PROGRAM & ABSTRACTS

44TH INTERNATIONAL

Arctic Workshop 2014

15-16 MARCH

BOULDER, COLORADO

Division of Polar Programs
National Science Foundation

Institute of Arctic & Alpine Research
University of Colorado at Boulder

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Cover photo:

"Studying erosion rates on Baffin Island". Kurt Refsnider evaluates a rock outcrop, searching for an optimal site to sample for cosmogenic radionuclide analysis to evaluate long-term erosion rates. August 2013. Photo Credit: Matthew Kennedy (Earth Vision Trust).

PROGRAM AND ABSTRACTS

44th ANNUAL INTERNATIONAL ARCTIC WORKSHOP

March 15 - 16, 2014

Boulder, Colorado

INSTAAR
Institute of Arctic and Alpine Research
University of Colorado, Boulder

Organizing Committee:

Gifford Milller
Wendy Roth
David Lubinski
Anne Jennings

Introduction

Overview and history

The 44th Annual International Arctic Workshop will be held March 15 - 16, 2014, on the campus of the University of Colorado, Boulder. The meeting is sponsored and 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 and sponsored by INSTAAR and other academic institutions worldwide.

2014 Theme

"ARCTIC'S NEW NORMAL - shifting environmental baselines over decades to millennia and comparisons with the Antarctic".

Web site

http://instaar.colorado.edu/meetings/AW2014

Check-In / Registration

Please check in or register on (1) Friday evening at the Icebreaker/Reception between 4:30 – 7:30 pm in INSTAAR building RL-1 rm 269 (1560 30th Street), or (2) Saturday morning between 7:40 – 8:00 am in the MacAllister building (4001 Discovery Drive). At registration you will receive the Program and Abstracts, as well as other materials.

MacAllister Building

This building will be part of INSTAAR's future home in SEEC (Sustainability, Energy, and Environment Complex). The building is actively under construction; so, for your own safety and our liability, do not explore beyond the bounds of the Workshop. Thanks.

Wi-Fi

Wireless internet access is available in the lobby, but not in the conference room.

Posters

At registration you will receive information on where to set up your poster. Please put it up as early as possible, and leave it up as late as possible during the workshop.

Presentation Files (i.e., PowerPoint)

Please load your presentation onto our computer during the Icebreaker/Reception on Friday 4:30 – 7:30 pm or the Check-In/Registration on Saturday 7:40 – 8:00 am. Time during breaks is limited.

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 2014
Program Summary

FRIDAY 14 MARCH		
4:30 – 7:30	**Evening reception, Check-In, Registration** (load presentations onto computer)	*INSTAAR RL-1 room 269*

SATURDAY 15 MARCH		
7:40 – 8:00	**Check-in & Registration** (load presentations onto computer)	*MacAllister Conf Rm*
8:00	**Welcome & Introduction**	“
8:10	**Arctic Old Normal I**	“
9:25	Morning Break	“
9:45	**Arctic New Normal I**	“
10:45	Second Morning Break	-
11:00	**Arctic New Normal II**	“
12:30 pm	LUNCH buffet provided	*MacAllister Cafeteria*
1:45	**Arctic New Normal III**	*MacAllister Conf Rm*
3:00	Afternoon Break	
3:00	**POSTERS I (odd numbered posters)**	“
5:00	End of Day	“
6:00	Student-only Pizza Party	*Boulder Inn (Green Rm)*

SUNDAY 16 MARCH		
8:30	**Announcements**	*MacAllister Conf Rm*
8:45	**Arctic Old Normal II**	“
9:45	Morning Break	“
10:00	**POSTERS II (even numbered posters)**	“
12:00 pm	LUNCH buffet provided	*MacAllister Cafeteria*
1:15	**Arctic New Normal IV**	*MacAllister Conf Rm*
2:15	Afternoon Break	“
2:30	**Arctic Old Normal III**	“
3:45	Closing Comments	“
4:00	End of Meeting	“

Program Details

PM - FRIDAY 14 MARCH 2014

4:30 to 7:30 **Evening Reception, Check in, & Registration** (*INSTAAR RL-1 269*)
Snacks and drinks will be served, including wine;
load presentations onto computer.

AM – SATURDAY 15 MARCH 2014

7:40 **Check-in & Registration** (*MacAllister Conference Room*)
(Load presentations onto our computer, put up posters)

8:00 **Workshop Welcome & Introduction** (*MacAllister Conference Room*)

Arctic Old Normal I
Chair: Anne Jennings

8:10 **BASALT AS A TRACER OF DIFFERENCES IN GLACIAL EROSION AND TRANSPORT---EAST VERSUS WEST GREENLAND ~ 70°N**
Andrews, John T; Eberl, Dennis D; Jennings, Anne E [pg 13]

8:25 **INCREASED SURFACE MELT APPEARS TO STIMULATE SILICATE WEATHERING UNDER THE GREENLAND ICE SHEET**
Graly, Joseph A; Humphrey, Neil F; Landowski, Claire M; Harper, Joel T [pg 52]

8:40 **ICE SHEET EROSIONAL IMPACTS IN THE LOW-RELIEF SHIELD TERRAIN OF NORTHERN FENNOSCANDIA**
Ebert, Karin; Hall, Adrian M; Kleman, Johan [pg 42]

8:55 **PLIOCENE/PLEISTOCENE INTERGLACIALS AND INTER-HEMISPHERIC POLAR LINKAGES SUGGESTED BY THE ARCTIC LAKE EL'GYGYTGYN PALEOCLIMATE RECORD OF THE PAST 3.6 MYRS**
Brigham-Grette, Julie; Melles , Martin; Minyuk, Pavel; Andreev, Andrej; Tarasov, Pavel; Deconto, Rob; Lozhkin , Anatoly; , et al. [pg 33]

9:10 **IS ECCENTRICITY THE PACEMAKER FOR ARCTIC PALEOCLIMATE DURING THE QUATERNARY?**
Ortiz, Joseph D.; O'Regan, Matt; Jakobsson, Martin [pg 92]

9:25 ☕ Morning Break

AM – SATURDAY 15 MARCH 2014

Arctic New Normal I

Chair: Martin Miles

9:45 **IMPACTS OF FUTURE SEA-ICE AND SNOW-COVER CHANGES ON CLIMATE, GREEN GROWTH AND SOCIETY (GREENICE)**

Ogilvie, Astrid E. J.; Einarsson, Niels; Keenlyside, Noel [pg 89]

10:00 **THE EFFECT OF CHANGING SEA ICE ON THE VULNERABILITY OF ARCTIC COASTS**

Barnhart, Katherine R; Anderson, Robert S; Overeem, Irina [pg 24]

10:15 **WIND-DRIVEN PROCESSES IN THE SURFACE LAYER OF THE MARGINAL ICE ZONE**

Bradley, Alice C; Palo, Scott; Maslanik, James; LoDolce, Gabriel; Weibel, Douglas; Lawrence, Dale [pg 30]

10:30 **CHANGES IN SEA ICE ALONG THE ARCTIC NORTHEAST PASSAGE SINCE 1979: RESULTS FROM REMOTE SENSING DATA**

Lei, Ruibo; Leppärantab, Matti; Wang, Jia; Xie, Hongjie; Jónsdóttir, Ingibjörg [pg 73]

10:45 Second Morning Break

Arctic New Normal II

Chair: Aslaug Geirsdottir

11:00 **ARCTIC BRYOPHYTE STABILITY THROUGH TIME WITH IMPLICATIONS FOR REFUGIA**

La Farge, Catherine [pg 70]

11:15 **EXPANSION DYNAMICS OF CROWBERRY (EMPETRUM HERMAPHRODITUM) ON SUBARCTIC SAND DUNES**

Angers-Blondin, Sandra; Boudreau, Stéphane [pg 15]

11:30 **CLIMATIC DRIVERS OF BETULA GLANDULOSA GROWTH IN SUBARCTIC QUÉBEC, CANADA**

Ropars, Pascale; Lévesque, Esther; Boudreau, Stéphane [pg 114]

11:45 **BIOGEOCHEMICAL CHANGE IN THE ARCTIC & SOUTHERN OCEANS: TRENDS IN ATMOSPHERIC OXYGEN (O2/N2) & SATELLITE OCEAN COLOR DATA**

Nevison, Cynthia; Keeling, Ralph; Kahru, Mati; Manizza, Manfredi [pg 85]

12:00 **THE CHUKCHI SEA ECOSYSTEM: ASSESSMENT OF CONTEMPORARY CONDITIONS AND VULNERABILITY TO POTENTIAL OIL SPILLS**

Kirievskaya, Dubrava [pg 65]

12:15 **THE POSSUM CAMPAIGN: POLAR SUBORBITAL SCIENCE IN THE UPPER MESOSPHERE**

Reimuller, Jason D; Fritts, Dave; Thomas, Gary E; Mitchell, Steve; Taylor, Mike; Lehmacher, Gerald; Sternovsky, Zoltan [pg 109]

12:30 **LUNCH BUFFET PROVIDED** (MacAllister Cafeteria)

PM – SATURDAY 15 MARCH 2014

Arctic New Normal III

Chair: Julie Brigham-Grette

1:45 **THE GREENLAND ICE SHEET - 80 YEARS OF CLIMATE CHANGE SEEN FROM THE AIR**

Bjørk, Anders A; Kjær, Kurt H; Larsen, Nicolaj K; Kjeldsen, Kristian K; Khan, Shfaqat A; Funder, Svend V; Korsgaard, Niels J [pg 28]

2:00 **DYNAMIC TERMINUS FLUCTUATIONS OF LANGJÖKULL ICE CAP DURING THE LITTLE ICE AGE**

Larsen, Darren J; Miller, Gifford H; Geirsdóttir, Áslaug [pg 72]

2:15 **EMERGENT DEAD VEGETATION CONSTRAINTS ON ICE CAP ACTIVITY, SOUTHERN BAFFIN ISLAND, NUNAVUT, ARCTIC CANADA**

Pendleton, Simon L; Miller, Gifford H [pg 102]

2:30 **LATE HOLOCENE EXPANSION OF LOCAL COLD-BASED ICE CAPS IN CENTRAL WEST GREENLAND**

Schweinsberg, Avriel D; Briner, Jason P; Miller, Gifford H; Bennike, Ole; Lifton, Nathaniel [pg 118]

2:45 **RECONSTRUCTING HOLOCENE SNOWLINE DECLINE ON SVALBARD, ARCTIC NORWAY, FROM THE 14C AGES OF ENTOMBED PLANTS**

Miller, Gifford; Landvik, Jon; Lehman, Scott [pg 81]

3:00 Afternoon Break

PM – SATURDAY 15 MARCH 2014

Poster Session I (odd numbers) 3:00 – 5:00 pm

1 **PALEOLIMNOLOGICAL RECORDS OF LAST INTERGLACIAL (?), LATE GLACIAL AND HOLOCENE CLIMATE AND ENVIRONMENTAL CHANGE IN NORTHWEST GREENLAND**

Axford, Yarrow; Kelly, Meredith A; Osterberg, Erich C; Francis, Donna R; Roy, Ellen; Richter, Nora; Farnsworth, Lauren; , et al. [pg 20]

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3 **ULTRA HIGH-RESOLUTION RECORD OF HOLOCENE CLIMATE VARIABILITY IN THE SE NORWEGIAN SEA**

Becker, Lukas W.M.; Sejrup, Hans Petter; Haflidason, Haflidi; Hjelstuen, Berit O.; Ólafsdóttir, Sædís [pg 25]

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5 **A 3000 YEAR MULTI-PROXY RECORD OF ENVIRONMENTAL CHANGE FROM GRIPDEILD, EASTERN ICELAND**

Bergþórsdóttir, Halldóra B; Geirsdóttir, Áslaug; Miller, Gifford H [pg 27]

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7 **TESTING MASSIVE ARCTIC SEA ICE EXPORT AS A TRIGGER FOR ABRUPT CLIMATE CHANGE**

Coletti, Anthony J; Condron, Alan; Bradley, Raymond S [pg 36]

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9 **CONSTRAINING THE TIMING AND DURATION OF EARLY HOLOCENE AND EARLY NEOGLACIAL ADVANCES ON BAFFIN ISLAND, ARCTIC CANADA**

Crump, Sarah E.; Miller, Gifford H. [pg 40]

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11 **GEOCHEMICAL AND STRATIGRAPHIC ANALYSIS OF THE LINNÉVATNET SEDIMENT RECORD: A PROVENANCE STUDY OF LATE HOLOCENE CIRQUE GLACIER ACTIVITY IN LINNÉDALEN, SPITSBERGEN, SVALBARD.**

Edwards, Graham H [pg 43]

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13 **RESPONSE OF THE ISOTOPIC COMPOSITION OF ARCTIC PRECIPITATION TO CHANGES IN SEA ICE EXTENT**

Faber, Anne-Katrine; Vinther, Bo M.; Sjolte, Jesper [pg 48]

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15 **A TWO-THOUSAND YEAR RECORD OF NORTHERN ICELAND LATE HOLOCENE COOLING FROM LAKES BÆJARVÖTN AND TORFADALSVATN**

Florian, Christopher R; Crump, Sarah E; Geirsdóttir, Áslaug; Miller, Gifford H; Zalzal, Kathryn S [pg 51]

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17 **ESTIMATION OF THE PERMAFROST CARBON FEEDBACK USING SIBCASA TERRESTRIAL CARBON CYCLE MODEL**

Jafarov, Elchin; Schaefer, Kevin; Watts, Jennifer [pg 60]

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19 **VALIDATION SYSTEM AND COMPREHENSIVE IN SITU TESTS OF POLAR REMOTE SENSING**

Li, Bingrui; Li, Qun; Li, Na; Lei, Ruibo [pg 76]

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21 **DIATOMS AS INDICATORS OF ICE EXTENT IN THE BERING SEA**

Nesterovich, Anna; Caissie, Beth [pg 82]

PM – SATURDAY 15 MARCH 2014

Poster Session I (odd numbers) – continued 3:00 – 5:00 pm

23 **A DEVELOPMENTAL APPROACH TO UNDERSTANDING REINDEER FORAGE AVAILABILITY IN RESPONSE TO TEMPORAL CHANGES IN REINDEER MIGRATION IN N. NORWAY**
Odasz, Ann Marie [pg 88]

25 **DEGLACIATION CHRONOLOGY IN THE CENTRAL UUMMANNAQ FJORD SYSTEM (WESTERN GREENLAND) DURING THE HOLOCENE – PRELIMINARY RESULTS**
Philipps, William; Briner, Jason P.; Schweinsberg, Avriel; Bennike, Ole [pg 104]

27 **MULTIPROXY STUDY OF LAMINATED GLACIOLACUSTRINE SEDIMENTS IN LINNEVATNET, WEST SPITSBERGEN, SVALBARD**
Retelle, Mike; Dowey, Colin; McCabe, Christiane [pg 110]

29 **BRIDGING THE WORK OF FIELD SCIENTISTS AND THE NEEDS OF DATA RE-USERS**
Rosati, Antonia; Yarmey, Lynn [pg 117]

31 **BUILDING CONSTITUTIVE RELATIONSHIPS BETWEEN TEMPERATURE, ELECTRICAL RESISTIVITY AND HYDRAULIC CONDUCTIVITY TO IMPROVE FIELD-SCALE ASSESSMENTS OF PERMAFROST**
Voytek, Emily; Singha, Kamini [pg 122]

33 **TO UNDERSTAND THE ARCTIC'S NEW NORMAL, YOU FIRST NEED TO FIND OLD DATA**
Yarmey, Lynn; Khalsa, Siri Jodha; Rosati, Antonia [pg 124]

5:00 **END OF DAY**

6:00 **Student-only Pizza Party** (Boulder Inn, Green Room), Beer will be served.

AM – SUNDAY 16 MARCH 2014

8:30 Announcements (*MacAllister Conference Room*)

Arctic Old Normal II

Chair: Joe Ortiz

8:45 **A STRATIGRAPHIC APPROACH TO CALIBRATE THE TIMING OF ICE DISCHARGE EVENTS IN HUDSON STRAIT AND HUDSON BAY AND TO DEVELOP A TEMPLATE FOR FRESHWATER FORCING FROM THE HUDSON STRAIT OUTLET INTO THE SUBPOLAR GYRE FROM 13-7 CAL KA BP**

Jennings, Anne E.; Andrews, John T.; Pearce, Christof [pg 61]

9:00 **MASSIVE SUBTROPICAL ICEBERGS AND FRESHWATER FORCING OF CLIMATE**

Condron, Alan; Hill, Jenna [pg 37]

9:15 **WEAKENING OF THE NORTH ATLANTIC OSCILLATION FROM THE EARLY TO THE LATE HOLOCENE**

Quillmann, Ursula; Jennings, Anne E; Marchitto, Tom M; Andrews, John T; Anderson, David M [pg 108]

9:30 **THE ENVIRONMENTAL EVOLUTION OF THE NORTHWEST PASSAGE: DEGLACIATION TO PRESENT**

Pienkowski, Anna J.; Furze, Mark F.A.; England, John; MacLean, Brian; Blasco, Steve; McNeely, Morgan [pg 106]

9:45 ☕ Morning Break

Poster Session II (even numbers) 10:00 – 12:00

2 **A LATE-HOLOCENE PALEOENVIRONMENTAL RECONSTRUCTION OF LINNÉVATNET, SVALBARD USING GEOCHEMICAL AND PRODUCTIVITY PROXIES**

Balter, Alexandra; Richter, Nora; Retelle, Michael; Edwards, Graham [pg 21]

4 **CONCORDANT 10BE/26AL AGES FROM HIGH-ELEVATION PLATEAUS, UUMMANNAQ FJORD REGION, WESTERN GREENLAND**

Beel, Casey R; Lifton, Nathaniel A; Briner, Jason P; Miller, Gifford H; Goehring, Brent M [pg 26]

6 **DETERMINATION OF BAFFIN BAY SEDIMENT COMPOSITION AND PROVENANCE**

Brenner, Alan R; Jennings, Anne E; Ortiz, Joseph D; Ó Cofaigh, Colm [pg 31]

8 **MICROPHYSICS AND PREVALENCE OF SURFACE-BASED CLOUDS AT SUMMIT STATION, GREENLAND: 2012-2013**

Cox, Christopher J.; Noone, David; O'Neill, Michael; Walden, Von P.; Shupe, Matthew D.; Berkelhammer, Ma [pg 38]

AM – SUNDAY 16 MARCH 2014

Poster Session II (even numbers) continued 10:00 – 12:00

10 **CONFIRMATION OF THE USE OF FTIR SPECTROSCOPY TO DETERMINE BIOGENIC SILICA CONTENT OF ARCTIC LAKE SEDIMENTS: A POWERFUL TOOL FOR HIGH-RESOLUTION PALEOCLIMATE RECONSTRUCTIONS**

de Wet, Greg; Davin, Sam; Bradley, Raymond; Balascio, Nicholas [pg 41]

12 **A PILOT STUDY OF THE EXTENT AND VARIATIONS IN MELTWATER PLUMES AND ICEBERGS EMANATING FROM NE GREENLAND TIDEWATER GLACIERS**

Eggering, Kenneth; Hudson, Benjamin; Andrews, John; Overeem, Irina [pg 45]

14 **A NEW NORMAL FOR THE SEA ICE INDEX**

Fetterer, Florence; Windnagel, Ann; Meier, Walter N. [pg 49]

16 **A PHYSICAL AND MINERALOGICAL STUDY OF SAND DEPOSITS IN THE SUMBURGH AND QUENDALE AREAS OF THE SHETLAND ISLANDS, UK**

Halsted, Christopher T; Retelle, Michael; Bigelow, Gerald [pg 54]

18 **A 2000 YEAR RECORD OF MARINE CLIMATE VARIABILITY FROM ARNARFJÖRÐUR, NW ICELAND**

Jónsdóttir, Ingibjörg R; Ólafsdóttir , Sædís; Geirsdóttir , Áslaug [pg 63]

20 **THE INTER-ANNUAL PICOPHYTOPLANKTON DISTRIBUTION: AN INDICATION OF ENVIRONMENTAL CHANGE OF BERING SEA**

Lin, Ling; Zhang, Fang; He, Jianfeng [pg 78]

22 **FOUR DECADES OF TEMPERATURE CHANGE AT SUMMIT, GREENLANDD**

Noone, David; Cox, Christopher J; Berkelhammer, Max; O'Neil, Michael [pg 86]

24 **POST-LGM PROVENANCE AND FLOW REGIME RECONSTRUCTION FOR THE BERING/ CHUKCHI SEAS THROUGH SEDIMENTOLOGICAL AND GEOCHEMICAL EVIDENCE**

Pelto, Ben M; Kocis , James J; Brigham-Grette, Julie; Petsch, Steven [pg 99]

26 **EARLY HOLOCENE ATLANTIC WATER INFLOW INTO THE CANADIAN ARCTIC ARCHIPELAGO: THE PLANKTONIC FORAMINIFERA (NEOGLOBOQUADRINA PACHYDERMA) SIGNAL**

Pienkowski, Anna J.; Furze, Mark F.A.; John, England; MacLean, Brian; Blasco, Steve [pg 107]

28 **LATE HOLOCENE PALEOCLIMATE RECONSTRUCTED FROM SEDIMENT GEOCHEMISTRY AND CHIRONOMID REMAINS, LAKE LINNÉVATNET, SVALBARD, NORWAY**

Richter, Nora; Balter, Alexandra; Axford, Yarrow; Retelle, Michael [pg 112]

30 **RECORDING ARCTIC ENVIRONMENTAL CHANGE: USE OF TECHNOLOGY BY INDIGENOUS PEOPLE**

Sheffield, Betsy; McCann, Heidi; Wallace, Allaina; McNeave, Chris; Collins, Julia; Pulsifer, Peter; Duerr, Ruth; , et al. [pg 119]

32 **BOTTOM WATER MG/CA RATIOS IN THE ARCTIC GATEWAY – NEW RESULTS FROM *C. WUELLERSTORFI* IN THE FRAM STRAIT**

Werner, Kirstin; Marchitto, Thomas M.; Not , Christelle; Husum, Katrine; Spielhagen, Robert F. [pg 123]

PM – SUNDAY 16 MARCH 2014

12:00 pm **LUNCH BUFFET PROVIDED** (MacAllister Cafeteria)

Arctic New Normal IV

Chair: Astrid Ogilvie

1:15 **RESPONSE OF GREENLAND RIVER SYSTEMS TO MODELED ICE SHEET MELT**

Overeem, Irina; Hudson, Benjamin; Mikkelsen, Andreas; van der Broeke, Michiel; Rennermalm, Asa [pg 96]

1:30 **THE GREENLAND ICE SHEET'S ROLE IN SETTING RIVER AND FJORD SUSPENDED SEDIMENT CONCENTRATION: A TEST CASE FROM TWO WEST GREENLAND RIVERS**

Hudson, Ben; Overeem, Irina; Syvitski, James; Mikkelsen, Andreas [pg 58]

1:45 **THE IMPORTANCE OF ICE FACE BACKWASTING ON THE THINNING OF THE DEBRIS-COVERED KENNICOTT GLACIER TERMINUS, WRANGELL MOUNTAINS, ALASKA**

Anderson, Leif S; Armstrong, William H; Anderson, Robert S [pg 11]

2:00 **ESTIMATING GLACIER THICKNESS FROM REMOTELY SENSED- AND GPS-DERIVED GLACIER VELOCITIES AND ICE DYNAMICS MODELING: A CASE STUDY ON THE KENNICOTT GLACIER, ALASKA, USA.**

Armstrong, William H; Allen, Jeffery; Anderson, Leif S; Anderson, Robert S; Rajaram, Harihar [pg 17]

2:15 Afternoon Break

PM – SUNDAY 16 MARCH 2014

Arctic Old Normal III

Chair: Jason Briner

2:30 **A CENTENNIAL-RESOLUTION HOLOCENE LEAF WAX HYDROGEN ISOTOPE RECORD FOR DISKO BUGT, WESTERN GREENLAND**

Thomas, Elizabeth K.; Ryan-Henry, John; Briner, Jason P.; Huang, Yongsong [pg 120]

2:45 **CLIMATE CHANGE AND THE PHYSICAL LIMNOLOGY OF LAKE VANDA, ANTARCTICA: PAST, PRESENT AND FUTURE SCENARIOS**

Castendyk, Devin; Hawes, Ian; Sumner, Dawn; Mackey, Tyler; Jungblut, Anne [pg 35]

3:00 **LATE HOLOCENE CLIMATE DEVELOPMENT OF BJØRNØYA (SVALBARD, NORWAY) BASED ON CHIRONOMID ANALYSIS - PRELIMINARY RESULTS**

Kivilä, Henriikka; Hormes, Anne; Luoto, Tomi P [pg 66]

3:15 **LATE HOLOCENE HYDROCLIMATE VARIABILITY INFERRED FROM SEDIMENTS OF TWO LAKES ON ADAK ISLAND, ALASKA**

Krawiec, Anne C; Vaillencourt, David A; Kaufman, Darrell S; D'Andrea, William J [pg 67]

3:30 **RECONSTRUCTING HOLOCENE CLIMATE AND GLACIAL EXTENT OF DRANGAJÖKULL, VESTFIRÐIR, ICELAND**

Harning, David; Geirsdóttir, Áslaug; Miller, Gifford [pg 57]

3:45 Closing Comments, Discussion about location of Arctic Workshop in 2015

4:00 **END OF MEETING** – THANKS FOR ATTENDING!

Notes

THE IMPORTANCE OF ICE FACE BACKWASTING ON THE THINNING OF THE DEBRIS-COVERED KENNICOTT GLACIER TERMINUS, WRANGELL MOUNTAINS, ALASKA

Anderson, Leif S [1]; **Armstrong**, William H [2]; **Anderson**, Robert S [3]

[1] University of Colorado/ INSTAAR; leif@colorado.edu
[2] University of Colorado/ INSTAAR;
[3] University of Colorado/ INSTAAR;

Debris covered glaciers are common in high-relief ranges where headwall erosion rates are large (e.g. Kirkbride, 2011). Currently, most debris-covered glaciers are adjusting to a period of negative mass balance and are therefore retreating. To mitigate the effects of this retreat, we need to understand how debris affects glacier terminal dynamics. When debris is greater than 2 cm thick, ice melt declines non-linearly. This can profoundly affect melt rates and should therefore suppress the thinning rate and the pattern of terminus retreat. Debris-covered glacier mass balance is complicated by strong local variability of debris thickness and by the backwasting of exposed ice faces, which tend to retreat at high rates relative to sub-debris melt rates.

In order to constrain the effects of sub-debris melt and ice face backwasting on glacier retreat, we documented patterns of melt rate on the terminal lobe of the Kennicott Glacier, and documented its surface velocities. The 26 km^2 of debris-covered ice in the terminus region of this valley glacier sports a high areal concentration of ice faces (34,000 total). Both laser altimetry and DEM differencing from repeat satellite imagery show that surface elevations have decreased in the debris-covered terminus by 1-2 m/yr (47 to 94 m from 1957-2000) while the glacier has only retreated 500 m (Das et al., in press). The deflation of the debris-covered terminus is the result of either reduced ice advection from up glacier or increased melt in the debris-covered terminus over the last half-century.

In order to understand the rapid surface elevation reduction, we 1) document melt beneath debris of variable thickness at 60 locations in the study area and debris thicknesses at 180 locations; 2) document the horizontal retreat of 62 ice faces; 3) digitize ice face geometry using a 2009 WorldView image; 4) model the summer balance of the glacier terminus using a positive degree day approach; and 5) determine glacier terminus surface velocities using WorldView, Landsat, and Aster imagery. We find that approximately 50% of the 2011 total summer melt in the debris-covered terminus is attributed to ice wall retreat. The pattern of surface elevation loss from 1957 to 2000 and from 2000 to 2007 mirrors the pattern of vertical melt produced by ice wall retreat, which suggests that surface elevation loss is at least partially paced by ice face retreat (Figure 1).

We also find that the distribution of ice faces and debris-covered glacier surface relief is controlled by mean debris thickness (Figure 2). Because of the non-linear nature of the melt to debris thickness relationship, thinner debris-cover results in greater changes in melt rate for a unit change in debris thickness, resulting in greater local melt rate differences and relief production. On the Kennicott Glacier, debris thicknesses less than 10 cm result in the majority of relief production in the study area. Future efforts will constrain the ice thickness in the terminal region in an effort to close the continuity equation and understand the coupling between debris-cover modulated ablation and the ice dynamics of retreating debris-covered glaciers.

Das, I., Hock, R., Berthier, E., Lingle, C.S., in press, 21st century increase in glacier mass balance loss in the Wrangell Mountains, Alaska from airborne laser altimetry and satellite stereo-imagery: Journal of Glaciology

Kirkbride, M.P., 2011, Debris-covered glaciers. In Singh V.P., Singh P. and Haritashya U.K. eds. Encyclopedia of snow, ice and glaciers. Springer, Dordrecht, p. 190–191

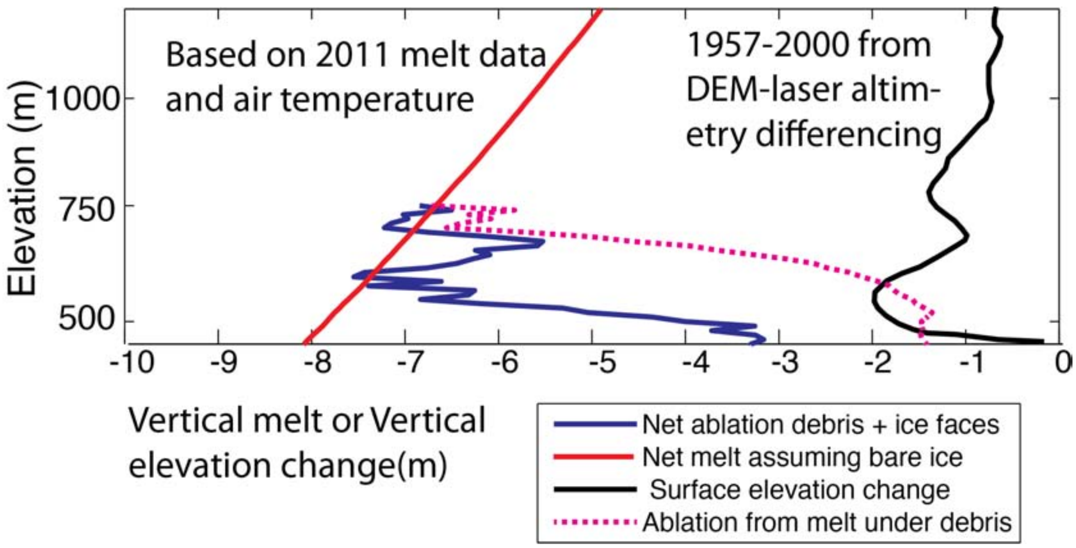

Fig 1. Net summer balance of the debris-covered portion of the Kennicott Glacier. Notice the similarity between the net ablation profile and the surface elevation change profile. The difference between the net mass balance profile and the surface elevation change profile is the ice emergence velocity.

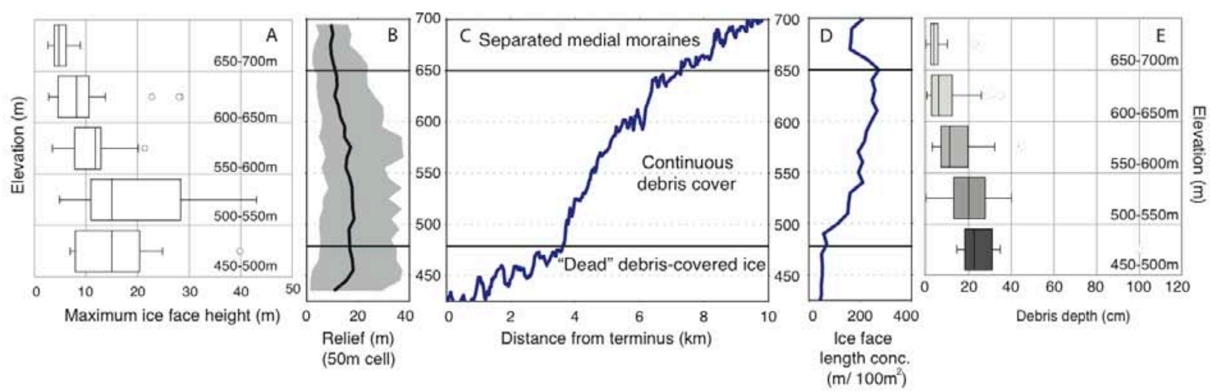

Fig 2. Plots comparing the Kennicott Glacier ice surface profile to several relevant data sets. A) Measured maximum ice face height, binned by elevation. B) Glacier surface relief within a 50m cell for a swath profile down the center of the glacier. Black line is the mean relief and the grey shading shows the range relief for each elevation band. C) Kennicott Glacier ice surface profile. D) Ice face length concentration per 100 m^2 with elevation. E) Measured and binned supraglacial debris thickness.

BASALT AS A TRACER OF DIFFERENCES IN GLACIAL EROSION AND TRANSPORT---EAST VERSUS WEST GREENLAND ~ 70°N

Andrews, John T [1]; **Eberl**, Dennis D [2]; **Jennings**, Anne E [3]

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The early Tertiary basalt outcrop on East and West Greenland cover 68,000 and 60,000 km2 respectively—thus nearly identical in area (Fig. 1). Both regions are presently flanked by fast flowing ice streams and in both cases these head large cross-shelf troughs that extend across a broad continental shelf and lead to extensive trough-mouth fans (TMF). In both areas the major drainage basin for the ice streams are floored by Precambrian basement rocks with outcrops of Cretaceous sediments—most extensive in the west. Marine coring expeditions recovered a variety of cores in Kangerlussuaq Trough (East Greenland) in 1991, 1993, 1996, and 1999 (Andrews et al., 2010; Jennings et al., 2011), and in 2008 and 2009 in the Disko and Umanak troughs (West Greenland) (Jennings et al., 2014; O'Cofaigh et al., 2013), as well as from the TMFs. Quantitative X-ray diffraction (qXRD) analysis (Eberl, 2003) of pulverized ice-rafted basalt pebbles imply that dominant indicator mineral is pyroxene (average 22.7 wt%), but with significant amounts of Ca-feldspar and saponite. A comparison of a transects of cores---from the inner trough to the TMFs---from East versus West Greenland shows a profound difference in the weight% of pyroxene (as determined by quantitative XRD). In Nansen Fjord (EG), within the basalt outcrop pyroxene constitutes on average 13.7 ± 1.4 wt% of the sediment, whereas on the adjacent inner shelf MD99-2317 in Blosseville Basin pyroxene averaged 17.8 ± 1.3 wt%. Holocene to deglacial sediments in the inner Kangerlussuaq Trough, (JM96-1213, -1214 and B1191-5) averaged 10-14 wt% , and on the TMP (HU93030-007) the values were on average high but very variable (15.4 ± 4.3 wt%). By comparison the wt% of pyroxene in sediments from the inner area of Disko to the TMF are lower by a factor of 2 to 6.

To quantify the wt% of basalt in our sediments we use a modified version of “SedUnMix” (Andrews and Eberl, 2012), which now allows a larger number of samples from postulated source areas and uses a Monte Carlo simulation. In this study we used a simple two-source approach (noting that the difference between the estimated total fraction and 1.0 = “yet to be identified source(s)”) that consisted of 8 pulverized felsic IRD pebbles from JR175VC24 in the Disko Trough plus a granite from Baffin Island, and 13 samples of basalt from IRD pebbles from East Greenland and West Iceland). We excluded 9 minerals from the 33 species listed--- including four carbonate minerals. The Greenland basalts indicated a slight contamination with crustal rocks as they often contained a small (<2%) of quartz The method was tested, successfully, by analyzing samples of sediment from a lake within the basalt outcrop on Disko Island. The estimated fraction of basalt in 6 samples varied between 0.72 and 0.83. On the TMF above Denmark Strait the estimated contribution from basalt varied between 30% and 90% (14-29 cal ka BP), whereas on the Disko TMF (HU2008029-012PC) the estimates are much lower averaging 6% but ranging between0 and 22%. A total of 26 cores from both West and East Greenland were processed with these two sources and averages, minimum and maximum % values were obtained for the percentage of basement, basaltic, or unidentified contributions (Fig. 1). We use stepwise multiple regression analysis to determine which minerals are most important in terms of each sample’s estimate of the fractions assigned to one of the two source components; this process confirmed the importance of pyroxene as the key indicator species for the estimate of the basalt fraction along with anorthoclase and labradorite feldspars, and (e.g. JR175 VC20) quartz (+), oligoclase (+), and pyroxene (-) were the only 3 minerals needed to estimate the “granite” fraction ($r2 = 0.92$).n examination of the data (eg Fig. 1) indicates that on average there is a significantly larger fraction of unidentified data, i.e. additional source(s) on the West Greenland margin than on the East Greenland side. We know that sources not in this analysis include the detrital carbonate contributions from northern Baffin Bay (O'Cofaigh et al., 2013; Simon et al., 2014; Jennings et al., 2014; Andrews et al., 2014) and the sand-dominated Cretaceous outcrop of West Greenland.e will explore reasons for the differences between West and East Greenland in terms of the erosion and transport of basalt---this may be due to the differences in the outcrop expression between the two areas with the Geikie Plateaux of East Greenland hosting 19 tidewater glaciers.

Acknowledgements: Research supported by NSF-ANS-1107761, OPP-0713755, and ARC-1203492. Samples from PO175/1-5 supplied by Dr J. Mienert and 34390 and 34300 by Dr M. Matthias, and Dr J. Briner supplied lake sediments from Disko Is.

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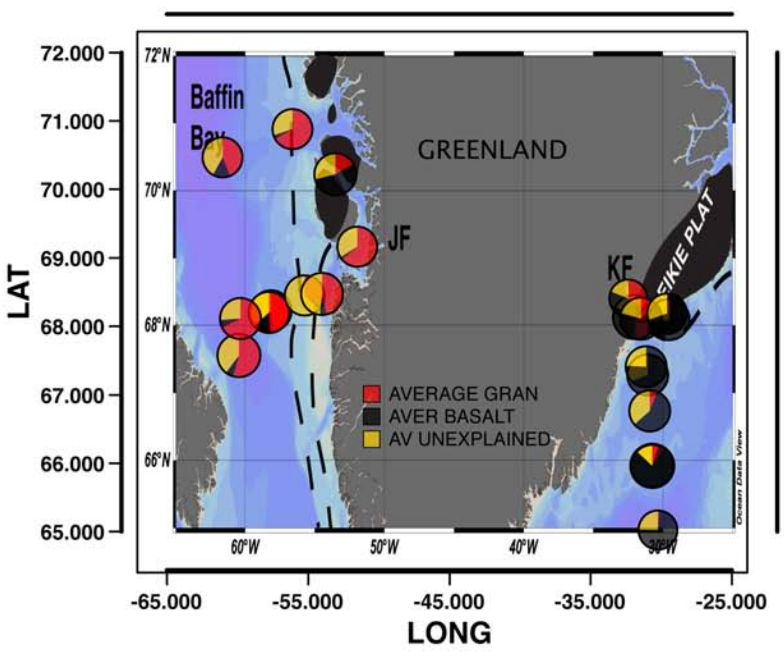

Fig 1. Pie diagram of the percentage of down-core sediment in 26 cores that are attributed to basement rocks (= GRAN), basalt, or unexplained. The outcrop on land is shown as black and the offshore limit as a dashed line. KF = Kangerlussuaq Fjord, and JF Jakobshavn Fjord.

EXPANSION DYNAMICS OF CROWBERRY (EMPETRUM HERMAPHRODITUM) ON SUBARCTIC SAND DUNES

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Arctic-alpine plant species are known to rely heavily on clonal propagation in harsh environments, a strategy with lower costs and higher survival probabilities than sexual reproduction. However, recent research suggests that sexual reproduction could be much more frequent than once thought, as demonstrated by high levels of genetic diversity found in clonal populations (Douhovnikoff et al. 2010, de Witte et al. 2012) and confirmed by in situ observations of seedlings (Boudreau et al. 2010, Hill et al. 2012).

Crowberry (*Empetrum hermaphroditum* [Hagerup] Böcher) is an ericaceous dwarf shrub species with a wide northern distribution. It usually forms dense clonal mats on the forest floor or in heathlands, but populations with isolated individuals established from seed can also be found, as it is the case on a subarctic sand dune system near Whapmagoostui-Kuujjuarapik in Nunavik (Northern Québec, Canada). We took advantage of a population survey conducted in 2007 (Boudreau et al. 2010) to describe the recent dynamics of this population and to evaluate individual performance in terms of growth and reproduction across the topographical gradient. We also investigated growth-climate relationships as a potential explanation for recent expansion.

To assess recent mortality, growth and recruitment rates, all individuals within the 2007 study plot (200 x 300 m) were mapped and measured again. We found that survival was very high, with only 5% of the individuals having died during the 5-yr span of the study (Fig. 1). Recruitment was frequent with 461 newly established individuals. These seedlings were concentrated towards the end of the environmental gradient (Fig. 1), where seed availability is greater and environmental stresses (e.g. wind, salt spray) are believed to be less severe. Over the entire plot, crowberry cover increased by 235 m2, a gain essentially attributable to the growth of pre-established individuals.

The study plot was subdivided into seven topographical zones to compare performance across the environmental gradient. Stem elongation for the period 2007-2012 was measured on 15-20 individuals in each zone. Fruit density, mean fruit mass, number of seeds per berry and germination were evaluated on 20-30 individuals per zone (except for Z4-5, where there were very few fruit-bearing individuals). Performance varied along the topographical gradient, but not according to our predictions. Stem elongation and many parameters linked to reproductive effort (fruit density, number of seeds/fruit) and success (germination) had higher values in the middle of the gradient, possibly because of lower competition levels. However, absolute seed availability and seedling establishment are higher at the end of the gradient because of greater population density.

We harvested the root collar of individuals located just outside the study plot for dendrochronological analyses. The resulting 40-year-long ring-width chronology was positively correlated to growing season length and thermal sum, but negatively to snow cover, stressing the importance of local factors in the response of shrubs to climate change.

This study is one of the first to monitor the demographics and dynamics of a dwarf shrub population. We have demonstrated that crowberry can effectively maintain itself through sustained sexual reproduction, a feature seemingly shared with other populations (Hill et al. 2012). This coastal population is rapidly expanding and, due to the high competitiveness and allelopathic character of E. hermaphroditum, further expansion of the population could lead to decreased biodiversity and delay succession on the sand dunes.

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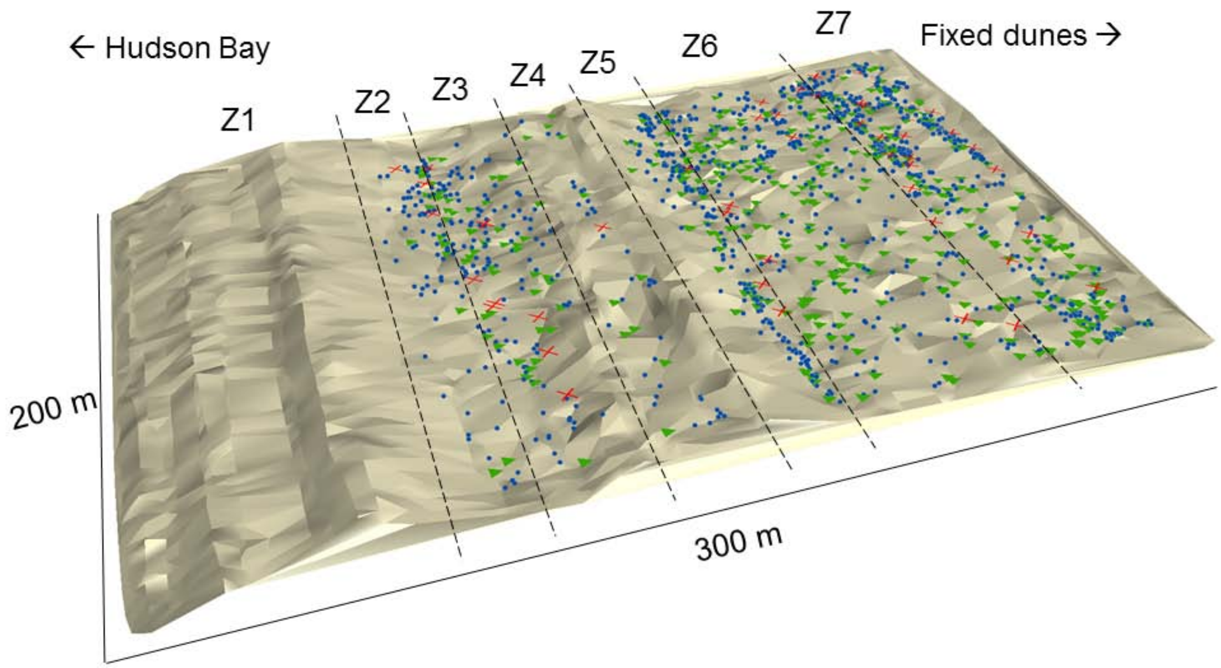

Fig 1. *Empetrum hermaphroditum* population map on a digital terrain model of the study plot (TIN structure with exaggerated elevation). Blue dots represent individuals recorded in 2007 and found again in 2012; red crosses indicate individuals recorded in 2007 that have died since; green triangles indicate seedlings recruited since 2007. Dotted lines delimit the topographical zones.

ESTIMATING GLACIER THICKNESS FROM REMOTELY SENSED- AND GPS-DERIVED GLACIER VELOCITIES AND ICE DYNAMICS MODELING: A CASE STUDY ON THE KENNICOTT GLACIER, ALASKA, USA.

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Accurate estimates of glacier thickness are important for constraining the volume of water stored in the cryosphere. This volume provides an upper bound on future eustatic sea level rise, much of which is currently attributable to alpine glaciers such as the Kennicott Glacier [Meier et al., 2007]. Ice thickness also governs speeds associated with internal deformation of the glacier, which in turn influences response of a glacier to changes in mass balance. Direct observation of glacier thickness requires time- and labor intensive field campaigns to drill to underlying bedrock, or image the bed using ice-penetrating radar. Both are often prohibitively expensive and the latter is difficult in thick, temperate ice. Previous ice thickness estimation techniques rely on area-to-volume relationships, assumed values of basal stress (e.g., Pierce, 1979), or reliable estimates of spatially distributed surface mass balance [Farinotti et al., 2009].

Here we present a physically-based method for estimating glacier thickness from optical satellite imagery, on-glacier GPS velocity observations, and two-dimensional cross-sectional glacier flow modeling. We study the Kennicott Glacier in the Wrangell Mountains of southeast Alaska, where we have collected three years of GPS-based ice speeds in an investigation targeting the coupling between subglacial hydrology and basal sliding. We employ these data to constrain glacier displacement due to time-variable basal motion, which would otherwise compromise our estimates of ice thickness.

We create high-resolution digital elevation models of glacier surface topography to document the ice surface slope and cross-glacier elevation profiles. We use pixel-tracking software to estimate glacier displacement from high-resolution, multi-temporal WorldView satellite imagery [Leprince et al., 2007]. These data provide spatially distributed glacier velocities on monthly to annual scales (Figure 1), from which we may deduce strain rates. We show that these satellite-derived speeds match well our GPS-based speeds over the same time interval, to within 5%, in both speed and direction. We then use on-glacier GPS-derived horizontal velocities to estimate the proportion of the observed glacier displacement that is attributable to basal sliding. This allows isolation of the spatially distributed ice surface speed derived from the satellite image correlation that is attributable to ice deformation. We then extract cross-glacier velocity profiles, at 100 m spacing across the 4 km wide glacier, which then serves as the top boundary condition that must be matched by our numerical model. We effectively invert for basal topography by finding the cross-sectional ice geometry that best fits the observed cross-glacier profile of horizontal ice speed (Figure 2). This method allows us to estimate glacier thickness with minimal ground-based data and without the restrictive assumption that the glacier is in steady state.

Future work may allow for estimation of glacier displacement due to sliding from comparison of satellite image correlations from different times of year, removing altogether the need for a GPS campaign and allowing glacier thickness estimation using remotely-sensed data alone.

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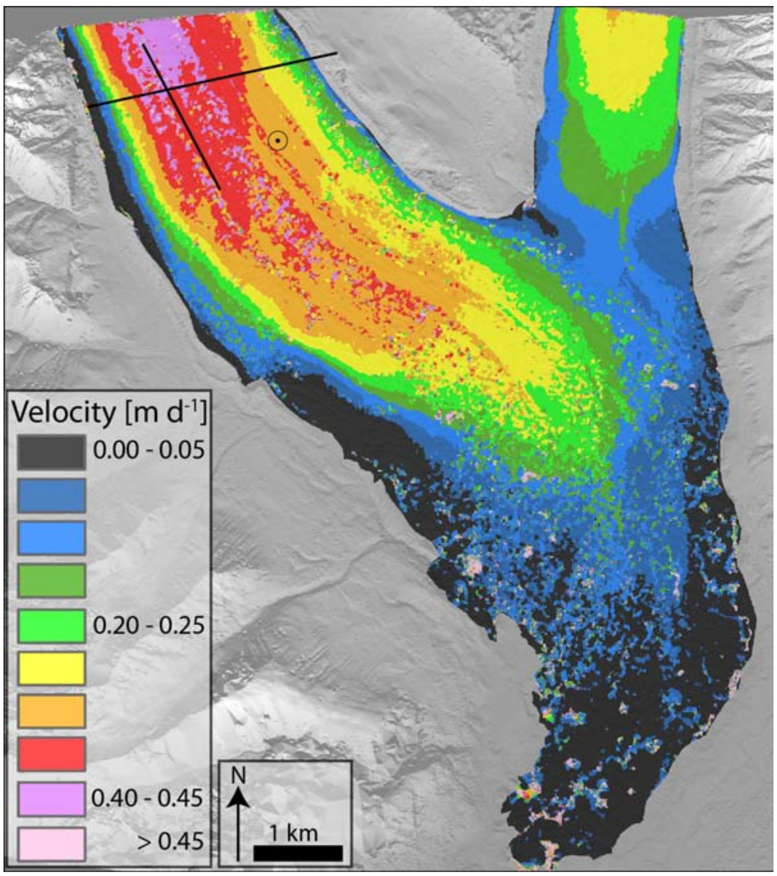

Fig 1. Glacier velocity estimated from WorldView satellite image correlation. The two black lines show transects from which we extracted glacier surface elevation and velocity profiles. The orange circle shows the velocity of an on-glacier GPS monument. The image pair spans June 19 to July 15 2013.

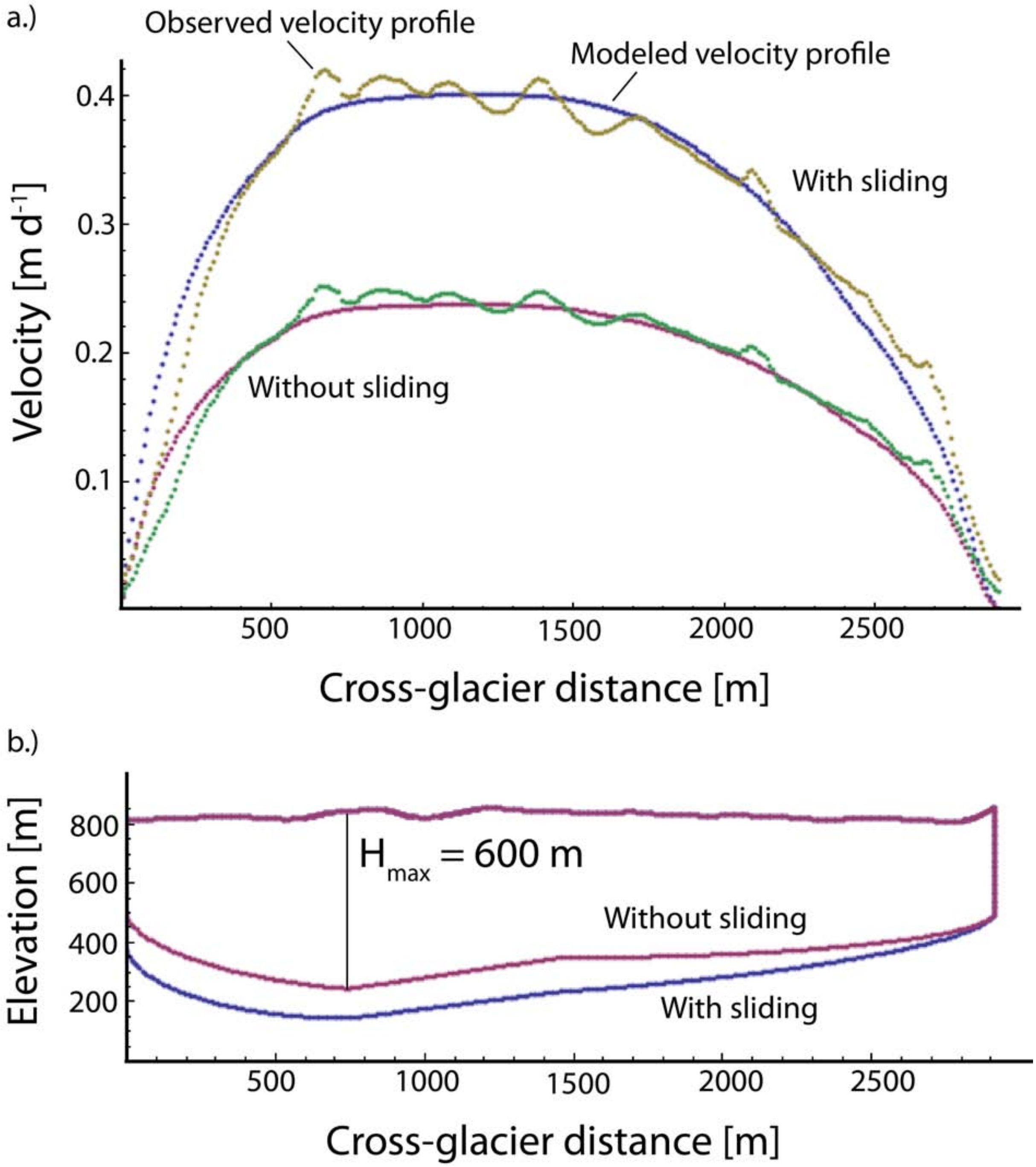

Fig 2. (a.) Observed and modeled ice surface velocities. The lower curve has been reduced by 40% to account for the fraction of glacier displacement attributable to sliding, estimated from GPS observations. (b.) The model domains that produce the velocity profiles in (a).

PALEOLIMNOLOGICAL RECORDS OF LAST INTERGLACIAL (?), LATE GLACIAL AND HOLOCENE CLIMATE AND ENVIRONMENTAL CHANGE IN NORTHWEST GREENLAND

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Here we present chironomid and other paleolimnological data from the sediments of two lakes in northwest Greenland, at ~77°N in the Nunatarssuaq region near Thule. These analyses are part of a collaborative project that also employs 10Be glacial geochronology, 14C dating of in situ plants emerging at glacier margins (Kelly et al. 2013), and analyses of firn and ice cores from ice caps to reconstruct the region's climate and environmental history through the Holocene.

The glacial lake Delta Sø, which currently receives meltwater from North Ice Cap, appears to contain a sedimentary record extending back ~14.9 cal ka (Corbett et al. 2013). Therefore, Delta Sø should provide paleoenvironmental reconstructions through the late glacial and Holocene, making it one of the oldest lake sediment records yet recovered from Greenland (e.g., Bjorck et al. 2002). Wax Lips Lake (informal name), a smaller, non-glacial lake situated ~2 km west of the Greenland Ice Sheet margin, contains an even longer record. The stratigraphy of Wax Lips Lake cores includes an upper organic lacustrine unit that records the Holocene beginning around 7 cal ka, and a denser, underlying organic lacustrine unit that yields pre-Last Glacial Maximum (pre-LGM) radiocarbon ages. Chironomid assemblages in the pre-LGM sediments suggest full interglacial conditions, and therefore we infer that these sediments may date to marine isotope stage 5, and possibly 5e (the Eemian). Paleotemperatures are modeled based upon chironomid assemblages through the Holocene at both lakes and at low resolution for the pre-LGM (Last Interglacial?) unit at Wax Lips Lake.

The preservation of in situ pre-LGM lake sediments in Wax Lips Lake, adjacent to the modern Greenland Ice Sheet margin, would require a minimally erosive glacierization style (and presumably cold-based ice) at this site throughout the last glacial period. The presence of inherited cosmogenic nuclides in bedrock and boulders elsewhere in the Nunatarssuaq region (Corbett et al. 2013) further supports the inference that portions of this sector of the Greenland Ice Sheet were cold-based during the LGM.

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A LATE-HOLOCENE PALEOENVIRONMENTAL RECONSTRUCTION OF LINNÉVATNET, SVALBARD USING GEOCHEMICAL AND PRODUCTIVITY PROXIES

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The last century is characterized by a rapid increase in greenhouse gas levels in the atmosphere, resulting in unprecedented global climate change. The Arctic is particularly sensitive to global changes in climate, and temperatures in the Arctic have risen at twice the global rate over the last century (IPCC, 2013). In order to accurately predict the effects of climate change in the Arctic, an understanding of past climate conditions must be established (D'Andrea et al., 2012). In Svalbard, the instrumental temperature record only extends back 100 years, so laminated lake sediments provide long term paleoclimate information that extends far beyond the instrumental record.

This study aims to reconstruct late-Holocene environmental change in Linnédalen, a glaciated valley in the Norwegian High Arctic, using a 1400 year geochemical and productivity record of proglacial lake Linnévatnet (Figure 1). A multi-proxy approach was utilized to document physical, chemical, and biological changes preserved in the lake sediments. An 82.5 cm long core was scanned using an ITRAX core scanner, which provided downcore elemental profiles at 200 μm resolution. The core was subsampled for carbon stable isotopes, organic and inorganic carbon, and chlorophyll at 1 cm resolution. An age model for the core was developed by comparing the downcore Ca:Ti ratio with that of a Linnévatnet core with a plutonium verified varve-count (Dowey, 2013).

Figure 2 shows downcore profiles of ITRAX and carbon stable isotope data. Ca:Ti ratios showed an increase from 0.25 to 1 at the onset of the Little Ice Age (LIA) in Svalbard around 1350 A.D, and remained high throughout the LIA. The Mn:Ti profile also shows a peak ~1350. At the same time, &delta^{13}C values of the sediment become enriched from -23 ‰ to -17‰. The sudden change in these parameters indicates rapid environmental change in Linnédalen at the onset of the LIA, which may have been related to a change in climate.

High Ca:Ti ratios and more enriched &delta^{13}C values during the LIA are interpreted as increased detrital carbonate input to the lake introduced from the Carboniferous Nordenskiöldbreen carbonate unit to the east of the lake (Snyder et al., 2000). A large carbonate fan is observed on the eastern shore of Linnévatnet, and sediment from this fan shows higher Ca:Ti values than other sediment sources to the lake. The fan appears to be seasonally active with a spring melt-water source in an upslope nivation hollow, although there is no glacier ice or perennial snowpack currently present to feed the fan.

The increased input of detrital carbonate at the onset of the Little Ice Age may be representative of a change in summer melt-water source to Linnévatnet, likely linked to a change in climate. D'Andrea et al. (2012) show an LIA in Svalbard characterized by increased winter precipitation and mild summers, which could contribute to increased snow pack occupying the upper slopes of the carbonate unit, and thus more carbonate enriched melt-water entering the lake. The chlorophyll profile will be used to evaluate changes in summertime productivity, which can be related to summertime temperature, and will indicate whether or not the increased detrital carbonate input to the lake is, in fact, related to a change in climate.

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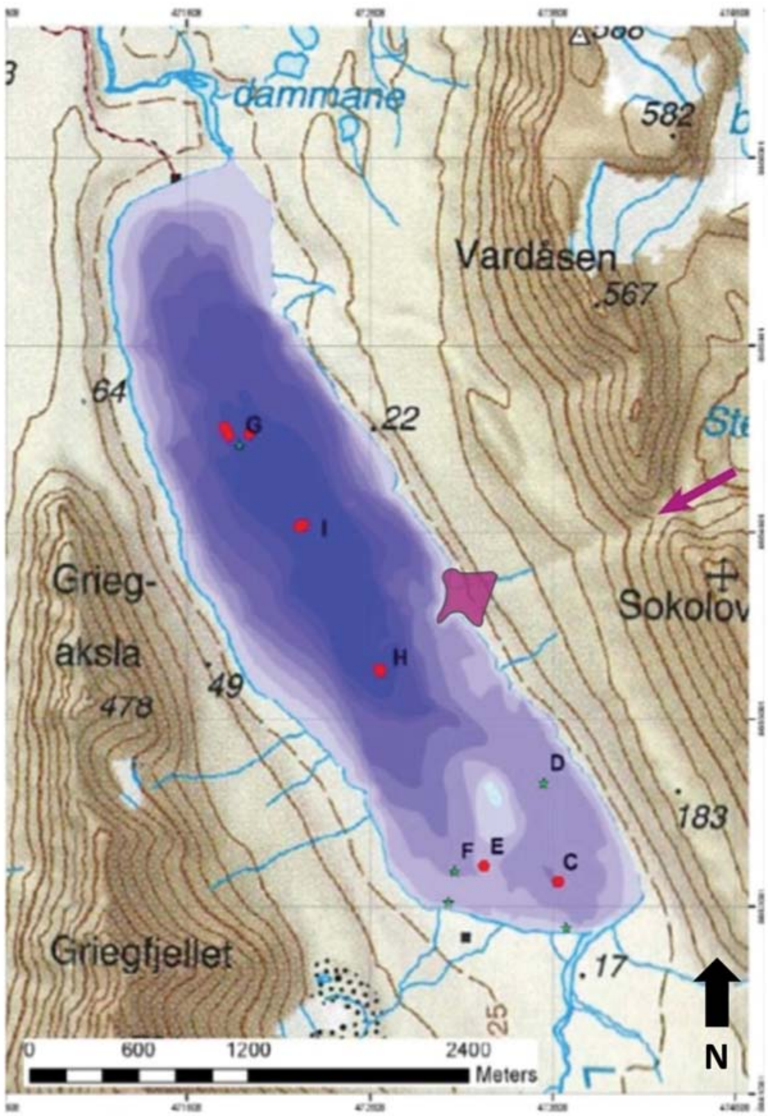

Fig 1. Map of Linnévatnet, Svalbard. The core analyzed in this study was recovered from Site I. The pink polygon to the east of the lake shows a large carbonate fan that is the most likely input of carbonate to the lake, and the pink arrow indicates a likely source for the fan.

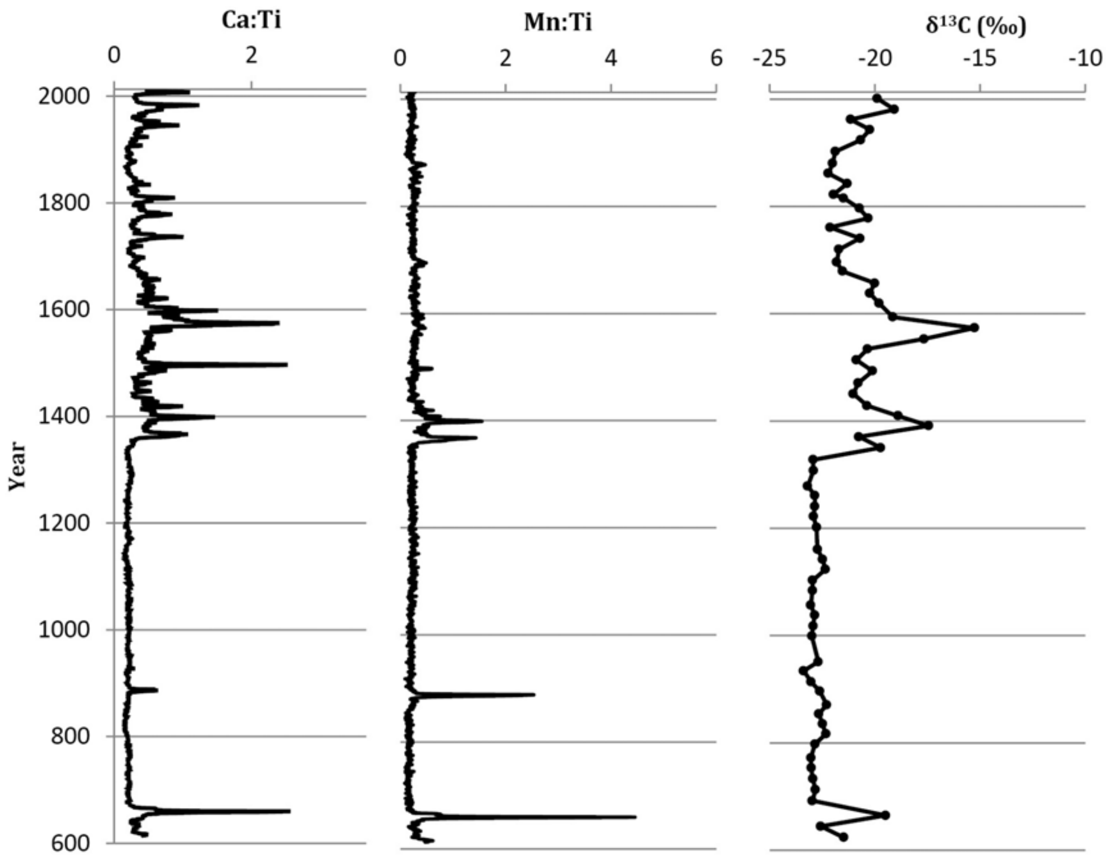

Fig 2. Downcore profiles of (a) Ca:Ti and (b) Mn:Ti obtained from an ITRAX core scanner, as well as (c) &delta[13]C.

THE EFFECT OF CHANGING SEA ICE ON THE VULNERABILITY OF ARCTIC COASTS

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Shorefast sea ice prevents the interaction of the land and the ocean in the winter and influences this interaction in the summer through fetch. Open water conditions persist longer in many parts of the Arctic and the summertime sea ice extents have decreased. The sea ice provides a first order control on the vulnerability of Arctic coasts to erosion, inundation, and damage to settlements and infrastructure. We present a pan-Arctic analysis of satellite-based sea ice concentration along the Arctic coasts which identifies regions with lengthening open water seasons including the Beaufort and Laptev Sea regions. The median length of the 2012 open water season in comparison to 1979 expanded by between 1.5 and 3 by Arctic sea sector. The increase in the duration of sea ice free conditions at the coast allows for open water during the stormy Arctic fall. Drew Point, Alaska is a site on the Beaufort Sea characterized by ice-rich permafrost and rapid coastal erosion rates. At Drew Point the duration of the sea ice free season and distance to the sea ice edge, particularly towards the northwest, has increased. We the concept of "directional fetch", or the distance to the sea ice edge in the direction the wind is blowing as an impact metric for sea ice edge retreat on a coast. Winds from the northwest result in increased water levels at the coast and control the process of submarine notch incision, the rate limiting step of coastal retreat at Drew Point. We combine sea ice and the local wind field to in a coastal impact analysis using a simple model of bathystrophic storm surge and wave generation for the period of 1979--2012. We find that average values of positive water level and wave height have not increased but that the extreme values have increased, consistent with increasing fetch.

ULTRA HIGH-RESOLUTION RECORD OF HOLOCENE CLIMATE VARIABILITY IN THE SE NORWEGIAN SEA

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The Storegga Slide scar in the SE Norwegian Sea offers an exceptionally high sedimentation rate over the last 8200 years. A 19.7 m long Calypso core (GS13-182-01CC) has been retrieved from 960 m water depth within this scar, at a location with highest post-slide accumulation rates. The core is furthermore located directly under the eastern branch of Atlantic water entering the Norwegian Sea. The core penetrates into the slide debris and the upper 17.8 m show continuous marine sedimentation. A preliminary chronology has been established through correlation with the Ca/Fe XRF-data to the nearby well-dated core P1-003. The chronostratigraphy will be further refined through the help of 14C-dates and palaeomagnetism measurements. An insight into the Holocene variability in Atlantic water inflow to the Nordic seas and climate variations will be explored through time series analysis. The analysis will be done on high-resolution (4 data-points per year) XRF proxies reflecting environmental parameters. These investigations will contribute to our understanding of seasonal and decadal variations in the development of the Holocene drift system along the Norwegian margin as well as variations in ocean currents (Norwegian Atlantic Current and Norwegian Coastal Current).

CONCORDANT 10BE/26AL AGES FROM HIGH-ELEVATION PLATEAUS, UUMMANNAQ FJORD REGION, WESTERN GREENLAND

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Paired measurements of in situ cosmogenic 10Be and 26Al from bedrock surfaces proximal to glacial margins enable estimates of cumulative exposure/burial duration. Recent studies from high-elevation plateaus bordering the Uummannaq fjord system have reported concordant 26Al/10Be apparent exposure ages that span the last glacial cycle (~120-20 ka), suggesting persistent ice-free conditions or only brief burial by cold-based ice (Roberts et al., 2013, J. Geophys. Res. Earth Surf. 118: 1-23. doi: 10.1002/jgrf.20032; Lane et al., in press, Quat. Sci. Rev.). Here we present three new pairs of 10Be and 26Al measurements from autochthonous blockfields immediately proximal to the current margins of cold-based ice caps in the Uummannaq fjord region. Exposure ages from this study and the two prior studies were calculated using a common scaling scheme and production rate to ensure compatibility.

Our results show concordant 10Be/26Al apparent exposure ages ranging from ca. 68 ka to 316 ka along the Nuussuaq Peninsula and Uvkusigssat Peninsula (unofficial name), respectively – supporting and extending the earlier studies. The concordance of the apparent exposure ages reveals a lack of significant cumulative burial (≤ 50 ka) of the inter-fjord plateaus in the Uummannaq fjord system during the latter part of the Quaternary, and implies that the inter-fjord plateaus may have remained largely ice-free during the bulk of the last few glacial cycles. These results are anomalous for many Arctic landscapes, as cold-based portions of polythermal ice sheets on similar plateaus typically yield discordant 10Be/26Al ages indicative of significant periodic ice cover. Additional multiple-nuclide analyses from these settings (including in situ 14C) may shed light on the mechanisms for these intriguing results.

Roberts, D.H., Rea, B.R., Lane, T.P., Schanbel, C., and Rodés, A. 2013. New constraints on Greenland ice sheet dynamics during the last glacial cycle: Evidence from the Uummannaq ice stream system. Journal of Geophysical Research: Earth Surface, 118: 1-23. doi: 10.1002/jgrf.20032.

Lane, T.P., Roberts, D.H., Rea, B.R., Cofaigh, C. Ó., Vieli, A., and Rodés, A. in press. Controls upon the Last Glacial Maximum deglaciation of the northern Uummannaq Ice Stream System, West Greenland. Quaternary Science Reviews xxx, 1-21.

A 3000 YEAR MULTI-PROXY RECORD OF ENVIRONMENTAL CHANGE FROM GRIPDEILD, EASTERN ICELAND

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The composite high resolution Holocene climate record for Iceland based on a glacial and non-glacial lake sediment cores suggests abrupt shifts in ocean/atmosphere circulation throughout the northern North Atlantic (Geirsdóttir et al., 2013). The strongest disturbances occurred after 2 ka, with initial summer cooling occurring between 1.4 and 1.0 ka, followed by a more severe drop in summer temperatures after 0.7 ka culminating between 0.5 and 0.2 ka. The reconstruction is based on lacustrine sediment from western Iceland, an area sensitive to fluctuations in the warm Irminger Current, a branch of the North Atlantic Drift. Here we present preliminary climate reconstructions from a 6.5 m long sediment core from Gripdeild, a non-glacial lake from the highlands of eastern Iceland, and compare it to the composite record over the last 3ka. The age model for Gripdeild is based on one 14C date and 4 tephra layers, with H3 tephra (2950 BP; 465 cm depth) as the lowest tephra identified so far. There are 185 cm of sediment below the H3 tephra, but we have no age constraints yet below the H3 tephra. Therefore we focus here on the uppermost 3ka. This is the first high-resolution lake record from this part of Iceland, where impacts from variations in the Irminger Current may be more subtle than felt in lakes farther west.

Physical and chemical environmental proxies extracted from the sediment fill of Gripdeild provide a sub-decadal-scale reconstruction of climate variability in eastern Iceland over the past 3ka. The impact of Neoglaciation can be seen as early as 3 ka when C:N ratios begin a consistent rise, intensifying early in the first millennium AD and again during the early Little Ice Age (LIA) ca. 1300 AD. C:N and TOC are tightly correlated over this interval, whereas d13C is inversely correlated with TOC departures. C:N becomes higher when d13C becomes depleted. Only during the transition into and during the Little Ice Age did soil erosion become a major feature of the record.

When compared to other Icelandic lake records, environmental proxies from Gripdeild indicate similar timing of environmental change for the past 3 ka. However, more subtle changes during the LIA and the lack of clear Medieval Warm Period suggests that eastern Iceland may have been more influenced by the closeness to the nearby Vatnajökull than by variations in the flow of the Irminger Current.

Geirsdóttir, Á., Miller, G.H., Larsen, D.J., Ólafsdóttir, S., 2013. Abrupt Holocene climate transitions in the northern North Atlantic region recorded by synchronized lacustrine records in Iceland. Quaternary Science Reviews 70, 48-62

THE GREENLAND ICE SHEET - 80 YEARS OF CLIMATE CHANGE SEEN FROM THE AIR

Bjørk, Anders A [1]; **Kjær**, Kurt H [2]; **Larsen**, Nicolaj K [3]; **Kjeldsen**, Kristian K [4]; **Khan**, Shfaqat A [5]; **Funder**, Svend V [6]; **Korsgaard**, Niels J [7]

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Danish Navy Lieutenant Erik Rasmussen had butterflies in his stomach as he sat in sat in the middle of the Arsuk fjord in South Greenland on the 10th of July 1932. Below him was a Heinkel seaplane, and in front of him the power of 460 horses just waiting to be released over the Greenlandic mountains.

The flight was the first of its kind, and marked the beginning of an enormous mapping quest. In five summers in the early 1930s more than half the Greenlandic coastline was photographed, black spots on the map became white as the open seaplanes flew distances equal to several times around the world. In temperatures down to minus 40 degrees Celsius and in 4,500 meters altitude with little oxygen, this was not a job for the faint of heart.

In the years that have passed since Erik Rasmussen first took off over Greenland things have changed. Climate is warming and the glaciers of Greenland are melting. The pictures from the early 1930s now give us a unique opportunity to study the glaciers reactions to climate change during a period much longer than that conventional satellite images can supply. The images from the early 1930s are of particular interest as they were recorded at the end of the early 20th Century Warming Period, a period of rapidly increasing temperatures in Greenland – temperatures that have just been surpassed in the last decade.

In the summer of 2013 researchers from the Natural History Museum of Denmark flew in the tailwind of the early pioneers along with colleagues from Aarhus University and aerial photographer Hans Henrik Tholstrup and photographed the exact same glaciers. The Greenland Ice Sheet - 80 years of climate change seen from the air tells the story of the legendary flights and vividly depicts what has happened to the glaciers and the ice sheet during the 80 years that has passed.

Surplus from the sale of each individual book is donated to the Child and Youth Organization NANU, which works for making a difference for Greenlandic children.

Kjær, K.H., Bjørk, A.A, Funder, S.V. et al., The Greenland Ice Sheet - 80 years of climate change seen from the air. Natural History Museum of Denmark. Copenhagen, 2014.

Bjørk, A.A. Kjær, K.H., Korsgaard, N.J. et al., 2012, An aerial view of 80 years of climate-related glacier fluctuations in southeast Greenland: Nature Geoscience, v. 5, p.427-432.

Fig 1. Pilot Erik Rasmussen preparing the Heinkel seaplane for a flight on the southeast coast of Greenland. Photo: Arctic Institute, Copenhagen.

Fig 2. The ship "Gustav Holm" lowers a Heinkel seaplane during Lauge Koch's Three-year Expedition to the northeast coast of Greenland. Painting by Johannes E. Møller.

WIND-DRIVEN PROCESSES IN THE SURFACE LAYER OF THE MARGINAL ICE ZONE

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As the Arctic transitions from a persistent multi-year ice pack to a seasonal pack dominated by first-year ice, the relative area and importance of the Marginal Ice Zone (MIZ) will continue to increase. The MIZ is subject to both ice and ocean dynamics and is typically considered the area with ice concentrations from 15% to 90% surrounding the remaining permanent ice pack. The 2013 Marginal Ice Zone Processes Experiment (MIZOPEX) used a number of instruments on unmanned aircraft (UAS) and air-deployed micro-buoys (ADMB) to study processes in the MIZ. The buoys measure sub-surface temperatures to depths of 2 meters and GPS to track position. This study uses measurements from the ADMBs, supplemented by satellite-based measurements and reanalysis data to address the interactions between surface winds and the upper ocean in the MIZ.

Comparisons of drift vectors (differential positions of the buoys) with interpolated NCEP reanalysis wind vectors show that surface currents are primarily driven by Ekman transport; drift vectors are typically slightly less than 45° clockwise dominant wind vector, accounting for surface currents and direct wind forcing contributing to the motion of the buoys. Subsurface temperature gradients are controlled by the wind speed. High winds induce mixing, strongly positive surface temperature gradients are possible only at low wind speeds, and negative surface temperature gradients can be set up by moderate winds in the proximity of ice floes.

