatial extent of unconformities and if they represent local or extensive changes in ice volume across the ice sheet.

Initial Results:

Initial observations at the Mount Waesche site reveal evidence for a potential previous ice-surface 15-30 m below the surface and is interpreted as evidence for a thinning event and subsequent readvance of. Alternatively, I will examine if this degree of surface lowering may be related to wind processes. At 120 m depth, GPR data reveal another, more extensive, unconformity that may indicate a regional draw down of ice because this layer can be traced at least 6 km in the profiles. The aim is to further investigate if similar unconformities exist at other locations around the WAIS and if the extent and timing of these observations are connected.

Acknowledgements: This research is supported by the National Science Foundation.

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The Limit Does Not Exist! Absent Critical Limits of the Thermoneutral Zone Basoendothermic *Tenrec Ecaudatus*

Ana M. Breit[1,2], Danielle L. Levesque[1,2]

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

Abstract: The tailless tenrec (*Tenrec ecaudatus*), endemic to Madagascar, has one of the most extreme body temperature regulation patterns of all eutherian mammals. To test their thermoregulatory limits, we measured their respiration at a range of ambient temperatures and photographed them using infrared thermography. At lower temperatures we found huge variation in metabolic rate and body temperature. Instead of either maintaining an elevated body temperature or saving energy and lowering body temperature and metabolic rate, there was a huge range in individual responses. Additionally, at colder temperatures, the amount of exposed surface area and the temperatures of individual body temperatures was also extremely variable across individuals. By studying tenrecs we can gain insight into the temperature regulation of early mammals.

The basoendothermic tailless tenrec (Tenrec ecaudatus), an oddity by mammal thermoregulatory standards, has one of the lowest eutherian mammalian body temperatures and can hibernate for months without interbout arousals. With their normothermic body temperature tracking ambient temperature, tenrecs exemplify the extreme end of thermolability, resulting in a hard-to-discern, if present, thermoneutral zone. To test thermoregulatory capabilities and the associated metabolic costs, we used flow-through respirometry to measure O_2 consumption and H_2O and CO_2 production of 16 individual tenrecs. We conducted 8-hour long trials over a range of ambient temperatures plus a separate test of acute exposure to ramping temperatures starting at 30°C and increasing by 1°C/hr until they showed visible signs of distress. In a separate experiment, we photographed tenrecs using a thermal camera to identify and quantify their thermal windows. We expected tenrecs to have higher metabolic rates at the lower and higher ranges of temperatures, but instead found high variation among individual's thermoregulatory responses (Figure 1). At low temperatures, individual tenrecs fluctuated between relatively high and relatively low metabolic rates, but these changes in metabolic rates were not correlated to changes in body temperatures. Tenrecs retain many of the ancestral mammal characteristics (nocturnal, insectivores, relatively unspecialized limbs) and inhabit environments similar to those present during the evolution of endothermy in mammals. A further understanding of thermoregulation in this unique mammal may therefore give us insight into the evolution of endothermy and the role of metabolism in thermoregulation.

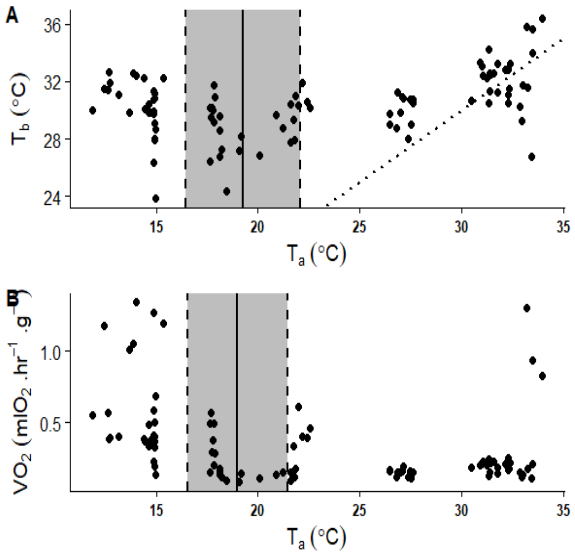

Figure 1. Body temperature (A) and VO_2 (B) of *S.muelleri* across a range of ambient temperatures. Dotted lines delineate the range of breakpoints and solid lines delineate the mean breakpoint.

Acknowledgements: This research was supported by an NSF RCN Genomes to Phenomes to Populations Laboratory Exchange.

Investigation of the ca. 1100 BP (900 AD) White River Ash in the Denali Ice Core Record

Hanna L. Brooks[1,2], Karl J. Kreutz[1,2], Andrei V. Kurbatov[1,2], Dominic A. Winski[1,2], Christopher Gerbi[2], Erich C. Osterberg[3], Martin G. Yates[2], Cameron P. Wake[4]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Department of Earth Sciences, Dartmouth College.*
4. *Institute for the Study of Earth, Oceans, and Space, University of New Hampshire.*

Abstract: The White River Ash eruption of Mt. Churchill in 1100 BP is a well known volcanic event in the Northern Hemisphere. Active cryptotephra geochemical research on the Denali Ice Core 2 indicates the potential that the eruption may as well characterized previously thought.

Project Goals: The White River Ash (eastern lobe, ~1100 BP) eruption is regarded as a well characterized eruption, making it a key marker when developing sedimentary and ice core chronologies[1]. However, preliminary tephra analyses from White River Ash in the Denali Ice Core 2 indicate that previous research assigning two explosive eruptions from the Mt. Churchill stratovolcano to the ash layer may not be entirely accurate[1]. Four prominent sulfate peaks with corresponding tephra matching the chemistry of White River Ash have been identified in ice ranging from 185.05 - 187.77 m deep (currently correlated to 890 - 1091 BP). Efforts are currently underway to determine if the tephra grains preserved in the ice core record are indeed the result of two discreet explosive volcanic eruptions, or if Mt. Churchill was erupting more consistently over a longer period of time between 800 and 1200 BP.

Methodology: Tephrochronological analyses using electron beam instrumentation employ the novel cryptotephra sampling methodology developed at the University of Maine[2]. The highly accurate (within ±5 years at 1500 CE[3]) developed chronology for Denali Ice Core 2 allows for precise identification of known volcanic eruptions, based on annual layer counting of coregistered continuous chemical, isotopic, and microparticle timeseries.

To identify the White River Ash, four sulfate microparticle concentration increases around 1100 BP were analyzed for tephra present. The ice was melted and filtered using 0.2 µm filters. The cryptotephra grains captured on the filter (Fig. 1), are currently being examined using secondary and backscattered electron imaging on the scanning electron microscope (SEM) with semiquantitative analyses conducted by an EDS detector. Completed SEM/EDS analyses have provided chemistry fingerprint of cryptotephra matching the White River Ash when compared with published major and minor element values[1]. To further verify these findings, accurate chemistry will be determined using epoxy mounted tephra samples on the electron probe micro-analyzer.

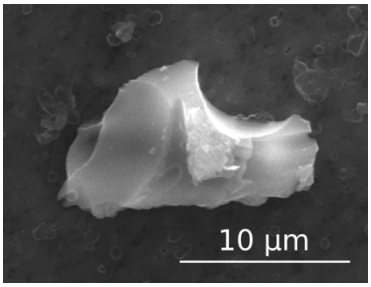

Fig. 1. White River Ash tephra particle analyzed by SEM from the Denali Ice Core (188.25 - 188.689 m)

Acknowledgments: The Ice Drilling Program and Ice Core Facility assisted with the retrieval and storage of the Denali Ice Cores. This work is funded by NSF (AGS-2002483; AGS-1806422; OPP-2002470) and the UMaine GSG.

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Quantifying Variability of Temperate Snow Properties using Ground-Penetrating Radar

Seth Campbell[1,2], Mikaila Mannello[1, 2], Jonathan Maurer[1,2], Scott Braddock[1,2,] Emma Erwin[1,2,] Emily Holt[1], Jordan Farnsworth[1], Michael Keedy[1], Ingalise Kindstedt[1,2]

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

Abstract: We used ~400 km of ground-penetrating radar (GPR) data with snow density observations to quantify snow-water equivalent (SWE) in Southeast Alaska. We show that radio wave velocities vary significantly both spatially and temporally (0.122 – 0.207 m ns^{-1}) within a temperate snowpack. These variations likely result in significant SWE uncertainties, globally, due to assumptions made in GPR survey methods. Our future research is geared towards reducing these uncertainties.

Annual winter snowpack provides water for ~30% of humans on Earth. Many water resources are stressed, making annual predictions of snowpack important for future humanitarian efforts. The Snow Ensemble Uncertainty Project provides a baseline of snow water equivalent (SWE) uncertainty across North America (Kim et al., 2021). This ensemble revealed the greatest snowpack uncertainty exists in mountainous environments where deep snow exists and in mid-to-high latitude boreal forests where vegetation creates a complex surface-atmosphere boundary. The boreal Northern New England forests (including Maine) and mountainous Pacific coast (including Coastal Alaska) fall within these regions of highest uncertainty. One technique heavily relied upon for SWE measurements is GPR (Holbrook et al., 2016). In dry snow, GPR radio wave velocity is dependent on snowpack density. Hence, with estimates of density, GPR is an effective tool for calculating SWE of dry snow. However, in snow which contains liquid water, radio wave velocity is dependent on density and water content resulting in a more complex quantitative estimate of SWE.

We used ~400 km of common offset (CO) GPR data collected on the Juneau Icefield, Alaska, between 2012 and 2021 to calculate snow thickness and SWE. GPR-derived thickness calculations were refined with snow pits and cores extracted along GPR profiles. We used the GPR signal two-way travel time within snow relative to ground truth of snow thickness to calculate radio wave velocities. We conducted variable velocity migration as an alternative measure of radio wave velocity. Lastly, we used these velocity estimates to calculate variations in relative permittivity (ε) based on the following:

$$V = \frac{c}{\sqrt{\varepsilon}},$$

where V is velocity and C is the speed of light in a vacuum (both in m ns^{-1}). Results revealed ε ranged between 2.1 and 6.0 which correspond to velocities from 0.122 to 0.207 m ns^{-1}.

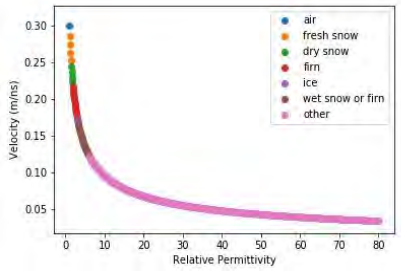

Fig. 1. Relative permittivity versus radio wave velocity in primary environments surveyed for this research (fresh snow, dry snow, dry firn, ice, and wet firn).

Future research will expand to multiple radar techniques and modeling to better constrain velocity variability and improve SWE estimates of temperate snow in both Alaska and Maine.

Acknowledgements: We thank the Juneau Icefield Research Program for supporting this research between 2012-2021.

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Importing Data from Irregular Spreadsheets

Sudarshan S. Chawathe[1, 2]

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

Abstract: This work addresses the task of transferring data from a spreadsheet to a well-structured relational (tabular) database. For spreadsheets that are also well structured and that conform to the relevant standards and conventions, this task borders on trivial. Many spreadsheets, however, are not so obliging and are rife with non-standard formats, conventions, irregularities, and errors. This paper defines an optimization problem that permits systematic exploration of solutions for such irregular spreadsheets.

The transformation of data from irregular and nonstandard spreadsheets to a regular and standardized format is an important prerequisite for deriving greater use and insights from scientific datasets that are in spreadsheet form. There is a large body of work on the problem of importing data from diverse sources into a well structured database system (that typically uses a relational or tabular representation). In a general setting, this problem is one of data integration in all its complexity. However, this work focuses on a specific version of this general problem: that of extracting data from irregular spreadsheets. Further, while spreadsheets produced by diverse software such as LibreCalc, Word, and Numbers may include diverse and often incompatible features, this work focuses on only those aspects that are captured by the rendering of such spreadsheets into a comma-separated value (CSV) format.

Since the CSV format is well standardized it may appear that the above specialization of the problem has defined away the problem. However, CSV files, even those that adhere to the standard (many do not), permit various irregularities that present challenges to importing data from them. One such irregularity, and one that is the focus of the sequel, is varying numbers of columns (fields) across rows (records). For instance, the first 10 rows may have 17 columns while the next two have 19, followed by 20 with 17 and then 100 with 5. While such an irregular CSV may at first appear a contrived example, it is in fact a sanitized version of a real CSV file encountered in an independent context.

While it is impossible to enumerate all causes of irregularities such as the above, a study of several CSV files points to two frequent causes: First, it is common for spreadsheet creators to include two or more conceptually distinct (albeit related) tables in the same spreadsheet. When such a multi-table spreadsheet is converted to CSV format, the number of columns is likely to vary as above. Second, the spreadsheet may have missing data and formatting errors that also lead to a varying number of columns.

One option for resolving the irregularities is to assume that whenever the number of columns changes (from one row to its successor), it is the end of one table and the beginning of the next. The result is a sequence of tables, each of which is fully regular (same number of columns in all rows of each table). However, with this option, an error in a single CSV row (resulting in a different number of columns) splits the table into three, which is not convenient for later use. Another option is to treat the first row of the CSV file as one defining its structure (in particular, the number of columns in each row) and then to treat any row that has a different number of columns as an error that is resolved by padding with null columns or ignoring additional columns as needed. The result here is a single table also with a fully regular structure. However, if the first row is erroneous, there is potential for much data loss. As well, if the CSV file represents a concatenation of multiple tables, as is often the case, there is loss of information as well as confounding of logically separate data.

Instead of being limited to using one of the above two extreme options, and others like them, this work frames the task as an optimization problem: Minimize the product of the number of resulting tables and the number of intra-table irregularities. This framing of the problem permits systematic solution using standard methods as well as tuning the desired output by modifying the objective function.

Non-Spherical Dust in Antarctica Affects Volume-Related Metrics

Aaron Chesler[1,2,3], Dominic Winski[1,2], Karl Kreutz[1,2], Bess Koffman[4], Erich Osterberg[5], David Ferris[5], Zeta Thundercloud[5], Joseph Mohan[1,6], Jihong Cole-Dai[7], Mark Wells[8], Michael Handley[1], Aaron Putnam[2], Katherine Anderson[5], and Natalie Harmon[2]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Environmental Studies Program, Goucher College.*
4. *Geology Department, Colby College.*
5. *Department of Earth Sciences, Dartmouth College.*
6. *Department of Chemistry and Biochemistry, South Dakota State University.*
7. *Ecology and Environmental Science, University of Maine.*
8. *School of Marine Sciences, University of Maine.*

Abstract: Atmospheric dust plays an important role in Earth's climate dynamics and paleoclimate reconstructions. However, particle shape data, which informs volume measurements, is sparse in Antarctica. Using Dynamic Particle Imaging techniques, we present the highest resolution record (41 measurements) of particle shape spanning 50 – 16 ka from the South Pole Ice Core.

While dust metrics have been used extensively to reconstruct atmospheric circulation, radiation balance, and chemical transport, assumptions have been made about particle shape which can significantly affect particle volumes. These assumptions can lead to order of magnitude differences between results based different methodological data collection techniques. Temporal measurements of particle shape to-date are sparse with only 2 measurements in Antarctica and 4 measurements in Greenland during the Last Glacial Period (54 – 10 ka). We use dynamic particle imaging (DPI), a novel technique for ice core microparticle dust analysis, to provide the highest-resolution record of dust particle shape in Antarctica spanning 50 – 16 ka.

We use DPI aspect ratio measurements and compare against, previously collected, continuous flow analysis (CFA) and discrete coulter counter (CC) microparticle data. The CFA collects 1-D particle information under the assumption of assumed particle length. The CC measures particle size through electrical resistivity and is the assumed standard for volumetric measurements in microparticle dust analyses. We measured 41 samples during Heinrich Stadial 1 (18 – 16 ka; n = 7), Last Glacial Maximum (27 – 18 ka; n = 20) and Heinrich Stadial 4 and 5 (50 – 36 ka; n = 16).

