

**Water and Environmental Research Center
Annual Technical Report
FY 2015**

Introduction

The UAF Water and Environmental Research Center provides water resource solutions for the State of Alaska. WERC is housed in the UAF Institute of Northern Engineering, and seeks to understand water resources in a fashion that is not limited by traditional disciplinary boundaries. WERC employs civil and environmental engineers, hydrologists, limnologists, ecologists, chemists, social scientists, permafrost scientists, and an array of other faculty, staff, and student researchers with a shared interest in arctic and subarctic water resources.

This year we split our funding between research projects and outreach/technology transfer activities. See Information Transfer Program below for a discussion of our outreach and technology transfer activities. For a discussion of this year's research project see Research Program Introduction below.

Research Program Introduction

The FY2015 104(b) grants reflect the diverse nature of our current research. The 104(b) grants we received for the funding period were instrumental in allowing a group of WERC-affiliated students to pursue research projects important to the State of Alaska. The topics covered this year include the relationship between peat accumulation and permafrost thaw during previous periods of rapid climate change; the use of ground penetrating radar to evaluate snow accumulation on glaciers; the relative contributions of glacier melt, snow melt, and rain to runoff in a glaciated stream in Interior Alaska; the relationship between landscape characteristics and stream temperature in Southeast Alaska; and the relationship between environmental conditions and lake levels over a 10,000 year period.

Please note that project number 2014AK123B is included in the current report as well as last year's report. That project had a no cost extension lasting from the end of the original period of performance (3/1/15) until 5/31/15. Thus, the project report was completed in time for inclusion in last year's annual report, but it is also included in this year's report due to the no cost extension.

Use of ground and aircraft-based radar to document the spatial pattern of snow accumulation on two well-studied Alaskan glaciers

Basic Information

Title:	Use of ground and aircraft-based radar to document the spatial pattern of snow accumulation on two well-studied Alaskan glaciers
Project Number:	2014AK123B
Start Date:	3/1/2015
End Date:	5/31/2015
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Climate and Hydrologic Processes
Focus Category:	Water Quantity, Water Supply, Hydrology
Descriptors:	None
Principal Investigators:	Michael Gregg Loso

Publications

1. Candela S, Loso M, O'Neel S, Dial R. 2014. Characterizing small--scale variability of snow thickness using GPR on Taku Glacier, Alaska. Poster C53A--0284 presented at the AGU fall meeting.
2. Candela, S. 2015. Small--scale variability of snow depth on Taku Glacier, Alaska as determined from ground-penetrating radar. Undergraduate Senior Project. Alaska Pacific University, Anchorage AK, April 2015.
3. McGrath D, Gusmeroli A, O'Neel S, Sass L, Arendt A, Wolken G, Kienholz C, McNeil C. 2013. Improved estimates of snow accumulation derived from ground penetrating radar on suite of Alaskan glaciers. Poster C21B--0633 presented at the AGU fall meeting.
4. McGrath D, Sass L, O'Neel S, Arendt A, Wolken G, Gusmeroli A, Kienholz C, McNeil C. Submitted. End-of-winter snow water equivalent variability on Alaskan glaciers. Submitted to Journal of Glaciology.
5. McNeil C, Pelto M, McGee S, Campbell S, Kavanaugh J. 2014. Taku and Lemon Creek Glacier, Alaska: North America's longest glacier records. Paper 334 -- presented at the GSA fall meeting.
6. Nothing new to report

NIWR Project Report

Title:	Use of ground and aircraft-based radar to document the spatial pattern of snow accumulation on two well-studied Alaskan glaciers
Project Number:	G11AP20064
Start Date:	March 1, 2014
End Date:	February 28, 2015, with no-cost extension to May 31, 2015
Funding Source:	WERC/National Institute of Water Resources Grant Program
Congressional District:	Alaska
Focus Category:	WQN, WS, HYDROL
Descriptors:	glacier runoff, sea level rise, snowpack, ground penetrating radar, water supply, Alaska
Principal Investigators:	Michael G. Loso, Associate Professor of Earth Science, Alaska Pacific University

Publications and Products of Project

Candela S, Loso M, O'Neel S, Dial R. 2014. Characterizing small-scale variability of snow thickness using GPR on Taku Glacier, Alaska. Poster C53A-0284 presented at the AGU fall meeting. (*direct outcome of work completed under this proposal*)

Candela, S. 2015. Small-scale variability of snow depth on Taku Glacier, Alaska as determined from ground-penetrating radar. Undergraduate Senior Project. Alaska Pacific University, Anchorage AK, April 2015. (*direct outcome of work completed under this proposal*)

McGrath D, Gusmeroli A, O'Neel S, Sass L, Arendt A, Wolken G, Kienholz C, McNeil C. 2013. Improved estimates of snow accumulation derived from ground penetrating radar on suite of Alaskan glaciers. Poster C21B-0633 presented at the AGU fall meeting. (*a product of work underway at the time of this proposal submission*)

McGrath D, Sass L, O'Neel S, Arendt A, Wolken G, Gusmeroli A, Kienholz C, McNeil C. Submitted. End-of-winter snow water equivalent variability on Alaskan glaciers. Submitted to *Journal of Glaciology*. (*direct outcome of work completed under this proposal*)

McNeil C, Pelto M, McGee S, Campbell S, Kavanaugh J. 2014. Taku and Lemon Creek Glacier, Alaska: North America's longest glacier records. Paper 334-1 presented at the GSA fall meeting. (*a product of work underway at the time of this proposal submission*)

Introduction: problem, objectives, and relevance

Alaska's critical need to predict the impacts of changing glaciers on downstream hydrology is dependent on a better understanding of the spatial and temporal variability of snow accumulation rates on glacier surfaces. In 2014, we proposed a modest expansion of efforts, already underway on two well-studied glaciers (Taku and Eklutna), to use ground-penetrating radar as a rapid, accurate measurement tool for the measurement of seasonal snow thickness. Our objectives, as stated in the original proposal, are

summarized in Table 1. In the results section, we summarize our accomplishments with respect to those objectives.

Table 1. Objectives of this project, from the original proposal.

Objective	Personnel	Timeline	Funding source
1. Collect ground--based GPR data on Taku and Eklutna Glaciers in year 1	McNeil, Candela, Loso	Summer 2013 (completed)	Outside match
2a. Process and analyze year 1 data from Taku Glacier	Candela	Spring 2014 (underway)	This proposal
2b. Process and analyze year 1 data from Eklutna Glacier	Collaborator	Fall 2013 (completed)	Outside match
3. Collect aircraft--based GPR data on Taku and Eklutna Glaciers in year 2	McNeil, Candela, Loso	Summer 2014	This proposal
4a. Process and analyze year 2 data from Taku Glacier	Candela/McNeil	Fall 2014	This proposal
4b. Process and analyze year 2 data from Eklutna Glacier	Candela	Fall 2014	This proposal
5. Ground--truth GPR with direct snow depth measurements	Loso, McNeil, collaborators	Summer 2013/2014	Outside match
6. Document temperatures and ablation rates on upper Taku Glacier in year 2	McNeil	Summer 2014	This proposal
7. Create maps of snow depth for years 1 and 2 at both glaciers	All	Spring 2015	This proposal

Results

Objective 1: Collect ground--based GPR data on Taku and Eklutna Glaciers in year 1

This task was already completed at the time of project submission. These existing radar lines, along with the lines proposed for completion in year 2 (see objective 3) are shown in Figure 1 and Figure 2.

Objective 2: Process and analyze year 1 data from a) Taku Glacier and b) Eklutna Glacier

The year 1 data were processed and analyzed by USGS collaborator Dan McGrath (for Eklutna Glacier and parts of Taku Glacier) and by APU undergraduate Sal Candela (for the remainder of Taku Glacier). Processed snow depths (shown in SWE: meters of water equivalent) from Taku are shown in Figure 3, and from Eklutna are shown in Figure 4. Additional radar analyses on Taku Glacier were completed by Candela as part of his undergraduate senior project, completed at APU in April 2015. One figure from that project, comparing radar measurements to direct snow depth measurements, is shown in Figure 5.

Objective 3. Collect aircraft--based GPR data on Taku and Eklutna Glaciers in year 2

In summer 2014, we successfully collected aircraft--based radar at both research sites. At Taku Glacier, we collected data on Taku, and also on Gilkey and a portion of Mendenhall Glacier. The Taku portion of that data is shown in Figure 6. At Eklutna, we collected data on Eklutna, and also on Eagle Glacier (Figure 7). An unusually early and warm spring of 2014 at both glaciers led to significant free water in the snowpack at the time of radar acquisition, which complicated later efforts to process these data.

Objective 4. Process and analyze year 2 data from a) Taku Glacier and b) Eklutna Glacier

The year 2 data were processed and analyzed by undergraduate Sal Candela, with assistance and advising from the PI, graduate student Chris McNeil, and collaborator Shad O'Neel. Processed snow depths from Taku are shown in Figure 8, and from Eklutna are shown in Figure 9. Completed but ancillary results for Gilkey, Mendenhall, and Eagle Glacier are not shown. Candela is currently working with USGS collaborator Dan McGrath to QC the processed data, which in some places presents interpretation challenges because of the free water content of the snow mentioned above.

Objective 5. Ground---truth GPR with direct snow depth measurements

Mass balance was measured on Taku and Eklutna in 2014, consistent with previous years in these ongoing, externally funded monitoring programs. We had 9 snowpits to ground---truth the radar measurements on Taku Glacier (Figure 6), and 5 snowpits to ground---truth on Eklutna. Measured annual balances were very negative on both glaciers, consistent with our observations—during the spring radar work—of an isothermal snowpack that underwent unusually strong melt early in the melt season.

Objective 6. Document temperatures and ablation rates on upper Taku Glacier in year 2

Seven ablation stakes were placed on Taku Glacier in 2014 by Chris McNeil, including three (on the upper glacier) with associated temperature loggers (Figure 10). This work, which was somewhat tangential to the radar work but intimately related to the mass balance re---analysis project being conducted as part of Chris's masters thesis, was inserted into the proposal because of the cost---efficiency of completing it in the context of the radar fieldwork.

Objective 7. Create maps of snow depth for years 1 and 2 at both glaciers

Maps of measured snow depths have been completed for both glaciers over both years and were presented above, but the primary proximal goal of this work is to develop *distributed* maps of snow depth at Taku and Eklutna Glaciers (maps that extrapolate measured snow depths to unmeasured areas), and to use those maps as tools both for constraining analyses of mass balance for the two years in question and also for understanding the factors that govern snow depth over longer timescales.

At present, we have one of the four maps (two glaciers over two years) completed. Distributed snow depth on Eklutna Glacier in 2013 (year 1) is shown in Figure 11, taken from McGrath et al (submitted). The spatial distribution of measurements on Taku in 2013 were judged by McGrath to be too limited to justify a distributed map. Measurements on both glaciers in 2014 are currently being QC'd, as discussed above, and will be combined with recent, externally---funded radar measurements from spring 2015 for a follow---up paper that examines year---to---year variability in the amount and spatial pattern of snow depths.

Summary of Project Outcomes

As described above, we were successful in accomplishing almost all of the objectives set forth in our original proposal. Because of the short timeframe of this proposal, however, it is important to place these accomplishments in the context of the work, still underway, which is occurring over a timeframe of multiple years. When we submitted our proposal, initial radar measurements had already been collected on Taku and Eklutna Glaciers, and analysis of those data was just beginning. NIWR directly funded a portion of the analysis of those records, most of the cost of collecting a second year of data, and most of the cost of analyzing those second---year records. At the time of this writing, a third year of

measurements have now been successfully completed on both glaciers (in spring 2015). And plans are already underway for year four.

In summary, our NIWR-funded work has contributed substantially to the establishment of what is becoming an ongoing project of measuring snow accumulation on Alaskan glaciers annually using ground-penetrating radar. A broad consortium of collaborators, led by USGS colleagues Dan McGrath and Shad O'Neel and including participants from APU, UAF, and AK DGGGS, have been meeting regularly to advance this project, discussing issues of data integrity and processing, funding, research objectives, and archival strategies. This group has already submitted one paper to *Journal of Glaciology* (cited above and focused on year 1 data), and is planning a second paper that will utilize a combination of years 1, 2, and 3 data. This paper, focused on interannual variability, will be the full showcase of the NIWR-funded work. But probably the most critical and successful outcome of this proposal is its contribution to the establishment and accomplishments of this Alaskan radar working group, which has the aim of collecting radar measurements on many glaciers, including Eklutna and Taku, in a consistent, regular, and publicly-archived format for the foreseeable future.

Finally, this project has contributed substantially to the professional development of three APU students/graduates. Chris McNeil (current APU graduate student), Sal Candela (recently graduated APU undergraduate now working for AK DGGGS on radar analyses), and Louis Sass (alumnus of APU graduate program and now USGS glaciologist) have all been intimately involved in this work, have all been supported in that work by the NIWR funding, and are continuing their work on glacier-related radar work.

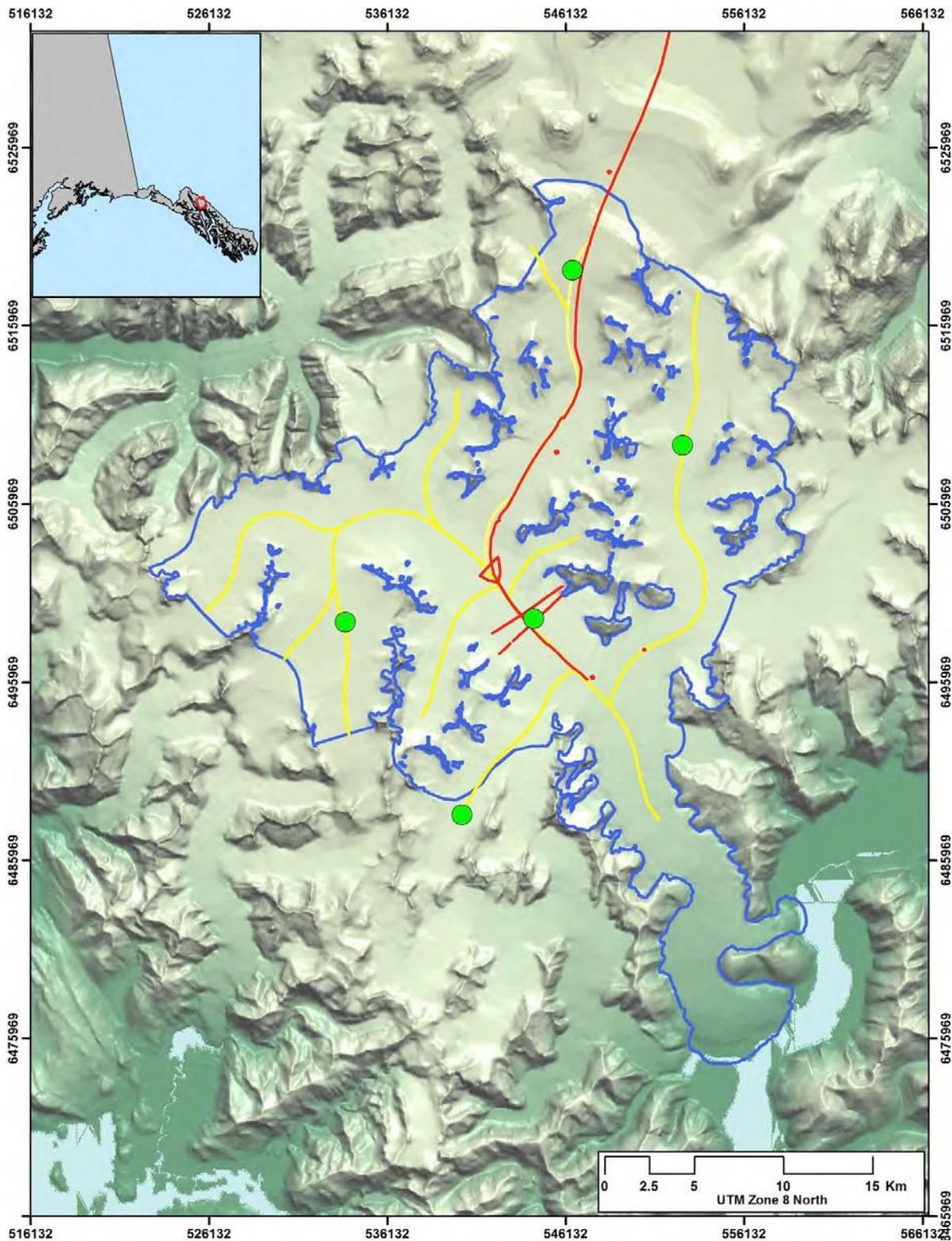


Figure 1. Taku Glacier. 2013 glacier boundary is outlined in blue. Existing (red) and proposed (yellow) radar lines are shown, along with ongoing mass balance measurement sites (green dots). Inset shows location of detailed map in southeast Alaska.

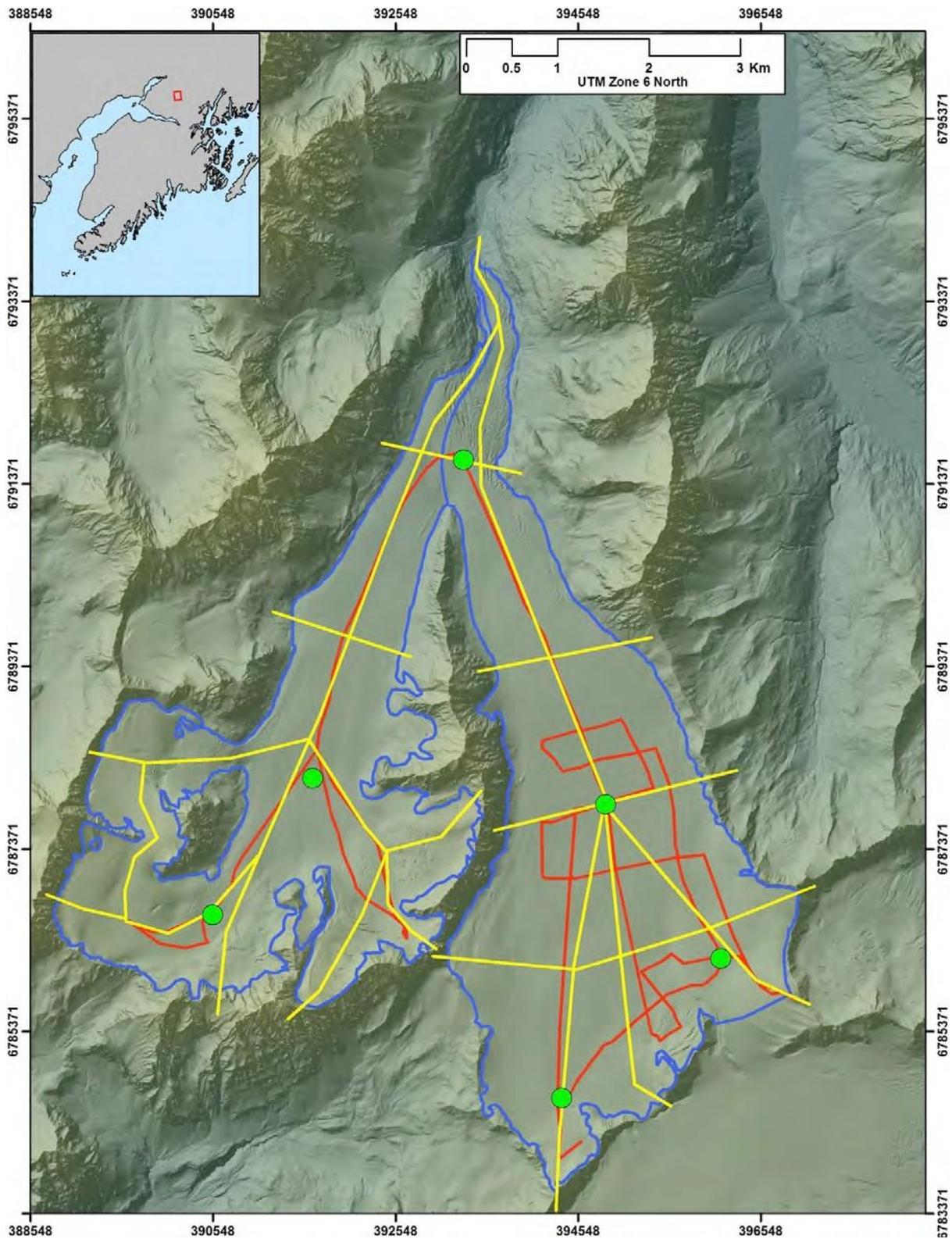


Figure 2. Eklutna Glacier. 2012 glacier boundary is outlined in blue. Existing (red) and proposed (yellow) radar lines are shown, along with ongoing mass balance measurement sites (green dots). Inset shows location of detailed map in southcentral Alaska.

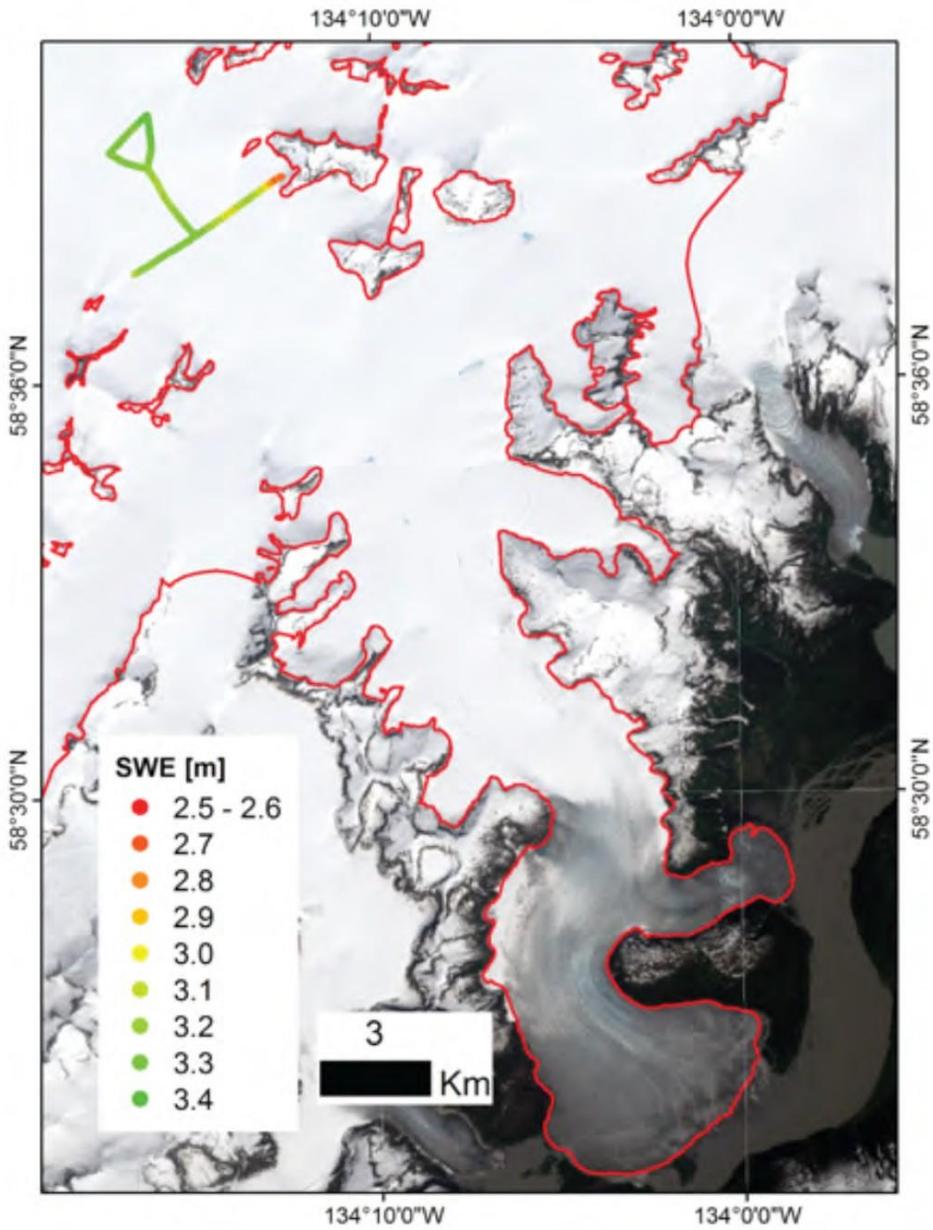


Figure 3. Inferred snow depths (in SWE: meters of water equivalent) for Taku Glacier in 2013.

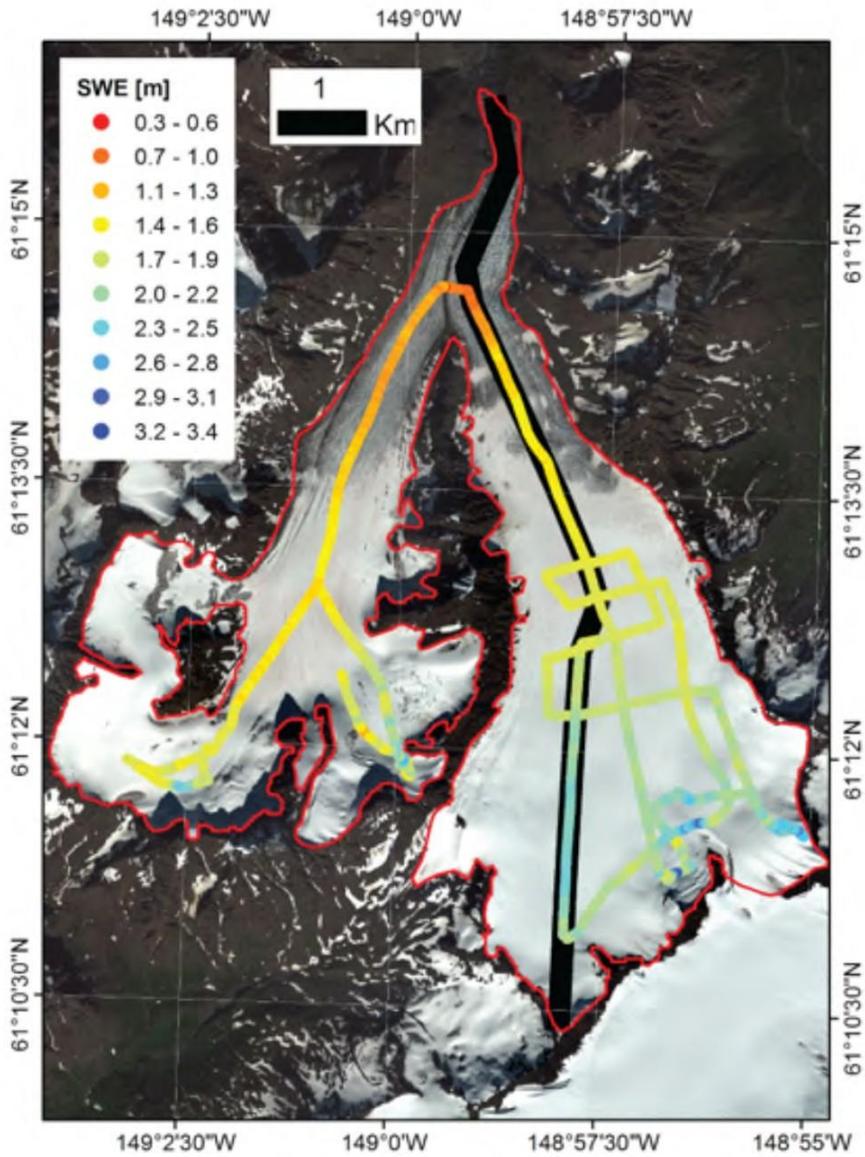


Figure 4. Inferred snow depths (in SWE: meters of water equivalent) for Eklutna Glacier in 2013.

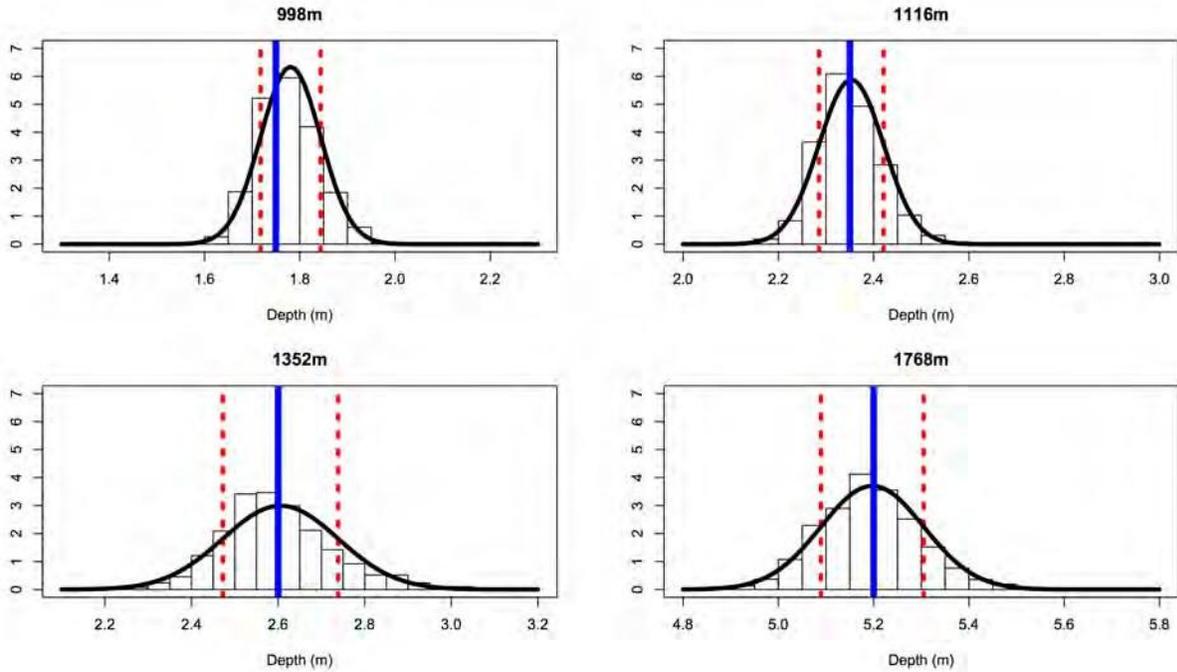


Figure 5. Comparison of radar and ground---truth based snow depths at four sites on Taku Glacier in 2013. Distributions of radar---inferred snow depths from grids surrounding single snowpits are shown by the histogram bars, and approximated by the normal distributions shown in bold black. Vertical blue bars represent measured snow depths in pits.

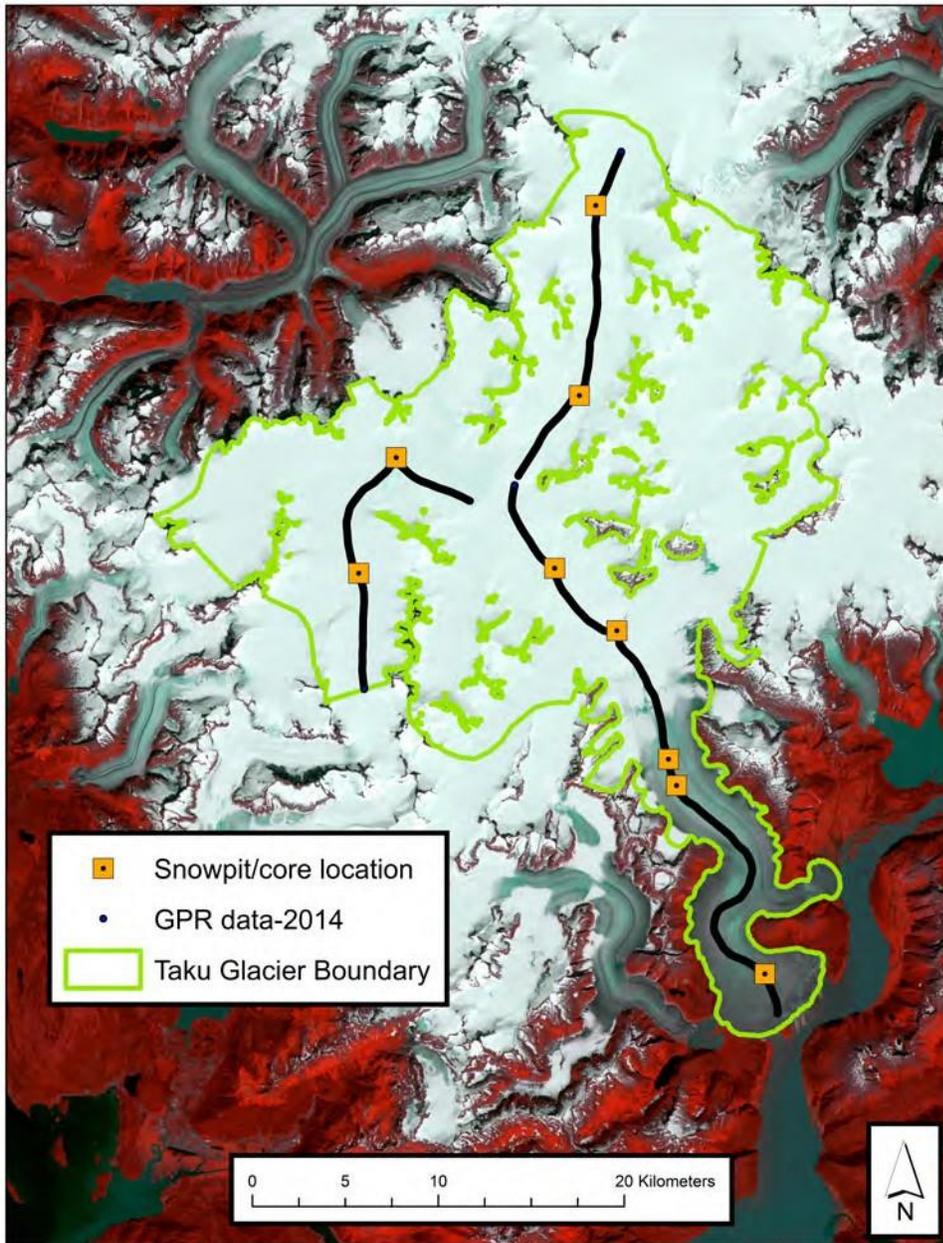
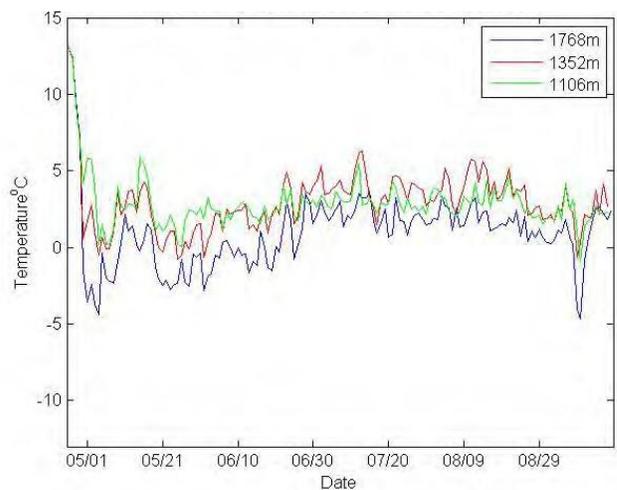


Figure 6. Taku Glacier. Collected 2014 (year 2) radar data is shown in black. Snowpits used for ground-truthing are shown with yellow squares. Measured temperatures are shown in the inset at right.



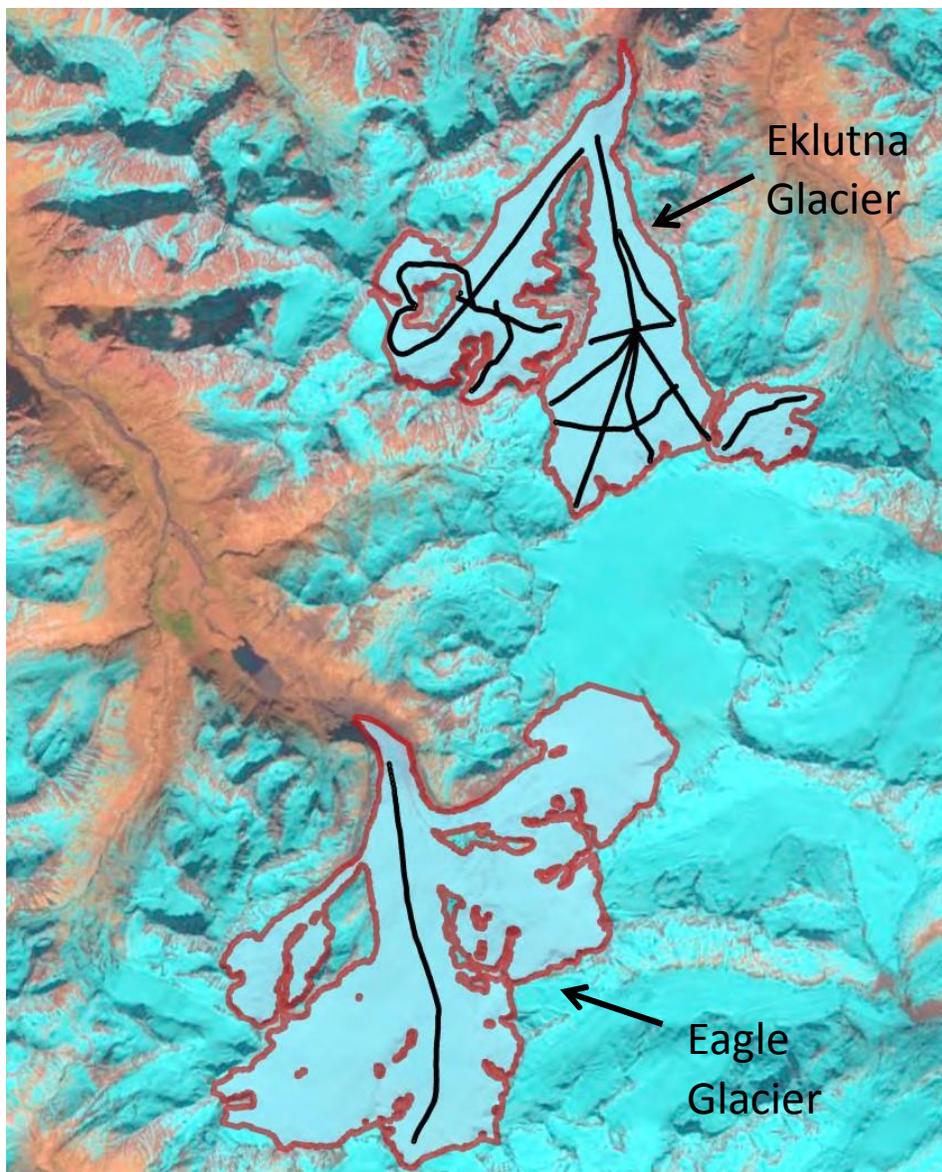


Figure 7. Eklutna and Eagle Glaciers. Collected 2014 (year 2) radar data is shown in black.

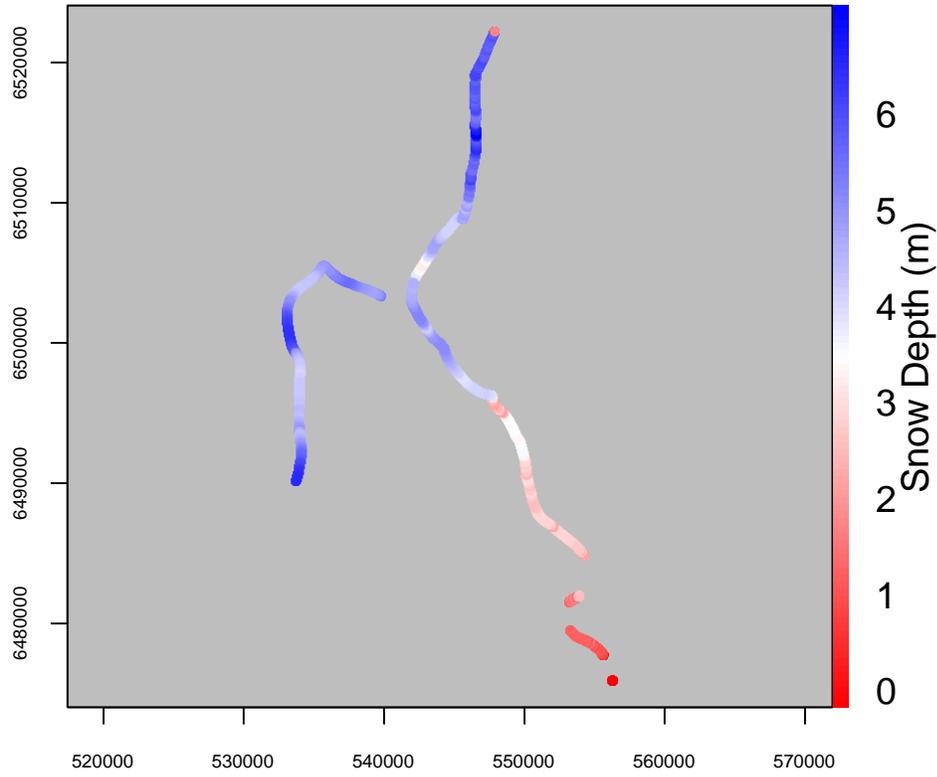


Figure 8. Inferred snow depths for Taku Glacier in 2014.

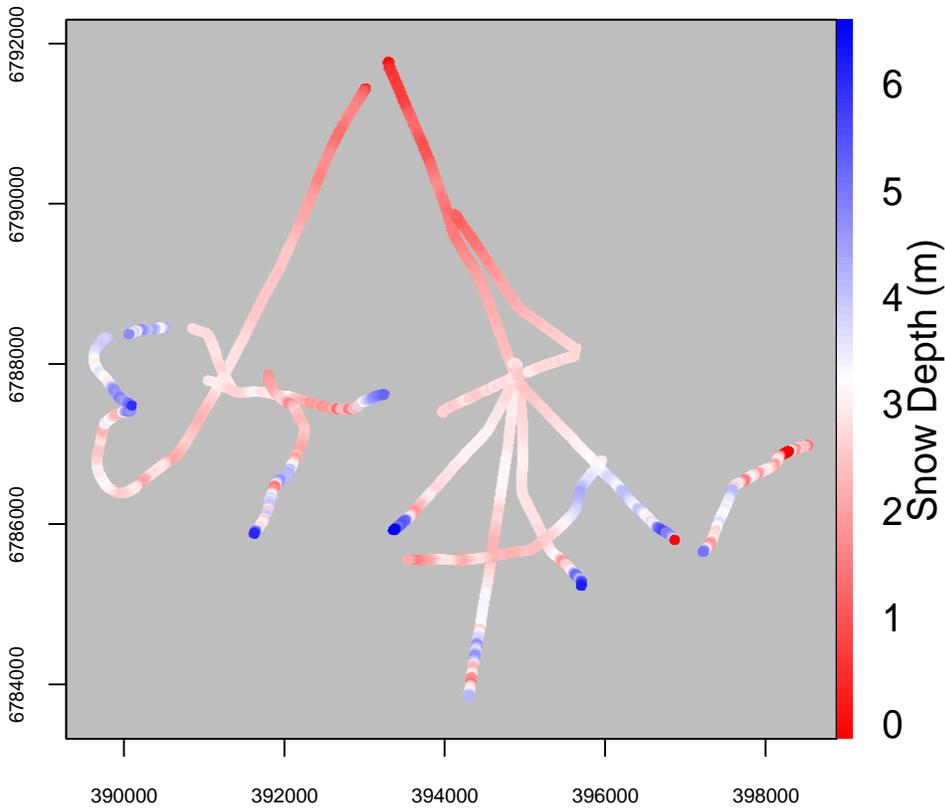


Figure 9. Inferred snow depths for Eklutna Glacier in 2014.

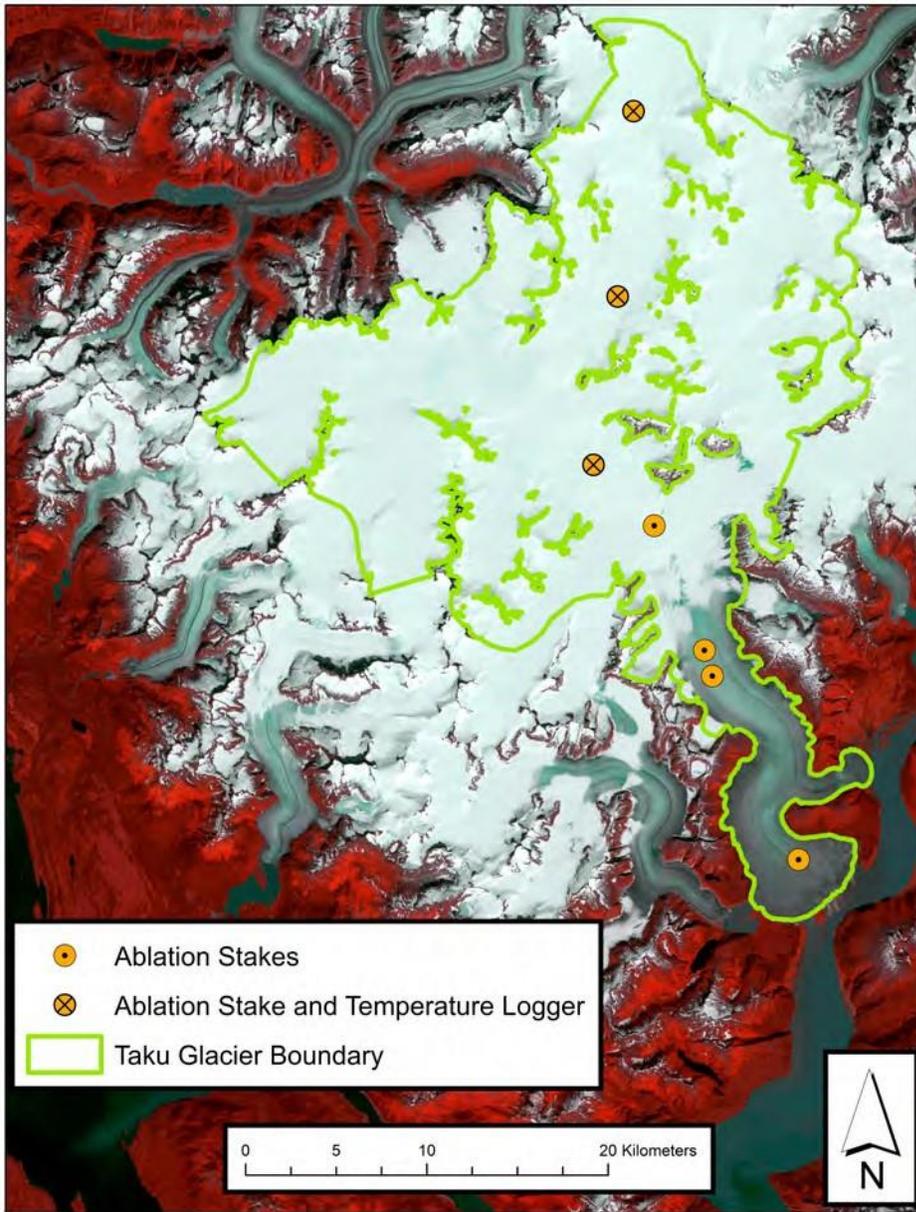


Figure 10. Locations of ablation stakes and temperature loggers placed on Taku Glacier in summer 2014.

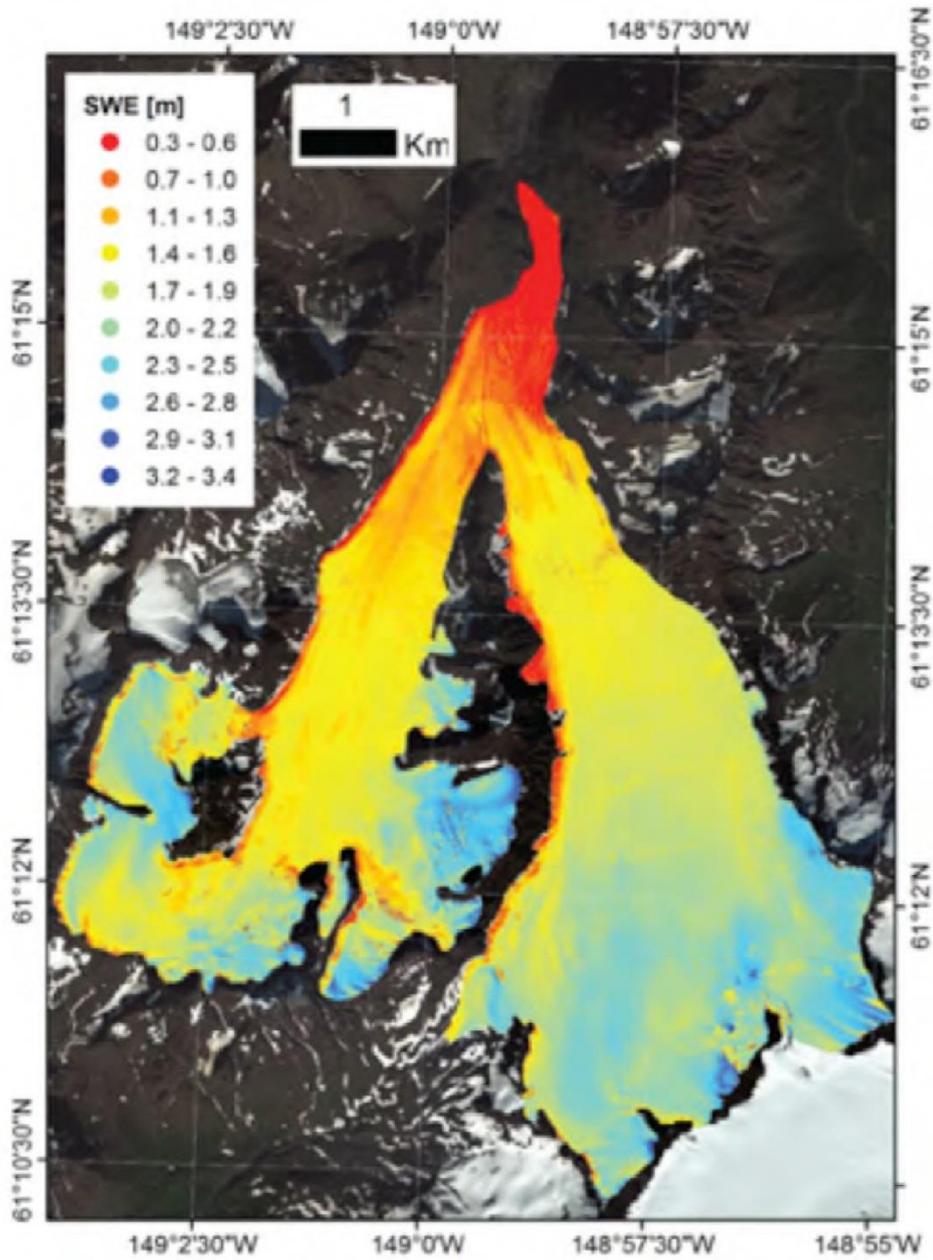


Figure 11. Distributed snow depth (in SWE: meters of water equivalent) in spring 2013 at Eklutna Glacier.

Linking landscape characteristics and stream temperature in the coastal temperate rainforest of southeast Alaska

Basic Information

Title:	Linking landscape characteristics and stream temperature in the coastal temperate rainforest of southeast Alaska
Project Number:	2015AK125B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Water Quality, Ecology
Descriptors:	None
Principal Investigators:	Eran Hood, Sanjay Pyare

Publication

1. Winfree, M.M., Hood, E.W. (2016). Stream temperature regimes in Glacier Bay. Research highlights brochure for Glacier Bay National Park. May 2016.

2015 Annual Report:

Title: Linking landscape characteristics and stream temperature in the coastal temperature rainforest of southeast Alaska

Introduction

The coastal temperature rainforest (CTR) of southeast Alaska is being strongly affected by climate change, with mean annual air temperatures expected to increase by 1.7-3.7°C by the end of the century. This projected temperature increase will have a variety of effects on landcover and hydrology in the CTR including shifts in treeline, annual precipitation, and the rain/snow fraction of precipitation. Ultimately these climate-driven changes have the potential to alter the physical characteristics of aquatic habitats in coastal streams within the region. Of particular interest are potential changes to thermal regimes in the region's ~4000 anadromous streams, which support culturally and economically important Pacific salmon runs. The purpose of this study is to quantify landscape controls on streamwater temperature in anadromous streams throughout southeast Alaska. This will not only increase our understanding of the variability in thermal regimes among streams across the region, but also provide a framework for linking future climate scenarios of air temperature and precipitation to thermal regimes of streams, and allow us to better identify how linked changes in landcover and temperature may impact Pacific salmon habitat.

Objective 1) *Establish a network of approximately 50 new stream temperature monitoring sites in anadromous streams across southeast Alaska.*

Research Approach: Through collaboration with multiple federal agencies and non-government organizations, MSc student M. Winfree collected stream temperature measurements in 59 watersheds in 2014 - 2015. These sites have broad geographic distribution across southeast Alaska and thus are representative of the wide variety of watershed types in the region (Figure 1). Sites were visited in spring and fall 2015 to download data and verify the sensors remain securely anchored and submerged beneath the water surface. The stream temperature data collection phase of the study ended with site visits in Spring 2016, however many of the installed sensors remain deployed,

representing the beginning of the first southeast Alaska stream temperature monitoring network.

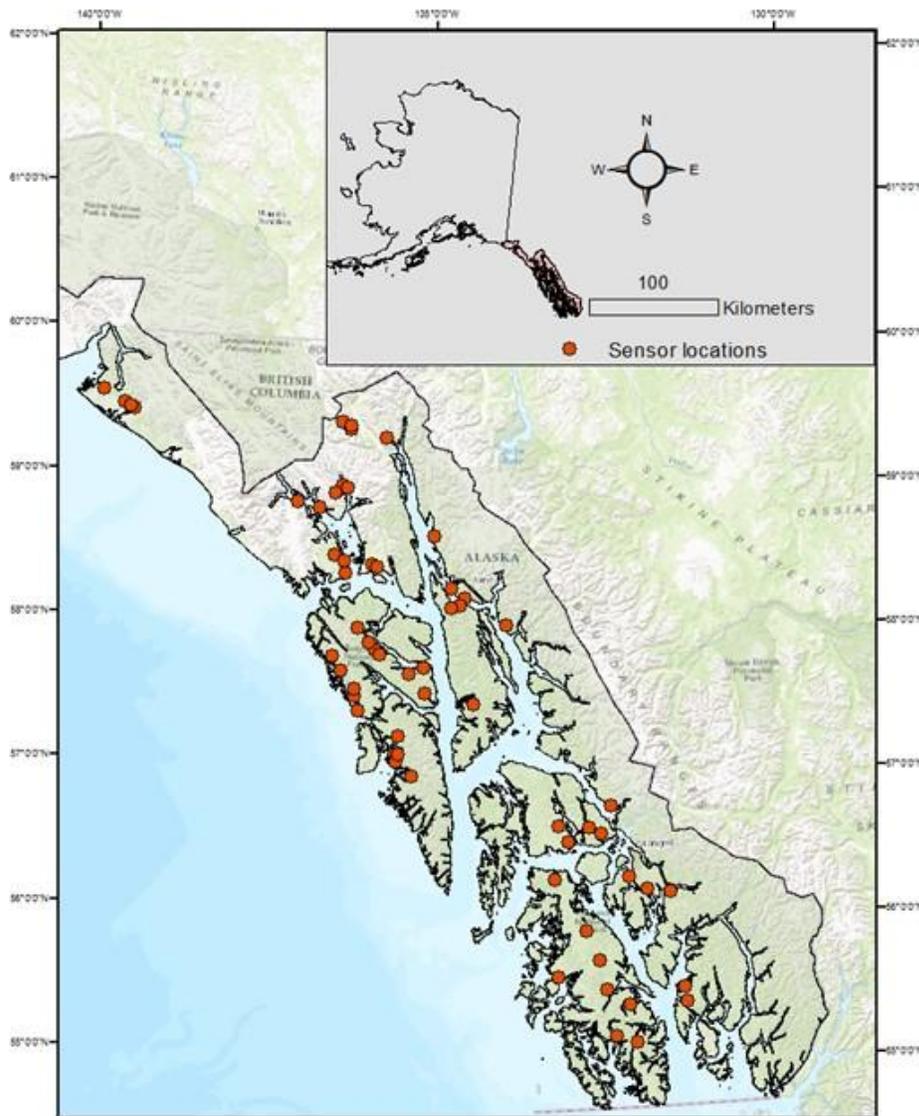


Figure 1. Stream temperature monitoring locations in southeast Alaska.

Objective 2) *Develop models identifying relationships between stream temperature and landscape characteristics within watersheds.*

ArcGIS (v10.2 Environmental Systems Research Institute, Redlands, CA, USA) was used to process available spatial data to delineate watershed boundaries and calculate geomorphic and landcover variables for each of the study watersheds. Air temperature data for the monitoring period was downloaded from the National Climatic Data Center

(www.ncdc.noaa.gov) and organized at a daily time step for analysis. Regional exploratory analysis was conducted to identify general trends in stream temperature data. Streamwater thermal regimes across the region were found to be highly variable. For example, maximum weekly average temperatures (MWAT) in 2015 from 40 selected watersheds varied from 4°C to 21°C (Figure 2). Multivariate time series analysis is currently ongoing to model stream temperature sensitivity to air temperature at a sub-regional scale.

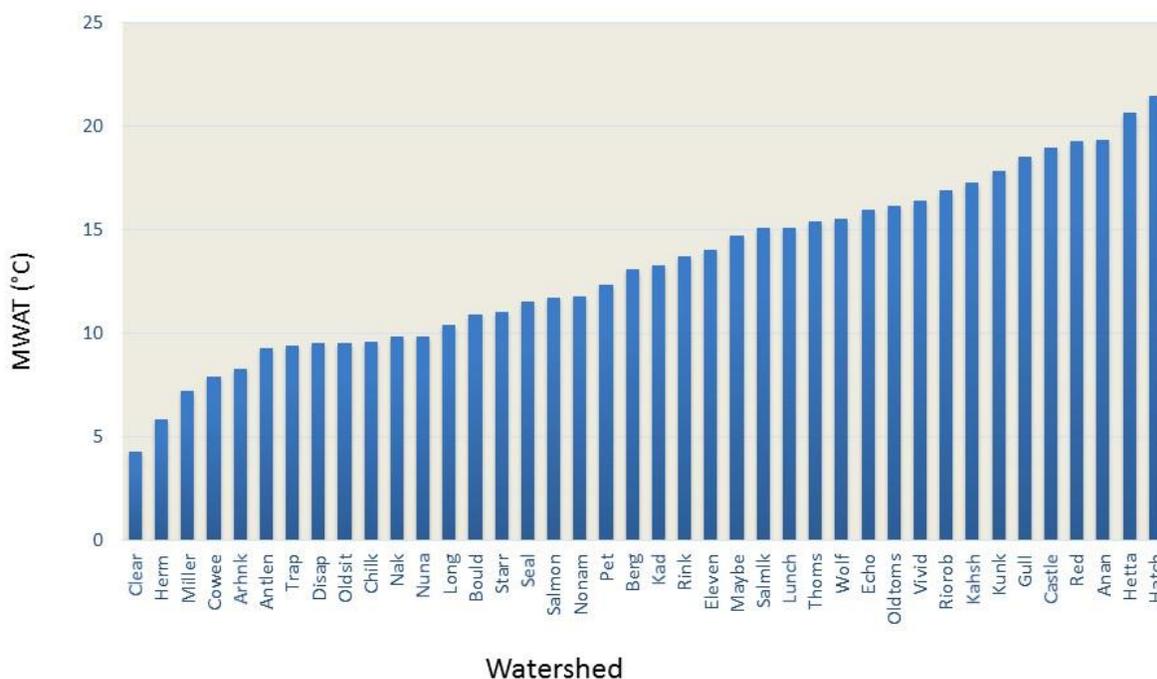


Figure 2. Summer 2015 maximum weekly average temperature (MWAT) in 40 sampled watersheds in southeast Alaska.

INFORMATION TRANSFER PROGRAM

Several streamwater temperature monitoring sites were located within Glacier Bay National Park and Preserve. In accordance with the research permit requirements, a research update brochure describing this project was developed for the Park’s visitor program. In addition, Winfree gave presentations about the project at professional scientific and academic venues (details below).

PRESENTATIONS

Winfree, M.M., Hood, E.W. (2014). Linking landscape characteristics to stream temperature in the coastal temperate rainforest of southeast Alaska. Oral presentation at the Water and Environmental Research Center Seminar Series. 31 October 2014, Fairbanks, AK.

Winfree, M.M., Hood, E.W. (2016). Linking landscape characteristics to stream temperature in the coastal temperate rainforest of southeast Alaska. Oral presentation at the USFS sponsored workshop: Climate Change in Southeast Alaska - Informing Sustainable Management of Water Resources and Anadromous Fisheries. 13 -14 April 2016, Juneau, AK.

Winfree, M.M., Hood, E.W. (2016). Stream temperature regimes in Glacier Bay. Research highlights brochure for Glacier Bay National Park. May 2016.

STUDENT SUPPORT

This grant provided research funding for one UAF Water and Environmental Research Center MSc student (Michael Winfree).

Did ongoing peat accumulation buffer permafrost carbon from Holocene climate fluctuations?

Did ongoing peat accumulation buffer permafrost carbon from Holocene climate fluctuations?

Basic Information

Title:	Did ongoing peat accumulation buffer permafrost carbon from Holocene climate fluctuations?
Project Number:	2015AK126B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Geomorphological Processes, Sediments
Descriptors:	None
Principal Investigators:	Daniel H Mann

Publications

1. Gaglioti, B.V., Mann, D.H., Jones, B.M., Pohlman, J.W., Kunz, M.L. and Wooller, M.J., 2014. Radiocarbon age-offsets in an arctic lake reveal the long-term response of permafrost carbon to climate change. *Journal of Geophysical Research: Biogeosciences*, 119(8), pp.1630-1651.
2. Gaglioti, B.V., 2016. Landscape sensitivity to climate change in northern Alaska: Lessons from the past (Doctoral dissertation, University of Alaska Fairbanks).
3. Gaglioti, B.V., Mann, D.H., Wooller, M.J., Jones, B.M., Wiles, G.C., Groves, P., Kunz, M.L., Baughman, C.A., Reanier, R.E., accepted. Oxygen isotopes from modern and ancient willows record post-glacial climate changes and exceptional rates of recent warming in Arctic Alaska. *Quaternary Science Reviews*.

Title: Did ongoing peat accumulation buffer permafrost carbon from Holocene climate fluctuations?

Principal Investigators: Dr. Daniel H. Mann & Dr. Benjamin V. Gaglioti

6/9/16

Research Summary:

Documenting how permafrost has responded to past climate change can greatly improve our understanding of how permafrost and the hydrological regime that depends on it will respond to warming climate in the future. In this project, we built on past NIWR-funded research to assess the sensitivity of permafrost carbon release through thaw to changes in past temperature and precipitation in arctic Alaska.

Our previous work reconstructed past changes in temperature, precipitation, and sea ice in arctic Alaska during the intervals of 14,000 to 7000 years ago (14-7 ka) and from 1 ka to present by using the stable oxygen isotope ratios in ancient willow wood as a paleoclimate proxy (Gaglioti et al., Accepted). We then used a lake sediment record that stratigraphically archives the thaw-driven release of sediment and ancient carbon (radiocarbon age-offsets) that was eroded from soils and permafrost in a representative watershed in the Arctic Foothills of the Brooks Range (Gaglioti et al., 2014). Comparing the paleoclimate and paleo-permafrost thaw records, we can test how sensitive the region's permafrost has been to past warming events and post-industrial warming trends.

Our previous results showed that permafrost carbon release was very sensitive to deglacial warming events, but not to recent warming, which suggests that over the last 8 ka the underlying permafrost has been buffered from warming air temperatures by the buildup of insulating peat deposits (Gaglioti, 2016). In this project we tested this hypothesis by first reconstructing past climate change over the last 8 ka by analyzing additional, radiocarbon-dated willow isotope samples, and then analyzing additional radiocarbon age-offsets to test if permafrost carbon release became insensitive to climate change after significant peat had built-up.

Results:

Paleoclimate

- We sampled and radiocarbon-dated ancient willow wood from a number of lake and river bluff sections to extend the paleoclimate record up to the present.
- Modern willow isotopes in individual growth rings are sensitive to average temperatures from the autumn prior to their growing season, and the extent of sea ice in the Chukchi, Beaufort, and Northern Bering Seas. More extensive sea ice in these nearby seas excludes proximal and enriched evaporative sources for North Slope precipitation, which fuels willow growth.
- In total, 346 willow cellulose samples from a 40-ka time series of radiocarbon-dated willow wood from a lake sediment record in the Arctic Foothills region suggest that rapid and far-ranging climate changes occurred since the end of the last ice age
- Before 16 ka, willow isotopes indicate that the climate was cold, more continental, and had perennial sea ice in the nearby seas.
- The climate of Arctic Alaska was sensitive to a weakening of the ocean conveyor during the Younger Dryas cold period, insolation and greenhouse gas-driven warming between 14 and 13 ka, and again between 11.5 and 8 ka, and gradual insolation-driven cooling over the last 7 ka.
- Post-glacial warming events were amplified by changes in regional sea ice extent, and tempered by a more maritime climate arriving to the region after post-glacial sea level rise flooded the Bering Land Bridge.
- The rate of warming that has occurred since industrial times exceeds the rate of change during past warming events over the last 15 ka.
- Despite the rate of inferred warming in recent times being exceptional, isotope values in modern willows growing in arctic Alaska are similar to those of the early Holocene, a time of widespread permafrost thaw and striking ecological changes.
- These results provide a summary of paleoclimate change for the region, and put the recent warming trends into a long-term context.
- This work is summarized in Gaglioti et al. (*accepted*).

Paleo-permafrost

- We collected 10 lake sediment cores to bring the paleo-permafrost record up to the present.
- Five additional radiocarbon age-offsets were analyzed from sediment representing the last 5 ka.

- Age-offsets in these samples were greatly affected by substantial lake level lowering at our study site that occurred when the migrating Etivluk River partially drained the lake ca. 5 ka (Mann et al., 2002; Gaglioti et al., 2014).
- Age-offsets indicate that lake level lowering caused within-basin sediment to be reworked to our core site, which continued for several thousands years and has the age-offsets there for the period between 5 and 1 ka.
- These results indicate that age-offsets since 5 ka cannot be interpreted as a paleo-permafrost record that is representative of the broader region. Instead these post-5 ka age offsets likely represent a stochastic, geomorphic event, and not the response of permafrost carbon release from the watershed.
- Because of this, we were unable to test the peat-buffering hypothesis, but are now pursuing this line of questioning at other lake sites that have had stable water levels since 15 ka.

References:

Gaglioti, B.V., Mann, D.H., Jones, B.M., Pohlman, J.W., Kunz, M.L. and Wooller, M.J., 2014. Radiocarbon age-offsets in an arctic lake reveal the long-term response of permafrost carbon to climate change. *Journal of Geophysical Research: Biogeosciences*, 119(8), pp.1630-1651.

Gaglioti, B.V., 2016. *Landscape sensitivity to climate change in northern Alaska: Lessons from the past* (Doctoral dissertation, University of Alaska Fairbanks).

Gaglioti, B.V., Mann, D.H., Wooller, M.J., Jones, B.M., Wiles, G.C., Groves, P., Kunz, M.L., Baughman, C.A., Reanier, R.E., *accepted*. Oxygen isotopes from modern and ancient willows record post-glacial climate changes and exceptional rates of recent warming in Arctic Alaska. *Quaternary Science Reviews*.

Mann, D.H., Peteet, D.M., Reanier, R.E. and Kunz, M.L., 2002. Responses of an arctic landscape to Lateglacial and early Holocene climatic changes: the importance of moisture. *Quaternary Science Reviews*, 21(8), pp.997-1021.

Publications and Presentations Resulting from this Project:

Gaglioti, BV, 2015 Sensitivity of permafrost carbon to past climate change. Invited Talk at the AGU Fall Meeting, December 14-18 2015.

Gaglioti, B.V., Mann, D.H., Jones, B.M., Pohlman, J.W., Kunz, M.L. and Wooller, M.J., 2014. Radiocarbon age-offsets in an arctic lake reveal the long-term response of permafrost carbon to climate change. *Journal of Geophysical Research: Biogeosciences*, 119(8), pp.1630-1651.

Gaglioti, B.V., 2016. *Landscape sensitivity to climate change in northern Alaska: Lessons from the past* (Doctoral dissertation, University of Alaska Fairbanks).

Gaglioti, B.V., Mann, D.H., Wooller, M.J., Jones, B.M., Wiles, G.C., Groves, P., Kunz, M.L., Baughman, C.A., Reanier, R.E., *accepted*. Oxygen isotopes from modern and ancient willows record post-glacial climate changes and exceptional rates of recent warming in Arctic Alaska. *Quaternary Science Reviews*.

Student Support:

This funding supported Benjamin Gaglioti's PhD research, which he defended in April 2016. He is now completed with his degree program.

Hydrograph partitioning of a glacierized watershed, Interior Alaska – YEAR 2

Basic Information

Title:	Hydrograph partitioning of a glacierized watershed, Interior Alaska – YEAR 2
Project Number:	2015AK127B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	ak-1
Research Category:	Ground-water Flow and Transport
Focus Category:	Hydrology, Hydrogeochemistry, Floods
Descriptors:	None
Principal Investigators:	Anna Liljedahl, Tom Trainor

Publications

1. Gatesman, T.A., Gatesman, T.A., Douglas, T., Liljedahl, A., Trainor, T., Gaedeke, A, Orr, A. (2016). Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska & Jarvis Creek Watershed Project. Poster presentation at the Delta Farm Forum. 20 February 2016. Delta Junction, AK.
2. Gatesman, T.A., Douglas, T., Liljedahl, A., Trainor, T., Gaedeke, A. (2015). Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska. Poster presentation at American Geophysical Union Annual Fall Meeting. 15 December 2015, San Francisco, CA.

TITLE

Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska: A geochemical analysis

RESEARCH SUMMARY

Objectives

Our study aim to quantify the contribution of glacier melt, snow melt, groundwater and rainfall to lowland streamflow and to assess hydrologic pathways of glacier wastage within of a glaciated Interior Alaska watershed (Jarvis Creek, 636 km²). The specific objective include:

- 1) *Assess the hydrologic pathways of glacier wastage within a watershed underlain by discontinuous permafrost.*
- 2) *Quantify the contribution of glacier melt, snow melt and rainfall to stream runoff.*

Methods/materials

Geochemical data has been collected and analyzed for the thaw seasons of 2011-2015. Field work in 2015 consisted of geochemical water sampling of precipitation, groundwater and streamflow, end-of-winter snow accumulation survey, glacier mass balance measurements, meteorological station maintenance, discharge measurements, stream and groundwater water levels. Stage-discharge relationships were produced at two locations in Jarvis Creek for 2015.

Laboratory analyses for all water samples include oxygen and deuterium stable isotopes as well as major ions and were made by the graduate student Tiffany Gatesman at the Cold Regions Research and Engineering Laboratory, Fairbanks, under the supervision of Thomas Douglas. Water samples include end-of-winter snow cores, rain, lowland streamflow, glacier surface meltwater, glacier terminus runoff, groundwater, and winter streamflow. Water samples were analyzed for stable water isotope values (δD and $\delta^{18}O$) and major ion concentrations (Ca^{2+} , Mg^{2+} , Na^+ , K^+ , NH_4^+ , Cl^- , F^- , SO_4^{2-} , PO_4^{2-} , NO_3^-). Quantification of glacier melt, snow melt and rainfall contribution to bulk stream runoff will be determined via geochemical hydrograph separation. For the purpose of this research, glacier melt will be defined as a mixture of surface ice melt, subglacial flow, snow melt and liquid precipitation. Methods will be adapted from a Matlab script published by Arendt et al. (2015). This model is integrated with multi-component statistical hydrograph separation and can account for uncertainties and assumptions in data (Arendt et al., 2015, Cable et al., 2011). After end-member analysis of the 5 years of geochemical data, hydrograph separation modeling will begin during the 2016 summer season

Result/discussion

The bulk watershed, groundwater and glacier terminus waters fall between rain and snow, suggesting a mixing of both rain and snow contribution (Figure 1). The end-member values of groundwater, glacier terminus and Jarvis Creek streamflow are not statistically unique. Therefore, dissolved ion content, specifically sulfate, will be used to differentiate the glacier and groundwater contributions to lowland streamflow. In general, $\delta^{18}O$ values decrease during spring as snowmelt is a dominating source to streamflow (Figure 2). Over the course of the summer, due to rain events, $\delta^{18}O$ values increase (towards rain water values). Values settle back into groundwater type values during dry periods. These variations are different year to year, which indicates dramatic inter-annual variability in the role of each individual contributing source, such as the role of snowmelt, glacier melt and rainfall in producing lowland streamflow. For example, 2011, 2014 and 2015 did

not show as strong of a snow melt signal as 2012 and 2013. Measured average snow water equivalent (SWE) for the watershed was 52-81 mm for 2011, 2014 and 2015 whereas SWE for 2012 and 2013 was much larger (121-123 mm, Figure 3). From our meteorological observations, 2011 and 2012 had low rain whereas 2014 was one of the wettest years of record and 2015 has more precipitation in later season than other years. The 2011 and 2012 summer show seasonal variation below the groundwater signature suggesting that there is little influence from rain and more influence from snow and glacier. 2014 and 2015 were high rainfall and the seasonal variation is above the groundwater signature suggesting a larger rain contribution. Hydrograph separation modeling for this research will allow a quantification of respective source and will be constrained with unique stable water isotope and dissolved ion end-member values.

INFORMATION TRANSFER PROGRAM

Outreach activities include the maintenance of a project website with near-real time data access from the meteorological stations and stream water levels (<http://ine.uaf.edu/werc/projects/jarvis/>), presentation at the Delta Farm Forum, Delta Junction, where Tiffany and undergraduate research assistant Aaron Orr presented a poster and showed several sensors that we use in our fieldwork. Outreach activities also included a larger half-day project workshop in fall 2015 at the UAF campus with about 15 participants including US Army, Salcha-Delta Soil and Water Conservation District, Cold Regions Research and Engineering Laboratory, University of Maine and North Carolina State University.

PUBLICATIONS/PRESENTATIONS

- Gaedeke, A., Liljedahl A.K., Gatesman T., Campbell S., Hock R., O'Neel S. (2015). Long-term linkages between glaciers, permafrost and hydrology at two glacierized watersheds in Alaska. Oral presentation at American Geophysical Union Annual Fall Meeting. 15 December 2015, San Francisco, CA.
- Gaedeke, A., Liljedahl A.K., Gatesman T., Hock R (2015). What role do glaciers play in subarctic hydrology? Arctic Observing Open Science Meeting, 17-19 November 2015, Seattle, WA.
- Gatesman, T.A., Douglas, T., Liljedahl, A., Trainor, T., Gaedeke, A. (2016). Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska. Oral presentation at American Water Resource Association National Spring Specialty Conference. 27 April 2016, Anchorage, AK.
- Gatesman, T.A., Douglas, T., Liljedahl, A., Trainor, T., Gaedeke, A. (2016). Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska. Oral presentation at UAF Environmental Chemistry Symposium. 22 April 2016, Fairbanks, AK.
- Gatesman, T.A., Gatesman, T.A., Douglas, T., Liljedahl, A., Trainor, T., Gaedeke, A, Orr, A.. (2016). Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska & Jarvis Creek Watershed Project. Poster presentation at the Delta Farm Forum. 20 February 2016. Delta Junction, AK.
- Gatesman, T.A., Douglas, T., Liljedahl, A., Trainor, T., Gaedeke, A. (2015). Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska. Poster presentation at American Geophysical Union Annual Fall Meeting. 15 December 2015, San Francisco, CA.

- Gatesman, T.A., Douglas, T., Liljedahl, A., Trainor, T., Gaedeke, A. (2015). Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska. Oral presentation at the American Water Resource Association Annual Water Resource Conference. 17 November 2015, Denver, CO.
- Gatesman, T.A., Douglas, T., Liljedahl, A., Trainor, T., Gaedeke, A. (2015). Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska. Oral presentation at the Water and Environmental Research Center Symposium. 16 October 2015, Fairbanks, AK
- Gatesman, T.A., Liljedahl, A.K., Douglas, T.A., Trainor, T.P. (2014). Hydrograph separation of a sub-arctic glacial watershed using stable water isotope variation. Oral presentation at the Northwest Glaciologists' Meeting. 17 October 2014, Fairbanks, AK.

STUDENT SUPPORT

One M.Sc. student, Tiffany Gatesman, was supported directly on this award.

NOTABLE ACHIEVEMENTS/AWARDS

- National AWRA. Outstanding Student Oral Presentation. American Water Resource Association National Spring Specialty Conference. 27 April 2016, Anchorage, AK.
- UAF Environmental Chemistry Symposium. Outstanding Graduate Presentation. Fairbanks, AK. April 22, 2016.
- AWRA Alaska Chapter. Student Travel Award to attend and present at AWRA National Spring Specialty Conference, Anchorage, AK. April 25-27, 2016.
- EPSCoR Travel Award: Travel to AWRA Spring Specialty Conference to present Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska, oral presentation. Anchorage, AK. April 25-27, 2016.
- CNSM Student Travel Grant: Travel to AWRA Annual Water Resource Conference to present Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska, oral presentation. Denver, CO. November 16-19 2015.
- AWRA Alaska Chapter. Outstanding Poster Presentation of the American Water Resources Association Alaska Chapter Spring Conference and Workshop. Fairbanks, AK. 13 May 2015.

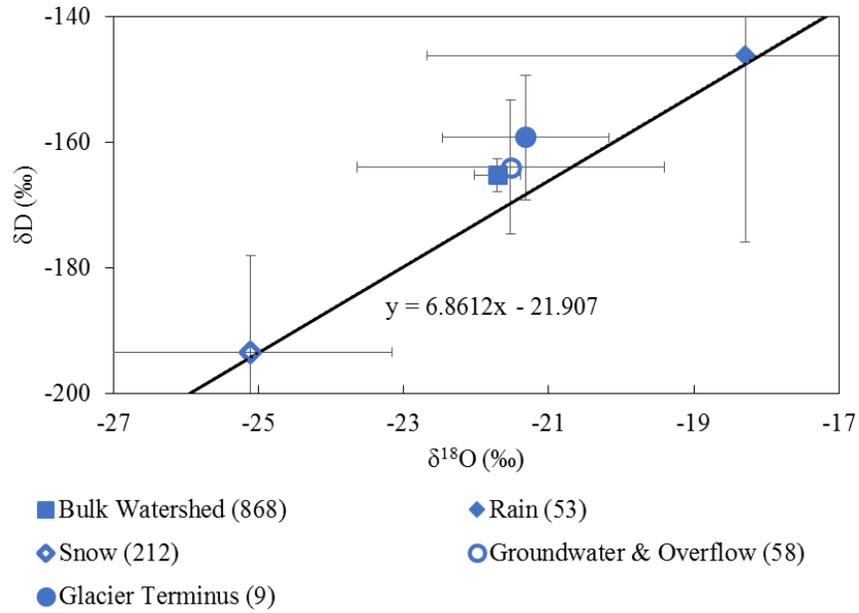


Figure 1. Compilation of average stable isotope values and standard deviations from 2011 through 2015. The black line is the local meteoric water line. Values on the upper end of this line are indicative of warm precipitation, i.e. this is where we find our average value of rain. Values at the lower section are indicative of colder precipitation, i.e. snow. Lowland streamflow, groundwater and glacier terminus waters fall between rain and snow, suggesting a mixing of rain and snow contribution.

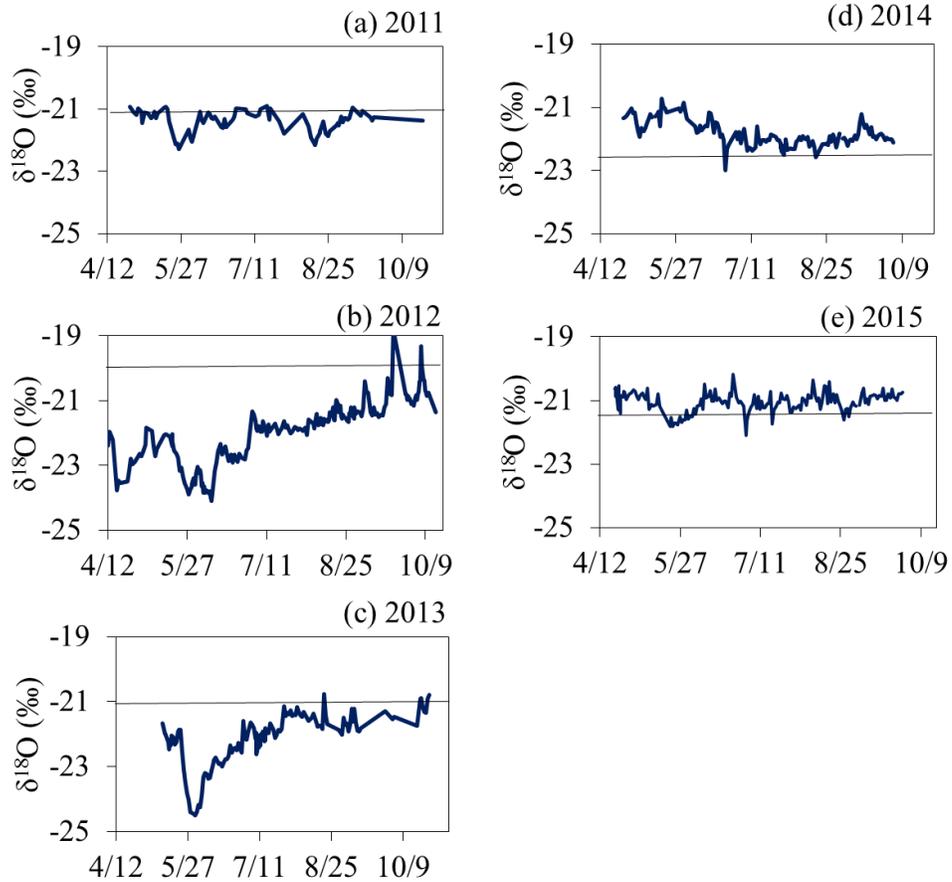


Figure 2. Seasonal variation of the $\delta^{18}\text{O}$ isotope values of Jarvis Creek streamflow 2011-2014. Black line on graphs symbolized the average groundwater value for each respected year.

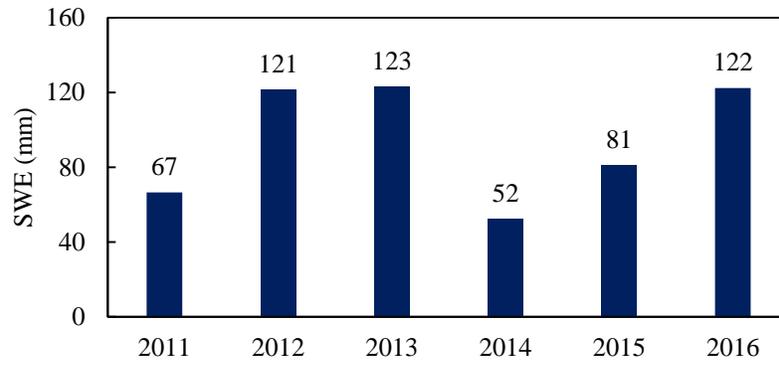


Figure 3. Average end of winter snow accumulation represented as snow water equivalent (SWE), 2011-2016.

Creating a 10,000-year record of lake level fluctuations at Quartz Lake, Interior Alaska

Basic Information

Title:	Creating a 10,000-year record of lake level fluctuations at Quartz Lake, Interior Alaska
Project Number:	2015AK128B
Start Date:	3/1/2015
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Category:	Geomorphological Processes, Sediments, Ecology
Descriptors:	None
Principal Investigators:	Matthew John Wooller

Publication

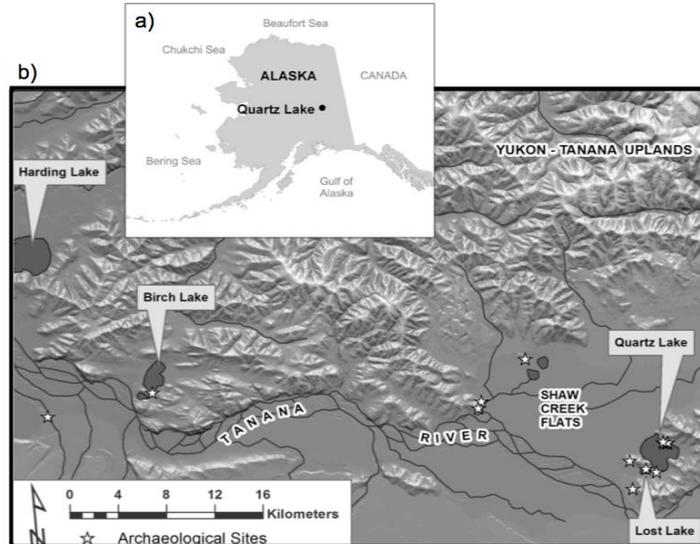
1. Fields, Stormy and Wooller, Matthew (2015). A ~14,000 year record of ecological change at and interior lake, Alaska (Poster). URSA Research Day, UAF.

Title: Creating a 10,000-year record of lake level fluctuations in Interior Alaska.

Research summary:

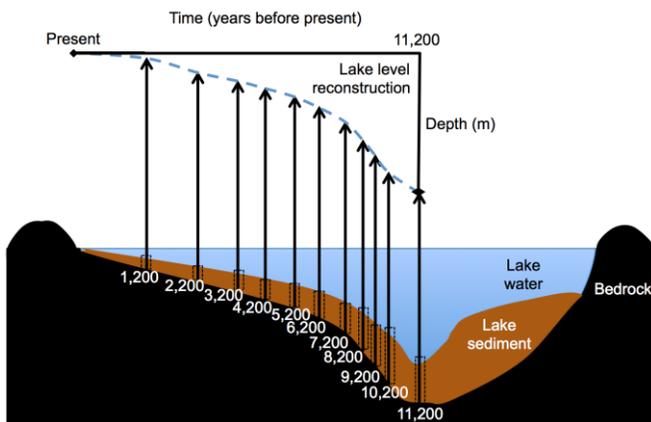
Objectives: The objectives of this project relate to developing a record of lake level change from a lake in interior Alaska to examine how lake levels have changed in response to long-term environmental changes. Lakes in interior Alaska, such as Quartz Lake and its neighboring Lost Lake, (Figure 1) are focal points for recreational use including sport fishing. Many of these lakes have been on the landscape for thousands of years and were also used by ancient people that populated interior Alaska thousands of years ago. However, many of these lakes are currently experiencing changes in

Figure 1: Location of Lost Lake in interior Alaska (a) and its location relative to other lakes in the region (b).



lake level and chemistry associated with hydrological changes. Efforts to successfully assess how future climate change will affect levels of lakes in interior Alaska are faced with a major challenge, which is that there are limited long-term records of how lake levels have changed in the past and how these changes have responded to environmental changes. Fortunately there are sediments in lakes, like Quartz Lake and Lost Lake that have been laid down over thousands of years since the lakes first appeared on the landscape. A core down through these sediments provides a time-line of a lake's history. Evidence of how the lakes changed over this time-line is preserved in the layers of mud. When multiple cores are

Figure 2: A conceptual figure showing a basic lake level reconstruction using basal ages of sediment cores taken from a hypothetical lake (Wooller unpublished diagram).



taken from sites on a transect across a lake, going from the deepest part of a lake to the shallow edge of a lake, they can be dated and lined up to show how a lake filled over time and also show when lake levels decreased (Figure 2). This is an approach that has been successfully used to construct coarse temporal resolution records of lake level fluctuations in some lakes in interior Alaska (e.g., Harding Lake and Birch Lake). However, the logistics associated with coring these relatively deep lakes has meant that the lake level reconstructions are relatively coarse in terms of their temporal resolution.

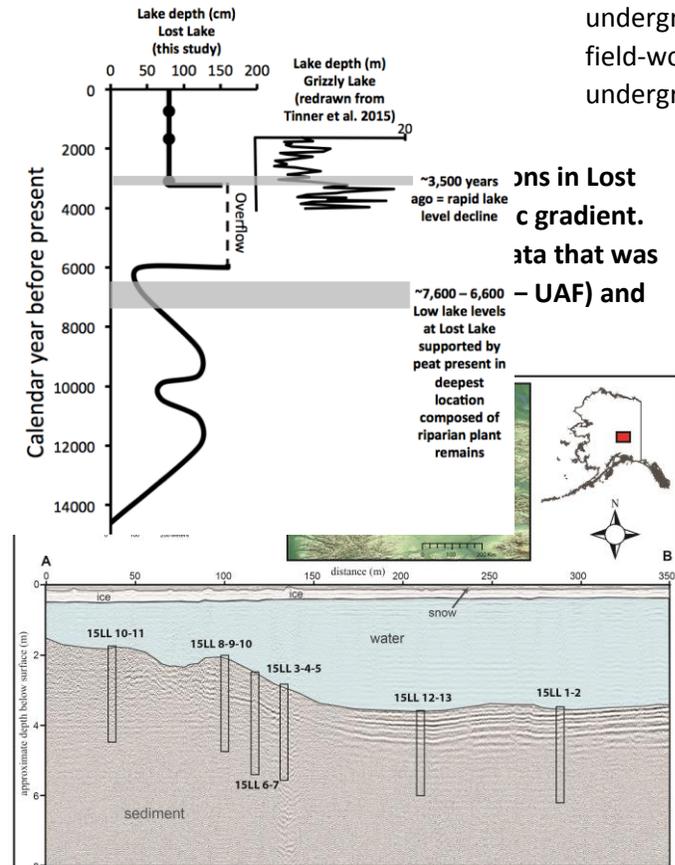
Methods/materials: For several reasons Lost Lake in interior Alaska (Figure 1) was

logistically a very attractive study site, compared with some other lakes in interior Alaska. Firstly, Lost Lake is on the road system and is very easily accessed by our team from the University of Alaska Fairbanks (UAF). Secondly, our team from UAF optimized the timing of field work at this relatively local site to coincide with ideal field conditions, including weather, day length and the lake ice being in place to be able to use it as a coring platform to work from. Thirdly, we had previously taken and dated a core from Lost Lake, which showed, by dating the base of the core, that the lake had initiated $\geq \sim 10,000$ years ago. In the spring of 2015 we took multiple cores from sites across a transect from Lost Lake (Figure 3), to date, compare and then construct a detailed picture of how the past lake levels have changed at the site over 10,000 years (Figures 4 and 5). This lake level reconstruction can be used to compare with our previously generated data that has illustrated how the chemistry, ecology and climate has changed at Lost Lake and other lakes over the last $\sim 10,000$ years.

Figure 3: Sediment coring at Lost lake conducted from the lake ice (2015), which was used as a platform to work from and allowed easy access to the coring location (Maio photo credit).



Figure 5: Composite Lake level reconstruction from Lost Lake compared with lake level record from Grizzly lake, Alaska (Tinner et al 2015).



Results/discussion: Based on radiocarbon dates (~20) from the multiple cores taken from Lost Lake (Figure 4) we produced a detailed lake level history covering the last ~10,000 years at Lost Lake in interior Alaska (Figure 5). This project supported the research of an undergraduate research student at UAF and provided field-work training for an additional group of undergraduate and graduate students from UAF. A

section of sediment from the core taken from the deepest location in Lost Lake showed the presence of peat bracketed by organic lake sediments, which provided a independent evidence that lake levels likely dropped considerably between ~7,600 and 6,600 years ago (Figure 5), to allow peat formation at the deepest location in the modern lake. Identification of the plant sub-fossils present in this peaty section revealed the presence of emergent riparian plants (rather than floating aquatic plants) layered horizontally. Both of these features support the scenario that lake levels decreased substantially between ~7,600 and 6,600 years before present (Figure 5). Another notable decrease in lake levels at Lost Lake also seems to correlate with a substantial decrease in

lake levels at another lake in Alaska (Grizzly Lake) at ~3,500 years ago presented by Tinner et al. (2015) (Figure 5). This transition also correlates with the time when Quartz Lake transitioned from a relatively open lake to a more closed lake system that was responsive to evaporative losses (Wooller et al., 2012).

Information transfer program: A poster was generated by the undergraduate student that was supported by this project. The poster was presented at the UAF research day for undergraduates.

Publications/Presentations: Fields Stormy., Wooller Matthew et al., (2015).A ~14,000 year record of ecological change at and interior lake, Alaska. URSA Research Day, UAF

Student support: One undergraduate student (Fields) was directly supported by funds from this project. Seven other undergraduate students and three graduate students (MS) were supported during their involvement in field work associated with this project. They received training in field techniques including lake coring and ground penetrating radar.

Notable Achievements/Awards: The undergraduate supported by this project was able to secure a Center for Global Change student award at UAF (2016) to extend her research on lake level changes at Lost Lake. These are very competitive awards. A following NIWR (2016) award was acquired by Wooller

to extend the research on lake level changes at Lost Lake to other lakes in interior Alaska, including Blair Lake and Quartz Lake. The long-term goal is to grow a network of lake level reconstructions covering the last ~10,000 years in Alaska.

Additional references cited in this report:

Wooller, M.J., J. Kurek, B. Gaglioti, L. Cwynar, N. Bigelow, J. Reuther, C. Gelvin-Reymiller, J. Smol. (2012). An ~11,200 year paleolimnological perspective for emerging archaeological findings at Quartz Lake, Alaska. *Journal of Paleolimnology*. 48: 83-99.

Tinner et al., (2015). Late-Holocene climate variability and ecosystem responses in Alaska inferred from high-resolution multiproxy sediment analyses at Grizzly Lake. *Quaternary Science Reviews*. 126: 41-56.

Information Transfer Program Introduction

The WERC Human Dimension (HD) lab director and Institute web developer collaborated to interview NIWR funded researchers and graduate students, soliciting photographs and research related stories to generate a concise and easily understandable description of each funded research project. They used these resources to create a visually appealing and easily accessible website compendium of ongoing Alaskan NIWR research. The NIWR website is linked directly on the Water and Environmental Research Center's front page and will continue to grow; adding researchers and content as new projects are funded and current projects publish their results. The WERC NIWR website can be found at: <http://ine.uaf.edu/werc/niwr/>. Additionally, NIWR was incorporated into the newly redesigned and re-written WERC brochure. This brochure is one of the primary pieces of physical media to communicate the mission, ongoing research and resources available at WERC. The brochure is used extensively at national science conferences, regional meetings, communicating to State legislature, and at community outreach events. One such outreach event dovetailed with an ongoing School of Education project. The HD lab director traveled to several rural Alaskan villages and conducted Institute related hands-on place-based STEM activities and talked to teachers and students about ongoing NIWR funded research projects. Students and teachers were engaged and interested in the NIWR related water and climate research activities.

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	9	0	0	0	9
Masters	7	0	0	0	7
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	17	0	0	0	17

Notable Awards and Achievements

National AWRA. Outstanding Student Oral Presentation. American Water Resource Association National Spring Specialty Conference. 27 April 2016, Anchorage, AK.

UAF Environmental Chemistry Symposium. Outstanding Graduate Presentation. Fairbanks, AK. April 22, 2016.

AWRA Alaska Chapter. