Program and Abstracts

52nd International Arctic Workshop 2024

NSF INSTAAR University of Colorado Boulder EGCS Earth, Geographic, and Climate Sciences

Compiled in 2024 by:

Department of Earth, Geographic, and Climate Sciences and The WCRP Climate and Cryosphere Office, University of Massachusetts-Amherst

This report may be cited as:

52nd International Arctic Workshop, Program and Abstracts 2024. Dept of Earth, Geographic, and Climate Sciences, University of Massachusetts-Amherst, 211 pp.

This report is distributed by:

Dept of Earth, Geographic, and Climate Sciences

University of Massachusetts at Amherst

627 N. Pleasant Street, Morrill Building

Amherst, MA 01003

https://www.geo.umass.edu/

Cover photo:

Coastal Nunivak Island, City of Mekoryuk, overlooking the Bering Sea.

Photo: Julie Brigham-Grette, Sept. 2023.

PROGRAM AND ABSTRACTS

52nd ANNUAL INTERNATIONAL ARCTIC WORKSHOP

March 13th – 16th, 2024

DEPT. OF EARTH, GEOGRAPHIC, AND CLIMATE SCIENCES

WCRP CLIMATE AND CRYOSPHERE PROJECT

SCHOOL OF EARTH AND SUSTAINABILITY

CLIMATE SYSTEM RESEARCH CENTER

University of Massachusetts, Amherst

Organizing Committee:

Julie Brigham-Grette

Tim Cook

Meghan Taylor

Samantha Bombard

Catherine Britt

Raymond Bradley

Introduction

Overview and history

The 52nd Annual International Arctic Workshop will be in person 13-16 March, 2024 at the University of Massachusetts Amherst Campus Conference Center. The meeting is traditionally hosted by the Institute of Arctic and Alpine Research (INSTAAR). This workshop has grown out of a series of informal annual meetings started by John T. Andrews in 1970, and sponsored by INSTAAR and other academic institutions worldwide.

Theme

"The Legacy of Arctic Change: Looking Back but Thinking Forward" The polar regions are undergoing rapid change, perhaps a transformation that can only be informed from our understanding of the climate system based on studies of the past, contemporary observations, and modeling of the future.

Website

https://umass.irisregistration.com/Site/Arctic

Program

The workshop takes place on 2.5 succeeding days, mostly from 9am to 6pm Eastern Standard Time. Time slots are 15 min, allowing for 12 min talks and a few minutes of questions and transitions. Posters should be up all day March 14 and 15 in the Campus Center Auditorium. Each is numbered and grouped. Two-hour poster sessions will be held with odd numbers on Thursday and even numbers on Friday. Lunches are served in the same room as the posters.

NSF

The National Science Foundation's Division of Polar Programs has a long tradition of being a supporter of the Arctic Workshop. *Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.*

Arctic Workshop 2024 Program Summary

All times are in Eastern Standard Time

Wednesday 13 March		
6 pm - 9:30 pm	Check-in and Registration, Evening Reception	Level 10, Amherst Room Campus Center

Thursday 14 March		
8:00 am - 8:30 am	Check-in and Registration	Campus Center Auditorium
8:45 am	Welcome and Introductions	
9:00 am	**SESSION 1:** Greenland	Campus Center Level 1, Room 163
10:15 am	Morning Break	
10:45 am	**SESSION 2:** Greenland	Campus Center Level 1, Room 163
12:00 pm	Lunch (included in registration)	Campus Center Auditorium
1:00 pm	**SESSION 3:** Diverse Perspectives	Campus Center Level 1, Room 163
2:30 pm	Afternoon Break	
3:00 pm	**SESSION 4:** Modeling	Campus Center Level 1, Room 163
4:00 pm	**Poster Session 1** (Odd Numbers)	Campus Center Auditorium
6:00 pm	End of Session	

Friday 15 March		
9:00 am	**SESSION 5:** Arctic North America	Campus Center Level 1, Room 163
10:15 am	Morning Break	
10:45 am	**SESSION 6:** From Cosmo to Ecology	Campus Center Level 1, Room 163
12:00 pm	Lunch (included in registration)	Campus Center Auditorium
1:00 pm	**SESSION 7:** Longer Records	Campus Center Level 1, Room 163
2:30 pm	Afternoon Break	
3:00 pm	**SESSION 8:** Movies of Arctic Adventure	Integ. Learning Building Rm S240
4:00 pm	**Poster Session 2** (Even Numbers)	Campus Center Auditorium
6:00 pm	End of Session, Cash Bar and Soft Drinks	
7:00 pm	Workshop Banquet **Keynote**: Gifford Miller, University of Colorado Boulder	Marriott Center Campus Center, 11th Floor

Saturday 16 March		
9:00 am	**SESSION 9:** Fire and Permafrost	
10:15 am	Morning Break	
10:45 am	**SESSION 10:** From Alaska to Greenland	
12:00 pm	End of Meeting	
1:00 pm	Afternoon Local Field Trip, Boxed Lunches Included	Pick up at Flint Circle
5:00 pm	Return to UMass	

Program Details

Wednesday 13 March

6 pm - 9:30 pm	**Check-in and Registration, Evening Reception**	Level 10, Amherst Room Campus Center Light Finger Food

Thursday 14 March

8:00 am - 8:30 am	**Check-in and Registration**	Campus Center Auditorium
8:45 am	**Welcome and Introductions** **Prof. Tilman Wolf**, Senior Vice Provost for Academic Affairs and **Prof. Rob DeConto**, Director of School of Earth and Sustainability	

Session 1: Greenland

9:00 am	**PROBING THE ORIGIN(S) OF BBDC EVENTS**
	Anne Jennings
9:15 am	**CLIMATE RESPONSE OF ADJACENT MARINE-TERMINATING GLACIERS IN SERMILIK FJORD, SOUTHEAST GREENLAND**
	Martin Miles
9:30 am	**EPISODIC NEOGLACIAL ADVANCES OF ØSTTUNGERNE ICE CAP, NORTHEAST GREENLAND FROM RADIOCARBON DATING OF ICE-MARGINAL SUBFOSSIL MOSS**
	Liza Wilson
9:45 am	**DID PRUDHOE DOME, NORTHWEST GREENLAND, DISAPPEAR DURING THE HOLOCENE?**
	Caleb Walcott

10:00 am	**RECONSTRUCTION OF TERRESTRIAL AND MARINE CLIMATE FROM SOUTHERN GREENLAND DURING THE PLEISTOCENE**	
	Emily Tibbett	

10:15 am **Morning Break**

Session 2: Greenland

10:45 am	**STABLE O AND H ISOTOPES OF LACUSTRINE ORGANIC MATERIALS AS PROXIES FOR LAKEWATER ISOTOPES: INSIGHTS FROM A DECADE OF RESEARCH IN GREENLAND**
	Yarrow Axford
11:00 am	**PALEOCLIMATE DURING EARLY HUMAN MIGRATION INTO INUTOQQAQ NUNAAT, NORTHERN GREENLAND**
	Raymond Bradley
11:15 am	**VULNERABILITY AND ADAPTATION ON THE ICECAP'S EDGE: FARMING COMMUNITIES IN SUBARCTIC SOUTH GREENLAND**
	Lisa Luken
11:30 am	**APPLYING CALIBRATION DATA TO HIGH LATITUDE SEDIMENTARY PLANT WAX HYDROGEN ISOTOPE VALUES TO RECONSTRUCT WATER ISOTOPE VALUES THROUGH TIME**
	Jamie McFarlin
11:45 am	**SCALING ARCTIC LAKE METHANE EMISSIONS: A CLOSER LOOK AT THE EFFECTS OF LAKE AREA, AQUATIC VEGETATION, AND DOUBLE-COUNTED WETLANDS**
	Ethan Kyzivat

12:00 pm **Lunch (included)**

Session 3: Diverse Perspectives

1:00 pm	**DONALD B. MACMILLAN'S ARCTIC LEGACY, RETRACED & RE-QUERIED IN POETRY**
	Elizabeth Bradfield
1:15 pm	**WHAT ISSUES FACE THE UNITED STATES GOVERNMENT IN THE ATLANTIC HIGH NORTH**
	Darryl Lyon
1:30	**WEATHERING OF ROCK SURFACES IN MIDTRE LOVÉNBREEN FORELAND (SPITSBERGEN)**
	Ireneusz Badura
1:45	**CLIMATE AND BIOCLIMATE CONDITIONS IN NAIN (LABRADOR) IN THE LATE 18TH CENTURY**
	Rajmund Przybylak
2:00	**IMPACT OF LAKE ANOXIA AND CLIMATE ON HOLOCENE BRGDGT AND PLANT DNA RECORDS IN ICELAND**
	David Harning
2:15	**GROUP DISCUSSION**
	Use this time to discuss and ask questions.

2:30 pm **Afternoon Break**

Session 4: Modeling

3:00 pm	**EVALUATION OF REGIONAL CLIMATE MODEL RUNOFF OVER TWO WATERSHEDS IN NW GREENLAND**
	Sarah Esenther
3:15 pm	**A PROMISING ARCHIVE OF HIGH ARCTIC HOLOCENE TEMPERATURE VARIABILITY: LAKE SEDIMENTS FROM LAKE SW IN PEARY LAND, NORTH GREENLAND**
	Tobias Schneider

3:30 pm **REGIME SHIFTS IN ARCTIC TERRESTRIAL HYDROLOGY MANIFESTED FROM IMPACTS OF CLIMATE WARMING**

Mike Rawlins

3:45 pm **Modeling Climate Sensitivity of Biogeochemistry at Two Ponds in the Yukon-Kuskokwim Delta, AK**

Andrew Mullen

4:00 pm Poster Session 1 Campus Center Auditorium

1 **CENTERING INDIGENOUS PERSPECTIVES IN SUSTAINABLE ARCTIC TOURISM**

Tracy Michaud

3 **NAVIGATING THE NEW ARCTIC: MEQ UNGUVATKARPUT (WATER IS OUR LIVELIHOOD): YEAR 1 OUTCOMES FROM THE OUTER KUSKOKWIM DELTA**

Julie Brigham-Grette

5 **FIRE RECONSTRUCTION IN THE FAR NORTH: LATE HOLOCENE ECOLOGICAL RESPONSES TO FIRE IN NORTHERN ALASKA**

Lee DePue

7 **HYDRO-GEOMORPHOLOGICAL DYNAMICS IN ALASKAN ICE WEDGE POLYGONS: A DEEP LEARNING APPROACH**

Michael Pimenta

9 **RADIOCARBON AGE-OFFSETS REVEAL CONTRIBUTION OF PERMAFROST-DERIVED ORGANIC CARBON IN LAKE E5, ARCTIC ALASKA FROM MIS 3 TO PRESENT**

Hailey Sinon

11 **BRGDGT BIOMARKER DISTRIBUTIONS IN ANOXIC KONGRESSVATNET, SVALBARD – LESSONS FROM WATER COLUMN SEDIMENT TRAPS AND DOWNCORE SAMPLES IN A UNIQUE ARCTIC LAKE SYSTEM**

Greg de Wet

13 **ENVIRONMENTAL MONITORING A HIGH ARCTIC PROGLACIAL LACUSTRINE WATERSHED IN A WARMING HYDROCLIMATE REGIME, LINNÉVATNET, SVALBARD**

Michael Retelle

15 **SCANDINAVIAN AND URAL BLOCKING PATTERNS MODULATE INTENSE RAIN EVENTS IN SVALBARD**

Francois Lapointe

17 **PALEOENVIRONMENTAL RECONSTRUCTIONS FOR PRE-HOLOCENE ICE-FREE PERIODS ON NORTHWESTERN GREENLAND USING LIPID BIOMARKERS IN CAMP CENTURY SUB-ICE SEDIMENTS**

John Michael Aguilar

19 **BIOCLIMATE CONDITIONS IN SW GREENLAND AND EASTERN COAST OF LABRADOR DURING THE INTERNATIONAL POLAR YEARS (1882/83, 1932/33, 1957/58, 2007/08 AND 2032/33)**

Andrzej Araźny

21 **RECONSTRUCTING PLEISTOCENE OCEAN CURRENTS NEAR SOUTHERN GREENLAND BASED ON FORAMINIFERAL ASSEMBLAGES**

Dakota Ishutina

23 **GLACIAL DYNAMICS ALONG MERCHANTS AND BROUGHTON TROUGHS (BAFFIN BAY) DURING THE LAST GLACIATION**

Alexis Belko

25 **SEDIMENT PROVENANCE INSIGHTS INTO LATE NEOGENE ICE SHEET BEHAVIOR IN THE ROSS SEA ANTARCTICA FROM IODP SITE U1522**

Kathy Licht

27 **TESTING THE SCHMIDT HAMMER DATING TECHNIQUE ON GLACIAL LANDFORMS IN ICELAND**

Tessa McDonald

29 **HIGH-RESOLUTION SUBMARINE GLACIAL LANDFORMS OF TIDEWATER GLACIERS IN CROKER BAY, THE CANADIAN ARCTIC ARCHIPELAGO**

Kerstin Brembach

31 **TIMING AND PATTERNS OF ICE SHEET RECESSION AND THINNING ACROSS NORTHERN ICELAND DURING THE LAST DEGLACIATION**

Joseph Licciardi

33 **ENGAGING COMMUNITIES: HARNESSING CITIZEN SCIENCE TO MONITOR NEW ENGLAND LAKE ICE THICKNESS IN A SHIFTING CLIMATE**

Simon Pendleton

35 **EXPLORING DEGLACIATION IN NORTHWEST GREENLAND USING RELATIVE SEA LEVEL CURVES AND COSMOGENIC NUCLIDE DATING**

Karlee Prince

37 **IDENTIFYING ENVIRONMENTAL AND CLIMATIC DRIVERS OF VARIABILITY IN GDGT DISTRIBUTIONS SINCE 24 KA IN THE POLAR URAL MOUNTAINS, SIBERIA**

Gerard Otiniano

39 **CENTER FOR BRAIDING INDIGENOUS KNOWLEDGES AND SCIENCE (CBIKS)**

Sonya Atalay

41 **EFFECTS OF CLIMATE CHANGE AND THAWING PERMAFROST: POTENTIAL PATHOGENS TO HUMAN, ANIMAL, AND PLANT HEALTH**

Annie Saganna and Violet Thomas

6:00 pm **End of Session**

Friday 15 March

Session 5: Arctic North America

9:00 am **THE LAST GASP OF THE LAURENTIDE ICE SHEET**

Gifford Miller

9:15 am **HEINRICH EVENTS, MEGAFLOODS, AND DROUGHT ALLEVIATION – INSIGHTS FROM A NUMERICAL ICEBERG MODEL**

Alan Condron

9:30 am **LAURENTIDE ICE SHEET RETREAT DURING TWO ICE-AGE TERMINATIONS CAUSED THRESHOLD ATMOSPHERIC RESPONSES IN THE CANADIAN AND RUSSIAN ARCTIC**

Elizabeth Thomas

9:45 am **CLIMATE RECONSTRUCTIONS ACROSS THREE INTERGLACIALS AT SADDLE LAKE, BAFFIN ISLAND, NUNAVUT**

Jonathan Raberg

10:00 am **EVALUATING PLANT WAXES AS TRACERS FOR RECONSTRUCTING MID-LATE HOLOCENE VEGETATION CHANGE IN A SOUTHERN BAFFIN ISLAND LAKE CATCHMENT**

Kurt Lindberg

10:15 am **Morning Break**

Session 6: From Cosmo to Ecology

10:45 am **DECIPHERING THE RETREAT OF THE SOUTHEASTERN MARGIN OF THE LAURENTIDE ICE SHEET DURING THE YOUNGER DRYAS AND EARLY HOLOCENE USING COSMOGENIC NUCLIDE EXPOSURE DATING**

Pierre-Olivier Couette

11:00 am **GLACIAL EROSION VS. PROTECTION IN COASTAL NORWAY: NEW 10Be DATA**

Hayley Martinez

11:15 am **RECENT ADVANCES IN MODELING PERMAFROST DYNAMICS AND CARBON CYCLING USING TERRESTRIAL ECOSYSTEM MODEL**

Elchin Jafarov

11:30 am **LONG TERM INSIGHTS INTO DRIVERS OF ARCTIC WETLAND ECOSYSTEM DEVELOPMENT**

Mariusz Galka

11:45 am **EFFECTS OF TIME AND TEMPERATURE ON MODERN PLANT COMMUNITIES IN THE EASTERN CANADIAN ARCTIC**

Martha Raynolds

12:00 pm **Lunch (included)**

Session 7: Longer Records

1:00 pm	**PLIOCENE-PLEISTOCENE WARM WATER INCURSIONS AND WATER MASS CHANGES ON THE ROSS SEA CONTINENTAL SHELF (ANTARCTICA) BASED ON FORAMINIFERA, IODP EXP 374**
	Julia L. Seidenstein
1:15 pm	**MIOCENE CLIMATIC OPTIMUM AND MIDDLE MIOCENE CLIMATE TRANSITION: A FORAMINIFERAL RECORD FROM THE CENTRAL ROSS SEA, ANTARCTICA**
	Sam Bombard
1:30 pm	**NESTED HOLOCENE MORAINE SEQUENCES IN THE SOUTHERN HEMISPHERE AND WAS THERE A NORTHERN HEMISPHERE-LIKE LITTLE ICE AGE?**
	Michael Kaplan
1:45 pm	**A 240,000-YEAR-LONG RECORD OF HYDROCLIMATE AND TEMPERATURE CHANGES FROM IMURUK LAKE, SEWARD PENINSULA, ALASKA**
	Yongsong Huang
2:00 pm	**SEDIMENT DELIVERY AND VARVE FORMATION IN A HIGH ARCTIC PROGLACIAL LAKE, ELLESMERE ISLAND**
	Pierre Francus
2:15 pm	**GROUP DISCUSSION**
	Use this time to discuss and ask questions.

2:30 pm **Afternoon Break**

3:00 pm — Session 8: Movies of Arctic Adventure — Integ. Learning Building Rm S240

3:00 pm	*The Frozen Road* — by Ben Page
3:30 pm	*Thrawn: A stubbornly Scottish Snow Film* — Patagonia

4:00 pm	Poster Session 2	Campus Center Auditorium

2 **CLIMATE AND THE CRYOSPHERE (CliC) IN THE ARCTIC**

Meghan Taylor

4 **CHARACTERIZATION OF SURFACE WATER AND OCEAN TOPOGRAPHY (SWOT) DATA USING FAST SAMPLING PHASE OVER NORTH SASKATCHEWAN RIVER, CANADA**

Sonam Sherpa

6 **DESCRIPTION OF ANCIENT VEGETATION EMERGING FROM UNDER ICE CAPS ON BAFFIN ISLAND**

Shawnee Kasanke

8 **LINKING REMOTELY SENSED VEGETATION HETEROGENEITY AND PERMAFROST THERMAL STATE DYNAMICS**

Margaret Farley

10 **RAPID WATER CYCLE CHANGES IN THE POLAR URAL MOUNTAINS DURING THE BØLLING WARMING AND HOLOCENE: THE RESPONSE TO CHANGING ICE SHEETS AND NORTHWARD TREELINE ADVANCE**

Harleena Franklin

12 **REGIONAL AND BASIN-SPECIFIC CONTROLS ON BIOGENIC SILICA ABUNDANCES IN A SUITE OF SOUTH GREENLAND LAKES**

Shayna Garla

14 **INVESTIGATING AQUATIC PLANT LEAF WAX PRODUCTION AND HYDROGEN ISOTOPE FRACTIONATION BETWEEN ARCTIC AND TEMPERATE LAKES**

Kayla Zhou

16 **PALEOECOLOGICAL RECORDS FROM THREE LAKES IN INUTOQQAT NUNAAT, NORTHERN GREENLAND**

Bianca Perren

18 **SPATIO-TEMPORAL VEGETATION PATTERNS ACROSS UNESCO WORLD HERITAGE SITE KUJATAA, GREENLAND, USING NASA MODIS DATA, 2000-2020**

Firooza Pavri

20 **POLLUTION DRIVES ENIGMATIC DECLINE IN SUBARCTIC BIOGENIC SULFUR**

Jacob Chalif

22 **EXTENDING RECONSTRUCTIONS OF BERING STRAIT FLOODING THROUGH THE LAST INTERGLACIAL USING FORAMINIFERA-BOUND NITROGEN ISOTOPES: INITIAL RESULTS AND PROSPECTS**

Jesse Farmer

24 **PRESENCE OF TETRA-UNSATURATED ALKENONES IN THE SOUTHERN OCEAN: DIRECT INDICATION OF GROUP 2I ISOCHRYSIDALES AND PROXY FOR SEASONAL ANTARCTIC SEA ICE**

Lucas Jepsen

26 **ORBITAL CYCLES AND THE SYMPHONY OF ICE SHEETS: EXPLORING THE ANTI-PHASE RELATIONSHIP OF ICE SHEETS AND SEA LEVEL DURING THE PLIOCENE**

Caitie Britt

28 **PROSPECTING SUBGLACIAL GEOLOGICAL TERRANES THROUGH DETRITAL ZIRCON ANALYSIS IN WEST GREENLAND'S ICE-COVERED REGIONS**

Nicole Shields

30 **A GLACIER THROUGH A GRAIN OF SAND: MICROMORPHOLOGY FOR A LAND-TERMINATING GLACIER IN WEST GREENLAND**

Kayla Woodie

32 **TARGETING CHANGES IN EROSION AND SEDIMENTATION RATES ACROSS ARCTIC PERIGLACIAL FAN UNDER A WARMING CLIMATE (NWT, CANADA)**

Bailey Nordin

34 **A DATA MODEL COMPARISON BETWEEN HOLOCENE GREENLAND ICE SHEET MARGIN CONSTRAINTS AND THE ICE-SHEET AND SEA-LEVEL SYSTEM MODEL (ISSM)**

Joseph Tulenko

36 **QUANTIFYING THE UNCERTAINTY IN THE FUTURE CONTRIBUTION OF THE ANTARCTIC ICE SHEET TO SEA LEVEL RISE FROM BED TOPOGRAPHY**

Danielle Mangini

38 **IMAGE-MAPPING GLACIAL FRONTS IN THE HIGH ARCTIC**

Katie O'Meara

40 **TRACING MICROBIAL FOOTPRINTS IN GREENLAND'S SUBGLACIAL NALED ICE MELTWATER: AN ISOTOPIC PERSPECTIVE**

Moses Jatta

6:00 pm	**End of Session** **Cash Bar & Soft Drinks**	Marriott Center Campus Center, 11th Floor
7:00 pm	**Workshop Banquet** **Keynote:** Gifford Miller, University of Colorado Boulder	Marriott Center Campus Center, 11th Floor

Saturday 16 March

Session 9: Fire and Permafrost

9:00 am **THE HOLOCENE FIRE HISTORY OF NORTHEAST ICELAND BETWEEN NATURAL AND ANTHROPOGENIC FORCINGS**

Nicolo Ardenghi

9:15 am **NEW EVIDENCE FOR THE PRE-LGM HUMAN MIGRATION TO THE AMERICAS FROM THE LONGEST SEDIMENTARY RECORD OF ARCTIC NORTH AMERICA**

Desmond Yeo

9:30 am **BIODIVERSITY OF PLANTS INCLUDING BRYOPHYTES AND OF LICHENS IN MODERN VEGETATION OF DIFFERENT AGE AROUND LAKES AND NEAR BARNES ICECAP IN THE EASTERN CANADIAN ARCTIC**

Helga Bültmann

9:45 am **TESTING THE STRENGTH OF THE PERMAFROST CARBON FEEDBACK DURING THE LAST DEGLACIATION**

Sam Mark

10:00 am **GROUP DISCUSSION**

Use this time to discuss and ask questions.

10:15 am **Morning Break**

Session 10: From Alaska to Greenland

10:45 am **A RECORD OF GLACIER LENGTH THROUGH THE HOLOCENE FOR A GLACIER IN THE JUNEAU ICEFIELD, ALASKA**

Andrew Jones

11:00 am **NOVEL LEAD (PB) ISOTOPE RECORD TRACKING THE IMPACT OF POLICY AND THE COVID-19 PANDEMIC ON ASIAN POLLUTION EMISSIONS DEPOSITED IN ALASKAN ICE CORES**

Hanna Brooks

11:15 am **A >50,000 YEAR MERCURY RECORD FROM LAKE E5, NORTH SLOPE ALASKA, DOCUMENTS A FOUR-FOLD CONCENTRATION INCREASE IN MERCURY CONCENTRATIONS DRIVEN BY MIDDLE HOLOCENE WARMING**

Melissa Griffore

11:30 am **A 7,000 YEAR ALKENONE-BASED TEMPERATURE RECORD FROM INUTOQQAT NUNAAT, NORTH GREENLAND**

Redmond Stein

11:45 am **GROUP DISCUSSION**

Use this time to discuss and ask questions.

12:00 pm	**END OF MEETING**	
1:00 pm	**Afternoon Local Field Trip, Boxed Lunches Included**	Pick up at Flint Circle (adjacent to the hotel entrance)
5:00 pm	**Return to UMass**	Drop off at Flint Circle

PALEOENVIRONMENTAL RECONSTRUCTIONS FOR PRE-HOLOCENE ICE-FREE PERIODS ON NORTHWESTERN GREENLAND USING LIPID BIOMARKERS IN CAMP CENTURY SUB-ICE SEDIMENTS

John Michael N. **Aguilar**, Elizabeth K. Thomas, Owen C. Cowling, Andrew Christ, Paul Bierman, Diana S. Aga, Jeff Salacup, Isla S. Castañeda, Juliana Guimares Riberio deSouza, Eric Steig

The terrestrial climate history of Greenland prior to the Holocene is poorly understood. However, reconstructing climate of pre-Holocene ice-free periods can provide valuable insights into how the Greenland Ice Sheet responds to warmth. Sediments recovered in the 1960s beneath the Greenland Ice Sheet at Camp Century in northwestern Greenland reveal five distinct stratigraphic units, each representing different depositional environments from bottom to top: Unit 1 is a till; Unit 2 is dominated by ice with few dispersed fine sediments; and the upper Units 3-5 are likely fluvial sediments. Optically stimulated luminescence ages suggest the uppermost sediment sample was likely deposited during Marine Isotope Stage 11. Here, lipid biomarkers were analyzed in samples from each of these units to infer past climate and environment: leaf wax distributions indicate vegetation communities, leaf wax hydrogen isotopes reflect plant source water isotopic composition, and branched glycerol dialkyl glycerol tetraether (bGDGT) distributions can indicate changes in temperature. All lipid biomarkers were likely produced on the northwestern Greenland landscape ice-free periods, and were either deposited *in situ* (Units 3-5), or were transported by ice and subsequently incorporated into sediments deposited at this site (Units 1 and 2). The abundance and the hydrogen (δ^2H) and carbon ($\delta^{13}C$) isotope values of long chain (≥C26) and mid-chain (≤C24) *n*-alkanoic acids were determined in all the samples. On the assumption that the apparent fractionation (ε) is constant over time, the empirically derived median epsilon values between leaf waxes and lakes and precipitation at high -latitude sites were used to convert the leaf wax to source water hydrogen isotope values.

The compositions of these leaf wax biomarkers are different between Unit 1, Unit 2, and Units 3-5. Unit 1 contains *n*-alkanoic acid distributions similar to modern terrestrial plant communities on Greenland. The $\delta^{13}C$ values of all carbon chain lengths are relatively stable throughout Unit 1. In this unit, the $\delta^{13}C$ values of long chain *n*-alkanoic acids are similar to modern shrubs, while the $\delta^{13}C$ values of mid-chain *n*-alkanoic acids are within the range of both modern shrubs and aquatic plants. Mid-chain waxes shared a similar pattern in terms of δ^2H values, as well as the long-chain waxes. Unit 2 had consistent high concentrations of *n*-alkanoic acids, with δ^2H values generally ^2H-enriched compared to other units. Units 3-5 contain more abundant mid-chain *n*-alkanoic acids and comparison to modern plant $\delta^{13}C$ values indicates both terrestrial and aquatic plants may have contributed biomarkers to these sediments. This is also supported by the distinct δ^2H patterns between the mid- and long-chain *n*-alkanoic acids.

Source-water δ^2H values inferred from leaf-wax δ^2H values are close to modern precipitation δ^2H values at Thule, Greenland: precipitation δ^2H values inferred from long-chain waxes in Unit 1 are close to modern summer precipitation δ^2H values and pore ice δ^2H, whereas precipitation δ^2H values inferred from long-chain waxes in Unit 1 are close to modern mean annual precipitation δ^2H values. Wax-inferred source water δ^2H values for all chain lengths in Units 3-5 fall between mean annual and summer precipitation δ^2H values, with long-chains ^2H-enriched relative to mid- chains and relative to pore ice. In Unit 2, wax-inferred source water δ^2H values are ^2H-enriched compared to other units, falling closer to modern mean summer precipitation δ^2H, and strongly ^2H-enriched relative to pore ice, which is ^2H-depleted relative to mean annual precipitation δ^2H.

The brGDGTs have different distributions between Unit 1, Unit 2, and Units 3-5, suggesting different environmental conditions or bacterial sources, but brGDGT distributions in all units fall within the range of those found in modern high-latitude lakes. Changes in the concentration distribution, and indices from Unit 3, through Unit 4, and into Unit 5 suggest different sources or environmental conditions. Given the similarity with modern lake brGDGTs, we applied a lake calibration to infer mean summer air temperature for each unit. The mean brGDGT-inferred summer air temperature for all units is 5.0 to 5.9°C, 2°C warmer than modern summer air temperature at Thule. These values are close to other regional records of early Holocene temperature. These temperature and source water hydrogen isotope results suggest that climate and vegetation on northwestern Greenland that led to pre-Holocene ice-free periods was similar to that of the Early Holocene.

BIOCLIMATE CONDITIONS IN SW GREENLAND AND EASTERN COAST OF LABRADOR DURING THE INTERNATIONAL POLAR YEARS (1882/83, 1932/33, 1957/58, 2007/08 AND 2032/33)

Andrzej **Araźny** [1,2], Konrad Chmist [1], Rajmund Przybylak [1,2], Przemysław Wyszyński [1,2], Garima Singh [1], Babak Ghazi [1]

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[2] Centre for Climate Change Research, Nicolaus Copernicus University in Toruń, Poland

International Polar Years (IPY) are an organised series of international scientific and research expeditions that have aimed to collect information about the Earth's polar regions. The first such expedition took place in 1882/83 and the second in 1932/33. The International Geophysical Year took place in 1957/58, and the fourth Polar Year took place in 2007/08. This last was extended by several months due to the particular importance given to research to explain the variability and changes taking place in polar regions. The fifth International Polar Year is planned for 2032/33. One of the main goals of IPYs has been and will be to determine the current state of the environment of polar regions by assessing the spatial and temporal variability of its physical, biological and social elements. The research has demonstrated the key importance of polar regions in shaping weather and climate at lower latitudes.

The aim of this study is to present changes in bioclimatic conditions over the last 140 years using data collected during IPYs in south-west Greenland and the eastern coast of Labrador (Fig. 1). Results were compared with contemporary conditions from the period 1991–2020. The meteorological data used for the study were taken from the Godthaab station (now Nuuk) in Greenland (Fig. 2) and from the Nain station in Labrador for 1882/83, 1932/33, 2007/08 and 1957/58. In Labrador for the last listed year the data were taken from Hopedale due to a lack of data from Nain. The Nain and Hopedale stations are relatively close to each other and correlate closely in terms of climatic conditions. However, to investigate biometeorological conditions for the future IPY 2032/33, we employed two General Circulation Models (MRI-ESM2-0 and UKESM1-0-LL) under two climate change scenarios, SSP1-2.6 (highest mitigation scenario) and SSP5-8.5 (highest greenhouse gas emission scenario).

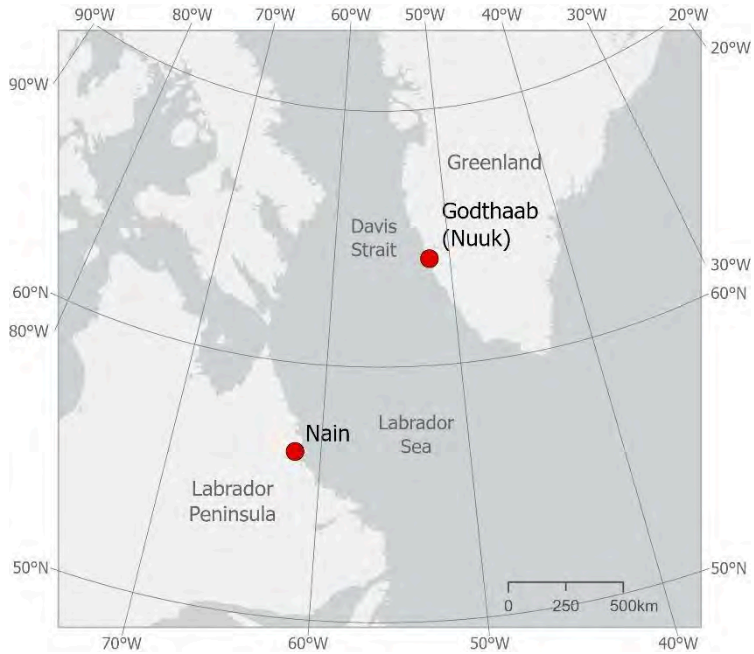

Fig. 1. Location of research area

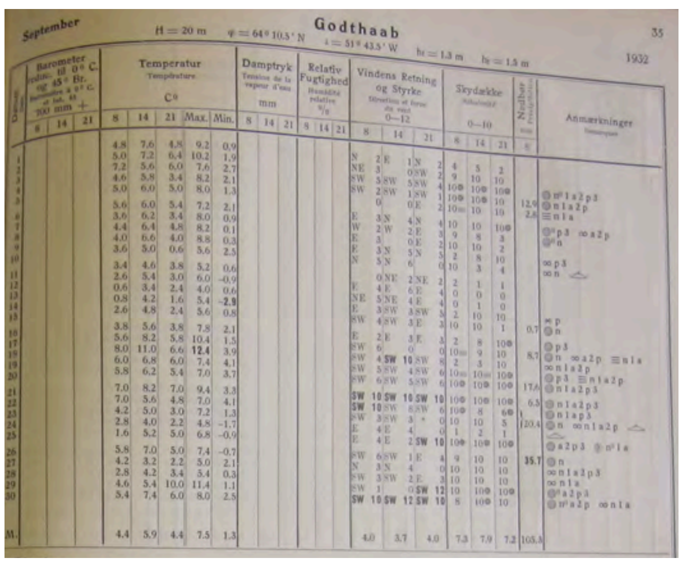

Fig. 2. Example of source data from the Danish *Meteorological Yearbooks* for Godthaab station

The study analysed two biometeorological indicators: Wind chill temperature (WCT) and predicted clothing insulation (Iclp). These indicators were calculated using the BioKlima 2.6 program (www.igipz.pan.pl/geoekoklimat/blaz/BioKlima.htm). The calculations employed data from measurements taken in the afternoon (mainly 1–2 pm LT). The wind chill temperature was used to examine apparent cold and to assess the risk of frostbite to the human body in SW Greenland and on the eastern coast of Labrador. A weather hazard scale is used that is based on the WCT value. The following apparent cold ratings can be assigned to WCT values: slight (0÷-10 °C), moderate (-10.1÷-25 °C), significant (-25.1÷-45 °C), severe (-45.1÷-60 °C) and very severe (<-60 °C). The predicted clothing insulation index was developed for thermophysiological tests of outdoor working conditions. It was calculated assuming a metabolism of 135 Wm^{-2} for a person moving outdoors at 4 km h^{-1}. Then, the expected insulation value of clothing (in clo) was determined for given meteorological conditions. Iclp values are assigned the following assessment of thermal conditions: very warm (<0.30 clo), warm (0.31–0.80 clo), neutral (0.81–1.20 clo), cool (1.21–2 .00 clo), cold (2.01–3.00 clo), very cold (3.01–4.00 clo), Arctic (>4.00 clo).

In the modern period (1991–2020), the average annual value of predicted insulation of clothing was 1.9 clo in both Nuuk and Nain. In Nuuk, during the 1932/33, 1957/58 and 2007/2008 IPYs, ~0.1÷0,2 clo less was needed to maintain the comfort of a warm person than today, whereas 0.1 clo more was needed during the IPY of 1882/83. Conditions were similar to these at the Nain station during the four IPYs. In the Nuuk and Nain stations, it is recommended that people in motion (~4 km/h) use clothing with thermal insulation of ~1.0–1.5 clo in summer up to over 3.0 clo in the winter months. However, in the planned IPY in 2032/33, the expected insulation of clothing will be similar to today.

At the turn of the 21st century, wind chill temperatures were comparable in Nuuk and Nain (-2.0 and -2.1 °C, respectively). In the modern period and in the four IPYs (1882/83, 1932/33, 1957/58, 2007/08), there has generally been no risk of frostbite in the study area from May to September. However, the most unfavourable conditions for humans occur, of course, in winter. Then, there is a risk of hypothermia for anyone outside for long periods without adequate protection. For a few days a year at both stations, a high and significant risk of frostbite has been recorded. On such days, it is possible for a person to suffer frostbite on uncovered face and hands after 5–30 minutes. The results of global climate models indicate that, in the planned 2032/33 IPY, WCT values will be similar to or slightly lower (less favourable) than those recorded today. This will probably be the result of higher wind speeds, despite the ongoing warming in the analysed area.

The work was supported by the National Science Centre, Poland project No. 2020/39/B/ST10/00653.

THE HOLOCENE FIRE HISTORY OF NORTHEAST ICELAND BETWEEN NATURAL AND ANTHROPOGENIC FORCINGS

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Iceland's Holocene paleoclimate provides insights into the climate dynamics across the northern North Atlantic, a critical area for global heat distribution. The interplay of orbitally driven cooling, volcanism, and human influence as forcings for local environmental changes, including fire and soil erosion, remains a subject of debate. Evidence suggests that human impact may have diminished environmental resilience amid deteriorating climatic conditions, yet the extent of the impact of human and natural factors on Iceland's landscape instability remains elusive due to a lack of data, including the pre- and post-human colonisation natural fire regime.

We introduce the first continuous Holocene fire record of Iceland, derived from lacustrine sediments in the northeastern region. Pyrogenic PAHs, generated from incomplete biomass combustion, offer insights into fire dynamics influenced by factors like fire temperature, biomass typology, and distance to source. Faecal sterols/stanols, employed in archaeological and paleoclimate studies, can function as markers for human and/or livestock/herbivore waste, providing a regional tracer of human settlement. We use other markers such as *n*-alkanes, perylene, biogenic silica, TOC and $\delta^{13}C$ to track shifts in soil erosion and lake productivity. The data provides new insights but also raise new questions about the interactions of natural and anthropogenic factors as well as on the applicability of such proxies in these environments.

Our findings unveil four pivotal phases characterising the northeastern Icelandic fire regime during the Holocene. Notably, a protracted era around the Holocene climatic optimum (approximately 9.5 – 4.5 ka BP) featured generally infrequent fires , which was accompanied by relatively low levels of faecal sterols/stanols. At 4.5 ka BP, a new phase commenced with a general escalation in all PAH values. A comparison with recent palynological and δD data from northwest Iceland suggests shifts in the North

Atlantic Oscillation (NAO) as the primary driver behind fire patterns in Iceland. Reduced precipitation likely influenced the regional vegetational community, enhancing biomass availability and flammability, resulting in widespread low-temperature fires easily triggered by frequent volcanic episodes.

We find no discernible increase in PAHs around the 9th century CE, a period linked to human colonisation. On the contrary, fire frequency appears to decrease following human settlement despite increasing aridity and a shift toward a more fire prone vegetation. This suggests that while natural factors must have been the primary factor controlling fire regimes through the Holocene, human activities might have suppressed fire frequency through land clearing for farming and increased erosion due to intensive grazing.

CENTER FOR BRAIDING INDIGENOUS KNOWLEDGES AND SCIENCE (CBIKS)

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CBIKS is examining how to effectively and ethically combine Indigenous Knowledges(IK) and conventional “western” science(WS) through research at the interface of three interconnected research areas of climate science, archaeology, and food systems. Combining IK and WS involves “plural coexistence” of two very different knowledge systems, a process Mi’kmaq peoples call ‘two-eyed seeing’ and which we refer to as ‘braiding knowledges’. We have evidence of IK’s scientific potential for better understanding long-term environmental shifts, biodiversity, and archaeological sites. Geoscientists, archaeologists, and climate scientists demonstrate an interest in knowledge co-production with Indigenous people. Yet IK remains at the margins of scientific research. Our vision is that braided IK/WS methodologies become mainstream in scientific research. That they are utilized by scientists in collaboration with Indigenous communities to address complex scientific problems and provide place-based solutions that address the existential threat of climate change and its urgent impacts on cultural places and food systems. We envision a generation of connected and supported students, scientists, and Indigenous communities with the skills and training to conduct and apply research using braided IK/WS methodologies. Funding began in October, 2023.

Our primary research questions are: How is research at the intersection of climate change, cultural places, and foodways planned, developed, and carried out in ways that effectively and ethically braid IK and WS throughout the research process? How are those methods, methodologies, protocols, and practices ethically adapted for research in other places and scientific disciplines? To address this, we take a wide scope (comparative, international, across multiple disciplines) with a sharp focus (specifically examining the ‘braiding’ framework of knowledge co-production). Using qualitative methods, we are developing a series of place-based IK/WS methodologies and generalizable prototypes, along with guidelines for ethically adapting them. Our research includes 3 concurrent, interrelated components:

1. Knowledge Base. CBIKS will meet the need for a common publicly accessible repository to store, organize, and share methods, ethics, and best practices of connecting IK and WS.

2. Regional Hubs. We are implementing community-based participatory research to develop and carry out Place-based Studies and Projects using a braided IK/WS methodology in partnership with 57 Indigenous communities in 8 Hubs across the U.S. and in Canada, Aotearoa New Zealand and Australia.

3. Thematic Working Groups. Key lessons from the Place-Based Studies will be distilled by Working Groups to produce generalizable methodologies and ethical guidelines for IK/WS research. An STC would allow our team of 54 scientists (including 34 Indigenous natural, environmental, and social scientists) to work cross-culturally, and involve Indigenous community members directly in science research, across multiple disciplines.

CBIKS aims for the geography of innovation to be expanded to include Indigenous peoples and lands, and for the intellectual talent of Native Americans, Native Hawaiians, and Alaskan Natives, all of whom are vastly underrepresented in the sciences, to be developed into a national cohort of Indigenous scientists who lead the world in IK/WS research. CBIKS will train a diverse group of postdocs, undergraduate and graduate students to braid IK and WS. Indigenous community members, including youth and elders, will be involved in research at all CBIKS Hubs. CBIKS PreK-12 education activities include Indigenous STEAM Camps, IK/WS Afterschool Program, and Indigenous Science Theater performances. When primary schoolers involved in CBIKS education activities enter the workforce, they will have vastly more knowledge and experience in IK than the majority of today's scientists and government agency staff. CBIKS research will provide scientists, resource managers, and Indigenous communities with methodologies for braiding IK/WS that are timely and relevant, leading to enhanced climate adaptation and mitigation planning and improved care for tribal homelands and U.S. public lands and cultural heritage. CBIKS knowledge transfer activities include IK/WS Trainings, and Community Reports that utilize storytelling and accessible arts-based formats such as graphic novels, animation, and Virtual Reality.

Reference: https://www.umass.edu/gateway/research/indigenous-knowledges

Implementing Strategy: Hub Co-Leads

- Place-based Decision-Making
- Locally-based operational protocols
- Shared responsibility
- Training and Mentorship

Regional Hubs

Northeast
UMaine
Newsom
Daigle
Ranco

Midwest
UMichigan
Michener
College of Menominee Nation
Kenote

Mountains & Prairies
UMontana
Simonds
Eggers

Pacific Northwest
W Washington U
Hatch
UC Santa Cruz
Daehnke

Local Autonomy with Connections to the Collective

Alaska/Arctic
Alaska Pacific U
Temte
UMass Amherst
Brigham-Grette

Southwest
N Arizona U
Marek-Martinez
Chischilly

Pacific Islands
Huliauapa'a
Uyeoka
U Waikato
Tuaupiki

Australia
Charles Darwin U
Pollard
Flinders U
Smith

CBIKS | Center for Braiding Indigenous Knowledges and Science

STABLE O AND H ISOTOPES OF LACUSTRINE ORGANIC MATERIALS AS PROXIES FOR LAKEWATER ISOTOPES: INSIGHTS FROM A DECADE OF RESEARCH IN GREENLAND

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Reconstructions of lakewater stable isotopes are used to infer past climate parameters including precipitation-evaporation balance, moisture source/path, and paleotemperature. In the many arctic lakes that do not preserve carbonate in their sediments, lacustrine organic materials play important roles as archives of lakewater isotopes. We review lessons learned from investigating the O isotopic compositions of aquatic insect (chironomid) larval chitin and aquatic mosses and the H isotopic compositions of sedimentary short-chain leaf waxes in lakes across Greenland.

Based upon modern waters and plants, spatial transects of surface sediments, and downcore sedimentary records, we observe that:

(1) Subfossil chironomids reliably reflect lakewater $d^{18}O$ values, most likely on an annually integrated basis but with some seasonal uncertainty (Lasher et al. 2017; Puleo et al. 2022; McFarlin et al. 2023). There is thus far no strong evidence for major differences in biological fractionations between species, although this has not been thoroughly investigated.

(2) Whole remains of submerged aquatic mosses yield reliable reconstructions of lakewater $d^{18}O$ values and agree well with $d^{18}O$ values of cellulose extracted from the same types of mosses (Lasher et al. 2017; Puleo et al. 2022; Puleo et al. in prep).

Importantly, utilizing either of the above demonstrably aquatic materials for isotope analyses removes water-source ambiguity as an uncertainty in paleoclimate reconstructions.

(3) Short-chain leaf waxes reflect lakewater $d^{2}H$ values in many settings, consistent with dominantly aquatic sources for those waxes. However, aquatic source cannot necessarily be assumed; we have discovered non-lakewater dominant sources of H to short-chain sedimentary waxes in some Greenland settings. Terrestrial plants can be a

major source of short-chain leaf waxes, such that short-chain wax d^2H values may be more reflective of precipitation than of lakewater d^2H values for some lakes (Dion-Kirschner et al. 2020; McFarlin et al. 2019). At some Greenland lakes we also find that very isotopically light H in short-chain plant waxes was likely sourced from methane during the middle Holocene, confounding attempts to reconstruct lakewater d^2H values in those systems but offering a previously unrecognized proxy for past shifts in aquatic methane and carbon cycling (McFarlin et al. 2023).

Overall, lacustrine organic materials have tremendous potential to record lakewater isotopes, but depth and confidence of interpretations remains hindered by the uncertain sources of some organic materials, the uncertain seasonal biases of most proxies, and the need to better constrain biosynthetic fractionations.

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WEATHERING OF ROCK SURFACES IN MIDTRE LOVÉNBREEN FORELAND (SPITSBERGEN)

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Introduction

The objective of this study is to investigate the rate of rock weathering in the proglacial environment in front of a retreating High Arctic glacier - Midtre Lovénbreen (Figure 1). Our project is based on the premise that freshly exposed rock surfaces at the glacier's snout signify the commencement of subaerial weathering processes. By analyzing moraines of varying ages, we aim to observe the evolution of weathering patterns over time. The research is conducted on rocks of uniform petrological composition, specifically fine-grained biotite gneiss.

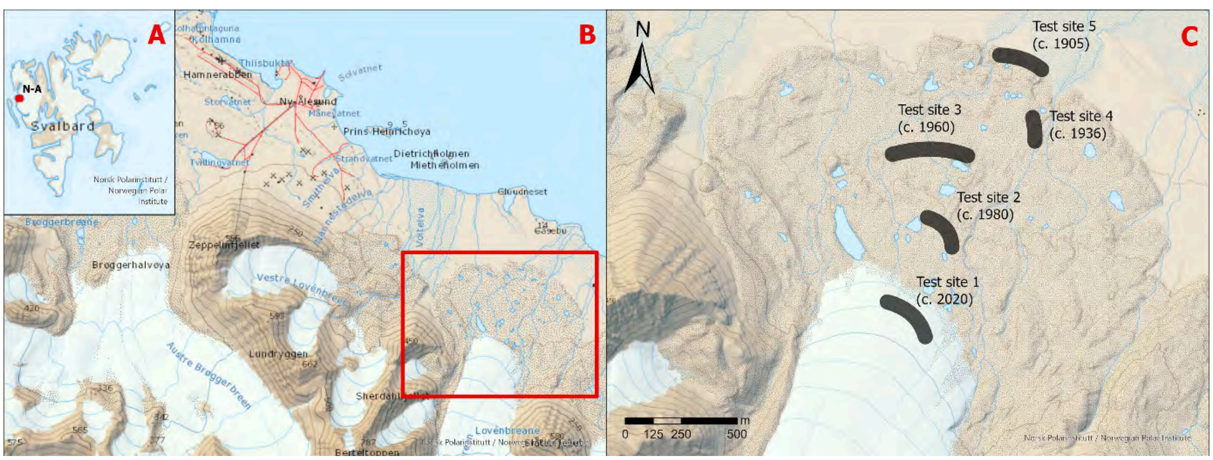

Figure 1. General location of the study site (A), Ny Ålesund area in marked Midtre Lovénbreen foreland (B) and location of test sites (1-5) and deglaciation ages (C).

Methods

Our research presents an interdisciplinary approach to the analysis of rock surfaces: i) micro-roughness, ii) hardness, iii) spectral reflectance, iv) petrographic and mineralogical characteristics (under optical microscopy, Scanning Electron Microscope

– SEM, and X-ray Diffraction – XRD), vi) micro-biological content (microbial cultures, SEM observations). Analyses i-iii were conducted directly at five designated test sites, following a chronological sequence: site 1, deglaciated around circa 2020 AD; site 2, circa 1980 AD; site 3, circa 1960 AD; site 4, circa 1936 AD; and site 5, circa 1905 AD (during the Little Ice Age glacial maximum), as depicted in Figure 1. Ten rock surfaces were chosen for measurements i-iii at each test site, while the remaining analyses were conducted on rock samples in controlled laboratory settings. Micro-roughness of the rock surfaces was quantified using a Handysurf+ profilometer, hardness was assessed with a Schmidt hammer N-type, and reflectivity was determined using an ASD FieldSpec 4 with a contact probe. Additionally, Unmanned Aerial Vehicle (UAV) surveys were conducted to gather detailed spatial data, facilitating the creation of precise environmental representations through Digital Elevation Models (DEM) and orthophoto maps, employing a DJI Mavic Enterprise RTK drone. LiDAR surveys, executed with a GeoSLAM ZEB Horizon handheld scanner, further enhanced the DEM accuracy for each examined site.

Results

Micro-roughness of rock surfaces increases as one moves from the glacier edge towards the Little Ice Age (LIA) moraines, accompanied by a subtle decrease in rock hardness. Although these differences are statistically significant, the changes do not follow a linear pattern, as evidenced by the leveling of micro-roughness at intermediate test sites and a slight increase in rock hardness at the oldest moraine (Figure 1 AB). The spectral reflectance curve obtained for test site 1 exhibits a notable elevation compared to the curves of the older sites. A general decline in reflectance towards the older moraines is particularly evident (and statistically significant) up to a wavelength of 1600 nm, noticeable only when comparing sites 1 and 2 with the older moraines. The curves derived for sites 3-5 exhibit striking similarity (Figure 1C).

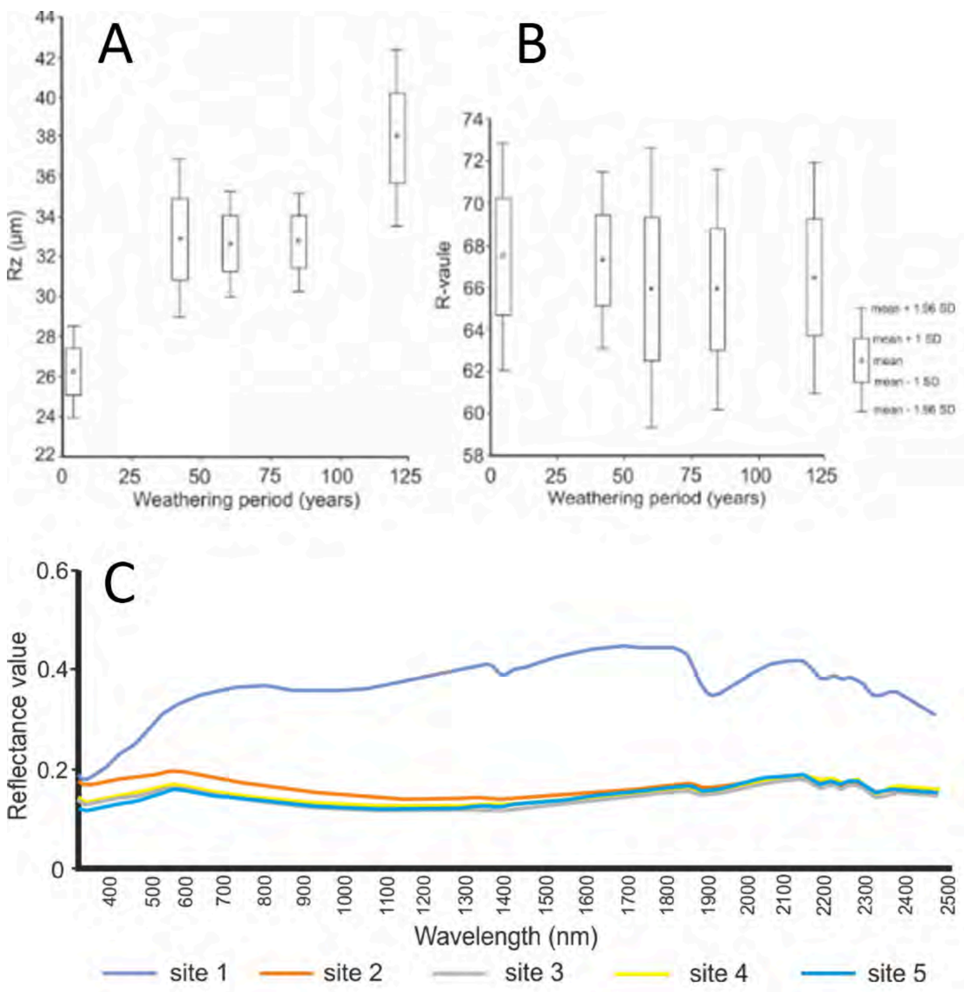

Figure 2. Rock surface micro-roughness (A), hardness (Schmidt hammer tests) measurement values (B) [test sites sequence from left (site 1) to right (site 5)]. Reflectance values from test sites 1-5 (C)

SEM images captured from the thin sections depict the formation of a weathering rind. The images display contrasting textures, with smooth surfaces characteristic of the glacier's influence at test site 1 (Figure 3A), and notably more porous textures observed at test site 5 (refer to Figure 3B). We also conducted SEM imaging of samples extracted from the surfaces of the investigated rocks, unveiling their colonization by lithobiontic microorganisms (refer to Figure 4 CD), which are known to potentially impact weathering processes. Subsequently, the rock samples were cultured on various liquid and solid media to isolate bacteria and fungi. These cultures are currently undergoing incubation and subsequent passages for further examination.

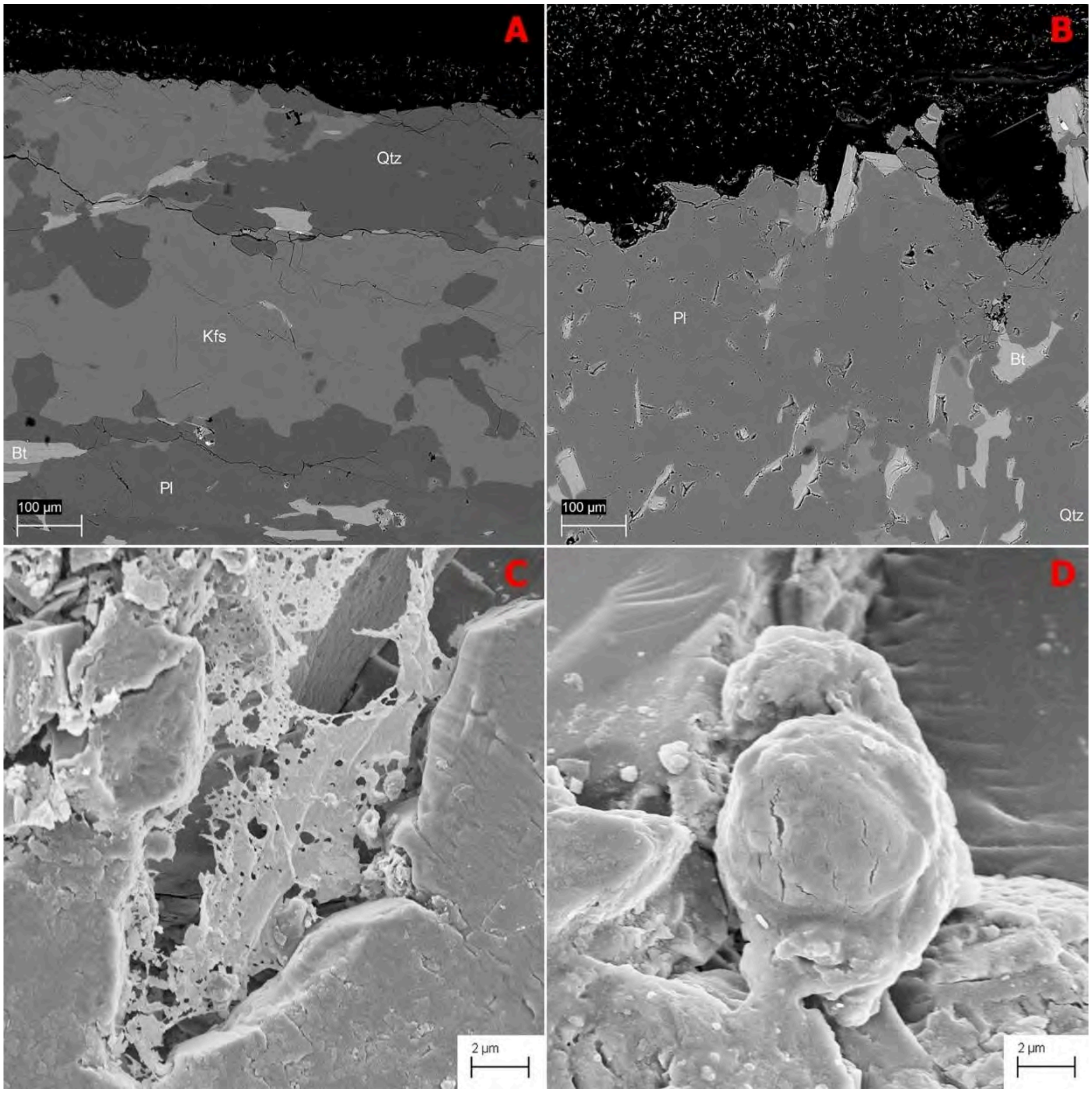

Figure 4. SEM images of the thin sections of the samples from test site 1 – c. 3 years of weathering (A), and test site 5 – c. 118 years of weathering (B). Examples of lithobiontic structures: a microbial biofilm on test site 2 (A) and cyanobacterial cells on test site 3 (B).

Preliminary outcomes from X-ray Diffraction (XRD) analyses have been gathered, highlighting variations in the mineral composition among the rock samples investigated. This includes both the altered layers within the weathering rind and the underlying unaltered parent material, as well as distinctions observed between various examination sites. These initial findings reveal measurable shifts in the concentrations of specific minerals.

Discussions and conclusions

This research progresses from previous investigations we conducted in the Hallstatter Glacier foreland in the Alps, focusing on limestone weathering (Dąbski et al., 2022). The current study shifts our examination to the Midtre Lovénbreen foreland, targeting fine-grained biotite gneiss. Our exploration continues over a similar timeframe but extends to different climatic conditions and rock types. The findings reveal a trend of increasing micro-roughness and mechanical strength over time, paired with a reduction in spectral reflectance. The structure of the rocks, influenced by their crystalline composition, exhibits changes in mineral weathering that appear to be primarily quantitative in nature. The presence of microorganisms was noted at every test site examined. Moving forward, our research will incorporate DNA sequencing of the environmental samples to enhance our understanding of the microorganisms contribution to the weathering processes.

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Acknowledgments

The authors express their gratitude to Marlena Kycko and Dominik Kopeć (MGGP Aero) for spectral reflectance measurements, and Anna Grabarczyk (RM TERRA) for petrographic analysis. This research was authorized by the Governor of Svalbard (RiS ID: 12096) and funded by the National Science Centre, Poland [grant number 2020/39/O/ST10/01068].

GLACIAL DYNAMICS ALONG MERCHANTS AND BROUGHTON TROUGHS (BAFFIN BAY) DURING THE LAST GLACIATION

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Today's high-latitude geomorphology of continental shelves has been shaped by the advance and retreat of ice sheets. In order to understand and predict how modern glacial margins and marine- based ice sheets will respond to future climate change and sea-level fluctuations, it is essential to reconstruct the advance and retreat of past ice-sheet margins that provide paleoglaciological analogues. High-resolution swath bathymetric data, seismostratigraphic data, sediment cores, radiocarbon dating and benthic foraminiferal faunas from the Merchant's and Broughton cross- shelf trough systems can improve our understanding of the past glacial dynamics (extent, flow, and decay) of the Laurentide Ice Sheet (LIS) during the last glaciation. This combination of techniques provides a high-resolution record of rates of glacial retreat along these cross-shelf troughs and highlights the importance of the meltwater of a polythermal-type glacier in the Canadian Arctic. The dating of deposits associated with turbidity currents and foraminiferal assemblages dominated by the calcareous species *Elphidium excavatum* suggest that the ice- sheet margin retreated from Merchants trough grounding zone wedge at 11.6 cal ka BP after stabilization. In Broughton, the movement of the glacier is indicated by the presence of diamictons and turbidites. Both troughs show asynchronous deglaciation record caused by the partitioning of inland ice masses.These results in both troughs suggest slightly later retreat than previously hypothesized and a perennial ice cover in the Merchants area until ice retreated after 11.6 kcal BP.

MIOCENE CLIMATIC OPTIMUM AND MIDDLE MIOCENE CLIMATE TRANSITION: A FORAMINIFERAL RECORD FROM THE CENTRAL ROSS SEA, ANTARCTICA

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The Ross Sea record of the Miocene Climatic Optimum (MCO, ~16.9-14.7 Ma) and the Middle Miocene Climate Transition (MMCT, ~14.7-13.8 Ma) provide critical insights into Antarctic ocean-cryosphere interactions during a time of extreme warmth and subsequent cooling. Here we report on lower to middle Miocene foraminiferal assemblages from IODP Site U1521 (Lithologic Units IV, III, and lower II) in the central Ross Sea to identify regional shifts in environmental and water mass conditions, and trace continental shelf evolution. We identified 15 benthic biofacies clusters, dominated by abundant *Globocassidulina* (indicator of proto-Circumpolar Deep Water, pCDW), *Uvigerina* (high productivity, enhanced bottom water currents, and/or coarser sediment), *Nonionella* (high productivity), *Melonis* (high productivity), and/or *Globobulimina* (high productivity, low oxygen and refractory organics) using a two-way Q-mode/R-mode analysis to develop preliminary regional paleoenvironmental interpretations.

Unit IV (representing the early MCO event) is a short-lived (~80 ka), progradational, clast poor sandy diamictite, likely deposited during two progradational cycles; the upper cycle is thinner and transitional with overlying Unit III. Unit IV sediments contain the most persistently abundant and diverse foraminiferal assemblages recovered at U1521, despite very high sedimentation rates. The benthic assemblages shift between *Globocassidulina* and *Uvigerina* dominance suggesting changes in pCDW influence relative to productivity and/or current activity. We suggest the decrease in *Uvigerina* (a shelf edge proxy) through the study interval tracks the northward progradation and shoaling of the Ross continental shelf during the late Early to Middle Miocene.

Unit III (MCO) was deposited in an open marine setting, evident both by the IRD clast-free, diatom rich/bearing muds and the foraminifera. The sporadic nature of foraminiferal abundances in Unit III is likely due to intervals of terrigenous mud alternating with more diatom rich/bearing muds; as in Unit IV, the muddier lithologies (higher natural gamma ray values) are more likely to preserve calcareous foraminifera whereas the most diatom-rich sediments (lower NGR values) are more corrosive to carbonate. We interpret the muddier intervals as interglacials with incursions of pCDW as indicated by increased *Globocassidulina subglobosa*, and sporadic occurrences of rare warmer water planktic foraminifera. Collectively, these multiple incursions of warmer water planktic foraminifera provide evidence for polar amplification in the Ross Sea during the MCO and MMCT. The diatom-rich muds are interpreted as glacials during the MCO with open marine conditions and higher productivity. The dominance of *Globobulimina* in the upper part of Unit III corresponds with the CM2 carbon maximum and low oxygen conditions in the sediments ~16.1 Ma. Subsequent glaciation, ice sheet grounding, and erosion on the shallow shelf are recorded by the widespread Ross Sea Unconformity 4 (RSU4; ~15.95-14.2 Ma) at Site U1521. Unit II (MMCT) represents sedimentation in the interval between the RSU4 unconformity and the Mi3 glaciation at ~13.9-13.8 Ma. The benthic biofacies composition of Unit II shows a further increase in neritic taxa including *Elphidium magellanicum* and *Epistominella vitrea*, suggesting shoaling of the continental shelf.

A preliminary isotope record reveals a connection between the U1521 benthic foraminiferal biofacies, water masses, relative sea level (paleobathymetry), and surface water productivity. The absence of agglutinated benthic foraminifera suggests that High Salinity Shelf Water was not produced during the MCO or MMCT. Lastly, our initial comparison with ANDRILL site AND-2A yields similar environmental interpretations, including peak warm intervals during the MCO, supported by the foraminifera and unit lithologies. Suspected glacial intervals during the MCO, including Mi2 at the top of Unit III, correlate well with the reconstructed deep sea estimates of ice volume changes (seawater $d^{18}O_{sw}$ record) from ODP Site 1171 on the Tasman Rise.

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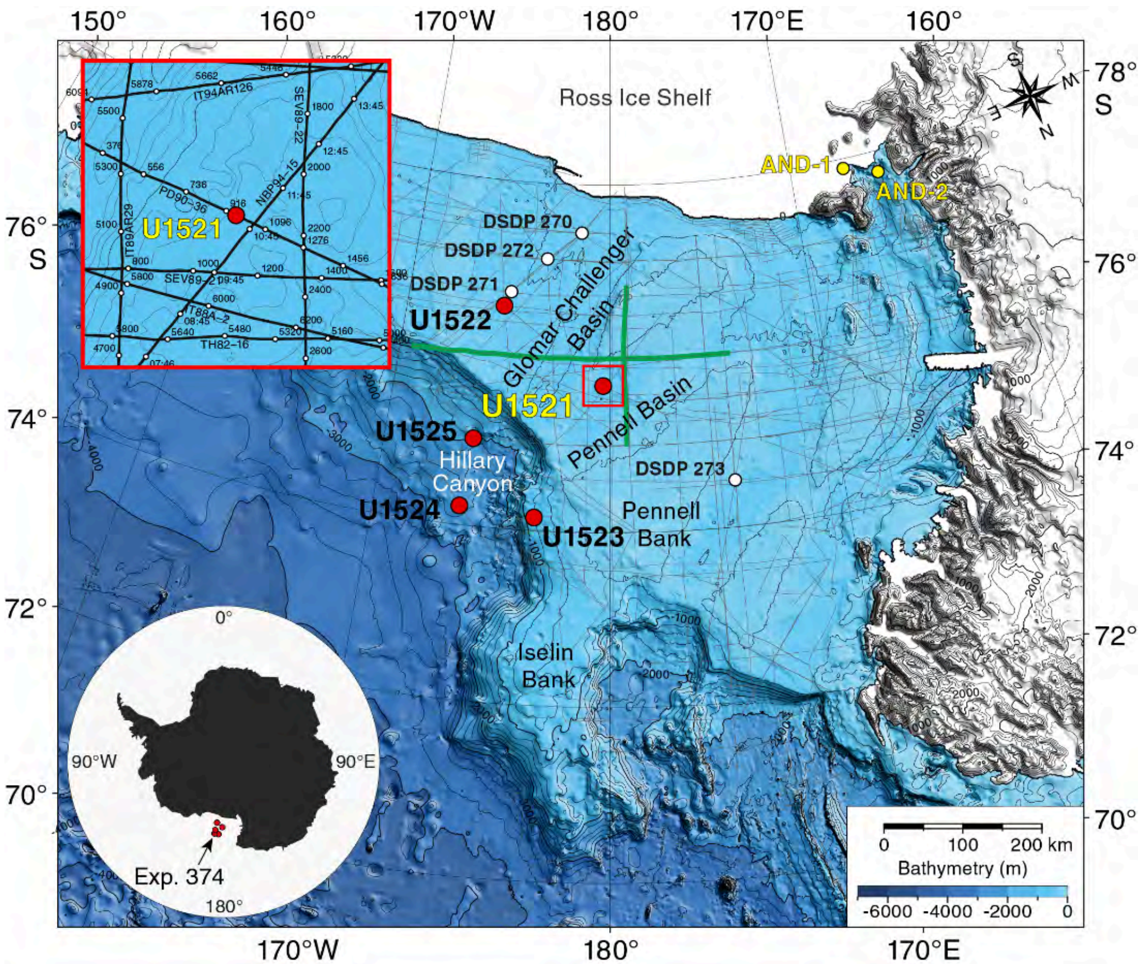

Figure 1: Map of IODP expedition 374 drill sites (red dotes), Site U1521 in red box, DSDP Leg 28 sites (white circles) and ANDRILL sites (yellow circles) (McKay et al., 2019).

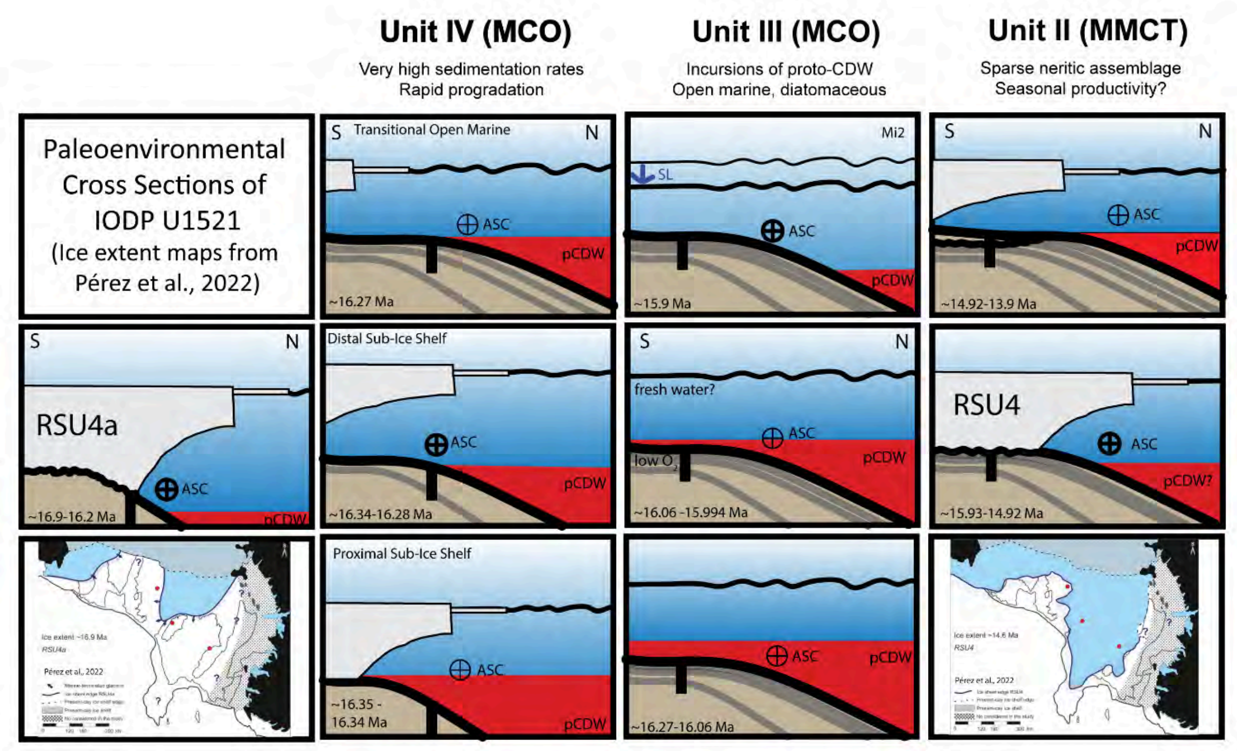

Figure 2. Environmental Reconstructions of Units IV, III, and II (age model b) and RSU4, and RSU4a Oldest to youngest from the bottom to the top and left to right. Inset maps in the bottom left and right are ice sheet edge figures for RSU4a (bottom left) and RSU4 (bottom right) (Pérez et al., 2022).

DONALD B. MACMILLAN'S ARCTIC LEGACY, RETRACED & RE-QUERIED IN POETRY

Elizabeth **Bradfield**

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Arctic explorers from the United States, particularly 20th century men from the "Lower 48" have a complicated legacy. Drawn north by fascination, what biases do they drag with them? How do their own retellings, when they return home, warp truths, bolster their own narratives, and obscure necessary awarenesses?

Elizabeth Bradfield, a poet/naturalist who has worked in the Arctic since 2008, will share work from her book-in-progress of poems that interweaves the lives of Rear Admiral Donald B. MacMillan, his wife Miriam, and her own experiences in the Arctic. Grounded in history and science, expressed in story and poetry, Bradfield's approach allows for a complex reckoning of knowledge and wonder, information and emotion, experience and fumbling.

Both MacMillan and Bradfield, in their own times, straddle the awkward space of a "southerner" who travels to the Arctic dedicated to science and education but also enabled, in part, by tourism. Both are working in times of radical technical and social change—for MacMillan, it was the advent of radio, film, and photography; for Bradfield, the internet, global awareness of climate justice and the disproportionate impact on Arctic communities, recent advances in Indigenous sovereignty, and LGBTIQ+ rights. The parallels and divergences of their stories allow a complex reckoning.

Donald B. MacMillan (1874 – 1970) was born and died in Provincetown, Massachusetts and spent most of his life sailing in Arctic Canada and Greenland. He was part of Peary's 1908 North Pole expedition but had to turn back because of frostbitten toes; from there, however, he his life was dedicated to Arctic work and he made over 30 trips north to Labrador, Baffin Island, and Greenland, many with his late-in-life wife, Miriam. He was the first to bring color film and motion film to the Arctic; on his 1913 – 1917 Crocker Land expedition, he ended up overwintering in Northwestern Greenland, a time he used to learn from local Inuit and to plan his future in the Arctic.

In 1921 MacMillan designed and had built the schooner *Bowdoin*, small of size, snub-nosed, round-hulled and thus ideal for Arctic work. He sailed the *Bowdoin* on over two dozen voyages and she sails still, to this day, under the captaining of the Maine Maritime Academy. MacMillan was an early citizen-scientist, bringing interested university “boys” on his expeditions both as a source of funding and through a sense of advocation—he wanted to build and preserve connections to and awareness of the North with southern scientists, businessmen, and researchers.

We can’t talk about the Arctic, as southerners, without talking about tourism. "Last chance tourism" is increasing as awareness and fear about climate change rises. Many people are querying how we travel and understand wild places, particularly icy ones. In May, 2017, *The New Yorker* published “The Complicated Relationship Between Cruise Ships and the Arctic Inuit,” by Peter Kujawinski. MacMillan’s trips were tourism-adjacent; he often conducted research, but his voyages were funded by the boys he took with him; Bradfield worked on small expedition ships in the Arctic. Both experiences both allow amazing access to a wide range of places and limit the deep friendships and complicated experiences a more settled, integrated time in a community on shore would allow.

What is MacMillan’s legacy today? What does it mean to write, as a queer, white American woman in the 21st century, about the experiences of a white man comfortable in his patriarchal position? What can we learn by trying to understand both the honest yearning and the fumblings, unintentional or not, in both positions?

Through all of this thrums the questions: How do we write truly and honestly about place? And what does “last-chance tourism” lay over that question? Not just the drive toward it within tourists themselves, but the industry and infrastructure that grapples with and takes advantage of that market? And what, beneath those self-aware questions, still sings as poetry, still drops the jaw with awe?

Let’s wonder together.

BIO: Writer/Naturalist **Elizabeth Bradfield’s** recent books are *Toward Antarctica, Once Removed*, and the anthologies *Cascadia Field Guide: Art, Ecology, Poetry,* co-created with CMarie Fuhrman and Derek Sheffield and winner of the 2024 Pacific Northwest Book Award, and *Broadsided Press: Fifteen Years of Poetic/Artistic Collaboration*, co-created with Alexandra Teague and Miller Oberman. Her poems have appeared in *The New Yorker, Atlantic Monthly, Poetry, The Sun,* and her honors include the Audre Lorde Prize in Lesbian Poetry and a Stegner Fellowship. Liz works as a naturalist and field assistant at home on Cape Cod, teaches creative writing at Brandeis University, and is Editor-in-Chief of Broadsided. www.ebradfield.com

PALEOCLIMATE DURING EARLY HUMAN MIGRATION INTO INUTOQQAQ NUNAAT, NORTHERN GREENLAND

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Around four thousand years ago, a remarkable migration took place: people crossed over Nares Strait from Ellesmere Island and entered Inutoqqaq Nunaat, the largely ice-free region of northernmost Greenland. Paleo-Inuit hunters (of the Independence culture) arrived in this remote region—an area that had never been occupied by human beings-- and survived mainly by hunting muskoxen. Then, the region was abandoned for over a thousand years, before another group of people (the Greenlandic Dorset) ventured north. Another millennium of abandonment followed, before a final wave of people arrived—the Thule people (ancestors of the modern population of Greenlanders) -- using whaling boats (umiaks) to navigate along the coast of the Arctic Ocean from Ellesmere Island.

The archeological record of these different periods of migration poses many questions: what was the climate like when people ventured into the region? Was the vegetation more extensive in the past, supporting more muskoxen? What conditions led to the periods of abandonment? How were Thule whalers able to navigate around northern Greenland where sea-ice is thick and persistent? How do conditions in the region today compare to those in the past?

To address these questions, we have recovered lake sediments from several sites in the core area of human occupancy—Wandel Dal, west of Independence Fiord. Multiproxy studies of those sediments are underway and preliminary results will be presented, with a particular focus on the Thule period.


HIGH-RESOLUTION SUBMARINE GLACIAL LANDFORMS OF TIDEWATER GLACIERS IN CROKER BAY, THE CANADIAN ARCTIC ARCHIPELAGO

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The Canadian Arctic Archipelago (CAA) is being severely affected by global warming. With more than 300 glaciers, it is a hotspot for increased glacier retreat and meltwater runoff. On a global scale, these ice masses are a significant contributor to eustatic sea level rise, ranking just behind Greenland, Antarctica and Alaska. Submarine glacial landforms can help understanding the past and recent dynamics of marine-based glaciers in a rapidly changing climate. This work reports on high-resolution bathymetry collected with a barge-mounted EM2040 multibeam echosounder during the Amundsen 2023 expedition at the terminus of Southern and Northern Croker Bay tidewaters glaciers, southern Devon Island. The combination of the swath bathymetry dataset with satellite and drone imagery allows explaining the glaciological context and timing of the formation various submarine glacial and proglacial landforms observed at the termini of these two glaciers, such as MSGLs, moraine ridges and crescent-shaped bedforms, that have been exposed in the last years by glacial retreat.

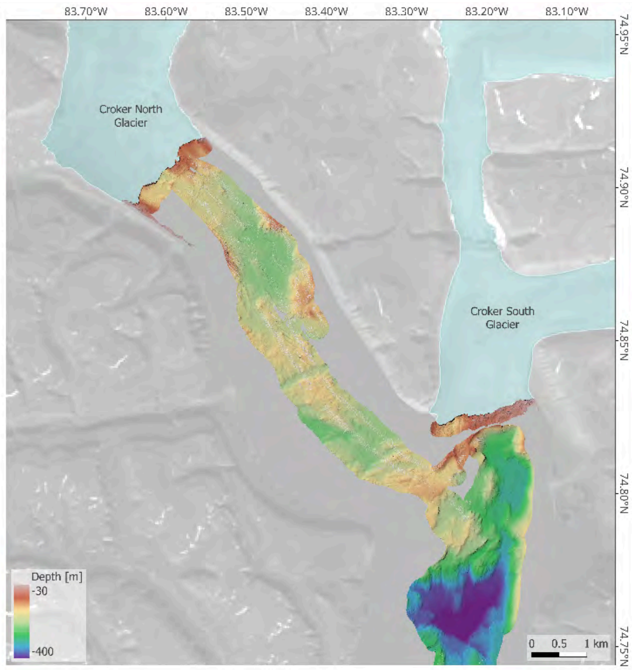

Figure 1: Swath bathymetry of the sea floor and glacier outlines of Croker North and Croker South Glaciers in Croker Bay.

NAVIGATING THE NEW ARCTIC: MEQ UNGUVATKARPUT (WATER IS OUR LIVELIHOOD): YEAR 1 OUTCOMES FROM THE OUTER KUSKOKWIM DELTA

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Coastal delta communities are among the most vulnerable to climate change, causing most communities to wonder what their lands and waterways will look like in decades to come. The State of Alaska identifies villages of the Yukon-Kuskokwim (YK) Delta as underserved with respect to basic government services and highlight areas threatened by sea level rise, coastal erosion, flooding, and permafrost degradation. Likewise, communities and traditional ways of life are threatened by sea level rise, salinization, and storm surge because of the low elevation of the delta. Additionally, the decrease in duration and extent of coastal sea ice has contributed to greater storm impacts increasing the vulnerability of the YK Delta to coastal hazards. These changes are forcing Alaskan Native communities to face new realities in their day-to-day lives. Changes in the water cycle driven by climate change are generating risks to health, sanitation, and infrastructure. Populations living in rural villages in the YK Delta region experience challenges in the quality, accessibility, and reliability of drinking water and sanitation services. These effects are exacerbated by changes in climate and water budgets that are increasingly influencing water cycles in the Arctic. As communities, like Kongiganak and Mekoryuk navigate the changing Arctic together, it is essential to chart a course that holistically considers the physical and human dimensions of these new realities.

Our co-produced research with Kongiganak and Mekoryuk aims to

- evaluate near-term and far-term prospects of providing safe, affordable, resilient, and locally acceptable drinking water, sanitation, and hygiene services in the context of environmental change (erosion, permafrost thaw, and flood hazards);
- measure, quantify, and model rates of landscape change and altered hydrology caused by rising sea level and the collapse of permafrost across the built environment and landscapes used for traditional livelihoods;

- utilize new baseline hydrographic data collected with community partners through bathymetric surveys, water level gauges, and coastal wave buoys to develop high-resolution 3D hydrodynamic models of storm surge flooding delivering predictive flood hazard maps and workflows for other communities;
- develop the first estimates of water/sanitation-related coping costs for rural Alaskan communities and quantify benefits/costs of various water/sanitation-service delivery models under different landscape and climate scenarios;
- co-develop community-based monitoring programs that allow for determination of how current rates of environmental change compare to historical trends and Indigenous Knowledge observations.

In our first year we established Community Advisory Boards for both communities and set up plans to meet with them on-line every 3 months (4 times a year). We held meetings with the Tribal and City Councils in Mekoryuk and the Tribal Council of Kongiganak and established signed charters outlining the intent of the project. Collaborations with the School Administrators in both villages (aka, school superintendent) allowed us access to the teachers and to middle school and high school students. We especially wanted to engage students concerning scientific use of drones and remote sensing and about the biology of what is in the water of our environments both inside and outside village infrastructure. The coastal and erosion group conducted real-time kinematic GNSS topographic surveys to map the position of the vegetation line and coastal/river bluffs especially around the village, harbor, cemetery, and village dump regions. High resolution topographic cross profiles were collected of the bluffs, beach, rip rap, sandbags, and any other structures reaching from the Village dump along the coast and round the villages proper to the edge of each town. We provided maps made so far of 1980 to 2022 erosion rates. In both villages, water samples were collected from the watering collection points, the river, several faucets, and other locations around the villages. The wastewater sewage lagoons were also sampled and analyzed to understand the microbial activity and effectiveness passive treatment process. Results showed overall good microbial water quality across town. We believe any microbial contamination observed in the water samples after treatment was due to water sitting in potentially unclean containers for an extended time. Semi-permanent permafrost temperature sensors were installed during a visit Oct. 2023, and permafrost cores for ice content will be taken in April 2024.

Based on work carried out in August 2022 and subsequent dating, we determined that Pleistocene loess exposed underlying parts of Mekoryuk dates from 60ka to 150 ka based on a section exposed near the village dump site. In Kongiganak, we have one upland site of loess dated to 26.8 to 49ka all based on OSL. We hypothesize that many of the so-called ecologically based “permafrost plateaus” of the YK Delta are relic Pleistocene loess uplands. Very little is known of the Pleistocene history of the region. Active to semi-stabilized dune complexes near Mekoryuk are of late Holocene in age, based on OSL.

We are documenting effective convergent workflows/co-production techniques to be applied broadly in the YK Delta and beyond where the same challenges of rapid climate change are playing out.