Average fine (1.1 – 4.5 μm) and coarse (5.1 – 6.4 μm) particle aspect ratios (width/length; 0.76 ± 0.10 and 0.70 ± 0.10, respectively) both indicate non-sphericity of particles. We calculate particle volume using length, width, and assumed particle height dimensions. Calculation of particle volumes using ellipsoidal shape where particle height is equal to particle width reduces temporal and volume discrepancy (221 – 105%) between CFA and CC techniques.

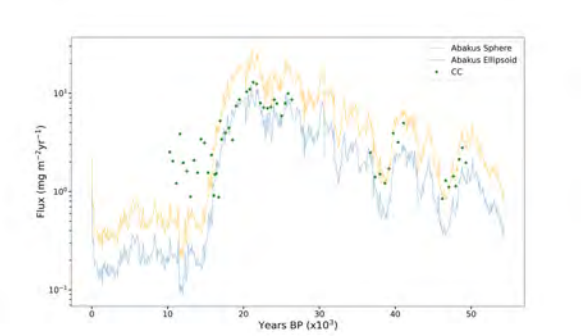

Fig. 1: Microparticle flux calculations with spherical volume (orange), ellipsoid volume (blue), and discrete CC measurements (green).

Acknowledgements: Support provided by the NSF award PLR-1443397 and Dr. Jasmine Saros.

Comparison of Shallow Firn Core Records from Quelccaya Ice Cap (Peru) and Nevado Illimani (Bolivia) and Potential for Ultra-High-Resolution Investigation

Heather M. Clifford[1,2,*], Mariusz Potocki[1,2], Paul A. Mayewski[1,2]

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

Abstract: We present chemical analysis from two Central Andean shallow firn core records and a near-basal ice core to develop a time scale based on multi-parameter glaciochemical annual layer detection; define annual layer thickness using ultra-high-resolution glaciochemical sampling, assess sources of chemical impurities and proxies for atmospheric circulation and compare them with existing glaciochemical records; and preface future directions for high- and ultra-high-resolution ice core records collected to bedrock.

Modern warming has created unsustainable conditions for high mountain glaciers, causing increased melt and degradation of ice core climate archives, only projected to worsen over the next century. Central Andes (10°S and 35°S) high altitude glaciers including Nevado Illimani and the Quelccaya ice cap, are influenced by maritime air masses from the tropical Atlantic Ocean modified by transit across the Amazon Basin.

Shallow firn cores, in addition to a near-basal ice core, were recovered in 2018 from the Quelccaya ice cap (5470-masl) in the Cordillera Vilcanota, Peru and in 2017 from Nevado Illimani glacier (6350-masl) in the Cordillera Real, Bolivia. The two sites are ~450-km (SE) apart. Despite meltwater percolation resulting from warming, particle-based trace element records (e.g., Fe, Mg, K, Na) in the Quelccaya and Illimani shallow cores retain well-preserved signals. The firn core chronologies, established independently by annual layer counting back to 2005 and 1999 respectively, show a convincing overlap indicating the two records contain comparable signals and therefore capture similar regional scale climatology (Fig 1).

High resolution (~1-4-cm) trace element records provide past records of anthropogenic emissions, dust sources, volcanic emissions, evaporite salts, and marine-sourced air masses. Using novel ultra-high-resolution (120 micron) laser technology, we identify annual layer thicknesses ranging from 0.3 to 0.8-cm in a section of ~2000-year-old radiocarbon-dated near-basal ice which compared to previous annual layer estimates suggest that Quelccaya ice cores drilled to bedrock may be older than previously suggested by depth-age models. With the information collected from this study in combination with past studies, we emphasize the importance of collecting new surface-to-bedrock ice cores from at least the Quelccaya ice cap, in particular, due to its projected disappearance as soon as the 2050s.

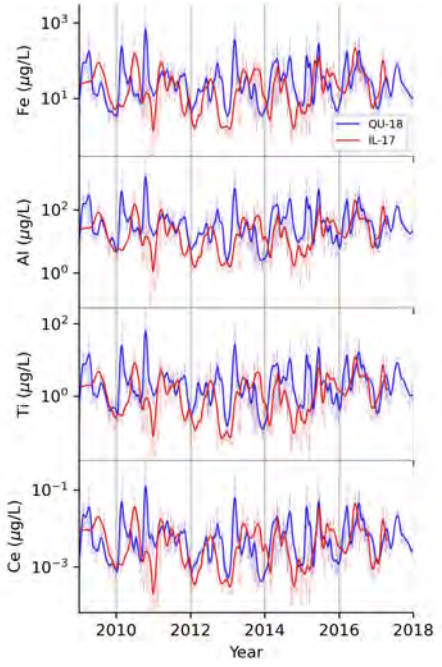

Fig 1. Smoothed (2σ gaussian**)** glaciochemistry measurements of Fe, Al, Ti, and Ce (ugL^{-1}) showing the corresponding overlaps of QU-18 (blue) and IL-17 (red) shallow ice cores by age from 2009 to 2018 CE.

Developing a Full Stokes Numerical Ice-flow Model of the Eclipse Icefield

Emma Erwin[1], Seth Campbell[1,2]

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

Abstract: The use of numerical models to quantify the kinematics of ice flow at ice core sites provides deeper insights into location-specific glaciological processes and allows for improved constraints on the age-depth field of ice cores. This project focuses on the development of a three-dimensional full stokes numerical model of the Eclipse Icefield.

Background

Analysis of ice cores drilled from the Eclipse Icefield (Yukon, Canada) in 1996 and 2002 have provided valuable high-resolution paleoclimate records due to the higher accumulation rates present at this site, which is positioned at a lower elevation than other alpine ice core locations in the Pacific Northwest. Ice core records from this location chronicle volcanic activity, atmospheric pollutants, stable isotopes, and snow accumulations rates, providing historical context for current changing climate by which the Pacific Northwest is highly affected.

The goal of this project is to develop a sophisticated numerical ice-flow model to characterize the flow fields and constrain the age-depth profile of ice on the Eclipse icefield. Results from this model will be used to identify a future coring location and improve the interpretation of paleoclimate proxies in existing and future cores recovered from the Eclipse Icefield.

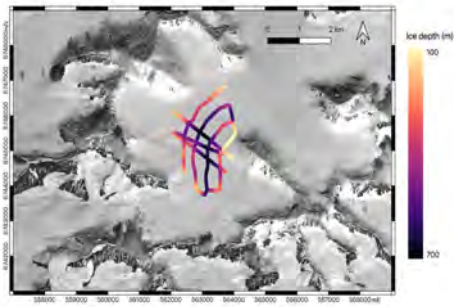

Fig. 1. Measured ice depths across the Eclipse Icefield Divide collected from ice-penetrating radar.

Preliminary Results

A preliminary full stokes ice flow model has been developed using interpolated ice depth measurements, a COMSOL-generated geometry, and the open-source modeling software Elmer/Ice[1]. In this model, the ice is considered isotropic, frozen to the bed, with a constant temperature of -10C. The boundaries of this model are set to no-slip conditions at the bed and prescribed velocities along its lateral margins and outflow boundaries based on surface velocity estimates acquired from previous fieldwork.

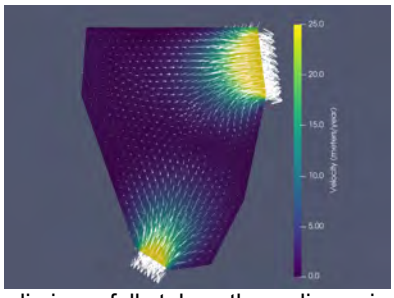

Fig. 2. Preliminary full stokes, three-dimensional ice flow model of the Eclipse Icefield.

Icepack[2] will be used in future work to improve the model by interpolating modeled ice thickness estimates[3] with measured ice depths to increase the domain size and more accurately represent the geometry of the outflow boundaries. Additionally, surface velocity measurements provided by the NASA MEaSUREs ITS_LIVE project[4] will be integrated into the model to produce more accurate flow conditions across the divide.

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Baselines, Shoreline Change and Beach Management Strategies

Katherine Follansbee[1, 2, 3], Kathleen Bell [2, 3], Caroline Noblet[3]

1. *Climate Change Institute, University of Maine.*
2. *Systems Approaches to Understanding and Navigating the New Arctic (SAUNNA) National Research Traineeship (NRT), National Science Foundation.*
3. *School of Economics, University of Maine.*

Abstract: As coastal managers respond to changing shorelines, many questions remain about appropriate beach erosion management strategies in Maine and beyond. We use survey data and insights from behavioral economics to assess the relationships between beach users' visitation patterns, awareness of shoreline change, and support for different beach management actions. Our social science research, done in collaboration with key coastal stakeholders, is helping to inform park and beach management strategies.

Project Goals

As changing shorelines alter coastal beaches, coastal managers are adapting beach management strategies and striving to understand what the public thinks should be done. The goal of this project is to assess visitor awareness of shoreline change and support for management actions. We examine how an individual's reference point impacts their attitudes and behavior using years of visitation to a specific beach as a baseline. We then assess whether familiarity with the beach changes awareness of shoreline change and support for active management. Our research analyzes responses to a 2016 survey conducted at Popham Beach State Park in Maine, in which visitors responded to questions about familiarity with the beach and opinions regarding erosion management actions.

Initial Results

Awareness of erosion increases with familiarity with the beach (Figure 1).

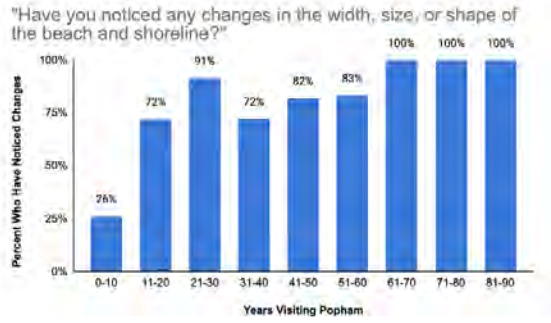

Fig. 1. Familiarity with the beach and awareness of changing shorelines.

When asked if the state should take management actions, 49% responded yes, while 40% preferred. let nature take its course. As shown in in Figure 2, there was no clear correlation with years of visitation.

Fig. 2. Familiarity with the beach and support for active beach management.

Familiarity with the beach is positively associated with awareness of erosion but is not correlated with support for alternative management options.

Our future work will leverage input from key stakeholders and perform more advanced modeling to look at these relationships.

Acknowledgements: National Science Foundation, Maine Coastal Program, Maine Geological Survey

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Evaluating Historical Climate Variability in Maine with Implications for Future Agricultural Productivity and Food Security

Carly Frank[1], Sean Birkel[1,2], Sandra De Urioste-Stone[3]

1. *Climate Change Institute, University of Maine.*
2. *Cooperative Extension, University of Maine.*
3. *School of Forest Resources, University of Maine.*

Abstract: This study uses an interdisciplinary approach to provide a holistic understanding of the challenge posed by climate change to the agricultural sector in Maine. In all, this work will help to inform climate adaptation and mitigation strategies for safeguarding the productivity and sustainability of food systems in Maine.

Climate change threatens food systems globally. In the state of Maine, where annual temperatures have increased approximately 3ºF and precipitation has increased by approximately six inches, future impacts to the productivity of potato, wild blueberry, and hay crops are of particular concern (Fernandez et al., 2020). To better understand possible future impacts, this study in progress examines historical climate trends of agricultural metrics and utilizes survey instruments to gauge climate change risk perceptions. The historical climate analysis evaluates daily and monthly climate data, 1981-present, to identify annual changes in growing-season length, accumulated degree-days, evapotranspiration, drought occurrence, and incidence of heavy precipitation. In addition to time series analysis (Fig. 1), this work will result in a series of maps depicting changes in agricultural climate metrics for historical periods, as well as mid and late-century estimates from climate model projections. One such set of maps will identify changes in plant-hardiness zones, which are calculated based on annual extreme minimum temperatures.

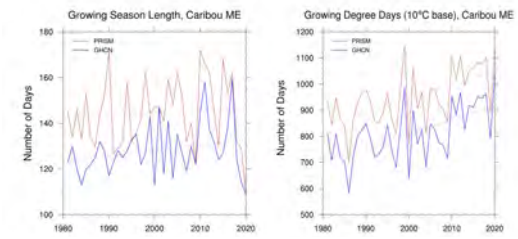

Fig. 1. Comparison of annual growing season length and growing degree day accumulation in Caribou, ME, calculated from station observations (GHCN; 2012) and gridded data (PRISM; Daly et al., 1994).

In accordance with warming temperatures, initial results show a lengthening growing season, primarily due to later fall frosts. Degree0day accumulation analyses will be conducted for multiple temperature baselines in accordance with the sensitivities of different crops.

To provide a holistic understanding of future climate impacts on crops, two survey instruments were designed with the intent to measure climate change risk perceptions. A short questionnaire was developed and administered to Maine wild blueberry growers, and a more extensive questionnaire is being developed to gauge climate change risk perceptions of migrant workers using the van der Linden Climate Change Risk Perception Model.

Acknowledgements: Supported by the National Science Foundation under award #1922560.

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Ultra-High-Resolution Sampling of Allan Hills Blue Ice Area Paleoclimate Archive, Using the CCI WM KECK Laser Ice Core Facility System

Lela Gadrani [1,2], Andrei V. Kurbatov[1,2], Paul A. Mayewski[1, 2], Elena V. Korotkikh[1]

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

Abstract: We measured the ice chemistry of 130-115 ka old samples from a core collected at the Allan Hills Blue Ice Area (AH BIA) using the ultra-high-resolution laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) method developed at CCI. The aim is to reconstruct changes in airmass sources using unique glaciochemical signatures of impurity levels preserved in ice during the last major paleoclimate transition into the Eemian.

Introduction

The Climate Change Institute WM Keck LA-ICP-MS system was used to sample paleoclimate archives from the ice core collected from the AH BIA in Antarctica (76^{0}43'S, 159^{0}40'E).[1] (Fig.1).

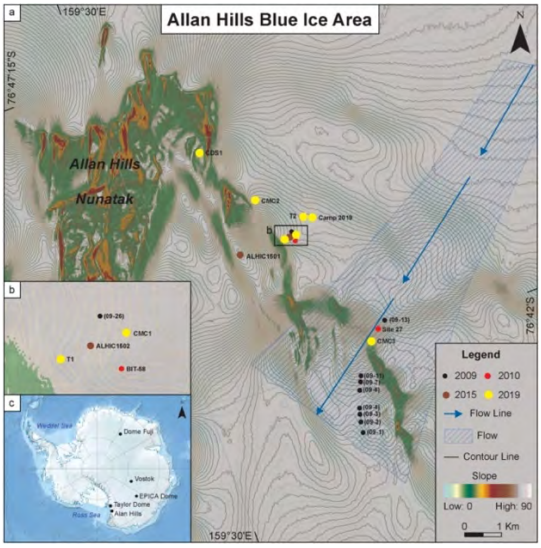

Fig. 1. Study Area, Allan Hills BIA

The last interglacial (Eemian) is well represented in AH BIA. Our goal is to reconstruct high resolution details of the Eemian onset using changes in glaciochemical signatures of airmasses during this transition. The developed ultra-high-resolution glaciochemical record is based on continuous single line profiles of ^{44}Ca, ^{27}Al, ^{56}Fe, ^{25}Mg, ^{23}Na, ^{63}Cu, ^{208}Pb sampled at 120 µm resolution. We measured six ice core sections, each ~60 cm in length, from the AH BIA site 27, with a total sampling length of 3.40m. LA-ICP-MS analysis allows identification of annual signals in compressed ice (Fig.2). In all selected sections from the time interval (~131-136 ka) we annually dated the ice core (see example Fig. 2) using sub-annual fluctuations in Mg, Fe and Al. We observed that not all elements show the same variability in magnitude and duration of changes in signal intensity in the studied intervals.

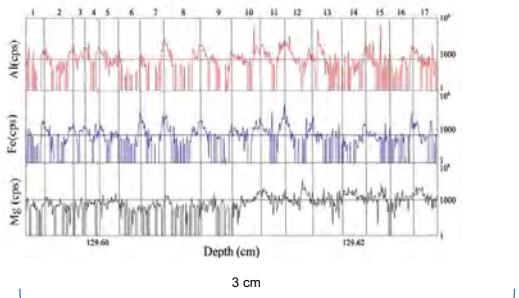

Fig. 2. Annual layers counting example. Ice core AH: site27, section #152 (Age B.P 129,595-129,625)

This work confirmed that annual layer counting is compatible with previously developed stable water isotopes and trapped gases time scales [1] We are currently investigating how fast the Eemian onset occurred and developing a proxy-based data framework to fingerprint the airmass sources and paleo pathway changes during the last interglacial period.

Acknowledgements: The National Science Foundation (NSF) Grant number: 1745007)

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Arctic Teleconnections to Maine Lake Ice-On Dates

Amanda Gavin[1,2], Jasmine Saros[1, 2]

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

Abstract: Increasing air temperature in the Arctic has led to a rapid decline in Arctic sea ice. Preliminary results show that there is negative relationship between Arctic sea ice minimum and fall air temperature in Maine, and this research will explore the impact on ice-on in Maine lakes.

Arctic amplification, an accelerated warming of surface air temperatures in the Arctic that is two to three times greater than the global average, is a phenomenon that has contributed to a rapid melting of Arctic sea ice [1]. Arctic sea ice minima, observed in late summer or early fall, began decreasing linearly in the 1980s followed by a "tipping point" or abrupt decline in 2007, leading to a 50% reduction in sea ice minimum extent over 4 decades [2]. Dynamic changes in arctic sea ice can act as a remote forcing, or teleconnection, that influence atmospheric circulation and weather patterns elsewhere in the northern hemisphere and mid-latitudes.

Research shows that central and eastern North America are most likely to experience extreme weather related to sea ice loss, and this results in persistent, warm air temperatures in the fall season [3]. Preliminary data analysis shows that there is a strong, negative relationship between arctic sea ice minimum and fall air temperature in Maine, where warmer falls are correlated with less arctic sea ice (Figure 1). For the first chapter of my dissertation research, I aim to understand the effect of arctic sea ice minima on interannual variability of ice-on dates in Maine lakes and the ecological consequences of a possibly warmer and ice-free fall.

It is well documented that the timing of ice-off in lakes is a coherent, sentinel response to climate change, and lakes across the globe have experienced later ice-on and earlier ice-off dates, resulting in less total ice cover [4]. Multi-century and multi-decadal ice-off trends show that ice-off in Maine lakes has become significantly earlier and can be linked to warmer winters and atmospheric teleconnection patterns [5]. However, ice-on dates are historically less studied than ice-off dates due to less historical recording of ice-on. As scientists work to close the data gap in winter limnology, advancements in remote sensing and a concerted push to encourage citizen scientists to record ice-on have been advocated for enhance the understanding of ice phenology and the lake ice continuum. [6].

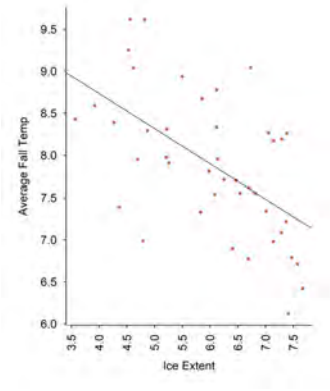

Fig 1. Significant linear relationship between arctic sea ice minima and fall Maine fall air temperature.

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Using New Paleoecological Methods to Advance our Understanding of Indigenous Connections to Maine's Interior Landscapes

Kit M. Hamley[1,2], Bonnie D. Newsom[1, 3], Jacquelyn L. Gill[1, 2]

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

Abstract: Understanding Maine's past ecological and human history has implications for modern conservation efforts and Indigenous sovereignty. Lipid biomarkers extracted from sedimentary lake records are an emergent proxy that have been used as a direct indicator of human presence and activity in various settings, but thus far have not been tested in the Northeast.

Fecal biomarkers extracted from sedimentary contexts are an emergent proxy that can shed light on past ecological contexts. Recent work has sought to quantify fecal biomarker ratios in sedimentary contexts to identify human presence and relative population size. Human fecal biomarkers extracted from lake sediments offer a direct record of human activity, unlike many other indirect paleoecological proxies. Together the combination of traditional and novel proxies offers a promising way forward for understanding the complexities of past human and ecological interactions.

We are conducting sedimentary fecal biomarker research at two culturally important locations in Maine: Chemo Pond and Sebasticook Lake. In the summer and fall of 2021, we retrieved a 595 cm long lake sediment core from *Chemo Pond* and a 432 cm sediment core from *Sebasticook Lake.*

The Chemo Pond core represents continuous sedimentation from ~12,000 cal BP to modern day. It covers the earliest known period of Native American occupation in the Penobscot River Valley (PRV), represented by artifacts from the Blackman Stream site downstream of Chemo Pond (Sanger et al. 1992; Kelley & Sanger, 2017). Analysis of sedimentary fecal biomarkers may provide insight into the antiquity of Indigenous connections to the cultural landscape of the PRV through to present day.

The Sebasticook Lake core was extracted near a fish weir complex dating to at least 5820 ± 60 ^{14}C yrs BP (Miller, 2006; Peterson et al., 1994). Pairing the core extraction with the weir complex offers a unique opportunity to identify human activity through analysis of fecal biomarkers in a well age-constrained setting.

This research is the first of its kind in the Northeastern United States and has the potential to enhance how we conduct anthropocentric paleoecological inquiries in this region. We are working closely with the Tribal Historic Preservation Officers (THPO) of the Wabanaki Nations to identify ways that this research can benefit Indigenous sovereignty and and serve other tribal interests.

Acknowledgements: We thank the Wabanaki Nations THPOs for continued partnership on this research. We are supported in part by MSGC and NSF CAREER- Grant EAR-1753186.

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Consequences of Ice-Out Timing Variability for Physical Structure of Small, Arctic Lakes in West Greenland

Václava Hazuková[1,2], Benjamin T. Burpee[3], Robert Northington[4], N. John Anderson[5], Jasmine E. Saros[1, 2]

1. *Climate Change Institute, University of Maine.*
2. *School of Biology and Ecology, University of Maine.*
3. *GZA GeoEnvironmental, Inc..*
4. *College of Science and Humanities, Husson University.*
5. *Department of Geography, University of Loughborough.*

Abstract: While lakes worldwide are losing ice-cover earlier during the year, we do not know how lakes respond to this phenological shift. We studied how ice-out timing variability affects thermal structure of lakes in West Greenland. In years with early ice-out, lakes were overall warmer with deeper mixed layer; however, responses of thermal structure were also modulated by air temperature.

Earlier loss of lake ice resulting from increasing winter and spring temperatures has been observed in lakes worldwide (Sharma et al., 2019); however, it is currently unclear what are the consequences of this phenological change on lake ecosystems—particularly in remote Arctic systems. To understand how ice-out timing variability affects lake thermal structure, we explored an extensive dataset of lake temperature profiles from a suite of lakes in Kangerlussuaq, West Greenland that have been monitored for over a decade.

The effect of ice-out timing on lake thermal structure and dissolved oxygen was strong. In general, West Greenland lakes tend be warmer and have deeper mixing depths in early ice-out years, accumulating more heat.

However, it is not that simple. The response of these lakes to early ice-out is modulated by summer air temperatures. For example, while lake water temperature of the surface layer will tend to be higher in early ice-out years, very high summer air temperatures can moderate the cooling effect of late ice-out, resulting in similar lake water temperature in the top layer (Fig. 1).

Discerning complex shifts in thermal structure driven by ice-out timing and air-temperatures is important because physical structure of lakes governs fluxes of gases and distribution of resources, with direct consequences for primary production and survival of higher, aerobic organisms such as fish.

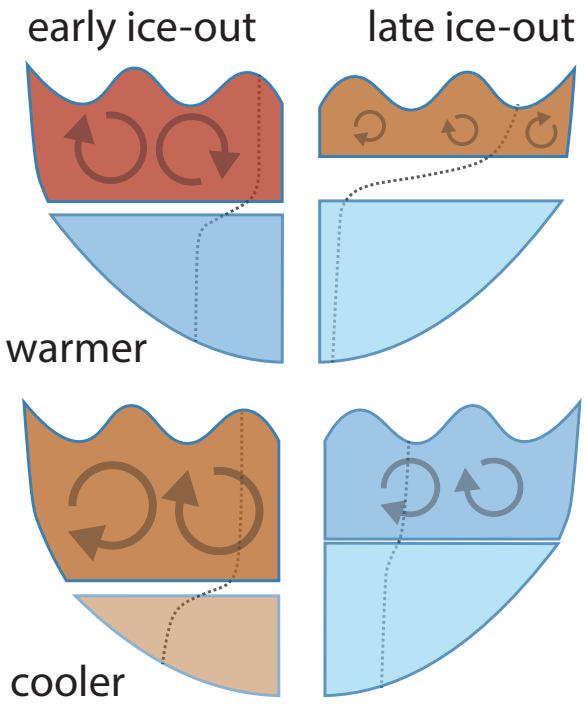

Fig. 1. Conceptual diagram showing interactive effects of air temperature (top and bottom) and ice-out timing (left and right). Color gradient from red, and brown to blue suggests changing temperature of the water from warmer to cooler.

Acknowledgements: Funding for this project was generously provided by Dan and Betty Churchill Exploration Fund and the following NSF awards: 1203434, 1144423.

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Revisiting the South Pole: New Tricks for Old Tephra

Meredith E. Helmick[1, 2], Andrei V. Kurbatov[1, 2]

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

Abstract: By using advanced methods and technology, we captured a wider range of cryptotephra compositions than previously reported for five tephra-bearing intervals of South Pole firn and ice. Several intervals contain particles likely of both sub-tropical and local origin. Analysis of a c. 1600 C.E. interval reaffirm the presence of Huaynaputina (1600 C.E.) tephra in South Pole ice.

Introduction:

Polar ice cores have proven to be valuable record keepers of past explosive volcanism. Gaseous (volcanic aerosol fallout) and solid (pyroclastic material, or *tephra*) eruption components that make their way to the polar regions are often deposited onto and later incorporated into the ice. Both components are important in our understanding of the timing, magnitude, and climactic impacts of volcanic eruptions. Traditionally, volcanic aerosol fallout indirectly measured as increases in acidity and electrical conductivity has been used to identify volcanic deposits in ice. However, few studies have chemically identified the sources of low concentration, ultra-fine volcanic ash (cryptotephra) deposits. A pioneering study of the PS1 ice core from South Pole identified five cryptotephra horizons corresponding to depth intervals of increased acidity[1]. Armed with improved technology, refined methodologies, and the recently drilled South Pole Ice Core (SPC14); we revisit these tephra-bearing volcanic intervals of South Pole ice.

Methodology:

Cryptotephra sampling of SPC14 was guided by the SP19 timescale and major ion data[2,3]. We were able to achieve finer sampling resolution than previously possible for each of the five volcanic intervals previously mentioned. Each sample was processed and mounted using recently developed methods designed for maximum cryptotephra particle retention, opposed to the meltwater filtration method employed by the previous study[1]. Sample mounts were then examined and analyzed by SEM-EDS.

Results and Discussion:

We report the composition of SPC14 cryptotephra span a wider range than previously reported for each targeted volcanic interval (see table 1), suggesting both sub-tropical (dacite-rhyolite) and local (trachyte) particle capture. Analyses of the 1593-1600 (CE) interval are comparable to those from the same interval in PS1 and from Huaynaputina (1600 CE) pumice[1], which should expel any doubt that tephra from the 1600 CE eruption was transported to the Antarctic continent. These findings are informative for understanding the volcanic eruption dynamics and atmospheric transport of local and distal tephra.

Table 1. Composition of South Pole Cryptotephra

Event Age Palais et al., 1990	Palais et al., 1990	This Work
1816-1821 (CE)	T	TA, T, R
1809-1813 (CE)	TA	TA, T, R
1593-1600 (CE)	R	R, T
1589-1593 (CE)	D	BTA, T
1258-1264 (CE)	T	RD, T

T = trachyte, TA = trachyandesite, R = rhyolite, D = dacite, BTA = basaltic trachyandesite, RD = rhyodacite

Acknowledgements: Support providing by NSF awards # PLR-1543454 and 1543361.

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Co-Creating Accountability Indicators with Alternative Seafood Networks

Paloma R. Henriques[1,2], Joshua S. Stoll[2,3]

1. *Climate Change Institute, University of Maine.*
2. *School of Marine Sciences, University of Maine.*
3. *Senator George J. Mitchell Center for Sustainability Solutions, University of Maine.*

Abstract: As awareness around overfishing, habitat loss, labor abuses and issues of equity and access in fisheries have increased, certifications are being used to incentivize sustainability. However, certification schemes have been criticized for not fulfilling their purpose, being inattentive to socioeconomic and cultural dimensions of sustainability, and disproportionately disadvantaging small-scale fishing operators. The University of Maine is collaborating with the Local Catch Network, a network based around small-scale fisheries, and Sitka Salmon Shares, a Community Supported Fishery, to conduct participatory action research on accountability indicators.

Project Goals: To design measurable metrics that can be used as the basis for a self-reflective or peer review tool. This applied research aims to take a step towards changing the way certifications are used and deployed in fisheries in North America and beyond by co-creating measurable metrics for accountability among small-scale seafood enterprises in North America and piloting a process that seafood enterprises can use to evaluate their operations.

Initial Results: We conducted a literature review of each of the nine core values of the Local Catch Network (LCN) with the goal of reaching a saturation of concepts for each. This resulted in 169 candidate indicators, which were further refined through workshops to a total of 79.

Figure 1. Preliminary indicators mined from a review of the literature organized into categories of 1) Organizational Structure, 2) Environment, 3) Production, 4) Consumption, 5) Spiritual Connection.

We then conducted a survey with members of the LCN to solicit input on the candidate indicators. A total of 43 people responded. The results of the survey were used to engage our Advisory Committee, a volunteer group of LCN members who are directly involved in seafood enterprises.

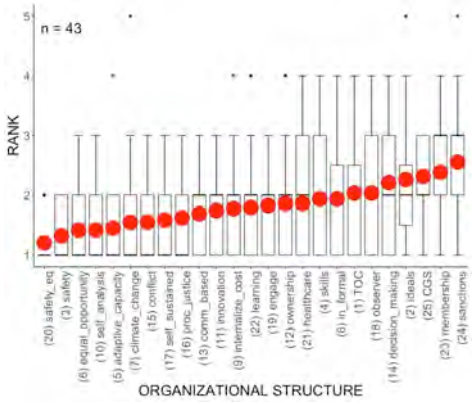

Figure 2. Survey results for Organizational Structure indicators.

We have held three meetings with the nine-member Advisory Committee, using an adaptation of the Policy Delphi method for consensus building. The committee is currently working on finalizing their feedback.

Acknowledgements: This research is funded by Sitka Salmon Shares, The Robert and Patricia Switzer Foundation, and the University of Maine. Thank you to Advisory Committee members Clint Benson, Hannah Feenstra, Pete Halmay, Michael Kohan, Emma Kramer, Natalie Sattler, Kevin Scribner, Sonia Strobel, and Feini Yin.

Roque Island Group and Holmes Point West: A Comparative Study of Archaeological Ceramics in Downeast Maine

Matthew James[1, 2], Bonnie Newsom[2]

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

Abstract: Ceramic manufacturing has been an underserved area of archaeology for several years but has the potential for new methods and methodologies to be employed. In 2017, the discovery of *Abies balsamea* conifer needle impressions within the ceramic assemblage from Holmes Point West (ME 62-8) provided a new avenue for examining manufacturing traditions and local variation. The inclusion of tempers not normally seen in the archaeological record can be seen as an indicator for the interactions between a unique ecosystem and cultural group.

Project Goals:

This study aims to further our understanding of regional variation in ceramic manufacturing traditions through a technological and comparative analysis of ceramic assemblages from the Roque Island Group and Holmes Point West. This analysis will refine Petersen and Sanger's (1991) framework for ceramic analysis in the Northeast and Canadian Maritimes, expand upon *Beyond Grit and Shell* (2019), and corroborate ecological models for the emergence of the maritime spruce-fir forest.

Site Overview:

The Roque Island Group (ME 61-16; 17; 34) and Holmes Point West (ME 62-8) are situated within the maritime spruce-fir forest ecoregion of Downeast Maine. These sites represent island and mainland communities respectively that were occupied during the middle ceramic period, which exhibit the impressions of *Abies balsamea*, a diagnostic species for the ecoregion, within their ceramic assemblages.

Ceramic Analysis:

Vessel lots have been created for each site using Petersen and Sanger's framework, with the inclusion of data specific to the *Abies balsamea* impressions. Identification of each vessel also did not begin with rim sherds, but with sherds that contained impressions. Most vessels utilized fine and well-sorted clay with <10% inclusion density for grit and shell temper. The high paste consistencies have provided some remarkably well-defined impressions. However, residue, breaks, or otherwise fragmentary impressions necessitates that each sherd be carefully analyzed under the microscope.

Fig. 1. Ceramic basal sherd #842.3, ME 62-8. Multiple *Abies balsamea* impressions can be seen.

Acknowledgements: Funded through the Maine Academic Prominence Initiative (MAPI) Grant. Special thanks to Dr. Bonnie Newsom, Dr. Daniel Sandweiss, Dr. William Belcher, and Dr. David Sanger.

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Boulder Clusters Improve Winter Habitat for Atlantic Salmon

Mark Jordan[1,2]

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

Abstract: Winter ice cover is important for the survival of Atlantic salmon. As the climate warms, the winter ice cover is likely to diminish. Several boulder clusters recently installed on the Narragugus River indicate that they can help reverse this trend. To better understand the associated hydrodynamics and ice-structure interactions, I am developing numerically models of ice bound boulder clusters.

Background:

Boulder clusters have the potential to be effective river restoration structures in Maine's rivers. During the past several centuries, modifications to Maine rivers and streams to enhance navigation, log drives, and other anthropogenic activities, resulted in substantial disturbances to aquatic and riparian habitats. Many of the modifications to the rivers and streams consisted of the removal of large roughness elements, such as natural log jams, boulders, and side channels. The degradation of habitat is considered one of the reasons for the substantial decline in the Atlantic salmon population in Maine's rivers and streams. van Zyll De Jong et al. (1997) evaluated the effectiveness of three types of restoration structures, V-dams, half-log covers and boulder clusters, and concluded that boulder clusters were the most effective at increasing the densities of juvenile Atlantic salmon.

Hedger et al. [2] showed that ice cover was important to the winter survival of Atlantic salmon and suggested that with climate warming, the duration and extent of river ice is likely to decline, resulting in adverse impacts on the juvenile salmon winter survival rates. Ice cover on rivers and streams forms because of several processes, including the formation of border ice, frazil ice and frazil ice pans. The freeze-up process is aided when there is a constriction in the river where the frazil ice pans jam up and allow the river to completely freeze over.

Initial Results:

During the last two summers, Project SHARE, a Maine based conservation organization, has installed several boulder clusters on the Narraguagus River in Washington County, Maine (Figure 1). During the last two winters, the boulder clusters have developed a ring of border ice early

Figure 1 - Boulder clusters on the Narraguagus.

in the season. In addition to their warm weather habitat benefits, it is likely that the combination of the boulder clusters and associated boarder ice act as a river restriction, trapping frazil ice pans and promoting river freeze-up earlier than otherwise would occur, thus helping to offset a potential adverse impact of climate warming.

I am just starting to develop 3D flow models to analyze the under-ice hydrodynamics and ice-structure interactions that are important to understand how well these structures will survive winter ice and spring floods (Figure 2).

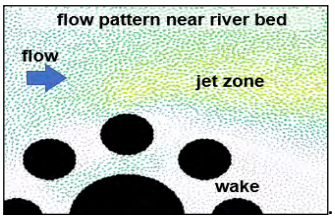

Figure 2 - Modeled flow patterns around an idealized boulder cluster.

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Maine Midden Minders: Confronting Climate Change Threats Through Interdisciplinarity, Citizen Science, and Community Engagement

Alice R. Kelley[1,2], Bonnie Newsom[1,3], Kristin Schild[1,2]

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

Abstract: Maine's shell middens/mounds are disappearing as a result of climate change-induced erosion. The Maine Midden Minders initiative works with conservation groups, historical societies, tribal communities, school groups and individuals to monitor and document these rich archives of cultural and environmental information before they are lost and provides a venue for public education and research.

Maine's approximately 2000 Indigenous shell middens/mounds are irreplaceable archives of archaeological, faunal, and floral material that record ancient Indigenous lifeways and past coastal environments. Ranging in age from 4,000 years old through European contact, these sites preserve organic material by buffering Maine's acidic soils through the decomposition of the carbonate shells. These important features represent a link to the archaeology pasts and cultural heritage of the Indigenous peoples of Maine.

Most shell middens along Maine's coastline are eroding rapidly due to climate change-related factors (sea level rise, increased storm frequency and intensity and greater numbers of freeze-thaw events). Many sites exist as remnants of much larger features, while an untold number have disappeared completely.

Research on shell heaps is impeded by limited resources, a marginalization of Indigenous heritage spaces, and few professionally-trained archaeologists. However, without action valuable information and irreplaceable cultural resources will be destroyed. The Midden Minders project confronts these issues by mobilizing citizen scientists to monitor erosion, record Maine shell heap information, and collect information to guide future cultural resource decisions. Additionally, the program provides a platform for research on past lifeways and environments.

The Midden Minders program works with conservation and historic preservation groups, tribal communities, schools, and individuals to establish monitoring programs to measure erosion, record storm impacts, and photograph eroded cultural material. This information is maintained in a secure database designed to protect site and landowner privacy. A robust outreach program includes public presentations, a website (umaine.edu/middenminders/), site visits, and a traveling photo exhibit.

Consultation with Tribal Historic Preservation Officers is an integral component of the Midden Minders program and essential for equity in heritage site management and research. Additionally, a webinar series is being developed to advance awareness of shell heaps within tribal communities and to inspire community conversations about shell heaps.

The Midden Minders program also serves as a research and teaching venue. Dr. Kristin Schild is piloting drone applications and Structure from Motion images as erosion monitoring and site identification tools in her Earth and Climate Science Geomatics classes. These data will help shape coastal cultural resource protection practices in the future.

In summary, the Midden Minders program collaborates with diverse stakeholders to preserve Indigenous heritage, address climate change impacts to cultural resources, increase the archaeological knowledge of Maine's past, and preserve information for the future.

Acknowledgements: Indigenous peoples of Maine; Original funding: ME SeaGrant, UM Mitchell Center for Sustainability Solutions. Website: ME SeaGrant, UM Public Affairs. Database: UM Advanced Computing Group, Research Funding: Maine Historic Preservation Commission, Historic Preservation Fund, Other Support: ME Historic Preservation Commission, Climate Change Institute, Maine Academic Prominence Initiative.

Thresholds for Melt Percolation at Eclipse Icefield, Yukon, Canada

Ingalise Kindstedt[1,2], Karl Kreutz[1,2], Dominic Winski[1,2], Colin Meyer[3], Luke Copland[4]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Department of Engineering Sciences, Dartmouth College.*
4. *Department of Geography, University of Ottawa.*

Abstract: Layers of refrozen melt in ice cores form when surface melt percolates into the snowpack before refreezing at the 0°C isotherm. Refrozen melt layers in ice cores may be used to infer surface temperatures at their time of formation if controls on percolation are understood. Here we use a percolation model based on Darcy's Law to show that melt percolation at ice core sites Eclipse Icefield and Icefield Divide (Yukon, Canada) may show threshold behavior controlled by the relationship between surface temperature and snowpack insulation.

Project goals:

The goal of this project is to examine the controls on surface melt percolation at Eclipse Icefield (Eclipse) and Icefield Divide (Divide) in the St. Elias mountains. Surface melting is driven by surface energy balance and correlates with surface temperature[1]. Refrozen melt layers preserved in ice cores may be used to infer surface temperatures at their time of formation if their percolation history is known[2]. However, the controls on melt percolation remain poorly understood, precluding easy interpretation of ice core melt layers. Here we use a percolation model[3] based on Darcy's Law for fluid flow through a porous medium to show that melt cannot be used as a temperature proxy at Eclipse or Divide because the surface energy flux and accumulation rate permit extensive percolation.

Initial Results:

We propose four distinct melt regimes separated by surface energy flux and accumulation thresholds. In the low melt regime, percolation is limited by melt supply. Here, melt layers can be used as a temperature proxy. In the lower intermediate melt regime, melt cannot be used as a temperature proxy because it percolates to depth, where it may refreeze (e.g. Eclipse, Fig. 1a) or remain liquid (e.g. Divide, Fig. 1b). In the upper intermediate melt regime, enough melt is produced to close off pore space, limiting percolation. Here, a melt-based temperature proxy may be possible.

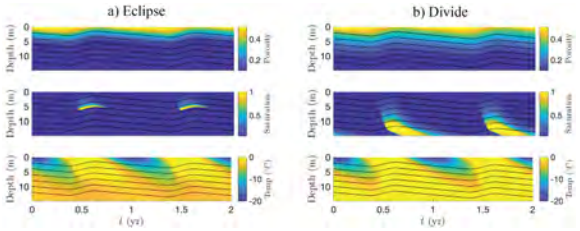

Fig. 1. Melt percolates to depth at Eclipse and Divide under mean conditions. The model was run with a mean annual accumulation rate of 1.4 m w.e. at Eclipse, a mean annual accumulation rate of 1.6 m w.e. at Divide, and a mean annual surface energy flux of -84.53 W m^{-2} at both sites.

In the high melt regime, runoff occurs and melt cannot be used as a temperature proxy. Results demonstrate the importance of surface energy balance and accumulation rate for melt layer preservation. More work is needed to validate our counterintuitive melt results and quantify the thresholds for transitions between regimes.

Acknowledgements: University of Maine Climate Change Institute.

[1] K.M. Cuffey and W.S.B. Paterson, *The Physics of Glaciers*, 4th ed. (Burlington, MA: Elsevier, 2010)

[2] Dominic Winski et al., "A 400-Year Ice Core Melt Layer Record of Summertime Warming in the Alaska Range," *Journal of Geophysical Research: Atmospheres* 123, no. 7 (2018): 3594–3611, https://doi.org/10.1002/2017JD027539.

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Evaluating the Links Between Warmer Winters and CyanoHABs in Maine Lakes Using Sediment Reconstructions and SedDNA

Avery N. Lamb[1,2], Jasmine E. Saros[1,2]

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

Abstract: Concern over increases in cyanobacterial blooms, the toxins they can produce, and the effect of climate change on these increases are becoming more prevalent in the Northeast U.S. This research will use photosynthetic pigment and sediment DNA (sedDNA) records at a decadal resolution across lakes in Maine to assess drivers of cyanobacterial harmful algal blooms (cyanoHABs), specifically the effects of warmer winters, over the past 150 years.

Project Goals:

Experiencing some of the most significant warming in the country, especially increases in winter temperatures, Maine has a unique climate setting with lakes that vary in trophic status situated across three climate zones (Fig. 1). Of specific concern to Maine's oligo- to meso-trophic lakes is the increase in abundance of *Gloeotrichia*, a toxin-forming cyanobacteria common in Northeastern U.S. lakes. The important roles of environmental conditions (e.g. light and temperature) on the recruitment and ultimate abundance of *Gloeotrichia* underscores the significance of understanding climate change impacts on the increasing frequency of cyanoHABs. This research capitalizes on Maine's limnologic diversity by using both more established (photosynthetic pigments) and novel (sedDNA) paleolimnological proxies to assess drivers of cyanoHABs at a decadal resolution over the past 150 years.

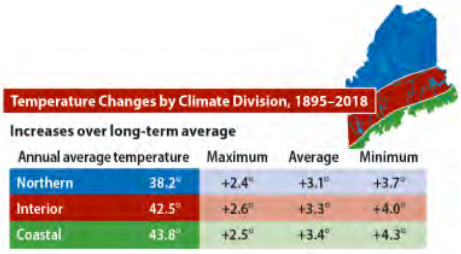

Fig. 1. Average annual temperature by climate division, with changes in minimum (winter), maximum, and average temperatures, 1895-2018. From Fernandez et al. (2020).

The objectives of this research are to 1) describe how the interactive effects of trophic state and climate change have altered overall cyanobacteria abundance in Maine lakes, and 2) investigate how decades of warmer winters have specifically affected *Gloeotrichia* populations in Maine lakes over the past 150 years.

Expected Results:

Photosynthetic pigments and sedDNA will be quantified in sediment cores from 12 lakes in the state. Quantification of specific toxin-producing cyanobacterial sedDNA, including *Gloeotrichia*, using ddPCR analysis and a larger reconstruction of whole-community algal dynamics via metabarcoding sequencing will be performed. The sediment cores collected will produce the longest time series of *Gloeotrichia* occurrence in a collection of lakes, as longer temporal reconstructions of cyanobacterial dynamics are needed to adequately assess climate-related drivers.

Broadly, a deeper understanding of the changing climate's effects on cyanobacterial abundance and potential cyanotoxin occurrence in Maine is necessary for management of valuable recreational and drinking water sources. In the future, federal, state, municipal, and public lake management organizations addressing increasing cyanoHABs in the Northeast can use these findings to better anticipate possible summer cyanoHAB occurrence based upon winter conditions.

Acknowledgements: USGS Grant Award #G21AP10180-00. Team members: Denise Bruesewitz, Peter Countway, Charlie Culbertson, Michael Kinnison.

Bibliography: Fernandez, I. et al. 2020. Maine's Climate Future 2020 Update. Orono: ME: University of Maine.

The Low Down on Lo Demás: an Inca Period Chincha Fisher Site

Heather A. Landázuri[1, 2]

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

Abstract: This project is ongoing and involves the processing, analysis and subsequent curation of previously unanalyzed archaeological materials from the site of Lo Demás in the Chincha Valley of Peru. The legacy collection that forms the basis of this research was excavated in 1984 by Dan Sandweiss. It was later stored at the University of Florida Natural History Museum for 38 years. In the Summer 2021, I was able to have the collection shipped to UMaine for analysis. The data it produces will inform my thesis. Here, I present a brief update on the progress of this research.

Background: Historic records and artifacts place Lo Demás's occupation during the Inca Period between 1480 and 1540 AD, just after the Spanish Conquest. Column samples were excavated from Sectors I (non-elite) & IV (elite) during Dan Sandweiss's 1984 field season but had remained unanalyzed since arriving at the University of Florida Natural History Museum shortly thereafter. My thesis focuses on the effects of ENSO on avifaunal consumption on the coast of Peru. The additional data collected from Lo Demás will add to my thesis work and further our understanding of environmental conditions during the site's occupation, the extent of differential access to goods between sectors, and the role of marine birds in Chincha/Inca ideology. Moreover, when compared to pre-Inca and post-Contact sites, data from this site can contribute to our understanding of how coastal communities operated under Inca and later Spanish rule.

Lo Demás was an important coastal polity under Inca rule. There, settlements were strictly divided by labor specialization and status; evidence indicates differential access to imported and exclusive resources (found in Sector IV) as well as differences in labor investments and responsibilities between the sectors. Whereas Sector I contained more avifaunal remains in subsistence contexts than Sector IV, avian motifs abound in the latter sector suggesting the importance of marine birds to the cultural identity of its inhabitants. Additionally, debris flow evidence at the site, likely associated with the 1578 El Niño, suggests the occurrence of ENSO related flooding. Considering the cyclical nature of these phenomena, it is extremely likely that this was not an isolated event. In fact, the initial analysis of domestic midden materials from Sector I suggests a shift in SSTs from a cooler "anchovy regime" to a warmer "sardine regime", with avifaunal remains dominated by marine species including cormorant, pelican, and gulls (Sandweiss, 1992; Sandweiss et al., 2004).