DETERMINATION OF BAFFIN BAY SEDIMENT COMPOSITION AND PROVENANCE

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This project aims at determining down-core marine sediment composition variability from fourteen Baffin Bay cores using visible derivative spectroscopy V-PCA (Varimax-Rotated Principal Component Analysis), and spectrafacial Analysis (developed here.) Visible derivative spectroscopy based on diffuse spectral reflectance (DSR) data is a relatively inexpensive, non-invasive and effective method to determine the composition of gravity deposited marine sediment (Mix et al. 1995). DSR data was collected at centimeter intervals down fourteen cores recovered from James Clark Ross JR175 and CCGS Hudson 2008029 cruises using a Minolta CM2600-D Spectrophotometer. The DSR data were put through IBM SPSS Varimax Rotated Principal Component Analysis; three principal components, selected with Eigenvalues greater than one as an indication of a significant variance contribution accounted account for 93.451% of the variability in the dataset. The signals for each of the three principal components were matched to known spectral reflectance values of minerals available from the USGS digital spectral library v.6, or measured in the Kent State Paleoclimate Lab. These components agree with previous studies (Ortiz et al, 2011) and are PC1 (actinolite+goethite), PC2 (dolomite+illite), and PC3 (chlorite+muscovite). Spectrafacies analysis developed here involves scaling down-core PC scores for these principal components by shifting values into the positive quadrant (adding the absolute value of the most negative number in the dataset to each value in the dataset), and then rescaling the components from 0-100% using a percent maximum transformation. Using data from all measurements from all cores, a ternary diagram was then plotted in which each principal components resides as a vertex of the ternary diagram. Twenty-five triangular regions, i.e. spectrafacies, together lie within ternary plot filter and define the composition of the sediments in rotated DSR space.

Next, reflectance component core logs were made for each of the fourteen cores showing down-core spectrafacial variability. Down-core combinations of Principal Component Scores were plotted by means of spectrafacies, enabling core-to-core correlations to be made. Productivity plots, i.e. binary groupings, of PC's are representative of provenance derived from Canada (PC1+PC2), the Atlantic (PC2 +PC3), or Greenland (PC1+PC3) based on their geographic distribution of the core logs when the spectrafacies are plotted in cross-section. The timing of elevated sediment production coincides with the end of the Younger Dryas arctic ice sheets retreat (Jennings et al., 2014).

Jennings, A.E., Walton, M.E., Ó Cofaigh, C., Kilfeather, A., Andrews, J.T., Ortiz, J.D., De Vernal, A., Dowdeswell, J.A., 2014. Paleoenvironments during Younger Dryas-Early Holocene retreat of the Greenland Ice Sheet from outer Disko Trough, central west Greenland. Journal of Quaternary Science 29, p.27-40.

Mix, A.C., Harris, S. E., Janecek, T.R. , 1995. Estimating lithology from nonintrusive reflectance spectra: Leg 138. Proceedings of the Ocean Drilling Program, Scientific Results, p.413-427.

Ortiz, J.D., Andrews, J.T. and D.D. Eberl, 2011. Geographic distribution of Labrador Sea and Baffin Bay sediment mineralogy based on visible reflectance derivative spectroscopy, 41th International Arctic Workshop, p.208-210.

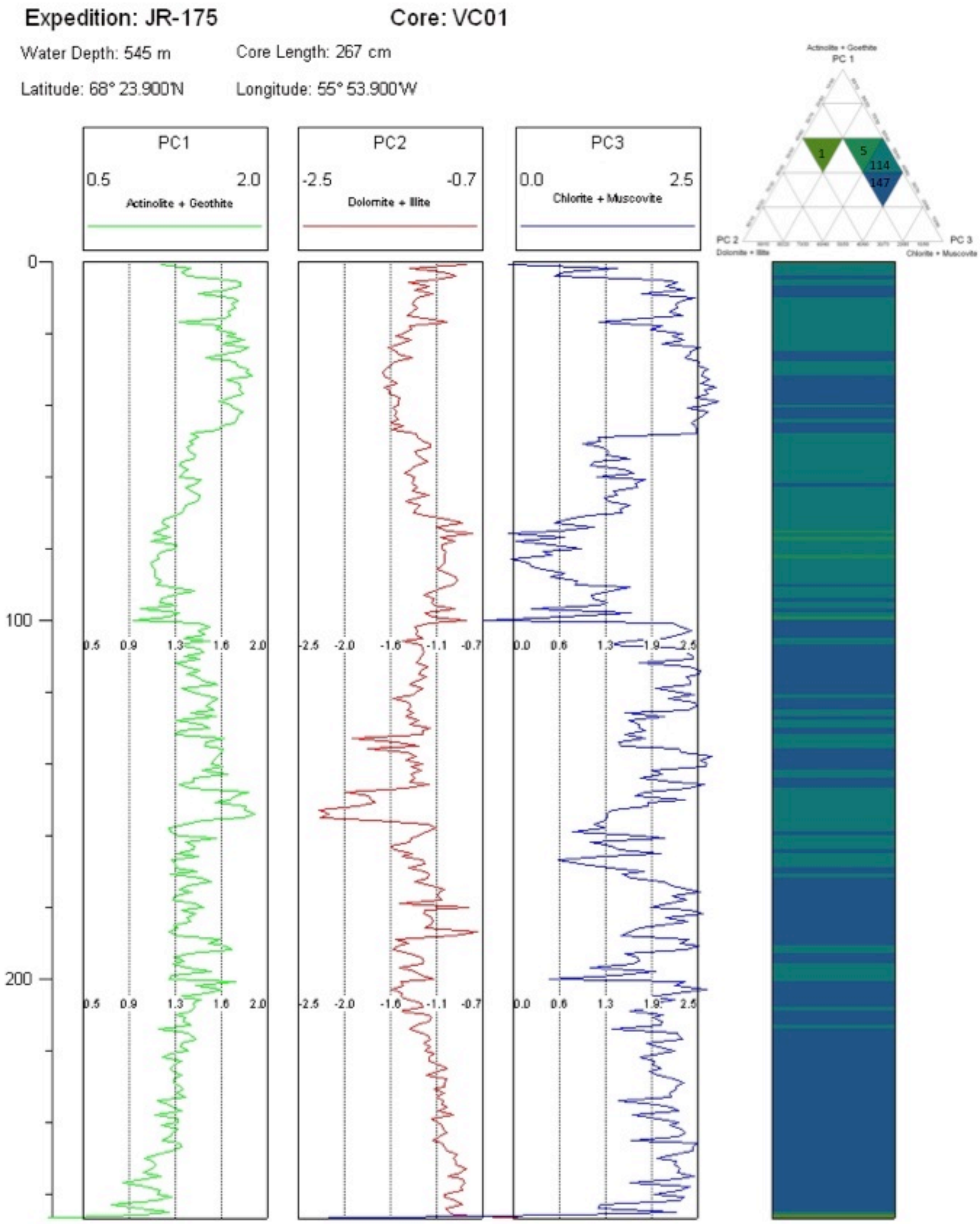

Fig 1. Reflectance component core log for core VC01 from James Clark Ross JR-175 (lead scientist Colm Ó Cofaigh). Expedition and core names are at top, with latitude and longitude locations in decimal degrees, as well as water depth. Each PC down-core signal is plotted, with a ternary diagram showing number of centimeter samples that fall in each spectrafacial region and the down-core spectrafacial results.

PLIOCENE/PLEISTOCENE INTERGLACIALS AND INTER-HEMISPHERIC POLAR LINKAGES SUGGESTED BY THE ARCTIC LAKE EL'GYGYTGYN PALEOCLIMATE RECORD OF THE PAST 3.6 MYRS

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Emerging evidence of earlier warm periods over the past few million years inform us about the sensitivity of the arctic system to change, particularly the rates and magnitudes of warmth that directly impact the seasonal extent and existence of sea ice, the greening of the arctic borderlands, the melt of glacial systems and changes in sea level. While there is some consensus about the rapid response of the sea-ice albedo feedback processes, it still remains difficult to model. The new record from Lake El'gygytgyn (Lake E), NE Arctic Russia, notably the largest, deepest, oldest unglaciated basin in the Arctic borderlands provides the first complete record of Pliocene and Pleistocene climate change from the terrestrial high latitudes [1, 2]. Lake El'gygytgyn evidence shows 3.6-3.4 Ma ago summer temperatures were ~8oC warmer than today. At the same time ANDRILL and new Wilkes Land Basin records suggest Antarctic ice sheets were smaller than today and perhaps more dynamic. Multiproxy evidence from Lake E suggests extreme warmth and polar amplification during the middle Pliocene with low amplitude changes between cold and warm Milankovitch cycles consistent with the LR stack and limited changes in global sea level. While different research groups have produced a variety estimates for pCO2 in the mid Pliocene ranging from 280 ppm to 400 ppm, most agree that pCO2 may have been like today in the 350 to 400 ppm range as a major forcing factor.

Sudden stepped cooling events during the Pliocene-Pleistocene transition recorded at Lake E are consistent with a number of marine proxies from the North Pacific and North Atlantic suggesting that polar amplification was recorded across the northern hemisphere in both marine and Arctic terrestrial environments. Summers warmer than present in the Arctic persisted with a few exceptions until ~2.2 Ma, after the onset of Northern Hemispheric glaciation and a more persistent WAIS. Yet brief cold intervals between 2.6 and 2.2 Ma had to have been of duration to allow low-slung ice sheets(?) to deposit glacial tills as far south as northern Missouri.

The warmth recorded at Lake E raises new questions about the size and geometry of initial ice over North America and elsewhere in the Arctic (especially during M2) as well as challenges the notion of perennial sea ice before 2.5 Ma. Our multi-proxy evidence is consistent with global sea-level records and other proxies indicating that Arctic cooling was really insufficient to support LGM-scale ice sheets in the NH until the early Pleistocene. Pleistocene super interglacials recognized in the Lake E suggest that periods of Antarctic warmth may have preceded periods of exceptional "Pliocene-like" warmth in the Arctic borderlands. This hypothesis begs further testing. Because many of these warm episodes at Lake E appear to surpass the warmth of the last interglacial when the Greenland Ice Sheet is thought to have been somewhat smaller than today, these new data will hopefully contribute to modeling efforts that test the vulnerability of Arctic sea ice and the Greenland Ice Sheet to ongoing global warming.

[1] Brigham-Grette, J., Melles M., Minyuk,P., Andreev, A, Tarasov, P., DeConto, R., Koenig, S., Nowaczyk, N., Wennrich, V., Rosén P., Haltia-Hovi, E., Cook, T., Gebhardt, T., Meyer-Jacob, C., Snyder, J., Herzschuh, U., 2013, Pliocene Warmth, Polar Amplification, and Stepped Pleistocene Cooling recorded in NE Arctic Russia: Science, v.340, p. 1421- 1427. plus supplemental.
[2] Melles, M., Brigham-Grette, J., Minyuk, P., and others, 2012, 2.8 Million Years of Arctic Climate Change from Lake El'gygytgyn, NE Russia: Science, v. 337, p. 315-320, plus supplemental.
See also 30 manuscripts in Lake El'gygytgyn Climate of the Past Special issue.

CLIMATE CHANGE AND THE PHYSICAL LIMNOLOGY OF LAKE VANDA, ANTARCTICA: PAST, PRESENT AND FUTURE SCENARIOS

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The 12 m rise in the level of Lake Vanda is the largest documented environmental change in the McMurdo Dry Valleys, Antarctica. The primary driver of this change is meltwater production at the coastal Wright Lower Glacier which feeds the headwaters of the Onyx River. The Onyx River drains into the lake, 32 km inland, and is the principle input. Ablation is the only loss mechanism. In this presentation, we synthesize historic and new information to describe the sensitivity of Lake Vanda to past, present and future climate change.

The earliest measurements of Lake Vanda in the 1960's coincided with a decade of stable level. At that time the lake was comprised of a 29 m thick salinity gradient at the base of the lake, overlain by an isothermal 20 m thick thermohaline convection cell, and a 12 m thick, stepped thermal gradient below the ice. Thermohaline convection was driven by solar heating of the deep saline zone, where high light transmission though ice and lake water allowed temperatures to exceed +25°C. Subsequent lake level rise has inserted a second convection cell, now 19 m thick, above the first. Comparison of modern and 1960 temperature profiles suggest that the upper limit of the lower convection cells marks a previous stable water level, more than 25 m shallower than the current surface, that probably prevailed in the early part of the 20th Century.

The stability of the unique mixing regime, within which the ecosystems of the lake are embedded, depends on heat flux. While location of the lower convection cell has remained constant, its temperature has declined since 1960 by 0.03°/y, and with it the flux of heat into the upper cell. In Dec 2013 the upper cell was 4.43 °C, 955 μS/cm, and 1000.404 kg/m3, and the lower cell 6.53 °C, 1610 μS/cm, and 1000.736 kg/m3. Between 30 Nov and 14 Dec, upper cell convective mixing was dependent on the heat flux across the pycnocline from the lower cell. A fine balance was apparent later in the season when temperatures between 5 and 10 m were highest, indicative of downward heating from solar radiation. This conflict between upward and downward heat flux is critical to maintaining the current lake mixing regime and is threatened by cooling of the lower layer as level rises.

Four future scenarios can be envisioned for Lake Vanda: (1) Continued coastal melting, lake level rise and heat loss in the lower cell. Convection stops and the water column stratification regime changes drastically. (2) The lake reaches a new stable level where ablation from the increased lake surface area balances increased inflow. Solutes increase in the upper cell until both cells mix. (3) Reduced meltwater production, and/or increased aridity inland, causes lake level to fall with similar results to (2). (4) Unstable climate conditions cause cycles of falling and rising lake level, each cycle generating a new convective cell. Implications for the unique biological communities that characterize the cells of the lake are discussed.

TESTING MASSIVE ARCTIC SEA ICE EXPORT AS A TRIGGER FOR ABRUPT CLIMATE CHANGE

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The discharge of freshwater from glacial lakes to the North Atlantic is repeatedly cited as the main trigger for abrupt centennial to millennial length climate change during the last deglaciation. Broecker et al., (1989) was a proponent of this idea suggesting that abrupt re-routing of pro-glacial lake freshwater to the North Atlantic through the St. Lawrence Valley weakened the strength of the AMOC. Yet, evidence for this is lacking, freshwater estimates in these lakes are relatively small and flood durations are rather short (<5 years), suggesting that floods may not have been the only mechanism driving these climate shifts. Using sophisticated ocean modeling, it has been shown that the release of freshwater originating from the Arctic is more effective at weakening the AMOC compared to freshwater released further south.

Here we investigate whether the break-up and mobilization of thick Arctic sea ice would have supplied enough freshwater to the Nordic Seas to sufficiently cause dampening of the AMOC and hinder NADW formation in the sub-polar North Atlantic. We use numerical climate models to assess 1) the maximum thickness of sea ice that can be formed during glacial periods and the volume of freshwater in the ice, 2) the mechanism which caused the collapse and mobilization of arctic sea-ice into the North Atlantic and 3) the impact of melting sea-ice on global ocean circulation. This hypothesis focuses on the potential impacts of sea-ice as a forcing mechanism for abrupt climate change events on geologic time scales.

Broecker, W.S., Kennett, J.P., Flower, B.P., Teller, J.T., Trumbore, S., Bonani, G., Wolfli, W., 1989. Routing of meltwater from the Laurentide Ice Sheet during the Younger Dryas cold episode. Nature 318–321.

MASSIVE SUBTROPICAL ICEBERGS AND FRESHWATER FORCING OF CLIMATE

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High resolution seafloor mapping shows incredible evidence that massive (>300m thick) icebergs drifted more than 5,000 km along the United States continental margin to southern Florida during the last deglaciation. Here we discuss how the discovery of icebergs in this location highlights a previously unknown ocean circulation pathway capable of transporting icebergs and meltwater from the Northern Hemisphere ice sheets directly to the subtropical North Atlantic. This pathway questions the classical idea that freshwater forcing from meltwater floods and icebergs occurred primarily over the subpolar North Atlantic (50N - 70N), with little penetration to subtropical latitudes, south of 40N.

Using a sophisticated, high-resolution (1/6 deg.) ocean model, capable of resolving the circulation of the coastal ocean in detail, we show that icebergs off the coast of Florida likely calved from ice streams in the Gulf of St Lawrence and Hudson Bay. We find that icebergs can only drift south of Cape Hatteras, and overcome the northward flow of the Gulf Stream, when they are entrained in a narrow, southward-flowing, coastal meltwater flood originating from the Laurentide Ice Sheet. This cold meltwater increases iceberg survival in the warm subtropics and flows in the opposite direction to the Gulf Stream along the coast, allowing icebergs to drift to southern Florida in less than 4 months. We conclude that during the last deglaciation, icebergs drifted south in massive meltwater floods that delivered freshwater to the subtropical North Atlantic. Our findings have important implications for understanding how changes in freshwater forcing triggered past abrupt climate change.

MICROPHYSICS AND PREVALENCE OF SURFACE-BASED CLOUDS AT SUMMIT STATION, GREENLAND: 2012-2013

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The mass balance of the Greenland Ice Sheet has become increasingly negative over the past several decades (Rignot et al. 2008). Changes in the surface mass balance have been linked to increasing surface air temperatures at some locations on the ice sheet (Hanna et al. 2008). Recent research shows that at decadal time scales, the sign of the surface mass balance changes due to exchanges in the dominance of accumulation and runoff rates (Box 2013). Clouds influence the surface mass balance because they play a role in both the hydrologic cycle and surface energy balance. Further, cloud and post-depositional processes influence the isotopic composition of the ice (Ciais and Jouzel 1994; Town et al. 2008) and therefore are important for understanding the climate history of the ice sheet from isotopic records recovered from ice cores. Despite this importance, relatively little is known of the properties of clouds over the Greenland Ice Sheet. This work focuses on observations of surface-based clouds, including supercooled liquid radiation fogs, ice fogs, diamond dust, and blowing snow. It is anticipated that the different types of surface-based clouds exhibit a range of radiative, dynamic, and hydrologic interactions with the surface.

The measurements are provided by two field projects located in central Greenland at Summit Station (72N 38W 3200m): boundary-layer observations from the Climate Processes Research Group (CPRG) and tropospheric observations from the Integrated Characterization of Energy, Clouds, Atmospheric state and Precipitation at Summit (ICECAPS) (Shupe et al. 2013). The period of study is June 2012 through October 2013 (17 months).

In situ observations of surface-based cloud microphysics are presented from measurements made by Droplet Measurement Technologies (DMT) Meteorological Particle Spectrometers (MPS) and Fog Monitors (FM100) positioned at 2 m and 10 m on a 50 m tower at Summit. MPS and FM100 data are combined with meteorology and observations from collocated remote sensors, including a radar and an infrared spectrometer. The remote sensors and meteorology are used to categorize the FM100 and MPS data into a surface-based cloud typology. The following questions are addressed: 1) how frequently do the various types of surface-based clouds occur at Summit?, 2) what are their microphysical properties?, and 3) what are the meteorological conditions under which they occur?

This work will provide a baseline characterization of surface-based clouds over the central Greenland Ice Sheet, informing future work that will quantify the influence that these clouds have on the surface energy and hydrologic budgets of the ice sheet, and constrain the influence of cloud processes on the isotopic ratio of surface accumulation.

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CONSTRAINING THE TIMING AND DURATION OF EARLY HOLOCENE AND EARLY NEOGLACIAL ADVANCES ON BAFFIN ISLAND, ARCTIC CANADA

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Throughout the Holocene, Northern Hemisphere climate has been primarily driven by a monotonic decline in summer insolation, but this linear climate driver has resulted in nonlinear environmental responses (Wanner et al., 2011)—especially in the Arctic, where reconstructions point to abrupt, stepwise, and episodic climate shifts (e.g., Geirsdottir et al., 2013). Documenting the regional expressions of climate evolution is critical in understanding how the cryosphere responds to nonlinear climate change, a particularly critical question to address as the Earth enters a phase of unprecedented warming. Arctic paleoclimate reconstructions suggest that a warm early Holocene was disrupted by an abrupt cold reversal and associated glacial advance at ~8 ka (Alley and Augustsdottir, 2005 and references therein) and that the onset of Neoglaciation (~5 ka) was followed by a series of a glacial advances and retreats preceding the Little Ice Age (~1275–1850 AD; Briner et al., 2009). Records of these short-lived glacial advances are poorly preserved on the landscape, so their climatic mechanisms remain incompletely understood. However, rare nested glacier moraine systems and associated proglacial lake sediments on Cumberland Peninsula, Baffin Island, offer an invaluable opportunity to better constrain the timing and character of these transient glacial events.

By dating early Holocene and earliest Neoglacial moraines and conducing multi-proxy analysis of adjacent glacially-dominated lacustrine sediments, I plan to develop a more complete chronology of Holocene glacial activity and climate evolution for southeastern Baffin Island. I am currently preparing 24 boulder samples from two moraine complexes, Snow Creek Glacier and Throne Glacier, for 10Be cosmogenic radionuclide dating. I will present anticipated results based on lichenometry and morphostratigraphy. I have also obtained two ~3-meter sediment cores from South America Lake and will present preliminary physical and bulk geochemical proxy data. Additionally, I plan to integrate these records with the emerging vegetation radiocarbon data from Miller et al. (2012, 2013), which constrain the onset of cold periods during the late Holocene. I anticipate being able to evaluate the temporal offset (decades to centuries) between the onset of coolings and the culmination of local cirque- or mountain-glacier advance during the Late Holocene. Identifying both the start and peak of cold periods will help to flesh out the paleoclimate record and will also provide a means of better understanding the cryospheric response to climate change in this region.

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CONFIRMATION OF THE USE OF FTIR SPECTROSCOPY TO DETERMINE BIOGENIC SILICA CONTENT OF ARCTIC LAKE SEDIMENTS: A POWERFUL TOOL FOR HIGH-RESOLUTION PALEOCLIMATE RECONSTRUCTIONS

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The biogenic silica (opal) content of sediments from Arctic lakes were determined using Fourier Transform Infrared Spectroscopy (FTIRS). Biogenic silica has been shown to record siliceous microfossil abundances in lakes (Conley, 1988) and has been interpreted as a paleo-producitivity/paleoclimate proxy (McKay et al., 2008; Brigham-Grette et al. 2013). Traditional wet chemistry extraction measurements (eg. Mortlock and Froelich, 1989; Conley, 1988) are time-consuming and expensive, prohibiting high-resolution analysis. A new method of determining biogenic silica using infrared spectroscopy (Vogel et al. 2008; Rosén et al. 2010) allows for large numbers of samples to be run quickly and cheaply, greatly increasing the usefulness of this proxy for paleoclimate studies.

FTIRS analysis requires only a small amount of sediment (~0.01g) and minimal pretreatment (mixing with non-toxic potassium bromide). When a sample is exposed to infrared (IR) radiation, molecules containing polar bonds vibrate at wavelengths specific to their structural and atomic composition and absorb the IR radiation (Vogel et al. 2008). By measuring the absorption spectra of a sample and integrating the peak area of certain molecules relative amounts can be determined. To quantify the actual percentage of biogenic silica in a given sample, absorbance peak areas characteristic of amorphous SiO4 were regressed against traditional measurements. A linear regression shows a significant correlation, with an r2 of 0.88 (n=21).

This calibration was then applied to all downcore samples from Nanerersarpik Lake in SE Greenland to produce a high-resolution paleo-productivity record for the Holocene. Preliminary analysis suggests some resemblance between the highly variable biogenic silica concentrations and reconstructed temperatures from the GISP2 (Kobashi et al., 2011) and Renland/Agassiz (Vinther et al., 2009) ice core compilations over the past ~2000yr. While the absolute agreement of these records is debatable, it nevertheless demonstrates the potential advantage of this type of analysis. The use of FTIR spectroscopy allows for many more samples to be analyzed than traditional methods would permit with the same application of resources and can provide high-resolution measurements of an informative paleoclimate proxy.

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ICE SHEET EROSIONAL IMPACTS IN THE LOW-RELIEF SHIELD TERRAIN OF NORTHERN FENNOSCANDIA

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Much previous work on Late Cenozoic glacial erosion patterns in bedrock has focussed on mountain areas. We here identify varying impacts of ice sheet erosion on the low-relief bedrock surface of the Fennoscandian shield, and examine the geological, topographical and glaciological controls on these patterns.

We combine GIS-mapping of topographical, hydrological and weathering data with field observations. We identify and investigate areas with similar geology and general low relief that show different degrees of ice sheet erosional impact, despite similar ice cover histories. On two transects with a total area of ~84 000km2 across the northern Fennoscandian shield, we first establish patterns of glacial erosion and then examine why glacially streamlined areas exist adjacent to areas of negligible glacial erosion. The northern transect includes two areas of exceptional glacial preservation, the Parkajoki area in Sweden and the so-called ice divide zone in Finland, each of which preserve tors and deep saprolite covers. The southern transect, overlapping in the northern part with the first transect, includes areas of intense glacial streamlining, with bedrock areas stripped of loose material and barely any weathering remnants.

For both areas, we firstly present the indicators we have availabe for ice sheet erosional impact: streamlined and non-streamlined inselbergs; parallel and dendritic/rectangular drainage patterns; the absence and presence of Neogene weathering remnants. This is followed by an investigation of factors that possibly influence ice sheet erosional impact: (pre-glacial) land surface elevation and topography, bedrock type and structure, and the ice cover history.

We find that the extreme preservation of pre-glacial relief in certain parts of the study area is likely explained by repeatedly divergent flow and frozen-based conditions, and that the most likely control causing glacial streamlining and strong erosion was acceleration of flow around major obstacles and convergence towards major bed depressions. No direct impact of rock type on glacial erosion patterns was found, but an indirect control appears clear. Bedrock geology and long-term differential weathering and tectonic evolution determined the topography of the pre-glacial landscape, and these topographic differences subsequently influenced ice sheet dynamics and thereby partly controlled ice sheet erosion on the Northern Fennoscandian shield.

GEOCHEMICAL AND STRATIGRAPHIC ANALYSIS OF THE LINNÉVATNET SEDIMENT RECORD: A PROVENANCE STUDY OF LATE HOLOCENE CIRQUE GLACIER ACTIVITY IN LINNÉDALEN, SPITSBERGEN, SVALBARD.

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Moraines and lacustrine sediment in Linnédalen, Spitsbergen, Svalbard, record fluctuations of a small glacier in a currently unglaciated mountain cirque during the Little Ice Age (LIA) (Snyder et al., 2000). This 'west basin cirque' is located on the western valley wall of Linnédalen, and is underlain by phyllite, which is lithologically distinct from the other bedrock units of the valley (Ohta et al., 1992). Consequently, glacigenic sediment from the west basin cirque can be distinguished by its unique geochemical characteristics. Modern snowmelt and runoff, and presumably historical glacial runoff, drain from the cirque into the western sub-basin of Linnévatnet.

This study attempts to reconstruct the historical glacial activity, and particularly onset of LIA glaciation, within the west basin cirque from the Linnévatnet lacustrine sediment record using geochemical and stratigraphic techniques. Core D10.5, 57 cm in length, was collected from the western sub-basin of Linnévatnet in July 2013 using a percussion corer. Profiles of spectral reflectance and magnetic susceptibility were measured at 5-mm intervals with a GeoTek Multisensor Core Logger, and semi-quantitative profiles of elemental composition were measured using X-ray fluorescence every 500 μm with an ITRAX Core Scanner. Thin-sections were prepared from Core D10.5 by removing sections of sediment, which were then set in epoxy and cut to a thickness of 30 μm. Core D10.5 was also subsampled for 239+240Pu radionuclide dating, as described by Ketterer et al. (2004), and for chemostratigraphic analyses to identify the ca. 1850 CE and ca. 1930 CE horizons from increases in metal concentrations (measured with Inductively-Coupled Plasma Mass Spectrometry) associated with elevated atmospheric deposition during the industrial revolution and local coal mining, respectively.

Peak concentrations of 239+240Pu, ascribed to peak bomb fallout in the years 1963/1964, occur at a depth of 1.89 cm, indicating slow sedimentation rates (0.38 mm yr-1) consistent with rates preceding the LIA (Snyder et al., 1994). Rises in aluminum-normalized Hg and Na concentrations at 10 cm core depth likely reflect the increased atmospheric deposition of Hg and Na associated with anthropogenic emissions (ca. 1850 CE). A further increase in Hg and rises in Ba and Cr at 4 cm are interpreted as the result of atmospheric deposition of coal ash from local sources (ca. 1932 CE). The calculated sedimentation rate within the 1850-1932 interval is 0.80 mm yr-1, representing glacial sedimentation rates. This region exhibits relatively abundant and well-defined, light-colored laminae, which are interpreted as the result of increased, cirque-derived sedimentation. An age-depth model was derived from these rates, applying the higher sedimentation rate to regions with abundant laminae and the lower rate to regions lacking well-defined laminae (Fig. 1).

The majority of XRF elemental profiles exhibit low signal-to-noise ratios, excepting the elements K, Ti, Mn, and Fe, each of which exhibit highly variable downcore trends in XRF peak area (Fig. 1). High XRF Ti peak areas are associated with cirque-affiliated sediments, likely supplied by elevated sedimentation from glacial erosion. Therefore, high Ti signals representing increased generation, transport, and deposition of glacigenic cirque sediment are expected to be correlated with abundantly laminated regions. However, there is no strong association between elevated Ti signal and increased laminae abundance (Fig. 1). Rather, laminae-rich regions are associated with gradual increases interrupted by rapid decreases in Ti signal (Fig. 1). This may represent complex hydrological, and perhaps glaciological, processes affecting erosion and transport to the Linnévatnet west basin. Three distinct regions of abundant laminae suggest three episodes of elevated sedimentation, the younger two (1340-69 CE and 1821 CE-Present) are coincident with LIA intervals (Grove, 1988). This suggests two periods of active glacial erosion and sediment delivery during these two periods. In contrast, Snyder et al. (2000) conclude that there was a single glacial episode beginning approximately 400 yr BP. Interestingly, a third region of abundant laminae falls within the Medieval Climate Anomaly, and perhaps represents a period of increased erosion and transport driven by elevated precipitation (Trouet et al., 2009). These findings suggest that stratigraphic and geochemical variation in the lacustrine record of the Linnévatnet west basin are complexly linked to glaciological and hydrological processes in Linnédalen.

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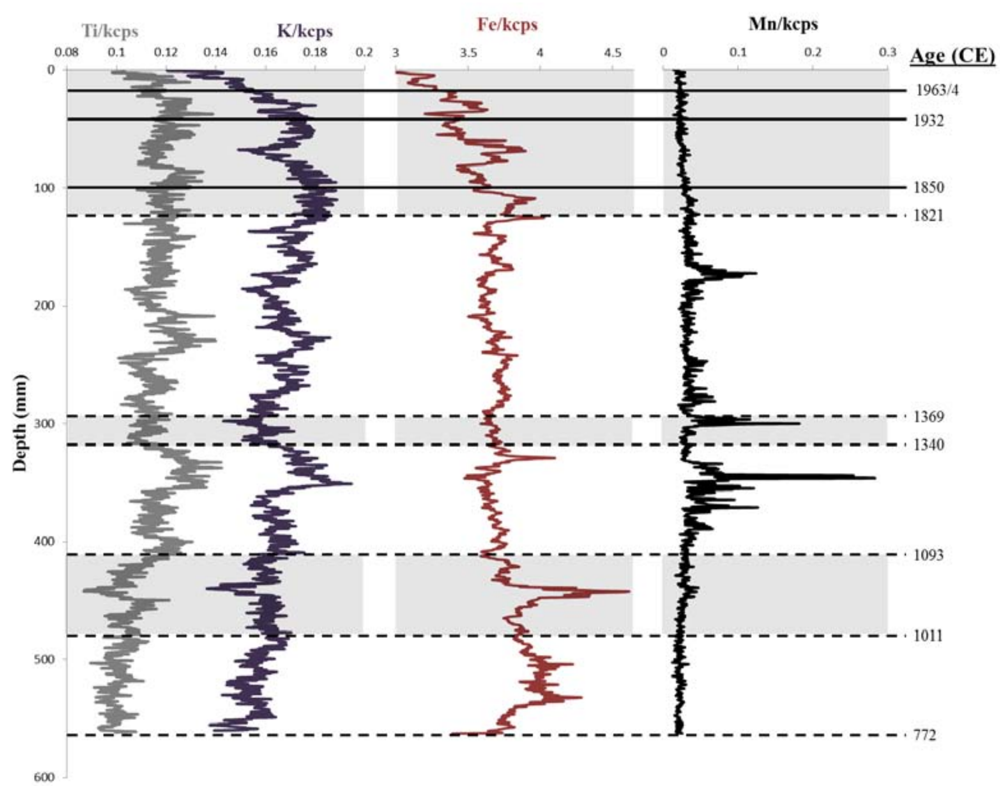

Fig 1. XRF profiles of Ti, K, Fe, and Mn in core D10.5, measured in peak area and normalized at each depth by kilocounts per spectrum (kcps). Shaded areas represent portions of core with closely spaced, light-colored laminae. Solid black lines represent absolute ages based upon 239+240Pu-dating (1963/64) and chemostratigraphic dating (1932, 1850), while dashed lines represent ages calculated from sedimentation rates.

A PILOT STUDY OF THE EXTENT AND VARIATIONS IN MELTWATER PLUMES AND ICEBERGS EMANATING FROM NORTHEAST GREENLAND TIDEWATER GLACIERS

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In 1993 the German research vessel Polarstern undertook a research cruise to the fjords and shelf of Northeast Greenland. A series of cores were collected (Figure 1) and initial results have been reported by Evans et al. (2002) and Stein (2008). As part of a collaborative research program with German scientists (Andrews et al., 2014) Andrews has investigated the downcore variations in grain-size and mineralogy in cores along a transect close to Kesjer Franz Joseph (KFJ) Fjord. Although considerable attention has been paid to variations in ice-rafted debris (IRD) along the Northeast Greenland margin, the grain-size spectra in the Holocene sediments is largely fine-grained (< 63 μm) suggesting transport in either meltwater plumes or possibly from sea ice (Darby et al., 2011).

To investigate the potential role of glacial meltwater plumes in sediment delivery to core locations we embarked on a pilot study using Landsat and Moderate Resolution Imaging Spectroradiometer (MODIS) imagery. Transferring our experience from West Greenland (Hudson et al., 2013) to the more ice-dominated fjords and shelf of Northeast Greenland we attempt to to determine the extent, and variation of sediment plumes on an interannual and intra-annual time scale. In addition to studying sediment plumes, we attempt to resolve iceberg concentration over the east Greenland shelf.

Our study area is in Northeast Greenland and consists of the KFJ fjord and approximately 100 km of the surrounding coastal shelf (figure 1). The KFJ fjord is approximately 90 km long by 12 km wide and has multiple rivers that drain into it. The largest glacier terminating in the fjord is the Waltershausen Glacier and is a significant source of icebergs. Within the study area are the locations of 13 cores taken during the 1993 Polarstern research mission.

Using MODIS, Landsat 7, and Landsat 8 satellite imagery we attempt to determine the extent and variation in plumes and icebergs over four years. Past studies have shown that different combinations of visible and near-infrared bands can be used to identify plumes and icebergs, and delineate both from cloud cover. This multi-year analysis consists of two lower melt years (2004, 2009) and two higher melt years (2010,2012) (Tedesco et al.,2013). For each study year an approximate date was identified that fjords were clear of sea-ice to mark the beginning of that study year. Landsat imagery with <60% cloud cover was downloaded via USGS EarthExplorer. Subsetted MODIS imagery of the study area was received from NASA. Without fjord samples of suspended sediment concentration (SSC), we use higher resolution Landsat imagery as a “ground truth” data set to validate near-daily lower resolution MODIS imagery.

Preliminary work shows sediment plumes extend only to inner fjord locations, such as core locations PS2633-1 and likely PS2632-7 in the main KFJ fjord channel (figure 2). Plumes have not been found to reach the core locations to the south of these or over the shelf. Plume extent appears to vary significantly over the melt season, with the plume peak occurring in early to mid-August. Sediment plumes have also been identified down-fjord emanating from small streams fed by local land-terminating glaciers. One interesting finding was a plume of considerable extent to the north of Waltershausen Glacier. This plume originates near an unnamed glacier that appears to terminate on land. We hypothesize that this plume is forced to stay at the surface due to it’s buoyancy, whereas plumes originating from tidewater glacier fronts may lose some of their volume as the plume moves vertically towards the surface.

Future work will analyze MODIS and Landsat imagery using automated Python scripts to quantify the extent and duration of plumes in these areas over entire melt season and expand the length of our study to include all years from 2002 to 2013.

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Fig 1. Study area, Northeast Greenland including core locations and identified glaciers

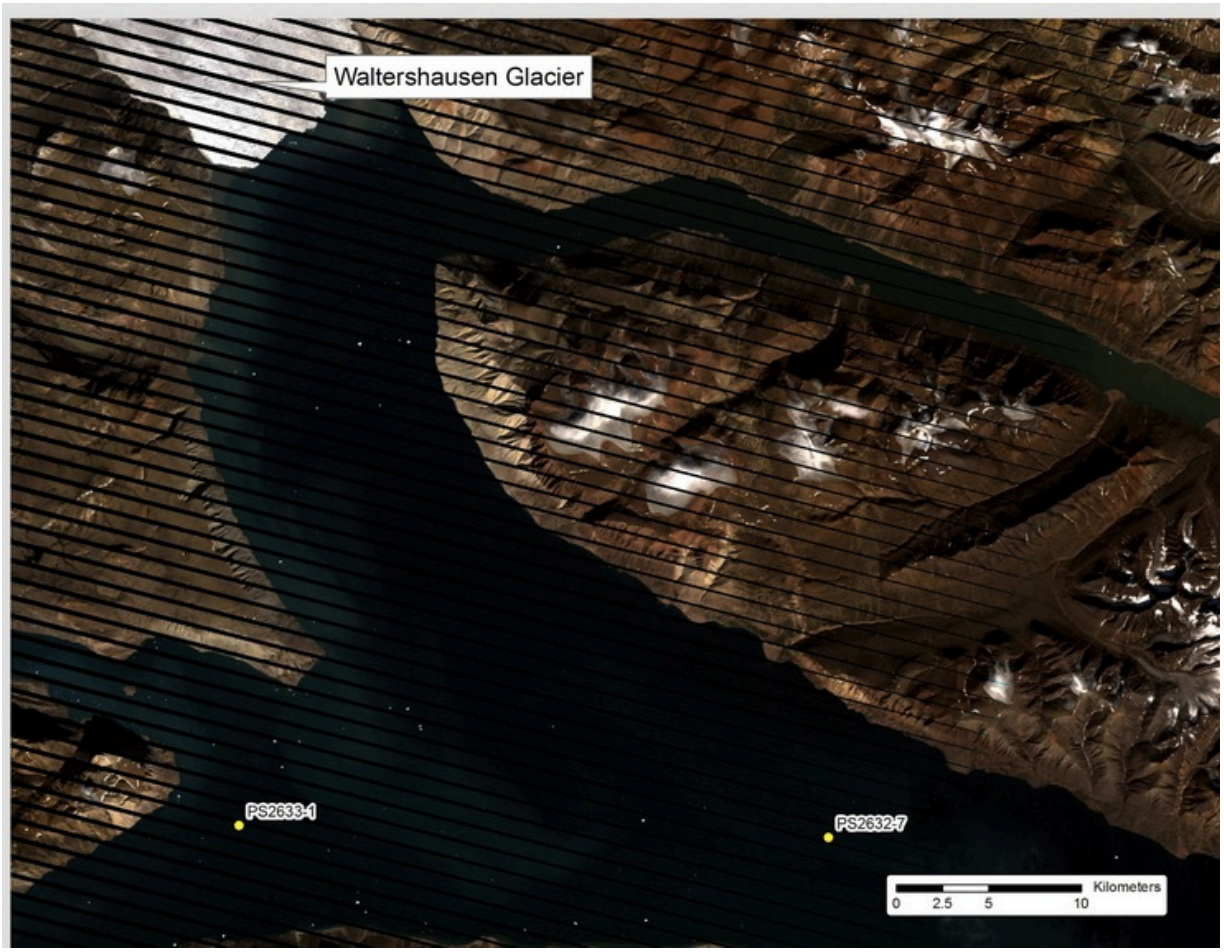

Fig 2. Sediment plume identified using Landsat 7. Sediment plume exits glacier and travels along the western edge of the fjord. Plume identified over core site PS2633-1 and likely PS2632-7 (both pictured).

RESPONSE OF THE ISOTOPIC COMPOSITION OF ARCTIC PRECIPITATION TO CHANGES IN SEA ICE EXTENT

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Stable water isotope records from Greenland ice cores are a useful tool to reconstruct regional past climate variations. Results have shown (Steen-Larsen et al., 2011) that the common assumption that the isotopic signal is a direct indicator of temperature proves to be misleading under certain circumstances, since the isotope signal is also influenced by variations in e.g. atmospheric circulation and origin of moisture sources. An improved understanding of the atmosphere effects on the isotope signal is therefore essential in order to improve our knowledge of past climate changes. Modeling studies of changes of past climate sea ice extent have stressed the importance of sea ice as essential for understanding the changes in isotopes in Greenland and Antarctic precipitation (Noone, 2004; Sime et al., 2013) Furthermore, this is supported by observational ice core studies from the Arctic that suggest sea ice to be important for the isotope composition. (Divine et al., 2011)

Artic Sea Ice cover has undergone a drastic reduction during the last decades, This has provided a great opportunity to use observational based data as input to isotope enabled GCM models in order to investigate the influence of sea ice cover on present day Artic isotopes. Here we use the model isoCAM3 (D.Noone), an isotope-equipped version of the National Center for Atmospheric Research Community Atmosphere Model version 3. Four simulations and one control simulation are performed. Each of the four runs simulates the atmospheric and isotopic response to SST and sea ice conditions for selected years within the satellite era (1979-2013). Results show that the isotopic composition of arctic precipitation is sensitive to changes in sea ice extent, with reduced ice extent causing more enriched isotopes and vice versa. Results also show that different configurations of sea ice cover yield different distributions of the isotopic response.

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A NEW NORMAL FOR THE SEA ICE INDEX

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The NSIDC Sea Ice Index is a popular data product that shows users how ice extent and concentration have changed since the beginning of the passive microwave satellite record in 1978. It shows time series of monthly ice extent anomalies rather than actual extent values, in order to emphasize the information the data are carrying. Along with the time series, an image of average extent for the previous month is shown as a white field, with a pink line showing the median extent for that month. These are updated monthly; corresponding daily products are updated daily.

The Sea Ice Index was first published online in 2002. A baseline period of 1979-2000 was used for calculating means and medians. In July 2013, we changed the product to use a 30-year baseline period (1981-2010). This new normal, by including the first decade of the 21st century with its record low extent years, changed the scale on the extent trend plots so the overall loss of ice looked less anomalous than before the change, and each month's median extent line generally moved further north in the Arctic (in Antarctica, the position of the median extent line did not change much).

A 30-year period is the standard used by organizations like the World Meteorological Organization (WMO) and NOAA for climatologies and climate normals. Thirty years is used because it is deemed a sufficiently long time to average out most interannual variability but short enough to clearly show longer-term climate trends. These maxims about climate normals come from the world of weather and climate. Sea ice responds to climate forcing differently, and the assumptions behind the use of 30-year normals for meteorology may not hold true for sea ice.

We moved to a longer baseline, but with reservations.

Should we have changed the baseline? If the baseline includes periods of significant change, the resulting means or medians do not necessarily represent "normal" conditions for comparisons. In other words, ideally the baseline period should be relatively stable with small or no trend. This is not the case for sea ice in the Arctic, particularly since 2000. The loss of Arctic sea ice may now appear less significant to casual users of the product.

Another consideration is that features that were once common may be lost in updated climatologies. The most notable example is the Odden ice tongue (Figure 1) that once routinely formed off the east coast of Greenland during winter. Associated with outbreaks of cold air temperatures along with the interplay of bathymetric features and ocean currents, the Odden has not formed frequently enough in the first decade of the 21st century to show up in the new monthly median extent line at all. The recent absence of the Odden illustrates an important change in the sea ice system, but without a median extent line from a "more-normal" normal period, information about the loss of the Odden is not carried by the Sea Ice Index data product as obviously as was the case before.

At this workshop, with its theme of the Arctic's new normal, we have an opportunity to hear and gather opinions, suggestions and ideas about how to better understand and explain the use of a "normal" in a sea ice product intended for a wide audience.

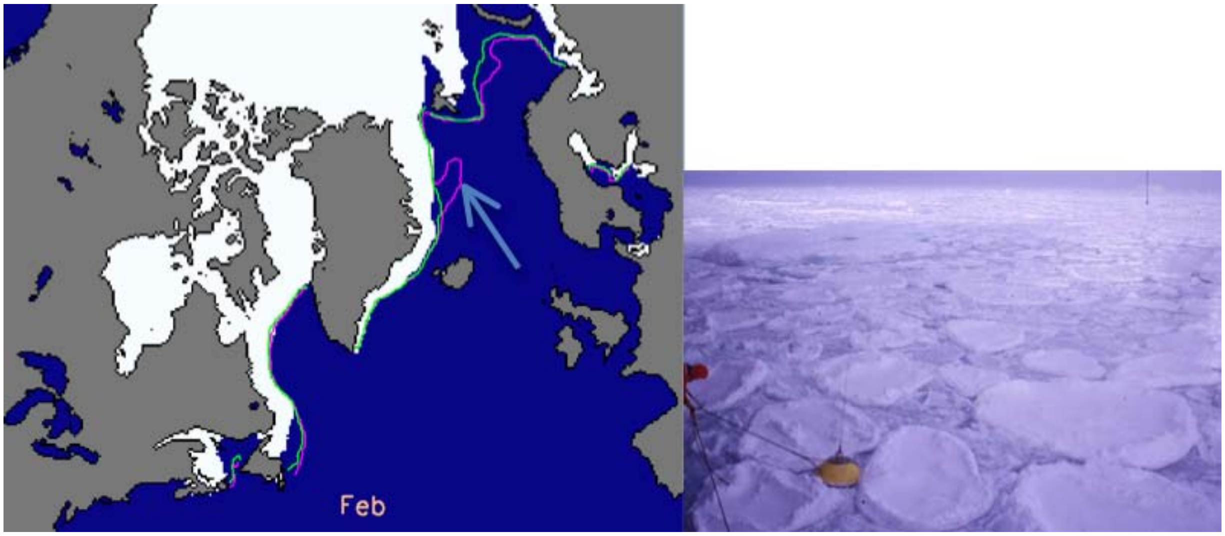

Fig 1. Left: February 2013 ice extent with the 1981-2010 median extent and 1979-2000 median extent lines overlain in green and pink respectively. The Odden feature in the 1979-2000 median is marked by the arrow. Right: Pancake ice within the Odden. Credit: Peter Wadhams

A TWO-THOUSAND YEAR RECORD OF NORTHERN ICELAND LATE HOLOCENE COOLING FROM LAKES BÆJARVÖTN AND TORFADALSVATN

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Lakes on the northern Icelandic coast are ideally poised to record the climatic effects of expanded sea ice during late Holocene cooling. Isolation from warm Irminger Current waters and exposure to the exported Arctic sea ice East Greenland Current makes this a climatically sensitive area. An ubiquitous indicator of late Holocene cooling across Iceland is the destabilization of terrestrial landscapes and the resulting increase in terrigenous organic matter content of lacustrine sediment cores. While this is a useful proxy, terrestrial destabilization likely exhibits a threshold response that is related to the resilience of landscape vegetation, and can be influenced by local human activity. Because of this, additional proxies should be utilized to gain a better understanding of the temporal structure and magnitude of regional late Holocene cooling. We present high-resolution climate proxy records from two Icelandic lakes, Bæjarvötn located on eastern Vestfirðir, and Torfadalsvatn, located 60 kilometers east on the Skagi Peninsula. Carbon-to-nitrogen ratios and stable C and N isotopes from bulk sediment show a distinct signal of terrestrial destabilization during the Little Ice Age at both sites. Sedimentary algal pigments were also measured in this study as proxies for past changes in magnitude and type of lacustrine primary productivity. Differences in the timing and structure of landscape destabilization between the two sites can be explained by comparing the catchment morphology and the algal pigment record. This comparison gives a better understanding of regional climate evolution.

INCREASED SURFACE MELT APPEARS TO STIMULATE SILICATE WEATHERING UNDER THE GREENLAND ICE SHEET

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Samples of subglacial water were collected from boreholes drilled into the western Greenland Ice Sheet (near Kangerlussuaq) and from outlet streams thereof. The underlying bedrock in the sampled region is a geographically extensive and moderately homogenous gneiss (Kalsbeek et al., 1987), allowing for a relatively constrained analysis of the reaction pathways controlling the observed water chemistry. Alpine glaciers underlain by similar rock types tend to show mixing between chemical compositions consistent with stoichiometric silicate weathering and those consistent with carbonate dissolution (Graly et al., 2014). However, the chemistry of the Greenland Ice Sheet waters is influenced by mixing with a third processes that gives the samples a substantially greater proportion of alkali metal elements (Na+ and K+) than is found in alpine glaciers. Due to the relatively small proportion of Cl- in the samples, we infer that the alkali metal elements source primarily from silicate rocks. Thus the influx of Na+ and K+ without stoichiometrically-balanced Si either represents Si precipitation or the incomplete reaction of freshly exposed silicate mineral surfaces (Blum and Stillings, 1995).

This dataset from Greenland has tentative implications for changing baselines in the arctic. In particular, it suggests that production and weathering of fresh mineral surfaces in subglacial environments will increase with increased surface melt. We infer this hypothesis from two lines of evidence. First, water chemistry data from a major terminal outlet show increased fluxes of alkali metals with increased meltwater over a four year period. The large melt year of 2012 showed substantially greater influxes of unbalanced Na+ and K+ (Figure 1). Low melt periods during 2010 showed chemistries approximately on the mixing line between carbonate and silicate weathering. The moderate melt years of 2011 and 2013 showed influence of Na+ and K+, but in smaller proportions, with slightly greater influence in 2011 (when melt was higher).

Secondly, a few boreholes drilled in temperate ice were sampled multiple times over a period of >24 hours. Such boreholes initially showed a greater proportion of Na+/K+ rich water, but shifted to a more stoichiometric silicate balance during later sampling (Figure 1). This result can be explained by the effects of the surface water introduced by drilling, which likely initiated silicate weathering reactions that were only completed by the later sampling period. This hypothesis complements the observation that Na+/K+ influence is greatest when natural surface melt is the highest, and rules out silicate precipitation as a mechanism for unbalanced Na+/K+ production.

Together these observations suggest that influx of water from surface melt on the Greenland Ice Sheet directly stimulates silicate weathering. Multiple mechanisms may explain this. The surface water carries dissolved atmospheric gasses (CO2 and O2) that facilitate weathering reactions, especially where these gases have become depleted within the basal hydrologic system (Tranter et al., 2002). Increased surface water in the basal hydrologic system may also increase the grinding and comminution of the glacial bed (possibly through increased sliding). Increased comminution would increase the exposed mineral surface area and stimulate weathering reactions – particularly surface cation exchange (Blum and Stillings, 1995). Substantially higher suspended sediment concentrations found during the high melt years also suggest that sediment grinding may have increased with the influx of surface water.

The increased production, transport, and weathering of the sediment beneath ice sheets increases the consumption of CO2 by weathering reactions and therefore represents a negative feedback on global warming. As this feedback is only tentatively suggested by a limited dataset, we are not yet able to quantify its magnitude.

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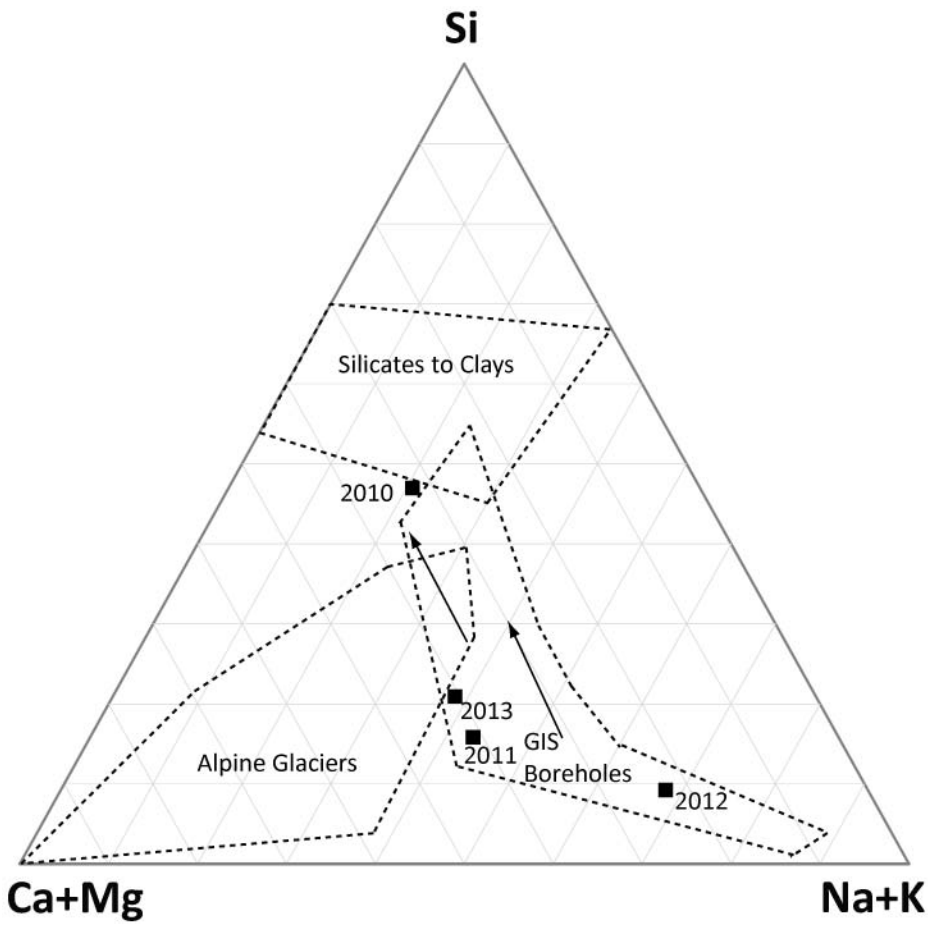

Fig 1. The dashed boxes represent the composition of waters retrieved from Greenland Ice Sheet (GIS) boreholes, chemical compositions found at terminal outlets of alpine glaciers (references in Graly et al., 2014), and the stoichiometry of silicate reactions to clays. The black squares represent average chemical compositions of terminal outlet waters at a major outlet of the Greenland Ice Sheet during 2010-2013. The arrows represent observed shifts in the chemical compositions of waters retrieved from single boreholes over 24 hour periods.

A PHYSICAL AND MINERALOGICAL STUDY OF SAND DEPOSITS IN THE SUMBURGH AND QUENDALE AREAS OF THE SHETLAND ISLANDS, UK

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Late Holocene climate fluctuations resulted in pronounced coastal changes throughout the North Atlantic (Dawson, S., et al., 1998, Jordan et al., 2010, Karpuz and Jansen, 1992). When the Medieval Warming Period gave way to the Little Ice Age in the sixteenth century AD (Dawson, A., et al., 2004), oceanic storminess increased significantly. Coastal communities across the North Atlantic experienced sand blows, some of which displaced entire communities (Tisdall et al., 2013, Dawson, S., et al., 2004). The Sumburgh and Quendale areas of southern Mainland, Shetland Islands, UK (Figure 1), contain extensive surface deposits of windblown sand that can reach depths of several meters. This sand hints at Little Ice Age periods of intense storminess that resulted in the complete burial of a multi-farm township near the Bay of Quendale and may have covered an inlet between the Bay of Scousburgh and the Loch of Spiggie (Bigelow et al., 2005). This study aims to understand the mechanisms behind the deposition of this sand using physical and mineralogical analyses of sand samples collected from the study area.

Grain size analysis was used in conjunction with quartz grain surface morphology in order to determine the physical parameters driving the movement and deposition of sand samples. To determine the provenance of the sand, x-ray diffraction was used to compare the mineralogy of the blown sand with local sediment sources, including glacial till.

Observations of organic horizons between sand layers in numerous excavations along with results from grain surface morphology indicate that the accumulation of sand occurred as a series of events as opposed to a single event. The topography of the landscape between the Bay of Quendale and the Broo archaeological site has forced large volumes of sand to collect in the form of high dunes at the base of a hill, on top of which the Broo site is located. It is possible that multiple storm events pushed sand from this base location up onto the top of the hill, progressively burying the Broo site.

X-ray diffraction results from the land bridge separating the Loch of Spiggie from the Bay of Scousburgh (Figure 1) are currently being compared to the mineralogy observed at the Bay of Scousburgh and in cores from the Lochs of Spiggie and Brow. These comparisons will be used in conjunction with grain surface morphology results to define the depositional history of the bridge and the lochs. Sand grains from these samples appear to have complicated transportation histories, including time spent in glacial sediments, littoral zones, and aeolian environments. Glacially-derived characteristics were present on a significant portion of the grains. Subaqueous characteristics overly these glacial indicators, and they themselves are overlain by aeolian characteristics (Figure 2).

The results from these physical and mineralogical tests will be used with OSL dating results to pinpoint the mechanisms and timing of the complete inundation of the Broo farmstead and the inlet between the Loch of Spiggie and the Bay of Scousburgh.

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Fig 1. Study area, south Mainland, Shetland Islands, UK

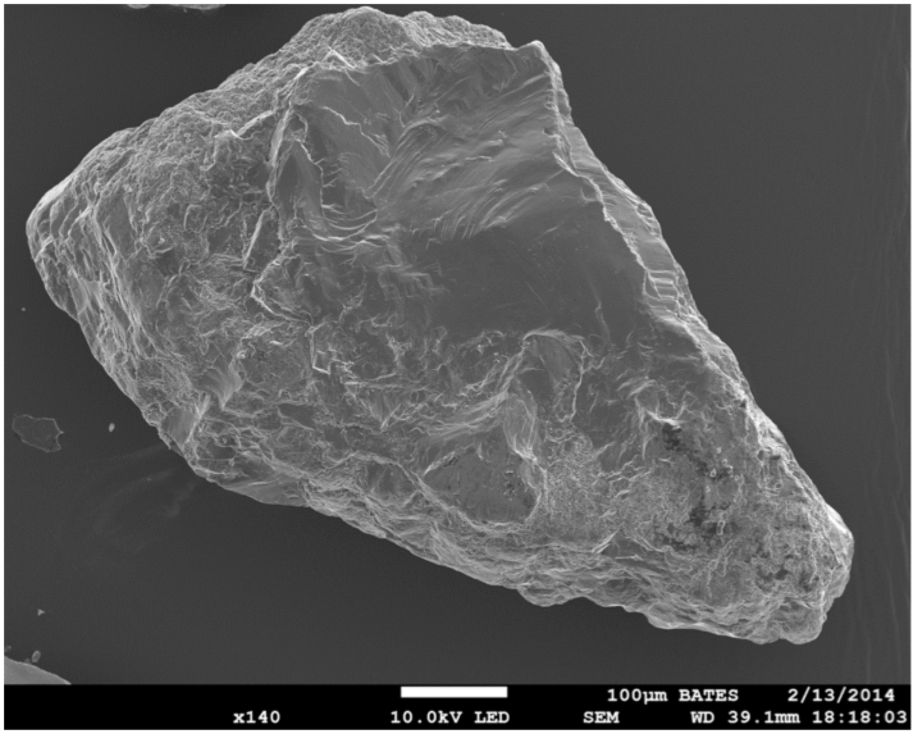

Fig 2. Example of a quartz grain from the land bridge separating the Loch of Spiggie from the Bay of Scousburgh.

RECONSTRUCTING HOLOCENE CLIMATE AND GLACIAL EXTENT OF DRANGAJÖKULL, VESTFIRÐIR, ICELAND

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In light of the Arctic's inherent sensitivity to abrupt climate change it is imperative to place current Arctic warming in the context of long-term natural variability. In this project we focus on utilizing a multi-proxy approach to reconstruct the Holocene climate history of northwest Iceland and the glacial extent of the region's large ice cap, Drangajökull. NW Iceland is particularly sensitive to climate change as it lies at the boundary between major oceanic and atmospheric circulation systems. A primary challenge facing the paleoclimate community has been the difficulty in securing continuous well-dated records from this region for the Holocene. Therefore, the first part of this project targets two Drangajökull-proximal lakes, Ljótárvatn and Tröllkonuvatn, and will apply a wide-range of well-established physical and geochemical proxies to sediment cores recovered from these lakes. This will provide the first high-resolution Holocene record of Drangajökull activity, bolstered by Iceland's high lacustrine sedimentation rate and the application of a secure geochronology (PSV synchronization supported by 14C, tephrochronology and potentially varved sediments). The second portion of this project capitalizes on the radiocarbon dating of emerging in situ vegetation from underneath Drangajökull as a proxy for past ice cap extent. Here we present preliminary work including recent seismic data of sediment fill from the targeted lakes, preliminary data for a sediment core from Tröllkonuvatn and initial dates on dead vegetation exposed by the recent retreat of Drangajökull.

THE GREENLAND ICE SHEET'S ROLE IN SETTING RIVER AND FJORD SUSPENDED SEDIMENT CONCENTRATION: A TEST CASE FROM TWO WEST GREENLAND RIVERS

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The rate of mass loss from the Greenland Ice Sheet (GrIS) has quadrupled since the 1990s. Yet it is largely unknown how this mass loss has and will impact terrestrial and coastal systems downstream of it.

We used Landsat-series imagery to assess surface melt impact on Greenland's cryo-hydrologic and river systems. Greenland is estimated to produce 7% of the global sediment output to the ocean while only covering 1% of the world's total land area. Yet, because of the immense scale of Greenland, few rivers are monitored. We have used NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) imagery to quantify discharge and turbidity of West-Greenlandic rivers and plumes on a near daily basis (Hudson et al., 2013; Overeem et al., subm 2014). Landsat-series images are another avenue to study Greenlandic river dynamics remotely and on a large scale, and offer a much higher spatial resolution (~30 m).

GrIS hydrologic and sediment dynamics are tightly coupled to ice sheet flow and surface mass balance. As glaciers flow under the weight of gravity they erode bedrock in two principal ways. First, subglacial water pressure can create and/or exploit cracks in bedrock that allow ice to then 'quarry' and erode bedrock. Second, rocks embedded in basal ice (e.g. those quarried) can abrade the basal bedrock surface. Both processes are partially controlled by melt water. Surface melt entering the ice sheet drives water pressure differences in the subglacial water system and can enhance quarrying. Erosion from abrasion is thought to be a function of the square of the velocity of ice slipping over the bed. In turn, surface melt water pulses are thought to influence ice velocity variations.

Sediment created by glacial erosion is then exported slowly by the flow of ice to its terminus or rapidly by entrainment in flowing subglacial water. The relationship between water emerging from a glacier and its sediment content is complex to characterize. It is thought that variability in sub-glacial hydrologic networks can drive variability of sediment emerging from glaciers and transient flushes of sediment from glaciers in Greenland have been observed. Water accessing areas of the bed not previously reached can cause increases in sediment concentration per unit discharge. On the other hand, areas of the bed often exposed to the sub-glacial hydrologic network can be depleted in sediment. Because subglacial water efficiently mobilizes sediment, it is hypothesized that that seasonal and inter-annual processes control fine sediment exported from the GrIS that then travels in suspension in rivers. Thus, imagery of pro-glacial rivers near the glacial termini could be diagnostic of subglacial processes.

Rivers often have a power law relationship between their suspended sediment concentration (SSC) and discharge, Q: SSC = aQb: a and b are rating parameters. Though this relationship has been shown to be valid for two braided rivers with glacierized catchments on Baffin Island (Church, 1972) it is unknown if this holds true for Greenlandic rivers.

Characterization of a river's SSC-Q relationship serves as an indicator of the GrIS's impact on river SSC dynamics. Rivers following a stable SSC-Q relationship indicate fluvial processes dominate. Rivers deviating from this relationship suggest other processes (e.g. glaciological) may be controlling river SSC. We test this relationship with an in-situ dataset of water discharge collected from 2007-2012 for the Watson River (Hasholt et al., 2013) and 2011-2013 for the Naujat Kuat River, near Nuuk, Greenland.

We find that Landsat imagery can monitor channel planform shape using short wave infrared bands

(Band 5) and SSC with a ratio of red and near infrared bands (Bands 3 and 4). At Landsat's 30m resolution this allows the imaging of SSC dynamics at ice sheet termini, through the entire course of the river, and into fjords that ultimately receive melt. From preliminary work, we find that some Greenlandic river's SSC appears to be controlled by fluvial processes while others do not follow any predicable SSC-Q relationship and are perhaps instead controlled by ice sheet dynamics.

For the Watson River we find seasonal hysteresis in the relationship with early season melt generally more turbid than late season for the same amount of discharge. For portions of the melt season the ice sheet termini reaches of the river are more turbid than river mouth sections. For other parts of the melt season the opposite is true. This may indicate that GrIS only controls SSC in the river for portions of the melt season.

We also find for the Watson River, a river with multiple ice sheet termini, different termini can vary in importance to the river's SSC and discharge over time. For example, Landsat measured river-mouth turbidity correlates well with the Leverett Glacier outlet turbidity for the years 2007, 2008, 2010, and 2012. However, during 2009, another terminus correlates most strongly with river mouth turbidity. This may indicate that the volume of water discharged by the Leverett Glacier in most years is larger than other termini, but in some years the ratio between termini's water contributions is more equal.

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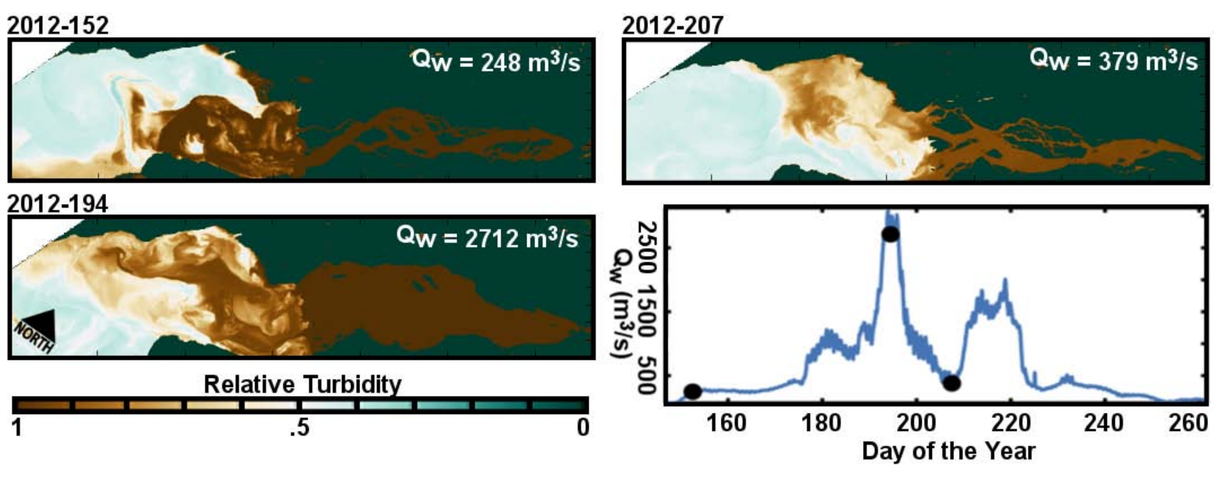

Fig 1. Processed ALI imagery, also plotted with reference discharge curve. Black dots on discharge curve show date and time imagery was acquired. Note river SSC hysteresis is present, possibly due to seasonal evolution of Greenland Ice Sheet hydrologic system. Land is masked as green. Comparison of day 152 and 207 also shows a channel avulsion to the southeast.

ESTIMATION OF THE PERMAFROST CARBON FEEDBACK USING SIBCASA TERRESTRIAL CARBON CYCLE MODEL

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The Permafrost Carbon Feedback (PCF) is an amplification of surface warming due to the release of CO2 and CH4 from thawing permafrost. Studies show that the extensive northern wetlands (>30N) contribute up to 25% of global CH4 emission, whereas 2.3% of CH4 emissions occurs from thawing permafrost in these regions. To improve estimates of the PCF we added prognostic organic layer to the Simple Bioshpere/Carnegie-Ames-Stanford (SIBCASA) Terrestrial Carbon Cycle Model and quantified CO2 and CH4 fluxes resulting from changes in terrestrial carbon storage in permafrost affected soils. Model simulations spanning 1801 to 2010 were driven using Climatic Research Unit-National Centers for Environmental Prediction (CRUNCEP) reanalysis, atmospheric CO2, and land use change information as modified by the Multi-Scale Terrestrial Model Intercomparison Project (MsTMIP). From 2011 to 2300, multiple projections of CO2 and CH4 emissions and changes in PCF were evaluated by scaling the CRUNCEP data using trends in weather data derived from the Fifth Coupled Model Intercomparison Project (CMIP5) for all Representative Concentration Pathway (RCP) scenarios. Implementation of the dynamic organic layer into the model lowered the effective thermal conductivity between the soil and the atmosphere and increased the resilience of permafrost to climate warming and decreased permafrost seasonal thawing depth. The ensemble mean for each RCP is our best estimate of CO2 and CH4 emissions from degrading permafrost and the standard deviation is a measure of uncertainty.

A STRATIGRAPHIC APPROACH TO CALIBRATE THE TIMING OF ICE DISCHARGE EVENTS IN HUDSON STRAIT AND HUDSON BAY AND TO DEVELOP A TEMPLATE FOR FRESHWATER FORCING FROM THE HUDSON STRAIT OUTLET INTO THE SUBPOLAR GYRE FROM 13-7 CAL KA BP

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Freshwater pulses into the North Atlantic from the Laurentide ice sheet (LIS) are thought to have interrupted and/or slowed the Atlantic meridional overturning circulation (AMOC), triggering climate instability during the last glacial period and the early Holocene. We develop a detailed history of the timing of ice-sheet discharge events from the Hudson Strait outlet of the LIS between 13 and 7 ka BP using high-resolution detrital carbonate (DC), ice rafted detritus (IRD), δ18O, and sediment color data from well-dated core MD99-2236 from the Cartwright Saddle, Labrador Shelf. MD99-2236 lies downstream of the Hudson Strait outlet in a position to capture a detailed sediment record of ice discharge events from the Hudson Strait outlet as icebergs and glacial meltwater were entrained in the Labrador Current.

Detrital carbonate peaks dominated by calcite (a signal of glacial erosion of the Paleozoic limestone that floors Hudson Strait) punctuate the MD99-2236 record in 7 distinct peaks between 11.5 and 8.15 cal ka BP. IRD and light oxygen isotope events are associated with the detrital carbonate peaks supporting the idea that these peaks mark distinct episodes of ice discharge from the Hudson Strait outlet. We assume that the main ice discharge phases would occur during ice advances across deep basins in the Hudson Strait or the SE Baffin Shelf, or during episodic ice retreat. These periods of increased calving and mass loss that would be recorded in the Cartwright Saddle as DC peaks. We use the age model of MD99-2236, based on radiocarbon age calibrations with ΔR=50±50 years, to assign a calibrated age and age range for each detrital carbonate peak in the core. We used a process of incrementally increasing ΔR to calibrate the radiocarbon-dated glacial events in Hudson Strait and Hudson Bay to find a 'match' between the MD99-2236 DC peaks and the known series of glacial events during the last phases of the deglaciation of Hudson Strait and Hudson Bay. The glacial events that we predict would produce DC peaks include: H0, Gold Cove advance, Noble Inlet advance, initial retreat of the Hudson Strait ice stream from Hudson Strait, opening of the Tyrrell Sea, drainage of glacial lakes Agassiz and Ojibway, the opening of the Foxe Channel and retreat of glacial ice from Foxe Basin.

We found that ΔR=350 years applied to the radiocarbon ages constraining the glacial events in Hudson Strait provided the best match with the MD99-2236 DC peaks. A very close age match between the 8.2 cold event in the Greenland ice cores (Rasmussen et al., 2006), the last DC peak in MD99-2236 at 8.15 cal ka BP, and the drainage of glacial lakes Agassiz and Ojibway, using published radiocarbon dates from James Bay Lowlands calibrated with DR=300 (Barber et al., 1999; Roy et al., 2011). Our stratigraphic comparison between the DC peaks in MD99-2236 and the calibrated ages of Hudson Strait/Bay deglacial events shows that Barber et al (1999) included ages constraining the retreat of the Hudson Strait ice stream out of Hudson Strait, the opening of the Tyrell Sea and the catastrophic drainage of glacial lakes Aggassiz and Ojibway in their attempt to correlate the drainage of glacial lakes Aggassiz and Ojibway to the 8.2 ka cooling in the Greenland ice cores. A broad interval of moderately high detrital carbonate content in MD99-2236 is bracketed by the timing of the opening of the Foxe Channel (DR=263±48; Ross et al., 2012) and the break up of the marine-based ice in Foxe Basin (DR=230; Dyke, 2004).

ΔR=350 years for the early Holocene outer Hudson Strait events is significantly larger than the pre bomb ΔR=140 years (McNeely et al., 2006) and might suggest that the ΔR used in the MD99-2236 calibrations is too small. However the close comparison in time of the freshwater forcing and IRD events in MD99-2236 with freshwater and IRD events in core MD99-2256 from the SW Iceland shelf indicates that DR=50±50 years is appropriate.

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A 2000 YEAR RECORD OF MARINE CLIMATE VARIABILITY FROM ARNARFJÖRÐUR, NW ICELAND

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A high-resolution sedimentary record from the subarctic Arnarfjörður in northwestern Iceland is being studied, with the ultimate goal to reconstruct the marine climate and the environmental history of Arnarfjörður for the past 2000 years. We believe that the fjord provides a regional oceanographic climatic signal reflecting changes in the Irminger Current, a branch from the warm and saline North Atlantic Current and the fresher East Greenland Current from the north, but also changes in sea ice cover in the region. The first mention of this fjord in the Icelandic historical accounts comes from Hrafna-Flóki, who named Iceland around 865AD due to the sea ice he saw in the fjords of Vestfirðir. That winter and spring were harsh and the fjord Arnarfjordur was full of ice according to Hrafna-Flóki. This is the first description of severe sea ice in Iceland's fjords described in the accounts.

The sediment core from Arnarfjörður is 520 cm long, collected from 98 m depth from the middle part of the fjord. Based on four radiocarbon dates, the sediment core spans approximately 2000 years and thus offers a high resolution record for that time interval, which includes both the Medieval Warm Period and the early to middle part of the Little Ice Age. We estimate approximately 150 years missing from the top of the section. The reconstruction is based on x-radiographs, which are used to identify ice rafted debris (IRD), together with magnetic susceptibility and density records, but with emphasis on benthic foraminifera study where down-core distributional patterns of benthic foraminifera are used to describe the oceanographic settings and identify environmental changes in the study area.Counts of presumed IRD from x-radiographs indicate four intervals of increased sea ice cover in the fjord: The first one coincides with the Dark Ages Cold Period between 600 and 750 AD. Despite Hrafna-Flóki's description of a fjord full of sea ice ca. 865 AD, no IRD is detected between 750 and 1000 AD, a period which may be related to the Medieval Warm Period (MWP). However, the last 1000 years have much coarser sediments than the lower part of the core with peak in IRD counts between 1250 and 1300, and again between 1450 and 1600 AD, although IRD continues towards the top of the core at ca 1850 AD, corresponding with the period of the Little Ice Age (LIA). MS and density records show two distinct peaks, at 1050 AD and between 1650 and 1750 AD, which may correlate with known tephra layers although not visually apparent. The benthic foraminiferal studies provide multidecadal time resolution. Three species dominate the benthic foraminiferal fauna: Cibicides lobatulus; Cassidulina reniforme and Elphidium excavatum. Less abundant are Astrononion gallowayi, Quinqueloculina stalkeri and Bucella spp. The foraminiferal assemblages indicate that considerable environmental changes have occurred during the last 2000 years in Arnarfjörður. The cosmopolitan species C. lobatulus, which reflects strong bottom water conditions, dominates the lower part of the core until 1350 AD years. The upper part has more of a modern faunal composition, like the arctic species C. reniforme and E. excavatum, which are known from other fjords in Vestfirðir today. E. excavatum which is often associated with near-glacial environments (cold waters, sea-ice cover) peaks around 700 AD (dark ages), it is less abundant from 800 – 1150 AD (MWP) and increases again in the upper part of the core (LIA). The most common method to estimate bottom water temperature is to measure the oxygen isotopic composition of a foraminifera shell which reflects the oxygen isotopic composition of the seawater in which the shell calcifies. However, this may proof difficult with fjord cores as the isotope signal may be affected by freshening from runoff or melt-water. Therefore we use transfer functions on the down-core faunal composition to estimate bottom water temperatures (BWTTF) and salinities (BWSTF) based on the Sejrup et al. (2004) recent benthic foraminifera database.

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THE CHUKCHI SEA ECOSYSTEM: ASSESSMENT OF CONTEMPORARY CONDITIONS AND VULNERABILITY TO POTENTIAL OIL SPILLS

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The location of the Chukchi Sea between the Bering Sea and the Arctic Ocean determines the mixed character of its fauna. Modern environmental conditions of the Chukchi Sea biota can be considered as being close to average long-term norms. The results of chemical element distributions in bottom sediments, and other geo-morphological and litho-chemical characteristics, as well as of total indices of pollution of bottom sediments lead to conclusions of stable low concentrations of pollutants. In comparison with previous work and data from other Arctic seas, the Chukchi Sea is relatively resistant to chemical pollution. However, the stability of biocenoses can be considered as vulnerable because in the eastern part of the sea and along the coast of the Chukchi Peninsula relatively favorable conditions for accumulation of pollutants are observed. The Chukchi Sea has a primary characteristic of being the most resistant to pollution than the other Arctic seas. We can summarize below the factors that significantly influence the future condition of the benthic ecosystem of the Chukchi Sea: - development of the shelf and sea port construction in the Chukchi Sea can lead to increase a number of geo-morphological traps or settling basins where pollutants are accumulated; - an increase in concentration of mobile heavy metals in bottom sediments (as a result of climate changes and man-caused pressures on the environment) will lead to their active migration into food chains; - an increase in near-bottom temperature as a result of climate changes can lead to redistribution of the described benthic communities. Increases in the modern level of heavy metals concentration (due to a resumption of shipping along the Northern Sea Route, cconstruction of military bases, developing the shelf, etc.) could lead to degradation of the bottom communities studied. In this research, we also conduct assessment of vulnerability from the potential oil impact for two parts of ecosystem: the coastal zone and water area. Vulnerability of ecosystem on water area from oil spills was connected to biotic components of the Chukchi Sea ecosystem such as zoo-plankton and phytoplankton, benthos, fish, marine mammals and birds. We showed that birds in cold climate have a most vulnerable to oil pollution as well as marine mammals have a smallest vulnerable because can be adapted to impact of oil spills. Also the base on relative vulnerability we indicate the regions of the Chukchi Sea which can be vulnerable from oil spills. Most of the determined vulnerable areas are located in coastal areas where there is human activities (for example, began the development of oil and gas field in the North Slope of Alaska), or potential human activities in the future. Analysis of relative vulnerability for various types of oil shows that film and dispersed oil most dangerous to the coastal part of the Chukchi Sea ecosystem. Birds are the most vulnerable to film oil impact because they are concentrated in the coastal part of the Chukchi Sea ecosystem.

LATE HOLOCENE CLIMATE DEVELOPMENT OF BJØRNØYA (SVALBARD, NORWAY) BASED ON CHIRONOMID ANALYSIS - PRELIMINARY RESULTS

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Bjørnøya (74°30' N, 19° E) is a small, isolated island in the southwestern Barents sea. Despite the location offering a unique opportunity for terrestrial paleoclimate records in the area, paleoecological and climatological studies are sparse (Wohlfarth et al. 1995). This study aims to produce the first Late Holocene climate reconstuction of the area from Lake Ellasjøen.

A 64 cm sediment core is analysed with a high resolution multi-proxy approach. Fossilised head capsules of chironomid larvae (Diptera: Chironomidae) are identified from the sediment and based on the species assemblages mean summer temperatures will be inferred via quantitive paleoenvironmental modelling, i.e. transfer function approach (e.g. Brooks 2006, Eggermont & Heiri 2012). For reference and calibration data from meteorological station approximately 10 km away will be used. In addition to chironomids the sediments are studied for physical proxies, i.e. water content, loss-on-ignition, magnetic susceptibility and spectrocolorimetry. While the three first mentioned methods are standard procedures widely in use, the latter offers a relatively new option to study sedimentary dynamics and components (Debret et al. 2011). Chronology is based on radiocarbon dating of selected terrestrial macrofossils and for the surface sediments on fall-out radionuclide concentrations (210Pb & 137Cs).

This new climate reconstruction contributes to the understanding of temperature development within Svalbard and gives further insight to the on-going discussion on driving climate factors during the past ~2000 years. While temperature trends have mainly been in good accordance with the broad picture, recent studies from Svalbard have suggested the importance of precipitation and possibility of increased seasonality (e.g. D'Andrea et al. 2012, Divine et al. 2011).

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LATE HOLOCENE HYDROCLIMATE VARIABILITY INFERRED FROM SEDIMENTS OF TWO LAKES ON ADAK ISLAND, ALASKA

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The abundance of sedimentary organic material and hydrogen isotope (δD) values in leaf waxes preserved in lake sediments from Adak Island, Alaska were used to infer past changes in hydroclimatic variability in the central Aleutian Islands. Sediment samples from Andrew Lake extending to 4800 calendar years BP (4.8 ka) were analyzed for δD of n-alkanoic acids. Sediment samples from Andrew Lake and Heart Lake extending to 7.2 and 9.6 ka, respectively, were analyzed for biogenic silica, organic matter, and chlorophyll-a content. The age models were based on the age of the sediment/water interface surface (2009), the peak in 239+240Pu activity in near-surface sediment, radiocarbon dates on vegetation macrofossils, and a 210Pu activity profile from the Andrew Lake surface core (Krawiec et al., 2013). Their records were synchronized using correlated tephra beds. Here we expand on the recent report of organic material abundance results (Krawiec and Kaufman, in press) by bringing together all available proxy evidence for the first time.

Shifts in precipitation amount and storminess are associated with shifts in the North Pacific hydroclimate, which is driven by the Aleutian Low Pressure system during fall and winter. Frequent storms, which generate abundant rainfall and extensive cloud cover on Adak Island, affect lake sedimentation and the organic proxies. In addition, Andrew and Heart Lakes are located 10 km apart; their contrasting physical characteristics cause the sedimentary organic matter to respond differently to rainfall and storms.

Over the instrumental period, Andrew Lake biogenic-silica content (BSi) is most strongly correlated with winter sunlight, which influences photosynthetic production, and river input, which influences the dilution of BSi by mineral matter. This is suggested by correlations among BSi, the North Pacific Index ($r2 = 0.23$, $p = 0.01$), and winter storminess ($r2 = 0.63$, $p = 0.09$). δD values of C28 n-alkanoic acids from Andrew Lake show a strong inverse correlation with October-May storminess (days with >19 mm of precipitation) over the meteorological record ($r2 = 0.58$, $p = 0.03$), and a similarly strong correlation with total precipitation amount. Considering the relatively weak correlations limited by the availability of instrumental data (1943-1995), we do not attempt to develop a quantitative calibration for storminess, and instead use the statistics only to guide our interpretation of the controls on the proxies.

Results from Adak Island were combined with evidence from previously published paleoclimate studies from southern Alaska and the Yukon to reveal a more complete spatial picture of hydroclimatological changes for the last 5000 years. The results indicate relatively stormy conditions from 9.6 to 4.0 ka, followed by drying between 4.0 and 2.7 ka, with the driest conditions from 2.7 to 1.5 ka. High precipitation amount and storminess during the Medieval Climate Anomaly (~850 to 1050 AD) and the latter half of the Little Ice Age (~1500 to 1900 AD) on Adak Island is consistent with evidence from other studies that suggest a weakened Aleutian Low during these periods.

This study presents the first lacustrine multi-proxy climate record for the central Aleutian Islands, filling a large gap in the network of sites that is needed to understand the long-term behavior of the Aleutian Low pressure system over its huge area of influence. Since 1950, the Aleutian Low Pressure system has strengthened and is projected to further intensify in most climate models (Salathé, 2006).

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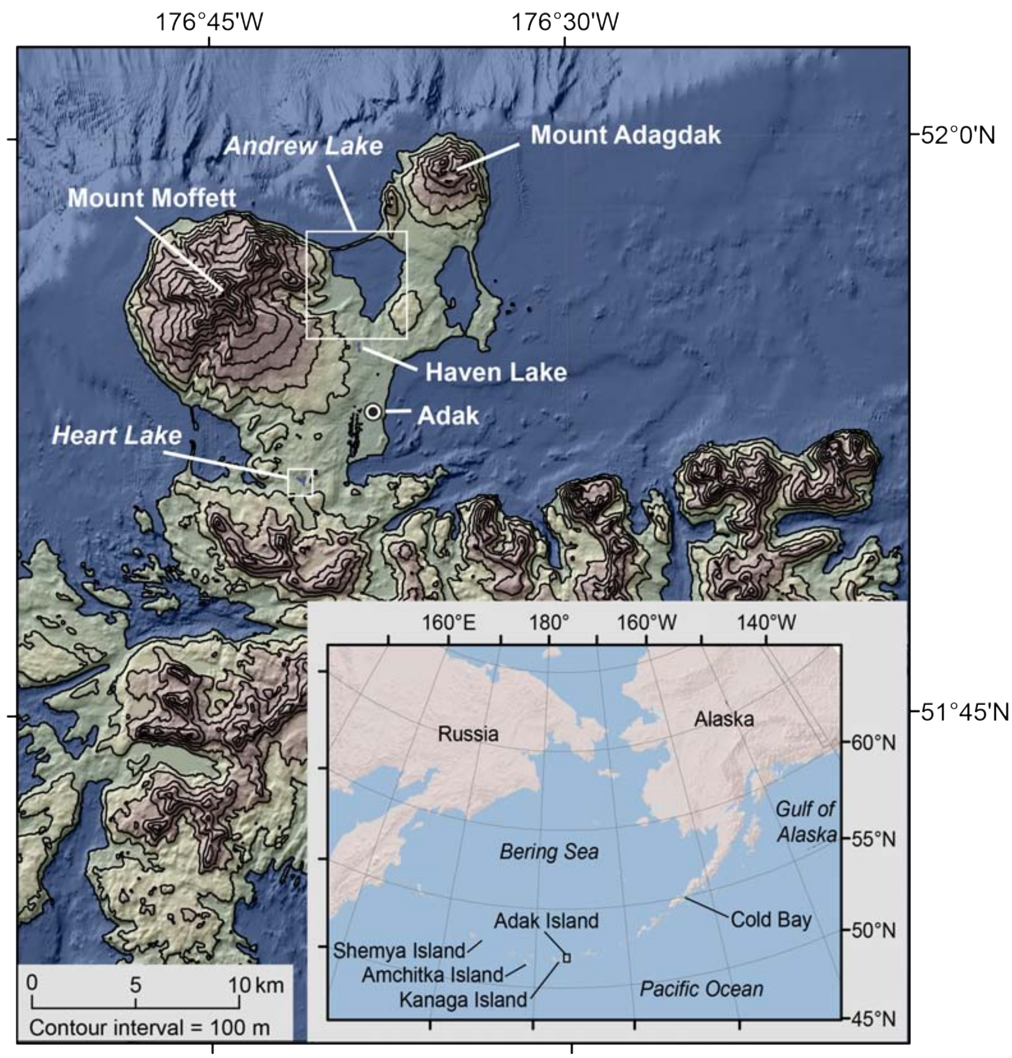

Fig 1. Northern part of Adak Island showing locations of Heart and Andrew Lakes. The base map is from a 1/9 arc-second (30 m/pixel) digital elevation model from The National Geophysical Data Center.

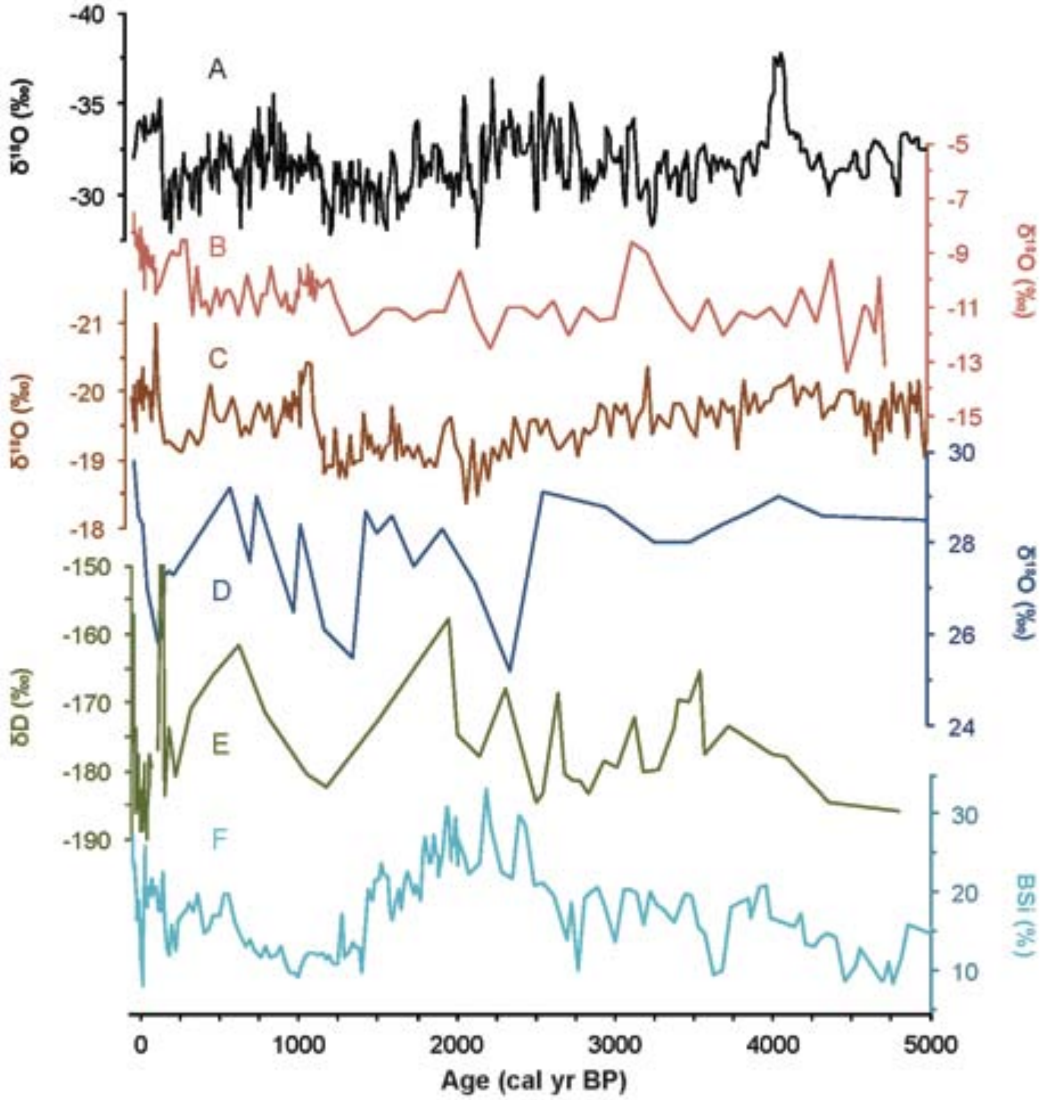

Fig 2. Select paleoclimate records from the North Pacific region used to infer the strength/position of the Aleutian Low pressure system. Refer to Figure 1 for site locations. (A) δ18O (‰) of ice from the Logan ice core (Fisher et al., 2008). (B) δ18O from sedimentary endogenic carbonate (algal Charophyte stem encrustations) from Marcella Lake (Anderson et al., 2007). (C) δ18O from sedimentary calcite in Jellybean Lake (Anderson et al., 2005). (D) δ18O in diatoms from Mica Lake, Prince William Sound (Schiff et al., 2009). (E) δD in C28 fatty acids from Andrew Lake (this study). (F) BSi (%) from Andrew Lake (Krawiec and Kaufman, in press). Y-axes have been flipped so that all changes in the up direction represent a stronger/eastward Aleutian Low, as inferred by each respective proxy. δD from Andrew Lake and δ18O from Mica Lake and Logan ice core are relative to V-SMOW; δ18O from Jellybean, and Marcella are relative to V-PDB.

ARCTIC BRYOPHYTE STABILITY THROUGH TIME WITH IMPLICATIONS FOR REFUGIA

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Bryophytes form a major floristic component of high latitude ecosystems. Their biological system, including *totipotency* and *poikilohydry*, provides critical adaptation to extreme environments, permitting resilience through time in an otherwise harsh landscape for land plants. The diversity of mosses from a given locality often outnumbers the other taxa (i.e., liverworts, algae, lichens, vascular plants). An examination of diversity both on a spatial and temporal scale supports the stability of the arctic moss flora since the late Tertiary. In a detailed study at Sverdrup Pass, central Ellesmere Island, formerly ice-entombed Little Ice Age communities (with >60 species) show strong similarity to the extant bryophyte assemblages. This similarity to modern extends further back into the Holocene (6400 yr BP) where a diverse bryophyte flora on northeast Ellesmere Island reveals a continuous section of *in situ* peat (4 m thick) that began accumulation at deglaciation. Much older (> 780 ka) autochthonous assemblages on southwest Banks Island - associated with intact ice wedge pseudomorphs on a buried, isochronous tundra surface of interglacial rank - record a wet meadow bryophyte assemblage similar to adjacent modern communities. It is noteworthy that this long-standing continuity in the Arctic bryophyte flora appears to extend back into the late Tertiary when the majority of the moss taxa within the Beaufort Fm (2-5 Ma) were comprised of the same species. Collectively, these bryophyte data contrast to the vascular plant record, which indicate a number of extinctions and instability in arctic regions (Matthews & Ovenden 1990). The biological significance of this persisting bryophyte element in the Canadian Arctic highlights their stability throughout diverse climatic fluctuations, suggesting that bryophytes, like those entombed during the Little Ice Age, have survived glaciation *in situ*, frozen in time. This challenges the established concept of refugia that has long-assumed dependence on postglacial recolonization from outside the glaciated region. Extreme nunataks habitats do not and could not support the diversity seen in this bryophyte record.

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Fig 1. David Evans by intact ice wedge pseudomorph at Duck Hawks Bluff, Banks Island, NT in 2012. Associated with this feature is an isochronous surface with thick bryophyte deposits representing wet meadow and shallow pond species at far right. (Evans et al. in press)

Fig 2. Thick bryophyte deposits at Duck Hawk Bluffs, Banks Island, NT in 2012. Excellent preservation of the organics from strata that are greater than 780 ka (Evans et al. in press).

DYNAMIC TERMINUS FLUCTUATIONS OF LANGJÖKULL ICE CAP DURING THE LITTLE ICE AGE

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Reconstructions of glacier fluctuations in response to past climate variability and internal dynamic processes can improve projections of future glacier changes, including estimates of their meltwater contributions to runoff and sea-level rise. Varved sediments from Hvítárvatn, a large proglacial lake in central Iceland, record changing dimensions of the adjacent Langjökull ice cap that can be evaluated at annual resolution. Langjökull achieved its maximum Holocene extent during the Little Ice Age, between ~1800 and ~1930 AD, when two outlet glaciers, Norðurjökull and Suðurjökull, advanced into the lake and maintained active calving margins. Here we use a combination of multibeam bathymetric data, seismic profiles, and multiple sediment cores collected from throughout Hvítárvatn to reconstruct the dynamic terminus fluctuations of these glaciers. We find that while Norðurjökull advanced into the basin stably and remained at or near maximum extension for most of the 19th century, Suðurjökull experienced a quasi-periodic series of eight surges between 1828 and 1930 AD. Each surge event resulted in fragmentation of the glacier terminus during advances of up to ~1.6 km that occurred in less than 2 years. Collapse of the expanded ice and re-establishment of the ice front at a near-shore grounding line occurred within 1 to 3 years of the surge. The surge periodicity was 14 ± 4 years (range: 10 to 20 years). This is the first definitive evidence demonstrating surging behavior of Suðurjökull during the Little Ice Age.

CHANGES IN SEA ICE ALONG THE ARCTIC NORTHEAST PASSAGE SINCE 1979: RESULTS FROM REMOTE SENSING DATA

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The shrinking and thinning of Arctic sea ice, induce this ice-covered ocean to be more accessible. The sailing distance between Far East and Europe via the Arctic Northeast Passage (NEP) is 30–40% shorter than the traditional "Royal Road" via the Strait of Malacca and the Suez Canal. There is a long history of sailing in the NEP. Recently, sailing through the passage has started to widen. Forty-six voyages carrying 1.26 million tons of cargo in 2012 tell of this economic viability of the NEP. To obtain the changes in sea-ice conditions along the Arctic Northeast Passage (NEP), products of remote sensing were combined and analyzed. The products comprised sea ice concentration, extent, type and melt season from SMMR and SSM/I, ice type from QuikSCAT, ice thickness from ICESat and CryoSat-2, and melt-pond coverage from MODIS. In October-November, the spatially averaged ice thickness in the NEP decreased from 1.17–1.28 m in 2003-2006 to 0.19–0.57 m in 2011-2012. From 1979 to 2012, the fastest decreasing trend of the monthly ice concentration in the NEP occurred in October (1.76% per year, $P<0.001$), when the ice started to rebuild up. The average trend of the freeze-up date to be later was 1.37 days per year from 1979 to 2011. The fractions of multiyear ice along the NEP were 5% in 2003, decreased to 1–2% in 2006, and approached to about 0 after 2007. Due to the shrinking of multiyear sea ice in the Siberian sector of the Arctic Ocean, the thinning of sea ice and the delayed surface freeze-up in autumn, the spatially averaged open period of the NEP defined by ice-concentration threshold of 50% increased from 84 days in 1980s to 114 days in 2000s, and reached its peak 146 days by 2012. Both the changes in open period and in surface melt season depended more on the changes in the onset of surface refreezing in autumn than on the onset of surface melt during spring or early summer. Along the NEP, sea-ice conditions in the Barents and Chukchi sectors were relatively mild, while the Laptev and East Siberian sectors were relatively heavy, especially in the sector 90-110ºE around the Vilkitskiy Strait. However, due to the enhanced positive polarity of summer Arctic Dipole Anomaly, associated with other forcing, the later sectors have become more accessible in recent years. In contrast to the summer DA, the winter DA could not be related to the summer opening of the NEP, because the depleted sea ice of the peripheral seas in the eastern Arctic, by the high positive winter DA, can be rapidly replaced by refreezing of open water. Highly developed melt pond on the ice in July to August may further benefit the weakening of the ice and the opening of sea route. The summer opening of the sea route in north of the islands in the eastern Arctic Ocean, with a distance comparable to the NEP, was also lengthened during last eight years. The summer ice-free period of this sea route reached to 47 days in 2012, which highlighted its potential for shipping. This sea route can avoids the shallow waters along the Russian shelf and benefits deeper-draft vessels to use the Arctic sea route.

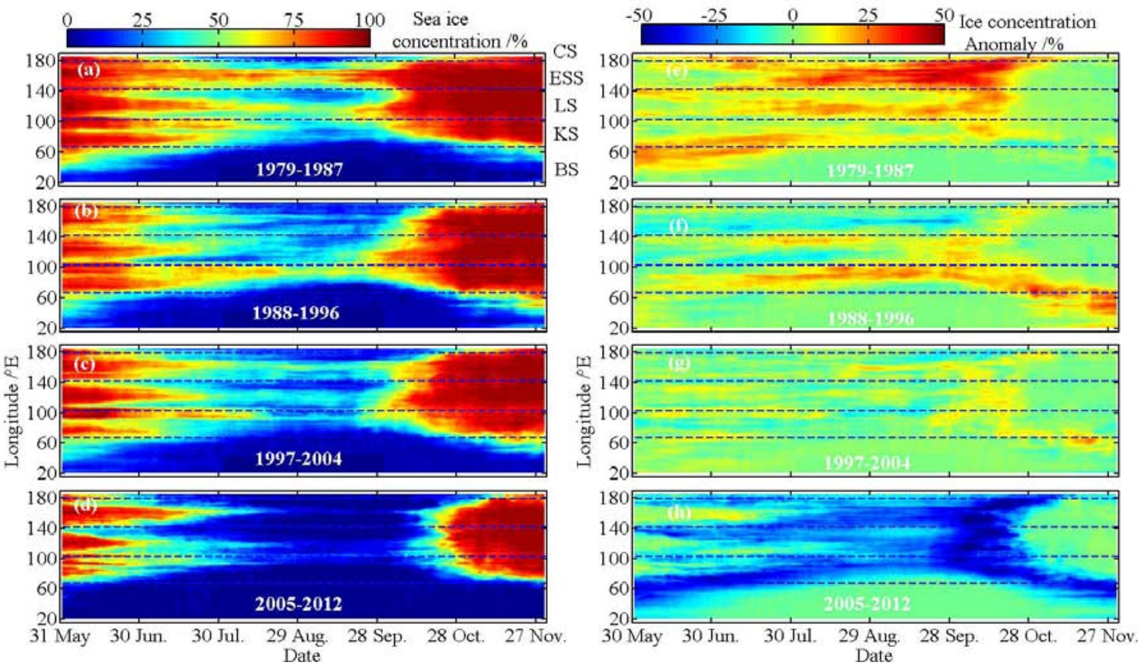

Fig 1. SMMR/SSMI-derived multi-year average sea ice concentration along the Arctic Northeast Passage from 1 June to 30 November in four periods between 1979 and 2012 (a-d), and their corresponding anomalies relative to the 1979-2012 average (e-h).

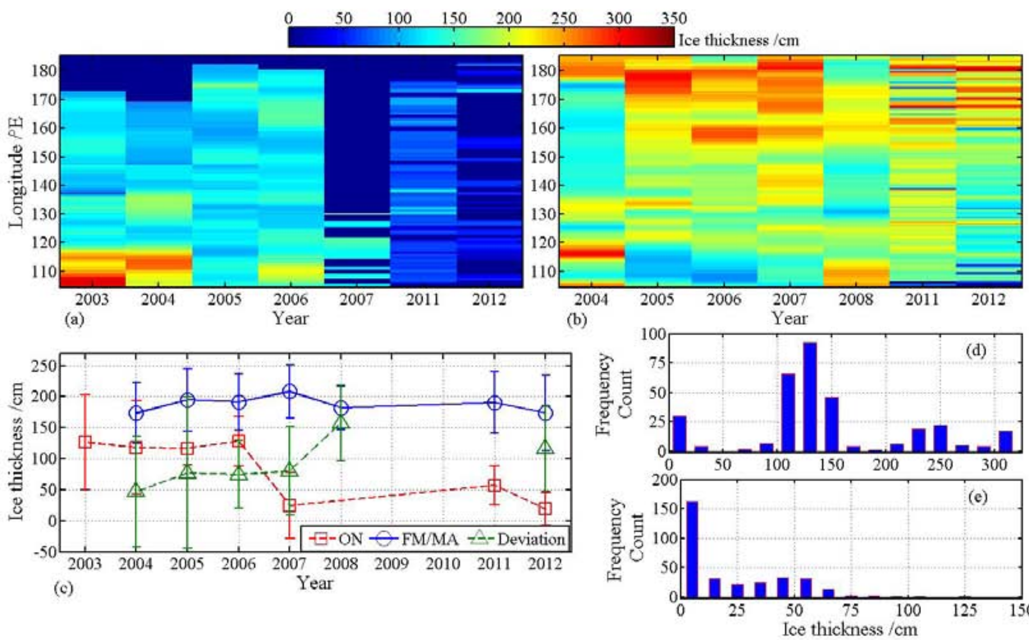

Fig 2. Sea ice thicknesses derived from ICESat from 2003 to 2008 and those derived from CryoSat-2 from 2011 to 2012 along the NEP during October-November (a), and February-March (b); their spatial averages and the deviations between the measurements in February-March and those in October-November (c): note that the spring value of 2007 were measured in March-April; frequency counts of test points within different ice-thickness bin in October-November of 2003 (d) and 2012 (e).

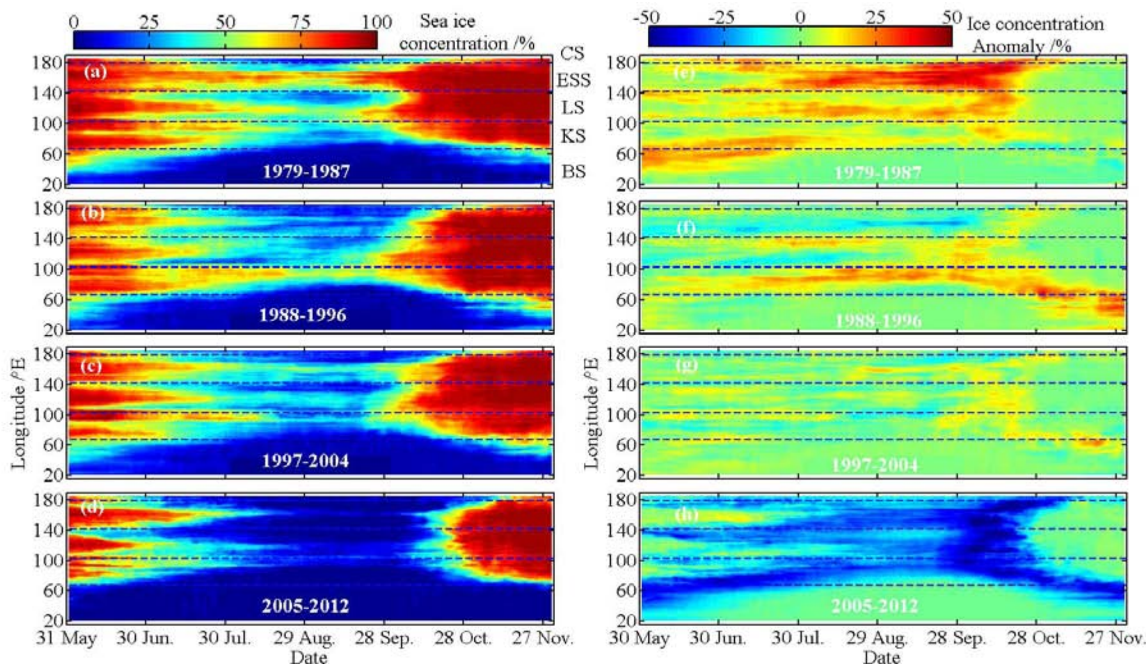

Fig 3. SMMR/SSMI-derived multi-year average sea ice concentration along the High Sea Route from 1 June to 30 November in four periods between 1979 and 2012 (a-d), and their corresponding anomalies relative to the 1979-2012 average (e-h).

VALIDATION SYSTEM AND COMPREHENSIVE IN SITU TESTS OF POLAR REMOTE SENSING

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Operational remote sensing needs field calibration and validation before its practical application. The inversion of remote sensing products is a complicated process, and is subjected to multi-factor and links. So whether remote sensing products reflect the physical truth, must be carried out field validation. According to the calibration requirement of CEOS and WGCV, it is applying independent methods to evaluate remote sensing products. The field validation including: obtaining remote sensing products, using independent methods to acquire field observation data, comparative analysis between remote sensing products and simultaneous observation data, according to the validation criterions to assess remote sensing products accuracy.
Supported by National High Technology Research and Development Program (No. 2008AA121705), researchers developed inversion algorithms of many parameters of polar environment, including atmosphere, sea ice, ocean and ice sheet. The validation methods and criterions were established for each remote sensing parameter according to filed validation requirement. In addition, researchers developed distributed wireless sensor network observation platform, and deployed three sets in the Antarctic ice sheet. The platforms have continuously steady operated exceed 1 year time, which improved the capacity of obtaining continuous monitor data. Based on environment monitoring means of Xuelong icebreaker ship, four polar stations and aviation platform, researchers participated in 26th, 27th CHINARE Antarctic explorations and 4th CHINARE arctic explorations, carried out three time comprehensive verification tests and obtained a lot of observation data, and independently examined the reality and accuracy of polar remote sensing products.

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2. Drue C, HeinemannAkers G., 2005. Accuracy assessment of sea-ice concentrations from MODIS using in-situ measurements. Remote Sensing of Environment, 95:139–149.
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Fig 1. Distributed wireless sensor network observation platform

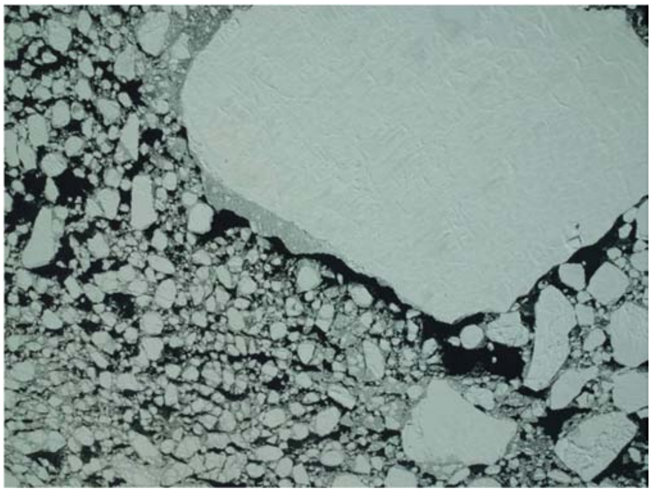

Fig 2. Aerial photo of sea ice at the edge of Amery Ice Shelf

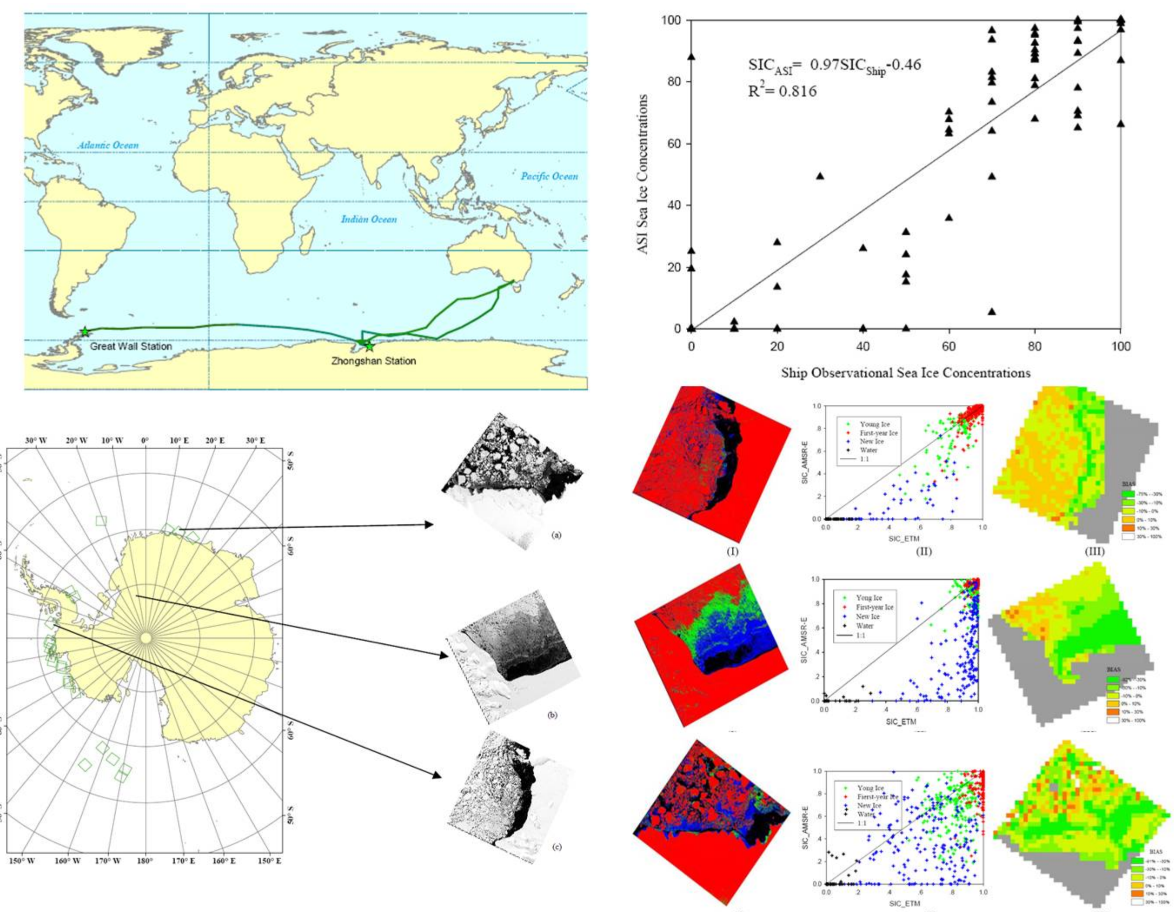

Fig 3. Some validation results of sea ice concentration

THE INTER-ANNUAL PICOPHYTOPLANKTON DISTRIBUTION: AN INDICATION OF ENVIRONMENTAL CHANGE OF BERING SEA

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In order to observe the response of microbes to Arctic environmental change, investigations toward picophytoplankton by onboard Flow Cytometry (FCM) were conducted at Bering Sea during the Chinese National Arctic Research Expeditions (CHINARE-3, -4 and -5 on July 2008, 2010 and 2012. Results show that Synechococcus (Syn) and pico-eukaryotes (P-euk) constitute the picophytoplankton on Bering Basin. However at most areas of Bering Shelf and Bering Strait, P-euk was major picophytoplankton, Syn only appears at a few coastal Alaska stations. The ranges of Syn abundance at upper 100 m water column were 0 ~ 41.27, 0 ~ 22.89 and 0 ~ 15.61 cells/μL, respectively at July 2008, 2010 and 2012, with average of 2.00, 1.64 and 1.34 cells/μL at each year. Meanwhile, the range of P-euk abundance were 0.05 ~ 30.70, 0.03 ~ 30.16 and 0.11 ~ 26.67 cells/μL, respectively at July 2008, 2010 and 2012, with average of 4.97, 4.98 and 5.84 cells/μL at each year. Otherwise, high abundance of P-euk (>2.5 cells/μL) distributed deeper in water depth and more north in latitudes over years. And at Bering Strait, high abundance of P-euk (>2.5 cells/μL) appeared further west over years. According the previous researches, high abundance of pico-eukaryotes often appeared at warm and nutrient poor Alaska Costal Water (ACW), and results of P-euk distribution indicated the strengthen influences of ACW, which means the nutrient supplement from Bering Sea inflow may weaken and then increases the nutrients poor situation and brings the variation of ecosystem at central Arctic Ocean

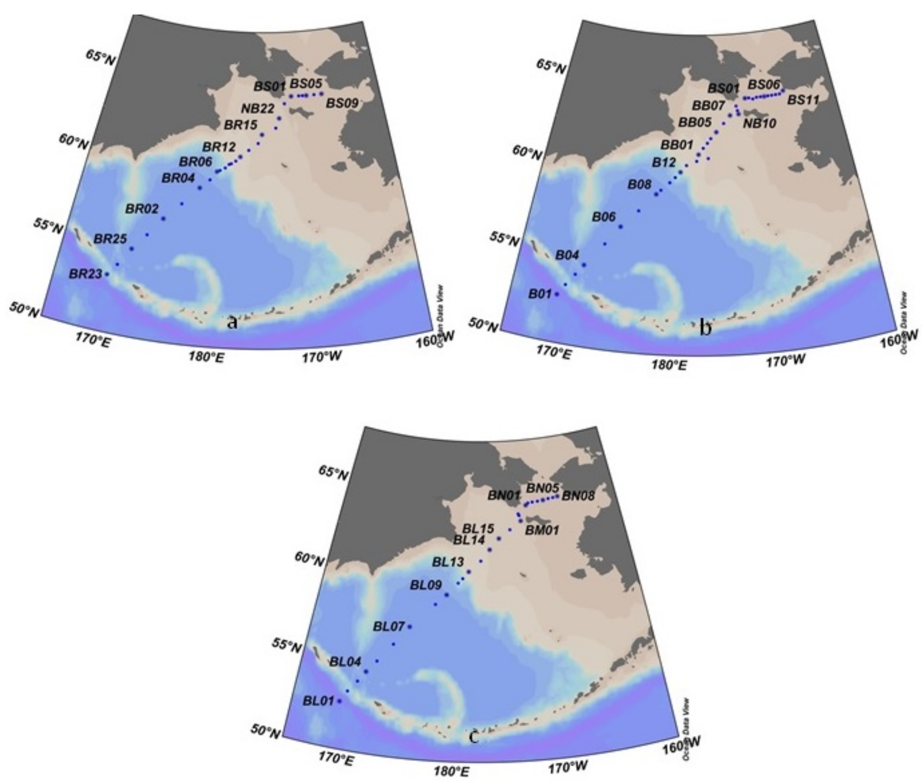

Fig 1. Location of sampling stations at Bering Sea during CHINARE 2008 (a), CHINARE 2010 (b) and CHINARE 2012 (c)

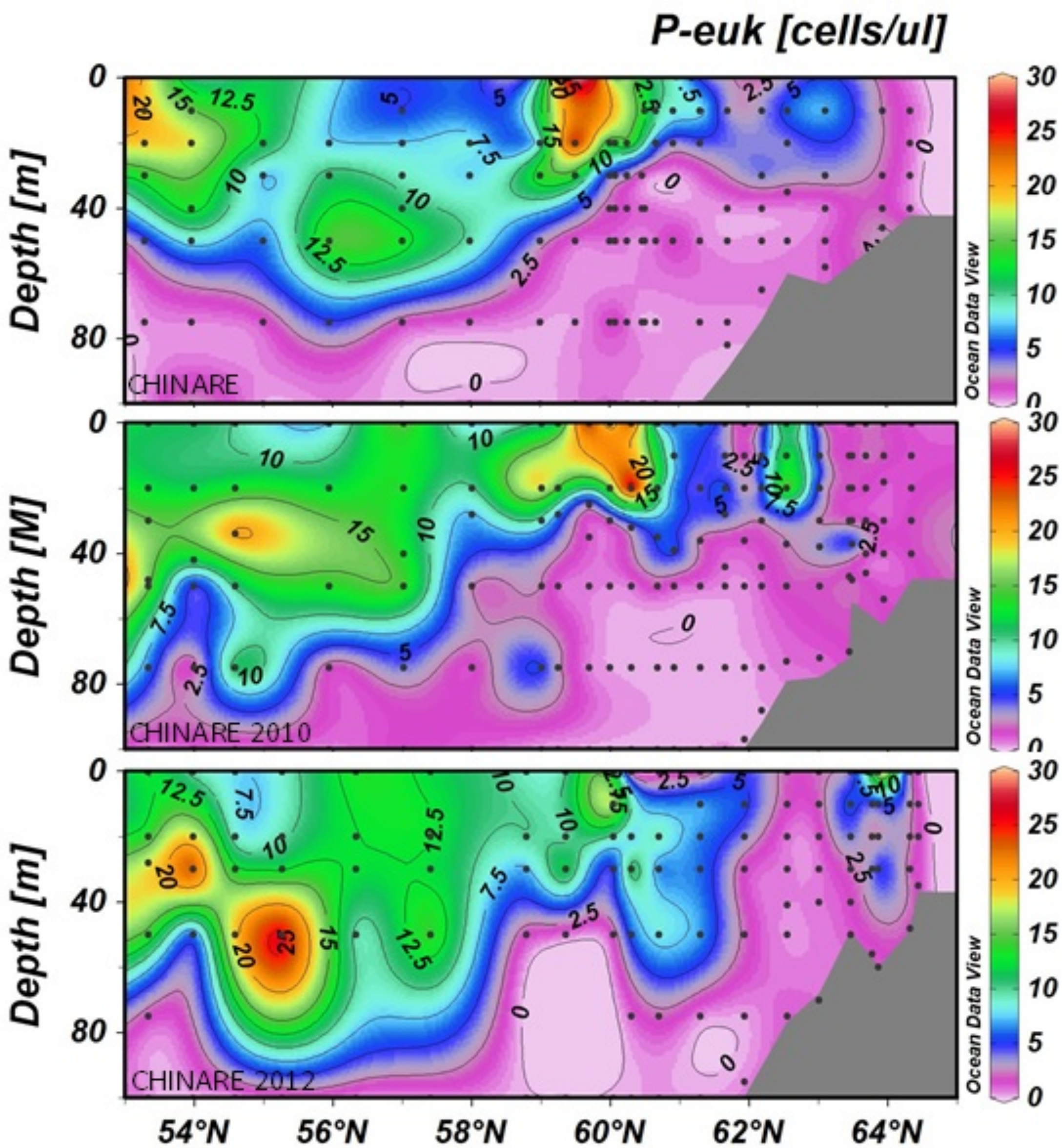

Fig 2. Pico-eukaryotes(P-euk) abundance distribution profiles at Bering Sea on CHINARE 2008, 2010 and 2012

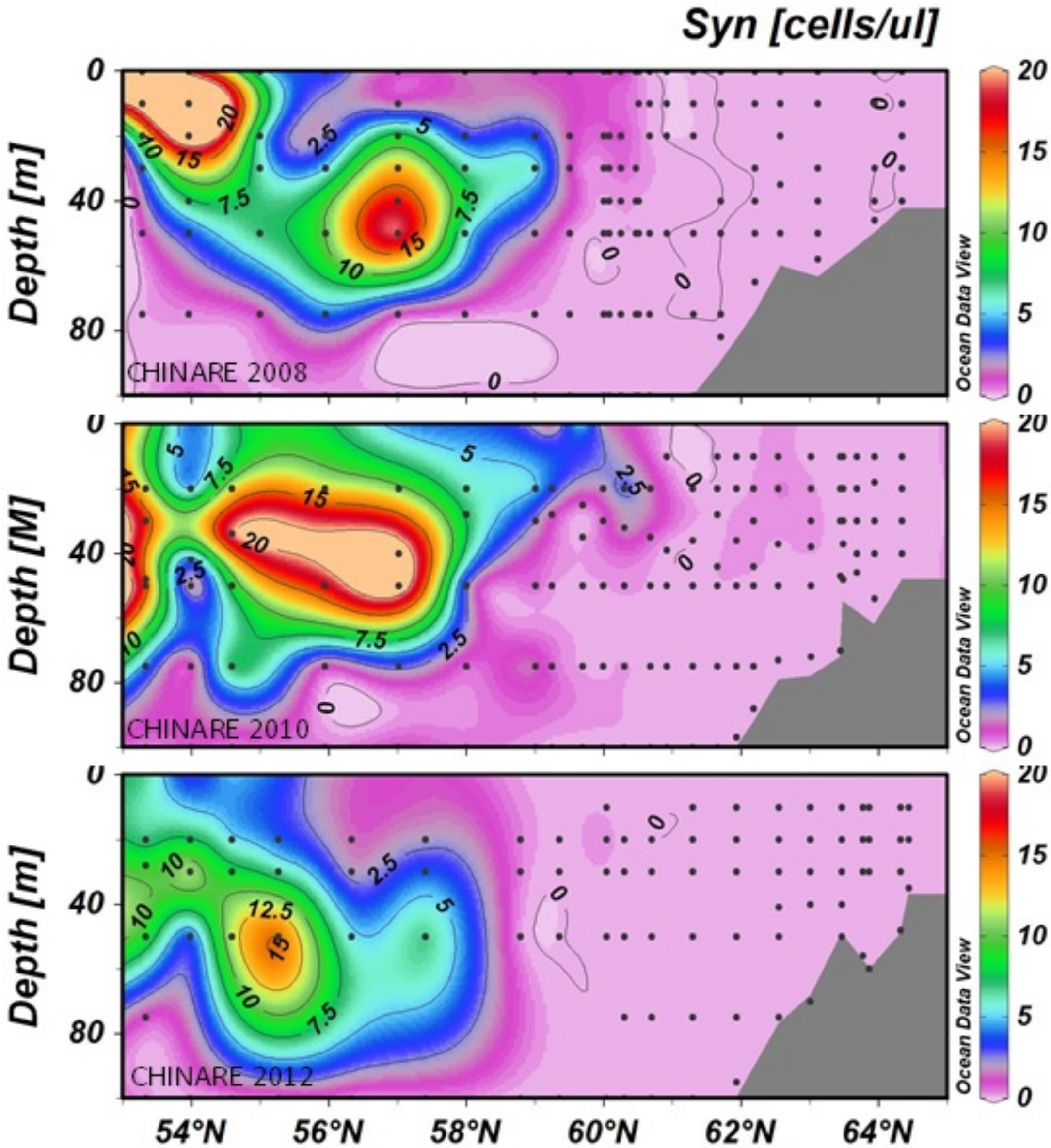

Fig 3. Synechococcus (Syn) abundance distribution profiles at Bering Sea on CHINARE 2008, 2010 and 2012

RECONSTRUCTING HOLOCENE SNOWLINE DECLINE ON SVALBARD, ARCTIC NORWAY, FROM THE 14C AGES OF ENTOMBED PLANTS

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The survival of rooted tundra plants beneath cold-based ice in Arctic Canada was documented more than half a century ago, as was the realization that their radiocarbon ages provide key climate information delimiting the timing of sudden summer cooling, a climate term rarely accessible in other archival settings. Despite that recognition, a concerted effort to develop a regional pattern of summertime cooling by dating dead plants emerging beneath retreating ice margins has only been undertaken in the past decade. Probably the most surprising outcomes of those efforts are the documentation of widespread settings suitable to plant preservation, as well as the wide range of kill dates for plants preserved beneath cold-based ice. In light of our results from Arctic Canada and West Greenland, we undertook a pilot study in July 2013 to evaluate whether Svalbard might also provide suitable environments for the preservation of rooted tundra plants, only now being exposed by widespread ice retreat. We collected 59 samples of rooted tundra plants at the receding margins of ice caps, as well as along 3 transects of dead plants away from ice margins, over an elevation range from 370 to 1196 m asl. We now have obtained 41 radiocarbon ages from our 2013 collections. Lingering winter snow complicated defining the actual ice margin at some sites. Calibrated radiocarbon ages range from more than 4 ka to sub-modern, the latter from sites where the ice margin was partially obscured by late-lying snow. The mid-Holocene ages reflect sites that have been continuously ice-covered for more than 4000 years, but are now being exposed by rapid ice cap retreat, recording in quantitative terms how unusual current summer warmth is for the Svalbard region. Although the current dataset is small (n = 41) the distribution of ages suggests that Neoglacial cooling and ice cap expansion occurred by the mid-Holocene, but that far more widespread persistent snowline lowering occurred early in the first millennium AD, with intermittent cooling continuing through the past 2000 years, culminating in the Little Ice Age.

DIATOMS AS INDICATORS OF ICE EXTENT IN THE BERING SEA

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INTRODUCTION Global climate change has undoubtedly affected the Bering Sea and its productivity. For example, it has already led to a decline in bottom-feeding sea ducks, such as spectacled eiders (*Somatera fuscgeri*), and marine mammals, such as walrus (*Odobenus rosmarus*) and gray whales (*Eschrichtius robustus*), due to a slight shift in bottom water temperatures. Changes in atmospheric circulation and currents intensified cannibalism on juvenile walleye pollock (*Theragra chalcogramma*), affecting the whole Bering Sea food web (Grebmeier et al., 2006). Still, little is known of the effects on the phytoplankton community. Some studies suggest that primary productivity will increase, others argue that it will dramatically drop, yet others believe that no considerable changes may be expected. Obviously, the question requires further study.

The Bering Sea is a perfect place to find a relationship between the presence of sea ice and diatom community composition because it is one of the most productive regions in the world (Sambrotto et al., 1986) and has a wide range of sea ice concentrations. Diatoms are a widespread and very diverse group of algae. They are sensitive and quickly respond to environmental conditions by changing their community composition and structure. Since their silica frustules often settle and are preserved in sediments, diatoms allow us to reconstruct sea surface environmental conditions of the past. Diatoms are also the most common primary producers in the Bering Sea. The ultimate goal of this research is to develop a diatom-based proxy for reconstructing the presence or absence of different types of sea ice and to apply this proxy to previous warm intervals recorded in the Bering Sea. But first, we aim to demonstrate a relationship between diatom assemblages in sediments and sea ice extent.

MATERIAL AND METHODS Sediment samples were collected on board the US Coast Guard Cutter Healy ice breaker in 2006 and 2007 (HLY0601 and HLY0702), as well as on board the Norseman II in 2008 (Shell08). Most surface samples were taken from HAPS cores. A HAPS core is a specially designed gravity multicorer that preserves the sediment-water interface. In the case of sandy sediments, the top 1 cm was scooped out of Van Veen grabs that were not over-loaded with sediment. Research has shown that there is no discernable difference between Bering Sea shelf sediments collected via the two methods (Pirtle-Levy et al., 2009). A total of 22 samples have been processed so far.

Quantitative diatom slides were prepared according to the method described in Scherer (1994). Cover slips were mounted on cleaned microscope slides using hyrax in toulene (refractive index: 1.7135). At least 400 diatom valves in random transects across the slide were identified using a Nikon Eclipse light microscope (see Scherer, 1994). The transects were measured using a stage micrometer. Partial valves were counted according to the methods of Schrader and Gersonde (1978). All diatoms were identified to the species level when possible following published taxonomic descriptions and images (Medlin and Priddle, 1990; Witkowski et al., 2000; ect.). For resting spores of Chaetoceros the classification by Suto (2004) has been used. Diatom counts were transformed into relative percent abundances.

These assemblages were compared to satellite-derived sea ice extent data. On the Bering Sea shelf, the upper 1 cm of sediments is estimated to represent 10 years of neritic sedimentation from phytoplankton communities developing above that spot (Caissie, 2012). Thus, daily extent for vegetation periods was averaged over 10 years. Plots have been made using R software.

RESULTS AND DISCUSSION In total 220 taxa were identified in 22 samples. Attempts to find a relationship between entire assemblages and ice have been unsuccessful. There is also no correlation between individual species and ice extent (the highest correlation is 0.53 for *Fragilariopsis oceanica* (Cleve) Hasle). However, low correlations are easily explained by the nature of the relationships.

Correlation would indicate a linear relationship between species abundances and sea ice, while from an ecological standpoint, we would expect species preferring one ice extent over others to demonstrate a binomial distribution around a particular ice concentration.

Of 220 identified taxa 166 were rare. Found in one to three samples, they couldn't be a basis for sea ice proxy. Most of the rest of the 54 species don't demonstrate any relationship with ice extent. For example, a plot of the relative percent abundance of *Bacterosira bathyomphala* (Cleve) Syvertsen & Hasle against ice extent shows no trend whatsoever (Fig. 1). However, some species, when plotted against ice extent, show a seemingly binomial relationship. For example, *Fragilariopsis oceanica* (Fig. 2) has a peak in abundance at 50-60%. Other species have other preferences. A good example of an "ice-loving" diatom is *Thalassiosira constricta* Gaardner, which rarely appears in samples with ice extent less than 70% and peaks in abundance at 90% ice coverage (Fig. 3). Among identified taxa, we found 10 species with a relationship with ice extent.

CONCLUSSIONS The preliminary results indicate that though the entire assemblage does not seem to show a relationship to sea ice concentration, certain species do show a relationship. The work will be continued to include 163 samples, which will give more data to construct proxies on the basis of both individual species and whole assemblages.

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Scherer, R.P., 1994, A new method for the determination of absolute abundance of diatoms and other silt-sized sedimentary particles: Journal of Paleolimnology, v. 12, p. 171–179.

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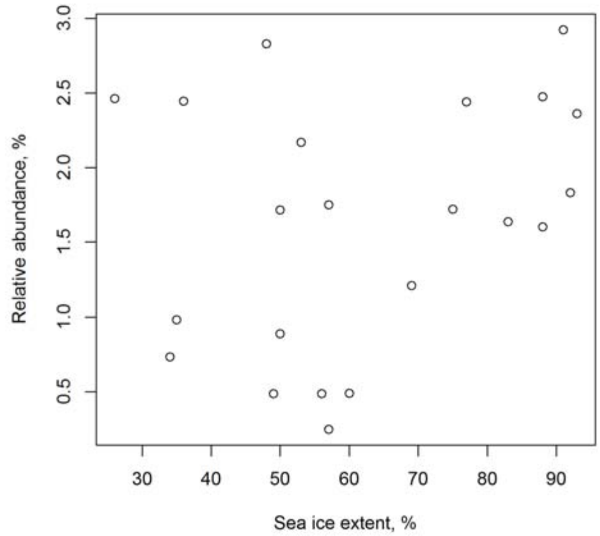

Fig 1. The distribution of *Bacterosira bathyomphala* in relation to sea ice extent.

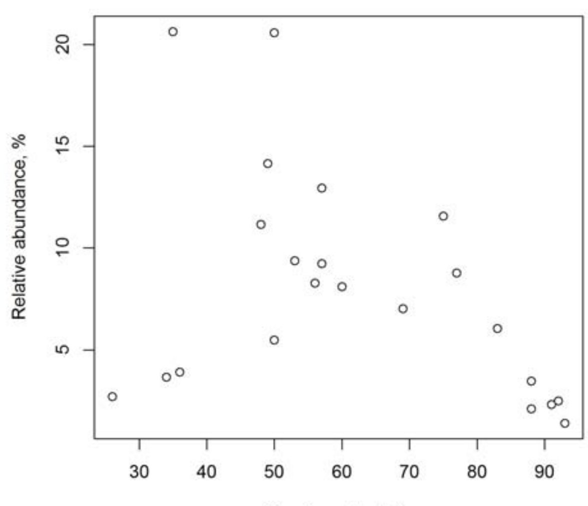

Fig 2. The relationship between the relative abundance of *Fragilariopsis oceanica* and sea ice extent.

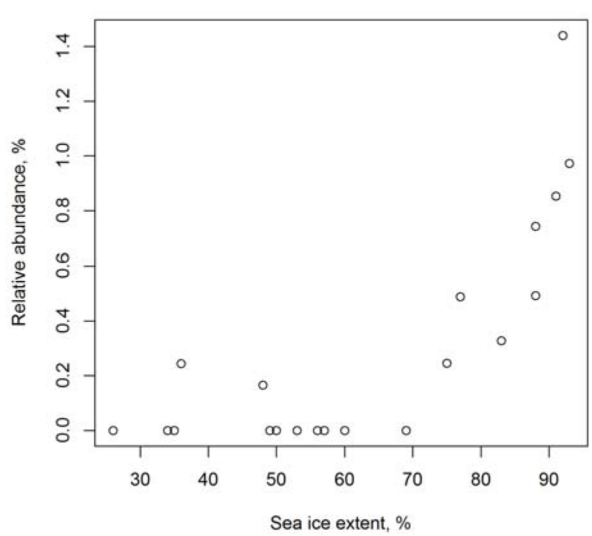

Fig 3. The relationship between the relative abundance of *Thalassiosira constricta* and sea ice extent.

BIOGEOCHEMICAL CHANGE IN THE ARCTIC AND SOUTHERN OCEANS: TRENDS IN ATMOSPHERIC OXYGEN (O2/N2) AND SATELLITE OCEAN COLOR DATA

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[3] Scripps Institution of Oceanography, La Jolla, CA;
[4] Scripps Institution of Oceanography, La Jolla, CA;

Time series measurements of the O2/N2 ratio of air samples from Arctic and Southern ocean stations have been conducted by the Scripps Institution of Oceanography since the early to mid 1990s. These time series comprise continuous geochemical records that can help quantify the magnitude of the seasonal air-sea exchanges of O2 between ocean and atmosphere, with direct relevance for understanding climate and biogeochemical changes at high latitudes. Satellite ocean color data have been available continuously from 1997 and allow the monitoring of ocean productivity from seasonal to inter-annual time scales. The most basic surface property derived from ocean color data is the surface chlorophyll-a (Chl-a) concentration. Starting from estimates of Chl-a, higher order fields like vertically-integrated net primary production (NPP) can also be derived. Satellite ocean color data and ground-based observations of the O2/N2 ratio of air provide independent information about the oceanic biogeochemical cycles of carbon and oxygen. Seasonal cycles in O2/N2 represent the integrated impact of air-sea oxygen fluxes across broad regions and provide a constraint on a combination of surface production and subsurface mixing processes. Ocean color data constrain near-surface biomass and productivity at high spatial resolution with near-simultaneous spatial coverage, but provide little information on subsurface processes. Here, we will present analyses of trends in the O2/N2 seasonal cycle at sites in both the Arctic and Southern Ocean. These changes will be compared to trends in productivity and timing of the Chl-a maximum derived from ocean color data. Observed O2/N2 and ocean productivity patterns will be compared to output from the ocean biogeochemistry components of 6 Earth System Models participating in the IPCC 5th Assessment Report, and the future projections of the IPCC models will also be examined.

FOUR DECADES OF TEMPERATURE CHANGE AT SUMMIT, GREENLANDD

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[4] CIRES, University of Colorado, Boulder;

The long ice core record from the summit of Greenland obtained during the Greenland Ice Sheet Project (GISP) provided unprecedented insight into the climate history of the ice sheet, the Arctic and the northern hemisphere as a whole. Recently, McGrath et al. (2013) noted evidence for warming at Summit using both in situ observations for the base few decades in contrast to temperatures derived from firn records. On the basis of their trend, they made a prediction that seasonal melt events like that observed at Summit in 2012 (e.g. Nghiem et al., 2012) could become more frequent and a regular feature of the Summit climate by 2025. The basis for such a prediction is inference that the observed trend is associated with continual climate forcing by greenhouse gases that will continue. On the other hand, recent modeling work has suggested that significant internal variability (Desser 1et al., 2012; Wetterson and Desser, 2014) can confound assessments of both trends on time scales of a decade or two and in regard to uncertainly in short term projections. Therefore there is a need to assess both the sensitivity of the Summit climate to natural internal variability and the dependence of the isotopic composition of snow and firn on regional circulation in addition to local temperature changes.

While much is known about many of the processes that set the isotope ratios in snow and accumulating firn (e.g., Ciais and Jouzel 1994; Rogers et al. 1998; Town et al. 2008), there remain significant challenges in advancing reconstruction of past climate beyond simple estimates of past temperature. Indeed it is typical for temperatures to be estimated from isotope ratios in snow and ice based on an assumed constant empirical relationship derived from the spatial regression between surface temperature and the mean annual isotope ratios. We use isotope ratio data from newly recovered short firn cores to relate the observed surface air temperature to the glaciological record. We construct seasonal and interannual relationship between the 18O and 2H isotope ratios in snow and temperature. A correlation between the 2H/H isotope ratio and the deuterium excess parameter (defined as a deviation of the 2H from a value predicted from 18O under equilibrium conditions) is found and which depends on season to the first order and secondarily to changes in regional circulation. This dependence on circulation is investigated on the in the context of the observed temperature record to evaluate changes in interannual variability in the observed temperature variations. We find that the different observations of temperature and estimates of temperature from atmospheric reanalyses have biases between them that are similar to the magnitude to the trend that has been detected. Unlike the temperature record, the isotope-based record shows significant variability during summertime indicating that the summer time hydrological balance may have changed in concert with the local temperature. Interannual variability in the isotopic record well captures regional circulation changes that are not correlated with local temperature change. The results are discussed in the context of using the ice core records from Summit for assessing the degree to which temperature changes in recent decades are unprecedented given uncertainty arising from internal variability.

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A DEVELOPMENTAL APPROACH TO UNDERSTANDING REINDEER FORAGE AVAILABILITY IN RESPONSE TO TEMPORAL CHANGES IN REINDEER MIGRATION IN N. NORWAY

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The Sami, commonly called the "people of the eight seasons", herd semi-domesticated reindeer following forage availability. The reindeer are herded from lichen winter pastures, on the high plateau of arctic Scandinavia, to spring and summer pastures at lower elevations. During the last two decades, total reindeer numbers have increased due to changes in the rules of inheritance of reindeer herds within Sami families (Løland, 2002). This leads to intense overgrazing of the winter lichen pastures. To find available forage for survival, reindeer are now herded to lower elevations earlier in the season.

This study reports on a field experiment on the model arctic-alpine perennial plant, *Bistorta vivipara* (L.) Delarbre. It dominates plant communities that have the widest distribution and highest forage value along reindeer migratory routes. The study determined the effect of earlier migration and increased grazing intensity on primary production, forage quality and number of primordia (preformed plant organs) on a short term basis, within one growing season, and on a long-term basis. Within a growing season, above ground biomass was stimulated by the early grazing treatment resulting in overcompensation, providing more available forage than if not grazed. However, during subsequent seasons the total number of primordia decreased. This suggests a net negative impact on the long-term forage biomass and nitrogen content, eventually degrading the natural resource base. Initiation of primordia, prior to maturation, is widespread and crucial for plant survival in arctic and alpine environments, where the annual cycle of growth must be completed during a short season. The developmental trajectory for each leaf and inflorescence primordia requires at least 3 years to progress from initiation to a functional above ground structure (Diggle, 1997). Results have far reaching implications because preformation of plant organs is a common survival strategy in arctic and alpine forage plant species. The negative long-term impact of temporal changes in grazing requires updated management strategies to mitigate degradation of reindeer pastures.

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IMPACTS OF FUTURE SEA-ICE AND SNOW-COVER CHANGES ON CLIMATE, GREEN GROWTH AND SOCIETY (GREENICE)

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[2] Stefansson Arctic Institute; ne@unak.is
[3] University of Bergen; noel.keenlyside@gfi.uib.no

This presentation will focus on GREENICE, a large interdisciplinary project that has recently been funded by NordForsk, (the Nordic Research Council) in a "Top-Level Research Initiative". The project will involve a 9-partner consortium from 5 Nordic countries and Russia, for 3 years beginning in February 2014. The project is led by Noel Keenlyside of the University of Bergen, Norway. Most of the collaborators are natural scientists; however Astrid Ogilvie and Níels Einarsson represent the social science focus of the project. The impetus for the project lies in the current dramatic changes occurring in the cryosphere, including Arctic Sea and Eurasian snow cover, and these are expected to accelerate over the next decades. However, there is large uncertainty associated with anticipated future changes, in particular with regard to the extent, timing, and impacts of such changes. These uncertainties compromise the ability to plan adaptation strategies with northern communities and to develop strategies for sustained green growth in an era of rapid climatic and social change.

The importance and timeliness of the GREENICE project hinges on the fact that changes in Arctic and adjacent Northern Hemisphere (NH) regions are occurring extremely rapidly in social, economic, political and environmental spheres, all inextricably linked locally and globally (see, e.g. Einarsson et al., 2004; the Arctic Monitoring and Assessment Program (AMAP) http://www.amap.no/; http://arcticcoasts.org/; http://dels.nas.edu/Report/Seasonal-Decadal-Predictions-Arctic/13515). As global warming causes sea ice and glaciers to diminish at an alarming rate, human observers note the effect of both changes in seasonality and society in general. At the same time, both Arctic and non-Arctic nations are eagerly assessing the potential for the acquisition of natural resources such as oil and gas, and the opening up of new fishing grounds and stocks (Arbo, et al., 2012). The potential for developing shipping routes in high northern latitudes also has far-reaching implications for coastal communities, as well as for global politics (http://www.arctic.noaa.gov/reportcard/). Tourism is booming (Einarsson, 2012), with many implications for global business and northerly communities, currently in rapid transition, with old ways of pursuing a livelihood undergoing rapid transformation. Arctic regions have increasing strategic value, and a warming climate is seen by many as a positive rather than a negative occurrence due to potential increased opportunities in economic development.

The GREENICE project will produce policy relevant conclusions identifying crucial climatic and resource governance factors impacting northern societies and their inhabitants, as well as possible adaptation strategies. A further outcome will be a contribution to a nuanced and sophisticated view of climate-people relations as complex and cumulative (Barnes et al., 2013). GREENICE will thus promote a theoretical approach that combines social and biophysical sciences in a multidisciplinary search for interlinked processes and systems influencing adaptive capacities of human societies in the north. This non-reductionist perspective and paradigm is scientifically solid and is likely to produce research results that are highly useful for the societies and stakeholders GREENICE is concerned with, and accountable to.

GREENICE will tackle one of the biggest uncertainties in the interaction between climate change and the cryosphere: how will the climate system respond to the future changes in sea-ice and snow cover? The spate of recent extreme weather events over the extra-tropical NH, including winter cold snaps and summer heat waves, were linked to the dramatic loss of sea ice and warming occurring in the Arctic, and to increases in Eurasian autumn and winter snow cover. Most of these changes in the cryosphere are likely to be a result of global warming, and thus may accelerate. Although observational, theoretical, and modeling studies indicate that the sea-ice and snow-cover changes have a significant impact on the large-scale atmospheric circulation and weather extremes, controversy exists regarding the magnitude of these impacts and their underlying mechanisms. In particular, natural unforced climate variability may partly explain the observed pronounced decadal climate fluctuations in the NH, including the recent changes in the cryosphere. Thus, the extent to which the observed extreme events were caused by cryospheric changes due to climate change or natural variability remains an open question. By means of a thorough analysis of observations and coordinated experiments with global and regional atmospheric models, GREENICE will improve our understanding of the atmospheric response to sea-ice and snow-cover changes and our ability to predict both anthropogenic and naturally-driven changes on 10-30 year timescales.

Future changes in the cryosphere, and in the large-scale atmospheric circulation and weather extremes over the extra-tropical NH will, with stressors of globalization, have major socio-economic impacts, particularly in high latitudes. GREENICE will consider uncertainties due to unforced natural climate variability, and will use model formulation and global-warming scenarios to enhance forecast reliability. A more comprehensive and sophisticated interdisciplinary understanding of future changes will facilitate the ability of Arctic societies to adapt to climate change, and address problems of green-growth development. By using case studies, GREENICE will assess vulnerability and resilience factors for specific communities, and evaluate culturally and contextually appropriate measures for effective adaptation to predicted future climate changes associated with sea-ice and snow-cover changes.

The main focus of the socio-ecological component of the project is on implications of changes in sea ice, climate and resource governance for the sustainability of northern communities. This part of the project directly addresses the main aim of the NordForsk call that was to support Nordic societies in developing sustainable, green-growth solutions as they adjust and adapt to rapid climatic and social change. Primary tasks are: To consider the societal implications of changes in sea-ice cover and extent, including whether internal climate variability could lead to unexpected impacts on societies; To undertake an historical-ecological study highlighting past changes in northern coastal economic practices, in particular with regard to fisheries, in the context of changes in sea-ice incidence, in order to illuminate present and possible future changes; To evaluate the incidence of extreme weather events such as increased storminess and human adaptation responses in our study areas in the past; To analyse the complex interactions between governance systems in fisheries, climate change, industrial development and coastal-community viability, in specific localities in northern Norway, Iceland, and Greenland.

Case studies will be carried out in and around two to three specific locations for each of these three northern countries. For Iceland, we will consider the coastal communities of Húsavík (pop. 2,200) in the northeast and Vopnafjörður (pop. ca. 800) in the east. These towns share common characteristics regarding general human ecology. They are small resource-dependent communities, in particular with regard to access to fish stocks. They are vulnerable with regard to ecosystem sustainability and exploitation of marine resources, so issues of resource governance, including responses to pollution and overexploitation, are key. The Greenland component will focus on regions in the vicinity of the coastal communities of Sisimiut (pop. 5,600) and Ilulissat (pop. 4,541) in the west and Tasiilaq (pop. 2,017) in the east. These communities share the common twentieth-century Greenlandic experience of a rapid transformation from scattered settlements based on hunting to an urbanizing post-industrial economy (Rasmussen, 2008; Hovelsrud and Smit, 2010). Seal and other marine-mammal hunting has, until recently, been an important part of mixed-economy subsistence activities. GREENICE will focus on the effects of greatly reduced sea ice, new resource governance regimes, and increased reliance on fishing, as opposed to seal hunting, on community social dynamics and local economic practises. For Norway, we will use as points of departure the towns of Honningsvåg in Finnmark (population 2,440) and Svolvær, which is located on the island of Austvågøy in the Lofoten archipelago (population 4,190). Both have had an economic basis in fisheries for centuries, but are currently undergoing rapid changes. Svolvær is under pressure with lay-offs in the fish processing industry; however, tourism is becoming increasingly important with approximately 200,000 tourists visiting annually. Honningsvåg is one of the Norwegian fishing communities impacted by the loss of local fishing rights. It is likely to undergo considerable social and economic transformation as a result of planned oil and gas development.

Findings will be synthesized in the context of the project as a whole, and in terms of prospects for: i) social impacts of changes in fisheries governance systems; ii) changes in fish-stock movements; iii) on going and future development and impacts of large-scale extractive industries; and iv) other industrial activities such as the use of hydropower.

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Fig 1. The photograph shows how spring ice is used as a platform for activites and as an ice-beach for boats by fishers and hunters in Ilullisat, western Greenland. (Photo Niels Einarsson).

IS ECCENTRICITY THE PACEMAKER FOR ARCTIC PALEOCLIMATE DURING THE QUATERNARY?

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One of the greatest challenges to progress in Arctic paleoclimate is the difficulty associated with developing reliable age constraints for Arctic marine sediment (Alexanderson et al., 2013; Jakobsson et al., 2013). Lack of carbonate material at many sites makes it difficult to employ nanofossil or foraminiferal taxonomies, and in many cases precludes the use of benthic δ18O as a target for orbital tuning (Ortiz, 2011). Likewise, the high inclination of the Arctic and redox changes across glacial-interglacial cycles can pose difficulties for paleomagnetic reconstruction (Darby et al., 2012).

As an alternative approach to age model development, we propose cyclo-stratigraphic orbital tuning of a sedimentary paleoclimate proxy derived from geochemical and physical properties data. Our tuning target is sedimentary %Mn, which varies in response to surficial processes, riverine input and marine redox cycling across glacial-interglacial cycles (Jakobsson, et al. 2000; Löwemark, et al. 2008; Löwemark, et al. 2013).

Visible derivative spectroscopy using diffuse spectral reflectance (DSR) data (400-700nm at 10nm resolution with a 3 mm spot-size) was measured at 1 cm resolution on the wet, split surface of the sediment cores using a CM2600d spectrophotometer (Ortiz, 2011). The cores were wrapped in Glad-wrap to protect the integration sphere of the CM-2600d spectrophotometer (Ortiz, 2011). The resulting data was derivative transformed to remove scattering, grain-size, and wetness effects, and then the resulting correlation matrix of the data was transformed using varimax-rotated, principal component analysis. Principle component regression of %Mn measured by XRF using an Innov-X Alpha-series analyzer against the difference between first and second of the DSR component scores was then used to generate a %Mn record at the full measurement resolution of the DSR data.

The tuning target selected is the La2010 solution a eccentricity reconstruction (Laskar et al. 2011). We select eccentricity as a suitable initial tuning target because the eccentricity signal, should be enhanced at these high latitudes, the generally low sedimentation rates in the Arctic provide a suitably long record for comparison against the tuning target, and eccentricity has been linked to variations in ice volume (Lisiecki, 2010). The tuning process consists of calculating the wavelet spectrum for each record as a function of depth to yield lithofacies cycle lengths. The %Mn record for each core is then filtered using an infinite impulse response (IIR) band-pass filter centered on each downcore lithofacies cycle. The extracted filters are then mapped against the eccentricity template to generate a depth to age transfer function, assuming no phase lag between the eccentricity target and the sedimentary %Mn response.

The quality of the tuning process is determined by evaluating the linearity of the depth-age transfer functions and by plotting the unfiltered %Mn curves on age to evaluate their fit. We have thus far applied this method to six cores raised from different ridges and basins of the Arctic. The resulting depth-age curves were remarkably linear (Figure 1), indicating little need to distort the sedimentary record to achieve a very strong fit between eccentricity and the filtered %Mn cycles. The stratigraphic cycle that best matched the eccentricity-tuning target varied in length from 40 cm to 274 cm due to variable sedimentation rates between sites (Figure 2a). The amplitude modulation of the filtered %Mn record matched that of the eccentricity template reasonably well, and the fit improved, when the next longer sedimentary cycle – presumably related to the 400 ka eccentricity cycle - was combined with the shorter, 100k-related %Mn component (Figure 2b). Plotting the %Mn records as a function of age resulted in a considerable improvement in the visual litho-stratigraphic correlations between records from different locations (Figure 3). These preliminary results demonstrate the great promise of the method as a potential stratigraphic tool for use with Arctic marine sediment.

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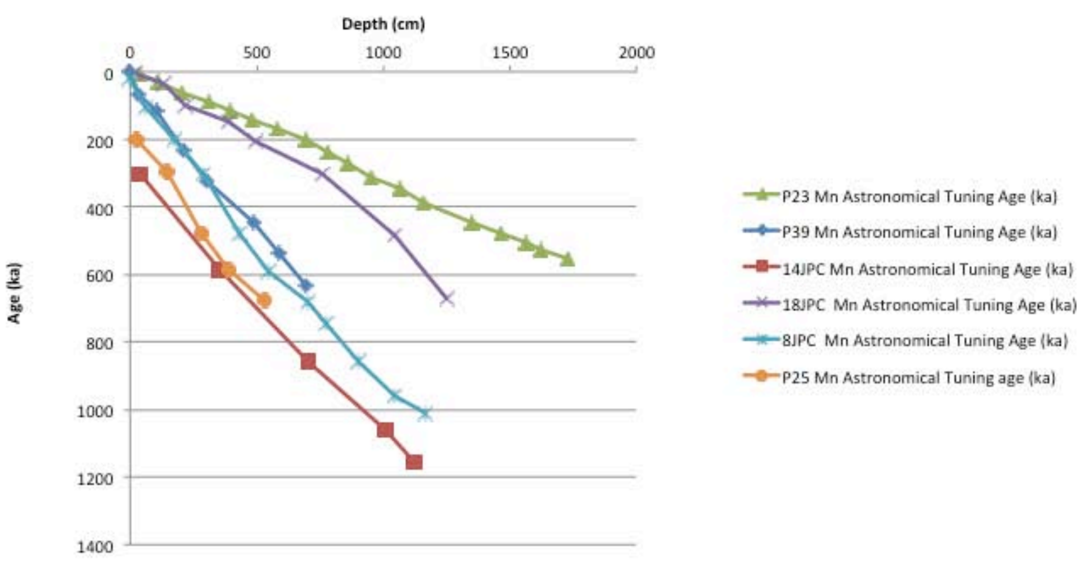

Figure 1. Depth-age mapping functions

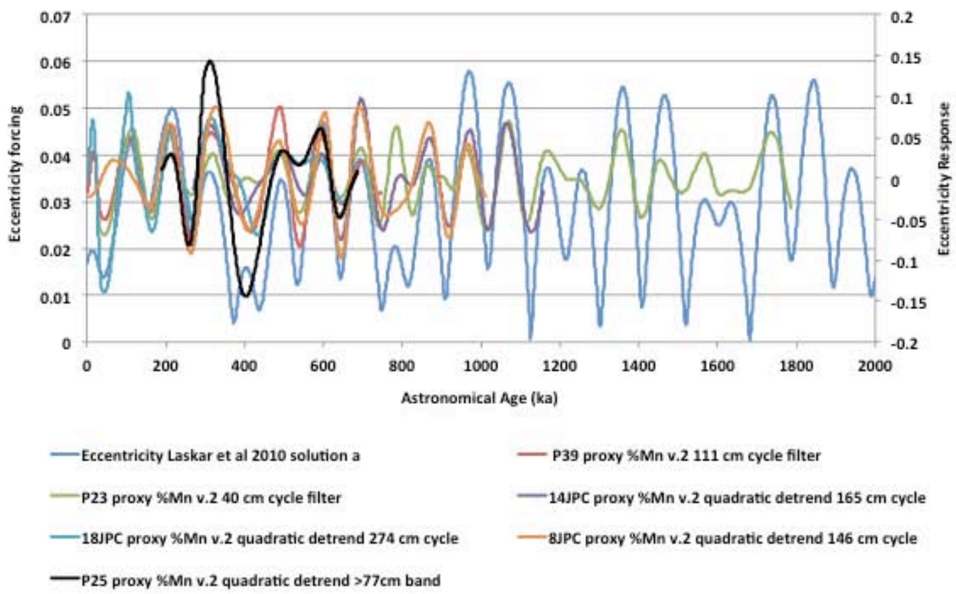

Figure 2a. Eccentricity forcing and 100ka filtered Arctic Mn response

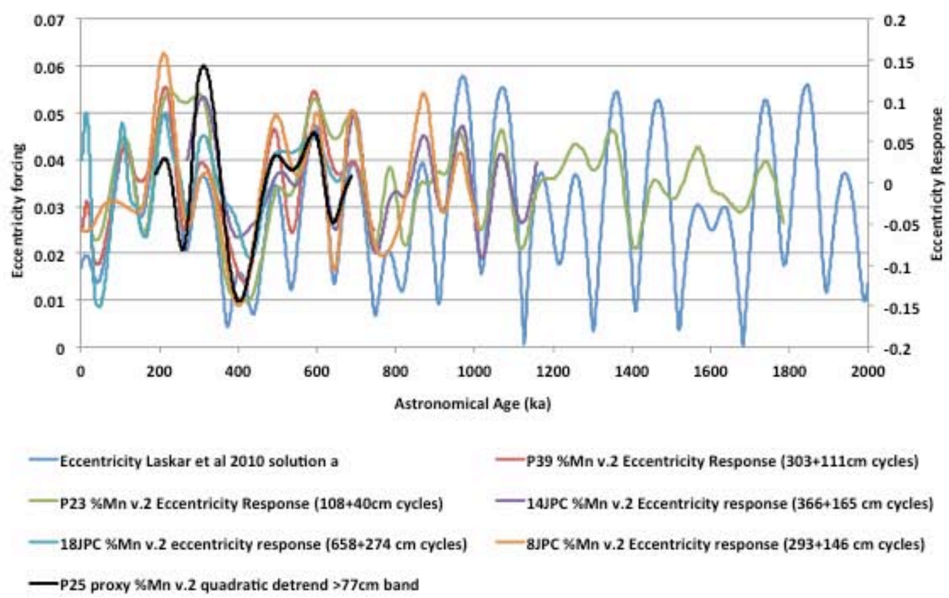

Figure 2b. Eccentricity forcing and 100+400ka filtered Arctic Mn response

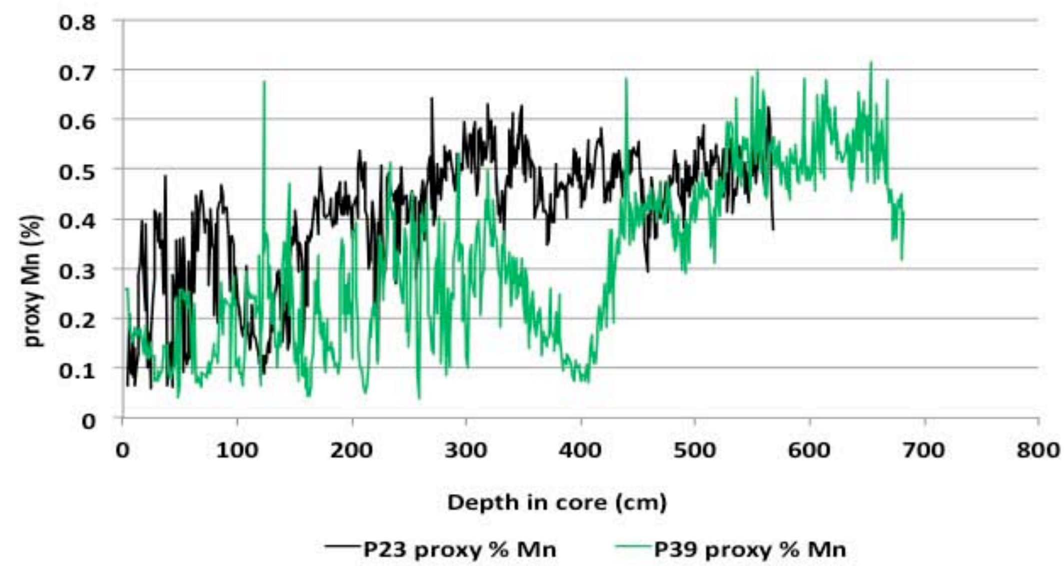

Figure 3a. Comparison of the unfiltered % Mn signals from cores P23 and P39 raised from the Northwind Ridge plotted on depth.

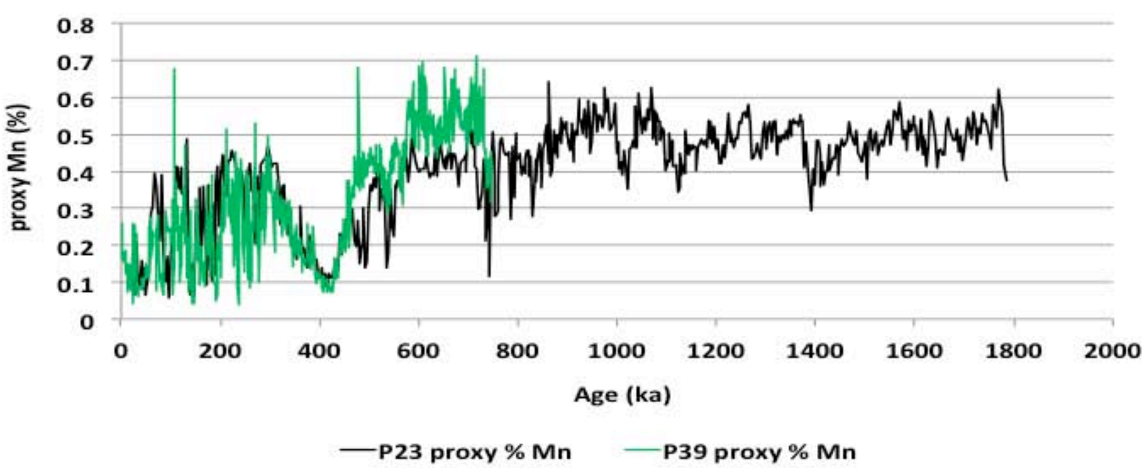

Figure 3b. Comparison of the unfiltered % Mn signals from cores P23 and P39 raised from the Northwind Ridge plotted on astronomically tuned age.

RESPONSE OF GREENLAND RIVER SYSTEMS TO MODELED ICE SHEET MELT

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Rapid warming of the Arctic Region has caused dramatic melt trends on the Greenland Ice Sheet (GrIS), which are projected to continue with future warming. Combined atmospheric-melt modeling and gravity measurements from satellites indicate that since the early 1990s, Greenland ice sheet mass loss has nearly doubled (Sheperd et al., 2012). However, storage of meltwater along its pathway to rivers and the global ocean is difficult to quantify, and recent observations point to the presence of a large snow/firn aquifer (Harper et al., 2012; Vernon et al., 2013). These observations are of critical importance for our estimates of GrIS meltwater contribution to global sea level rise. In addition to the impact of mass loss on global sea level, water and sediment discharged from the GrIS has significance to the coastal zone delivering fresh buoyant water to fjords and the coastal ocean that impacts ocean circulation and sea ice formation. The melt conveys sediment that is a significant, bioavailable source of iron to the ocean. High levels of suspended sediment in fjords negatively impact biological productivity and light availability. We hypothesize that if indeed the pathways of surface melt water to the global ocean is complex, the flux of surface meltwater would be dampened and delayed along this pathway, and proglacial rivers receive an attenuated meltwater flux. This hypothesis leads us to investigate the water discharge dynamics of ice marginal rivers in response to predicted surface melt.

As a first step, we formulate a reduced complexity model to explore the discharge changes of ice margin river systems. We hypothesize that ice sheet geometry, systematic drainage extent variation, albedo variation, snow and firn aquifer properties and supra-glacial drainage network evolution over a melt season pose inherent non-linear controls on river discharge. We use this simple model to explore first-order response of annual pro-glacial river discharge and peak discharge to a warming climate. Our simple model suggests that the hypsometry of the ice sheet drainage basins plays an important role in characterizing their response to ongoing and future melt. We infer from our model predictions that smaller, more low-lying on-ice drainage basins are ablating over their entire extent already, whereas larger drainage basins still have buffer capacity in snow/firn and their extent subjected to melt can increase dramatically with relative modest changes in the regional ELA. These characteristic responses can result in distinctly different annual hydrographs for the proglacial rivers.

To further explore the validity of our simple concept model, we compare sophisticated surface melt model predictions with in-situ river runoff for two monitored West-Greenland catchments and reconstructed decadal discharge records from satellite discharge proxies (Overeem et al., subm. 2014). We use observed river discharge data for the Watson River near Kangerlussuaq (2007 - 2013) and for the Naujat Kuat River near Nuuk (2010-2013). This short-term observations dataset is supplemented by a proxy record of river discharge based on daily NASA MODIS remote-sensing reflectance of the respective river braidplains. Our MODIS technique allows us to hindcast the short observation records to a decadal period (2000-2013) (Overeem et al., subm. 2014). In addition we use surface melt predictions of the surface melt model of the high-resolution climate model RACMO2. (Ettema et al. 2009; Bamber et al., 2012). RACMO2 boundary conditions originate from the global reanalysis meteorology of the European Centre for Mediumrange Weather Forecasts. We retrieve monthly melt totals for precisely those gridcells in the RACMO2 model that directly overlay the GrIS drainage basins of the studied river systems (Hudson et al., 2013).

We find that interannual variability of the summer river discharge based on remote-sensing of inundation of the braidplains over the last decade, matches the overall pattern of modeled meltwater runoff for co-located outlets. High on-ice melt years are reflected in relatively high river discharge years, and likewise lower melt years are accompanied by lower summer total discharge. The high on-ice melt years 2010 and 2012 stand out as high discharge years, but our proxy data indicates that equivalent high discharge years occurred in 2000 and 2003. Our results show that RACMO2/GR estimates are consistently higher than both direct observations (Hasholt et al. 2013) and MODIS-derived discharge reconstructions. This discrepancy can be related to the problematic delineation of on-ice catchments and possible 'leakage' to unresolved bedrock controlled pathways, however we are now exploring other possible mechanisms. Rennermalm et al., (2013) found small discharge events occur in the Fall, when effectively there is no melt occurring. The RACMO/GR has no lag in the model between melt and runoff and no englacial routing, so a delayed river response would affect the direct comparison. It appears that over 2007-2011 the measured river water discharge volumes draining in September (and October) were far too low to account for as much as a missing component of 40% of the June-July-August totals. We also consider that RACMO/GR does not model evaporation of meltwater once it has melted and has become runoff, possibly explaining the observed bias. Recently, in-situ observations have quantified large meltwater storage components in the snow and firn of the percolation zone (Harper and others 2012; Forster and others, 2014), which are a likely explanation for the discrepancies between modeled runoff and observed river discharge. The RACMO2/GR model has water retention and refreezing components, but it still is possible that there is increased englacial and subglacial storage during the melt season and/or greater snowpack retention than is estimated within the model. It is noteworthy that neither of the two catchments show a change in the discrepancy between modeled melt runoff and river discharge over the last 13 years. A decrease of the storage component over time perhaps is to be expected with a slowly saturating aquifer, especially since both on-ice catchments have little to none of their contributing area above the ELA. We find no evidence of changes in the storage component, yet. Our simple model predict that the response of the larger catchment should have a higher amplitude response to extreme melt events. Both catchments had strong peaks in their river discharges for the July 2012 melt year, suggesting that runoff from that event was released almost instantaneously.

Whereas our reconstructed river discharge dataset carries inherent limitations and uncertainties, we can investigate the timing of events in more detail and independently assess meltwater runoff. Then, the comparison of on-ice surface melt and the river discharge reconstructions can be used to enhance understanding of GrIS surface meltwater, on-ice aquifers, and the pathways of meltwater to the global ocean.

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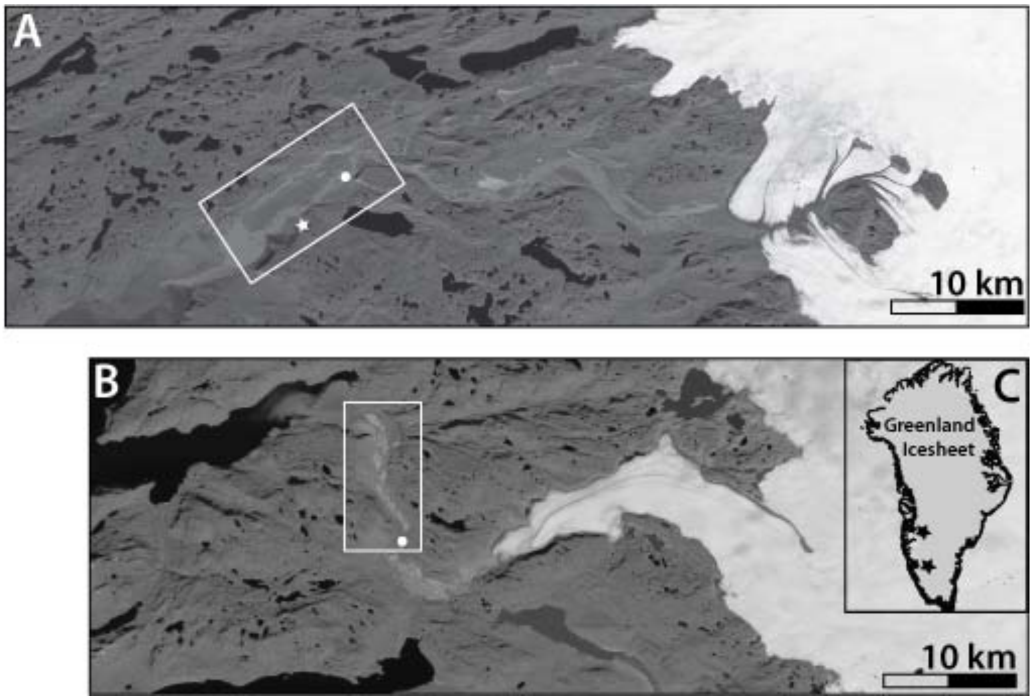

Fig 1. Satellite imagery of the two selected river systems in West Greenland; Watson River near Kangerlussuaq and the Naujat Kuat River near Nuuk.

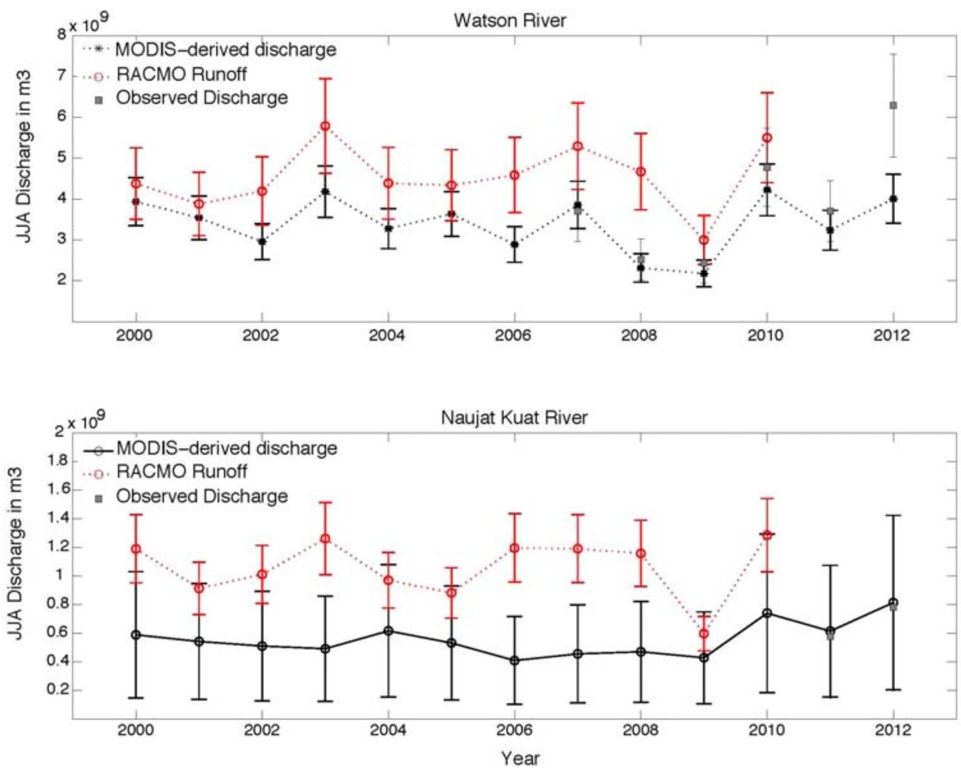

Fig 2. Comparison of summer totals of modeled surface melt and river runoff for the two selected rivers.

POST-LGM PROVENANCE AND FLOW REGIME RECONSTRUCTION FOR THE BERING/ CHUKCHI SEAS THROUGH SEDIMENTOLOGICAL AND GEOCHEMICAL EVIDENCE

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The exposure of the Bering Land Bridge during the Last Glacial Maximum (LGM) cut off the connection between the North Pacific and Arctic Ocean. By extension, this closed the connection of the North Pacific and North Atlantic Oceans, ending Bering Strait (BS) throughflow. North Pacific Water (NPW) comprises a major portion of the fresh water input to the Arctic Ocean and is of vital importance to the formation of North Atlantic Deep Water formation (NADW) [Wijffels et al., 1992; Aagaard and Carmack, 1994; Keigwin and Cook, 2007]. The flooding of the Bering Strait is thought to have acted as an "exhaust valve" [De Boer and Nof, 2004] for North Atlantic freshwater anomalies when open by enabling more vigorous circulation, and thus quicker dispersion of a freshwater cap over the North Atlantic. Thus the inundation of the Bering Strait around 12-11 ka BP [Elias et al., 1996; Keigwin et al., 2006] and reestablishment of modern oceanography in the Bering and Chukchi Seas was a critical part of global climate change as the Holocene began. Pronounced shifts in sedimentological and geochemical data at crucial climatic intervals such as the Bølling-Allerød warm period, and Younger Dryas (YD) stadial, elucidate changes in sediment sourcing and regional oceanography. A suite of five cores were selected, two in the Chukchi, three in the Bering Sea, in order to bracket the Bering Strait for our examination of the reestablishment of modern oceanography following the LGM and Land Bridge flooding. The age control models (Figure 2) were developed using radiocarbon dates on forams and paired shells obtained by previous studies. Major and trace element geochemistry spanning the past ~20 ka were investigated using an ITRAX XRF core scanner. Biogeochemical investigation of organic matter (OM) sourcing included %TOC, and δ13Corg measured on a PDZ-Europa 20/20 Isotope Ratio Mass Spectrometer at Oregon State University. These data, in concert with the other sedimentological data (Corg/N ratios, δ15N, bulk grain size, bulk density, x-radiographs, and magnetic susceptibility), infer shifts in paleo-flow conditions and sediment provenance during this time period.Core JPC3 is located on the western side of the Bering Sea Shelf Slope between Navarin and Pervenets Canyons. Elemental XRF data from JPC3 indicates geochemical change during the BA warming (~15 ka), and the opening of the BS (between 11 and 12 ka). During both of these periods there is a decrease in the relative concentration of Ti, Fe, K, and Ba with a corresponding increase in counts of Cl, Ca, and Br (Figure 3). Carbon isotope values (δ13Corg) post LGM in JPC3 are relatively enriched at around -22.5‰, and then drop precipitously to -25‰ at ~17.5 cal ka BP (Figure 3). These values rise slightly through the BA (with variability), and are lower during the YD. Following the YD, δ13Corg rises rapidly to below -22‰ by 10 ka BP. GDGT biomarker sea surface temperature estimates contribute our understanding of water mass changes over time. JPC3 records the transgression of sea level: terrestrial (δ13Corg relatively depleted) sources of OM become more distal, the site became an open water (relatively enriched) location, sea ice cover (relatively enriched) duration decreased, and North Pacific water was able to flow north over the site through the flooded Bering Strait. Interpreting shifts in relative elemental concentrations will require principal component analysis to determine covariance of sedimentologic and geochemical properties of these sediments. Our sedimentological and geochemical evidence from Bering and Chukchi Sea sediment cores both independently and in concert with biomarkers, allows for investigation of the oceanographic change that marked this region following the LGM, and its influence on global climate.

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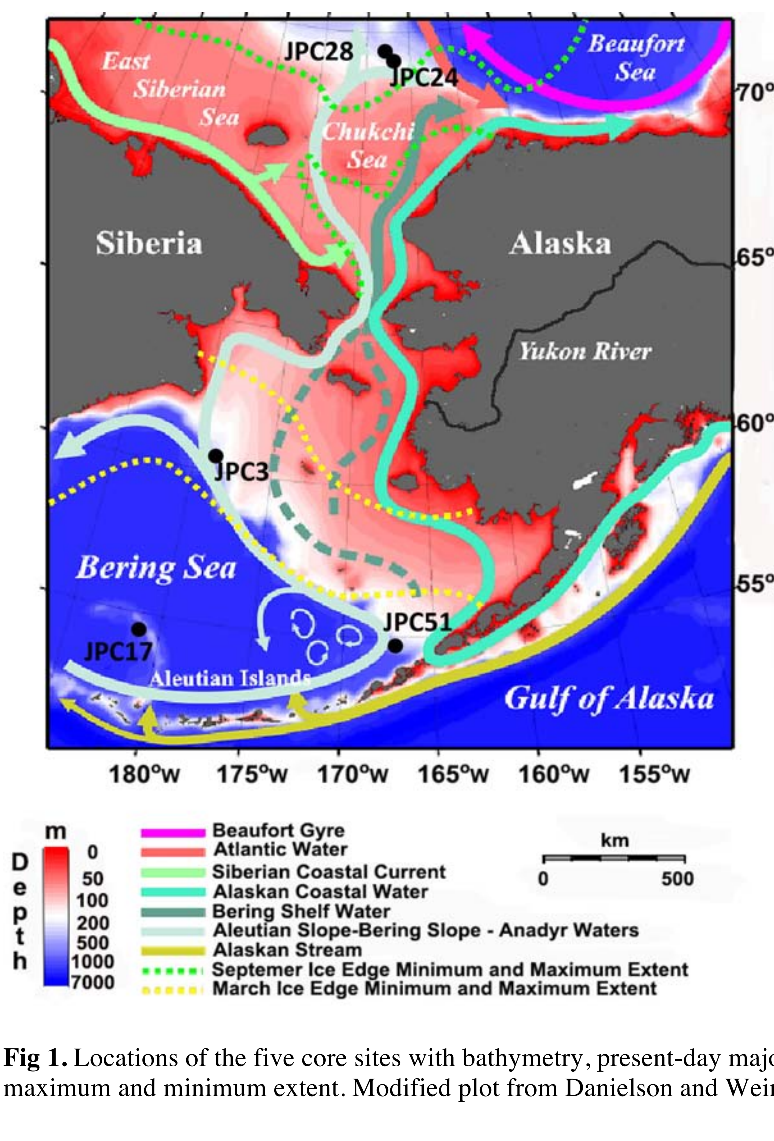

Fig 1. Locations of the five core sites with bathymetry, present-day major currents, and present-day sea ice edge maximum and minimum extent. Modified plot from Danielson and Weingartner.

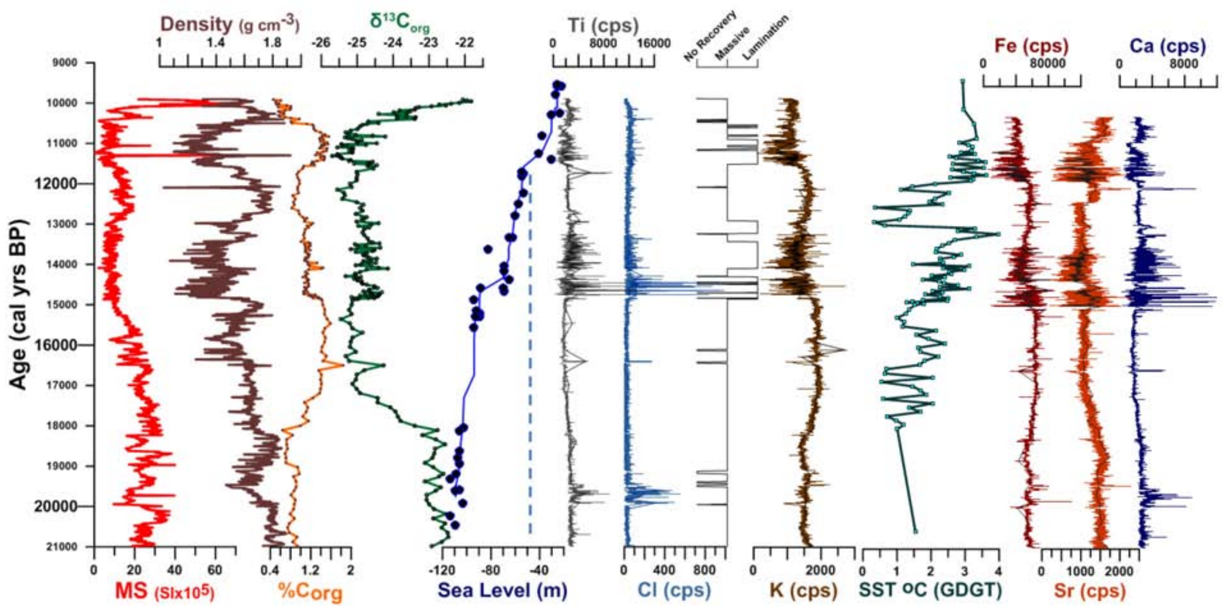

Fig 2. JPC 3 Sedimentologic and geochemical data. GEOTEK core scanner data: Red, Magnetic susceptibility, dark brown, GRAPE bulk density from gamma ray attenuation on a split core. EA-IRMS data: Orange, %Corg and green , δ13Corg. Blue dots, Barbados Sea level curve relative to present day, from Fairbanks (1992), dashed blue line indicates the 50 m threshold where the Bering Strait would flood. XRF data from ITRAX core scanner: grey, titanium, light blue, chlorine, and light brown, potassium, red, iron, orange, strontium, and violet, calcium. XRF data are in raw counts taken on ITRAX XRF core scanner at 1000 μm in massive sediment sections, and 200 μm in laminated sections. General sediment lithology black line, 0=no recovery, 1=massive sediment, 2=laminated sediment. Teal, SSTs are GDGT based from Jim Kocis (UMass Amherst).

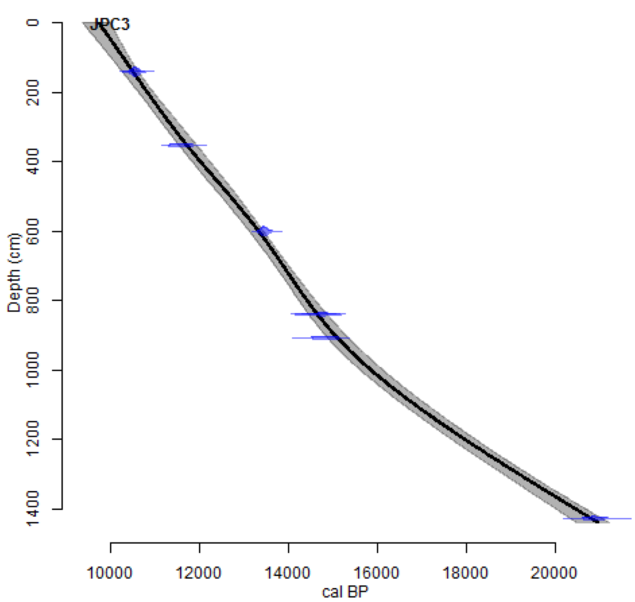

Fig 3. Age Depth Model JPC3. Six radiocarbon dates on N. pachyderma (sinistral) by Cook et al.(2006). Model developed using Clam 2.2 [Blaauw, 2010] using ΔR = 400 and a spline smoothing curve.

EMERGENT DEAD VEGETATION CONSTRAINTS ON ICE CAP ACTIVITY, SOUTHERN BAFFIN ISLAND, NUNAVUT, ARCTIC CANADA

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In situ dead vegetation emerging from beneath cold based ice in the eastern Canadian arctic have been shown to provide important constraints on ice fluctuations during the Holocene and perhaps even earlier (Anderson et al., 2008; Miller et al., 2013). During the summer of 2013, we conducted a sampling campaign in the Cumberland Peninsula area of south eastern Baffin Is, Nunavut, CA in an effort to better constrain ice fluctuations in the region back through the last interglacial (~125 ka). In August, during the peak of the melt season, we visited 88 sites along the margins of the Penny Ice Cap and other local ice bodies, collecting 184 samples of in situ dead vegetation (mainly Polytrichum mosses) emerging from under the ice edge. The cold-based nature of the ice in this region means that the land surface underneath the ice is largely undisturbed and mosses and lichens remain in the position they were growing in when the snowline dropped below the site, entombing the plants. Thus the 14C age of these plants is interpreted as the time when ice growth resulting from summer cold killed the vegetation, providing important constraints of past climates. Therefore, the 'kill date' for each plant records when cold summers dropped regional snowline below the site, and remained below until our collection date. In a few cases the kill dates refer to when permanent ice last advanced over the site (Margeth et al., 2014 in press). The kill dates also represent the last time that the climate was warm enough to expose the sampling location.

From the 2013 field season, 19 vegetation samples from the Penny Ice Cap region between ~800 and 1600 m elevation have returned ages ranging from modern to 4296 cal. BP, producing significant age populations at ~0.5, 1.4, 2.3, and 4.0 ka. The absence of ages between ~1.8-2.2 ka and ~2.5-3.2 ka suggest periods of either no snowline depression or stability. This pattern of both ages of snowline depression and gaps in between is in general agreement with emergent dead vegetation data across Baffin Island (Miller et al., 2013; Margeth et al., 2014 in press). The lack of Holocene radiocarbon ages older than ~5 ka across all data sets suggests that no early Holocene snowline depression below our highest site persisted through to the late Holocene.

Six 2013 vegetation samples returned ages of >45 ka (1 revisited site from 2010, 5 new), bringing the number of ice caps with classified as radiocarbon dead to nine. It is postulated that these radiocarbon dead samples were last exposed during the last interglaciation (~120 ka), when climate was at least as warm as today. This claim is awaiting support from paired in situ 14C rock samples, which should have no 14C inventory. In addition to plant collections, bedrock exposures (n=46) at the ice margin were sampled for 10Be/26Al cosmogenic nuclide dating. These data will provide cumulative exposure and burial histories of the land surfaces only now being exposed by retreating ice. Ultimately, the combination of the above methods provides a powerful tool for reconstructing past glacial histories and investigating possible mechanisms of ice cap changes in this region of the Arctic.

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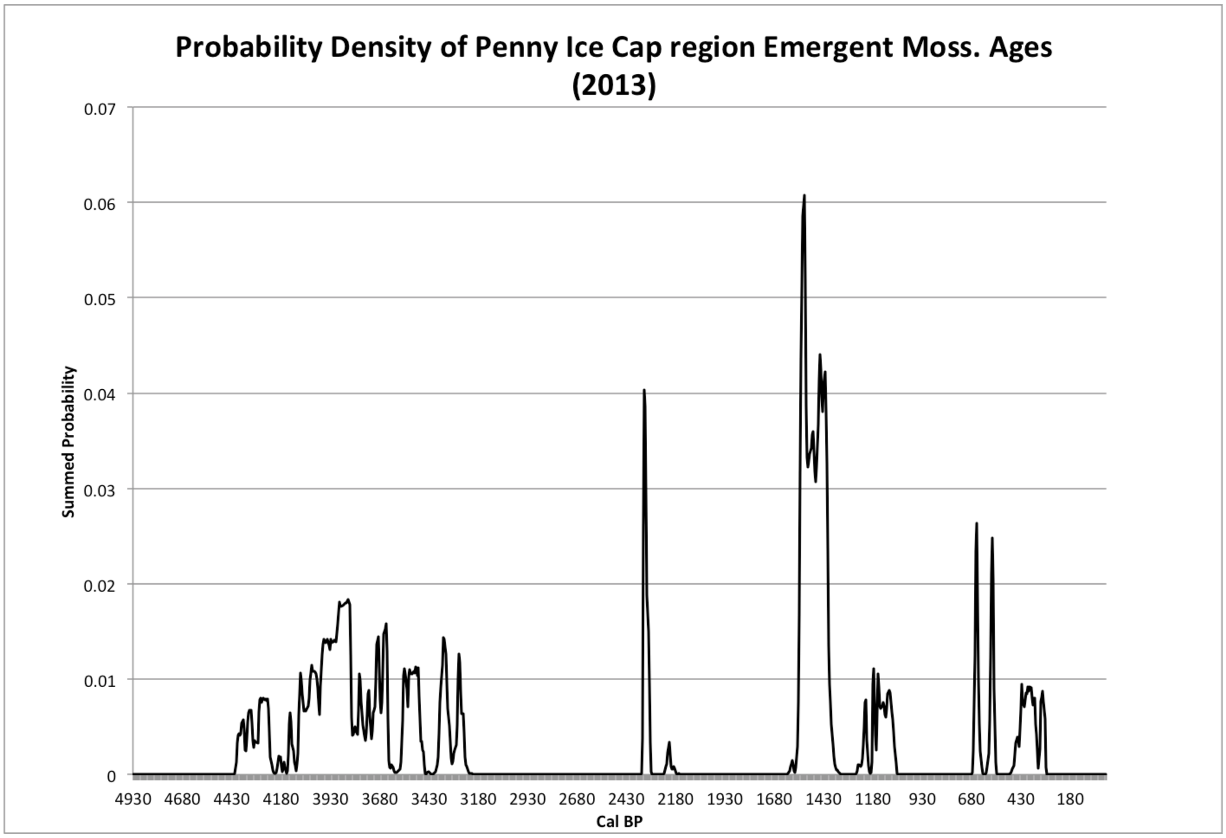

Fig 1. A cumulative probability plot of the 18 14C moss ages returned from this past summers field season. Note the sample populations clustered at ~0.5, 1.4, 2.3, and 4.0 ka.

DEGLACIATION CHRONOLOGY IN THE CENTRAL UUMMANNAQ FJORD SYSTEM (WESTERN GREENLAND) DURING THE HOLOCENE – PRELIMINARY RESULTS

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The Uummannaq Ice Stream System in western Greenland is hypothesized to have drained approximately six percent of the Greenland Ice Sheet during the Last Glacial Maximum (Roberts et al., 2013). Ice dynamics in Uummannaq and elsewhere on the Greenland Ice Sheet are highly variable on millennial time scales and as a result mechanisms that control glacier behavior in the region remain poorly understood. Currently no deglaciation chronologies exist for the central Uummannaq Ice Stream System or on any of its land terminating glaciers. This study examines the deglaciation of a land-terminating ice sheet margin in the central Uummannaq Fjord system using lake sediment cores from three lakes located near the present day ice margin at 71° 5' 22.93" N, 50°49' 56.83" W. Our goal is to compare the ice sheet history of central Uummannaq to records from elsewhere in the Uummannaq Fjord system and western Greenland.

We obtained two sediment cores from a proglacial-threshold lake impounded by the ice margin at 725 m a.s.l., two cores from a smaller lake down valley of, and receiving outflow from, the first lake, and two cores from a third “control” lake that has a small non-glacial catchment that is independent of the other two lakes. The sediment cores reveal two main sediment units consisting of organic-rich gyttja and mineral-rich inorganic sediments. We characterized sediments by measuring magnetic susceptibility, moisture content, and loss on ignition at 0.5 cm resolution to determine transitions of sediment units from inorganic to organic with the goal of tracking glacial advance and retreat. We obtained eight radiocarbon ages on macrofossils (n=7) and a bulk sediment sample (n=1), determined at the National Ocean Sciences Accelerator Mass Spectrometry Facility at Woods Hole Oceanographic Institute. Radiocarbon ages from basal organic-rich sediments from the two connected proglacial-threshold lakes are 10,065±131 cal yr BP and 9,595 ±65 cal yr BP. The non-glacial lake has a radiocarbon age of 10,638±114 cal yr BP near the basal contact. The stratigraphy of the lower glacier-fed lake shows four distinctive transitions of sediments from inorganic to organic inputs, possibly indicating multiple advances and retreats of the glacial front over the last ~10,000 yr. We developed an age depth model of the 122-cm-long core from this lake based on radiocarbon ages (n=5) strategically located at transitions within the sediment layers. In addition, two samples from erratic boulders and one bedrock sample are pending beryllium-10 analysis to determine the timing for deglaciation of the landscape adjacent to the lakes.

This data set bridges existing chronologies of marine terminating glaciers in the northern and southern portions of the Uummannaq Ice Stream System. We found that deglaciation of the central Uummannaq Ice Stream System occurred between 11 and 10 ka. On the other hand, Lane et al. (2013) found that final deglaciation of the area around Rink Isbræ (northern Uummannaq Ice Stream System) occurred ~5.3 ka cal yr BP. Furthermore, Roberts et al. (2013) concluded that the Store Gletscher area in south-eastern Uummannaq Fjord System deglaciated at ~8.7 ka cal yr BP. The three studies show wide variation of the timing of deglaciation within the inner parts of the Uummannaq Ice Stream System. These contrasting results highlight the need to better constrain the variability of ice-sheet-wide deglaciation chronology (Bennike, 2008; Briner et al., 2013).

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THE ENVIRONMENTAL EVOLUTION OF THE NORTHWEST PASSAGE: DEGLACIATION TO PRESENT

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The Canadian Arctic Archipelago (CAA), characterised by an extensive network of marine channels ("the Northwest Passage"; ~1.1 million km2), represents a fundamental link in the global climate system via large-scale oceanic and atmospheric circulation, heat transport, and freshwater budgets. Nonetheless, our knowledge of late Quaternary environments in this region is principally based on radiocarbon-dated materials (molluscs, marine mammal remains, driftwood) from coastal sediments now isostatically uplifted above modern sea-level.

Here we present direct marine data from four marine (piston and trigger weight) cores from the Parry Channel, the east-west axis of the Northwest Passage. These records were investigated for sedimentology, micropalaeontology (dinocysts, non-pollen palynomorphs, benthic and planktonic foraminifera, ostracods), and biogeochemistry (stable isotope ratios, total organic carbon, biogenic silica), aided by a chronological framework of 52 AMS radiocarbon dates. All cores extend to the end of the last regional glaciation, bottoming out on diamicton. Our data suggest grounded glacial ice, followed by rapid deglaciation, with a progression from ice-proximal to ice-distal conditions interrupted by an interval of pervasive landfast sea-ice. Although the timing of deglaciation is difficult to determine due to the absence of dateable materials at the diamicton/glaciomarine transition and chronological complexities such as the Portlandia Effect, age model extrapolations suggest deglaciation at ~11.5-10.8 cal ka BP (region-dependent). Noticeable biological activity commences in the early Holocene (~10.0 cal ka BP) with a prominent signal of planktonic foraminifera (Neogloboquadrina pachyderma). This marks the penetration of deeper (Atlantic-derived) Arctic Intermediate Water (AIW) into the archipelago following deglaciation, likely facilitated by higher sea-levels permitting increased flow across inter-channel sills. Postglacial amelioration (open-water season greater than at present) is subsequently recorded at ~10.0-7.0 cal ka BP, corresponding to a possible regional "Holocene Thermal Optimum". The exclusion of AIW due to glacioisostatic shallowing, coupled with generally cooling climate, eventually leads to increased sea-ice and modern microfossil assemblages. Near-modern conditions commence at ~6 cal ka BP. Our data indicate that although climate ultimately forces long-term environmental shifts, regional dynamics, especially sea-level changes, exert a significant control on marine conditions throughout the CAA.

EARLY HOLOCENE ATLANTIC WATER INFLOW INTO THE CANADIAN ARCTIC ARCHIPELAGO: THE PLANKTONIC FORAMINIFERA (NEOGLOBOQUADRINA PACHYDERMA) SIGNAL

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Marine sediment cores from the central Canadian Arctic Archipelago (CAA) uniformly show a prominent early Holocene (~10 cal ka BP) appearance of planktonic foraminifera immediately after deglaciation. These planktonic populations are exclusively composed of *Neogloboquadrina pachyderma* [sensu Darling et al. 2006 = *Neogloboquadrina pachyderma* sinistral (Ehrenberg 1861)], and include several morphotypes previously described from the Arctic Ocean, as well as some aberrant, right-coiling forms. Today, planktonics are rare in the central CAA, rather dwelling in adjacent offshore areas influenced by Atlantic water, such as Baffin Bay. The early Holocene planktonics signal is interpreted to reflect the inflow of deep water into the archipelago, likely facilitated by higher deglacial sea-levels (due to glacio-isostatic depression) permitting increased flow across inter-channel sills at the CAA entrances. Collectively with other proxy data, this indicates a potentially different oceanographic circulation and water mass structure at the time, marked by greater oceanic connection to adjacent basins, notably Baffin Bay. Though the precise pathway of Atlantic water is cryptic, an eastern source via Baffin Bay Atlantic Water is likely, given palaeo-water-depths to the west across the oceanographically critical Lowther sill. As glacio-isostatic rebound progresses, deeper waters carrying planktonics are progressively excluded from the central CAA and channels and sills shoal, establishing an essentially modern oceanographic circulation by ~6 cal ka BP. The early Holocene planktonics peak is noted throughout Parry Channel (the main east-west axis of the Northwest Passage), from Lancaster Sound in the east to as far west as southern McDougall Sound/Barrow Strait. This implies a regional, valuable marker for the entry of Atlantic-derived oceanic waters upon deglaciation into the CAA.

WEAKENING OF THE NORTH ATLANTIC OSCILLATION FROM THE EARLY TO THE LATE HOLOCENE

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The North Atlantic Oscillation (NAO) is a prominent weather-maker, expected to vary in the past as well as in the future. To understand the timescales of past variability we investigated marine sediment cores from the subpolar gyre region (SPG) in the North Atlantic. During the last 60 years, when the winter NAO was strong, the SPG expanded and these core locations cooled; when the winter NAO was weak, the SPG contracted and these locations warmed. We reconstructed temperature (Mg/Ca) and d18Osw in the subpolar gyre region (SPG) and observed that through the Holocene, the SPG region warmed and the d18Osw values became heavier. We attribute this trend to the weakening of NAO-like atmospheric circulation in response to the increasing winter insolation through the Holocene. However, nearly half the variance in temperature is concentrated at sub-Milankovitch frequencies. Four distinct periods of variability above and below the Milankovitch-driven trend were identified on the basis of SST and δ18Osw, including a prominent interval (10,000 to 8,000 cal yr BP) when melt-water influenced the SPG. These cores are the first analyzed from within the SPG, and add to the growing body of evidence revealing a rich spectrum of NAO.

THE POSSUM CAMPAIGN: POLAR SUBORBITAL SCIENCE IN THE UPPER MESOSPHERE

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Project PoSSUM, an acronym for Polar Suborbital Science in the Upper Mesosphere, is a pending 501(c)3 suborbital research project that uses imaging and remote sensing techniques from Reusable Suborbital Launch Vehicles (rSLVs) for atmospheric science, aeronomy, and Earth observation applications. The initial POSSUM campaign will employ a manned rSLV launched from a high-latitude spaceport during a week-long deployment scheduled for July 2016. This campaign will address critical questions concerning noctilucent clouds (NLCs) through flights that transition the cloud layer where the clouds will be under direct illumination from the sun. PoSSUM grew from the opportunity created by the Noctilucent Cloud Imagery and Tomography Experiment, selected by the NASA Flight Opportunities Program as Experiment 46-S in March 2012.

The PoSSUM Noctilucent Cloud Campaign seeks to answer several unanswered questions relating to our understanding of noctilucent clouds, such as: 1) What are the small-scale dynamics of noctilucent clouds and what does this tell us about the energy and momentum deposition from the lower atmosphere?; 2) Are fine structures observed in the OH layer coupled with NLC structures?; and 3) What is the geometry of NLC particles and how do they stratify? PoSSUM will also validate a repeatable, low-cost means to study seasonal trends of NLCs through instrumentation that will include video and still-frame visible and infrared cameras (PoSSUMCam), the MCAT mesospheric temperatures experiment, a depolarization LiDAR system (PoSSUMLiDAR), and the MASS meteoric smoke detector.

PoSSUMCam is modular and readily integrated on-board suborbital spacecraft to obtain low-cost, rapidly repeatable, and high-altitude imagery and remote sensing data, enabling observation of mesoscale phenomena in the atmosphere or on the ground. The PoSSUMLiDAR is an operator-controlled depolarization LiDAR system designed to profile aerosol particle shapes and size distributions in the upper atmosphere. The PoSSUM Aeronomy Laboratory consists of the Mesospheric Aerosol Sampling Spectrometer (MASS) and the Mesosphere Clear Air Turbulence (MCAT) instrument. MASS is an electrostatic mass analyzer that can determine the concentration of both positively and negatively charged aerosols. The MCAT system is a extremely sensitive pressure gauge coupled with an accelerometer that can measure atmospheric densities form the ground to an altitude of 120km, from which atmospheric temperatures may be calculated.

MULTIPROXY STUDY OF LAMINATED GLACIOLACUSTRINE SEDIMENTS IN LINNEVATNET, WEST SPITSBERGEN, SVALBARD

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Varved glaciolacustrine sediments are have been utilized to develop paleoclimate reconstructions in regions such as the arctic where instrumental records are of relatively short duration (Kaufman, 2009). Strong seasonality and the inherent close link to glacio-hydrological processes favor the development of annually laminated sediment couplets in proglacial lakes. Over longer time scales, the sediment record in proglacial lakes is controlled by glacier activity where sedimentation rates are controlled by sediment production and availability in the watershed (Leonard, 1997). The main goal of this study is to develop a high resolution record of late Holocene glacier activity in Linnédalen from the varve record in Linnévatnet to understand both interannual and longer timescale variability in the sediment record. Presently, the main glacier meltwater source in the watershed is Linnebreen, a small valley glacier at the south end of the valley. During the late Holocene numerous small cirque glaciers also advanced and contributed to the sediment flux to the system. Pervious research on the Linnevatnet sediment record by Svendsen and Mangerud (1997) has shown that the valley was likely deglaciated during the early Holocene and ice gradually returned during late Holocene, reaching a Holocene maximum during the Little Ice Age. Among other proxies they documented the presence and absence of strongly laminated sediments as evidence of glacier activity. A major goal of this present study is to attempt to analyze the laminated sediment record using thin section analysis and varve counting techniques, in hand with high resolution scanning techniques to define the character of the laminated sediments and a precise timing of varve formation. A 50cm long universal K-B type surface core, previously described by Dowey, (2013) and an overlapping 1.4 meter long modified Nesje percussion core were recovered from the ice surface in April 2012 to extend the varve chronology recovered in short surface cores in previous summer studies. The cores were recovered from the central deep basin at a depth of 34 meters. Cores were split and visually logged. Half cores were scanned on a Geotek multisensory core logging system providing magnetic susceptibility and color spectral data at 0.5 cm intervals downcore and high resolution core imagery. Bulk density and grain size were also measured at 0.25 cm increments. Sediment grain size was measured on a Beckman-Coulter laser particle size analyzer. Elemental profiles were measured on the ITRAX x-ray fluorescence scanner. Large format thin sections were made for varve counting and thickness measurement. A composite varve chronology was constructed by overlapping the surface core and long core from the same core site. Visual overlap of each thin section was made using distinct series of marker beds. Varve counts were calibrated on the surface core using 239+240 Pu (Ketterer et al.,2004). On visual inspection, the composite short and percussion cores appear to be finely laminated. However, thin section analysis has shown that structures vary with depth. The upper 50 cm of the core contains distinct varve couplets extending back to ca. 1575 AD. The thinnest and most well defined couplets were deposited in the mid-1700's and mid-to late 1800's. Below this section, laminated couplets are thick and less well defined becoming thicker and more diffuse at depth. The lower section of the percussion core is faintly laminated to massive. The upper 50 cm of the cores is also finer grained than the lower section of the cores (median grain size ~ 5 microns). Grain size increases gradually with depth where at the base median grain size is 6.5 microns and mean is ~ 10.5 microns. Elemental profiles measured with ITRAX xrf scanner show abrupt changes in input of Ca in the upper 50 cm likely related to a carbonate bedrock source intermittently feeding alluvial fans on the eastern shore of the lake during over the last ca. 500 years. Research in progress is focused on development of a varve thickness time series which will be used to develop the age model for physical and geochemical measurements and also will provide a more detailed record of late Holocene glacier activity.

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LATE HOLOCENE PALEOCLIMATE RECONSTRUCTED FROM SEDIMENT GEOCHEMISTRY AND CHIRONOMID REMAINS, LAKE LINNÉVATNET, SVALBARD, NORWAY

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Lake Linnévatnet is located on the western coast of Svalbard, Norway. The lake has a drainage area that is partly glaciated and it receives sporadic inflows from a neighboring karst system. A laminated sediment core was retrieved from the deep northern basin to develop a multi-proxy paleoclimate reconstruction of the past ~1,400 years that can be related to changes in glacial input or other environmental factors.

Elemental composition of bulk sediments was assessed using X-ray fluorescence scans. An age model was developed by correlation of major changes in elemental composition with previously studied, varve-counted sediment cores from Lake Linnévatnet (Dowey 2013). Chironomid (Diptera: Chironomidae or non-biting midge) remains were analyzed at six levels in the core.

Chironomid assemblages are dominated by cold-water species, indicating consistently low temperatures in the lake. Chironomid concentrations in the upper 30 cm of the core are extremely low relative to the bottom, indicating either increased minerogenic sediment influx or a decrease in chironomid productivity at ~1500 CE. This could correspond to the two-part Little Ice Age (LIA) in Svalbard separated by a short warm period (Werner 1993). Spikes in Ca and Mn abundance are common in the upper 38 cm (since 1350 CE), a period also characterized by generally higher Ca and lower chironomid concentrations and less depleted bulk sediment δ13C (A. Balter, 2014, This volume). There are only two major spikes in the bottom half of the core (870 CE and 640 CE).

We hypothesize that Ca and Mn spikes correlate to changes in sediment input over time that relate to changes in glaciation and/or climate. The stabilization of the oldest moraines and the glaciation of a western cirque in the southwest part of the lake basin occurred around 600 CE, which corresponds to the spikes in Ca, Mn, and a slight enrichment in δ13C (Snyder et al. 2000; Werner 1993). A second period of moraine stabilization occurred ca. 1,000 years ago, which may correspond to a spike in Ca and Mn around 870 CE (Werner 1993). The LIA in Svalbard experienced a two-stage glacial advance followed by periods of moraine stabilization with the first occurring between 1250 and 1300 CE and the second taking place in the 18th to 19th century (D'Andrea et al. 2012; Svendsen & Mangerud 1997; Werner 1993). The record shows an increase in Ca, Mn, and δ13C around 1350 CE. This is followed by a slight decrease in Ca and Mn with another increase in Ca and δ13C around 1900 CE. These shifts in elemental composition may be related to sediment influxes that are distinct to bedrock lithologies in different parts of the watershed. Results from this core will be further correlated to lake records from other arctic areas to distinguish regional from more localized changes in the watershed, and to determine likely climatic changes or other drivers.

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CLIMATIC DRIVERS OF BETULA GLANDULOSA GROWTH IN SUBARCTIC QUÉBEC, CANADA

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Shrub expansion has been recorded in many subarctic regions across North America (Tape et al. 2006, Ropars and Boudreau 2012, Tremblay et al. 2012) and Eurasia (Forbes et al. 2010, Rundqvist et al. 2011). Dwarf birch (Betula glandulosa Michx.), a deciduous shrub species known for its morphological plasticity, is the main species responsible of this phenomenon in subarctic Québec (Ropars and Boudreau 2012, Tremblay et al. 2012). Even though the recent increase in temperature is thought to be the main driver of shrub expansion, very few studies have directly assessed the influence of climate on shrub growth. In this study, we aim to evaluate the influence of climatic parameters on radial and axial growth of dwarf birch in three largely distributed environments of the Québec's forest-tundra ecotone (sandy terraces, low altitude hilltops and snow patches). This study took place in the Boniface River region, western Nunavik, Canada (57° 45' N, 76° 20' W).

In the field, we harvested 15 dwarf birch individuals on 9 different sites (135 individuals in total, 3 sites per types of environment). The root collar and the two main branches were collected for each individual, brought back in the lab and left to dry at air temperature for at least 2 months. In order to evaluate the radial growth, the root collar of each individual has been sliced with a sledge microtome, stained with a 1% solution of safranin, and mounted on slides using a low-viscosity mounting medium. The radial growth was measured with LignoVision software (Rinntech Compagny, version 1.37), using high-resolution photos of each slide. COFECHA software was used for age validation (Holmes 1983) and building average ring chronology for each site. Response functions were then used to assess significant correlation between the different chronologies and climatic parameters (package bootRes, R Environment). To infer axial growth, we sampled the two main branches of each individual at 25 cm intervals. Each sample was sliced, stained and mounted on slides before being count under a dissecting microscope. Climatic data were taken from the nearest station, Inukjuak Meteorological Station (58° 28' N, 78° 05' W), 135 km west of the study site.

Nine growth-ring chronologies were built (one for each site; Figure 1), the oldest beginning in the late 1920s and the youngest, in the mid-1960s. Correlation between the three sites of a same environment was higher for terraces ($r2 = 0.82$), intermediate for hilltops ($r2 = 0.79$) and lower for snow patches ($r2 = 0.63$). For terraces and hilltops, radial growth was positively correlated with July, August (current year) and September (previous year) mean temperatures, as well as with March mean precipitations (Figure 2). Warm summer could indeed promote high productivity, and mild temperatures in September could allow dwarf birch to produce numerous leaves bud. The climatic signal for snow patches was not as clear as it was for terraces and hilltops. Because the growth season is limited and snow cover is important, local factors could be more important than regional ones for B. glandulosa growth in the snow patches. However, snow patches were the only ones to support an increasing trend in radial growth after 2004 (Figure 1). Expanding shrubs could have rapidly emptied the low resources in nutrients of well-drained sites with coarse substratum such as terraces and hilltops. Even if temperatures were still increasing, these environments could not support an increase in radial growth. Snow patches, however, benefit from a higher amount of nutrients and could still support an increase in annual shrub growth.

Dwarf birch axial growth rate is higher from the decade 1990 for all types of environments, independently of the year the branch started to develop. This increase corresponds to the increase in mean temperature recorded in the studied region. Axial growth was minimal for hilltops, and maximal for snow patches. The latter, with their high snow cover and nutrient reserve, could promote faster axial growth, whereas harsh winter conditions on hilltops could limit it.

In this study, we demonstrated the relationship between dwarf birch growth and climate. We also demonstrated that this relationship was not uniform across the landscape. Further investigations for climatic measurements (snow depth, snow duration, soil nutrient content) would be necessary for a better understanding of dwarf birch growth.

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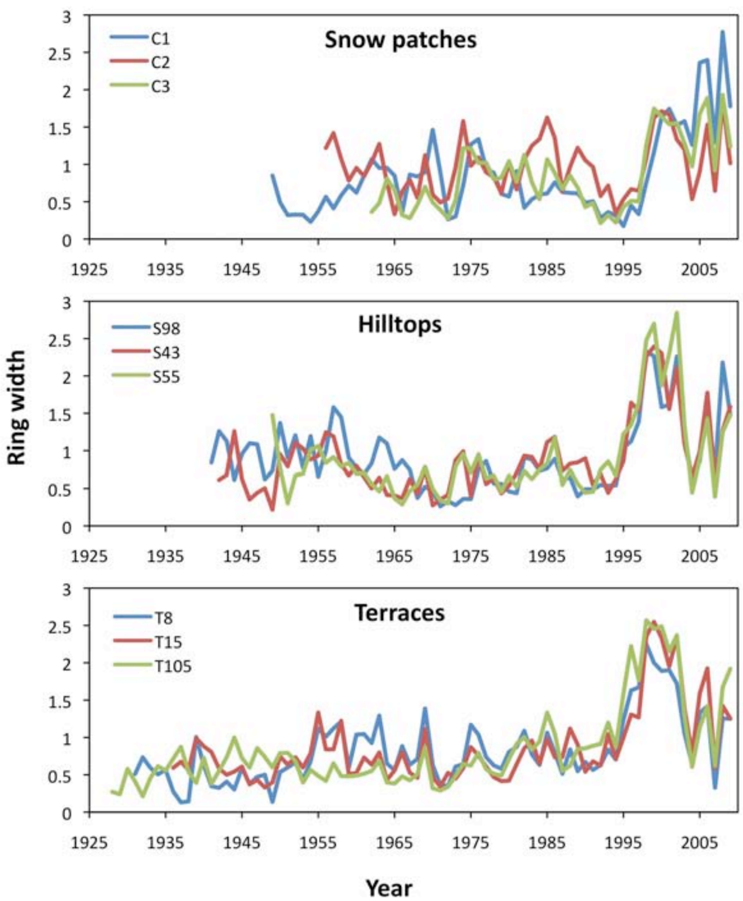

Fig 1. Growth-ring chronologies for each of the nine sites studied. Ring width were detrended with a horizontal line fitted to the mean to allow comparisons

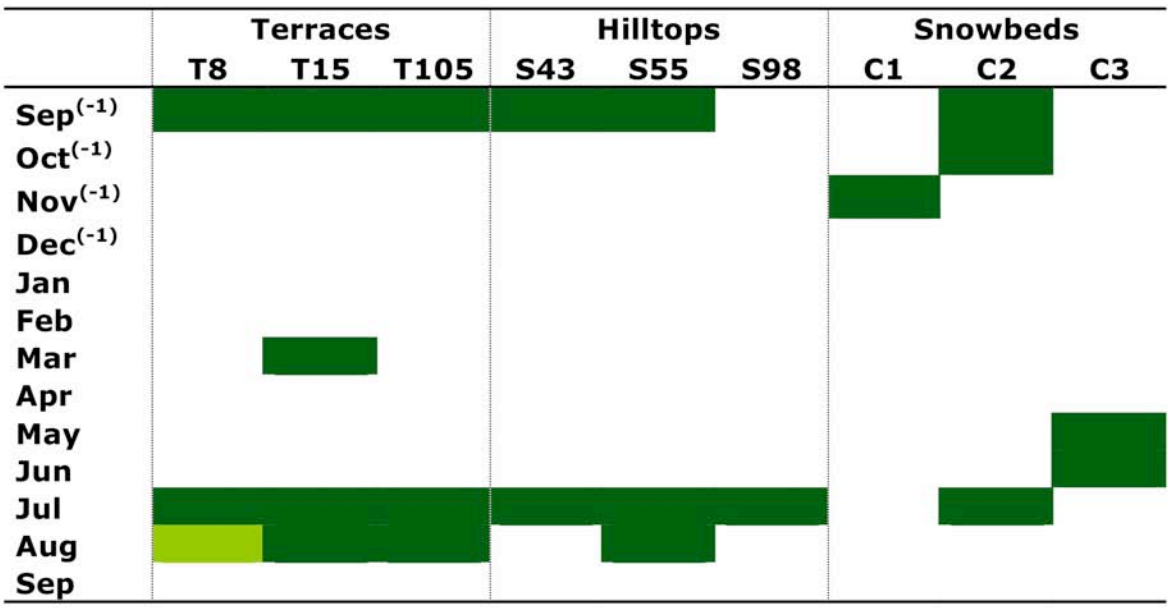

Fig 2. Response functions for mean monthly temperatures from September of the previous year to September of the current one. Dark and light green boxes correspond to positive correlations at $p < 0.01$ and $p < 0.05$, respectively

BRIDGING THE WORK OF FIELD SCIENTISTS AND THE NEEDS OF DATA RE-USERS

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The National Science Foundation requires Principal Investigators to make the data they collect and create publically available. To assist PIs with this requirement, NSF funded the Advanced Cooperative Arctic Data and Information Service (ACADIS). ACADIS houses data from the Division of Polar Programs (PLR), provides data management assistance to PIs, and advances search and data discovery tools. In short, ACADIS exists for NSF Arctic researchers by providing a safe home for data and encouraging data reuse.

ACADIS is a group of specialist organizations comprised to create a repository of Arctic data that encompasses spatial, temporal, and attribute granularity of data so that "big science" and "small science" may better integrate. The ACADIS project fosters scientific synthesis and discovery by providing services that make data from multiple disciplines freely available for access and analysis. ACADIS provides the arctic research community with data archival and data management services as well as value-added products to make the data more useful to more people. Essentially, the goal is to improve the usability and interdisciplinary re-use of arctic data.

But just putting a data file online is not useful enough. Many researchers and data providers understand their own data so intimately that it may seem that all the necessary information is contained in the file structure itself. This is clearly not the case with re-use. Placing the data and research in the greater scientific context is vital.

ACADIS is a far-reaching program that provides assistance with data submission, data preservation and data sharing services. This poster discusses the various tools and services available through ACADIS. These include pieces from each step of the research process – from proposal writing to meeting NSF requirements to maximizing citations.

ACADIS, funded by NSF, is a joint effort by the National Center for Atmospheric Research (NCAR), University Corporation for Atmospheric Research (UCAR), and the National Snow and Ice Data Center (NSIDC). For more information about ACADIS; to send feedback; or to submit, retrieve and search data; please visit their website, contact support@aoncadis.org, or call 720-443-1409.

Rosati, A., and M. Mayernik. "Facilitating Data Discovery by Connecting Related Resources." Semantic Web Journal (2013).

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LATE HOLOCENE EXPANSION OF LOCAL COLD-BASED ICE CAPS IN CENTRAL WEST GREENLAND

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Local glaciers and ice caps adjacent to the Greenland Ice Sheet (GrIS) respond sensitively to climate change and experienced varying climatic conditions during the Holocene similar to those that influenced the GrIS marginal zones. Here, we reconstruct the late Holocene history of mountain ice caps in central West Greenland based on radiocarbon ages of in situ tundra plants emerging along the margins of retreating non-erosive, cold-based ice caps. We interpret ages from recently exposed moss within one meter of the current ice margin to indicate when the regional snowline dropped below a particular site and caused subsequent ice cap expansion, as well as record the last time the site was ice free prior to its modern exposure. These radiocarbon ages, or moss "kill dates," therefore imply that the summer temperatures upon collection may be as high or higher than when the plants were last alive (Miller et al., 2013). The primary objectives of this research are to (1) determine the precedence of the ice caps' current size, (2) compare with similar records from Baffin Island (Anderson et al., 2008; Miller et al., 2013) and in Liverpool Land, eastern Greenland (Lowell et al., 2013) to identify the pattern of Neoglaciation across the northwestern North Atlantic, and (3) compare this record of Neoglaciation with that of the adjacent GrIS margin.

We present our first 32 radiocarbon ages from in situ moss along recently exposed plateau ice cap margins on the island of Disko, the peninsula of Nuussuaq and the Uummannaq region. Moss "kill dates" range from ~ 0.3 to 4.8 cal yr BP with major age clusters at ~3.8 – 4.0 ka and at the onset of the Little Ice Age. These peaks suggest periods of abrupt summer cooling and snowline depression across this region. The absence of radiocarbon ages prior to ~5 ka suggest no regional net snowline lowering occurred until this time. A distinct lack of radiocarbon ages ~2.2 – 2.6 ka may indicate a period of snowline rise or stability. When corrected for the modern regional snowline gradient (Humlum, 1986), the moss radiocarbon age versus elevation pattern reveals net snowline lowering throughout the past ~5 ka of at least ~440 meters. This implies a net temperature decrease of ~2.2 °C assuming no change in precipitation. In addition, these records demonstrate that many local ice caps in this sector of the Arctic are receding more at present than any time in the past ~5 ka, consistent with rising equilibrium-line altitudes over western Greenland (McGrath et al., 2013). Ongoing efforts include supplementing our dataset with moss versus woody plant age comparisons, and increasing the number of radiocarbon dates along plateau ice cap margins and the spatial coverage of sites across western Greenland.

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RECORDING ARCTIC ENVIRONMENTAL CHANGE: USE OF TECHNOLOGY BY INDIGENOUS PEOPLE

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[8];

Although often ignored or disregarded, Indigenous local and traditional knowledge (LTK) is an important source of data for understanding long-term environmental change. Historically, LTK has been conveyed orally from generation to generation. However, cultural shifts over time and adoption of digital technologies have introduced new forms of preserving and learning about the rapid changes in Arctic climate. To support the cultural shift, the Exchange for Local Observations and Knowledge of the Arctic (ELOKA) program implemented specific technologies to assist in the preservation and dissemination of local and traditional knowledge. These web-accessible technologies include video interviews with local hunters in their native language with subtitles, an application allowing access to Indigenous observations of weather and environment, and a geospatial mapping application of local knowledge. Lastly, to ensure the long-term preservation of the data, ELOKA is collaborating with the Data Conservancy to develop curation systems for LTK data. The ELOKA project is funded by the National Science Foundation's Division of Polar Programs.

A CENTENNIAL-RESOLUTION HOLOCENE LEAF WAX HYDROGEN ISOTOPE RECORD FOR DISKO BUGT, WESTERN GREENLAND

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Predictions of Greenland Ice Sheet (GIS) contributions to sea level rise by 2100 AD range from 2-25 cm (Church et al., 2013). This large range is due to a limited understanding of the mechanisms that drive outlet glacier discharge: dynamic thinning, oceanography, and local climate (Holland et al., 2008; Pritchard et al., 2009). Geological evidence indicates that the entire western GIS margin responded sensitively to Holocene climate change (Young et al., 2011). Despite recent advances in understanding past ice margin dynamics and oceanography (Perner et al., 2013; Young et al., 2011), a lack of high-resolution terrestrial climate records near GIS margins makes it difficult to decipher which mechanisms exert the strongest control on GIS discharge. Here, we generate a centennial-resolution leaf wax hydrogen isotope (δ^2H_{wax}) record from Lake N3 in the southern Disko Bugt region, western Greenland. The GIS retreated out of Lake N3's catchment around 8 ka, allowing continuous, organic-rich sediment accumulation in the Lake N3 basin from 8 ka to present. We obtained an age model on a 2.5-m-long sediment core based on eight radiocarbon ages of aquatic macrofossils and a ^{210}Pb surface sediment profile.

δ^2H_{wax} records growing season precipitation δ^2H (Sachse et al., 2012), which changes depending on source area δ^2H composition, transport history, and temperature. Modern monthly precipitation δ^2H at Thule in northwestern Greenland is most strongly correlated with temperature, whereas modern monthly precipitation δ^2H at Groennedal in southwestern Greenland is influenced by precipitation source area and transport history (IAEA/WMO, 2011). There are no precipitation δ^2H data for Disko Bugt, but we hypothesize that precipitation δ^2H in this region reflects a combination of both temperature and source area. Cold Baffin Bay surface waters would yield ^2H-depleted vapor, resulting in regionally ^2H-depleted precipitation. δ^2H_{wax} also responds to changes in the local plant ecosystem, since different plant species fractionate hydrogen isotopes differently during leaf wax synthesis (Sachse et al., 2012).

δ^2H_{wax} at Lake N3 was most ^2H-enriched (ca. -165‰) from 8.0 to 7.0 ka, when early-succession herbs and mosses, which produce relatively ^2H-enriched leaf waxes, likely dominated the landscape. From 7.0 to 0.7 ka, δ^2H_{wax} ranged between -190 and -175‰. Lake N3 δ^2H_{wax} was most ^2H-depleted (ca. -195‰) from 0.7 to 0.3 ka, and increased to -187‰ during recent decades. If interpreted in terms of temperature, the N3 δ^2H_{wax} record would suggest warmest conditions from 8-7 ka, and coldest conditions during the Little Ice Age, 0.7-0.3 ka, with a recovery to mid-Holocene-like temperatures during the 20th century. Indeed, Lake N3 δ^2H_{wax} from 4 ka to present correlates well with temperatures reconstructed at Summit, Greenland using gas fractionation techniques (Kobashi et al., 2011). However, in contrast to Lake N3 δ^2H_{wax}, chironomid-inferred summer air temperatures from nearby North Lake were cool from 7 to 6 ka and warm from 6 to 4 ka (Figure 1; Young et al., 2011). Marine records suggest that surface ocean temperatures were warmest from 5 to 3 ka, because ice sheet melt water suppressed surface ocean temperatures prior to 5 ka (Perner et al., 2013). We hypothesize that precipitation δ^2H was relatively ^2H-depleted from 7 to 5 ka due to cold surface Disko Bugt waters that produced ^2H-depleted vapor. Our findings suggest that, when coupled with regional temperature reconstructions, δ^2H_{wax} provides an unprecedented ability to reconstruct high-resolution temperature and hydrological variability in western Greenland, with important implications for understanding the mechanisms that cause ice sheet advance and retreat.

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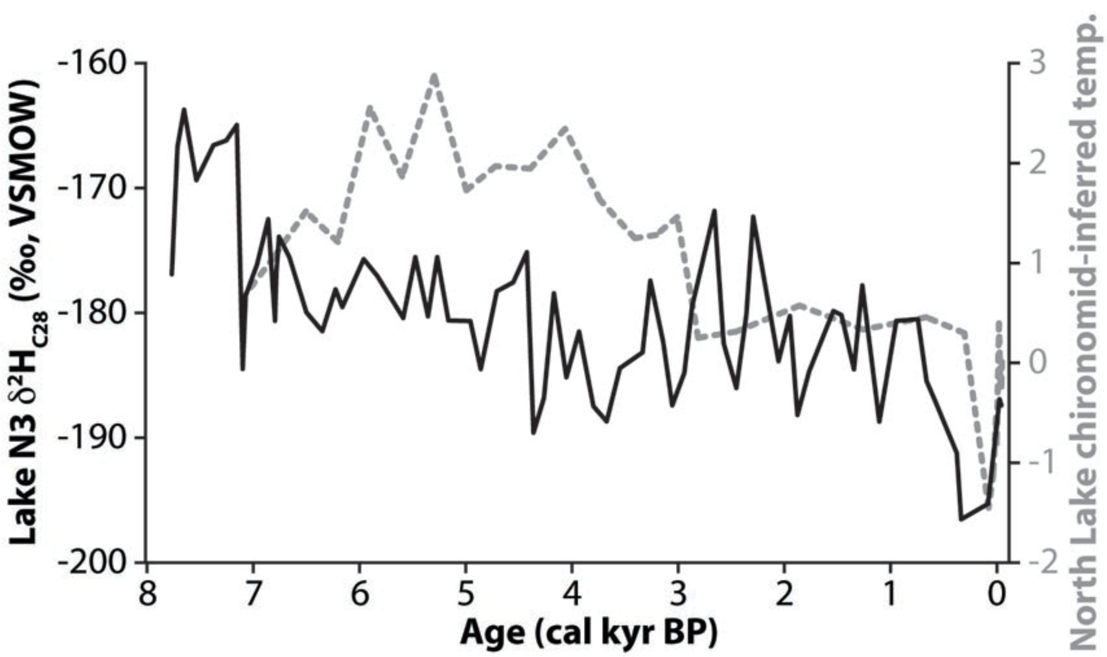

Fig 1. Holocene terrestrial paleoclimate reconstructions near Disko Bugt, western Greenland. Lake N3 leaf wax hydrogen isotopes (black) and North Lake chironomid-inferred temperature anomaly (gray dashes; Young et al., 2011).

BUILDING CONSTITUTIVE RELATIONSHIPS BETWEEN TEMPERATURE, ELECTRICAL RESISTIVITY AND HYDRAULIC CONDUCTIVITY TO IMPROVE FIELD-SCALE ASSESSMENTS OF PERMAFROST

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A fundamental issue in Arctic regions is quantifying the distribution of permafrost in response to changing climate including how freeze/thaw processes affect the hydrologic cycle in the shallow subsurface. Warming climate leads to thawing of permafrost, but the response is not uniform. The overarching goal of this project is to better understand the effects of cryologic and hydrologic processes associated with thawing permafrost on infrastructure, and how these processes can be remotely detected using geophysical tools. Electrical resistivity (ER) is a powerful tool for imaging permafrost since the data are sensitive to sediment type, pore-water chemistry, moisture content and temperature. However, there is currently a gap in understanding the relationships between temperature, electrical resistivity and hydraulic conductivity. Such understanding is essential for non-invasive assessment of the structural integrity of both built and proposed infrastructure, and projecting those properties decades into the future. Laboratory experimental work will be conducted to develop constitutive relations between temperature, bulk electrical resistivity, permeability and thermal conductivity as a function of temperature and degree of permafrost thaw —properties required for accurate mapping and modeling of water/ice dynamics in the shallow subsurface. After stationary relationships have been determined, we will expand our experiments to include time-varying forces. These relationships can eventually be incorporated into field-scale thermophysical modeling and be used to assess the response of permafrost to perturbations induced by a changing climate. Development of modeling approaches to assess the impacts of changing climate on infrastructure will be transferable to a wide array of energy sector developments.

BOTTOM WATER MG/CA RATIOS IN THE ARCTIC GATEWAY – NEW RESULTS FROM *C. WUELLERSTORFI* IN THE FRAM STRAIT

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During the past decades, Mg to Ca ratios have been increasingly used in order to estimate past temperature variations independent from faunal assemblages. Studies of Mg/Ca ratios of the epibenthic foraminifer species *Cibicidoides wuellerstorfi* reveal that it is strongly controlled by temperature. It therefore has great potential for reconstructing bottom water temperatures, especially from the lower end of the temperature range (0-6°C; Tisserand et al., 2013). In the Fram Strait, where main water mass exchanges between the Arctic Ocean and the world's oceans occur, new temperature estimation tools independent from faunal assemblages can help to better understand the complex interplay of different water masses with possible implications to changes in the meridional overturning circulation and the heat flux to the Arctic Ocean. Mg/Ca temperatures can also help unravelling the local impact (e.g., of brine-enriched waters) from general trends in bottom water circulation. In order to apply Mg/Ca-derived temperatures to sediment records from the Fram Strait, a calibration relationship between modern Mg/Ca ratios to bottom water temperatures, which fits the environmental conditions of the Arctic Gateway, needs to be developed. We therefore studied Mg/Ca ratios of *C. wuellerstorfi* in a set of core top samples from the Fram Strait and the Norwegian margin where bottom temperatures range between -0.5 and -1°C. For the calibration to modern temperatures, we used modern oceanographic data from both existing conductivity-temperature-depth (CTD) casts and the World Ocean Data Base 2013 (Boyer et al., 2013). The new calibration data are combined with published data in order to extend the existing Mg/Ca-temperature calibration for *C. wuellerstorfi* down to -1°C for the northernmost part of the North Atlantic Ocean.

Boyer, T.P., Antonov, J.I., Baranova, O.K., Coleman, C., Garcia, H.E., Grodsky, A., Johnson, D.R., Locarnini, R.A., Mishonov, A.V., O'Brien, T.D., Paver, C.R., Reagan, J.R., Seidov, D., Smolyar, I.V., Zweng, M.M., 2013, World Ocean Database 2013. Sydney Levitus, Ed., Alexey Mishonov, Technical Ed., NOAA Atlas NESDIS 72. 209 pp.

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TO UNDERSTAND THE ARCTIC'S NEW NORMAL, YOU FIRST NEED TO FIND OLD DATA

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At a polar scale, well-described and open data are key to understanding shifting Arctic environmental baselines. Dense observational records over time and across geospatial scales and domains are crucial for setting baselines and understanding rapid polar changes. Recognizing the importance of open data availability, the International Polar Year (IPY) effort made progress in promoting data sharing across research communities. Despite these gains, data needed to understand Arctic change remain scattered in diverse formats with different levels of documentation and accessibility. Different governments, funding agencies, domain organizations, and various operational and industry groups maintain separate systems for polar data. Those looking to reuse data need a good deal of insider knowledge, time, and luck to find data of interest.

The Arctic Data Explorer is a web-based search tool that advances Arctic research through one-stop data search across many repositories. Rather than going to each data center website individually, researchers can use the Arctic Data Explorer to search and find data from diverse disciplines and scales whether their interest is in regional sea ice datasets or data from a specific reindeer herd. Local in-situ observations are made available alongside remote sensing data. Launched in April 2013 with five pilot repositories included in the search, the Arctic Data Explorer has increased search coverage and now includes metadata from NASA, NOAA, NSF, and international data catalogs. The Advanced Cooperative Arctic Data and Information Service (ACADIS) team is building the Arctic Data Explorer tool to maximize data discovery across organizations, research groups, funding agencies, and countries.

There are significant informatics research questions behind the technologies used by the Arctic Data Explorer. For example, relevance ranking of search returns, i.e. how datasets are ordered in a search result set, is an area of active research. As more data are shared and technology enables search across many thousands of datasets, understanding and representing data quality also becomes more important. Of 3 (or 3000) similar datasets that, on the surface, match search criteria, which are likely to be the best, most useful, and/or most valuable for a particular research question? Understanding researcher search strategies and behaviors is necessary in order to improve discovery, access, and use of data. For example, do physical oceanographers and terrestrial ecologists search for data the same way? Does a search system built to meet the needs of field scientists also work for modelers, and if not, why? How do the search behaviors of senior and early career scientists compare? Can we encode semantic relationships between the vocabularies used in different domains, and if so, what are the appropriate uses and limitations of the result?

Work remains before technologies can meet the promise of an integrated cyberinfrastructure. However, projects like ACADIS and the Arctic Data Explorer advance informatics research goals to support Arctic research goals by making it easier to find data capturing dramatic polar changes.

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