References: NNA-YKD website - https://websites.umass.edu/nna-ykd/

ORBITAL CYCLES AND THE SYMPHONY OF ICE SHEETS: EXPLORING THE ANTI-PHASE RELATIONSHIP OF ICE SHEETS AND SEA LEVEL DURING THE PLIOCENE

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Summer insolation between the northern (NH) and southern hemisphere (SH) can be considered in-phase or anti-phase. An in-phase record would show a similar amplitude of summer insolation between 70N and 70S, while an anti-phase record would have large amplitude differences. These phase relationships could cause the growth and melt of the NH and SH ice sheets, either in tandem (in-phase) or independently (anti-phase). During the Pliocene, the climate is generally considered warmer than today, with some exceptions such as Marine Isotope Stage (MIS) M2 (~3.3 ma), a period of substantial cooling. Prior research on MIS M2 has focused on the Northern Hemispheric and Antarctic ice sheets growing in tandem to match proxy data of sea level fall. Modeled ice sheet configurations during MIS M2 can vary with the possibility of global ice sheet volumes of 40–60 meters (sea level equivalent) greater than today. Insolation calculations of the thousand years surrounding 3.3 ma show anti-phased hemispheres, which is not compatible with proxy data indicating that both northern and southern ice sheets contributed to M2 sea level fall. Phase relationships during Pliocene interglacials are similar. For example, previous research on the MIS KM5c interglacial shows an in-phase relationship between the two hemispheres, with total sea-level ~10.5 m higher than today. In contrast, the MIS K1 interglacial has an anti-phase insolation relationship between the two hemispheres. In this interval, total sea-level was on average ~12 m higher than present. Most studies have focused on the total contribution of global sea level from both hemispheres but have not uncovered the possibility of an anti-phase period where the growth of one ice sheet dampens (or hides) the signal of ice loss from the other. Idealized ice sheet model simulations with boundary conditions representing MIS M2 are run to explore ice volume phase relationships between the hemispheres. Preliminary results show during anti-phase orbital cycles substantial growth of NH ice sheets can mask Antarctica's contribution to sea level, with Antarctic contributions exceeding the global mean.

NOVEL LEAD (PB) ISOTOPE RECORD TRACKING THE IMPACT OF POLICY AND THE COVID-19 PANDEMIC ON ASIAN POLLUTION EMISSIONS DEPOSITED IN ALASKAN ICE CORES

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The study of Pb in ice cores allows examination of the critical changes in culture (*e.g.*, industrialization), technology (*e.g.*, advancement of industrial recycling), policy (*e.g.*, phase out of leaded gasoline), and global health (*e.g.*, Spanish Flu and COVID-19) that have impacted Pb emissions through time. Additionally, Pb isotope data can be used to fingerprint pollution sources, as the ratio of U/Th remains fixed during extraction and processing of raw ore and the subsequent atmospheric transportation of aerosol particles (Hoffman et al., 2022; Gross et al., 2012). Here we seek to evaluate changes in Pb emissions and determine pollution source trends using a newly developed dataset of Pb concentration and isotopes spanning from 340 to 2022 CE.

We developed this 1,200 year dataset using ice samples from four ice cores taken on Begguya (Mt. Hunter), Alaska: DEN-13A and DEN-13B (210 m) drilled in 2013, DEN-19A (51 m) drilled in 2019, and DEN-22A (21 m) drilled in 2022. To collect the data, we melted each ice core using a melting system and ultra-clean sample preparation procedures at Dartmouth College (Osterberg et al., 2006). Using the UMaine Climate Change Institute (CCI) Inductively Coupled Plasma Mass Spectrometer (ICP-MS) facility, samples were analyzed for trace metal concentrations and Pb isotope ratios following established methodologies (Gross et al., 2012). The CCI ICP-MS facility is equipped with a Thermo Element XR with a JET interface system. With this system, samples can be analyzed directly from ice core meltwater, without the need for column chemistry. We achieved sensitivity of ~70 M cps for 1 ppb In with a U oxide ratio of 10%.

Pb concentration data from the Denali Ice Cores shows the same increasing trend from 1700 to the present seen previously in other North Pacific records (Figure 1). Preindustrial levels have been recorded at Mt. Logan (Osterberg et al., 2008) and Begguya (this study). We expected to find three signals: (a) the large rise in Pb concentration associated with the European and American industrial revolutions (1750s – 1840s), (b) continued rise due to coal mining and tetraethyl lead in gasoline, and (c) fall associated with the banning of leaded gasoline. While these three signals are found in Greenland ice cores, all three are absent in the North Pacific records (McConnell et al., 2019). Rather, the record remains relatively unchanged until the 1950s when Pb concentration experiences a large increase from the 1970s to present (Figure 1). Therefore, these records reflect China's industrial revolution in 1978 and the subsequent explosion of industrial output from China over the last 45 years (Wen, & Fortier, 2019).

Preliminary Pb isotope data indicate a shift in Pb isotope ratios from previously published values (Gross et al., 2012; Koffman et al., 2022). For example, in 2021 the Pb isotopes have an average $^{208}Pb/^{207}Pb$ ratio of 2.42648 and $^{206}Pb/^{207}Pb$ ratio of 1.13571 (Figure 2). This $^{206}Pb/^{207}Pb$ ratio is lower than Pb ratios previously published for the North Pacific. For comparison, Koffman et al. (2022) sets their 2016 pollution end-member as $^{206}Pb/^{207}Pb$ of 1.1542 and $^{208}Pb/^{207}Pb$ of 2.4386. The trend of much lower than anticipated $^{206}Pb/^{207}Pb$ values is present from the preindustrial through the present (2022 CE). The meaning of these lowered ratios is still under consideration.

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BIODIVERSITY OF PLANTS INCLUDING BRYOPHYTES AND OF LICHENS IN MODERN VEGETATION OF DIFFERENT AGE AROUND LAKES AND NEAR BARNES ICECAP IN THE EASTERN CANADIAN ARCTIC

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In the context of studies on lake sediment cores, vegetation was sampled around lakes on Baffin Island and one site on northern Labrador (see the abstract of Raynolds et al.). The time for the development of the studied vegetation varied from about 100 to 12,000 years.

About 300 plots were sampled in eight sites, recording vascular plants, bryophytes and lichens. The vegetation is mostly pioneer vegetation as lichen covered boulder, lichen vegetation on lake shore rocks, liverwort snowbeds or glacier forefield pioneer vegetation but ranges to open hemi-arctic spruce forest in Labrador.

Vascular plants depend on the summer season, nonvascular plants don't. Thus we could expect different diversity patterns of vascular plants and bryophytes and lichens along our climate gradient and higher diversity of the nonvascular plants in early stages.

The species richness (species number per plot) for vascular plants, bryophytes and lichens and the diversity of functional types will be compared across vegetation types and sites. Functional types here are for trees, shrubs, dwarf shrubs, herbs and graminoids for vascular plants, acrocarpous mosses (upright cushions), pleurocarpous mosses (horizontal carpets), peat mosses and liverworts for bryophytes and crustose, small foliose (leaf-like), large leafy, fruticose (shrub-like) growth form for lichens.

Bryophytes and lichens are known to propel Arctic maximum species richness on small plots up to the famously rich calcareous grasslands in eastern Europe (80-100 terrestrial species per square meter) and on the traditionally applied log-log species-area relation, Arctic richness can be comparable to tropical forest.

In a first display of four of the eight study areas, two younger and two older sites, the richest plots are with 50 and 59 species for the younger and 63 and 71 for the older sites, already rich, but still below maximum values.

The maximum vascular plant richness is 22 (in the southernmost study site on Labrador 3LN) and 16 for the other older site (CF-3), while the younger sites only host 6 resp. 3 vascular plants as maximum (see Figure 1).

The drivers of diversity in all study areas are fruticose and crustose lichens and acrocarpous mosses (Table 1) with surprisingly little difference for younger and older sites. Vascular plant and pleurocarpous moss richness is higher in the older sites.

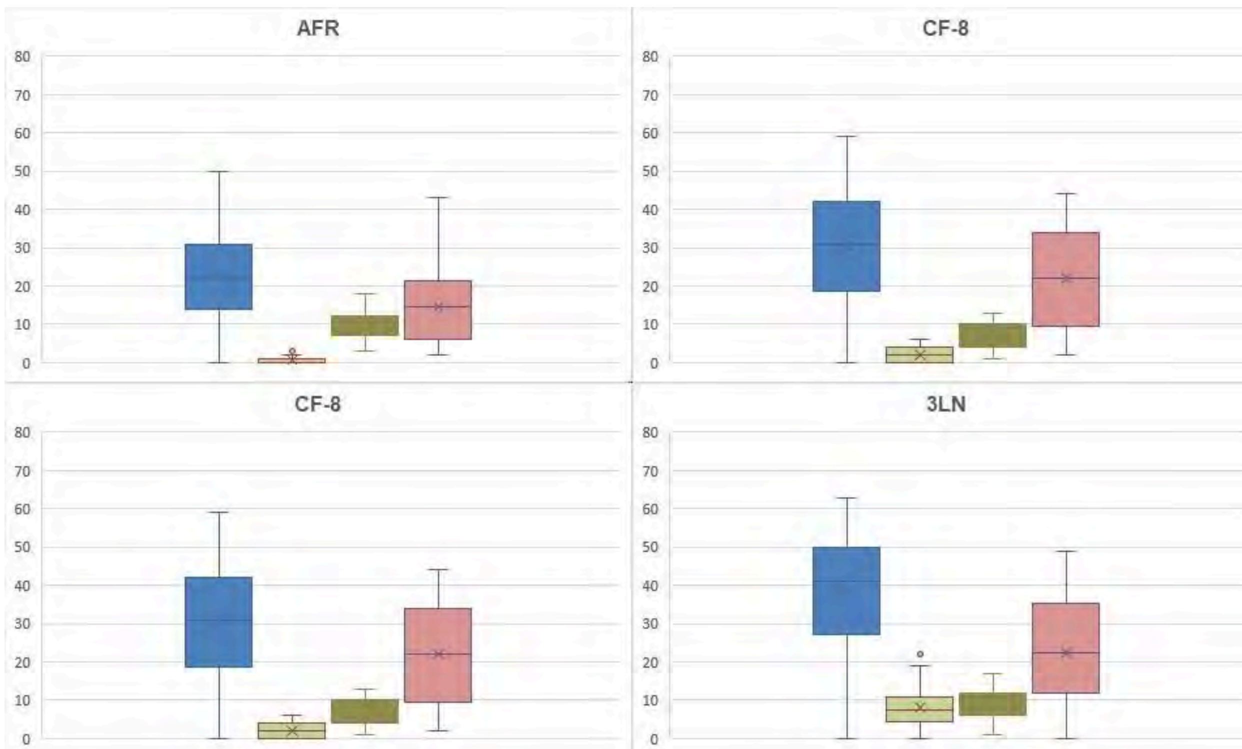

Figure 1. Box.plots species richness of 4 sites, young AFR and CF-8, older CF-3 and 3LN. Column 1: all species, 2: vascular plants, 3: bryophytes, 4: lichens.

mean values		AFR	CF8	CF3	3LN
tree	0,1	0,0	0,0	0,0	0,4
shrub	0,2	0,0	0,0	0,0	0,6
dwarf shrub	1,1	0,0	0,4	0,6	3,0
herb	1,1	0,1	0,4	5,2	2,2
graminoid	1,4	0,4	1,4	3,0	1,9
moss acrocarp	4,7	5,9	4,3	7,2	3,8
moss pleurocarp	0,9	0,3	0,1	1,8	2,1
peat moss (Sphagnum)	0,5	0,0	0,3	0,8	1,0
liverwort	2,5	2,9	2,5	3,4	2,0
lichen crust	7,6	6,9	9,2	7,6	6,2
lichen foliose	2,0	1,9	1,7	0,8	2,6
lichen small foliose	1,4	0,3	0,4	0,4	3,8
lichen fruticose	9,2	5,3	10,8	11,0	9,8

Table 1. Mean species richness of functional typesBox.plots species richness of 4 sites, young AFR and CF-8, older CF-3 and 3LN. Column 1: all species, 2: vascular plants, 3: bryophytes, 4: lichens.

A few plots of dead vegetation are compared with the modern vegetation (see the abstract of Kasanke et al.)

Furthermore we will focus on the species turnover across sites and vegetation types, especially for those functional types, which are rich in species, with the aim, to find indicator species for landscape age, which are not limited by slow dispersal. Possibly mosses are good candidates, because they have durable remains, which are often found in the macrofossils in cores.

Acknowledgements: We thank the people of the communities of Qikiqtarjuaq, Clyde River, Iqaluit and Pond Inlet and Kuujjuaq and of the Nunavut Research Institute for permission and invaluable support. Funding was provided by grants to Martha Raynolds NSF OPP # 1737750 and # 1927148.

POLLUTION DRIVES ENIGMATIC DECLINE IN SUBARCTIC BIOGENIC SULFUR

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An industrial-era drop in Greenland ice core methanesulfonic acid (MSA) is thought to herald a collapse in North Atlantic marine phytoplankton stocks related to a weakening of the Atlantic Meridional Overturning Circulation[1]. In contrast, stable levels of marine biogenic sulfur production contradict this interpretation, and point to changes in atmospheric oxidation as a potential cause of the MSA decline[2]. However, the impact of oxidation on MSA production has not been quantified, nor has this hypothesis been rigorously tested. Here we present a multi-century MSA record from the Denali, Alaska, ice core, which shows an MSA decline similar in magnitude but delayed by 93 years relative to the Greenland record. Box model[3] results using updated chemical pathways[4] indicate that oxidation by industrial nitrate radicals has suppressed atmospheric MSA production, explaining most of Denali's and Greenland's MSA declines without requiring a change in phytoplankton production. The delayed timing of the North Pacific MSA decline, relative to the North Atlantic, reflects the distinct history of industrialization in upwind regions[5] and is consistent with the Denali and Greenland ice core nitrate records[6]. These results demonstrate that multidecadal trends in industrial-era Arctic ice core MSA reflect rising anthropogenic pollution rather than declining marine primary production, with important implications for MSA-based Arctic sea ice proxies.

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HEINRICH EVENTS, MEGAFLOODS, AND DROUGHT ALLEVIATION – INSIGHTS FROM A NUMERICAL ICEBERG MODEL

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MITberg is a dynamic-thermodynamic iceberg model developed at the Woods Hole Oceanographic Institution. This presentation will illustrate three areas of research that the model has recently been employed to understand. The first will focus on Heinrich Events, and in particular how thick deposits of ice-rafted debris found across the entire subpolar North Atlantic from Canada to Portugal were created. Insight into the sediment load, size, and shape of the icebergs required to form these layers will be given. The second theme will explore how megafloods from Hudson Bay, Canada, created narrow buoyant coastal currents that transported icebergs as far south as Florida Keys ~30,000 years ago. Finally, results from experiments looking at whether icebergs can be harvested for safe clean drinking water will be presented.

DECIPHERING THE RETREAT OF THE SOUTHEASTERN MARGIN OF THE LAURENTIDE ICE SHEET DURING THE YOUNGER DRYAS AND EARLY HOLOCENE USING COSMOGENIC NUCLIDE EXPOSURE DATING

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The Laurentide Ice Sheet was the largest ice sheet of the Northern Hemisphere during the Last Glacial Maximum. The consequences of its demise on global climate and sea level changes during the subsequent deglaciation are unequivocal. Understanding the interplay between ice sheet behavior and climate is critical for assessing the contribution of melting ice masses to past and future sea level rise. Here, we present cosmogenic nuclide surface exposure ages from multiple moraine systems in eastern Québec and subarctic Labrador (Canada) that allow refining the regional deglaciation history. This extensive chronological dataset document the occurrence of five stillstands and/or readvance stages of the ice margin during the Younger Dryas and early Holocene. Our results highlight a strong sensitivity of the entire margin of the Laurentide Ice Sheet to temperature changes in the Northern Hemisphere, as the documented stabilizations span over a distance of nearly 1000 km and coincide with cooling events recorded in Greenland ice cores at ~12.9 ka, ~11.5 ka, ~10.4 ka, ~9.3 ka and ~8.2 ka. These results further support the hypothesis of a negative feedback mechanism induced by meltwater forcings into the North Atlantic Ocean, which triggered repeated cold reversals in the Northern Hemisphere during the last deglaciation. Overall, this chronology provides valuable insights regarding the behavior of the southeastern Laurentide Ice Sheet margin during the Younger Dryas and early Holocene, a period of highly dynamic changes to the global cryosphere which could be use as an analogue for present-day polar ice sheets.

BRGDGT BIOMARKER DISTRIBUTIONS IN ANOXIC KONGRESSVATNET, SVALBARD – LESSONS FROM WATER COLUMN SEDIMENT TRAPS AND DOWNCORE SAMPLES IN A UNIQUE ARCTIC LAKE SYSTEM

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Over the past ~20 years, a suite of bacterial molecular biomarkers known as branched glycerol dialkyl glycerol tetraethers (brGDGTs), have been increasingly utilized for paleotemperature reconstructions from sedimentary archives. Modern calibration studies have shown that distribution of these biomarkers is strongly related to environmental temperature (e.g. Raberg et al. 2021), and their presence in sediments across a range of latitudes and lake settings has led to their widespread application as a paleoclimate proxy. Questions remain, however, about other environmental factors beyond temperature that influence brGDGT distributions. For example, changing oxygen levels have previously been demonstrated to impact brGDGTs (e.g. Colcord et al. 2015; Weber et al. 2018), though this effect has not been well-constrained, particularly in modern Arctic settings.

Here we present brGDGT data from lake Kongressvatnet, in Svalbard, Norway. Kongressvatnet is a 55 meter deep meromictic lake, where suboxic conditions exist from ~depths 30-50 meters and where anoxic conditions exist in the bottom 5 meters. brGDGTs were measured in sediment trap samples from 5 different depths in the water column (traps K1 through K5) over the course of three years, with samples collected annually in July. Temperature loggers were deployed with each sediment trap to constrain temperature throughout the water column, and local air temperature was also measured. brGDGT based-indices, such as the ratio of brGDGTs IIIa to IIa, suggest the majority of production occurs within the water column, and not in local soils/permafrost. Using the calibration of Raberg et al. (2021), the warmest reconstructed temperatures were consistently found in the uppermost K1 sediment trap. Traps K2 and K3, below the thermocline but above the anoxic zone in Kongressvatnet, produced similar brGDGT temperatures within each year, with values generally in between the surface and bottom water. In two out of the three years, Trap K4 (~2-3% dissolved oxygen) produced the lowest reconstructed temperatures of the 5 traps. Trap K5, in the anoxic layer, also produced relatively low temperatures, but warmer than K4 in two out of three years. Our results suggest that oxygen levels, in addition to environmental temperature, are affecting brGDGT distributions in the lake.

We also collected sediment cores from Kongressvatnet. brGDGTs in surface sediment samples do not directly match any specific zone of production within the lake, but rather seem to represent a mixture of biomarkers from the water column, along with some evidence for in-situ production within the sediments themselves. We will also present a downcore brGDGT temperature reconstruction from Kongressvatnet, likely spanning the past ~1500 years. This record will be compared against the alkenone-based temperature reconstruction of D'Andrea et al. (2012)) from the same lake, which suggested that summer temperatures during the Little Ice Age were actually relatively warm on Svalbard, and that increased winter precipitation was likely the cause of glacier advances during this time. By comparing our data from Kongressvatnet against an independent temperature record from the same system, we will test the efficacy of a sedimentary brGDGT reconstruction from a lacustrine system with varying oxygen levels in the water column.

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FIRE RECONSTRUCTION IN THE FAR NORTH: LATE HOLOCENE ECOLOGICAL RESPONSES TO FIRE IN NORTHERN ALASKA

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The fire ecology community has identified a number of goals and challenges for future and ongoing research, including constraining the changing nature of fire under ongoing climate change and elucidating the relationship between vegetation succession and fire (McLauchlan et al., 2020; Shuman et al., 2022). Paleofire reconstructions allow for the evaluation of characteristic fire activity for a region and can reveal how drivers such as anthropogenic climate change and vegetation change influence the fire system. Here we add to our knowledge of millennial-scale fire activity in tundra ecosystems by creating four new charcoal-based paleoecological reconstructions from lake sediments on the Alaskan North Slope. The North Slope has experienced record-setting fires in recent years, yet there are a limited number of existing paleofire reconstructions, highlighting the need to better constrain the sensitivity of far-northern tundra regions to fire regime disturbance (Chipman et al., 2015; Hu et al., 2015; Chipman and Hu, 2017). This work extends the zone of existing paleofire reconstructions southwards relative to earlier work, bridging the network of sites with fire information from the southern edge of the 2007 Anaktuvuk River Fire to the northern foothills of the Brooks Range. Additionally, all four study sites are within 25 km of the Toolik Field Station, an environmental research center supporting local monitoring of vegetation and climate dynamics for over 40 years. This research therefore adds to the broad network of paleoecological data, extends the regional-scale paleofire dataset, and supports the local mission of the Toolik Field Station.

These new records are evaluated with both novel and standard approaches. Charcoal accumulation rate (CHAR; # charcoal particles cm^{-2} yr^{-1}) preserved in lake sediments can be used to quantify fire activity in the past, and is a standard method used in sedimentary fire studies (Higuera et al., 2009; Chipman et al., 2015; Vachula et al., 2019). Charcoal input to lake basins can vary with fire size, distance from study site, and material burned (Clark, 1988; Peters and Higuera, 2007; Leys et al., 2017). To differentiate between local and regional burn signals, charcoal particles were enumerated at continuous resolution in each sediment core and separated into multiple size fractions (90-125 μm, 125-250 μm, and >250 μm). Because larger particles move shorter distances by sedimentary transport mechanisms (Clark, 1988; Peters and Higuera, 2007; Vachula et al., 2021), we interpret the largest size fraction as a signal of local fires while the smallest size fraction captures charcoal from distant burning.

Continuous charcoal particle counts were quantified as CHAR based on Bayesian age-depth models developed for each sediment core from a combination of ^{210}Pb and ^{14}C dating methods (Blaauw and Christen, 2011; Aquino-López et al., 2018). Sediment metrics such as magnetic susceptibility and geochemical composition was used to evaluate the impact of sediment deposition on CHAR values. Statistical analyses were used to estimate both individual and mean fire-return intervals (FRI, years/fire) at each site. In addition, preexisting charcoal-based reconstructions from this area of the North Slope, located between 10 and 30 km of our study sites, provide additional charcoal counts at the 125 µm size fraction (Hu et al. 2010; Chipman et al. 2015), and will be used with the new data generated in this study to create a composite fire history of the region.

Comparison between fire-related proxies and proxies for changes in vegetation cover can yield a more complete picture of a region's fire history, drivers, and feedbacks (e.g., Hu et al., 2010; Mekonnen et al., 2019; Chipman and Hu 2019; Napier and Chipman, 2022). Thus, in addition to CHAR calculations, all identified charcoal particles were binned using a modified morphological key from Enache and Cumming (2006), and then analyzed by fuel type hypothesized to correspond to each morphotype (Frank-DePue et al., 2022). Morphological binning of charcoal is a growing analytical technique, used to link charcoal to its fuel source (Jensen et al., 2007; Crawford and Belcher, 2014; Feurdean, 2021). The shape of charcoal may indicate source differences and be used to broadly understand the fuel type combusted in each fire (Leys et al., 2017; Pereboom et al., 2020; Frank-DePue et al., 2022), or can be interpreted as deriving from a specific botanical material (Mustaphi and Pisaric, 2014). Differentiation between herbaceous and woody fuel sources is the predominant application of morphological keys across regional studies. Only one such study has focused on tundra-specific charcoal, but it noted similar morphological differences to other studies (Pereboom et al., 2020). We compare the temporal variability in CHAR, FRI, and herbaceous versus woody fuel types from charcoal morphology to two pollen-based vegetation reconstructions within a 25-km radius of all four sites to evaluate fire-vegetation linkages through time (Oswald, 2003).

Two sediment cores displayed highly variable magnetic susceptibility and distinct stratigraphic features suggestive of terrigenous sedimentary inputs, indicating that changes in CHAR values were related to sediment accumulation rates rather than changes in fire activity. The remaining two records showed no such stratigraphic features, and thus we interpret the variability in CHAR to be associated with changes in fire dynamics. Our longest sediment core from Lake I4 (21-RTS7-U2) captures over 7000 years of fire history and shows an increase in background CHAR values (>90 um) after ~3ka. This shift is accompanied by a distinct change in mean fire return interval (mFRI, mean years between fire events), with a mFRI of 1255 (1200-1310) years between 7000 and 3000 cal yr BP and a mFRI of 239 (166-320) years after 3000 cal yr BP. These data suggest both an increase in biomass and/or area burned in the latter portion of the record, as well as more frequent burn events toward present. These trends from Lake I4 are supported by a higher-resolution record spanning the past 800 years at Lake RTS5, located 30 km from Lake I4, which shows a mFRI of 198 (105-333) years.

The enhanced fire regime after 3000 cal yr BP is concurrent with the onset of Neoglacial cooling in northern Alaska. Paleoclimate records suggest that after ~4000 ka, Arctic areas of Alaska began to experience increased cooling, reduced moisture, and decreased lake levels associated with a combination of boreal insolation changes and an enhanced eastern Aleutian low pressure system (Broadman et al., 2020). Proximal pollen records from two lakes within 30km of our sites demonstrate no distinct vegetative compositional change at this transition to a colder, drier climate (Oswald et al., 2003). However, morphological analyses of all charcoal at our sites show the emergence of herbaceous charred particles after ~3ka, associated with increased CHAR and reduced FRIs. Production rates of charcoal per unit of burned biomass vary broadly by fuel type, with herbaceous morphotypes requiring more biomass burned to yield same amount of charcoal produced by a given amount of woody fuel (Leys et al., 2017). Thus, the emergence of herbaceous morphotypes in the record likely reflects an increase in biomass burned under drier conditions, as pollen records indicate no notable compositional shift over this time period to more flammable species.

When only the >125-μm size fraction is considered, these new records show comparable magnitude of background CHAR values to existing regional records at the same size fraction (Chipman et al., 2015), which will be used to create a local-scale composite fire history for the Toolik Lake area. However, the expanded total size range of these new records to include smaller particles (<90 um) draws from a larger potential source area than previous work. The mFRIs generated from this more regionally-sourced charcoal suggest fire regimes over the past 3000 years comparable to shrub tundra systems, with fire cycles on the order of hundreds of years instead of thousands (Higuera et al., 2011). This research supports new findings on modern North Slope fire regimes, with recent studies noting previously unrecognized fires in the region (Jones et al., 2009) as well as evidence of reburned areas within a decade of initial fire (Miller et al., 2023). These paleo analyses offer new insight into broad-scale fire activity and temporal burning trends in this region, and provide valuable new baseline estimates of fire activity by which to examine recent and ongoing changes to Arctic systems.

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EVALUATION OF REGIONAL CLIMATE MODEL RUNOFF OVER TWO WATERSHEDS IN NW GREENLAND

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Meltwater runoff from the Greenland Ice Sheet is a primary contributor to global sea level rise. Mass loss from regional climate/surface mass balance (RC/SMB) models are used to estimate these sea level contributions, but comparisons between RC/SMB and in situ measurements of runoff discharge show systematic differences. While use of increasingly complex routing methods have shown improvements in recreation of in situ discharges in southwest Greenland, the abundance of moulins, crevasses, and weathering crust in this region inhibit confident attribution of discharge discrepancies over this area of the ice sheet. The recent multiyear, multiseason river stage datasets from three watersheds in northwest Greenland with minimal subglacial interference (Esenther et al., 2023, Goldstein et al., 2023) were collected over an ideal location for the evaluation of total volume of RC/SMB runoff production; however, previously these stage measurements could not be compared directly with RC/SMB runoff flows. We present four years (2019-2022) of daily proglacial in situ discharge measurements at the gauge stations and four years (2019-2022) of comparable daily regional climate model estimates of discharge. We find overall strong agreement between the daily volume of regional climate model runoff and in situ runoff. Comparison of these hydrographs reveals that surface mass balance processes are represented relatively accurately by regional climate models. These findings imply that inaccuracies in the southwest are likely the result of en- and subglacial process interferences, not the regional climate estimates of runoff. The alignment of the routed RC/SMB and in situ discharges in a hydrologically simple region of the Greenland Ice Sheet increases confidence in discharge estimates from other regions with minimal subglacial connections and

provides a roadmap for identification of the source of inaccuracies in the high melt southwest.

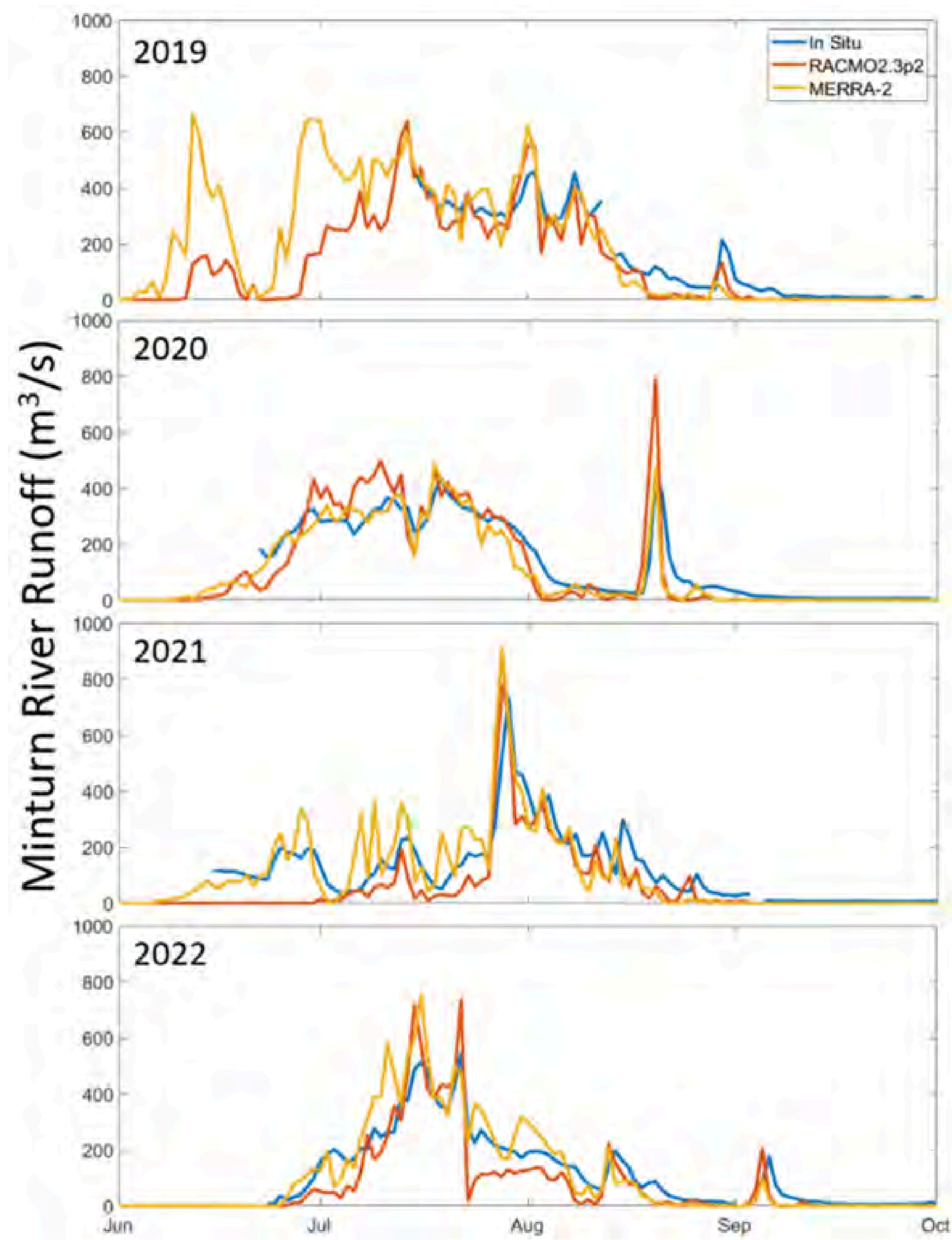

Figure 1. Four years of daily melt season hydrographs at the Minturn River show strong agreement between climate model estimates of meltwater runoff and in situ measurements. RACMO2.3p2 was downscaled from native 5.5km to 1km and MERRA-2 was used at native 0.5° × 0.625° resolution.

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EXTENDING RECONSTRUCTIONS OF BERING STRAIT FLOODING THROUGH THE LAST INTERGLACIAL USING FORAMINIFERA-BOUND NITROGEN ISOTOPES: INITIAL RESULTS AND PROSPECTS

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The Arctic Ocean receives fixed nitrogen via isotopically distinct nitrate inputs from the Atlantic and Pacific Oceans (Fripiat et al., 2018; Granger et al., 2018; Farmer et al., 2021). Nitrogen isotope measurements on the planktonic foraminifera *Neogloboquadrina pachyderma* (hereafter, FB-d^{15}N) record past changes in the sources of nitrogen to the Arctic in addition to changes in nitrate consumption by phytoplankton in the surface Arctic Ocean, which is driven primarily by stratification (Farmer et al., 2021). Recently, we showed that the N input to the western Arctic Ocean transitioned rapidly from a Pacific to Atlantic source around 36,000 years ago (36 ka), then reverted to a Pacific source after 11 ka. These FB-d^{15}N records require a flooded Bering Strait and high sea level during Marine Isotope Stage (MIS) 3, a sea level fall that exposed the Bering Land Bridge around 36 ka, and reopening of the Bering Strait during the postglacial sea level rise around 11 ka (Farmer, Pico et al., 2023). While the postglacial reopening of the Bering Strait had been previously dated (see summary in Pico et al., 2020), the FB-d^{15}N records provide the first geochemical constraint on past sea level in Beringia prior to the Last Glacial Maximum.

Here we extend reconstructions of Arctic Ocean nitrogen inputs back through the Last Interglacial MIS 5e (~130 ka) using FB-d^{15}N measurements in piston cores P1-92AR-P40, P193AR-P21, and P1-94AR-P9 collected from the Northwind and Mendeleev Ridges in the western Arctic Ocean. Given continued uncertainty about Arctic Ocean sediment chronologies prior to ~50 ka (e.g., Farmer, Keller et al., 2023; Razmjooei et al., 2023), we also revisit the age control for these sediment cores using ^{14}C dating of *Neogloboquadrina pachyderma* and sedimentological and microfossil zonation.

The new piston core FB-d^{15}N records are discontinuous due to the absence of calcareous microfossils during the diamict depositional events thought to occur in MIS 4 and 6. Of 85 new FB-d^{15}N samples from these cores, only nine indicate an absence of

Pacific nitrogen. This demonstrates that foraminifera-bearing sediment in the western Arctic Ocean derived predominantly from times of elevated global sea level when the Bering Strait was flooded; these results support the longstanding interpretation that microfossil-rich sediment in the Arctic Ocean corresponded to interglacial climates. Although it remains to be clarified whether closure of the Strait was rare before 36 ka, FB-d^{15}N data from Mendeleev Ridge core P1-94AR-P9 reconstruct three intervals of interpreted Bering Land Bridge exposure prior to 50 ka. These events may correspond to global sea level falls sufficient to expose the Bering Land Bridge during MIS 4, 5d, and 5b.

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SEDIMENT DELIVERY AND VARVE FORMATION IN A HIGH ARCTIC PROGLACIAL LAKE, ELLESMERE ISLAND

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Strathcona Lake (unofficial name) lies at the head of Strathcona Fjord, west-central Ellesmere Island and 10 km downstream of the Prince of Wales Icefield. Our comprehensive mapping of lakebed and terrestrial landforms (Chassiot et al. in press) combined with updated radiocarbon information (Ó Cofaigh C., 1999) suggests the lake formed between ~5 ka and ~3 ka cal BP after the retreat of the icefield and the lake's isolation from the fjord. Located below the local marine limit, the lake has two basins, 58 m and 30 m depth, and is fed by multiple tributaries originating from watersheds with different lithologies (Fig. 1). Multi-proxy investigations on a set of sediment cores were performed by X-rays Computed-Tomography, X-rays Fluorescence (µ-XRF), laser particle size analysis, and on thin-sections observed using Scanning Electron Microscopy in backscatter mode.

The analyses outline two main facies: (1) pluricentimetric clastic varves (Zolitschka et al. 2015) typical of proglacial sedimentation controlled by glacial meltwaters; and (2) rapidly deposited layers interrupting the background sedimentation interpreted as turbidites produced from the erosion of glacio-isostatically raised glaciomarine deposits and landforms surrounding the lake (Fig. 2).

Proglacial varve counting reveals very high (>10 $cm.a^{-1}$) and variable sedimentation rates responding to the dynamics of the western margin of the POW. A drastic sedimentary change from the end of the 19th century suggests a shift in glacial dynamics and associated sediment delivery to the lake. The record suggests the varved sediments from Strathcona Lake can be used to reconstruct the melting history of the Prince of Wales Icefield.

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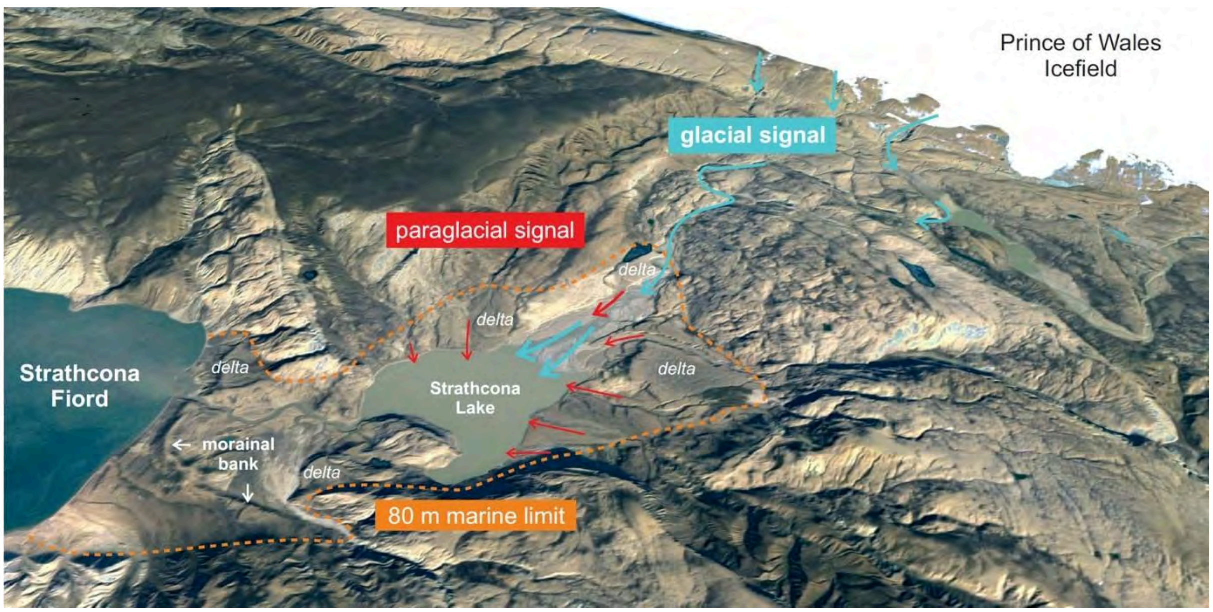

Fig. 1. Strathcona Lake and surroundings. From Chassiot et al., in press.

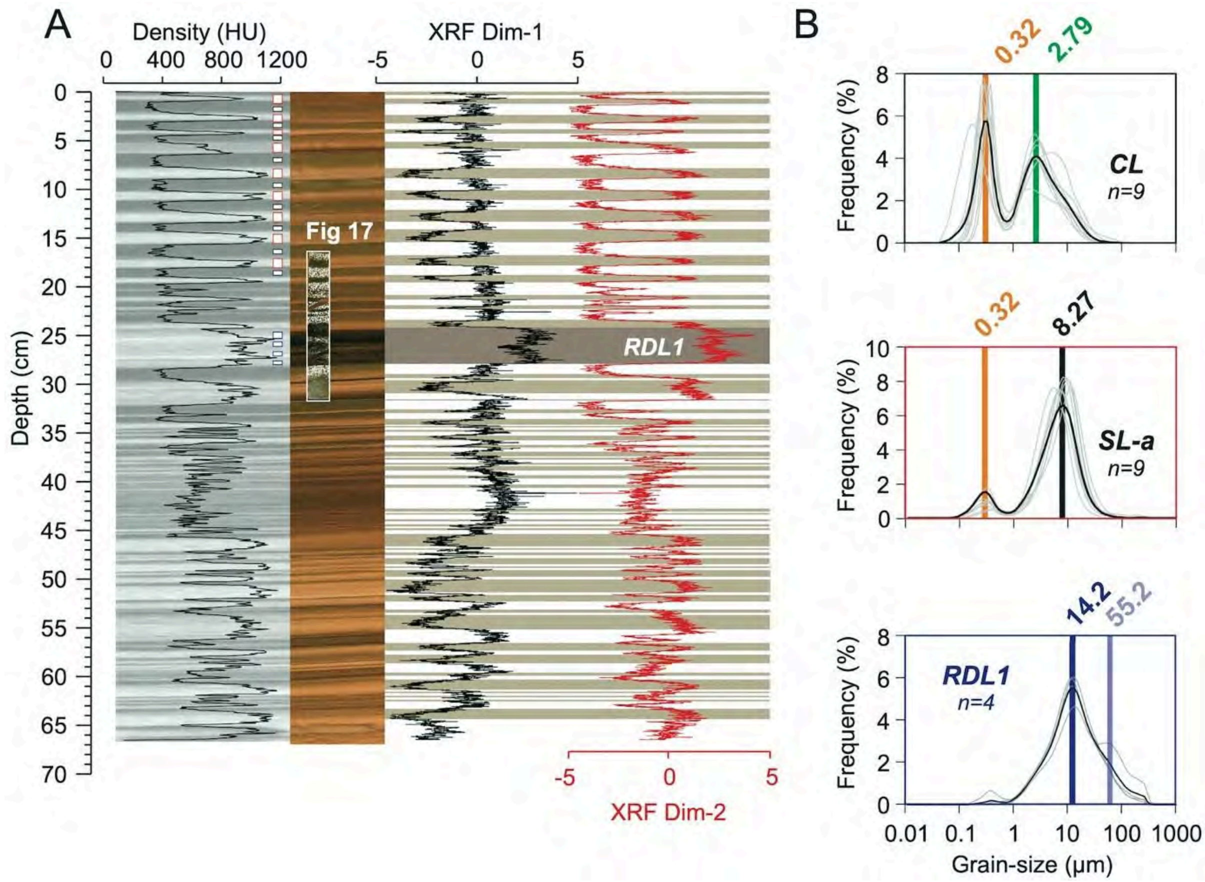

Fig. 2. A) X-ray and digital images of core STR19-15 along with PCA depth plots. The density is measured by Hounsfield units (HU). The horizontal bars underline the contrasted geochemical signature of sedimentary facies (light brown = silty layers SL-1a; dark brown = rapidly deposited layer). B) Grain-size distributions for sedimentary facies samples in core STR19-15. The location is indicated in A by coloured squares. From Chassiot et al. (in press).

RAPID WATER CYCLE CHANGES IN THE POLAR URAL MOUNTAINS DURING THE BØLLING WARMING AND HOLOCENE: THE RESPONSE TO CHANGING ICE SHEETS AND NORTHWARD TREELINE ADVANCE

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Arctic precipitation is expected to increase up to 50% by the end of this century as a result of climate change. However, uncertainties remain regarding the seasonality and magnitude of these hydrological changes. Understanding Arctic hydrologic cycle change during past rapid warming events will shed light on the mechanisms that caused these changes. A record of lake water and summer precipitation hydrogen isotope values (δ^2H) spanning the past 24,000 years from Lake Bolshoye Shchuchye, in the Polar Ural Mountains, contains evidence for extreme hydrological changes. In this study, we better constrain the timing, duration, and magnitude of two key isotopic shifts (~14.4 ka and ~10.2 ka) in the record. We add age-depth constraints and increase the resolution of the δ^2H records from ~100 to ~50 years. A previously published 100-year resolution record contains a 15‰ ^2H-enrichment at ~14 ka, several hundred years after the start of the Bølling warm period, despite pollen and ancient DNA (*a*DNA) evidence of vegetation change at the start of the Bølling (14.6 ka). We find that the ^2H-enrichment occurred at the start of the Bølling, and was not delayed, as previously thought based on the 100-year resolution record. At ~10.2 ka, there was a 40‰ ^2H-enrichment, 1.5 ky after the beginning of the Holocene, which contains a smaller ^2H-enrichment. Our higher resolution record reinforces the magnitude of rapid ^2H-enrichment, and suggests that this event spanned 400 years. To test if the ^2H-enrichment at ~10.2 ka is regional or specific to the core, we generate two lower resolution δ^2H records, one from a separate Bolshoye Shchuchye core and another from nearby Lake Maloye Shchuchye, which contain a ^2H-enrichment of 40‰ and 30‰, respectively. From ~10.2 ka through the rest of the record, lake water, which reflects δ^2H of mean annual precipitation plus evaporative enrichment, was up to 32‰ ^2H-enriched relative to summer precipitation ($\varepsilon_{28\text{-}22}$). The $\varepsilon_{28\text{-}22}$ values were highest from ~10 to ~7.5 ka, when deciduous trees and shrubs were most abundant in the *a*DNA record. We will use isotope-enabled climate model simulations and multiproxy data to test several working hypotheses regarding the mechanisms causing the rapid ^2H-enrichment at ~10.2 ka: shifting atmospheric circulation caused by the retreat of the Laurentide Ice Sheet, increased local terrestrial moisture recycling due to an increase in woody plants in the region, for which there is *a*DNA evidence, and others. These results will strengthen our understanding of how shifts in atmospheric pressure, moisture source, and vegetation influence the hydrologic cycle during times of rapid warming.

LONG TERM INSIGHTS INTO DRIVERS OF ARCTIC WETLAND ECOSYSTEM DEVELOPMENT

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Rising temperatures impact wetland ecosystem development particularly in the Arctic. However, most of the observations on the response of living organisms to recent warming come from observational and experimental studies, with comparatively limited data concerning centennial to millennial temporal scales. Hence, there is a need to undertake deeper detailed long-term palaeoecological studies in various types of wetland ecosystems to understand the relationships between climate, fire, vegetation, and hydrology, as well as the response of high-latitude peatland ecosystems to past and current climate changes.

Wetlands ecosystems (especially peatlands) in the Arctic are not only globally relevant carbon stocks but also important archives for palaeoecological reconstruction due to their sensitivity to climatic and hydrological change. Detailed analysis of peat monoliths enables us, for example, to reconstruct the evolution of plant communities and hydrological changes over the last centuries and millennia, and it also enables identification of the respective factors that impacted their development.

In our multiproxy studies we reconstructed decadal to millennial changes in wetland development in Northern Alaska during the late Holocene. We applied a high-resolution palaeoecological analysis: plant macrofossils, pollen, micro and macro charcoal, testate amoebae, and elemental analysis and stoichiometry, supported by radiocarbon and lead dating on a total of 14 peat monoliths sampled in various types of peatlands (rich fens, poor fens, string fens) along a N-S gradient from the northern slope of Brooks Mts. range to the Arctic Ocean coast (Prudhoe Bay) along the Dalton Highway. To better constrain the history and development of various types of peatlands, we collected peat monoliths from peatlands that developed on the slope of a neighboring lake, on a vast plain, in a river valley, on the top or on the slope of a hill.

The main aims were: i) to estimate the time of the peat initiation in Arctic Alaska; ii) to reconstruct wetland ecosystems development and assess their response to climate changes documented during the last decades and millennia; iii) to reconstruct plant succession of both, local moss populations, and regional vegetation changes during the late Holocene; iv) to evaluate the influence of palaeohydrological changes on plant succession and plasticity of the communities; v) and to reconstruct the history of fires in Arctic Alaska and assess their impact on peatland development.

Our ongoing study allow us drawing the following insights:

1. The peat initiation process began at different times in the studied region, which allows to assume that next to climate, local geomorphological conditions and ground water level played an important role in peatland initiation.
2. We observed that the strongest shifts in plant communities are visible over the last decades. This is manifested as an abrupt increased in shrub macrofossils e.g. Ericaceae, *Betula nana*, *Salix* sp. linked to the warming stages of the climate. In addition, we documented an expansion of *Sphagnum* species (e.g. *S. lenense*) and some brown mosses (*Tomentypnum nitens, Aulacomnium turgidum, Loeskypnum badium*) that usually grow in relatively dry habitats over the last decades. Plant communities composed of *Carex* spp. and other brown mosses (*Scorpidium scorpioides* and *Drepanocladus trifarius*) showed resilience to climate changes over the last 2,000 years.
3. Fires were rare in the studied region, with no impact on the studied plant populations.
4. At some sampling sites we documented the lowest water table depth over the most recent studied period, indicating a strong drying of the sites under current climate conditions.

REGIONAL AND BASIN-SPECIFIC CONTROLS ON BIOGENIC SILICA ABUNDANCES IN A SUITE OF SOUTH GREENLAND LAKES

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Biogenic silica concentration is often measured in Arctic lake sediments as a proxy for lacustrine primary productivity by diatoms. Changes in biogenic silica abundance are frequently attributed to changes in regional temperature but can also result from within-lake processes, such as changes in lake level or stratification. To investigate the impacts of regional temperature shifts versus changes in lake level and stratification, we compared the biogenic silica concentration in sediment cores from four small, non-glacial lakes in southernmost Greenland throughout the Holocene.

Three of the lakes are through-flowing, 8 – 26 m deep, 0.01 – 0.13 m^2 in area, and show no evidence of lake level changes (coastal lake N14, studied by Andresen et al. (2004), nearby Lake N17, and alpine lake UMEL at 675 m elevation on the Mellemlandet plateau near Narsarsuaq; all lakes names are informal). We interpret these lakes as having been hydrologically stable throughout the Holocene (Andresen et al., 2004; Puleo & Axford, 2023). The biogenic silica concentrations of these lakes were relatively constant throughout their respective records – with the longest record from N14 going back to 14,300 cal yr BP. The biogenic silica concentrations slightly increase around 10,700 cal yr BP in UMEL and N14, reflective of diatom community establishment following deglaciation. In UMEL, following this initial increase in productivity, the biogenic silica concentration fluctuates – with changes as large as 10% – but averages to around 35%. Biogenic silica concentrations in N14 during the late glacial period and early Holocene are low (≤ 10%) but increase to about 11% by 12,100 cal yr BP. The biogenic silica concentration decreases until 10,700 cal yr BP, when it increases to 20%, then to 30% around 9,300 cal yr BP. The biogenic silica concentration remains stable around 30% from 9,300 cal yr BP through the top of the record, with the exceptions of 5 – 7% declines occurring between 3,800 – 2,400 cal yr BP and 2,200 – 800 cal yr BP. The record in N17 only extends back to 2,800 cal yr BP, and the biogenic silica concentration fluctuates between 35 – 43% from 2,800 – 100 cal yr BP. Fluctuations as large as 15% occur from 100 cal yr BP to the present, and the overall trend in biogenic silica concentration decreases during this period. Some larger fluctuations in biogenic silica concentration (± 5 – 10%) occur in the mid- to late-Holocene in all of the lakes, but an overall increasing or decreasing trend is not observed at any of the sites.

The fourth lake in our study, Lake MEL3, is similar in size to the other three lakes (13 m deep, 0.07 m^2 area). Satellite imagery reveals that the water level of Lake MEL3 has fluctuated seasonally within the past decade, as the lake becomes hydrologically closed during periods of reduced snowmelt or precipitation. The Holocene sediment stratigraphy and ^{14}C dating of MEL3 suggest a period of very low lake level for part of the past 1,500 years (Tuccillo et al., 2023). In addition, we tentatively interpret sediment color and laminations as recording a multi-millennium period of intensified summer stratification in the middle Holocene, perhaps in response to warmer climate. We examine how biogenic silica production responded to these major, within-lake environmental changes. The MEL3 biogenic silica records varied more significantly with time. A peak of 60% biogenic silica (+30% increase) occurs at 6,200 cal yr BP. A more gradual increase and decrease occurs between 4,000 and 1,200 cal yr BP, reaching biogenic silica concentrations as high as 42%. The biogenic silica stabilizes around 18 – 20% between these two peaks, which are lower concentrations than observed in the other three lakes in this study. Additionally, sediment cores collected 40 m apart in the basin at only slightly different water depths had distinct records in the sediments from 1,500 cal yr BP to present. These results suggest that changes in lake level or stratification can trigger large, abrupt changes to primary productivity in Greenland lakes. The results reinforce that basin-specific characteristics must be considered when analyzing sedimentary proxies, as they can overwhelm the influence of regional climate shifts, including temperature changes. The extreme influence of lake level and stratification regime on primary productivity demonstrated here needs to be considered as we predict future consequences of anthropogenic climate change in Arctic lakes.

This project was supported by a Northwestern University undergraduate summer research grant and NSF OPP Award 2022515.

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A >50,000 YEAR MERCURY RECORD FROM LAKE E5, NORTH SLOPE ALASKA, DOCUMENTS A FOUR-FOLD CONCENTRATION INCREASE IN MERCURY CONCENTRATIONS DRIVEN BY MIDDLE HOLOCENE WARMING

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Arctic permafrost soils have recently been identified as the largest mercury (Hg) reservoir on Earth[1]. Predictive models indicate a drastic reduction in surficial permafrost extent over the next century due to accelerated warming and increased precipitation[2]. As permafrost degrades, Hg, which has been sequestered for millennia, is being released into the environment[1]. Consequently, there is growing concern over the potential rapid discharge of Hg from permafrost-affected soils into Arctic watersheds[3,4]. Mercury contamination poses a substantial challenge in the Arctic, with elevated levels detected in various Arctic wildlife species and indigenous communities reliant on subsistence hunting of fish and marine mammals[5]. Despite initiatives to monitor Hg levels in Arctic ecosystems, the consistent surveillance of such extensive and remote regions remains challenging. Moreover, there is a scarcity of long-term records assessing the impact of climate change on the mobilization of Hg in permafrost- affected watersheds. This presents a significant research gap that impedes our capacity to constrain the impacts of climate change on the Arctic Hg cycle.

In this study, we present a continuous lake sediment record spanning >50 ka from Lake E5 located on the northern foothills of the Brooks Range (68.643°N, 149.458°W). Lake E5 lies within 6 km of the Toolik Field station and, therefore, is situated in one of the most extensively studied areas in the Alaskan Arctic. The region's rich body of research includes regional paleoclimate data that can be drawn upon to interpret how climate change has influenced the E5 Hg record. Our results show that Hg concentrations during MIS 3 were relatively low, but variable, with an average of 81 µg/kg ±21 (n=32) and two notable peaks at ~48 ka (155.7 µg/kg) and ~51 ka (118. µg/kg). Organic mater (OM) concentrations remained low and comparatively stable with an average of 3.6±0.9% (n=158). After ~40ka, Hg tracks August insolation (Pearson's r= 0.89, p<0.01), whereas OM is more strongly correlated with July insolation (Pearson's r=0.83, p<0.01). Hence, Hg and OM displayed overall increasing trends, with OM peaking at 28.3 ka (5.8%) and Hg peaking at 25.1 ka (125.7 μg/kg) before transitioning to a decreasing trend. Beginning ~19 ka scanning X-Ray Fluorescent (XRF) proxies, including calcium to potassium (Ca:K) ratios and iron to magnetic susceptibility (Fe:k) ratios, suggest the onset of increasing effective moisture and saturated soil conditions are consistent with permafrost thaw. Likewise, a notable shift in OM begins at ~19 ka when OM increases to 12±2% (n=75) until 15.0 ka. Organic matter then rapidly increases and peaks (26.2 wt %) at 11.0 ka. Hg concentrations, on the other hand, begin to increase at 17.3 ka, synchronous with increasing greenhouse gas radiative forcing. Mercury continues a variable, but relatively steady increase through to the early Holocene and reaches a pre-anthropogenic maximum of 400.0 μg/kg at 6.2 ka. The Hg concentration then begins to decline, reaching a late- Holocene minimum of 209.7 μg/kg at 1.6 ka when it starts to increase rapidly again. The E5 Hg record maximum occurs at 429.8 μg/kg in 1990 CE.

This study contributes to furthering our understanding of how rising air temperatures, shifting hydrology, ecosystem changes, and permafrost thaw influence the mobilization and accumulation of Hg in Arctic watersheds. Such insights can help inform model prediction studies in addition to the development of effective management and mitigation strategies.

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IMPACT OF LAKE ANOXIA AND CLIMATE ON HOLOCENE BRGDGT AND PLANT DNA RECORDS IN ICELAND

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Recent scientific advances have enabled increasingly more detailed interpretations of past environmental change based on molecular proxies such as lipid biomarkers and sedimentary ancient DNA (*sed*aDNA). However, the degree to which the proxy records reflect an environmental variable of interest, such as temperature or plant community, remains less clear. For example, lipid-based temperature indices and *sed*aDNA preservation can both be confounded under various oxic conditions. In this study, we provide a Holocene case study from two coastal lakes in northeast Iceland that sheds light on the impact of different lake types on the preservation and interpretation of these two environmental proxies. The two lakes are at similar elevations (142 and 151 m asl), separated by only 0.6 km, and are therefore influenced by the same local climate. However, due to their different surface areas (2.51 vs 0.21 km^2) and depths (48 vs 2.5 m), the lakes exhibit variations in seasonal stratification and water chemistry. In sediment cores from both lakes, we reconstruct temperature and vascular plant communities based on bacterial branched glycerol dialkyl glycerol tetraethers (brGDGTs) and *sed*aDNA metabarcoding, respectively. Using a local brGDGT lake temperature calibration, the large lake produces a summer temperature record consistent with many qualitative proxies from Iceland, reflected by peak warmth in the Early-Middle Holocene followed by cooling summers in the Late Holocene. In contrast, the small lake produces a relatively flat temperature record. Additional GDGT-based indices indicate that this is likely due to long- term Holocene anoxia, which can lead to microbial community changes that complicate the sources of brGDGT-producers. In terms of local plant history, *sed*aDNA records for both lakes are largely the same, except for two key differences. The first is that the small, shallow lake has relatively larger contributions of aquatic and emergent plants. Second, the earliest portion of the small lake's record did not have any amplifiable DNA. Based on GDGT indices, this period corresponds with an oxic environment, which is less

conducive for DNA preservation, before the switch to long-term low oxygen conditions that prevailed for the rest of the Holocene. Therefore, for the small lake, both brGDGT-based temperatures and DNA preservation seem to be impacted by the redox state of the water column and/or sediment-water interface. Given that the larger lake did not seem to experience the same degree of oxygen depletion, we suggest that such settings may be more suitable for the application of paired brGDGT and *sed*aDNA climate proxies.

A 240,000-YEAR-LONG RECORD OF HYDROCLIMATE AND TEMPERATURE CHANGES FROM IMURUK LAKE, SEWARD PENINSULA, ALASKA

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We present a 240,000-year-long, high-resolution temperature and hydroclimate reconstruction from Imuruk Lake in northwest Alaska. The age model is established by radiocarbon dates, geomagnetic excursions, high-resolution pollen analysis and correlating with Chinese cave records. Our hydroclimate proxies show prominent variance at the precession and obliquity bands. Importantly, precession-scale precipitation variance during the glacial is stronger than that during interglacial times. Group I alkenone provides cold season temperature reconstructions, showing consistently warmer conditions during glacial periods than the interglacials, consistent with transient deglacial climate model simulations that indicate the advance of the Laurentide Ice Sheet (LIS) during the glacial times can increase cold season temperature and precipitation in eastern Beringia by deflecting Westerly moisture transport to the northwest Alaska. We also identified the Old Crew Tephra at ~ 174 ka in the core.

RECONSTRUCTING PLEISTOCENE OCEAN CURRENTS NEAR SOUTHERN GREENLAND BASED ON FORAMINIFERAL ASSEMBLAGES

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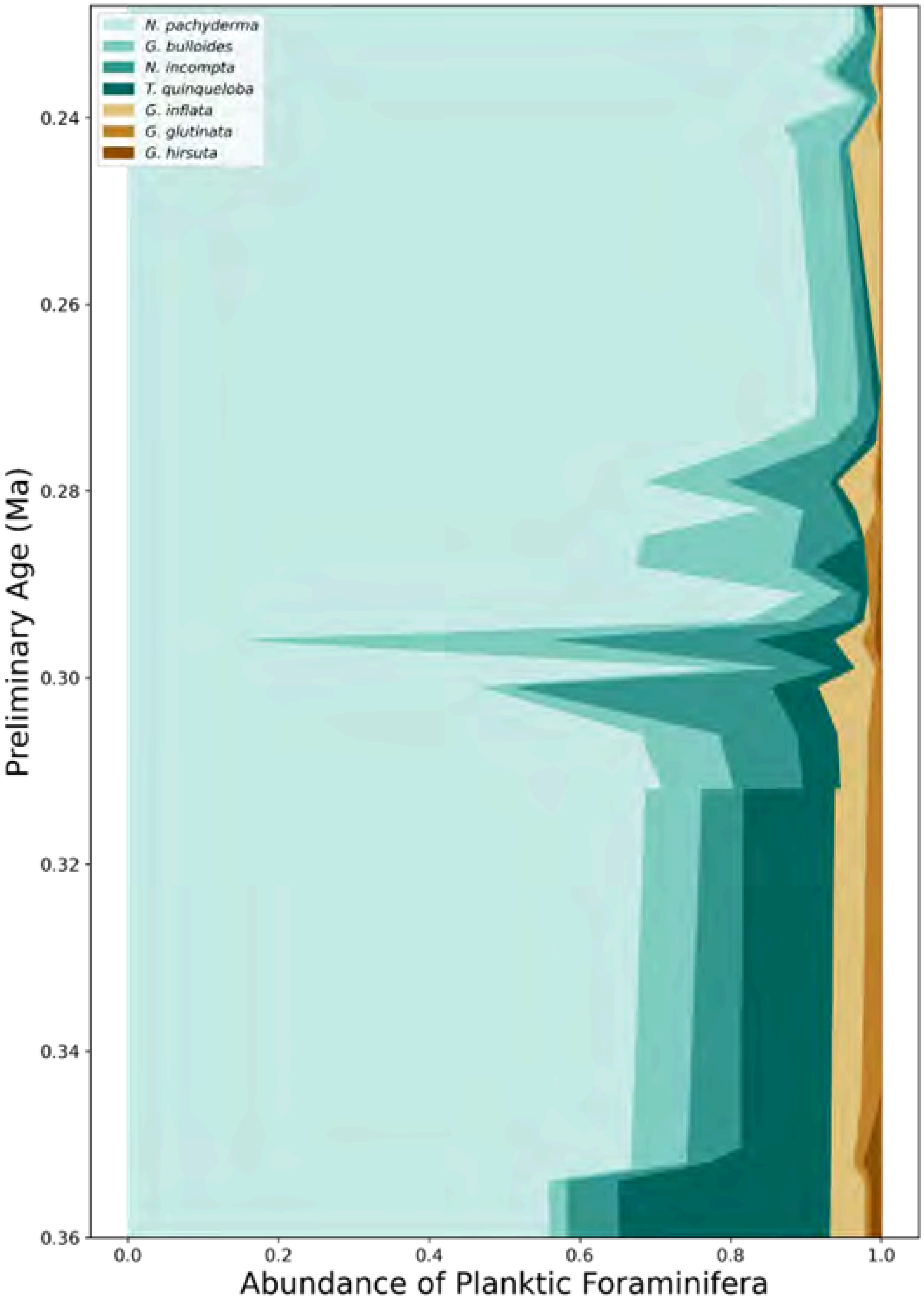
Changes in ocean currents have a significant effect on Greenland and its ice sheets, with warm currents increasing melting rates and contributing large amounts of freshwater into the polar ocean. Reconstructing past temperatures and environments from the Pleistocene can allow us to understand how Arctic Ocean and Northern Atlantic currents have shifted alongside sea surface temperatures (SSTs) during periods of rapid glaciation and deglaciation. In this study, we examine Pleistocene sediments from Ocean Drilling Program (ODP) Site 647 from the southern Labrador Sea for foraminiferal assemblages. Foraminiferal species assemblages were assessed in 44 samples spanning 0.228 Ma to 2.577 Ma, to track changes in the currents influencing the Site (North Atlantic Current, Irminger Current, Labrador Current). A total of 18 different planktic species were observed across the various samples, with 6 samples barren. Throughout the Pleistocene, notable changes in the foraminiferal assemblages occur with older parts of the core (≥2.416 Ma) being barren. The record shifts to consistently warm currents, based on increasing *Neogloboquadrina incompta*, around ~1.508 Ma and later, while the younger parts of the core are dominated by *Neogloboquadrina pachyderma* suggesting colder conditions. There is a significant decrease in diversity and abundance of warmer water species, and increase in *N. pachyderma* from 16.5% at 0.296 Ma, corresponding with Marine Isotope Stage (MIS) 9, to a maximum of 96.9% *N. pachyderma* at 0.238 Ma corresponding with MIS 8. Results indicate that warmer waters of the North Atlantic Current were displaced northward during interglacial MIS 9 ~0.296 Ma, while colder polar waters dominated over the Site by ~0.238 Ma during glacial MIS 8. The large peaks found between ~0.306 Ma and 0.275 Ma (Figure 1) may represent the transition between warmer interglacial MIS 9 to colder glacial MIS 8, as the North Atlantic Current shifted southward. The assemblage of the older sediments suggests this boundary between the warmer and colder water masses was closer to Site 647, with the presence and higher abundance of warmer species, while younger sediments show an overwhelming dominance of polar species, possibly indicating the southward shift of the North Atlantic Current. Assemblages are compared to sea surface temperature (SST) (Tibbett et al., 2024). SSTs and the species assemblage follow a similar pattern with the appearance and higher abundance of warmer species such as *Globoconella inflata* and *N. incompta*, when higher temperatures are observed. Analyzing the shifts in the assemblages provides crucial information regarding the behavior of ocean currents during times of global warming and cooling throughout the Pleistocene providing insights into how these same water masses may shift in the near future with anthropogenic forcing increasing global temperatures.



N. pachyderma
G. bulloides
N. incompta
T. quinqueloba
G. inflata
G. glutinata
G. hirsuta
Preliminary Age (Ma)
0.24
0.26
0.28
0.30
0.32
0.34
0.36
0.0
0.2
0.4
0.6
0.8
1.0
Abundance of Planktic Foraminifera

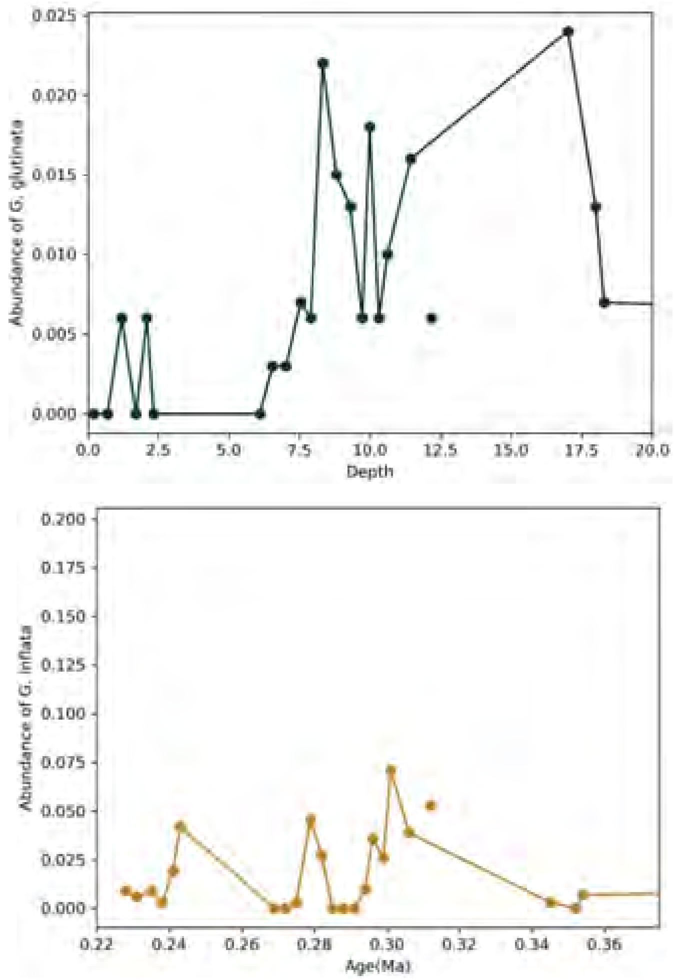


Figure 1: Summary of the 7 most prevalent planktic species found throughout the 44 samples, with the addition of *Globorotalia hirsuta* which is an indicator species for warmer, temperate waters. The ages range from 0.228 Ma to 0.360 Ma. The shaded areas represent the percentage of each species in a sample to show the shifts in abundance of these key species.

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RECENT ADVANCES IN MODELING PERMAFROST DYNAMICS AND CARBON CYCLING USING TERRESTRIAL ECOSYSTEM MODEL

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Introduction

Almost a quarter of the land in the Northern Hemisphere's vast expanse of land is covered by permafrost, which has been warming rapidly for the last 40 years. Integrating permafrost processes into Land System Models (LSMs) and Earth System Models (ESMs) is a complex and challenging task due to the intricate interplay between permafrost dynamics, hydrology, carbon cycling, and their impacts on climate. To tackle this complexity, our team is deploying an offline regional model to analyze permafrost carbon cycling and its future implications. To address disturbances that could lead to rapid permafrost thaw, our team is developing wildfire and thermokarst processes to include in the model. Leveraging data from the existing flux tower network in the Northern Hemisphere, we are enhancing model-data congruence. Our approach includes developing calibration and sensitivity analysis tools for automated parameter calibration using specific flux tower data. Additionally, we've created a tailored map of vegetation classes for more accurate spatial modeling and are developing a data assimilation tool aimed at reducing model biases. Here we highlight our recent advancements in modeling as part of the Permafrost Pathways project, which unites climate scientists, policymakers, and environmental justice advocates to devise strategies for adapting to and mitigating the impacts of permafrost thaw.

Parameter Calibration

We utilized the MADS (Model Analysis and Decision Support) software for parameter calibration within the Terrestrial Ecosystem Model to reduce the gap between observed and modeled data at various sites (Vesselinov, V.V., 2022). We use the Terrestrial Ecosystem Model with Dynamic Vegetation and Dynamic Organic Soil Layers (DVM-DOS-TEM), a process-based biosphere model designed to simulate biophysical and biogeochemical processes between the soil, vegetation, and atmosphere (Genet et al., 2018). MADS' user-friendly interface and robust optimization algorithms provided efficiency and flexibility, outperforming other tools like PEST and PECAN (Jafarov et al., 2020; Euskirchen et al., 2022). Additionally, a sensitivity analysis tool was developed to work in tandem with MADS, improving initial parameter estimates, constraining the parameter space, and aiding in understanding parameter interactions (Briones et al, in review). This semi-automated calibration approach streamlines the process, allowing for the handling of larger datasets and the use of parallel computing, thus enhancing efficiency. This method has been applied to five different sites, showcasing its effectiveness across diverse environmental conditions.

THERMOKARST MODELING

To address the cryohydrological impacts of thermokarst in the DVM-DOS-TEM, we analyzed changes at four sites in Alaska with varying drainage and permafrost conditions. The objective was to assess the model's accuracy in simulating carbon cycling and permafrost dynamics in ecosystems with varying moisture levels and permafrost continuity. The sites included a thermokarst bog and a black spruce permafrost plateau in boreal Alaska's discontinuous permafrost, as well as a wet sedge fen and moist tussock tundra in the continuous permafrost of the Alaskan Arctic. Comparisons of model outputs with field data showed that the model performed better in continuous permafrost areas, attributing to simpler thermal and hydrological dynamics during a shorter growing season. However, larger discrepancies were observed at the discontinuous permafrost and wetland sites, especially in carbon fluxes and active layer depth predictions. Attempts to correct hydrology in wetlands improved the active layer depth predictions but negatively affected carbon flux estimates, suggesting a need for better process representation. We found that soil moisture was consistently under-predicted, affecting respiration rates. Our findings highlight the need for improved hydrological and carbon cycling representations in models to more accurately simulate these complex and carbon-rich ecosystems (Maglio et al, 2024).

FIRE MODELING

We employed a DVM-DOS-TEM to study how black spruce and birch forests in Alaska respond to changes in fire frequency and how this impacts carbon cycling and permafrost interactions under shifting climate conditions. By simulating typical stands at Murphy Dome near Fairbanks and validating against field-measured carbon stocks, the study explored the effects of fire return intervals ranging from 50 to 250 years. The findings revealed that the model accurately reflects the distinct ecosystem dynamics of spruce and birch forests. More frequent fires were found to significantly decrease vegetation carbon, particularly in evergreen species, with soil organic carbon also severely impacted, and shorter intervals between fires hampering its recovery. Notably, soil carbon losses during moderate-severity fires were higher than those from vegetation. The study underscores the substantial role of fire in altering boreal forest composition and carbon reserves, which is critical for understanding landscape changes due to climate change. This work emphasizes the need to incorporate variations in fire frequency, moisture gradients, and changes in vegetation types into models to predict future carbon dynamics in boreal forests and calls for further investigation into the complex interplay between disturbance, succession, and carbon processes in this evolving ecosystem (Briones et al., 2024a).

Spatial modeling

All existing model developments will be incorporated into spatial model simulations. Currently, our team is working on the development of the monthly input data at high spatial resolution. The input dataset will be used with a newly completed Pan-Arctic vegetation map customized for our model (Briones et al., 2024b). In parallel, we are working on spatial data assimilation that will be used to fine-tune model parameters and outputs using in-situ and remotely sensed data.

Acknowledgments

This study was made possible by funding catalyzed through the Audacious Project (Permafrost Pathways) and the Quadrature Climate Foundation (QCF Prime Grant Number 01-21-000094). We would also like to acknowledge great sources of data from the National Science Foundation (NSF) funded Bonanza Creek and Arctic members of the LTER Network, and the Circumpolar Active Layer Monitoring (CALM) Network. Additionally, we would like to thank the Department of Energy (DOE) Office of Biological and Environmental Research's (BER) AmeriFlux and its contributors, as well as the ABCFlux database available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

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TRACING MICROBIAL FOOTPRINTS IN GREENLAND'S SUBGLACIAL NALED ICE MELTWATER: AN ISOTOPIC PERSPECTIVE

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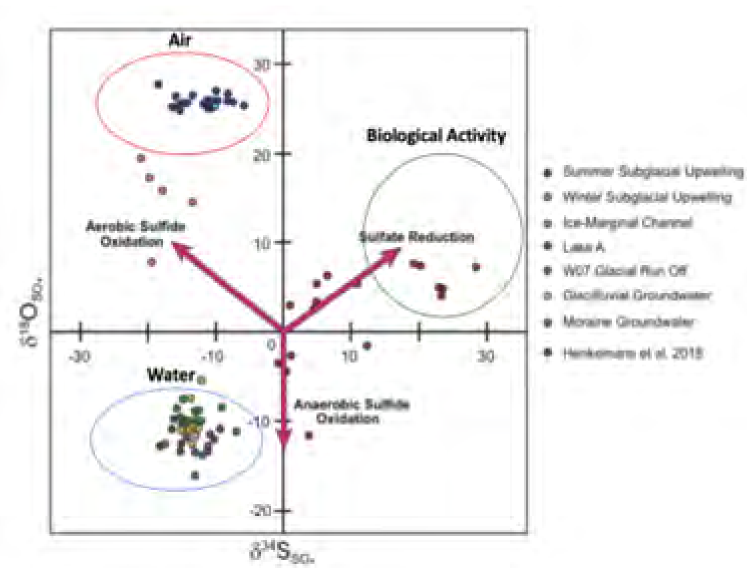
The Greenland Ice Sheet (GrIS) is rapidly melting, accelerating to a rate of 42 Gt of ice per year over the last two decades (Greene et al., 2024). This meltwater chemistry can be characterized as subglacial waters emerge at the glacial terminus. The outflow of subglacial super cooled water (<0˚ C) that comes into contact with air at the proglacial environment and refreezes creates platforms of accreted ice called naledi. We propose studying the naled along with the subglacial meltwater can reveal insights into the geomicrobiology that influences meltwater chemistry of the dynamic environment of the GrIS, particularly as the meltwater flow conditions shift between distributed and channelized flow. The study site is located at Isunnguata Sermia in western Greenland, recognized as one of the largest land-terminating outlets of the GrIS. This research of the waters flowing into the Atlantic Ocean holds crucial importance in the context of our warming climate. This significance stems from the potential for shifts in ocean circulation patterns, sea level rise, and feedback mechanism, which, in turn, can profoundly impact weather patterns and the distribution of heat.



Drawing from the research of Wadham et al., (2004, 2007, & 2010) and Henkenmans et al., (2018), our investigation extends the exploration of $\delta^{34}S$-SO_4 and $\delta^{18}O$-SO_4 values in polar regions. Wadham et al., (2004, 2007, & 2010) conducted research in the high Arctic region of Svalbard, with a specific focus on subglacial conduits. In contrast, Henkenmans et al., (2018) conducted research in Greenland, examining groundwater fed lakes to investigate microbial sulfate reduction. Their study focused on surface waters and did not include subglacial conduits. Our data compiled from the literature (see figure) illustrates a spectrum of values and their associated interpretations. Values situated in the top-left quadrant of the plot with low $\delta^{34}S$, characteristic of pyrite, and high $\delta^{18}O$, characteristic of atmospheric oxygen, suggest a system primarily dominated by aerobic sulfide oxidation. In contrast, values positioned in the bottom-left quadrant closely resemble oxygen values associated with water, indicating a closed system with restricted atmospheric exchange—a characteristic feature of anaerobic sulfide oxidation. Values located in the top-right quadrant are closely linked to microbial sulfate reduction where the residual sulfate becomes enriched in ^{34}S and ^{18}O.

We propose naled ice provides a record of subglacial meltwater conduits, microbial activity, chemical weathering, and the critical role of seasonality that can help us understand hydro-biogeochemical processes in the GIS. We use the concentration and isotopic composition of sulfate ($\delta^{34}S$-SO_4 and $\delta^{18}O$-SO_4) and dissolved inorganic carbon ($\delta^{13}C$-DIC) to distinguish microbial processes from the weathering of minerals such as pyrite and carbonates. Skidmore et al., (2002) have examined kinetic isotopic fractionation during carbonate dissolution because the low values of $\delta^{13}C$-DIC are similar between microbial CO_2 generation and carbonate dissolution, which poses is a challenge in applying conventional isotopes mass balance technique in systems with high carbonate content in the sediment and short water interaction time. We hypothesize that there will be greater microbial activity during the transition from winter to spring, attributed to a subglacial distributed flow regime with limited oxygen availability. We anticipate an increase in $\delta^{34}S$-SO_4 and $\delta^{18}O$-SO_4, and a decrease in $\delta^{13}C$-DIC as low oxygen conditions promote microbial sulfate reduction. Conversely, during periods of elevated temperatures such as summer and fall, a channelized flow regime circulates oxygenated waters that erode minerals such as pyrite and carbonate. If there is pyrite oxidation, we expect a decrease in $\delta^{34}S$-SO_4 and $\delta^{18}O$-SO_4, as well as a decrease in $\delta^{13}C$-DIC during these warmer periods.

We will present concentration and isotopic composition of DIC and sulfate at the conference. Currently, we have isotopic concentration of sulfate obtained from a gravimetric analysis of samples collected in May to June 2023 and September 2023. Sulfate concentrations were high and ranged from 0.28 to 0.00017 micromole of SO_4 in meltwater flow during the months of May to June 2023. The sulfate concentrations in the samples collected in September were lowered and exhibited a wide range, spanning from 0.025 to 0.00071 micromole of SO_4. The gravimetric analysis of sulfate concentrations indicated a notable increase during the spring melt, likely attributable to the oxidation process of subglacial pyrite. This observation serves as an indicator that elevated temperatures result in increased melting, potentially leading to the oxidation of subglacial pyrite. Our research on West Greenland naledi will add new insights into the time and conditions that influence meltwater chemistry.

Keywords: Greenland Ice Sheet, Microbial Communities, Subglacial Melt Conduits, Isotopic Composition, Hydro-Biogeochemical Processes, Geomicrobiology, Climate Change

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PROBING THE ORIGIN(S) OF BBDC EVENTS

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Baffin Bay Detrital Carbonate (BBDC) events stand out in Baffin Bay marine sediments as intervals of light brown and tan calcareous mud with abundant coarse clasts. These events have been mainly attributed to iceberg calving from the Lancaster Sound ice stream (LSIS) which drained confluent Laurentide and Innuitian ice sheets over areas of Paleozoice carbonate bedrock via Lancaster Sound, NW Baffin Bay. The youngest two events, BBDC 1 and 0, are well known and distributed throughout Baffin Bay within a consistent age interval of ~14.5 to 10.5 cal ka BP. However, several less prominent and less well studied BBDC events were deposited within MIS 2 and 3. We question whether these earlier events reflect similar ice extents and processes to BBDC 0 and 1. To explore this idea, we use combined geophysical and sediment core evidence to investigate BBDC 2, 1 and 0 in cores 2013029-064PC, on the upper slope SW of Lancaster Sound, and 2008029-59PC, within Lancaster Sound. Previous mapping of glacigenic landforms: megascale glacial lineations, grounding zone wedges (GZWs) and retreat moraines show that 064PC lies within the LGM limit of the LSIS on the northwestern Baffin Island shelf. Adjacent to the huge LSIS were smaller outlets of the Laurentide Ice Sheet (LIS) that extended onto the eastern Baffin Island continental shelf; GZWs of these outlets suggest that fringing ice shelves formed during stillstands in the retreat of the LIS after initial LGM retreat. Using multiproxy sedimentary evidence from the two cores combined with geophysical data, we reconstruct the retreat history and intervening ice shelf development during phases of the deglaciation from the LGM. Newly acquired radiocarbon dates confirm that the LSIS had retreated northwest of 59PC by 15.3 cal ka BP, with retreat onto the Paleozoic carbonate bedrock manifested by BBDC 1 and 0 and ending with opening of Parry Channel. The lithofacies in 59PC document one ice retreat sequence, with potential pausess, but no significant readvances. The older event, BBDC 2, is present in shelf core 64PC but is not present within Lancaster Sound core 59PC. We conclude that deposition of BBDC 2 predates ice retreat into Lancaster Sound. It likely represents release of Paleozoic carbonate entrained in ice stream basal ice during the LGM and released as the ice stream retreated from its LGM maximum extent on the upper slope and shelf. An overlying finely laminated sequence with sediments reflecting both Pond Inlet and Lancaster Sound provenance provides evidence for a pause in ice retreat of the Pond Ice Stream with formation of an ice shelf fronting the Pond ice stream after BBDC 2. BBDC 2 in 64PC lacks foraminifera and is undated. We are assessing the correlations between BBDC 2 in 64PC with the sequences of BBDC events in other dated cores in Baffin Bay.

Identification of BBDC events in cores collected along the west Greenland margin on CSS Hudson cruise 2013029 and during the BadEx cruise, AR2307 of the R/V Neil Armstrong will increase the potential for dating the earlier BBDC events and test the potential for advection of Atlantic Water in the West Greenland Current as an initiator of ice retreat in northern Baffin Bay.

PRESENCE OF TETRA-UNSATURATED ALKENONES IN THE SOUTHERN OCEAN: DIRECT INDICATION OF GROUP 2I ISOCHRYSIDALES AND PROXY FOR SEASONAL ANTARCTIC SEA ICE

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Antarctic Sea ice is a vital component of the Earth's climate system, contributing to climate regulation, ocean circulation and global carbon cycling. Sea ice in the Southern Ocean is dynamic and difficult to predict. In recent years, specific regions such as Western Antarctica, have experienced significant declines. The satellite record only captures changes in sea ice distribution over the past 40 years, and the dynamics of sea ice change before the satellite record are largely unknown. To fully understand how Antarctic Sea ice will change in the future, an understanding of past changes in sea ice distribution is essential.

To date, there are few proposed proxies for the reconstruction of seasonal sea ice distributions. IP_{25} is one of the commonly used organic geochemical proxies for tracing presence of sea ice in the high latitudes. Previous studies have shown correlation between the presence of IP_{25} and spring sea ice diatom blooms in the arctic. However, the proxy faces several critical challenges including unknown stability in deep time sediment records, and general uncertainty about the relationship between production and deposition.

Here, we present a new potential proxy signifying seasonal sea ice cover, using seawater samples collected around the Southern Ocean and analyzed for organic biomarkers. We have identified the presence of the C39:4 alkenone in regions characterized by perennial and/or heavily sea ice-cover, pointing to the exclusive origin from Group 2i Isochrysidales production (Liao et al. 2022). Group 2i Isochrysidales produce a specific alkenone profile and have been shown to reflect sea ice distribution (Wang et al. 2021). Previously, Southern Ocean water samples analyzed for alkenones were unable to detect the presence of alkenones in concurrence with sea ice, or above 60°S using traditional Gas Chromatography methods and have attributed the collapse of U^{K}_{37} ratios at near freezing temperatures to microalgae physiology (Sikes et al. 1993, Sikes et al. 1997). Our study reveals the presence of alkenones as high as 75°S, and attributes the unusual alkenone profiles in extreme high latitudes to Group 2i.

Methodologically, our study emphasizes the indispensable role of High-Performance Liquid Chromatography-Mass Spectrometry (HPLCMS) for a more thorough quantification of alkenones across low concentrations and for all chain lengths, surpassing the limitations of conventional Gas Chromatography with Flame Ionization Detection (GCFID). This newly developed method of alkenone detection provides higher sensitivity and selectivity than traditional GCFID methods and allows for the quantification of alkenone compounds in concentrations previously too low to detect (Liao et al. 2023). In contrast to conventional IP_{25}, tetra-unsaturated alkenone percentages are internal ratios, offering a more robust and quantitatively reliable relationship to sea ice. Our study highlights the presence and distribution of the C39:4 alkenone in the Southern Ocean and near the Antarctic continent. Although samples collected during the austral summer may not be directly indicative of winter sea ice conditions, we show that the alkenone signature left behind by group 2i is still present in the surface water, particularly in regions with little circumpolar current influence.

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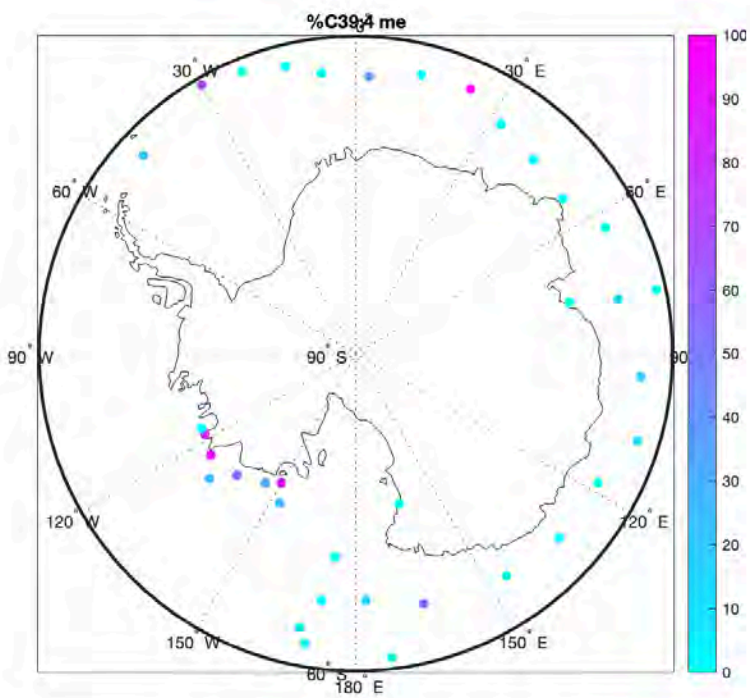

A RECORD OF GLACIER LENGTH THROUGH THE HOLOCENE FOR A GLACIER IN THE JUNEAU ICEFIELD, ALASKA

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Whether North American glaciers disappeared during the so-called Holocene Thermal Maximum remains debated. As numerous North American glaciers are projected to disappear this century, the answer has implications for measuring the human impact on the cryosphere and demarcating the Anthropocene. Prior work in western Canada documents several glacier advances between ~8 ka and the end of the Little Ice Age in ~1880 CE, but many questions persist about the magnitude of advance and retreat during these episodes. *In situ* cosmogenic ^{14}C-^{10}Be concentrations in proglacial bedrock provide quantifiable constraints on bedrock exposure and burial that we apply in a novel sampling pattern to reconstruct glacier length through time.

We present a preliminary record of Holocene glacier length for a glacier in the Juneau Icefield, Alaska, USA. We measured ^{10}Be concentrations in bedrock samples (n=27) along a transect from the modern glacier terminus to its Holocene maximum (Little Ice Age) moraine, making paired *in situ* ^{14}C measurements on five of those samples. Apparent ^{10}Be exposure ages generally increase down-valley from the glacier toward the Little Ice Age moraine, ranging from near-blank levels at the glacier's terminus to a maximum of 7,240 ± 410 years near the moraine. *In situ* ^{14}C-^{10}Be ratios, reflective of burial, are lower by the glacier and higher by the moraine. These two trends provide evidence of successively greater Holocene glacier expansion as predicted by decreasing summer insolation and regional proxy temperature reconstructions. Modeled exposure-burial histories and sample 'stratigraphic position' suggest the glacier has retreated to its smallest position of at least the past 8,000 years. This occurred despite only a 30% reduction in length, which we hypothesize is indicative of a persistent glacier over the Holocene.

NESTED HOLOCENE MORAINE SEQUENCES IN THE SOUTHERN HEMISPHERE AND WAS THERE A NORTHERN HEMISPHERE-LIKE LITTLE ICE AGE?

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Advances in ^{10}Be dating, since I was an INSTAAR grad student in the last century, have deepened understanding of Holocene glacier activity in both hemispheres. This is especially so where moraines are difficult to date directly, or there has been a reliance in the literature on minimum-limiting ^{14}C ages. In the Southern Hemisphere, sites in New Zealand, Patagonia, and the Antarctic Peninsula document a Holocene glacier history quite unlike that in the Northern Hemisphere (most records?). Guides for Holocene glacier behavior based on Northern Hemisphere records have not been so applicable to the middle latitudes of the Southern Hemisphere.

In the Southern Hemisphere middle latitudes, the largest Holocene glaciers occurred in the early or middle Holocene Epoch and the associated moraines are far outside the limits of the last few centuries. Moraine sequences document repeated, advances of successively less extent. On the other hand, glaciers did advance at least 2-3 times between ~1400 A.D. and ~1850 AD.; maximum extents were in the earlier part of the last ~600 years. Glacier advances during the last millennium may have even been at similar times in both hemispheres (e.g., 1400s, 1700s, 1800s). In addition, existing ELA reconstructions in the Southern Hemisphere even show the depression may have been similar to analogues findings in Europe and North America. However, in the Southern latitudes, the ELA depressions that caused advances during the last millennium were less than during earlier, middle and early Holocene expansions.

A net decrease in glacier size during successive expansions, over the last ~12 ka, may parallel a gradual rise in local summer insolation intensity during the Holocene. Moreover, we infer the timing of individual advances occurred during persistent negative Southern Annular Mode (SAM)-like states at centennial to millennial timescales. SAM is a dominant mode of sub-decadal climate variability in the Southern Hemisphere and reflects northward/southward changes in the westerlies. Present efforts in (at least) South America involve filling in spatial-temporal details and gaps, especially for the early Holocene, which remains unresolved. In addition, we are focusing on study areas northward of recently obtained records, to see how “the Southern patterns” may change towards the lower latitudes.

To the Arctic Workshop audience, I present at least the following questions. During the Holocene, when glaciers advanced in the Southern Hemisphere, did expansions typically occur also in the Northern Hemisphere? If yes, was just the relative magnitudes in area/length (i.e., ELA depression) different between the hemispheres, with Southern Hemisphere glacier advances being smaller during the Little Ice Age interval, compared with expansions during the earlier parts of the Holocene? If century-scale Holocene glacier advances do occur at a similar time in both hemispheres, what respective drivers influence the relative magnitude of climatic changes?

DESCRIPTION OF ANCIENT VEGETATION EMERGING FROM UNDER ICE CAPS ON BAFFIN ISLAND

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Polar amplification is causing Arctic regions to warm faster than the rest of the globe. This amplified warming is resulting in rapid retreat of Arctic glaciers and ice caps. As glaciers retreat, plant communities encapsulated by ice are generally scraped away. However, retreating ice caps behave differently during retreat because they are cold-bottomed, non-moving and non-erosive ice, allowing plant communities to remain mostly intact upon exposure. These intact communities provide important windows into past Arctic vegetation community structure and development under different environmental circumstances. This allows for direct comparison with modern plant communities and environmental conditions. Additionally, exhumed mosses can and have been used to constrain dates on various glacial advances, creating a more precise historical record of Arctic ecosystem shifts. Arctic feedbacks are important for the construction of climate models designed to predict effects of newly exposed areas on existing ecosystems. Only a few formal surveys of plant communities exposed by retreating ice caps have been conducted to date. Here, we provide the first complete descriptions of vegetation communities recently exposed by two retreating ice caps on Baffin Island, Nunavut and compare them with modern vegetation in the surrounding areas in both structure and estimated establishment rate.

SCALING ARCTIC LAKE METHANE EMISSIONS: A CLOSER LOOK AT THE EFFECTS OF LAKE AREA, AQUATIC VEGETATION, AND DOUBLE-COUNTED WETLANDS

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INTRODUCTION

Arctic methane (CH_4) emissions are a climate-sensitive component of the global carbon cycle dominated by emissions from wetlands and lakes (Wik et al., 2016). The absence of small lakes and ponds (hereafter: lakes) in surface water inventories is a known problem [1,2]. A second factor gaining attention is the role of aquatic vegetation in lake methane emissions (Bastviken et al., 2023; Kyzivat et al., 2022). Aquatic vegetation and lake littoral zones have long been recognized as "hot spots" of methane production and emission [6–8], but to our knowledge have not yet been used as upscaling variables. A third, chronic problem with published lake inventories, statistical extrapolations, and remotely sensed lake products is inclusion of open water bodies otherwise classified as wetlands in other data products, leading to "double-counting" of the same area in merged total aquatic estimates [9,10]. Double-counting is thought to be particularly common between non-inventoried lakes and coarse pixels in Arctic wetland maps [10] and may contribute to a large observed discrepancy between bottom-up (statistically upscaled) and top-down (inverse atmospheric modeled) methane budgets [9].

Here, we examine the relative importance of non-inventoried small lakes, aquatic vegetation, and double-counting in upscaled Arctic lake methane emission estimates. First, we obtain high-resolution Arctic lake/pond maps comprising 626,000 water bodies >0.0001 km^2. Next, we merge these maps with HydroLAKES to estimate the relative area contribution from lakes <0.1 km^2. We provide a simple estimate for corresponding methane emissions based on individual lake area and temperature. Then, we estimate lake aquatic vegetation coverage and quantify double-counting, and discuss how these factors change our pan-Arctic estimate. We find that contributions from non-inventoried small lakes < 0.1 km^2 are significant (12 [range: 3.9-31] %), but very small ponds < 0.001 km^2 only contribute 0.5% [0.0-1.4] of area and 2.6% [0.1-6.8] of emissions, far less than previously thought. We conclude by comparing the effects of the three selected variables on pan-Arctic lake methane emissions and giving recommendations for future research.

METHODS

Data fusion of HydroLAKES (Messager et al. 2016) with three high-resolution (HR) remotely-sensed datasets was used to supplement HydroLAKES coverage (**Supplementary Text S1**). These datasets were primarily derived from optical remote-sensing and exclude vegetated portions of lakes. In total, some 97,000 km^2 of HR airborne and satellite images were compiled, including lakes >0.0001 km^2 within 75 diverse regions around the pan-Arctic. Small lake areas were extrapolated from HydroLAKES based on the mean HR lake area distribution. This method, which we consider empirical, not parametric, estimates binned areas and not individual lake counts. This approach was validated over the independent WBD-NAHL [14] dataset over North America, with excellent agreement in distribution, i.e. + 3.3% difference in extrapolated lake area.

We provide a first estimate of aquatic vegetation coverage using the 30 m resolution Global Surface Water (GSW) dataset (Pekel et al. 2016), which derives water occurrence frequency from 30 years of Landsat satellite imagery. To avoid double-counting of lakes and wetlands, the major global wetlands dataset WAD2M and Global Carbon Project methane budget [9] both use a 50% GSW occurrence threshold to mask out permanent surface water (assumed lakes), which we adopt as an indicator of potential wetland double-counting. To estimate lake aquatic vegetation coverage, the distribution of occurrence values was obtained for vegetation pixels in each of the four regions analyzed in Kyzivat et al. (2022). Bayes theorem was used to convert this distribution to a prediction across HydroLAKES based on underlying water occurrence values.

To explore the sensitivity of upscaled methane emission estimates to inclusion of small lakes, aquatic vegetation, and double-counting, a baseline methane emission must be assigned to every lake. Lake area and temperature were chosen as easily obtainable upscaling variables, and equations for lake area and temperature were tested using multiple linear regression against open-water (diffusive plus ebullitive) methane emissions from the comprehensive BAWLD-CH4 dataset (Kuhn et al., 2021a).

RESULTS

Over the pan-Arctic domain, we estimate small lakes (<0.1 km^2) not inventoried in HydroLAKES comprise 12 [range: 3.9-31]% of lake area, 30 [3.7 – 89]% of lake aquatic vegetation area, and 30 [9.0-82]% of open-water CH_4 emissions. A first pan-Arctic estimate of lake aquatic vegetation covers some 108,000 [20,000-325,000] km^2, comprising 7.8 [1.5-24]% of lake area and the equivalent of 3.3% of BAWLD wetlands. This map offers a first data product to enable pan-Arctic upscaling of aquatic vegetation contributions to lake methane emissions. Double-counting affects 123,000

[82,000-168,000] km^2 (12 [8.2-17]%) and 155,000 [86,000-263,000] km^2 (11 [6.3-18]%) of inventoried and total lake areas, respectively. This double-counting in conjunction with potential over-estimation of inventoried lake areas suggests even HydroLAKES, the leading global lake inventory, needs to be modified before using it to upscale methane emissions.

The best-performing regression equation for open-water emissions used lake area in conjunction with ERA5-model soil temperature from 1-7 cm. The following equation ($R^2 = 0.221$, $p < 0.001$) was used to obtain baseline estimates of methane emissions for the 1.37 million km^2 of lakes in this study:

$$\log_{10}(F + 0.01) = -0.18 * \log_{10}(A) + 0.06 * T + -16.10$$

where F is open-water emissions (mg CH_4/m^2/day), A is lake area (km^2), and T is modeled soil temperature (K). The total estimated emissions for this baseline scenario are 2.4 Tg CH_4/yr.

DISCUSSION AND CONCLUSION

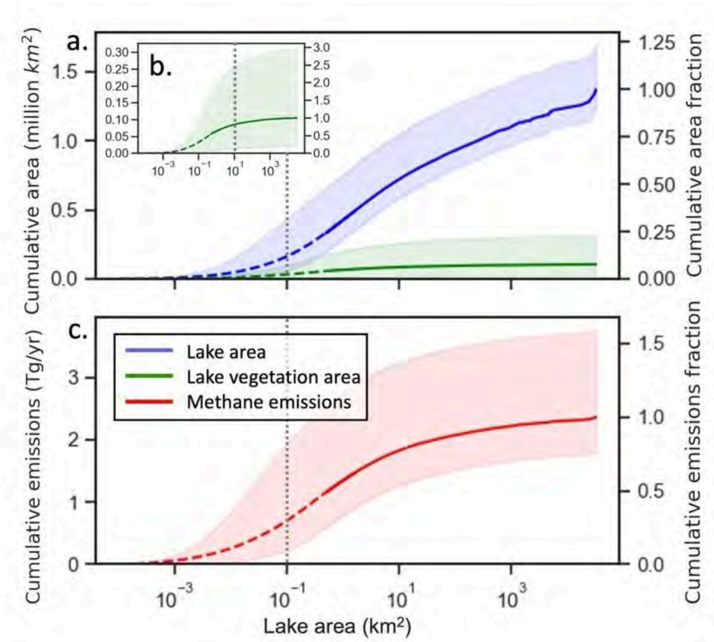
Our empirical, satellite-based analysis finds that very small ponds <0.001 km^2 comprise only 0.5 [0.0-1.4]% of pan-Arctic lake area and 2.6 [0.1-6.8]% of lake methane emissions, closely matching the findings of Ludwig et al. (2023) in Arctic delta lakes (1.1% of area and 2.3% of emissions). In contrast, global studies using parametric extrapolations find much greater emissions from very small ponds. Holgerson & Raymond (2016), for example, estimate 8.6 [5.9-11.2]% of area and 40.6 [0-68.8]% of diffusive emissions from ponds <0.001 km^2. Similarly, Rosentreter et al. (2021) estimate 37% of open-water (diffusive plus ebullitive) emissions from this size class. Although our study examines the pan-Arctic, this lake-dense region includes 78% of HydroLAKES by count and 40% by area, so differences in geographic domain cannot explain the entire discrepancy.

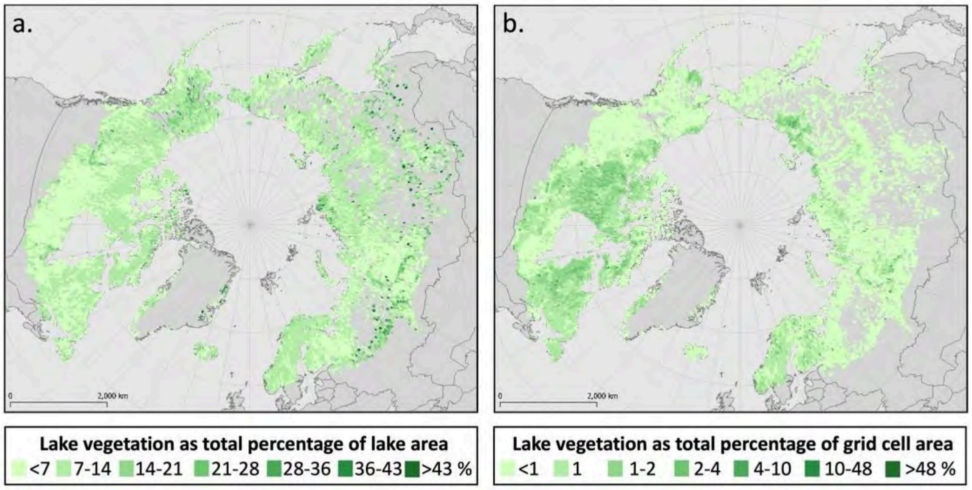
Use of the Pareto distribution—or indeed any other parametric-based extrapolation— to estimate the abundance of small lakes may no longer be necessary, given the growing availability of remotely sensed HR lake inventories. The approach presented here—a hybrid of direct observation and statistical extrapolation—fits data empirically, regardless of the onset of power-law behavior.

As supported by recent reviews (Bastviken et al., 2023, Bodmer et al., 2024), aquatic vegetation contributes a significant proportion of lake emissions and area—if it is not already double-counted as wetlands in other data products. In sum, vegetated zone emissions, though still highly uncertain, appear to be comparable in magnitude to the total open-water emissions from non-inventoried small lakes, before correcting for double-counting.

Thornton et al. (2016) introduce Arctic double-counting as a scale mismatch problem due to non-inventoried lakes being conflated with coarsely gridded wetlands. We find that most double-counted area comes from small inventoried lakes (0.1-10 km^2), due to their abundance and potential for extensive littoral zones. The double-counting problem can be solved by defining lakes in such a way as to completely avoid littoral wetlands (Bastviken et al., 2023) or by using the same lake inventory both for bottom-up lake estimates and for subtracting from wetland maps. Clearly, HydroLAKES is insufficient as an open-water lake dataset and needs further corrections, such as demonstrated here, for mutually-exclusive comparison to wetland emissions.

In this study, we assess the most impactful variable on methane estimates is the area of small lakes (+30%), followed by double-counting (-20% of emissions) and lake aquatic vegetation (+14%), which partially offset each other. Importantly, our finding of just 2.6% emissions from very small ponds is far lower than previous global estimates (37 - 41%). High resolution remote sensing of small lakes is thus preferable to statistical extrapolation, which overestimates small lake abundance and consequently total methane emissions. Upscaling uncertainty should be especially reduced when lake inventories to 0.001 km^2 become globally available (e.g. only ~0.5% of area and ~2.6% of emissions missed), and focusing on finer resolutions would yield diminishing returns. Due to their small total surface area, we submit that very small non-inventoried ponds <0.001 km^2 have received excessive interest relative to their CH_4 emissions at the pan-Arctic scale.





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SCANDINAVIAN AND URAL BLOCKING PATTERNS MODULATE INTENSE RAIN EVENTS IN SVALBARD

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The Arctic is witnessing a significant acceleration in temperatures, far outpacing the global average, with certain areas experiencing even more pronounced shifts. Among these regions, the Svalbard archipelago, positioned between Norway and the North Pole, stands as a prominent example of the rapid climatic transformations unfolding in the Arctic. Over the last century, Svalbard has encountered a troubling surge in temperatures, with an alarming rise of approximately 4°C. Particularly concerning is the intensified warming trend observed since 1991, which exceeds the already elevated Arctic temperature average by more than twofold.

In a warming Arctic, precipitation patterns are shifting, with rain becoming increasingly common. Svalbard thus serves as an ideal natural laboratory to study drivers of long-term hydroclimate variability, shedding light on the impending changes that can be expected across in the wider Arctic region. Here, we reveal a connection between wet and warm extremes in Svalbard over the past two millennia and the presence of atmospheric blocking regimes over Scandinavia and the Ural Mountains. Our analysis, focusing on Linnévatnet, a lake in southwest Svalbard, demonstrates that rainfall episodes during atmospheric blocking events lead to the deposition of coarse sediment particles and elevated calcium levels (Fig. 1). The paleo temperature data extracted from tree-ring records in Northern Scandinavia effectively capture these summer blocking events. Through a comparative analysis between our dataset and the summer temperature records of Northern Scandinavia, we can validate the consistent link between blocking events and intense precipitation in Svalbard over the past 2,000 years. This is further corroborated by the transient simulation conducted with the MPI-ESM1-2-LR model for the past two millennia. Our paleo record indicates a millennial-scale decline in Svalbard precipitation until the mid-19th century, followed by unprecedented extreme events in recent years. With ongoing warming and sea ice retreat, future Svalbard floods are projected to intensify during episodes of Scandinavian and Ural blocking.

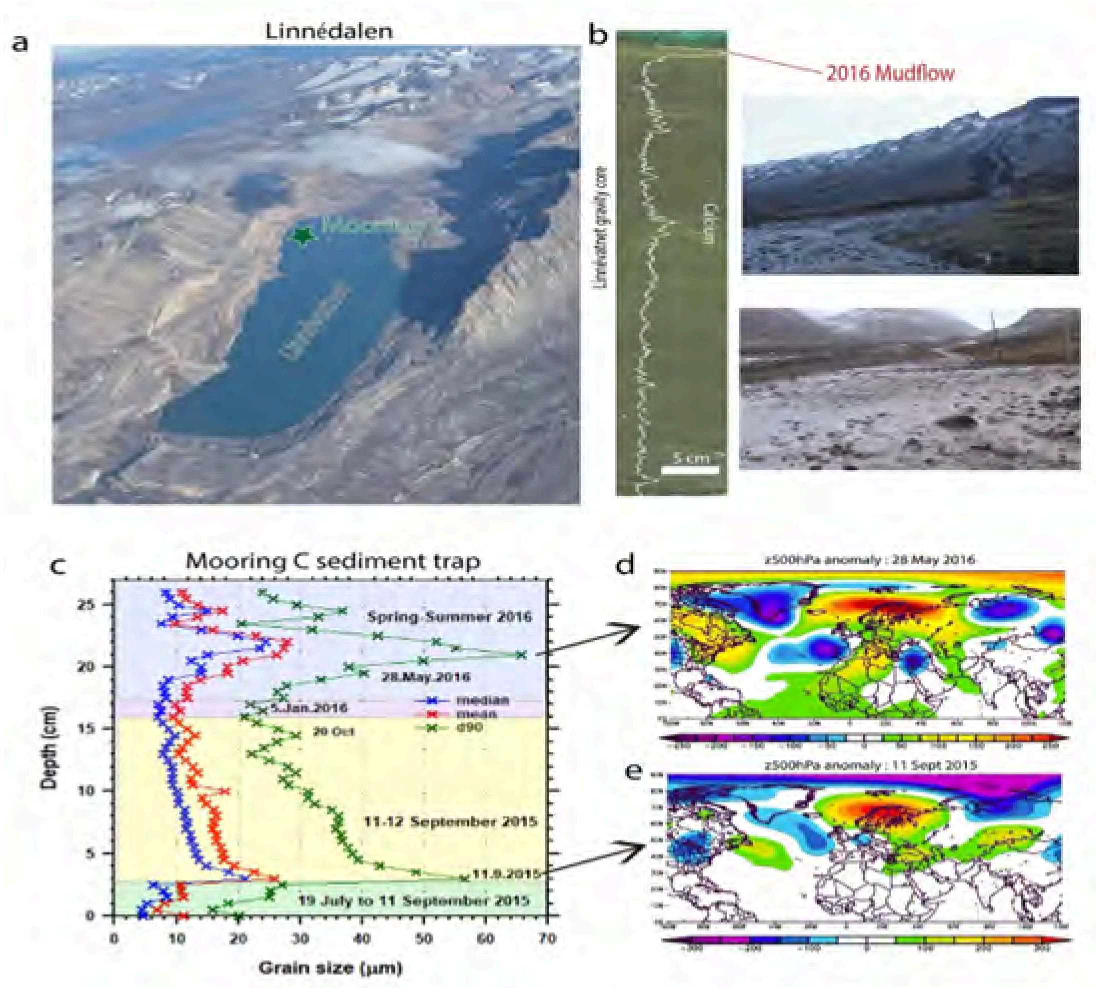

Figure 1. Linnévatnet's sediment traps reveal the influence of atmospheric blocking in regulating flooding events. a Air photo of Linnévatnet and location of intervalometer at mooring C (coring site). **b** Photograph of the gravity sediment core collected in 2019 showing the µ-XRF calcium variation throughout the first 41cm. The year 2016 is characterized by highest Ca values. The worst mudflow in 40 years occurred that year with roads being completely flooded in Longyearbyen (**c** and **d**). **e** Grain-size data collected from the sediment trap at mooring C in 2015–2016 showing two days with coarsest grain-size peaking on September 11, 2015 and May 28, 2016, respectively. The background colors are from bottom to top: Green = summer 2015, yellow = fall 2015, purple = winter 2015/2016 and blue = spring and summer 2016. The sample symbols Blue = median, d50, red = mean and green = d90. **f** and **g**, atmospheric pressure anomalies at 500 hPa Geopotential height (Z500) (relative to 1980–2010 climatology) during those two days with floodings.

TIMING AND PATTERNS OF ICE SHEET RECESSION AND THINNING ACROSS NORTHERN ICELAND DURING THE LAST DEGLACIATION

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A more complete understanding of Icelandic Ice Sheet behavior during past interglacial periods provides valuable long-term context for instrumental records of recent glacier and climate changes in the high latitudes that document accelerating ice retreat in response to rising temperature. Moreover, numerical modeling of ice sheet geometry and behavior requires reliable and detailed geochronologic data on ice configurations (Patton et al., 2017). Although the history of late Pleistocene and early Holocene glacial events in Iceland has been established by many previous studies at key locations that are widely distributed around the country (e.g., Pétursson et al., 2015; Benediktsson et al., 2022), large gaps remain in the documented timing of ice sheet recession across northern Iceland, especially in the northeast.

In order to develop a more comprehensive chronology of ice retreat from northeastern coastal regions to the interior highlands, we collected a suite of samples from prominent moraines, perched erratics, and glacially scoured bedrock along a ~100-km transect from Vopnafjörður to Vatnajökull for cosmogenic ^{36}Cl surface exposure dating. New ages being developed from these samples are compiled with available age control on glacial features at key sites across northern Iceland that constrain the timing, style, and rate of ice-sheet thinning and margin retreat during the last deglaciation. Our data synthesis includes a network of unpublished ^{36}Cl ages on glacially scoured bedrock and erratics from the Húnaflói region which date ice margin retreat inland of the modern coastline (Houts, 2016), along with published ^{36}Cl ages of deglaciated bedrock and moraines in the Vestfirðir peninsula (Principato et al., 2006; Brynjólfsson et al., 2015). Further insight on the timing of ice recession is derived from previously published ^{3}He and ^{36}Cl exposure ages of tuya summits in the Mývatn area that are interpreted to date their emergence from the ice sheet as it thinned (Licciardi et al., 2007).

The moraine, erratic, bedrock, and tuya summit exposure ages collectively suggest a broad regional pattern of ice-sheet thinning and margin retreat across northern Iceland from ~12–10 ka. Ongoing and future work is aimed at combining additional ^{36}Cl exposure ages with the identification of independently dated tephra marker horizons inside ice-marginal features in northeastern Iceland, with preliminary data pointing to rapid terrestrial deglaciation of the Iceland Ice Sheet during the Early Holocene.

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SEDIMENT PROVENANCE INSIGHTS INTO LATE NEOGENE ICE SHEET BEHAVIOR IN THE ROSS SEA ANTARCTICA FROM IODP SITE U1522

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The greatest uncertainty in sea level rise predictions is the future of the Antarctica ice sheet, particularly the West Antarctic Ice Sheet (WAIS), and the study of past ice sheet dynamics is important for inferring ice sheet dynamics of the future. The history of Antarctic ice in the Ross Embayment comes from continental shelf-wide ice sheet overriding events. To constrain central Ross Sea ice sheet history since the late Miocene, we assessed the provenance of glacial sediments from IODP Expedition 374 Site U1522. IODP site U1522 is located on the central Ross Sea continental shelf and recovered late Miocene-Pleistocene glacial tills. It fills gaps in the sediment record at a prime location that captures ice derived from both East and West Antarctica and thereby informing ice sheet provenance through this period.

Multi-suite provenance analysis is of particular value to interpreting the ice sheet history of Antarctica because more confidence is offered with combined datasets. A total of 3,869 zircon U-Pb dates from sixteen different samples were interpreted alongside clast lithology data and neodymium isotope compositions. Three distinct provenance shifts occurred from the late Miocene to the Pleistocene, two of which coincide with Ross Sea Unconformities 2 and 3. Late Miocene samples have abundant Cretaceous zircons, epsilon Nd values of ~-7, and clasts diagnostic of a West Antarctic provenance. In the latest Miocene, there is an abrupt transition to samples with zircons of mostly Ross Orogeny age (c. 470-615 Ma) and epsilon neodymium values of ~-9, with dolerite clasts present. This signals a shift to East Antarctic derived ice. Above Ross Sea Unconformity 3, early to mid-Pliocene samples show a shift back to West Antarctic provenance. Permian-Triassic zircon U-Pb ages are particularly abundant and epsilon Nd values reach ~-5, potentially suggesting significant retreat of the ice sheet margin towards the West Antarctic interior. Above Ross Sea Unconformity 2, Late Pliocene to Pleistocene samples likely reflect mixed East/West Antarctic provenance. Additional efforts are underway to refine the age-depth model and interpret seismic data and sediment lithofacies associated with provenance shifts so we can increase confidence in environmental interpretations of ice margin waxing and waning.

EVALUATING PLANT WAXES AS TRACERS FOR RECONSTRUCTING MID-LATE HOLOCENE VEGETATION CHANGE IN A SOUTHERN BAFFIN ISLAND LAKE CATCHMENT

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Anthropogenic climate change is causing the northward expansion of shrubs in the Arctic, which may serve as an additional positive feedback that accelerates regional warming. Documenting this “shrubification” process in the past can help us understand the time scales and mechanisms of plant-climate feedbacks in the Arctic today. Plant wax carbon chain-lengths and their stable carbon isotopes ($\delta^{13}C$) preserved in lake sediments have been shown to be effective tools for such reconstructions, however, their application to Arctic studies is limited. To address this knowledge gap, we use plant wax data and a Bayesian mixing model, MixSIAR, to reconstruct vegetation and biomass change at Lake Qaupat (QPT), Baffin Island, Nunavut, Canada over the past 5,800 years. In this model framework, plant wax data, including *n*-alkanoic acid (C_{20}-C_{32}) and *n*-alkane (C_{21}-C_{33}) chain-length concentrations, as well as *n*-alkanoic acid $\delta^{13}C$, produced for this study from downcore Lake QPT sediment intervals (n = 17) were treated as mixtures of Eastern Canadian Arctic (Baffin Island and Nunavik) plant wax data from modern vegetation endmembers. Vegetation endmembers were defined using two different methods: 1) grouping by broad plant growth forms and habitats (terrestrial vascular plants, terrestrial bryophytes, and aquatic plants), and 2) grouping via agglomerative hierarchical cluster analysis using our three plant wax data types.

Cluster analysis created groupings with a mix of plant types from grouping method one, suggesting that singular Eastern Canadian Arctic plant wax data types do not sufficiently fingerprint different plant types. To improve the uniqueness of each endmember, we ran MixSIAR using chain-length concentration-dependent *n*-alkanoic acid $\delta^{13}C$, effectively combining two plant wax data types. Our MixSIAR results showed that Lake QPT waxes over the past 5,800 yrs were primarily sourced (78%) from terrestrial vascular plants (shrubs and graminoids). Mid-chain *n*-alkanoic acids, C_{22} and C_{24}, had more aquatic plant contribution (21%) than long-chain *n*-alkanoic acids, C_{26} and C_{28} (10%). However, these results may be at odds with the published *n*-alkanoic acid $\delta^{2}H$ record from Lake QPT, which suggests a greater separation in vegetation/moisture sources between the mid- and long-chain *n*-alkanoic acids. We also split the terrestrial vascular plant endmember into graminoids and shrubs to better reconstruct shrub biomass change at Lake QPT. We find that shrubs are the dominant source (60%) of plant waxes throughout our record, with their contribution being the greatest from 5.8-4.7 ka and 1.2 ka to present. Our preliminary results provide an important framework for using plant waxes to reconstruct past Arctic vegetation change and its relationship to climate.

VULNERABILITY AND ADAPTATION ON THE ICECAP'S EDGE: FARMING COMMUNITIES IN SUBARCTIC SOUTH GREENLAND

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Climate shifts are dramatically altering the landscapes and livelihoods of peoples of the northern high latitudes. Such escalating trends have numerous and distinctive consequences at the local and regional scale and the ability to adapt to such rapid changes will challenge cultural, social, and economic systems across Arctic regions. This study provides an in-depth qualitative analysis of sheep farming communities in subarctic South Greenland adapting to such changes. Our study includes local voices and helps document climate-related and other challenges to remote subarctic regions. We interviewed four farming households and two additional key informants with local knowledge to understand the broader context, the challenges and vulnerabilities, and the persistence of agriculture in this high north region.

Our analysis reveals four overarching themes influencing the sustainability of sheep farming: (1) multi-generational farming heritage, (2) reciprocity and community support, (3) shifting climate influences and farming livelihoods, and (4) farm operations and new opportunities. Findings from this study fill a gap in the literature on local and regional impacts of climate change in remote regions. Through the inclusion of local Inuit and other voices, we document how geographically dispersed subarctic communities living under harsh climatic conditions are adapting to broader climo-socio-economic shifts.

WHAT ISSUES FACE THE UNITED STATES GOVERNMENT IN THE ATLANTIC HIGH NORTH?

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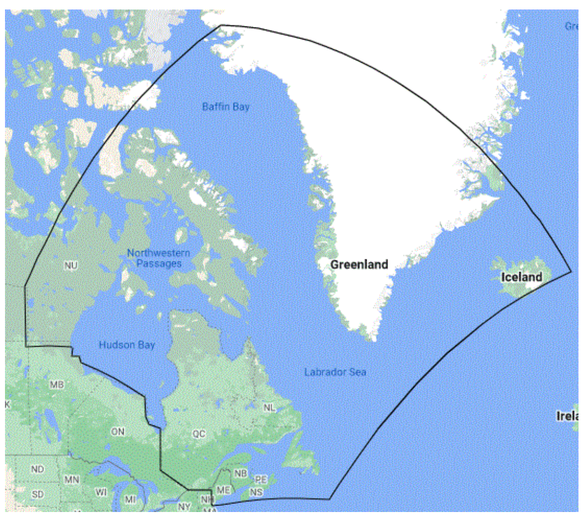
The United States' Arctic strategy centers on Alaska. This focus is understandable because Alaska has significant energy infrastructure, economic activity, military importance, cultural concerns, geographical relevance and political influence. The United States is an Arctic nation because of Alaska but, the United States is not an Arctic nation simply due to Alaska.

There is significant activity in the US' eastern Arctic exposure that must be addressed by the United States Government (USG). The "Atlantic High North" is a vibrant area that has significant energy, economic, scientific, political and cultural activity. The region starts in Portland, Maine extends eastward across the North Atlantic ocean to Iceland turns northward to include Greenland and extending westward to the eastern half of Canadian Territory of Nunavut, south to Ottawa, crosses eastward to Montreal, including all of Quebec and returns to Portland, Maine, USA.



"Atlantic High North"

The area is rich in rare earth minerals, has significant shipping lanes, fishing fields, is culturally diverse, geopolitically complex and is experiencing upheaval due to Climate Change. The USG's Arctic Strategy pursues an end state of "an Arctic region that is peaceful, stable, prosperous, and cooperative." The strategy outlines four "pillars" to advance US interests: Security, Climate Change and Environmental Protection, Sustainable Economic Development, and International Cooperation and Governance

(The White House, National Strategy for the Arctic Region, October 2022, Washington D.C.). This strategy is Alaska focused and overlooks issues associated with the Atlantic High North.

In order for the US to achieve its desired end state, the entire Arctic region must be addressed, not just Alaska. Issues exist in the AHN that could prevent the USG from achieving its goal of a peaceful, stable, prosperous and cooperative region. There are capability gaps that hinder the US ability to deter threats, build resilience to the effects of climate change, pursue sustainable development, and uphold international law in the AHN. The USG may not have the ability to respond to environmental catastrophe, conduct search and rescue missions and deter potential adversarial/competitor action in the region. This research investigates what issues the USG faces in the Atlantic High North in a comprehensive, methodical way to inform decision makers who are responsible for writing and influencing Arctic policy and strategy.

1. Security. The West "trails Russia in military presence in the Arctic region" (Vijdan Mohammad Kawoosa,"Dark Arctic" Reuters, November 16, 2022). The majority of Russian naval, air and ground forces are based near the Atlantic High North. The three strategic objectives outlined in the US strategy address Arctic situational awareness, presence, and allied and partner unity of effort. Much of which will occur in the Atlantic High North.

The Russian submarine threat is greater in the European Arctic because of Russian subsurface activity off of the Kola Peninsula and there is also a marked increase in Russian military activity near NATO members in the region. The "GIUK" Gap (Greenland, Iceland and the United Kingdom) is an avenue of approach through the North Atlantic Ocean from the Russian fleet headquartered in Murmansk. All surface and subsurface activity from Russia's Northern Fleet Joint Strategic Command travels these routes to access the rest of the world.

Following the end of the Cold War, the United States decommissioned much of its ability to find and track Russian subsurface activity when the US closed its bases in Iceland and Winter Harbor and Brunswick, Maine. This capability shortcoming is an issue that the USG faces in the Atlantic High North.

2. Climate Change & Environmental Protection. Climate Change is driving complexity in the Atlantic High North. Warmer temperatures have affected summer ice accumulation resulting in more accessible water ways, extraction of potential hydrocarbon and critical minerals and new human involvement. An understanding of the science behind the change is necessary for articulating the urgency towards accelerated Arctic interest.

The Arctic Ocean is the smallest and shallowest of the world's major oceans. It is bordered by eight arctic nations who all use it for commercial and military purposes. It is a global maritime crossroads and countries other than the eight Arctic nations (i.e., China) share its waters. The ocean is governed by international law and accepted practice. Understanding the United Nations Convention on the Law of the Sea (UNCLOS) its usages and interpretations is critical to defining the Arctic maritime nations' roles and responsibilities.

The region is home to a diverse population of First Nations who are being affected by Climate Change. The US strategy calls for working with all partners and allies to build resilience and reduce emissions from a "broader global mitigation effort." As climate change occurs and Western governments respond with new policies, the native populations of the AHN are affected. Addressing only the state of Alaska's concerns is but a small part of this complex problem.

3. Sustainable Economic Development. Sustainable economic development is crucial to the Atlantic High North and the success of the US Arctic Strategy. The United States Navy's Arctic Strategy states "Despite containing the world's smallest ocean, the Arctic Region has the potential to connect nearly 75% of the world's population." The Northern Sea Route and the Northwest Passage will open to increased shipping activity during the coming decades as summer ice becomes thinner. Both of these routes begin and end in the Atlantic High North. Increased shipping will require improved weather and ice prediction capability, search and rescue resources, environmental disaster response capability and enforcement of the Law of the Sea. While Alaska has a significant shipping industry, it is small in comparison to the activity in the North Atlantic Ocean. And that's only the maritime aspect! The area is rich in precious metals, iron ore and rare earth elements like Uranium (Greenland) and Lithium (Maine).

China, seeing the economic viability of the region, has set its sights on Arctic resources and convenient maritime conveyance. China has declared its self a "near Arctic" nation. The Chinese government is actively inserting its blue water navy, dual use academic research vessels, aircraft, and diplomatic effort into the AHN. The situation updates daily as this international competition plays out in the region.

4. International Cooperation and Governance. Arctic international cooperation and governance up until the Russian invasion of Ukraine, has been a model of state cooperation. Sometimes referred to as "Arctic Exceptionalism" the ability to meet, discuss and agree on issues related to the High North have been facilitated by the fact that the eight Arctic Nations were assumed to be governed by stable and responsible governments. During the 2021, Camden Conference ("Geopolitics of the Arctic; A Region in Peril) held in Camden, Maine, the Norwegian Institute of International Affairs and Gunn-Britt Retter of the Norwegian Saami Council state that the Arctic region is well governed and "boring." But, all of that has changed because of Russian actions in

Ukraine.

The Atlantic High North plays an important role in the international cooperation and governance of the region. Here are some bullets for consideration:

- 4 NATO allies – cooperate and "govern" in the AHN; Russia borders the AHN
- Multiple Indigenous populations inhabit the AHN
- Two US Combatant Commands are responsible for the AHN (i.e., Northern Command and European Command)
- Eastern termination of the Northern Sea Route & Northwest Passage occur in the AHN
- Portions of the disputed Arctic Sea Region occur in the AHN (United Nations Convention on the Law Of the Sea)
- Iceland (NATO member; no military) plays an important role in the governance & international cooperation in the AHN
- Half of the time the Arctic Council is chaired by an AHN country
- Senator King (I- Maine) is co-chair of the US Senate's Arctic Caucus

Without considering the issues the USG faces in the Atlantic High North, the US Arctic Strategy is in jeopardy. The strategy's lines of effort are clear "ways" of achieving its desired end state of "an Arctic region that is peaceful, stable, prosperous, and cooperative." However, by focusing the "ways" towards the Alaskan Arctic, significant security, environmental, economic and governance issues are missed. Resources, research, and attention focus on only part of this complex problem thus creating bigger issues than were initially conceived.

On April 5, 2023, Jim Garamone of the Department of Defense News reported that the new office of the Deputy Assistant Secretary of Defense for Arctic strategy and global resilience will begin working on a new DOD Arctic Strategy based on President Biden's 2022 Arctic Strategy. The issues the USG faces in the Atlantic High North must be considered in this new and important document.

QUANTIFYING THE UNCERTAINTY IN THE FUTURE CONTRIBUTION OF THE ANTARCTIC ICE SHEET TO SEA LEVEL RISE FROM BED TOPOGRAPHY

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Despite more than a decade of rapid improvements in ice sheet modeling, deep uncertainties in future projections remain. One major source of uncertainty is the bed topography beneath the Antarctic Ice Sheet (AIS). Bed Topography, for example, controls the stability and pattern of retreat of grounding lines. Marine Ice Sheet Instability (MISI) has the potential to trigger rapid retreats of the West Antarc- tic ice sheet which could overall lead to an increase in Sea Level Rise (SLR). MISI is directly controlled by the topography and can influence this instability. On the other hand, topography can create pinning points that can stabilize the ice sheet or slow down its retreat. The topography that ice sheet models are parameterized by are compiled from radar missions by airplanes. This then leads to sparse measurements in between each flight track creating a gap of data and overall, increasing the uncertainty of topography measurements. In order to quantify the uncertainty in future sea level rise projections due to the un- certainty of bed topography, we generated 368 different bed topographies by using the Discrete Wavelet Transform (DWT). Preliminary results from Thwaites Glacier show that by the end of 2300 that there was an average sea level equivalent (SLE) of 27.8 mm compared to the standard of BedMachine which would produce 29.7 mm of SLE.

TESTING THE STRENGTH OF THE PERMAFROST CARBON FEEDBACK DURING THE LAST DEGLACIATION

Sam **Mark**

Permafrost soils currently hold about twice as much carbon as Earth's atmosphere. Anthropogenic warming puts this carbon at risk by releasing CO_2 and CH_4, further accelerating warming. This hypothesized process represents the potentially disastrous Permafrost Carbon Feedback (PCF). The transition of Earth's climate from the Last Glacial Maximum (LGM: 26 to 19 ka) into the Holocene (11.7 to present) affords us a valuable natural experiment that can help explain how carbon stored in permafrost responded to past periods of rapid warming. Episodes of permafrost degradation are recorded in several geological archives. These include the basal ages of thermokarst lakes, speleological deposits whose accretion indicates overlying unfrozen ground, geomorphic and stratigraphic indicators of degrading ground ice, and biogeochemical records of active layer thickening and export of pre-aged carbon. Here we synthesize more than 600 such records of permafrost degradation during the late Pleistocene and early Holocene to test whether the timing of widespread permafrost thaw was temporally associated with changing atmospheric concentrations of CO_2 and CH_4 between 21-7 ka. We also use transient climate model simulations to estimate the amount of permafrost carbon put at risk of remineralization by both warming and rising sea levels during this same interval. Results provide little direct evidence of permafrost thaw prior to the Bølling-Allerød warm period (14.7-12.9 ka), and suggest that most permafrost thaw occurred several thousand years after the major increases in greenhouse gases (Fig. 1). The observed record of permafrost thaw bears striking similarity to records of Northern Hemisphere peatland establishment and enhanced boreal forest productivity (Fig. 1), suggesting that an increase in the size of the Northern Hemisphere terrestrial carbon reservoir as the Laurentide, Cordilleran, and Fennoscandian Ice Sheets retreated may have acted as an important brake on permafrost-derived carbon emissions.

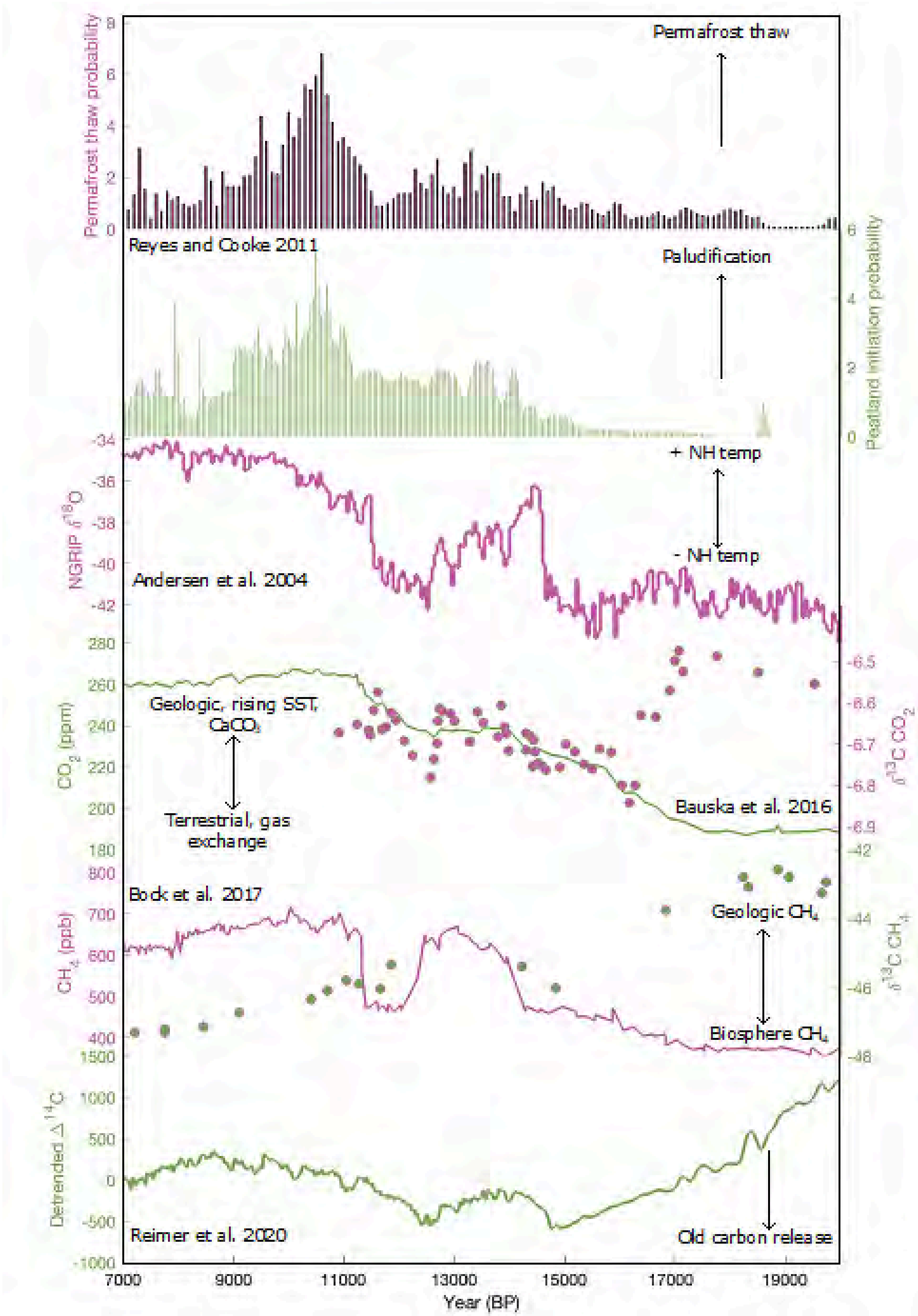

Fig. 1: (From top) Aggregated record of permafrost degradation cumulative probability (this study), circum-Arctic peatland establishment cumulative probability (Reyes and Cooke 2011), NGRIP $\delta^{18}O$ record (Andersen et al. 2004), Taylor Glacier, Antarctica atmospheric CO_2 concentrations and $\delta^{13}C$-CO_2 record (Bauska et al. 2016), Talos Dome, Antarctica atmospheric CH_4 and $\delta^{13}C$-CH_4 record (Bock et al. 2017), and detrended northern hemisphere atmospheric $\Delta^{14}C$ record (Intcal20, Reimer et al. 2020).

GLACIAL EROSION VS. PROTECTION IN COASTAL NORWAY: NEW ^{10}Be DATA

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Ice sheets greatly alter landscapes, particularly where ice flow is focused, creating deep fjords. Fjords serve as excellent examples of erosive processes occurring at the ice-bedrock interface. In contrast, there are cases where an ice sheet can leave behind little evidence of their overriding, and instead protect the landscape underneath. Our work focuses on addressing a small portion of the classical problem of erosive versus non-erosive landscapes in Norway.

We use Beryllium-10 inheritance as a key metric in identifying previous areas of non-erosive ice, which are potential patches of cold-based glaciation. We measured Beryllium-10 in 11 bedrock samples collected in 2 subregions in coastal Norway, documenting areas of inefficient glacial erosion.

Results show that despite the deglaciation of Ulriken during the Younger Dryas at ~11.5 ka, three apparent ^{10}Be ages are ~17 ka at the summit (626 m asl). On the coastal mountain of Bremanger, our main research site, we have results from 8 samples spanning from near sea level to 686 m asl. Our two low-elevation samples are 17 ka, composed of heavily ice sculpted and polished bedrock. Our mid-elevation samples are around 40 ka, being somewhat glacially sculpted. The highest-elevation samples range from 65 to 110 ka with no evidence of glacial modification, only heavy surface weathering.

Elucidating patterns of erosive and non-erosive glacial processes in coastal Norway is essential to gain a better understanding of ice sheet and climate dynamics. Additionally, finding areas of cold-based ice cover could open the door for new lake-sediment records of pre-LGM sediments, such as those dating to the Last Interglacial (~130-115 ka; Miller et al. (2022))

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TESTING THE SCHMIDT HAMMER DATING TECHNIQUE ON GLACIAL LANDFORMS IN ICELAND

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While the glacial history of Iceland is well-studied, critical gaps in the reconstruction of ice flow throughout the Quaternary remain. We aim to elucidate the glacial history of part of Iceland using the Schmidt Hammer (SH) dating method, which uses surface hardness (given as an r-value) as a proxy for age. The SH operates on the assumption that surface hardness has an inverse linear relationship to exposure age (lower r-value = older age) (Matthews and Winkler, 2022). We concurrently assess the efficacy of the SH as a relative and numerical dating tool. We used the SH at five locations across Iceland: two bedrock sites with erratics (Borgarvirki and Vopnafjorður) and three morainal deposits (Skessugarður, Fiskidalsháls, and Fláajökull). Previous studies suggest that these sites range in age from Younger Dryas to Little Ice Age (LIA). Significant differences in the median r-values between Borgarvirki (r = 48.5) and the Skessugarður (r = 52.5) and Fiskidalsháls (r = 55.5) moraines show the expected chronology, with sites closer to the modern ice margin producing higher r-values. The Vopnafjorður median r-value (r = 51.5) was not significantly different from the other northern sites, potentially indicating rapid ice retreat north of Vatnajökull, consistent with paleo-ice streams mapped in this region (Benediktsson et al., 2022). We measured r-values on two moraines on the Fláajökull morainal complex south of Vatnajökull. The significant difference in the median r-values of the outermost (1880-1890 A.D.) moraine (r = 65.3) and an inner (1945 A.D.) moraine (r = 70) matches the known relative age order (Evans, 2016). These r-values are significantly higher than northern Iceland sites, demonstrating that the SH provides reliable relative ages for moraines. An r-value-age calibration curve for northern Iceland was constructed using cosmogenic ^{36}Cl dates from Skessugarður (10.8±0.2 ka) and Fiskidalsháls (10.2±0.5 ka) and this curve was used to estimate SH ages for Borgarvirki (11.6±0.7 ka) and Vopnafjorður (11.0±0.5 ka). These r-value-calibrated ages do not agree with the proposed Younger Dryas extents in these regions (Figure 1; Benediktsson et al., 2023). Previous ^{36}Cl dating of the Borgarvirki sites used in this study yielded an age of 8.7±0.5 ka, disagreeing with both the relative and numerical age given by the SH (Houts, 2016). Further numerical dating in Borgarvirki and Vopnafjorður is necessary to better constrain the deglaciation of these regions and provide more control points for numerical r-value-age calibration, however the SH does provide relative ages of retreat of the Iceland Ice Sheet largely consistent with existing literature, presenting a low-cost method for dating landforms in Iceland.

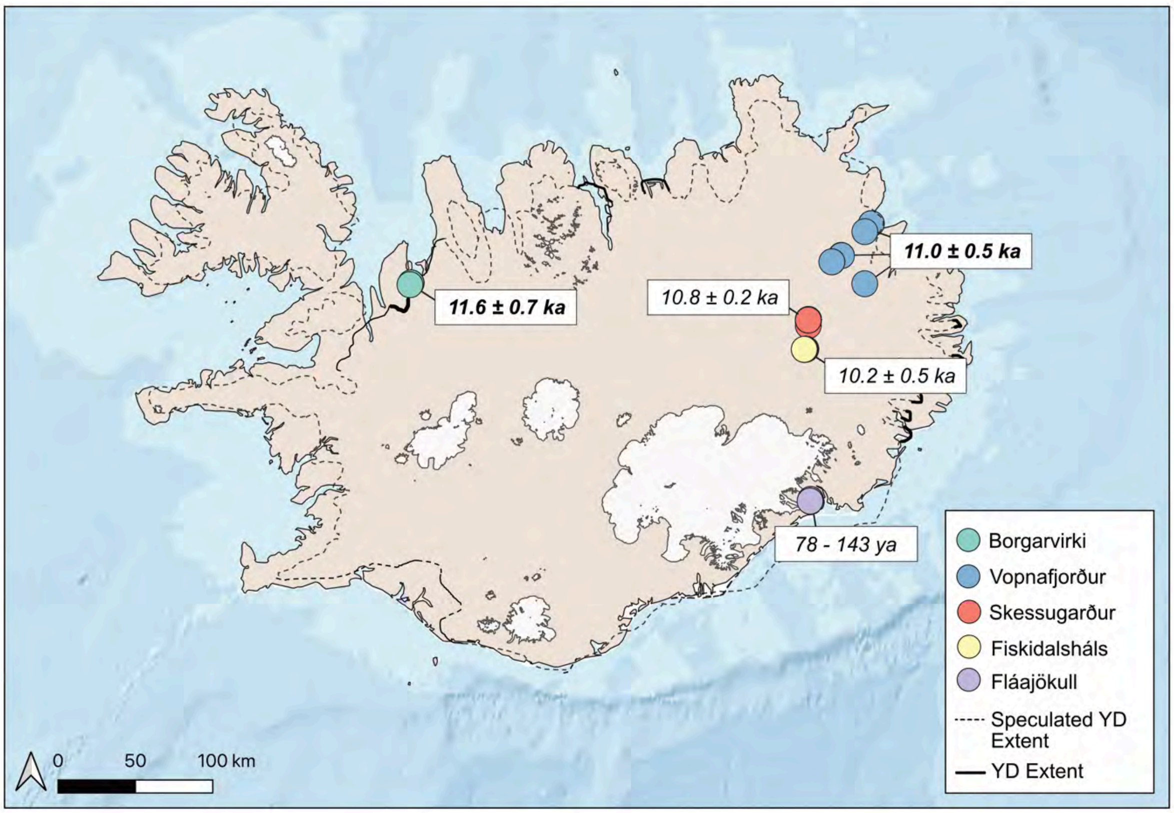

Figure 1. Map of study sites. R-value calibrated ages (bold) were calibrated using ^{36}Cl ages of Skessugarður and Fiskidalsháls. Fláajökull inner (1945 A.D.) and outer (1880-1890 A.D.) moraine ages are from aerial imagery (Evans, 2016). Younger Dryas extent adapted from Benediktsson et al. (2023).

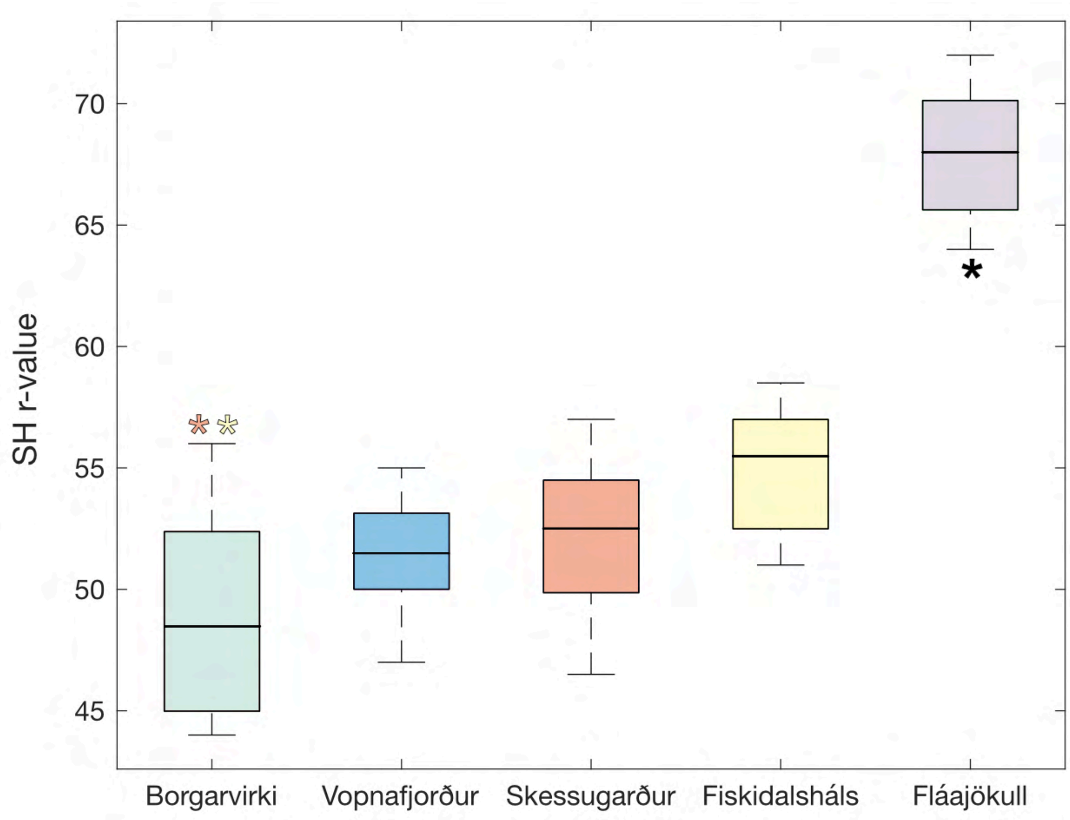

Figure 2. Distribution of r-values across sites. Asterisks indicate significance at α = 0.05. Borgarvirki r-values are significantly lower than Skessugarður and Fiskidalsháls (indicated by asterisk color). Fláajökull r-values are significantly higher than all other sites.

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APPLYING CALIBRATION DATA TO HIGH LATITUDE SEDIMENTARY PLANT WAX HYDROGEN ISOTOPE VALUES TO RECONSTRUCT WATER ISOTOPE VALUES THROUGH TIME

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The hydrogen isotopic composition of plant wax demonstrate a robust and widely documented relationship to the isotopic composition of local meteoric water at global scales. This relationship provides the basis for estimating past precipitation isotopes through time in an increasingly quantitative manner(Sachse et al., 2012; McFarlin et al., 2019). Applications of plant wax isotope data range from reconstructing the isotopic composition of annual precipitation to inferring changes in relative humidity (Rach et al., 2017), elevation (Feakins et al., 2018), precipitation seasonality (Thomas et al., 2020), and even lake redox conditions (McFarlin et al., 2023). These innovative and interesting uses of plant wax H isotope data are pushing forward understanding of hydroclimate and environmental dynamics with past warming. However, there are not clear, common approaches to the treatment of plant wax isotope data across published literature. Here, we discuss how using calibration data to place plant wax H isotope values into absolute water isotope value space provides important context for hydroclimate interpretations. We also explore how different assumptions made in applying calibration data, or foregoing estimating water values from wax values entirely in favor of relative trends, can affect interpretation of that data in some published and some unpublished high-latitude Holocene records from Greenland. O isotope values, which provide an independent estimate of lake water isotope values, are used comparatively to plant wax H isotope values through time where available to further evaluate the changes in hydroclimate drawn from plant wax H isotope data. Overall, we'll review examples where calibration data clearly informs past changes in paleoclimate and other examples where the interpretation is more nuanced but nevertheless impacted by what assumptions are made in treatment of the plant wax H isotope data.

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CENTERING INDIGENOUS PERSPECTIVES IN SUSTAINABLE ARCTIC TOURISM

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Launched by the U.S. Department of State in 2020, the Arctic Education Alliance (AEA) is a collaboration between Greenlandic and American education institutions to build education capacity in Greenland for land and fisheries management, sustainable tourism, and hospitality. After two years of knowledge exchanges, Greenlandic partners requested a collaboration with US higher education institutions in preparing for an anticipated influx of North American tourists following the completion of new international airports.

The University of Southern Maine (USM) and partners from Wabanaki Public Health and Wellness, an organization that serves federally recognized tribes in Maine, USA, created a new curriculum with Campus Kujalleq, a tourism college in Greenland. Thirty students and faculty facilitated sustainable tourism assessments in South Greenland communities, including UNESCO World Heritage sites. The cross-cultural team grounded this initiative with community-led participatory research to create recommendations for future tourism development, while emphasizing the co-production of knowledge with the Greenlandic Inuit to center Indigenous voices. Greenlandic students will continue their educational collaboration at USM during summer 2024.

With Indigenous knowledges, experiences, and perspectives, this work emphasizes the potential for success of an indigenous-led approach in education and sustainable development. Results of the project inform education, tourism, research, and sustainability frameworks; identifying opportunities for co-management of cultural sites with Indigenous partners; promoting self-determination; and embracing a shifting cultural narrative that emphasizes diverse worldviews. Overall, this initiative has contributed to ongoing recognition of the importance of creating space for Indigenous voices in education systems and international collaborations.

CLIMATE RESPONSE OF ADJACENT MARINE-TERMINATING GLACIERS IN SERMILIK FJORD, SOUTHEAST GREENLAND

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Mass losses from marine-terminating Greenland Ice Sheet outlet glaciers account for about half of the overall net mass loss from Greenland. Changes in marine-terminating glaciers in east and southeast Greenland in the past two decades have been reported to be rapid and synchronous in response to climate forcing. However, the relative roles of climate forcing and internal glacio-dynamics are dependent on the temporal and geographic context. To address this issue, there is the need to constrain and explain long-term glacier-front variability of adjacent glaciers in a setting with similar climate forcing. An essential research question is the degree to which the covariability of advance/retreat behavior is synchronous, or rather asynchronous.

Here we perform a long-term (40^+ year) case study with high temporal resolution that examines multidecadal trends and decadal, interannual and seasonal co-variability of the three major marine-terminating in the Sermilik Fjord, southeast Greenland – Helheim, Fenris and Midgard glaciers. We use satellite remote-sensing data from multiple sensor systems (Landsat TM, ERS-1/2 SAR, Landsat ETM), together with long-term auxiliary data on meteorological, oceanographic and ice mélange (sikkussaq) conditions. Standard statistical and time-series analysis techniques are used to constain and characterize the variability and co-variability.

Results show a strong negative trend (retreat) from 1980–2022, though with large differences and similarities in both trends and variability. The largest net retreat is for Midgard glacier (~12 km), while Helheim and Fenris glaciers show a ~9 km retreat. These negative trends are clearly in line with the positive trends in surface air temperature (SAT). and ocean temperatures. In the 2000s, each glacier had a large, though asynchronous rapid retreat: Helheim (2002–05), Midgard (2008–12) and Fenris (2018–20). However, despite notable differences in the absolute magnitude and timing of changes, when using standardized anomalies to account for the intrinsic differences, a conceptual model emerges that supports the theory of a relatively simple climate response of Greenland marine-terminating glaciers.

THE LAST GASP OF THE LAURENTIDE ICE SHEET

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As the Laurentide Ice Sheet (LIS) receded under increasing Northern Hemisphere insolation at the end of the last glaciation, the ice sheet receded most slowly across the Eastern Canadian Arctic. As Northern Hemisphere summer insolation declined through the Holocene local glaciers began to reform by ~5ka (Neoglaciation), whereas the remnant LIS continued to recede toward its ancestral home on the central plateau of Baffin Island. Despite additional expansion of local glaciers after 5 ka as summer insolation continued to decline, the remnant LIS still receded, finally stabilizing as the Barnes Ice Cap (6000 km^2; 700 m thick) early in the Common Era. Field studies in the 1960s confirmed Barnes started to advance "recently", but lacked secure age control. Glaciological studies in the 1950s and early 1960s, confirmed the ice cap was then in quasi mass balance equilibrium. However, by the late 1960s, Barnes began to slowly lose mass at all elevations under contemporary greenhouse warming, and ice-recession began around all margins. Repeat airborne surveys in the early 2000s documented surface elevation lowering ~0.5 m a^{-1} at the highest elevations and ~2 m a^{-1} approaching the margins (Sneed et al., 2008; Webb et al., 2009). This led to lateral recession of ~10 m a^{-1} everywhere around the margin. In 2022, as part of an interdisciplinary project, we collected ice-entombed plants exposed at the contemporary ice margin and un-eroded dead plants between the ice margin and the veg-kill-zone that defines the LIA maximum ice position. Ice-killed plants were collected at 126 sites over a 140 km transect along the southern third of the ice cap, including a 750 m transect from the LIA trimline to the contemporary ice margin at the south end of the ice cap. We also sampled erratic boulders on moraine crests that cross the valley of paleo-Generator Lake to constrain deglaciation ages.

Radiocarbon ages were obtained on 46 *in situ* tundra plant samples killed by an advancing Barnes Ice Cap, and recently exposed as by ice-margin recession after 1960 CE. Most of the samples are of the common mosses *Polytrichum* sp. and *Andraea* sp., but also a woody stem of *Cassiope tetragona*. All samples date from the second millennium CE. The ages are youngest along the northern margin, consistent with modeling showing the Barnes Ice Cap is expected to slowly migrate to the NE (higher land) as it continues to lose mass (Gilbert et al., 2016). At the SE margin of the ice cap we collected 10 samples of dead moss along an 800 m profile from the LIA trimline to the contemporary ice margin, that range from 90 calibrated years BP near the LIA trim line, increasing in age to ~1000 CE at the ice edge, with over half the expansion occurring after 1450 CE, during the Little Ice Age. All nine of the moss samples from the northern margin are from 1750 CE or younger, confirming that Barnes Ice Cap reached its latest Holocene maximum extent late in the Common Era.

After receding from its LGM Maximum (21 ka) for 20,000 years, the Laurentide Ice Sheet finally stabilized as the Barnes Ice Cap and began to advance again about 1000 CE, with maximum dimensions reached in the late 1800s CE, in what was likely the start of the “Next Ice Age” in response to orbitally-forced declining summer insolation. From historical aerial photography the ice-margin remained at its LIA maximum until ~1960 CE, after which anthropogenic greenhouse-driven summer warming terminated the “Next Ice Age”, with mass loss at all elevations and recession along all margins of the Barnes Ice Cap. Ice-sheet modeling predicts complete disappearance of the Barnes Ice Cap in 150 to 500 years (Gilbert et al. 2017).

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MODELING CLIMATE SENSITIVITY OF BIOGEOCHEMISTRY AT TWO PONDS IN THE YUKON-KUSKOKWIM DELTA, AK

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In high-latitude tundra ecosystems, small ponds significantly influence hydrological and permafrost dynamics, serving as key nodes for biogeochemical activities. However, the extent of their contribution to the carbon balance, especially in the context of climate change, remains under-researched. We employed in-situ measurements to calibrate a numerical model, focusing on two distinct ponds in Alaska's Yukon-Kuskokwim Delta. These ponds differ in size, depth, and proximity to recent wildfires. We utilized the LAKE model, a one-dimensional tool adept at simulating thermodynamics, hydrodynamics, and biogeochemical processes, informed by meteorological data from nearby eddy covariance towers. Model evaluations, benchmarked against data from June to August 2022, revealed a high degree of accuracy, especially in predicting water temperatures. Our numerical simulation shows variations in dissolved CO_2 levels between the ponds, while CH_4 concentrations remained similar. We developed a sensitivity analysis tool to help refine our understanding of the biogeochemical parameters and their influence on CO_2 and CH_4 fluxes. Simulations under warming scenarios provided insights into the ponds' responses to climatic changes. The results of this modeling experiment will improve the understanding of the drivers and trajectory of biogeochemical cycling in disturbed and undisturbed high-latitude ponds. Future research will explore the relationship between pond methane concentrations and methylmercury, with implications for aquatic ecosystem health.

TARGETING CHANGES IN EROSION AND SEDIMENTATION RATES ACROSS ARCTIC PERIGLACIAL FAN UNDER A WARMING CLIMATE (NWT, CANADA)

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Anthropogenic warming in the Arctic accelerates changes in already dynamic periglacial landscapes, increasing permafrost degradation and upland erosion and transport from rock fall, soil creep, and landsliding, all of which are hazards to Arctic communities. This sediment ultimately moves into Arctic rivers and depositional settings, such as alluvial fans. Constraining the timing of alluvial fan deposition therefore has critical implications for modern warming, but also for understanding a region's long-term geomorphic response to climate change. In order to disentangle climatic signals from tectonic influences across an actively eroding catchment and fan system (the Black Mountain fan, Fig. 1A) in the Aklavik Range in the Northern Richardson Mountains (Northwest Territories, Canada), we apply a multi-chronometer approach to compare modern transport and deposition rates to long-term uplift and erosion rates. As the site was previously glaciated, a focus of our work is to distinguish between a response to modern warming and continued disequilibrium and post-glacial erosion following the retreat of the Laurentide Ice Sheet from the region during the late Pleistocene. Here, we present constraints on background erosion and uplift rates from apatite and zircon (U-Th)/He thermochronology (Fig. 1B) on four samples from a 1 km transect across the rock walls of our catchment. Our results suggest a regional background exhumation rate of between 0.05-0.07 mm/yr since 25 Ma (Fig 1C). Our continued thermochronologic and cosmogenic work will clarify whether we can expect this signal to increase or decrease with modern warming, as well as how much of present-day erosion and fan formation is a result of continued landscape response to the glacial history of the region.

In addition, we also plan to use a combination of radiocarbon (14C) dates of woody debris and Optically Stimulated Luminescence (OSL) dates of quartz grains from distributary channel and sheetflood deposits, we aim to calibrate the background sedimentation rate of the Black Mountain fan and probe its response to recent warming. We hypothesize that sediment fluxes have accelerated over the past ~100-1000 years due to elevated landslide activity, independent of local isostatic adjustments or long-term warming. Although this approach has been used to constrain depositional and fault slip processes on temperate fans, this would be its first application to periglacial systems, arguably one of Earth's most dynamic, fragile landscapes.

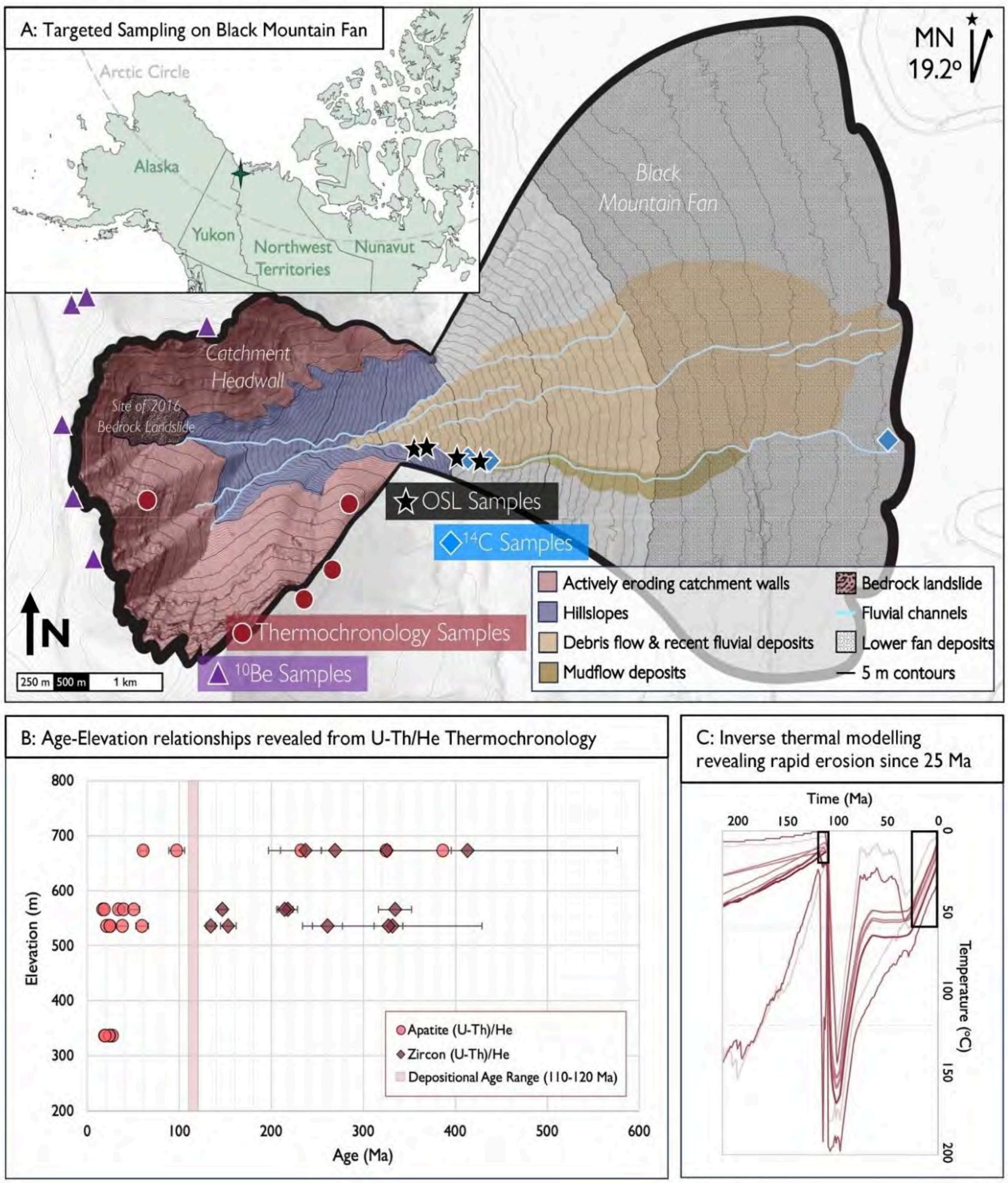

IMAGE-MAPPING GLACIAL FRONTS IN THE HIGH ARCTIC

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Katie O'Meara's aerial cartography captures high resolution imagery of the terrain deep within the arctic circle. Working from a sailing ship less than 500 miles from the North Pole, flying an UAV on repeated flight missions, O'Meara has assembled sequences of nadir images into detailed maps. O'Meara returns to Svalbard in August 2024 to continue work in this vein.

O'Meara spent June 2022 as a fellow on the Arctic Circle Residency Expedition exploring the changing relationship between land, sea and ice in the Svalbard archipelago. These assembled image-based maps are a part of the image and data mapping that O'Meara has been developing across a range of terrains and methods.

Katie O'Meara
June 11, 2022 Scheibukta 79°37'29.4495" N 11°9'42.7448" E
19.50x60" photograph on metal

Katie O'Meara
June 18, 2022 Holmiabukta 79°47'46.3849" N 11°35'32.747" E
48"x80" photograph on metal

IDENTIFYING ENVIRONMENTAL AND CLIMATIC DRIVERS OF VARIABILITY IN GDGT DISTRIBUTIONS SINCE 24 KA IN THE POLAR URAL MOUNTAINS, SIBERIA

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Accurate predictions of future climate scenarios require a comprehensive understanding of climate sensitivity, which is gained through reconstructions of past climate conditions. These reconstructions are especially important in regions like Siberia, where climate is currently undergoing rapid change (Rantanen et al. 2022). However, climate proxy records are often limited in high-latitude areas due in part to Quaternary (2.6 Ma to present) glaciation resulting in the destruction of terrestrial sedimentary records. Here, we aim to characterize environmental changes since 23.9 cal ka BP using a sediment core from Lake Bolschoye Schuchye in the Polar Ural Mountains. We analyzed two lipid biomarkers, branched (br-) and isoprenoidal (iso-) glycerol dialkyl glycerol tetraethers (GDGTs), which are thought to predominantly derive from bacteria and archaea, respectively.

The MBT'_{5Me} index of brGDGTs and Tex_{86} index of isoGDGTs from the Lake Bolschoye Schuchye sediment core display remarkably similar trends (Fig. 1), indicating that the lipid groups share a similar environmental driver. At the global scale, these indices show strong correlations with temperature; however, in Lake Bolschoye Schuchye, these indices suggest general cooling since ~ 23.9 cal ka BP (Fig. 1), which is inconsistent with expected warming following the termination of the Last Glacial Maximum at ~ 20.0 cal ka BP. As such, the GDGT records from Lake Bolschoye Schuchye likely capture non-climatic signals that may be driven by local environmental changes.

Previous environmental and climatic reconstructions from Lake Bolschoye Schuchye suggest that local alpine glaciers drove high sedimentation rates until ~ 18.7 cal ka BP. Sedimentation rates then slowed as alpine glaciers retreated until full ablation by ~ 14.4 cal ka BP. Concentrations of br- and isoGDGTs generally cohere with this glaciation history, displaying a pronounced increase after ~ 15 cal ka BP (Regnéll et al., 2019). Potential drivers of GDGT variation will be identified via comparisons of GDGT fractional abundances and indices against previously reported independent proxy records, which include ancient DNA records, pollen and chironomid assemblages, and $\delta^{18}O$ values measured from diatoms (Clarke et al., 2020; Meyer et al., 2022). This multiproxy approach will improve our understanding of key environmental drivers of lacustrine GDGT variability and better constrain the uncertainty associated with GDGT paleothermometry. Moreover, the 24 kyr temperature reconstruction will shed new light on polar climate sensitivity during intervals of rapid climatic change.

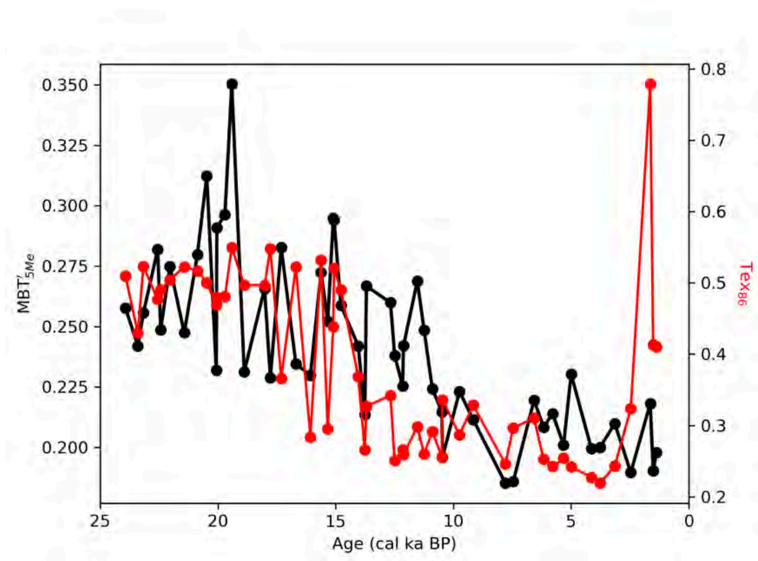

Fig. 1. MBT'_{5Me} (black) and Tex_{86} (red) index values from GDGTs in the Lake Bolschoye Schuchye sediment record.

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SPATIO-TEMPORAL VEGETATION PATTERNS ACROSS UNESCO WORLD HERITAGE SITE KUJATAA, GREENLAND, USING NASA MODIS DATA, 2000-2020

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Vegetation plays an important role in Earth's carbon balance and the expansion of vegetation from high latitude warming and the lengthening of the growing season has both regional and global implications. In this study, we focus on the UNESCO World Heritage site of Kujataa in Kujalleq municipality of South Greenland and use the Normalized Difference Vegetation Index (NDVI) from NASA's Moderate Resolution Imaging Spectrometer (MODIS) sensor to monitor two decades of shifts in the spatial patterns of vegetation coverage. A sheep farming landscape, Kujataa, has a long, though intermittent, history of agricultural communities thriving under challenging subarctic conditions on the very edge of the Greenlandic icecap. As shifts in climate once again impact temperature, precipitation and growing season length across subarctic communities, we examine how these play out across South Greenland. Our results suggest considerable inter annual and seasonal variability in vegetation patterns across the region.

Keywords: South Greenland, Kujataa UNESCO World Heritage, vegetation shifts, satellite imagery

ENGAGING COMMUNITIES: HARNESSING CITIZEN SCIENCE TO MONITOR NEW ENGLAND LAKE ICE THICKNESS IN A SHIFTING CLIMATE

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Lake ice cover is an important component of regional hydroclimate systems, plays a critical role in physical, biogeochemical, and ecological processes of the lake, and impacts human activities on lakes (Sharma et al., 2020). Lake ice cover also responds strongly to climate change, as evidenced by later ice-on and earlier ice-off dates, as well as more erratic ice cover across New England under the warming and shifting of winter temperature and precipitation patterns (Hodgkins, 2013; Beyene and Jain, 2015).

Despite is importance, ice cover and thickness are notoriously difficult to observe, especially over wider regions (Sharma et al., 2020). Citizen science initiatives have emerged as a powerful tool for collecting lake ice phenology data and have been successfully deployed in place such as Maine and New Hampshire where residents have been involving the recoding of ice-on and ice out dates (Magnuson et al., 2000; Sharma et al., 2016). However, changes in ice thickness on New England lakes and its impact on the hydrologic, physical, and biologic character of those lakes remains less studied, partly due to the difficulty in obtaining sufficient observational data. Here we report on the pilot phase of a citizen science-driven project focused on the collection of ice thickness observations from New England lakes, including implementation and outcomes.

The project is centered around a simple to use online survey, designed to be utilized on volunteers' mobile devices that steps them through the measurement and recording process. To leverage community engagement, multiple methods of distribution and promotion of the project have been employed to assess how best to engage citizen scientists. Through collaboration with local organizations and educational institutions, this initiative not only enhances scientific understanding but also fosters environmental stewardship and resilience within communities. We will highlight the challenges, and lessons learned from this citizen science endeavor thus far, emphasizing its potential for addressing critical climate-related research questions and empowering individuals to become active participants in scientific inquiry and environmental monitoring.

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PALEOECOLOGICAL RECORDS FROM THREE LAKES IN *INUTOQQAT NUNAAT*, NORTHERN GREENLAND

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The Wandel Dal Project seeks to understand interactions among arctic system components (climate, people, ecosystems, sea-ice and glacier extent) in *Inutoqqat Nunaat* (the Land of the Ancient People), north of the Greenland Ice Sheet, where people lived for prolonged periods during the past ~4500 years. Using sediments recovered from a suite of lakes in the region, we are in the process of producing multi-proxy high resolution, quantitative records of climate and vegetation over the past ~8000 years. Here we present diatom records from three lakes, "Lake Southwest" (~1400 cal yr BP), Nedre Midsommersø (~8000 cal yr BP), and "Late Sommersø" (~7500 cal yr BP), which record shifts in aquatic ecosystems in response to climate and ice cover over these periods. With additional proxies, we explore the extent to which periods of settlement and times of abandonment were related to climatic/environmental fluctuations and how these compare with warming in Northern Greenland over the last several decades.

HYDRO-GEOMORPHOLOGICAL DYNAMICS IN ALASKAN ICE WEDGE POLYGONS: A DEEP LEARNING APPROACH

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Conventional methods for mapping and analyzing trough networks in Alaskan ice wedge polygons present significant challenges, typically necessitating intensive fieldwork and manual interpretation of satellite imagery. This study proposes a deep learning-based approach to automate and refine the detection and segmentation of these trough networks using high- resolution satellite imagery. Our novel method integrates the YOLO (You Only Look Once) algorithm with the Spatial Attention Module (SAM) for initial feature identification and enhanced spatial focus. The YOLO-SAM combination, potentially effective in areas requiring focused spatial analysis, shows promise for enhancing hydro-geomorphological studies and our understanding of Arctic environments. This innovative approach is anticipated to facilitate the automated detection and delineation of trough networks across diverse environmental conditions, aiming to achieve both accurate and precise results. Beyond detection and segmentation, this research aspires to conduct a speculative analysis of the morphological characteristics of trough networks. This aspect of the study is expected to yield new insights into the adaptability and evolution of these networks in response to shifting climatic conditions. Our ongoing research is set to enhance the understanding of landscape formation and change in Arctic and tundra environments, showcasing the capabilities of deep learning in advancing geomorphological investigations. By establishing a novel standard in methodological approaches for cold region landscapes, this study aims to provide scalable and adaptable solutions for similar geomorphological challenges on a global scale.

EXPLORING DEGLACIATION IN NORTHWEST GREENLAND USING RELATIVE SEA LEVEL CURVES AND COSMOGENIC NUCLIDE DATING

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We report a new relative sea level curve and cosmogenic nuclide surface exposure dating results from northwestern Greenland. Rensselaer Valley (78.58, -70.71), on the northern coast of Inglefield Land, contains a flight of raised marine deltas. We sampled *in-situ* marine bivalves and terrestrial plant macrofossils from delta sediments at a variety of elevations to constrain relative sea level fall through the Holocene. Our results from five sampled terraces range from 8700 – 9010 (91 m asl) to 4860 – 5530 cal yr BP (11 m asl). Our oldest bivalve age of 8700-9010 provides a minimum-limiting constraint for deglaciation and the marine limit at 91 m, which agrees well with regional ice sheet reconstructions (Georgiadis et al., 2018; Søndergaard et al., 2020). Relative sea level fell rapidly from 91 m asl to 42 m asl (7830 – 7970 cal yr BP) at a rate of ~50 m/kyr. The rate of sea level fall slowed from 42 m to 11 m (4860 – 5530 cal yr BP) at a rate of ~10 m/kyr. There is evidence elsewhere in Inglefield Land that sea level was within 5 m of present sea level after 670 - 795 cal yr BP (Mason, 2010), indicating sea level fall slowed to ~2 m/kyr in the late Holocene.

These rates agree with the expected rapid fall after initial deglaciation and a slower rate of change long after deglaciation, as predicted by the solid-earth response to ice unloading. Our data agree well with timing of beach ridge morphology from Inglefield Land (Mason, 2010). The rate and timing of the early Holocene emergence is comparable with Glueder et al. (2022) in Hall and Washington Land, but our data is at odds with their mid-Holocene history.

Finally, we will also report forthcoming cosmogenic nuclide ages from glacially transported boulders on Nordvesvtø, the largest island in the Carey Islands, situated in southern Nares Strait (76.72, -73.17). These dates should provide a deglaciation age for the opening of Nares Strait. We expect the ages to be between 14,150 – 14,000 cal yr BP (after the breakup of the Baffin Bay Ice Shelf; Couette et al., 2022) before 10.8 ± 0.6 ka (the deglaciation around Thule; Corbett et al., 2015). Determining the opening of Nares Strait at this key area will provide a valuable constraint for data-model comparisons.

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CLIMATE AND BIOCLIMATE CONDITIONS IN NAIN (LABRADOR) IN THE LATE 18TH CENTURY

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This study focuses on the analysis of climate and bioclimate conditions in Nain (Labrador) in the late 18th century. For this purpose, we used invaluable instrumental meteorological observations made by Moravian Missionaries. These records were sourced from three primary archival collections: the Moravian Archives in Herrnhut (Germany) and the Moravian Archives at Muswell Hill and the Archives of the Royal Society in London (Great Britain) (Fig. 1). The 18th-century Moravian missionary observations offer a unique perspective on the climate and bioclimate of the Labrador coast, providing essential data on temperature, precipitation and wind force and direction, and short descriptions of the weather. Observations were made two, three, or four times a day from Oct 1771 until July 1786, but include two gaps: 20th Oct 1774 to 16th Sep 1775 and 12th – 30th Sep 1784. For this study, we utilized sub-daily air temperature (1771–86) measurements in Nain and wind speed (1776–85) estimates using a six-degree scale (1–6). Nain is located on the eastern coast of Labrador (j = 56°32′N, l = 61°41′W, H = 11 m a.s.l.) (Fig. 2).

All available historical data were quality controlled and converted to present units (°C and ms^{-1}). In the next step, the original daily air temperature means (calculated from different measurements times) were corrected to real means calculated from 24 hourly measurements. Corrections for each month were calculated based on contemporary data (1991–2010). The corrected daily means have been used to calculate monthly, seasonal and yearly means, as well as other statistics such as number of different categories of cold/warm days, growing degree days sum (GDD), air thawing index degree-days sums (ATI), positive degree-days sum (PDD) and air freezing index degree-days sum (AFI). The last four indices were calculated using definitions proposed by Nordli et al. (2020).

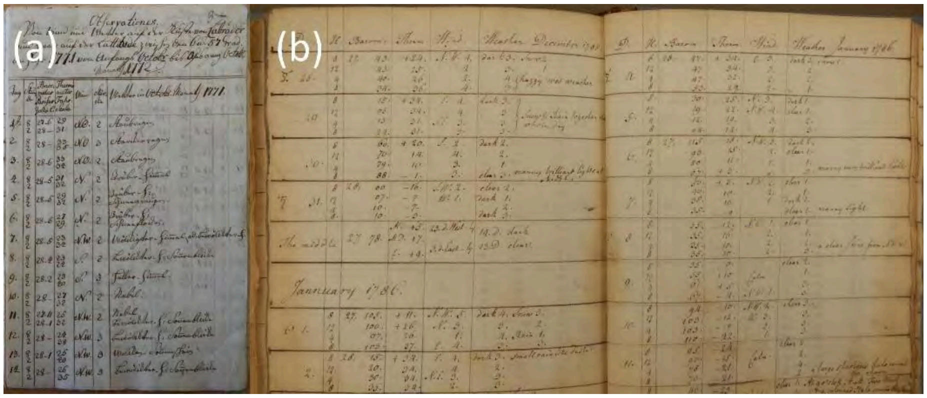

Fig. 1. Examples of manuscripts presenting meteorological observations: (a) for Nain (1 Oct 1771 to 31 July 1786), source: Unitatsarchiv MDF.1817, The Moravian Archives in Herrnhut (Germany). Data presented in the manuscript: 1 to 14 January 1771, (b) Nain, data presented in the manuscript: 28 Dec 1785 to 11 Jan 1786, Source: R.S.MA 143, The Archives of the Royal Society in London (Great Britain)

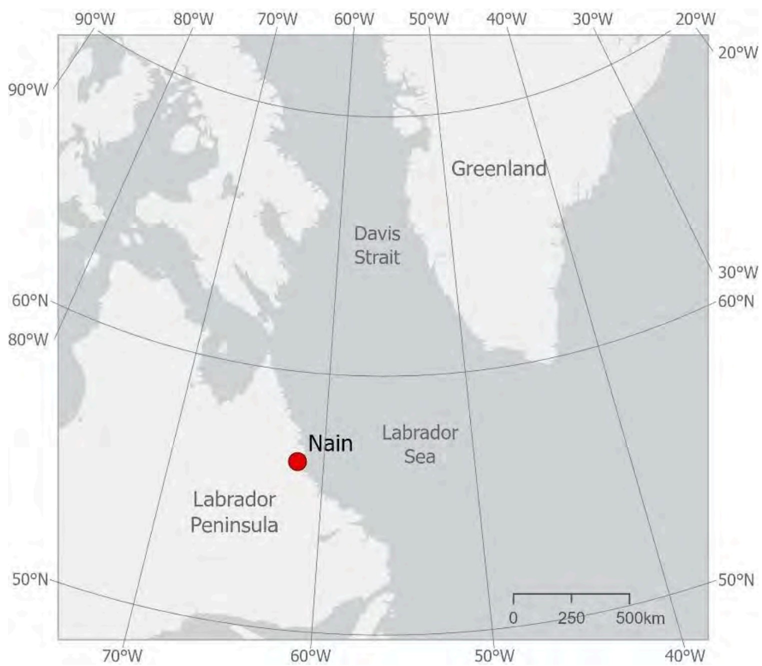

Fig. 2. Location of the study area

Bioclimatic conditions at the Nain station were estimated for a full 10 years of observations (1776–85) using three bioclimatic indices: Wind Chill Temperature (WCT), Insulation Predicted (Iclp) and Wind-Chill Index (WCI). For the calculation of the indices, the daily meteorological measurements taken at 12:00 local time were used. In the abstract, however, we briefly present only the results of the most known WCT index, which indicates the risk of frostbite to parts of the body in specific weather conditions.

Thermal and bioclimatic conditions of the study period in the coastal part of Labrador were also compared to present-day ones.

Compared to the present day (1991–2010), the historical period of 1771–86 was colder in all months, but particularly in winter and autumn (Table 1, Fig. 3a). Mean annual air temperature was 2.4 °C colder than today. Analysis of Fig. 3a reveals that the majority of mean monthly air temperatures in historical times lie within two standard deviations of the modern mean. The average monthly GDD and ATI values in the period 1771–86 are usually very close to minimum values from 1991–2010. Most of the individual monthly values oscillate between average and minimum values from the contemporary period. The PDD during the cold season (Oct–Apr) in the period 1771–86 were noted mainly in April and October and their values were significantly lower than at present. On the other hand, the average monthly AFI values were clearly higher than the present-day norm.

Table 1. Mean monthly, seasonal and yearly differences between historical and contemporary periods of: 1) daily air temperature (T), temperature from 12h (T12), wind speed (V) and Wind Chill Temperature (WCT) index. Standard deviations (SD) were calculated using contemporary data from the reference periods.

Variables	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**SON**	**DJF**	**MAM**	**JJA**	**YEAR**
1771-86*																	
T(°C)*	-3.1	-3.3	-3.2	-6.0	-2.2	-2.7	-1.9	-0.5	-0.5	-1.7	-2.0	-1.7	-3.2	-3.6	-1.0	-1.8	-2.4
1 SD	2.3	2.3	3.4	7.1	7.1	8.4	6.8	5.1	3.3	2.8	2.7	2.4	2.7	7.5	5.1	2.6	4.5
1776-85**																	
T12(°C)	-0.6	-1.6	-1.8	-4.4	-0.2	1.0	1.5	2.3	1.7	0.9	0.3	0.3	-1.3	-1.2	1.8	0.5	-0.1
1 SD	4.0	3.4	4.3	6.7	7.5	6.9	6.7	5.0	3.9	5.0	5.4	4.8	3.9	7.0	5.2	5.1	5.3
V(m*s^{-1})#	-1.4	-0.5	-0.5	-0.5	0.0	0.1	-0.1	-0.3	-0.8	-0.7	-0.7	-0.6	-0.8	-0.1	-0.4	-0.7	-0.5
1 SD	2.1	2.3	2.0	2.5	2.4	2.5	2.5	2.4	2.2	2.0	1.9	2.0	2.1	2.5	2.4	2.0	2.2
WCT(°C)	0.9	-0.4	-0.2	-2.3	1.7	2.6	3.0	3.8	3.3	2.1	1.2	1.1	0.1	0.7	3.4	1.5	1.4
1 SD	4.6	4.1	5.4	8.0	9.3	8.5	8.5	6.3	4.7	5.6	6.0	5.3	4.7	8.6	6.5	5.7	6.4

* – reference period 1991-2010

** – reference period 1991-2020

\# – wind speed at a height of 1.2 m a.g.l.

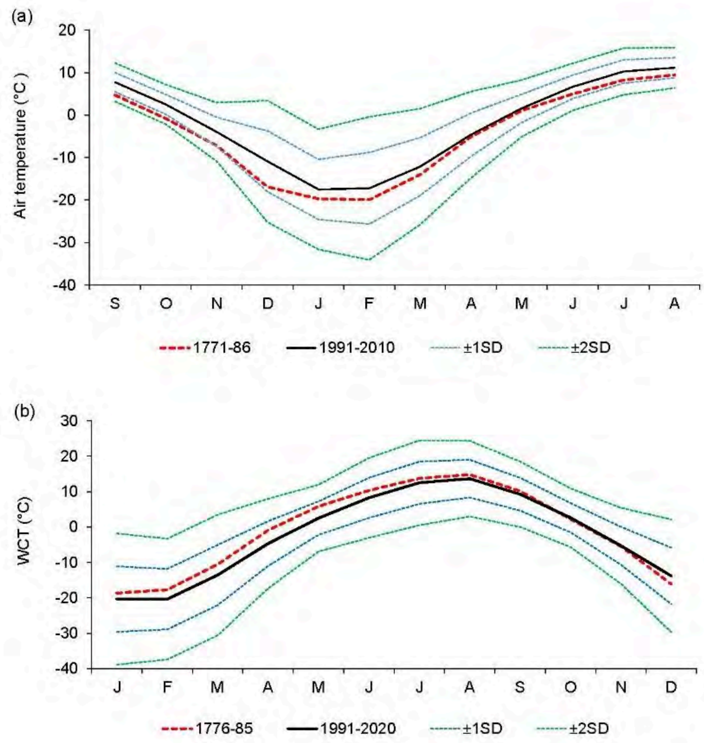

Fig. 3. Annual courses of historical and modern air temperatures (a) and WCTs (b) in Nain based on monthly means. SD calculated using present data.

Comparing the average monthly values of the WCT index at the Nain station in the historical period with the conditions prevailing there today, it is clearly visible that in the past there were more favourable bioclimatic conditions than currently, except period from October to December (Table 1, Fig. 3b). All monthly average historical values lie within the distance of one standard deviation from the present mean.

From February to June in the historical period, the monthly average conditions were much more favourable, the differences ranging from 2.1 to 3.8 °C (Table 1). From July to September, these differences were smaller (0.9–1.2 °C) but still more favourable in the historical period. Nowadays, the last three months of the year turned out to be more comfortable compared to the past, especially December, when the WCT was 2.3 °C higher than in historical times.

On the basis of this WCT index (and other indices not shown here), it follows that in the years 1776–85 in Nain, the bioclimatic conditions were more comfortable than current conditions. The main reason for this was wind conditions, i.e. smaller wind force in the historical period than at present (see Table 1).

This work was supported by the National Science Centre, Poland project No. 2020/39/B/ST10/00653.

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CLIMATE RECONSTRUCTIONS ACROSS THREE INTERGLACIALS AT SADDLE LAKE, BAFFIN ISLAND, NUNAVUT

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As the most recent time in geologic history when global temperatures likely reached ~1°C above the pre-industrial average, the Last Interglacial (LIG; Marine Isotope Stage [MIS] 5e, ~129-116 ka) is an important analog for future warmth. In the Arctic, LIG temperatures were substantially higher due to the effects of polar amplification, with temperatures in the Eastern Canadian Arctic (ECA) and Greenland reaching ~+4-8°C and shrubs migrating as much as 400 km northward. Despite its clear importance as a future climate analog, however, few high latitude temperature reconstructions exist, largely due to the scouring of sedimentary records by ice during the last glacial period. On Baffin Island in the ECA, however, a number of lake sedimentary records were preserved under cold-based ice sheets, allowing for the recovery of sediment from multiple interglacials. One such record is preserved at Saddle Lake (SAD), a small (7 ha), shallow (3 m) lake on Paallavvik (formerly Padloping) Island off the coast of Baffin Island, where newly retrieved sediment cores indicate that sediment has likely been accumulating since at least the Penultimate Interglacial (PIG; plausibly MIS7; ~186-245 ka). In these sediments, we measured both branched (br-) and isoprenoidal (iso-) glycerol dialkyl glycerol tetraether (GDGT) lipids, biogenic silica, and bulk sedimentary properties to reconstruct the climate history at Saddle Lake across three interglacials (PIG, LIG, and Holocene). Together, these proxies show a period of peak warmth during the LIG that is unrivaled in either the Holocene or the PIG. Specifically, brGDGTs indicate that peak LIG temperatures were ~2.5 °C warmer than modern and ~1 °C warmer than the Holocene Thermal Maximum, though we note that isoGDGTs indicate periods of anoxia that may lead to underestimated brGDGT-derived temperatures in some places. Macrofossil and pollen analyses from this interval corroborate this period of peak LIG warmth, however, and indicate that plant communities present during the LIG have not reestablished since. Together, these records provide valuable paleoclimate data, including quantitative paleotemperature and ecological constraints for climate models.

REGIME SHIFTS IN ARCTIC TERRESTRIAL HYDROLOGY MANIFESTED FROM IMPACTS OF CLIMATE WARMING

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Anthropogenic warming in the Arctic is causing hydrological cycle intensification and permafrost thaw, with implications for flows of water, carbon, and energy from terrestrial biomes to coastal zones. To better understand likely impacts of the changes, we used a hydrology model driven by meteorological data from atmospheric reanalysis and two global climate models for the period 1980-2100. The hydrology model accounts for soil freeze-thaw processes and was applied across the pan-Arctic drainage basin (Fig 1). The simulations point to greater changes over northernmost areas of the basin underlain by permafrost (Fig 2a), and the western Arctic. An acceleration of simulated river discharge over the recent past is commensurate with trends drawn from observations and reported in other studies. Between early (2000-2019) and late century (2080-2099) the model simulations indicate an increase in annual total runoff of 17-25%, while the proportion of runoff emanating from subsurface pathways is projected to increase 13-30%, with the largest changes noted in summer and autumn, and across areas with permafrost (Fig 2b). Most notably, runoff contributions to river discharge shift to northern parts of the Arctic basin that contain greater amounts of soil carbon (Fig 2c,d). Each season sees an increase in subsurface runoff, spring is the only season where surface runoff dominates the rise in total runoff, and summer experiences a decline in total runoff, despite an increase in the subsurface component. The greater changes that are seen in areas where permafrost exists supports the notion that increased soil thaw is shifting hydrological contributions to more subsurface flow. The manifestations of warming, hydrological cycle intensification, and permafrost thaw will impact Arctic terrestrial and coastal environments through altered river flows and the materials they transport.

Fig 1. Pan-Arctic drainage basin (gray outlined) and the six largest river basin. The study domain encompasses 22.45 million square kilometers which drain to the Arctic Ocean and Bering Strait..

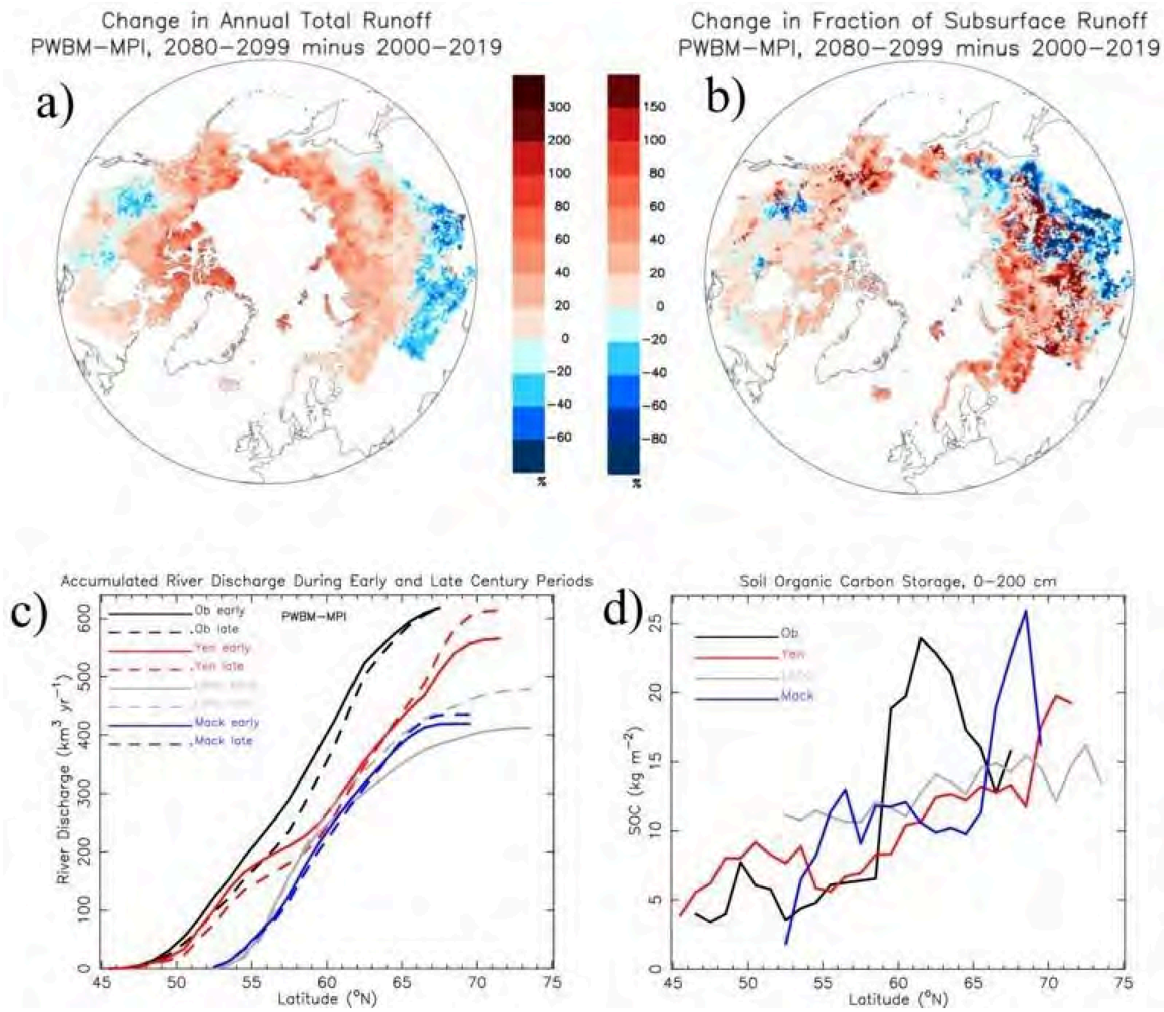

Fig 2. Change in (a) annual total runoff (%) and (b) fraction of subsurface to total runoff (%) from the model simulations. (c) Accumulated annual total river discharge (km^3 yr^{-1}) for the Ob, Yenesey, Lena, and Mackenzie Rivers for 1° latitude bands as averages over early (solid line) and late (dashed) century periods from PWBM-MPI. (d) Soil carbon storage (kg m^{-2}) in soil 0-200 cm zone from the Northern Circumpolar Soil Carbon Database.

EFFECTS OF TIME AND TEMPERATURE ON MODERN PLANT COMMUNITIES IN THE EASTERN CANADIAN ARCTIC

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The eastern Canadian Arctic encompasses the entire Arctic bioclimate gradient, from treeline to ice caps. The study of plant communities along this climate gradient is being used to compare current vegetation with evidence of past vegetation found in lake sediment cores, which include times both warmer and colder than present. The differences along the climate gradient are also helpful in predicting the response of vegetation to current and future climate warming.

We sampled and mapped the vegetation around a series of lakes chosen for their sediment core potential (Fig. 1A). The ideal lake has a relatively small watershed and simple basin morphology, and is covered by cold-based, non-erosive ice during glacial periods. This produces lake sediments that record ice-free episodes over long time periods. The eight sites include one near Pond Inlet, Baffin Island, Nunavut (next to an ice cap, 72.4 °N), one near Clyde River, one by the Barnes Ice Cap, three in the Merchants Bay area, one near Iqaluit, and one near Kuujjuaq, Nunavik, Quebec (at treeline, 58.1°N).

The time that the landscapes were most recently available for plant colonization varied from around 100 years to around 12,000 years. These dates are complicated by the fact that the two southernmost sites were below sea level when they were deglaciated, and were only available for colonization after they experienced enough glacial rebound to emerge from the ocean ~6,000 years ago. Our northernmost site (AFR) was deglaciated about 9,000 years ago, but then reglaciated about 3,000 years ago, and only emerged from under the ice around 100 years ago. Sites near the Barnes Ice Cap varied in age depending on their distance from the ice cap, but most plots were from an area deglaciated about 3,000 years ago.

Vegetation plots (n = 278) were sampled around the lakes, and cover values were recorded for lichens, bryophytes and vascular plants. Vegetation types ranged from lichens growing on rock to open spruce forest with dense low shrub and moss understory. Vegetation was mapped in a 1 km^2 area at each site, using a consistent legend, so that vegetation units could be compared between sites. Vegetation cover varied from mostly barren at our coldest site, the most recently deglaciated, with only 6 vascular plant species, to mostly well-vegetated at the southern sites, where we found 82 vascular plant species around the lake. Unlike vascular plants, nonvascular plant diversity did not decrease with summer temperature and latitude.

The analysis showed both local and regional differences in vegetation. Variation in vascular vegetation between sites was due mostly to temperatures during the summer growing season. Variation within a site was due to variation in substrate. All sites included both rocky areas and wet areas, but the amount of unvegetated rock (bedrock and fell-field) varied. Continuous vegetation only occurred in areas that had finer substrates and some soil development, which play an important role in retaining moisture and supporting plant growth.

The vegetation and mapping data are also supporting analyses by other researchers that are part of this project, including temperature proxies from the cores, precipitation and other hydrological information gathered from leaf wax data, as well as plant colonization and succession trajectories to match past and future climate conditions.

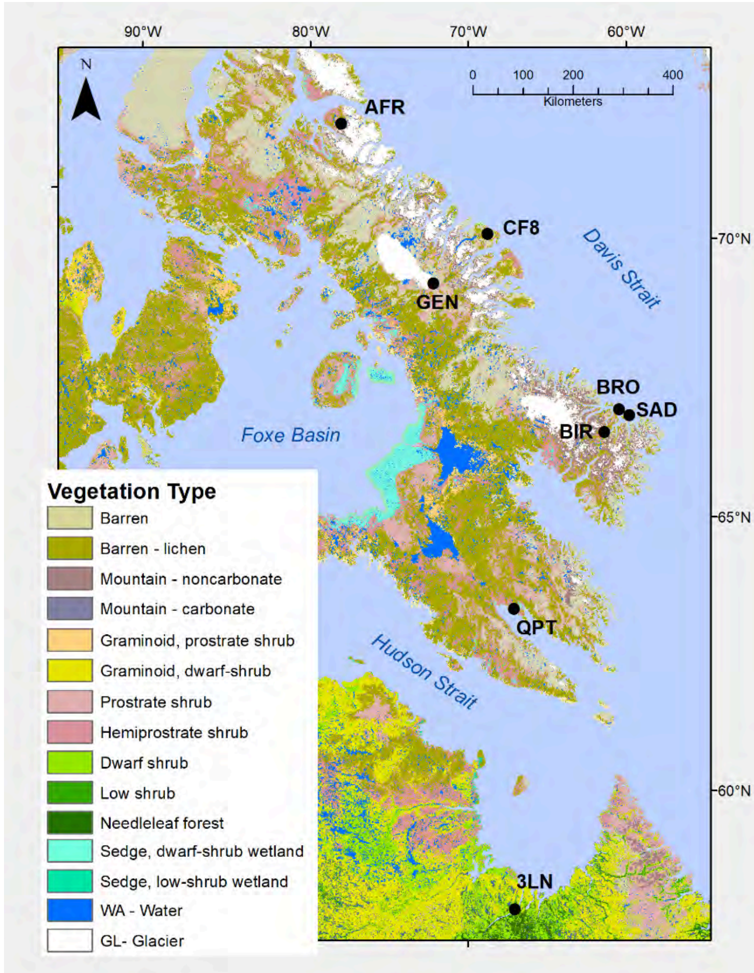

Figure 1. Map of 8 sites sampled in the Northeastern Canadian Arctic, on Baffin Island and in northern Quebec, 2018-2023.

Acknowledgements: This work took place on the lands of the Qikiqtani Inuit and the Nunavik Inuit. We thank the Nunavut Research Institute for their permission and support. The project would not have been possible without local logistical support from members of the communities of Qikiqtarjuaq, Clyde River, Iqaluit, Kuujjuaq and Pond Inlet. The research was funded by NSF OPP # 1737750 and # 1927148.

ENVIRONMENTAL MONITORING A HIGH ARCTIC PROGLACIAL LACUSTRINE WATERSHED IN A WARMING HYDROCLIMATE REGIME, LINNÉVATNET, SVALBARD

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The northern Barents Sea and Svalbard archipelago are located in a “hotspot” (Lind et al., 2018) in the Arctic, which as a region is warming as much as four times faster than the global average (Rantenan et al., 2022). Increased “Atlantification” along the west coast of Svalbard has contributed to increased sea surface temperatures and reduced sea ice accompanied by heightened cyclonic activity in the past two decades (Nilsen et al., 2008; Barton et al., 2018; Wickstrom et al., 2020), enhancing the relative warmth and wetness of the regional high arctic maritime climate (Eckerstorfer and Christiansen, 2011). The impact on the terrestrial system has led to prolonged melt seasons where precipitation and stream flow events can occur into the fall and even during the winter (Nowak and Hodson, 2013).

Environmental monitoring in Linnédalen, western coastal Svalbard from 2003 to 2023 provides a baseline for understanding the evolution of the hydroclimate in the rapidly warming 21st century (Hanssen-Bauer et al., 2019). From 2003 to present, environmental sensors in the 31 km^2 Linnédalen glacial watershed include an automated weather station, snow depth and stream water temperature sensors, and time-lapse cameras. Moorings with sediment traps, temperature loggers and other instrumentation are deployed across Linnévatnet and are recovered and redeployed on an annual basis.

Measurements and observations in the Linnédalen catchment reveal that hydroclimatic processes have accelerated over the past decade in this west coast maritime setting. Linnébreen, a polythermal glacier at the head of the valley, has retreated ~1.6 km from the Little Ice Age maximum. Ice marginal retreat increased from an average of 26m/year (2004 to 2012) to ~55 m/year (2012 to 2021). Streamflow duration has increased (74 days in 2005 to 167 in 2016) with late season heavy rainfall events occurring more frequently in recent years. River temperatures reached 15°C through late July-early August 2020 and lake surface water reached 10°C for over a week, the highest temperatures since 2003. Since 2013, lake ice formation has occurred later in the autumn, as late as late November or early December (Tuttle et al., 2022). Lake sediment trap analysis and camera imagery shows that peak river discharge occurs in two main modes: the nival flood from spring snowmelt runoff and/or in the late summer and autumn “shoulder season” associated with heavy rainfall events (Schiefer et al., 2018). The shoulder season mode (Nowak and Hodson, 2013) has been more persistent in the last decade (Retelle et al., 2019). The sediment trap and sediment core records from Linnévatnet also document increased annual accumulation due to enhanced regional warmth and rainfall.

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EFFECTS OF CLIMATE CHANGE AND THAWING PERMAFROST: POTENTIAL PATHOGENS TO HUMAN, ANIMAL, AND PLANT HEALTH

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Public health and subsistence lifestyles are potentially at risk in a changing Arctic climate, which has seen sea-ice decline, thawing permafrost, changes in plant and animal migration, as well as changes in microbial community. Our study investigates the microbial population in the Arctic tundra in Northern Alaska. When dormant bacteria are released with the thawing of the arctic soil, a common effect of climate change, some of these bacteria may be pathogenic that become viable, survive, and cause disease.

Previous studies indicate that *Mycobacterium simulans* (Figure 1) was isolated in the permafrost layer of Utqiaġvik, AK. *M. simulans* is a potential pathogen mimicking *Mycobacterium tuberculosis* causing respiratory disease. Our research focuses not only on understanding the microbial diversity but also on identifying potential threats to human, plant, and animal health. Tundra soil and core samples were collected from the arctic tundra permafrost, topsoil, and organic layers February 2015 - April 2023. Some data (2015 – 2022) obtained from culture dependent and culture independent DNA extraction, sequencing from Omega Bioservices, and analysis from Illumina indicate *Cithioniobacter flavus*, *Serratia liquefaciens, Pseudomonas fragi* and *Pseudomonas brassicacearum* are present in the arctic tundra. *Chthoniobacter flavus* is known to concur with the parasite Toxoplasma gondii suggesting a complex human environment interaction2,7. Toxoplasma gondii causes Toxoplasmosis, the leading cause of death from foodborne illness*1*. *Serratia liquefaciens* is noted to cause increasing mortality rates with blood transfusions and urinary tract infections*4,6*. *Pseudomonas fragi* is an environmental psychotropic species and can cause meat spoilage*5*. *Pseudomonas brassicacearum* is known to be both beneficial or pathogenic to plants*3,8*. An increase in pathogenic microbial activity from a warming environment could potentially have long-term negative effects on human, plant, and animal health and should not be understated.

A PROMISING ARCHIVE OF HIGH ARCTIC HOLOCENE TEMPERATURE VARIABILITY: LAKE SEDIMENTS FROM LAKE SW IN PEARY LAND, NORTH GREENLAND

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Global warming exhibits heterogeneity, leading to alarming rates of warming and amplified impacts, particularly in temperature-sensitive regions such as the Arctic. In the Arctic, this phenomenon is referred to as Arctic amplification and rapidly changes terrestrial landscapes and lacustrine ecosystems. To constrain the sensitivity of High Arctic sites and make meaningful predictions about future warming, we must examine the sensitivity of these regions to past changes using natural archives. Here, we will report on the potential of the varved lake sediments of "Lake SW" in Peary Land (82.1°N, 35.7°W), located 3km northeast of the Storm Iskappe glacier, as a high-resolution temperature archive to expand the regional temperature history beyond the instrumental measurement period. The sediments were collected in August 2021 and a robust chronology was established using a combination of varve counting and radionuclides (^{210}Pb, ^{137}Cs, ^{241}Am and ^{14}C). A suite of scanning techniques was then employed (computed tomography, µX-ray fluorescence scans, hyperspectral imaging) together with alkenone-thermometry (U_{37}^{K} U_{37}^{K}), C/N- and diatom analyses (refer to the contribution of B. Perren) to reconstruct the lake's productivity (green pigment concentrations and fluxes, *GP*), anoxia (bacterio pheophytin concentrations and fluxes, *BPhe*), and temperature histories over the last millennium.

Highest *BPhe* values were observed between ~1490-1900CE suggesting a phase characterized by prolonged anoxia. Simultaneously, the diatom assemblage along with low alkenone-derived temperatures indicate cold and dark icy conditions characteristic for heavy ice cover. This phase coincides with the LIA, and thus might be caused by regular perennial ice-cover extents that increase thermal stratification of the water column (oxygen depletion). Between ~1900-1990CE an increase in *GP*, and a diversification in the benthic diatoms may be associated with larger moating around the lake, more nutrient input and slightly higher water temperatures. The period after

~1990CE is characterized by the arrival of planktonic diatoms, the warmest observed alkenone-derived temperatures, and a significant decrease in *BPhe* suggesting extended periods of open water. Further statistical comparison of the *GP* and temperature will reveal whether the productivity is limited by temperature, which would allow proxy-to-proxy-calibration to increase temporal resolution of the temperature record.

We present evidence that sediments from “Lake SW” are a promising high-resolution archive of local temperature variability for the late Holocene in an area that is lacking high-resolution terrestrial paleoclimate records.

PLIOCENE-PLEISTOCENE WARM WATER INCURSIONS AND WATER MASS CHANGES ON THE ROSS SEA CONTINENTAL SHELF (ANTARCTICA) BASED ON FORAMINIFERA, IODP EXP 374

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International Ocean Discovery Program (IODP) Expedition 374 sailed to the Ross Sea in 2018 to reconstruct paleoenvironments, track the history of key water masses, and assess model simulations that show warm water incursions from the Southern Ocean led to the loss of marine-based Antarctic ice sheets during past interglacials (McKay et al., 2019). IODP Site U1523 (water depth 828 m) is located at the continental shelf break, northeast of Pennell Bank on the southeastern flank of Iselin Bank, where it lies beneath the Antarctic Slope Current (ASC) (Figure 1). This site is sensitive to warm water incursions from the Ross Sea Gyre and modified Circumpolar Deep Water (mCDW) today and during times of warming climate. Multiple incursions of subpolar or temperate planktic foraminifera taxa occurred at Site U1523 after 3.8 Ma and prior to ~1.82 Ma (Figure 2). Many, but not all, of these warm water taxa incursions likely represent interglacials of the latest Early Pliocene and Early Pleistocene, including Marine Isotope Stages (MIS) Gi7 to Gi3 (~3.72-3.65 Ma), and Early Pleistocene MIS 91 or 90 (~2.34-2.32 Ma) and MIS 77-67 (~2.03-1.83 Ma) and indicate warmer than present conditions and less ice cover in the Ross Sea. However, a moderately-resolved age model based on 4 key events prohibits us from precisely correlating with Marine Isotope Stages established by the LR04 Stack; therefore, these correlations are best estimates.

Diatom-rich intervals during the latest Pliocene at Site U1523 include evidence of anomalously warm conditions based on the presence of subtropical and temperate planktic foraminiferal species in what likely correlates with interglacial MIS G17 (~2.95 Ma), and a second interval that likely correlates with MIS KM3 (~3.14 Ma) of the mid-Piacenzian Warm Period. Collectively, these multiple incursions of warmer water planktic foraminifera provide evidence for polar amplification during super-interglacials of the Pliocene and Early Pleistocene. High abundances of planktic and benthic foraminifera in the mid- to Late Pleistocene associated with interglacials and glacials of the MIS 37-31 interval (~1.23-1.07 Ma), MIS 25 (~0.95 Ma), MIS 15 (~0.60 Ma), and MIS 6-5e transition (~0.133-0.126 Ma) also indicate a reduced ice shelf and relatively warmer conditions, including multiple warmer interglacials during the Mid-Pleistocene Transition (MPT).

A decrease in sedimentation rate after ~1.78 Ma is followed by a major change in benthic foraminiferal biofacies with the decrease in *Globocassidulina subglobosa* and a decrease in mud (<63 mm) after ~1.5 Ma. Subsequent dominance of *Trifarina earlandi* biofacies beginning during MIS 15 (~600 ka) indicate progressive strengthening of the Antarctic Slope Current along the shelf edge of the Ross Sea during the mid- to Late Pleistocene. A sharp increase in foraminiferal fragmentation after the MPT (~900 ka) and variable abundances of *T. earlandi* indicate higher productivity, a stronger but variable ASC, and/or corrosive waters, suggesting changes in water masses entering (mCDW) and exiting (High Salinity Shelf Water or Dense Shelf Water) the Ross Sea since the MPT. Collectively, the foraminiferal abundance data show that the Ross Sea had intervals warmer than today during the Pliocene and Early Pleistocene, cooled through the MPT, and that the mean strength of the Antarctic Slope Current has been more vigorous since the MPT.

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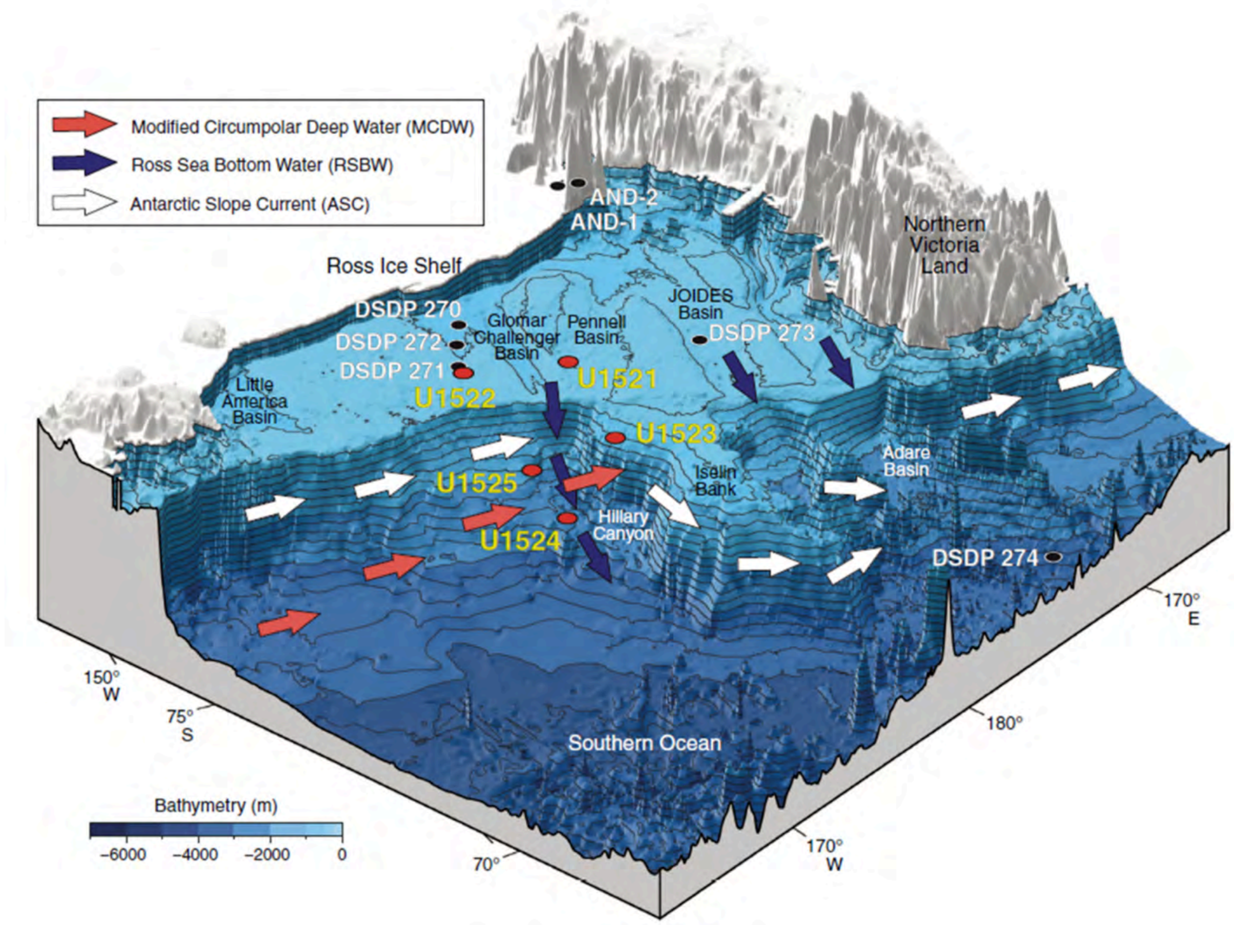

Figure 1. Bathymetric diagram showing the locations of IODP Expedition 374 Sites U1521-U1525 (red circles), DSDP Leg 28 Sites 270-274 (black circles), and ANDRILL Cores AND-1B and AND-2A (black circles). Figure from McKay et al. (2019).

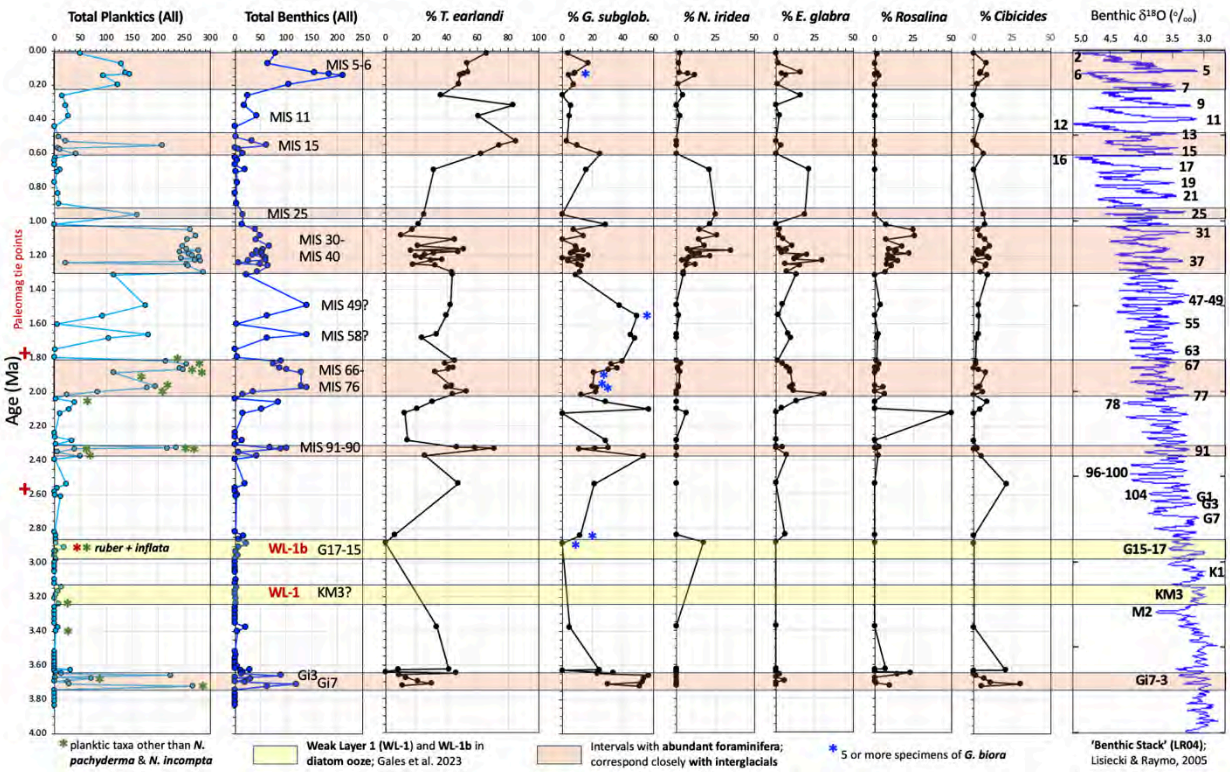

Figure 2. Summary of foraminiferal data from Site U1523, including the numbers of planktic and benthic foraminifera in all 131 samples investigated, and the percent of key benthic foraminifera based on all samples with at least 10 benthic specimens (66 samples; 50.4%). Pink bars highlight intervals of the studied section with greater abundances of foraminifera. Carbonate dissolution in Unit II sediments is suspected to be the principal reason for barren samples or low foraminiferal abundances between ~3.6 Ma and 2.4 Ma. The two yellow bars represent intervals of diatom ooze that were glide planes for submarine landslides above Hillary Canyon (Weak Layers WL-1b and WL-1; Gales et al., 2023). Weak Layer WL-1b likely correlates with Marine Isotope Stage G17, a super-interglacial of the latest Pliocene (see discussion in text). Note the last occurrence of warmer water planktic foraminiferal taxa (green asterisk: *Globigerina bulloides, G. falconensis,* and *Turborotalita quinqueloba*) is ~1.82 Ma at Site U1523.

PROSPECTING SUBGLACIAL GEOLOGICAL TERRANES THROUGH DETRITAL ZIRCON ANALYSIS IN WEST GREENLAND'S ICE-COVERED REGIONS

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This study focuses on the analysis of 271 detrital zircon grains from Isunnguata Sermia's riverbank outwash, targeting the identification of subglacial geological terranes beneath ice-covered areas of West Greenland. It also explores the potential of these findings to enhance our understanding of offshore ice-rafting records, thereby offering insights into past climatic and geological conditions. The bedrock geology around the collection site (Hollis et al., 2006) contains a range of ages with the oldest rocks dating back to the Neoarchean Era (2,532-2,832 Ma), indicative of significant crustal differentiation leading to the formation of stable Archean cratons and greenstone belts. Rocks of the Paleoproterozoic Era (1,782-1,832 Ma) are primarily orthogneisses and granitoids associated with the Nagssugtoqidian Orogeny. We are testing the hypothesis that detrital zircon grains in the outwash have ages that reflect the local bedrock.

The sediment sample was collected at the confluence of two outlet streams approximately 1 km from Isunnguata Sermia's ice margin (67.18342° N, 50.35843° W), in spring 2023. The sample was sieved to isolate the 125-500 micron fraction for density separation using heavy liquids. U-Pb was measured in individual zircon grains using a laser-ablation multicollector ICP mass spectrometer at the University of Arizona's LaserChron Lab following methods described in Gehrels (2010). Results revealed a broad distribution of zircon dates, ranging from 1,730 Ma to 2,925 Ma, with notable age groupings around 1,780-1,830 Ma and 2,580-2,780 Ma.

Overall, the measured detrital zircon U-Pb dates are broadly consistent with the ages of the local bedrock, supporting our initial hypothesis. For the Paleoproterozoic dates, numerous grains overlap the timing of the peak Nagssugtoqidian metamorphism. However, most dates are younger than this event and are similar in age to pegmatite intrusions outcropping west (downstream) of our sample site (Connelly et al., 2000). Additional U-Pb zircon analysis of outcrops adjacent to Isunnguata Sermia's outwash valley is needed to further evaluate the source of zircons in the outwash. Dates representing the Kangamiut dykes were absent. Analysis of the Archean dates is ongoing.

The U-Pb dates from outwash sediment at Isunnguata Sermia are useful in evaluating the geographic extent of zircon-crystallization events and can be used to efficiently fingerprint the range of dates from glacial catchments.

Figure 1. Detrital Zircon collection site of Isunnguata Sermia, upstream view (A) and the local pebbles of the riverbank outwash (B).

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CHARACTERIZATION OF SURFACE WATER AND OCEAN TOPOGRAPHY (SWOT) DATA USING FAST SAMPLING PHASE OVER NORTH SASKATCHEWAN RIVER, CANADA

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The recently launched Surface Water and Ocean Topography (SWOT) Ka-band radar interferometry satellite mission is providing new measurements of water surface elevation (WSE) and inundation extent of rivers and lakes globally (Fu et al., 2024). Here, we compare daily SWOT observations from the 2023 Fast Sampling orbit with in-situ measurements and optical observation over the North Saskatchewan River, Canada, a Tier-1 SWOT calibration and validation (cal/val) site. In situ, measurements of WSE were acquired from dates May 26 to June 11, 2023, and May 17 and June 14, 2023, respectively using pressure transducers (PT) and Global Navigation System Satellites (GNSS) drift data at nodes and reaches. Sentinel-2 images for dates similar to in-situ measurements were classified using a fast-marching algorithm to estimate the open-water area. Additionally, Pleaides images were obtained for date June 25, 2023, and July 11, 2023. We characterize SWOT level-2 High-Rate data to examine and compare inundation extent, and SWOT's signal changes over shorelines and compare them with high resolution optical and in-situ measurements to 1) understand the spatiotemporal variability of in-situ and SWOT observations; 2) quantify sources of error and uncertainty in SWOT data.

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RADIOCARBON AGE-OFFSETS REVEAL CONTRIBUTION OF PERMAFROST-DERIVED ORGANIC CARBON IN LAKE E5, ARCTIC ALASKA FROM MIS 3 TO PRESENT

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The stability of Arctic permafrost and carbon contained within is currently threatened by a rapidly warming climate. Understanding the patterns of erosion, transport, and deposition of permafrost-derived organic carbon through past climate variability is essential to predicting how permafrost will react to future global warming. The organic carbon (OC) stored in frozen permafrost soil ages prior to being transported and deposited into a lake. This source of OC introduces a component of the lake sediment that is older than the depositional age of the sediment. As a result, the downcore variation in the range of radiocarbon (^{14}C) ages (herein age-offsets) of OC in lake sediment can document changes in the relative amount of permafrost-derived OC that was incorporated into the lake sediment. Here, we used age-offsets from Lake E5, eastern Arctic Alaska, to reveal changes in the age of permafrost-derived OC deposited in the lake sediment through time. The Lake E5 age-offset record was developed using two independent methods: 1) ^{14}C measurements on paired bulk sediment and plant macrofossils from the same stratigraphic layer of lake sediment and 2) ramped pyrolysis-oxidation (RPO) ^{14}C analysis which separates different fractions of OC from a single bulk sediment sample based thermochemical differences through continuous heating.

The Lake E5 sediment revealed small age-offsets (1,300 yr) during the post-glacial period, large age-offsets (10,000 yr) during the Last Glacial Maximum (LGM), and moderate age-offsets (3,400 yr) during the MIS 3 interstadial. During the LGM, the low temperature fraction of each RPO sample, which is expected to isolate the youngest OC present in the sample, is as much as 15ka older than the depositional age of the sediment. These results directly contradict the general hypothesis that warm periods will mobilize older OC, instead suggesting that older material is deposited in the lake during the cold glacial period than the warm interglacial. As a result, this record necessitates consideration of the different erosion and transport processes during each climatic period and the impact that those processes have on the source and apparent age of the OC that was deposited in the lakebed. The erosion and transport processes of soil OC into the lake sediment can be separated into two components. First, the chemical breakdown and transport of young, shallow dissolved organic carbon (DOC) via groundwater flow which is dominant during the post-glacial and MIS 3. Second, the physical weathering of ancient particulate organic carbon (POC) via gullying, incision, or shifting shorelines which is dominant during the LGM. The overall trend in the Lake E5 age-offsets show great agreement with a similar study on Burial Lake in western Arctic Alaska. The new addition of the Lake E5 data to the age-offset story told by Burial Lake adds robustness to the possibility that the terrestrial-to-aquatic mobilization of ancient OC in Arctic Alaska was not positively correlated with air temperature over the last 50ka.

A 7,000 YEAR ALKENONE-BASED TEMPERATURE RECORD FROM INUTOQQAT NUNAAT, NORTH GREENLAND

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Located near Independence Fjord in Northern Greenland, Inutoqqat Nunaat was first occupied by ancient people around 4500 years ago. Archeological studies show that a subsistence hunting culture (Independence I) persisted at Inutoqqat Nunaat for over 500 years before the site was abandoned ca. 3850 yrs BP. Lithic and faunal materials from this settlement period point to an abundance of food resources in the region, including muskoxen, hares, foxes, and Arctic char [Jensen & Gotfredsen, 2022]. Questions therefore remain as to why the site was originally occupied and later abandoned by ancient people of the Arctic, and it is still unclear what influence climate and environmental changes may have had on historical settlement patterns. To better understand the climatic context for discontinuous settlement of Inutoqqat Nunaat – later occupied by the Independence II Culture (2900-2250 yrs BP) and briefly by the Thule people (~600 yrs BP) – we present a 7000-year lake sediment record of summer temperature change derived from lacustrine alkenones. Sediment cores were recovered from lake Nedre Midsommersø, adjacent to the primary settlement area at Inutoqqat Nunaat, which receives meltwater from the nearby Hans Tausen Ice Cap. Alkenone unsaturation indices (U^{K}_{37}) reflect lake water temperature and show a gradual increase from 6500 yrs BP to 4700 yrs BP, representing ~10℃ of warming. Rapid cooling is observed after 4700 yrs BP, leading to temperature decreases of ~4.8℃ by 4500 yrs BP and an additional ~2.5℃ of cooling by 4200 yrs BP. This cool phase lasted until at least 4000 yrs BP, at which point temperatures gradually rose ~2.5℃ by 3700 yrs BP. This cold period documented in the alkenone record corresponds with the timing of Independence I settlement at Inutoqqat Nunaat (~4500-3850 yrs BP). Another cold period is evident from ~3000-2400 yrs BP, with temperatures ~8.5℃ cooler than the warmest point at 4700 yrs BP, coinciding with the occupation of Inutoqqat Nunaat by the Independence II Culture. Our record therefore indicates that pre-Thule settlement phases at Inutoqqat Nunaat align with periods of low summer temperatures, which perhaps drove favorable changes in the distribution of vegetation and/or grazing mammals (i.e. muskoxen) or increased the viability of sea ice migration routes into the region.

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CLIMATE AND THE CRYOSPHERE (CliC) IN THE ARCTIC

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Climate and the Cryosphere (CliC) is a core project of the World Climate Research Program (WCRP) that works through dedicated initiatives, experiments, scientific advisory committees, and panels. CliC comprises a global community of researchers with expertise in the cryosphere and its interactions with climate and society. Our goal is to identify key research priorities and challenges pertaining to the cryosphere, and to coordinate international cooperation to help address these gaps. CliC also works to emphasize the importance of the cryosphere to policy makers, funding agencies, and the general public. Here we will present some of the CliC co-sponsored Arctic model intercomparison projects, working groups studying sea ice and ice sheet mass balance, linkages between polar climate and midlatitude weather extremes, permafrost and polar oceans. Looking to the future, CliC is sponsoring new working groups to help assess impacts on human societies of a diminished cryosphere. We always have opportunities for engaging with CliC science activities, international leadership roles, especially for early career researchers.

LINKING REMOTELY SENSED VEGETATION HETEROGENEITY AND PERMAFROST THERMAL STATE DYNAMICS

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Since 1979, the Arctic has warmed at a rate almost four times faster than the globe (Rantanen et al., 2022). Permafrost soils, which are continuously frozen for two consecutive years, are a significant component of the arctic landscape, comprising 15% of the northern hemisphere (Obu, 2021). However, permafrost regions can consist of only 50-90% permafrost soils, resulting in spatially discontinuous permafrost across the southern edge of the permafrost region (Brown et al., 1997; Obu et al., 2019). Warming climate in the Arctic and subsequent permafrost thaw (Smith et al., 2022) leads to landscape scale impacts for soil erosion and hydrology (Rowland et al., 2010) and global scale impacts on carbon fluxes from the landscape to the atmosphere (Miner et al., 2022).

As air and ground surface temperatures increase, the depth of the seasonally thawing active layer increases (Jorgenson et al., 2010). Deepening active layer thickness results in ground surface instability (Hjort et al., 2022), increased hydrologic connectivity between hillslopes and rivers (Lafrenière & Lamoureux, 2019), and exposes previously frozen soil carbon to microbial degradation (Schuur et al., 2015), potentially releasing substantial quantities of carbon to the atmosphere (Turetsky et al., 2020). Warming permafrost soils have damaged infrastructure across the northern hemisphere (Hjort et al., 2022); 44-47% of roads, railways, pipelines, and airports in the northern hemispheres are projected to be in high permafrost hazard zones under worst case climate projections, resulting in billions of dollars of damage (Jin et al., 2024). High-resolution maps of permafrost are urgently needed to inform hazard mitigation in these potentially affected communities (Hjort et al., 2022) and assess potential changes in landscape morphology, hydrologic connectivity, and carbon fluxes (Thaler et al., 2023).

Permafrost maps derived from remote sensing data can improve our understanding of permafrost thaw patterns in the Arctic by visualizing and extrapolating field data (Thaler et al., 2023). Permafrost has frequently been mapped at kilometer resolution (Gruber, 2012; Obu et al., 2019; Ran et al., 2022) but at that scale local variability is not captured, limiting the usefulness of these maps for hazard planning (Gruber, 2012). Finer scale maps have been produced, down to 30 meters for all of Alaska (Pastick et al., 2015) and 3 meters for parts of the Seward Peninsula, Alaska (Thaler et al., 2023). However, these permafrost maps (Obu et al., 2019; Pastick et al., 2015; Ran et al., 2022; Thaler et al., 2023) have significant disagreement in their predicted permafrost areas (Thaler et al., 2023). Analysis of the most important predictive features in the high-resolution permafrost maps revealed the importance of remote-sensing vegetation indices for predicting permafrost presence/absence across several watersheds (Thaler et al., 2023).

In regions of discontinuous permafrost, vegetation type is indicative of the permafrost thermal state. For example, tall shrub-dominated areas accumulate more snow and consequently have high ground temperatures, leading to deeper active layer thicknesses beneath shrub-dominated areas than graminoid-dominated areas, which maintain frozen ground (Uhlemann et al., 2021, 2023). In a steep watershed on the Seward Peninsula in Alaska, spatio-temporal variability in permafrost thaw and active layer thickness have been suggested to correspond to variability in vegetation type (Fiolleau et al., 2024). Cold, intermediate, and warm soil temperatures matched co-located vegetation type, graminoid tundra, dwarf shrub tundra, and tall shrub tundra respectively (Wang et al., 2024). Rather than supporting a graminoid-dominated community expected of thin active layers, areas with rapidly/actively deepening active layers may support a community of both woody and herbaceous vegetation, leading to high spatial heterogeneity in vegetation type.

Here we explore a remote-sensing workflow, which leverages permafrost-vegetation dynamics, to delineate areas of deepening active layer thickness for a watershed within the discontinuous permafrost region on the Seward Peninsula, Alaska. We ask the question: Can we use spatial heterogeneity in vegetation type to characterize the ground thermal state? We cluster borehole temperature measurements and active layer depths from the site into three permafrost thermal classes: cold, intermediate, warm following procedures used in other watersheds on the Seward Peninsula (Wang et al., 2024) and assess the heterogeneity of vegetation types within each of the clusters. We examine vegetation heterogeneity by calculating the standard deviation of remote-sensing vegetation indices (derived from 3m Planet satellite imagery) within a range of buffer radii around each of the temperature measurement locations. Preliminary results indicate spatial heterogeneity of vegetation is significantly greater in areas with ground surface temperatures in the intermediate thermal class. As permafrost thaws, ground surface deformation on steep slopes exposes bare soil and creates opportunities for woody shrubs to colonize areas previously vegetated by graminoids. The colonization by shrubs leads to patchy vegetation cover in areas of warming ground temperatures. Permafrost with ground surface temperature in the cold class have the least amount of spatial heterogeneity, consistent with the frozen ground providing stability for its established graminoid tundra.

The method presented here provides an approach for utilizing vegetation indices to predict the thermal state of soil in permafrost landscapes. A mapping approach developed from spectral data greatly increases the opportunity for high-resolution mapping of permafrost due to the greater spatial and temporal coverage of high-resolution imagery compared to high-resolution ground temperature data. Given the remoteness and large spatial extent of landscapes underlain by permafrost, remote sensing methods to predict permafrost presence and thermal state are critical for predicting landscape change and infrastructure vulnerability at high spatial resolution.

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LAURENTIDE ICE SHEET RETREAT DURING TWO ICE-AGE TERMINATIONS CAUSED THRESHOLD ATMOSPHERIC RESPONSES IN THE CANADIAN AND RUSSIAN ARCTIC

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Changes in ice-sheet size impact atmospheric circulation, a phenomenon documented by models but constrained by few paleoclimate records. We present records of Holocene summer temperature and summer precipitation hydrogen isotope ratios (δ^2H) from Baffin Island, northeastern Canadian Arctic and from the Kola Peninsula, western Russian Arctic. Summer precipitation δ^2H values at both sites exhibit stepwise changes during the early Holocene: on Baffin Island around 10 and 8 ka and on the Kola Peninsula around 8 ka. These precipitation δ^2H changes were asynchronous with temperature changes, but synchronous with rapid Laurentide Ice Sheet retreat. Model simulations demonstrate that the strength and position of high-pressure systems across the Northern Hemisphere changed as ice sheets lowered. We interpret the dramatic early Holocene precipitation δ^2H changes in Canada and Russia to be caused by moisture source changes, which in turn were due to shifts in prevailing winds during Laurentide Ice Sheet retreat. We also present a record of precipitation δ^2H values on Baffin Island spanning the end of the penultimate glacial period and the Last Interglacial (Marine Isotope Stages 6 and 5). This record contains evidence for rapid changes early in the Last Interglacial, likely due to Laurentide Ice Sheet retreat earlier during the penultimate deglaciation compared to the early Holocene. These proxy and model results suggest that ice-sheet retreat can cause threshold responses in atmospheric circulation both proximal to and downwind of sites of ice-sheet change.

RECONSTRUCTION OF TERRESTRIAL AND MARINE CLIMATE FROM SOUTHERN GREENLAND DURING THE PLEISTOCENE

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The Arctic region is experiencing ongoing rising temperatures at levels higher than the global average. Increasing atmospheric and ocean temperatures will impact the melting rate of the Greenland ice sheet. To better understand future changes in this region we look to sedimentary records with material from the southern Labrador Sea to assess changes in ocean currents, freshwater inputs, sea surface temperatures, and atmospheric temperatures. Here we compiled both a terrestrial and marine record from a North Atlantic Ocean Discovery Program legacy core from Site 647 between Labrador and southwestern Greenland. Site 647 captures the Pleistocene (~2.6 Ma to 200 kyr), a time period where the Greenland Ice Sheet underwent partial deglaciation likely during noted super interglacials, although pCO_2 was similar to today. Organic compounds including leaf waxes and branched glycerol dialkyl glycerol tetraethers (*br*GDGTs) were used to assess changes in the terrestrial environment, likely sourced from Nova Scotia, Canada. Mean annual air temperature was calculated using brGDGTs and the Bayesian regression model of the methylation of branched tetraethers (BayMBT) index ranging from 6 to 12°C where applicable. Plant wax concentrations remained fairly stable from 0.2 to 2.2 Ma but older samples have more variable *n*-alkanoic acid concentrations reaching values up to 8 µg/g at 2.2 Ma. The combination of these proxies with previous pollen work suggests decreasing temperatures and more sparse vegetation from the early to late Pleistocene. Multiple sea surface temperature (SST) records were generated from the isoprenoid glycerol dialkyl glycerol tetraethers (isoGDGTs) using the TEX_{86} index with the Bayesian spatially-regression (BAYSPAR) calibration with temperature ranging from 2 to 12°C and from the ring index of hydroxylated (OH)

isoGDGTs with RI-OH (Lü et al., 2015) estimates of 1 to 8°C and RI-OH' (Fietz et al., 2020) of 2 to 7°C. SSTs were also estimated from alkenones using the $U^{K'}_{37}$ index and the long chain diol index; however, $U^{K'}_{37}$ and LDI temperatures were warmer than expected for the Pleistocene but the temperature shifts are similar to those estimated from TEX_{86} and OH-GDGTs. Long chain diols were also used to assess freshwater inputs (via the fraction of the $C_{32\ 1,15}$ *n*-alkyl diol; Lattaud et al., 2017) and upwelling (Diol upwelling Index 1; Willmott et al., 2010) in the region. Freshwater inputs remained consistent through the record with decreasing inputs around 200 ka associated with an increase in upwelling and decrease in SST. The results were compared to planktic foraminiferal species assemblage to assess glacial-interglacial shifts in currents of the subpolar gyre northwest of the North Atlantic Drift (see abstract by Ishutina et al., 2024) with notable absence of foraminifera at the oldest section of this Site from ~2.4-2.6 Ma. Both the marine and terrestrial records add new data to a region with sparse records capturing Quaternary climate variability.

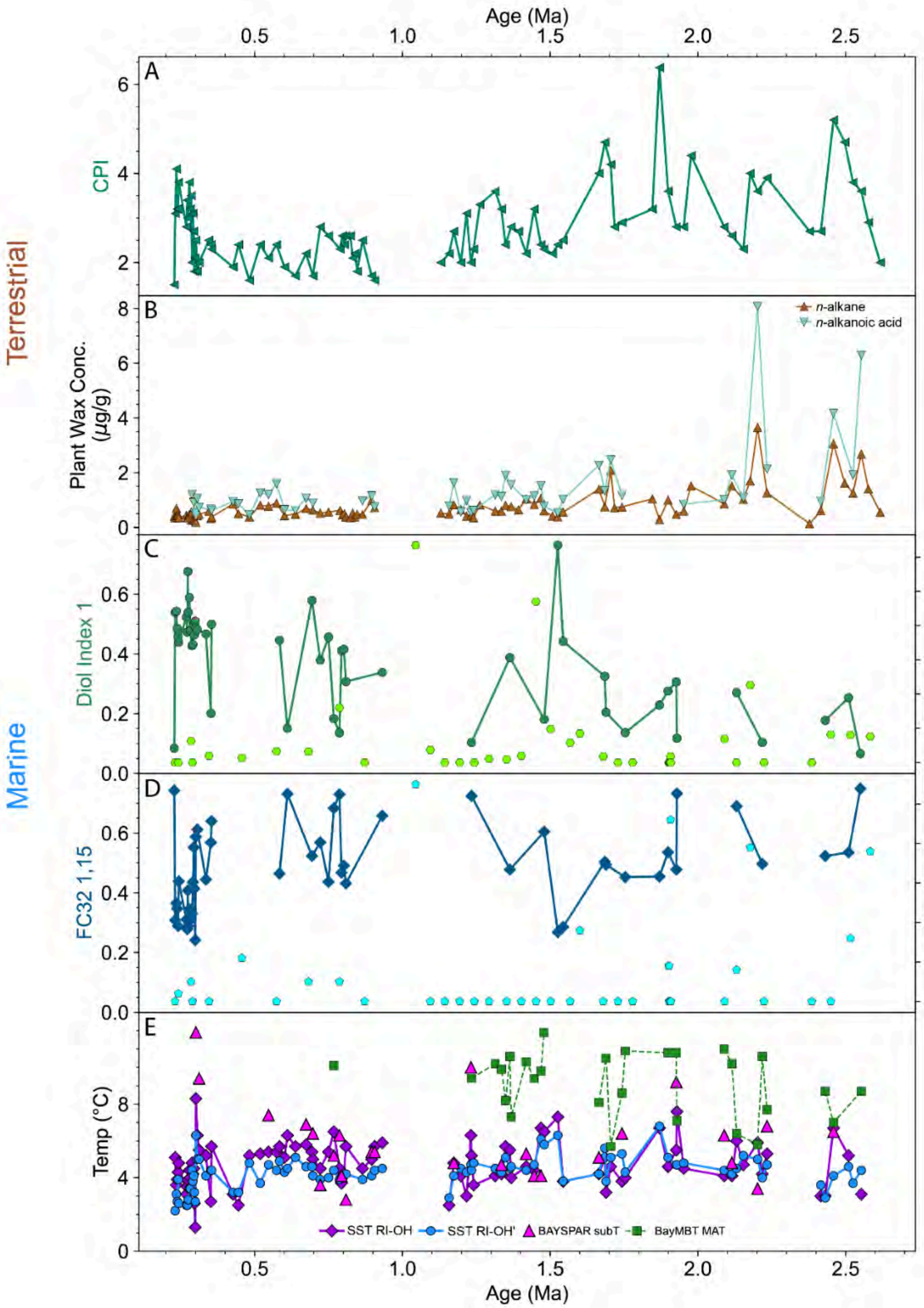
Age (Ma)
A
CPI
B
Plant Wax Conc. (µg/g)
n-alkane
n-alkanoic acid
C
Diol Index 1
Peridiniaceae cysts (#/cm^3)
D
FC32 1,15
Pediastrum (#/cm^3)
E
Temp (°C)
SST RI-OH
SST RI-OH'
BAYSPAR subT
BayMBT MAT
Terrestrial
Marine

Figure 1: Compiled proxy records for Site 647 a) Carbon preference index (CPI) b) b) plant wax concentration for both *n*-alkane (brown triangle) and *n*-alkanoic acids (blue downward facing triangle, and pollen counts c) Diol index 1 (dark green circles) used as an upwelling indicator and Peridiniaceae cyst counts (lime green hexagon). d) $FC_{32\ 1,15}$ (dark blue diamonds) used as a freshwater input proxy with *Pediastrum* counts (light blue pentagon) e) Temperature proxy reconstruction for the subsurface temperature using the BAYSPAR calibration (Tierney & Tingley, 2014) (pink triangles), SST from RI-OH (purple diamonds), SST from RI-OH' (blue circles), and mean annual air temperature reconstructed using BayMBT (Dearing Crampton-Flood et al., 2020). Data points presented were screened for nonthermal influence in MBT'_{5me}.

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A DATA MODEL COMPARISON BETWEEN HOLOCENE GREENLAND ICE SHEET MARGIN CONSTRAINTS AND THE ICE-SHEET AND SEA-LEVEL SYSTEM MODEL (ISSM)

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We present a status report on the ongoing data-model comparison efforts between the Ice-Sheet and Sea-Level System Model (ISSM) and geochronologic constraints of Greenland Ice Sheet (GrIS) change during the Holocene. Forecasting the fate of the GrIS under changing global climate conditions requires the use of accurate models, which can be evaluated against geologic data. Such an evaluation allows us to explore climate forcings and several different considerations for handling ice-ocean interactions. We hope that our ongoing exercises give confidence in our ability to accurately forecast GrIS mass change under future warming scenarios.

In many settings along the coast and ice-free regions around Greenland, glacial landforms that track the recession of the ice sheet through the Holocene have been mapped and dated, thoroughly in some regions, sparsely in others. Thus, spatiotemporal limits reconstructed through joining geochronology (e.g., the ICE-D project; Balco, 2020) with detailed mapping (e.g., Leger et al., *CP discussions*) provide robust targets for comparison with ice-sheet model output. Here, we focus on comparing the geologic record with recent simulations of GrIS recession from ISSM.

To compare ISSM outputs against the geologic record, we first take a holistic approach and consider the entire Greenland-wide record of deglaciation through the Holocene. Each product that we compare – ISSM simulations and mapped extents from Leger et al. (*CP discussions*) – spans at least 12.5 ka - 7 ka, and we compare only the overlapping areal extent of the two products in this time frame. For each product, we calculate the total area of ice recession at evenly spaced time intervals every 0.5 kyr and determine the proportion of ice loss per time step by dividing the area lost at each step by the total overlapping areal extent. As a proof-of-concept, we start with only one ISSM output that uses climate forcing from Badgeley et al. (2020) and updated physically based parameterizations of calving and submarine melting at the ice-ocean boundary. In future steps, we will apply this workflow on a suite of ISSM simulations to assess each result against the geologic data.

Initial results from our workflow indicate, based on the geologic mapping, that steady but increasing retreat occurred from ~12.5 ka – 9 ka, with a somewhat steep decrease in the rate of recession following 9 ka. Recession rates simulated by ISSM appear to generally follow this trend as well, although the peak recession at ~10 ka is higher than from the geologic record and the decreasing rate of recession following ~10 ka is much sharper. Testing different simulations in the ISSM ensemble using the presented workflow will help us thoroughly explore how various simulated forcings impact the pattern of Greenland Ice Sheet recession through the Holocene.

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DID PRUDHOE DOME, NORTHWEST GREENLAND, DISAPPEAR DURING THE HOLOCENE?

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The Greenland Ice Sheet is the leading single contributor to present sea-level rise and is predicted to continue to be so for at least the next century. Accurate predictions of sea-level rise contribution from the Greenland Ice Sheet rely on knowledge of interactions between the ice sheet and climate beyond the satellite era. To this end, the GreenDrill project is testing the hypothesis that the northern Greenland Ice Sheet was more susceptible to past climate warming than southern portions by collecting transects of sediment and bedrock cores from the coast to under the ice sheet for cosmogenic nuclide and luminescence analyses.

We present a new infrared stimulated luminescence age from sediments collected from beneath the center of Prudhoe Dome (78.11, -70.81), an ice dome of the Greenland Ice Sheet in Inglefield Land, NW Greenland. We targeted Prudhoe Dome as it is hypothesized to be a key area for testing the response of the ice sheet to imminent warming and meets key drilling criteria: it is cold bedded, overlies crystalline, quartz-bearing bedrock, and <700 m thick. We chose a site near the center of Prudhoe Dome (1284 m asl) above a prominent rise to maximize the chances of collecting bedrock. We recovered a 7.4 m long core (~3 m of sediments overlying ~4.4 m of bedrock) using the Agile Sub-Ice Geologic (ASIG) drill, operated by the United States Ice Drilling Program, from under 509 m of ice. We collected the uppermost 10 cm of sediment in lightproof conditions and analyzed these using single grain post-infrared infrared stimulated luminescence. Our luminescence burial age records the deposition of sand grains after a period of sunlight exposure. We observe a Holocene burial age, precluding continuous ice cover throughout the Holocene. Our result instead requires that the drill site was exposed subaerially at some point during the Holocene, allowing for sediment mobilization and deposition. Prudhoe Dome then regrew to its present size sometime after this, before reaching its Little Ice Age maximum.

The disappearance of Prudhoe Dome during the Holocene is consistent with records showing that ice caps in northern Greenland were absent around the same period. Indeed, this is further supported by regional temperature records from northwest Greenland suggesting that Holocene Thermal Maximum summer temperatures were 3 – 4 ºC higher than the pre-Industrial. Our result indicates that parts of the northwestern Greenland Ice Sheet are dynamic and highly susceptible to climate warming.

EPISODIC NEOGLACIAL ADVANCES OF ØSTTUNGERNE ICE CAP, NORTHEAST GREENLAND FROM RADIOCARBON DATING OF ICE-MARGINAL SUBFOSSIL MOSS

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Using paleoclimate proxies to determine the timing of glacial advance and retreat contributes to our understanding of past climate change. The established method of radiocarbon dating of glacier-entombed plants at retreating ice margins is used to date past advances of small, cold-based glaciers. We collected ice-marginal subfossil Polytrichum moss samples to identify the timing of Neoglacial advances of Østtungerne, an 120 km^2 ice cap on Germania Land Peninsula, Northeast Greenland. We generated 10 new radiocarbon ages from 15 sites distributed around Østtungerne. The glacier advanced, killing moss at ~670 (n=2), ~1000 (n=3), and ~1780 (n=2) cal yr BP. Individual dates ~500, ~1200, and ~2200 cal yr BP may also indicate Neoglacial advances at these times due to agreement with previously published dates from other studies. Overall, there is agreement with other records of Neoglacial advances from Svalbard [2], Baffin Island [3], West Greenland [4], and Scoresby Sund [1], further indicating synchronicity of climate responses across the Arctic. We also find agreement with new radiocarbon ages (~2900 and ~2800 cal yr BP) from the organic/minerogenic sediment transition in Heart Lake, a nearby proglacial lake.

Map of Østtungerne ice cap with dates from ice-marginal subfossil moss

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A GLACIER THROUGH A GRAIN OF SAND: MICROMORPHOLOGY FOR A LAND-TERMINATING GLACIER IN WEST GREENLAND

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Isunnguata Sermia is a land terminating glacier in West Greenland with prominent upwellings of subglacial water in the outwash plain. This supercooled water freezes into layered accretions similar to naled ice. Sediment that is suspended in the upwelling water is preserved in the ice, creating a window into the subglacial environment. Due to the glacier's Holocene retreat and re-advance to its current position, (Carrivick et al., 2018), current moraine and outwash sediment deposits are likely at least partially sourced from previous proglacial deposits that were re-entrained and recycled. Sediment grains fracture and are abraded as they mature. The presence of certain established microtextures, such as those caused by fluvial or high-stress processes, is indicative of a grain's impact and transport history.

In order to characterize quartz microtextures, sediment samples were collected from different, semi-isolated depositional environments around Isunnguata Sermia to form 'endmembers': till samples from the glacial margin and end moraines, fluvial and aeolian samples from the outwash plain, regolith samples from the glacial valley wall. Samples collected from accreted ice cores represent the subglacial facies. An initial hypothesis of this work was that the selected endmembers would have distinct distributions of textures that can be used to interpret the sources of core sediment.

Twenty three sediment samples were given codes for blinded analysis, rinsed, and sieved to coarse-medium sand. Twenty five quartz grains per sample were picked at random for scanning electron microscopy (SEM) analysis. Following the texture classification indices of Mahaney (2002), Sweet and Soreghan (2010), and Sweet and Brannan (2016), presence data for observed microtextures through SEM imaging was recorded for 575 total grains. Four samples were analyzed in triplicate to estimate observational consistency.

Across the different glacial depositional environments and the accreted ice of Isunnguata Sermia, the microtexture distributions are extremely similar despite their different transport processes. In conjunction with the study site's de- and reglaciation, the sediment's similarity indicates a high degree of sediment recycling in a basin that includes both the subglacial and the proglacial environment. While the hypothesis that the different endmembers will have different texture distributions is not supported, these results can also be used to judge the viability of sediment microtexture analysis in close geographic proximity.

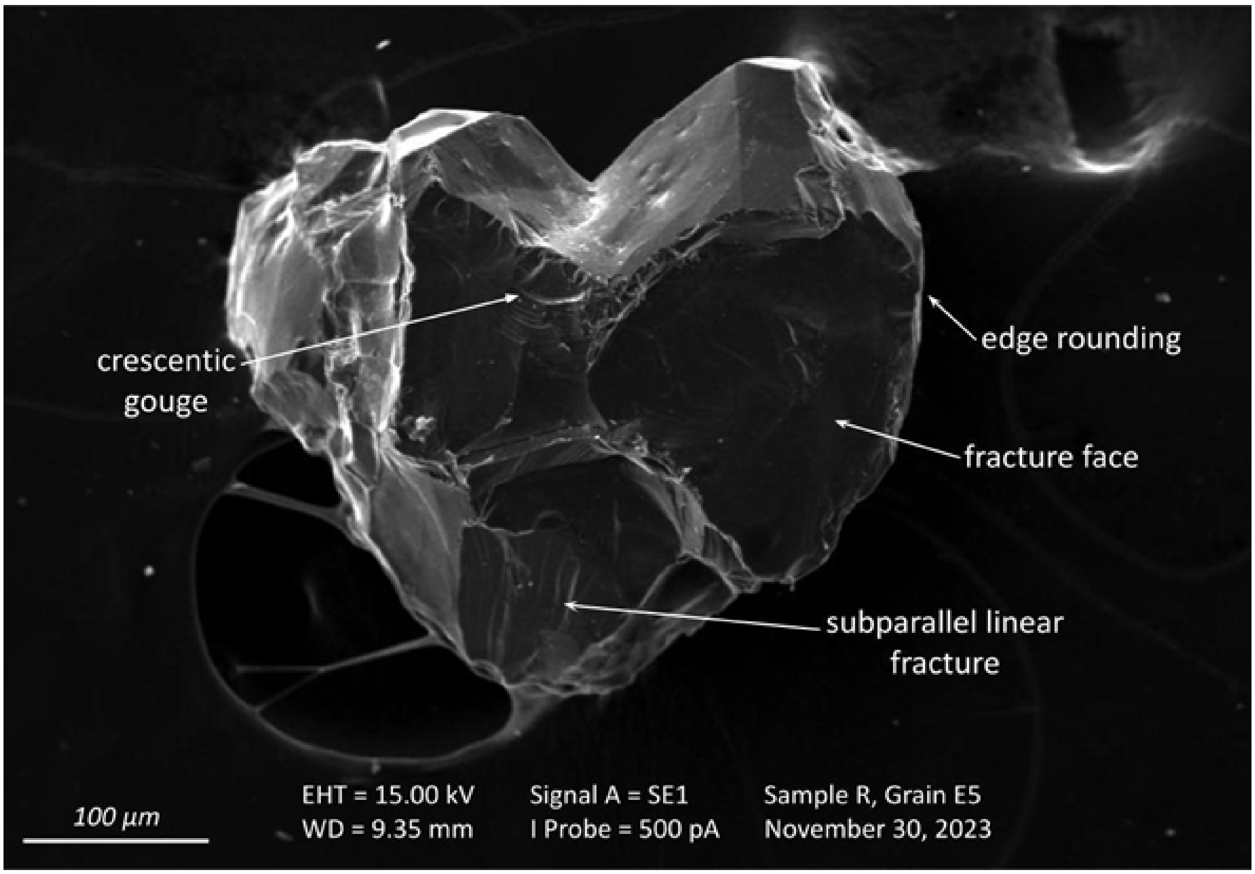

Figure caption: Annotated image of a quartz sand grain following the terminology of Mahaney (2002). Fracture faces and subparallel linear fracture are generic textures, edge rounding and crescentic gouges are associated with fluvial saltation and glacial comminution respectively. Imaged with a IUI's ZEISS EVO-10 in secondary electron mode. Grain is from an accreted ice core.

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NEW EVIDENCE FOR THE PRE-LGM HUMAN MIGRATION TO THE AMERICAS FROM THE LONGEST SEDIMENTARY RECORD OF ARCTIC NORTH AMERICA

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The Americas were the final continents to be colonized by *Homo sapiens*. Migration via the Bering Land Bridge is agreed upon, but the timing is heavily debated. Microblade artifacts from human settlement sites have radiocarbon ages which point to migration between 14,000 to 15,000 years ago, prior to the complete submergence of the Bering Strait due to postglacial sea level rise. However, genomic data point to a genetic divergence of the ancestors of modern Native Americans from east Asians occurring ca. 25 – 24 ka. forming the basis for the Beringia Standstill Hypothesis. More recently, the discovery of human footprints in White Sands in New Mexico dated to 23 ka. reignited the debate on the arrival timing of Homo sapiens in the Americas. Fire and fecal sterol records from lakes in northern Alaska suggest human presence in Beringia beginning ~ 36,000 years ago, but the validity of fire as evidence of humans in Alaska is debated, as climatic factors influence fire frequency and severity.

Testing the utility of fires to detect human activity in northern Alaska requires records from the previous glacial (Marine Isotope Stage 6, 191-130 ka.), prior to the arrival of *Homo sapiens* in the Americas. We present a high-resolution reconstruction of fires and human presence using polycyclic aromatic hydrocarbon (PAH) and coprostanol biomarkers, respectively, from Imuruk Lake in northwest Alaska. Our record is one of the longest continuous sedimentary records in Arctic North America, spanning the past 240,000 years, and contains sediment deposited continuously during MIS 6. We document a 3.5-fold sustained increase in the average PAH flux during MIS 2 (29 – 14 ka.) compared with MIS 3 (57 – 29 ka.), similar to our previous findings. No such sustained increase in PAH flux is observed during MIS 6; rather, we observed elevated fire levels during warmer periods and associated with volcanic eruptions such as those that formed the Old Crow tephra. In addition, there was a sudden increase in the coprostanol:cholesterol ratio at ca. 21.5 ka., suggesting the presence of early *Homo sapiens* at Imuruk Lake at that time. An elevated value of the ratio was also detected at ca. 48.8 ka. Taken together, our records from Imuruk Lake suggest the increase in fire and fecal biomarkers during the last ice-age result from the arrival of *Homo sapiens* during the LGM. However, *Homo sapiens* could have been present in the region during early MIS 3, ca. 49 ka. The spread of ages of *Homo* sapiens arrival, ranging from as early as 49 ka. to as late as 14 ka. suggests that early migration in Beringia was unlikely to be a singular event in time and space. Early *Homo sapiens* were likely nomadic, moving in search of prey and other resources.

INVESTIGATING AQUATIC PLANT LEAF WAX PRODUCTION AND HYDROGEN ISOTOPE FRACTIONATION BETWEEN ARCTIC AND TEMPERATE LAKES

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Leaf waxes, including *n*-alkanoic acids and *n*-alkanes, and their compound-specific stable isotopes in aquatic plants play an important role in paleoclimate reconstructions. Leaf wax stable hydrogen isotopic composition (δD) can provide essential information about past lake water hydrology, and in turn climate change. However, different types of aquatic plants within the same lake may have varying leaf wax distributions and may fractionate hydrogen isotopes differently during biosynthesis (biosynthetic fractionation). Additionally, environmental factors along large environmental gradients from temperate to Arctic regions may influence chain-length distributions and biosynthetic fractionation. Despite the importance of aquatic plant leaf waxes, only a few scattered studies have analyzed their chain-length distributions and hydrogen isotope fractionation. To address this knowledge gap, we collected aquatic plant samples from three different sites, each in a separate bioclimate: Saddle Lake, eastern Baffin Island (*n* = 4), East Essowah and Noyes Lake, Southeast Alaska (*n* = 4), and Red Pond, Western New York (*n* = 13). Our samples cover three different plant growth forms: forbes, graminoids, and mosses, and two different aquatic habits: emergent/floating and submerged. The average chain-length (ACL) of emergent/floating (24.3/26.4; *n*-alkanoic acids/*n*-alkanes) and submerged aquatic plants (25.4/25.8) are relatively close in range, suggesting that leaf wax production is similar between different aquatic plant habitats. We calculated the apparent fractionation (ε_{app}) between aquatic plant *n*-alkanoic acids and lake water δD values. Emergent and floating aquatic plants display an average ε_{app} of -124.3 ± 18.2 ‰ (*n* = 15). Emergent and floating aquatic plants have their roots and stems in the water but their leaves are exposed, causing evapotranspiration and δD enrichment. Submerged aquatic plants have an average ε_{app} of -149.5 ± 13.8 ‰ (*n* = 6). These aquatic plants are below the surface of water and are subject to no direct evapotranspiration, resulting in a larger apparent fractionation compared to floating/emergent aquatic plants. We observed that ε_{app} is more depleted in northern bioclimates (Red Pond ε_{app} = -121.8 ± 15.4 ‰, Southeast Alaska = -138.4 ± 20.3 ‰, Saddle Lake = -155.8 ± 12.2‰) which may be due to the change in plant types from forbs and graminoids to mosses. This dataset improves our understanding of the variability in modern aquatic plant leaf wax production and hydrogen isotope fractionation for future paleoclimate reconstructions using these proxies.