Methods and Findings: Samples were dry screened through an 1/8" geological sieve and sorted by material type. Due to the unusually good preservation conditions found on the desert coast of Peru, notable findings to date include textile and twine fragments, pottery sherds, bird and fish bone, marine shell, as well as beautifully preserved archaeobotanical remains such as peanut shells (and charred peanuts), maize cobs, and cucurbit and chili seeds.

Acknowledgements: Special thanks to the Churchill Exploration Fund for supporting this research, to Brenda Hall for her assistance with USDA foreign soils compliance, and to our undergraduate volunteers AJ, TM, LY for their assistance in the lab.

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Looking Back to Plan Ahead: Indigenous Coping Strategies in Response to the Devastating 1578 A.D. El Niño in Colonial Peru

Heather A. Landazuri[1,2], Elizabeth L. Leclerc[1,2], Daniel H. Sandweiss [1,2]

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

Abstract: Historical eye-witness accounts describe a devastating El Niño event that struck the north coast of Peru in 1578 A.D., less than 50 years after the beginning of Spanish colonization. Although convoluted by their colonial framing, changes in language and meaning, and our modern Western perspective, the accounts provide information about Indigenous strategies to cope with and adapt to El Niño. We link the historical record of these strategies to archaeological evidence to investigate the development of millennial traditional ecological knowledge (TEK) surrounding El Niño, with implications for future responses to this phenomenon. The study also increases our knowledge about El Niño's impacts on past human communities.

In 1578 A.D., a severe El Niño event devastated the north coast of Peru, causing extensive flooding, infrastructure damage, loss of lives, loss of crops and livestock, and plagues of rats, birds, and insects. In the wake of the event, local leaders petitioned the colonial government for tribute relief. Royal Scribe Francisco de Alcocer collected eyewitness accounts to determine whether such relief was warranted. About half of these transcripts have been recovered and published (Huertas Vallejos 1987).

Building on previous work (Copson and Sandweiss 1997), we've begun investigating the testimonies for coping strategies reflective of 16th century TEK. Our approach uses a relational database organized around place to extract and store information related to witnesses, the event, its impacts, and responses. This lets us identify patterned behavior and compare responses across communities. Spatial analysis allows further comparisons with the physical environment. For example, Figure 1 shows the relative difficulty of potential escape routes to *huacas* (ancestral monuments typically elevated above the floodplain) to which people fled for safety in 1578 and in modern times.

Emphasizing the resilience of Indigenous and local populations during a time of great distress, we found that some of the TEK mentioned in these witness statements reflects millennia of practice evidenced in the archaeological record with continuity into the present and value for future El Niño planning and response.

Figure 1. Relative difficulty of terrain and potential escape routes to known *huacas* in the Lambayeque Valley.

Acknowledgements: Funding provided by the McGillicuddy Humanities Center Faculty Grant Program and the National Science Foundation.

Bibliography: Alcocer, Francisco de, 1987 [1580]. *Probanzas de Indios y Españoles Referentes a Las Catastróficas Lluvias de 1578, En Los Corregimientos de Trujillo y Saña*, transcribed by Lorenzo Huertas Vallejos. Chiclayo, Peru: CES Solidaridad.

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Investigating Maine's Indigenous Fire Pre-History

Madeleine Landrum[1, 2], Erin Cabral[2], and Jacquelyn Gill[1, 3]

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

Abstract: Historical observations and Indigenous place names indicate that the Wabanaki people used fire to clear land for agriculture and improve hunting grounds, though our archaeological understanding of Indigenous fire use is geographically and temporally limited to the western quarter of the state and the last 500 years pre-contact. This study aims to expand our knowledge of Maine's history of agriculture and human fire use prior to colonization.

Project Goals:

As warmer temperatures and drought increase the frequency and intensity of forest fires in New England[1], the need to understand long-term natural and human fire history has never been more critical. Most of our knowledge about Indigenous fire use in New England is based on journals and other written accounts by early European settlers [2]. These only describe fire use post-settlement and from a colonialist perspective. This study aims to use Wabanaki traditional ecological knowledge (TEK) and paleoecology to further explore the human-forest relationship in Maine going back to deglaciation.

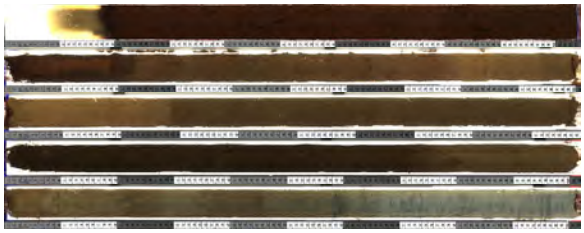

Figure 1. High resolution imaging of the Perch Pond core, courtesy of the CSD Facilities

Initial Results:

During the summer and fall of 2021, we collected a small hollow core from the Hirundo Wildlife Refuge (Old Town, Maine) and a lake core from the nearby Perch Pond (Figure 1) to investigate sediment accumulation over the last 14,000 years. These sites were selected due to their proximity to one of the longest known occupied sites in the state of Maine and allow for the comparison of fire record sensitivity across methodological scales. Cores were collected using a modified Livingstone piston coring device and extruded into PVC. They were then split, photographed, and tested for magnetic susceptibility and gamma density at the CSD Facilities. The samples are now being analyzed for macrofossils and charcoal. Radiocarbon dating of macrofossil leaves and twigs has shown the age of the Hirundo core to span from modern times to 9865 uncalibrated years before present (BP) and the midpoint of the Perch Pond core to be 8700 years BP. Continuous charcoal samples are currently being processed, examined under a dissecting microscope, counted, and classified by type. The charcoal record will provide us with a more localized fire history of the sites in central Maine.

Next Steps:

Once the charcoal analysis is complete, we will begin loss on ignition (LOI), phytolith, pollen, and human fecal sterol analysis of the Perch Pond, Hirundo, and other cores. When combined with climate data, these proxies will give us insights into human use of fire and agriculture in Maine prior to colonization.

Acknowledgements: Thanks to the BEAST Lab, Andrea Nurse, Bonnie Newsom, Darren Ranco, Donald Socktoma, Chris Sockalexis, Isaac St. John, Kendyl Reis, and the Hirundo Wildlife Refuge Board.

Funding: NSF Graduate Research Fellowship, Dan and Betty Churchill Exploration Fund, CSD Visiting Graduate Researcher Grant, and GSG Grant.

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Paleoclimate Influences on ENSO's Hydrological Risks and Opportunities

Elizabeth Leclerc[1, 2]

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

Abstract: The El Niño–Southern Oscillation (ENSO)'s land-based impacts in Peru are largely tied to water flows, distribution, and availability. Archaeologists interested in coastal communities' responses to ENSO frequently focus on the immediate and local impacts of canonical Eastern Pacific El Niño (EN) events. However, these events as well as other types of ENSO disturbances have basin-wide impacts that propagate through hydrological systems to again affect the coast in delayed, differing ways. Having synthesized paleoclimate records across the Andes, I use a model of paleohydrological dynamics in north-central coastal basins to examine how ENSO events departed from past conditions to present different suites of challenges and opportunities.

Background:

ENSO is a coupled oceanic and atmospheric phenomenon affecting the equatorial Pacific with events every 2-8 years. Spatial variability is organized into several types of events, of which four affect Peru (Sandweiss et al. 2020): Eastern Pacific (EP) EN, Central Pacific (CP) EN, Coastal (COA) EN, and La Niña (LN). These events disrupt "normal" climate patterns across Peru that themselves have varied through time.

Paleoclimate Review:

EP, CP, and LN events all affect highland precipitation, the primary source of runoff into coastal rivers. Thus, background highland conditions influence ENSO's impacts on coastal water availability. I reviewed 21 paleoclimate studies from the central Andes relating to atmospheric circulation, moisture balance, glacier mass balance, sea surface temperatures (SSTs), and ENSO. From these I identified millennial scale trends summarized in Figure 1.

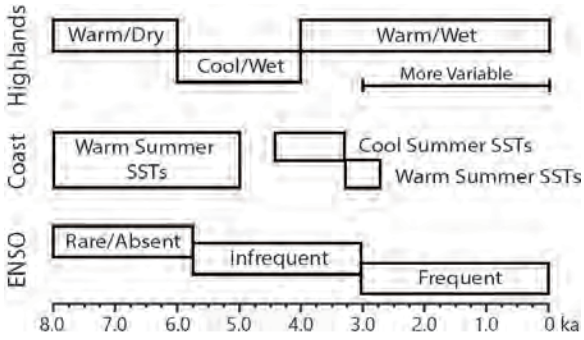

Fig. 1. Climate trends for north-central coast basins.

Paleohydrology, Risk, and Opportunity:

I used the climate synthesis to define four "zones" influencing hydrological dynamics at the basin scale: above snowline, highland, coastal, and fog precipitation areas. I then modeled how ENSO modes would have influenced hydrology in different periods. For example, from 6.0 to 4.0 ka, lower snowline and glacial resurgence increased highland water storage capacity and would have moderated increased (decreased) precipitation and runoff during LN (EP/CP) events. However, warmer temperatures after 4.0 ka would have rapidly diminished snowpack while glacier melt initially increased. LN events were more likely to cause rain (vs. snow) and flooding while EP and CP droughts were likely more severe, especially in newly de-glacierized basins. Highland climates affected ENSO influence on timing, duration, and amount of river flow to coastal valleys on top of coastal impacts such as flooding. Different ENSO modes yield different combinations of immediate and delayed impacts with varying consequences for flood risk, river stability, and agriculture productivity.

Acknowledgements: This research is funded by the National Science Foundation Graduate Research Fellowship Program.

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Change in Firn Thickness Across the Juneau Icefield Between 2012-2021

Mikaila Mannello[1,2], Jonathan Maurer[1,2], Seth Campbell[1,2], Ian Nesbitt[1,2], Jordan Farnsworth[2], Emily Holt[2]

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

Abstract: Firn is a crucial component of glaciers, indicating their health and ability to act as a regulator of meltwater flux. Changes in the volume of firn across the Juneau Icefield (JIF) have been observed since 2012 using ground-penetrating radar (GPR). The change in firn thickness between 2012 and 2021 is spatially variable and complex with an average decrease of 3 m. Overall, the decrease in firn thickness and distribution will have implications on the stability of the JIF in future years and affect regional downstream hydrology and ecology.

The goal of this project is to determine the change in firn volume across the JIF between 2012 and 2021 using over 150 km of repeated 400 MHz GPR profiles. Firn both regulates meltwater flux and is a necessary component in the metamorphosis of glacier ice. Changes in firn thickness and volume across the JIF are expected to impact the downstream hydrology and ecology of this region of Southeast Alaska[1].

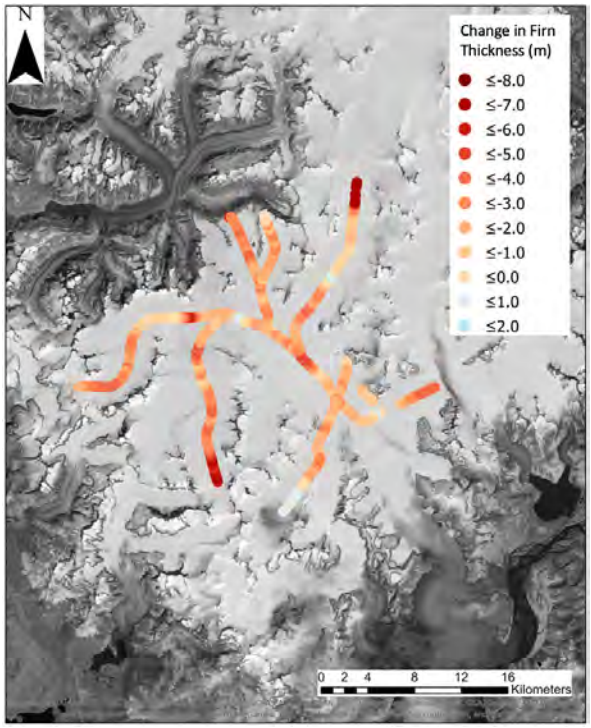

Fig. 1. Difference in firn thickness (m) between 2012 and 2021 along GPR transects where red values indicate a decrease in firn and blue shows an increase.

GPR surveys have been useful for decades to study englacial features[2]. We used a GPR with a center frequency near ~400 MHz to survey snow and firn thickness across the JIF. This system penetrates ~20m depth in temperate snow and firn which is approximately the maximum firn thickness on the JIF. Through delineating the annual accumulation and firn-ice transition layer depths, we determined the thickness of the firn layer in each year. The change in firn thickness was then calculated by differencing 2012 and 2021 thickness values (Fig.1).

A crucial component of this analysis is determining a method for applying a relative permittivity to the calculations for depth using two-way travel time. The relative permittivity and radar-wave velocity is affected by the water content and density of the snow or firn. To constrain this, we extracted several shallow snow cores and measured the accumulation layer thickness along GPR survey tracks. We observed the calculated relative permittivity of the accumulation layer to be spatially variable between 2.1 to 2.6. Future plans include quantifying the change in firn volume and using multi-offset radar and variable velocity analyses to determine the meltwater content of the firn.

Acknowledgements: This research was made possible through extensive support from students, faculty, and staff of the Juneau Icefield Research Program over the past nine years.

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Quantifying Temperate Firn Thickness: Integrating Geophysics and Deep Learning in Coastal Alaska

Jonathan Maurer[1,2], Mikaila Mannello[1,2], Seth Campbell[1,2]

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

Abstract: This project seeks to quantify and predict the spatial extent and thickness of glacial firn in temperate environments through geophysical remote sensing and deep learning methods. For this approach, a regression-based deep learning network was implemented and trained on labeled outputs from 400 MHz ground-penetrating radar (GPR) surveys collected across the Juneau Icefield (JIF), Alaska, in the summers of 2012, 2015, 2017, 2018, 2019, and 2021. In addition to validating GPR data, topographic, glaciological, and meteorological data are incorporated into the training dataset as predictor variables. Initial results from this model return a reasonable loss rate and a mean square error of 0.007

Firn is a key component in both glacial mass balance and regional hydrology but remains under-studied in temperate environments. Between 1961 and 2016, Alaskan mountain glaciers have exhibited a near constant negative average mass balance, with the resulting meltwater contributing significantly to global sea level change[1]. Further, the Pacific Coastal Temperate Rainforest glacier mass loss is among the highest rates in the world with the average area accumulation ratio of the JIF decreasing from 0.85 between 1946-2011 to 0.57 in 2018 [2,3]. This anomalous rate of mass loss and potential impacts on downstream systems makes the lack of understanding in these environments important to address.

The purpose of this study was to create a tool for predicting firn thickness and distribution on JIF. This required the creation of a dataset containing the target variable, firn thickness, and the predictor variables, slope, aspect, elevation, marine proximity, wind speed, wind direction, temperature, and accumulation layer thickness. For the target variable, 400 MHz GPR profiles were collected and processed to isolate the thickness of the firn layer. For the predictor variables, meteorological data are derived from the European Center for Medium-Range Weather Forecasting ERA5 reanalysis product and physical variables are collected from two Digital Elevation Model derived in 2012 and 2018. Compiled data were then fed to a densely connected neural network that trained for 100 epochs and returned a mean square error of 0.07 (see Fig 1). Next steps for this project include expanding the network to other years, modifying network parameters, and incorporating more data into the training process.

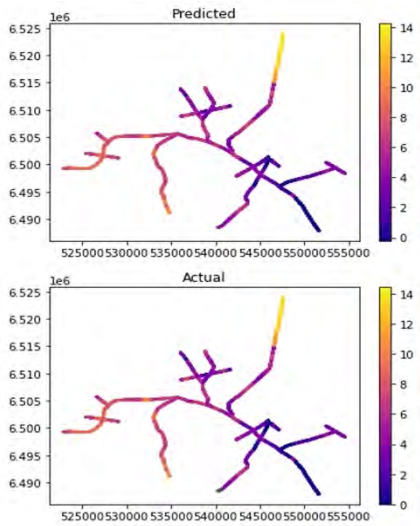

Figure 1. Network outputs (top) and ground truth measurements (Bottom) for 2012 radar profiles on JIF.

Acknowledgements: Support for this research was provided by the Foundation for Glacier and Environmental Research and the School of Earth and Climate Sciences.

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Oh, The Places They'll Go!: Examining Contemporary Tree Range Shifts

Bailey P. McLaughlin[1, 2], Brian J. McGill[1, 2]

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

Abstract: The geographic range of a species is a fundamental unit of ecology and biogeography. Efforts to understand geographic ranges and how they shift through time and space suggest widespread and multi-directional range shifts across taxa, which runs counter to predictions that species will migrate uniformly northward in latitude and upward in elevation as climate warms. Little effort has been made to systematically summarize the *variability* in range shift dynamics in a large-scale, multi-species context. Aiming to fill this gap, we evaluate the geographic ranges of all U.S. tree species partitioned into their distinct life-history stages (seedling, sapling, adult) and measure range shifts as a change in the size, position, and/or direction of the range between life-stage transitions. We evaluate tree range shifts in contemporary environments, on policy-relevant, generational timescales over which birth and death, the processes that ultimately set range limits, readily play out.

The rapidly growing availability of species occurrence data presents opportunities to readily estimate species' geographic ranges.[1] Importantly, species' ranges are dynamic in time and space.[2] Efforts to understand this dynamism and document range shifts suggest non-uniform and multi-directional shifts for a diversity of taxa.[3] Currently missing from the literature, however, is a large-scale, multi-species effort to evaluate range shifts in a quantitative context, capable of measuring the variation embedded in these dynamics.

We seek to fill this gap by partitioning species' ranges into distinct life-stage components to assess geographic range shifts in contemporary environments on generational timescales. Considering a species' range divided into its life-stage components presents the opportunity to quantify and track range shifts by snapshotting the range through time, using life-stage as a proxy for time. Trees are a model taxon with which to assess range shifts via this proposed life-stage-range-mapping comparison given their long lifespans and clear life-stage classes (seedling, sapling, adult).

We operationalize this approach for 380 tree species. Occurrence data from the Forest Inventory and Analysis database is partitioned into life-stages and mapped onto the contiguous U.S. Convex hull polygons and their centroids are drawn to represent each species' three distinct life-stages. Range shifts are measured as the change in range size, position, and/or direction between polygons/centroids.

Preliminary results suggest that tree species are shifting their ranges in contemporary environments, with considerable variation.

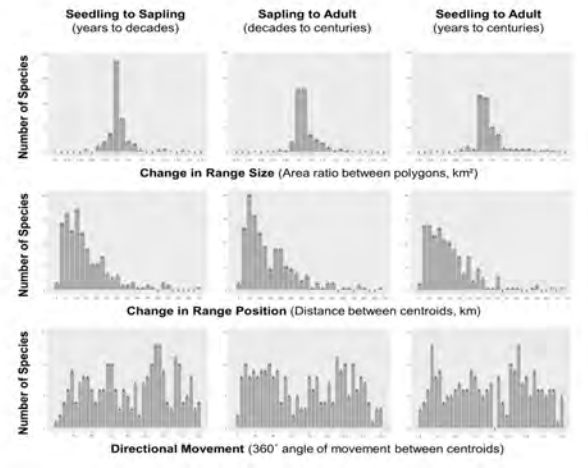

Fig. 1. Range shift metrics summarized.

Considering where juveniles exist in relation to conspecific adults presents an opportunity to evaluate incipient range shifts, moving beyond predictive models and historical inferences to query real-time empirical data.

Acknowledgements: Research supported by NSF, UMaine SBE, and UMaine MAEFES.

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Coproecology of the Mammoth Steppe: Reconstructing Diet and Environments of Pleistocene Arctic Megaherbivores

Alessandro Mereghetti[1, 2], Jacquelyn L. Gill[1, 2]

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

Abstract: The analysis of coprolites (fossil dung) is a powerful tool to reconstruct the diet of extinct animals. By studying coprolites, we can learn how animals interacted with their environment and what food they ate. The cold Arctic temperatures allow for excellent fossil preservation, but until now the number of coprolites found was too low to understand how the extinct herbivores differed in their diets. In 2019, an expedition organized by the University of Maine recovered 59 coprolites from Siberian locations rich in mammoth steppe fossils. I used those samples to reconstruct diet and environment of Arctic megafaunal herbivores over 20,000 years using pollen, macrofossils, and ancient DNA.

Description: The mammoth steppe was a mosaic of grassland and tundra that covered most of the Arctic during the last 100,000 years. This ecosystem was shaped by the action of abundant populations of large, cold-adapted herbivores (woolly mammoth, woolly rhinoceros, steppe bison, caribou, muskoxen, wild horses) and disappeared around 10,000 years ago, along with most of its dwellers. The community structure of the mammoth steppe's herbivores is still subject to debate: the prevailing hypothesis is that their coexistence was possible thanks to a high level of dietary specialization (different animal species were each feeding on a different set of plants). Studies based on the shape and structure of skeletons of extinct Arctic herbivores, however, suggest that they were all feeding on grass, with a low level of specialization. To understand the dietary profile of Arctic Pleistocene megaherbivores, we conducted a multiproxy investigation on 59 coprolites that we collected during the 2019 CCI expedition to the Republic of Sakha (Russia). We analyzed the pollen, macrofossil and ancient DNA content of the coprolites, revealing that they were deposited over a timespan larger than 40,000 years during the Late Pleistocene. Pollen results shows that the environment experienced by the megaherbivores didn't change significantly over that period of time. Further analysis of the plant and DNA content of the coprolites will shed light on the similarity and differences between species diets, and allow us to understand the community ecology of the now-disappeared mammoth steppe ecosystem.

Figure 1. Pollen spectra and aDNA identificaton of the coprolites

Acknowledgement: The expedition was founded through NSF CAREER grant awarded to Jacquelyn Gill. The analysis of the samples was funded through the NSF CAREER grant, the GSA Charles A. and June R.P. Ross Research Grant and the University of Maine GSG grant.

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Abrupt Climate Change During the Last Glacial Termination in Maine

Maraina Miles[1,2], Brenda Hall[1,2]

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

Abstract: The termination of the last ice age (17.8-11.7 ka) provides a unique view into how the global climate system responds to rapid warming. Extreme seasonality, with drastically unequal temperature changes in summer and winter may have played a key role in abrupt climate changes during the termination, but the full implications - and even the existence - of this seasonality remain controversial. Here, I will test the hypothesis that extreme seasonality affected the North Atlantic region during the termination and that this has skewed our interpretation of iconic climate events, such as the Bølling-Allerød (BA; 14.6-12.9 ka). Specifically, I will use changes in the extent of the Maine Ice Cap, constrained by 10Be exposure ages of a newly discovered moraine sequence in northern Maine to reconstruct summer temperature variations.

The global warming of the last glacial termination (~17.8 – 11.5 ka) marks the most recent analog for our planet's current rapid warming. It was characterized by abrupt climatic oscillations, including the Bølling-Allerød in the Northern Hemisphere and the simultaneous Antarctic Cold Reversal in the Southern Hemisphere (BA and ACR; 14.7 – 12.8 ka). The conventional view is that during these abrupt changes, the hemispheres were climatically anti-phased as the result of an ocean and atmosphere driven 'bipolar seesaw' (Broecker, 1998). However, recent data on the timing and extent of alpine glaciers suggest this may not be the case and that the hemispheres instead may behave synchronously during these abrupt changes, and that the discrepancy between records is due to increased seasonality (Denton, 2005).

Here, I will test whether the Maine Ice Cap advanced during the BA which would favor the seasonality hypothesis. New LiDAR has exposed a previously unknown moraine complex in the southern section of Baxter State Park (Fig. 1). Preliminary data, including one radiocarbon age from a nearby pond and exposure-ages of boulders located ~30 km south of the moraine suggest that this landform may have formed during the BA. To determine the timing of ice readvance, I have collected samples from boulders along the moraine complex for cosmogenic 10Be surface exposure-age dating and will compare these ages with other records to determine if seasonality played a role in the last glacial termination.

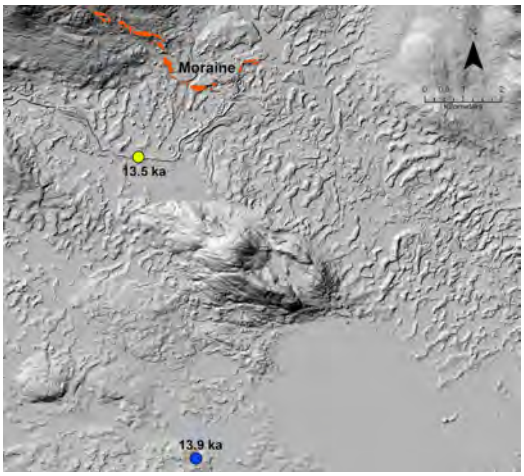

Fig. 1. Newly discovered moraine complex (orange) in the southern portion of Baxter state park. Age in yellow is a proximal basal limiting radiocarbon age from Davis, 2015 and the age in blue is a distal unpublished exposure age by Hall. Both ages suggest that this moraine may have been deposited during the Bølling-Allerød (BA; 14.6 - 12.9 ka).

Acknowledgements: Thank you to the Dan & Betty Churchill Exploration Fund for support.

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Water Quality in the Rapidly Changing Environment of Southwest Greenland

Ligia Naveira[1, 2], Paul A. Mayewski[1, 2,] Mariusz Potocki[1, 2], Kevin Anderson[1, 2], Douglas Hasson[1], Kristina Grimaldi[3], Charles Norchi[1,3], Kiley Daley[1], Cory Limberger[1,3]

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

Abstract: Water interweaves all components of the Arctic complex system. In southwest Greenland, we plan to monitor water quality that originates from melting ice, permafrost, snow, and streams.

The Arctic is a multifaceted complex system interconnected by biogeophysical and social components that interact dynamically within the region and the Earth system. Over the past decades, it has undergone significant changes mainly driven by an increase in temperature, such as the abrupt rise in temperature in the eastern Arctic of 5°C in the period 2007-2012. In Greenland, the increase in the mean temperature by 3°C on the west coast and consequent ice melting have caused substantial changes in all ecosystems (Mayewski et al. 2014). Our portion of the NSF funded Navigating the New Arctic NRT project focuses on southwest Greenland and aims to attain a system-level understanding of the role of changing water quality in the Arctic. The region captures an array of sub-systems and linkages, such as atmosphere, ocean, Greenland Ice Sheet (GIS), localized glaciers, land, and human aspects. The area is also home to a UNESCO World Heritage Site.

Water is a crucial component that interweaves all sub-systems in this rapidly changing environment, including the local population and ecosystem. Since the Industrial Revolution, aerosols from North America and Eurasia have been transported and trapped in the GIS. Together with natural sources, pollutants can alter water chemistry with potentially serious implications to human and ecosystem health, marine productivity, and the economy. Our research focuses on assessing and monitoring water quality originating from the melting of the GIS, permafrost, snow, and stream waters.

We will carry out analyses of the chemical composition of snow, surface and stream waters, and ice that provide a measure of: (1) major soluble ions (Na^+, K^+, Ca^{2+}, $Mg^{2+,}$ Cl^-, NO^{3-}, SO_4^{2-}); (2) major elements (Al, S, Ca, Fe, Na, Mg); (3) trace elements (Sr, Cs, Ba, Bi, U, As, Hg, Tl, Li, Ti, V, Cr, Mn, Co, Cu, Zn); (4) rare earth elements (La, Ce, Pr, Nd, Sm, Eu, Tb, Dy, Ho, Er, Tm, Yb, Lu); (5) stable water isotopes (δ18O and δD); (6) microplastics and (7) per-and polyfluoroalkyl substances (PFAS). Additionally, we will estimate background values and examine how the chemical composition of water has changed over time and spatially using past ice cores studies. This study will provide a framework for future water quality monitoring in Greenland.

Figure 1: Map of the study area. Source: UNESCO website, “Kujataa Greenland”.

Acknowledgements: A grant from the NSF NRT-NNA System Approaches to Understanding and Navigating the New Arctic (SAUNNA) program (PI Saros).

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Mt. Everest, South Col Glacier Ice Core – Collection, Sampling and Preliminary Results

Mariusz Potocki[1,2], Paul Andrew Mayewski[1], Heather Clifford[1,2], Elena Korotkikh[1]

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

Abstract: The world's highest ice core, extracted from Mt. Everest's South Col glacier, reveals well-preserved annual layers and a several hundred-year record of past climate and environmental changes.

Himalayan glaciers are sensitive indicators of climate change. The 0.6°C increase in global temperature since mid 20th century has contributed to the widespread melting of high elevation glaciers in this region.

Climate in the Himalayas is strongly influenced by the Asian Monsoon. Mt. Everest is at the boundary of air masses associated with this system and the Asian high pressure system, and thus is sensitive to changes in monsoon and Tibetan Plateau weather patterns.

In April/May 2019 the National Geographic and Rolex Perpetual Planet Mt. Everest Expedition conducted the most comprehensive scientific expedition to the mountain in history. This international, multi-disciplinary expedition resulted in the world's highest ice core - Mt. Everest's highest glacier - South Col Glacier (8020m), in addition to other ice cores collected at lower elevation. Ice cores from this elevation are generally characterized by very low ion burdens representative of relatively clean upper tropospheric air. Glaciochemical, oxygen and nitrogen isotopic analyses of the South Col ice indicate that the climate record is well preserved.

Aerosol-based micro-radiocarbon (Uglietti et al., 2016) dating of the ice core from 10 to 69cm below the surface reveals an age of 1966+/-179 (cal BP). Mean annual layer thickness in the recovered ice is about 27 mm w.e. a^{-1} based on laser analysis of selected ice sections (Fig. 1). Assuming this is representative of the past ~2,000 years, multiplying by the near surface age this yields an estimated net thinning of SCG of ~55 m w.e. since the 1990s (Potocki et al., 2022).

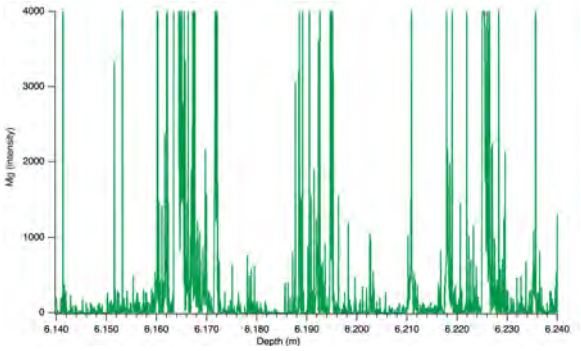

Fig. 1. Example of ultra-high resolution (153 micron) laser sampling from 6.14-6.24 m depth in the South Col ice core. Winter/spring maxima in magnesium (intensity counts per second) allow the identification of net annual layering of ~27 mm w.e. a-1.

Moreover, our South Col Glacier ice core provided the first such a high-altitude record of heavy metal and trace element measurements (eg. Pb, Cd, As, La, Ce, Pr, Ti) from the Pre-Industrial Era, and the first high-resolution Asian record from which natural baseline concentrations and subsequent changes due to anthropogenic activities can be determined.

Acknowledgements: Funding for this project was provided by National Geographic and Rolex Perpetual Planet.

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Elements and Frameworks of Arctic Systems Thinking By Who and For Who

Maya Reda-Williams[1, 2], Darren Ranco[1, 2]

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

Abstract: As the world of science grows and evolves there is becoming an increasing need across all disciplines to combine their efforts and skill sets in order to more fully grasp the picture of a rapidly changing world. This has lead to an increase in systems thinking. However, the intellectual frameworks used to interpret systems is not always representative of the disciplines involved, or, more importantly, the people involved in the system in question. In this theoretical paper I examine three elements that are necessary for a holistic and caring approach to interdisciplinary cross-cultural science systems thinking: interconnectedness, relationality, and context. These elements are well established in the ICC Ethical And Equitable Engagement Synthesis Report as well as the ICC Food Security Summary and Recommendations Report and can be used as a helpful framework for researchers engaging in 'for who' systems thinking beyond the science.

Interconnection, Relationality, and Context:

Establishing interconnection is a combination of one's own intellectual work and the discourse between one's self and their community research partners. When we're establishing interconnection, we're establishing a story and a framework with which to interpret the story. Without those who have intimate knowledge of and experience living within these interconnections there is no way to accurately communicate and represent them outside of one's own personal mental frameworks and the research becomes about the researcher.

Identifying *who* research is for, not *what* research is for, is the beginning of the bridge between interconnection and relationality. That slight shift in perception gives us a sense of the relationship that exist between the environments we work in, and people we work with. Without relationality, we never truly understand the system holistically and the research becomes a translation of the system instead of an understanding of and feeling of the system in its own right and context.

However necessary these elements are to our holistic understanding of a system, they only serve their purpose when combined with context. Without context, we see the wrong interconnections and, most importantly, we feel the wrong relationships. As a result, we, again, lose for whom the research is for. Instead of being informed by and done for the community, it becomes for us because the context is implicitly and, therefore, our own.

"[Indigenous knowledge (IK)] and science tend to ask different questions and may use different information to inform decisions. Consider an IK holder obtaining salmon. Multiple relationships between the salmon, the rest of the environment and among the dimensions of food security must be considered to understand changes that are occurring or may occur. It is important to understand the salmon's health, the texture of the salmon meat, color of the meat and scales, interaction between the salmon and its environment, changes in salinity of the water and temperatures in the water and air… All of this information is needed to inform decision-making... On the other hand, scientists often base an understanding of salmon health on population dynamics and similar variables… IK… is very successful in identifying connections between variables in order to address multi-dimensional questions. Both approaches are often needed to better understand the Arctic environment and rapidly occurring changes." - (ICC Food Security Report, 2015, pg. 77)

Acknowledgements: This research is funded by the National Science Foundation National Research Traineeship: Systems Approach to Understanding and Navigating the New Arctic

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Feature Upgrades and Enhancements to iceREADER.org

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

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

Abstract: For the last decade, the International Trans-Antarctic Scientific Expedition (ITASE) community has used the iceREADER.org website as a resource for visualizing data collection locations and facilitating access to Antarctic data sets. Since iceREADER.org's conception, technology has changed, and while iceREADER.org has continued to serve the community dutifully, the hardware, software libraries, and data access methods eventually required upgrades. We describe some of the technical items that have been addressed for iceREADER.org to continue to serve the ITASE community now and into the future.

iceREADER.org is a data storage system that facilitates sharing and collaboration of data sets. Users may store data for individual management or mark data sets for varying access levels. The types of data access levels are *public*, *member*, and *private*. iceREADER.org shares public access data without the need for account registration. The iceREADER website is straightforward to use.

The web portal contains two main components: 1) A mapping component that displays ice data locations on Antarctica using EPSG:3031 map projection explicitly for the region, and 2) the ability to obtain and view stored data sets via a listing page.

We performed maintenance on the iceREADER website to upgrade hardware from a 32-bit processor server to a 64-bit processor server with RAM and storages increases. In addition, we upgraded the software system components from an older version of Debian to a current stable version. We also upgraded the database version to a recent version of PostgreSQL. To preserve user accounts and data from the previous database, we performed text-based data dumps and manually edited them to import into the new system.

We increased the iceREADER.org mapping interface from OpenLayers version 2 to version 3. By changing the version, we addressed a compatibility issue with recent versions of the Firefox web browser.

In addition, we modified the map API interface to access recent versions of map tiles. We updated the Antarctic Cryosphere Access Portal (A-CAP) *blue marble next-generation satellite*[1], the A-CAP *cryosphere sea ice concentration*[1], and the GMRT *south polar bathymetry*[2] imagery API URLs. These changes corrected map tiling issues from the previous version (For example, missing or failing to load promptly) and increased the map interface's responsiveness.

We upgraded iceREADER.org's list interface to accommodate modern browsers better. These changes make the site more accessible on devices with varying screen sizes. The content rendering change is significant with mobile devices, which have physically smaller screen sizes. Another critical feature enhancement is data access through the Climate Data Workbench API, allowing programmatic access to data in JSON and XML formats.

Finally, SSL has been made ubiquitous throughout the website. While not necessarily required for publicly facing data, this makes the server and website in line with the standard industry practices of today.

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Observational Evidence for Depth- and Geometry-Dependent Iceberg Melt Rates

Kristin M. Schild[1,2]

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

Abstract: Through an intensive 2019 summer field campaign in southeast Greenland, we collected a variety of helicopter-based and ship-based measurements enabling the construction of 3D iceberg geometries and comparison between established and emerging methods of calculating iceberg melt rates. In this paper, we focus on a single iceberg and construct a detailed picture of variable iceberg melt rate magnitudes and spatiotemporal variability that is dependent on both iceberg geometry and depth in the water column.

Why Icebergs?

The increasing input of freshwater to the subpolar North Atlantic, both through glacier runoff and the melting of calved icebergs, has significant implications for fjord stratification and circulation. However, constraining this meltwater input has been difficult due to complex iceberg geometry and subsequently complex melt behavior.

Field Methods:

During the summer of 2019, we used ship-based drone imagery and multibeam sonar to construct full iceberg (above and below water) geometry[1] as well deploying high resolution GPS and ApRES on the iceberg via helicopter. In differencing the multiple scans, and post-processing the GPS and ApRES data, we were able to quantify mass loss with depth and compare results against common melt rate calculation methods.

Results:

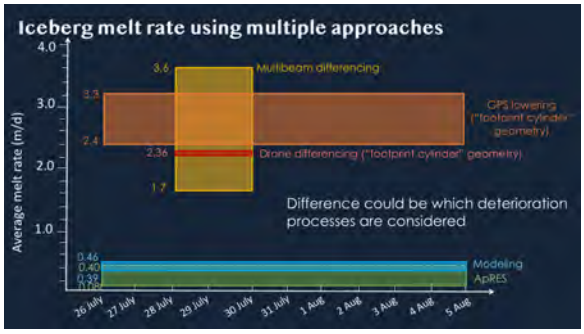

Fig. 1: Comparison of calculated melt rate using 5 different methods applied to the same iceberg over ~ the same period of time in 2019.

We found a bimodal distribution of melt rates, with the separation between modes dependent upon those methods that calculated mass loss rate (melt and mechanical deterioration; multibeam differencing, GPS lowering, Drone differencing) and those only considering melt rate (modeling, ApRES) (Fig. 1). Methods that included mechanical deterioration were an order of magnitude higher than those that only considered melt as a method of iceberg deterioration. As seen in Fig. 2, evidence of both melt and mechanical deterioration are present in icebergs, suggesting that those methods including mechanical deterioration are most accurate. This comparison of methods highlights the need for inclusion of both forms of deterioration in iceberg models and global climate models, in order to more accurately predict future iceberg impacts.

Fig. 2: Photo of deteriorating iceberg, showing evidence of both melting and mechanical deterioration.

Acknowledgements: Funding provided by NSF CAREER Award # 1552232 (D.A. Sutherland) and NASA NIP Award # 80NSSC21K0945 (K. M. Schild).

Bibliography: [1]Schild, Kristin M., David A. Sutherland, Pedro Elosegui, and Daniel Duncan. "Measurements of iceberg melt rates using high-resolution GPS and iceberg surface scans." *Geophysical Research Letters* 48, no. 3 (2021): e2020GL089765.

Tracking the Southern Hemisphere Westerlies Through Plant Wax Records of the Falkland Islands Through the Termination

Meghan Spoth[1,2], Brenda Hall[1,2]

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

Abstract: The Southern Hemisphere Westerly Winds (SHW) have a tremendous impact on the climate and ocean currents of the mid-latitudes in the Southern Hemisphere. Paleorecords suggest that the SHW have changed in average position and intensity since the Last Ice Age and may be a potential driver of abrupt climate change. This research reconstructs the paleoclimatic history of the Falkland Islands, situated within the modern belt of the SHW, to identify shifts in the location and/or intensity of the SHW and its effect on regional climate through the Holocene.

The goal of this project is to provide constraints on the meridional location and/or intensity of the Southern Hemisphere Westerlies (SHW) since the last glacial maximum (LGM). This will assess their influence on climate change and improve models predicting the movement and impacts of this system on future climate.

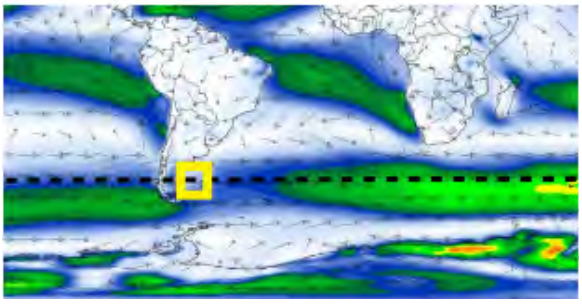

Fig. 1. The modern location (dash line) and intensity of the Southern Hemisphere Westerly Winds. The map shows arrows for wind direction and warmer colors for increased wind speed (Climate Reanalyzer, 2018). The Falkland Islands are boxed in yellow.

The Falkland Islands (52°S, Fig. 1) currently have a relatively warm, wet climate within the SHW belt. Episodes of cooler, drier climate are expected to coincide with northward shifts in the SHW. Thus, I hypothesize that changes in the position of the SHW will be expressed in the Falkland Islands through variations in temperature, precipitation, and wind intensity. My work reconstructs paleoenvironmental changes reflective of the SHW in the Falkland Islands using plant wax isotopes (∂^2H and ∂^{13}C) of lake sediments from high-elevation tarns on Mt. Usborne, East Falkland.

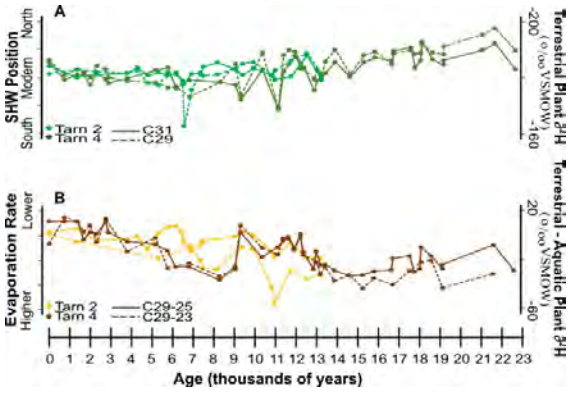

Fig. 2. The plant wax records of Tarn 4 and Tarn 2 plotting A) terrestrial plant ∂^2H for precipitation moisture sources as a proxy for SHW migration, B) difference between terrestrial and aquatic plant ∂^2H as a relative evaporation rate proxy.

The plant-wax record of terrestrial plants (*n*-alkanes C_{29} and C_{31}) and aquatic plants (*n*-alkanes C_{23} and C_{25}) shows significant hydrologic variation over the past 23 ka at 52°S. Combined, these records give insight to the change in storm tracks and their moisture sources in response to SHW migration (Fig. 2A) along with the direct effect on local hydrology (Fig. 2B). From the Termination to late-glacial, there is a southern migration of the SHW paired with a steady evaporation rate. Over the Holocene there is a more gradual northward migration and a decrease in evaporation rate with significant millennial-scale fluctuations.

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

Bibliography: Climate Reanalyzer 2018.

Archaeological Bivalves as El Niño-Southern Oscillation (ENSO) Proxies

Frankie St. Amand[1, 2, 3], Alice R. Kelley[1, 3, 4], Daniel H. Sandweiss[1, 3, 4]

1. *Climate Change Institute, University of Maine.*
2. *Interdisciplinary Ph.D. Program, University of Maine.*
3. *Department of Anthropology, University of Maine.*
4. *School of Earth and Climate Sciences, University of Maine.*

Abstract: Research on stable oxygen isotopes ($\delta^{18}O$) in Peruvian bivalves aims to improve our understanding relationships between biomineralization and abrupt shifts in environmental parameters associated with ENSO. Examining correlations between $\delta^{18}O$ in bivalve growth rings and sea surface temperature (SST) can improve our confidence in archaeological bivalves as paleo-ENSO. This research also examines the accuracy of satellite SST data, which could be used to assess bivalve $\delta^{18}O$ SST records sourced from areas without in-situ instrumental records.

Project Background: ENSO is an aperiodic climate phenomenon with a primary impact in the east-central Equatorial Pacific Ocean. El Niño events occur every ~2-7 years, have an epicenter just off the north coast of Peru, and are associated abnormally-high SST, heavy rains, and terrestrial flooding. This research examines the utility of bivalves as paleo-ENSO proxies, which are plentiful in the archaeological record and can be used to examine human resilience to past abrupt climate events.

Objectives: (1) identify if *Tivela hians* has identifiable growth rings and examine the relationship between samples' $\delta^{18}O$ signatures and SST records to determine if archaeological *T. hians* may be reliable paleo-ENSO proxies; (2) identify which species may be more reliable paleo-ENSO proxies by conducting cross-species comparisons of $\delta^{18}O$ variation in *Trachycardium procerum*, *Anadara tuberculosa,* and *Mesodesma donicium;* and (3) identify if 1km Multi-scale Ultra-high Resolution (MUR) SST data may be used to assess the reliability of $\delta^{18}O$-derived SST data when these samples are harvested from regions of the Peruvian coast lacking in-situ buoys.

Methods: The author harvested bivalves along the Peruvian coast and obtained samples from collaborators. Growth ring analyses and sample preparation were conducted at Universidad Peruana Cayetano Heredia in Lima, Peru. $\delta^{18}O$ analysis was performed by the Stable Isotope Lab at Iowa State University. Reconstructions of SST were completed using a modified version of Grossman and Ku's $\delta^{18}O$ SST equation. Both raw isotope and $\delta^{18}O$ SST values were compared to *Instituto del Mar del Perú* (IMARPE) SST records to identify relationships between SST and $\delta^{18}O$. MUR data is compared to IMARPE records to identify if satellite data may be used in place of in-situ instrumental records for assessing bivalves as paleo-ENSO records when harvested from parts of the Peruvian coast lacking monitoring buoys.

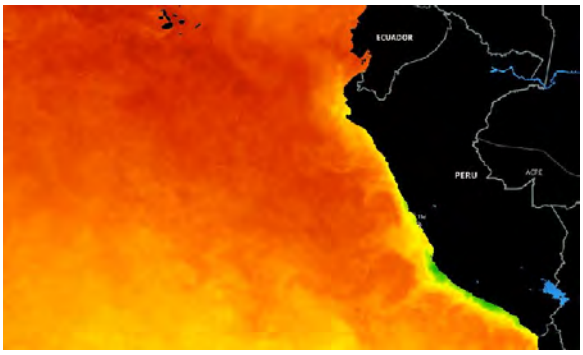

Fig. 1. March 2019 CHRSST L4 MUR SST image. Source: EOSDIS Worldview.

Acknowledgements: NSF GRFP, Janet Waldron Doctoral Research Fellowship, Dan and Betty Churchill Exploration Grant, UMaine GSG grant, Phi Kappa Graduate Research and Love of Learning grants.

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The Last Glaciation and Last Glacial Termination Documented in the Southern Alps of New Zealand and the Altai Mountains of Western Mongolia

Peter D. Strand [1,2], Aaron E. Putnam [1,2], Joerg M. Schaefer [1,3], George H. Denton [1,2], David J.A. Barrell [4], David E. Putnam [5], Oyungerel Sambuu [6]

1. *Climate Change Institute, University of Maine.*
2. *School of Earth and Climate Sciences, University of Maine.*
3. *Lamont-Doherty Earth Observatory, Columbia University.*
4. *GNS Science, New Zealand.*
5. *Dept of Environmental Science and Sustainability, University of Maine at Presque Isle.*
6. *School of Geology and Mining Engineering, Mongolian University of Science and Technology.*

Abstract: A more complete understanding of the timing and magnitude of past glacier fluctuations in the Southern and Northern Hemisphere mid-latitudes will allow for an evaluation of the role for radiative drivers of ice-age climate changes, such as orbital forcing and greenhouse gases, and will help to solve orbital and millennial-scale ice-age puzzles. 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 and the Altai Mountains of western Mongolia.

The last glacial termination (~18,000 – 11,000 yrs ago) represents the last great global warming and the last time CO_2 rose by a substantial amount before the industrial period. In addition, a prominent version of the Milankovitch hypothesis of ice ages is that variations of Earth's climate 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 therefore glacier landforms afford insight into past climate conditions. Here, 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).

In New Zealand, 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, ^{10}Be ages from moraines and glacial topography indicate that the warming which ended the Last Glacial period occurred contemporary with that in New Zealand. This finding also implicates a powerful, global climate driver. 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.

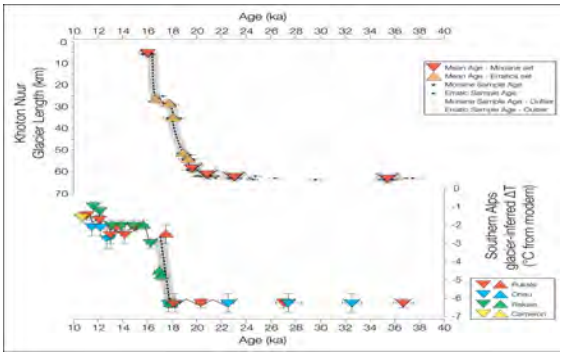

Figure 1. Time-Distance plots comparing glacier recession in the Mongolian Altai and New Zealand

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

A Sky Island Perspective: Understanding and Preserving Present Day New England Alpine Plant Communities

Andrea J. Tirrell[12], Michael Cianchette[2], Caitlin McDonough MacKenzie[3], Jacquelyn Gill[12]

1. *Climate Change Institute, University of Maine.*
2. *School of Biology & Ecology, University of Maine.*
3. *Environmental Studies, Colby College.*

Abstract: New England alpine plant communities may be vulnerable to changes in climate and human activity, but their future vulnerability cannot be qualified without baseline surveys. Baseline surveys done in 2021 reveal factors that may influence species distributions, including size and proximity to other alpine islands. During these surveys, we also used a new method of baseline data collection that allows for minimal disturbance in vulnerable alpine areas.

Introduction:

On New England's highest mountaintops, alpine plant communities exist as isolated island patches of varying size and levels of isolation. Arctic and alpine species once occupied much of New England after deglaciation, but now are found only on high peaks with strong winds, scouring ice, and are sustained by short growing seasons[1]. However, their vulnerability in the face of present day climate change remains unclear without baseline surveys. Our goal is to use the baseline surveys completed in the summer of 2021 to assess what factors may influence alpine species presence and abundance across New England. We predicted that factors such as size of the alpine area, proximity or connectivity to neighboring alpine areas, slope, aspect, length of growing season, and hiker visitation may impact species distributions. We also propose a new method of surveying New England's alpine zone, by creating virtual permanent plots using photogrammetric models

Initial Results:

Our initial results suggest that alpine species distributions across New England are partially determined by size and proximity to other alpine islands, as supported by island biogeography theory. We hope to continue with regression analyses of other variables, specifically climatic variables that may be influencing species distributions. Through creation of photogrammetric models, we were able to identify species and estimate species coverage, without disrupting the alpine environment with permanent structures.

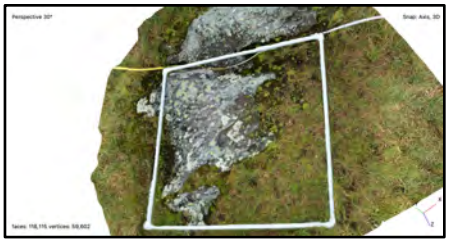

Figure 1: 3D image model of a virtual permanent plot.

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Acknowledgements:

Churchill Exploration Fund, Graduate Student Government Grant, members of the BEAST Lab, committee members Brian McGill and Jose Meireles, and Aaron Putnam for photogrammetry inspiration.

Re-Entangling Plastic and Climate Entanglements

Erin Victor[1, 2, 3]

1. *Climate Change Institute, University of Maine.*
2. *Department of Anthropology, University of Maine.*
3. *Senator George J. Mitchell Center for Sustainability Solutions, University of Maine.*

Abstract: Plastics are synthetically produced materials that emit significant greenhouse gases throughout the entire product life cycle. Scientific inquiry and policy interventions have largely treated climate change and plastics as separate "wicked problems." I argue that effective and just solutions require recognizing the interconnected nature of the climate and plastics crises.

Climate & Plastics

Plastics were originally framed as an environmentally friendly solution to an overreliance on scarce resources such as ivory and tortoiseshell. However, recent evidence suggests that the current production of these "novel entities" outpace society's ability to assess, monitor, and address the risk of plastics in the environment[1].

While predominantly made from petrochemical feedstocks with considerable energy inputs in the synthesis process, the connections between plastics and climate change are just starting to gain attention. A new report found that the U.S. plastics industry alone accounts for more than 232 million tons of CO2e gas emissions each year. This is equivalent to the carbon emissions from 116 coal-fired power plants.[2] If the current growth in plastic production continues, plastics are expected to account for 15% of the total global carbon budget by 2050[3].

Current Solutions

Many proposed solutions to the "plastic crisis" assume that growth in plastics production can be decoupled from environmental and social "externalities" through market-based incentives and technological innovations. Modeling future scenarios where fossil-fuel-based plastics are replaced with bio-based plastics, the plastics supply chain is decarbonized, and all plastics are recycled, Zheng and Suh (2019) determined that an absolute reduction in the global plastic carbon footprint would require aggressively doing all of these and decreasing overall growth in plastic production.

Furthermore, this analysis did not account for the human and environmental health hazards such as entangled marine species or the bioaccumulation of toxic chemical substances used in the production of plastics[4].

Conclusion

Climate and plastics are largely treated as separate topics for scientific inquiry and political intervention. As the fossil fuel industry invests in expanding plastic production capacity as a strategic response to the decarbonization of transit and energy grids[5], it is critical that these largely siloed topics are addressed conjointly. I argue that we must be skeptical of market-based solutions that promise technological innovations that can "close the loop" to create a circular economy for plastics and tend to mask unequal distribution and accumulation of the socio-economic benefits and harms of plastics.

Acknowledgments: Dr. Cindy Isenhour

Funding: Canadian-American Center Fellowship

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The Effects of Research Learning Experiences on First-year Undergraduates

Holly White[1], Katharine J Ruskin[1], Alison Jolley [2], Debra Allen[3]

1. *School of Biology and Ecology, University of Maine.*
2. *Te Puna Ako - Centre for Tertiary Teaching and Learning, University of Waikato.*
3. *Office of Institutional Research and Assessment, University of Maine.*

Abstract: Research experiences have the potential to provide an array of benefits to students. Research Learning Experiences (RLEs) at the University of Maine engage first-year students in research, creativity, and hands-on learning. Here, we use a mixed methods approach to investigate RLE courses by exploring various course characteristics and student outcomes.

Project Background and Methods

Undergraduate research experiences have been recognized for providing an array of benefits to students. There are various positive outcomes associated with these experiences, including increased retention and persistence in college[1], confidence in research skills[2], and interest in graduate studies[3]. However, further research is needed to better understand the effects of these experiences[2].

This project aims to improve undergraduate education at UMaine through Research Learning Experiences (RLEs). The RLE program consists of 26 courses spanning various disciplines that engage first-year students in discovery, knowledge creation, and research to prepare them for future careers. Using a mixed methods approach, we investigate how RLEs affect various student outcomes.

Quantitative and qualitative data were collected in the form of pre/post-semester student and faculty surveys, and course artifacts such as syllabi and student coursework. An assessment timeline is shown below in Figure 1.

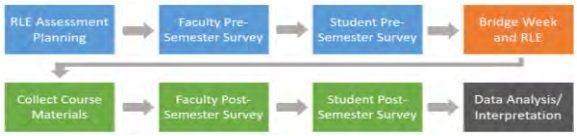

Fig. 1. Assessment timeline.

Initial Results

Analyses of the RLE post-semester survey indicate that 93% of students are still interested in research/exploration after RLE participation. Furthermore, students reported an array of benefits from the RLEs (Figure 2), such as Bridge Week and gaining a support system. Students also reported challenges, such as RLEs not matching their expectations in terms of research activity, course goals, and Bridge week.

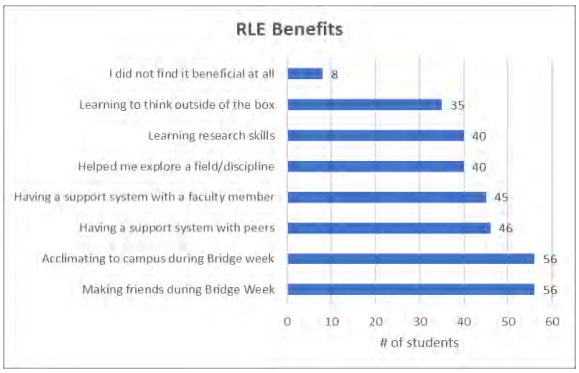

Fig. 2. Self-reported RLE benefits.

Next steps include analyses of pre/post data to compare outcomes and gains among RLE students and those in traditional courses. We will explore how the RLE affects various student outcomes such as self-efficacy, sense of belonging, and retention. We will also explore how unique characteristics within the RLEs influence student outcomes. This work will assist in the refinement of the RLE program and improve the undergraduate experience for students at UMaine. Findings may serve as a guide for other universities.

Acknowledgements: This work is supported by the Harold Alfond Foundation and the Coalition for a Life-Transformative Education.

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Smoothed Particle Hydrodynamics Extends Predictability Beyond Traditional Models of the Probability of Infection by Respiratory Viruses

Nicholas R. Whiteman[1, 2]

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

Abstract: Empirical observations and modelling efforts demonstrate that defining the trajectory of airborne pathogens is critical to understanding risk. Common to most spreading events is the shared air all people inhale in the same room. Utilizing parallel-process particle solutions to model indoor airflow, I identify trajectories that influence health risks arising from complex aerosol transport.

Airborne transmission:

Confirmation that Covid-19 virus could be transported as fine (<100□m) airborne, aerosolized particles (Wang et al., 2021) has driven our hypothesis that characterization of complex indoor airflow is critical to identifying Covid-19 transmission and human health risk. The standard methods of identifying risk lacks the spatial-temporal context of moving air, instead treating air in terms of homogenized averages dominated by gravitational settling and is inadequate for characterizing infection risk in dynamic settings. Capable of staying aloft for hours, aerosols can be advected by air currents with the potential to accumulate in eddies and still air. Here we demonstrate that by modelling airflow patterns in detail, we can predict and remediate airflow patterns critical for aerosol transport.

Using Smoothed Particle Hydrodynamics:

Predicting the evolution of complex airflow is only feasible with the use of modern computational methods such as Smoothed Particle Hydrodynamics (SPH) (Domínguez et al., 2021) that allow us to capture the eddying behavior necessary to anticipate the trajectory of aerosols. By approximating a full solution to the Navier-Stokes equations using millions of freeto-move meshless particles rather than a standard mesh system SPH allows us to examine the interaction of air currents, lingering eddies, or the potential carrying capacity of a draft, each with considerable public health implications for the people within such spaces. Of the many testable applications, a model hallway and airflow driven by an airplane gasper are presented here (Figures 1 and 2).

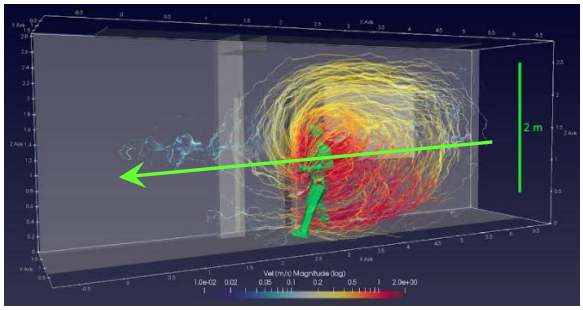

Figure 1. $5.2*10^{13}$ particle interactions simulate the displacement of air (visualized as streamlines) after a figure moves through the hallway, from right to left. Warmer colors represent greater velocity magnitude.

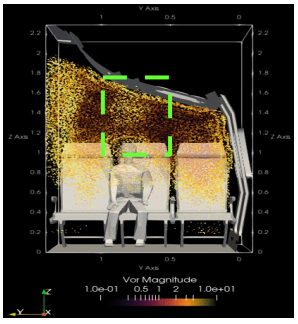

Figure 2. A 3D model of a gasper jet in an airplane passenger cabin. The use of gaspers is likely to be an effective personal defense strategy by enforcing an exclusive region of filtered air across a person's face.

References:

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Wang, Chia C., et al. 2021. doi:/10.1126/science.abd9149

Acknowledgements: funded by NSF grant 2019299 to R. Turner, P.O. Koons, H. Xue, B. Segee. Special thanks to the developers of DualSPHysics (https://dual.sphysics.org/) for making SPH methods accessible by providing free and open source access to their solver.

A Key to Past Ocean Temperatures: Mg/Ca of Foraminiferal Calcite in the North Atlantic (*N. incompta*)

Madelyn N. Woods[1,2], Katherine A. Allen[1, 2]

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

Abstract: The Holocene (0 - ~11,000 Cal. yrs. BP) is a warm interglacial climate mode. Reconstructing ocean temperatures and oxygen isotopes ($\delta^{18}O$) in the Gulf of Maine region could provide essential context for understanding and predicting modern climate change.

Holocene Ocean-Climate Dynamics:

The Holocene epoch has been characterized by long-term shifts in mean conditions (e.g., SST, precipitation, and ocean circulation) punctuated by abrupt ocean-climate events[1]. The causes of these events are not fully understood, but the fairly stable mean annual solar insolation at 45˚N suggests ulterior driving forces caused by internal feedbacks in the ocean-climate system. High-resolution paleo-reconstructions of the North Atlantic (NA) during a warm interglacial climate mode could provide essential context for understanding and predicting modern climate change.

The North Atlantic is an ideal location to understand natural ocean-atmospheric dynamics during an inter-glacial period. The Gulf of Maine (GOM) in particular has the potential to experience major temperature changes due its unique position at the confluence of the Northern Hemisphere Westerlies, the warm, salty Gulf Stream, and the colder, fresher Labrador current[2]. Different water sources entering the GOM are characterized by different seawater oxygen isotope ($\delta^{18}O_{SW}$) signals[3], and changes in North Atlantic ocean circulation are likely to be reflected in temperature and $\delta^{18}O$ values of the GOM.

GOM Reconstructions:

The goal of this project is to generate continuous ocean temperature and $\delta^{18}O_{SW}$ records in the GOM for the past ~11,000 years. A principal proxy used for determining sea surface temperatures is the ratio of magnesium to calcium (Mg/Ca) in foraminifera calcite shells[4]. Temperature is considered the primary factor controlling foraminiferal Mg/Ca, but uncertainty still exists for secondary controls such as salinity

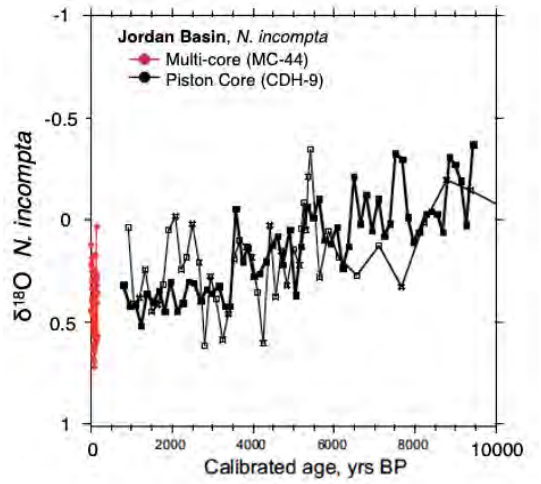

Fig. 1. The $\delta^{18}O$ of calcite from *N. incompta* in sediments from the Jordan Basin, GOM, indicating a possible cooling during the Holocene[5].

and carbonate system influences[6]. We will utilize prior Mg/Ca proxy calibrations and corrections obtained from the North Atlantic to complete paleotemperature reconstructions downcore in the GOM, using the planktonic foraminiferal species *Neogloboquadrina incompta.* A rigorous assessment of Mg/Ca in *N. incompta* from the GOM will improve our paleo-reconstructions and help us to better understand temperature and circulation changes during the Holocene.

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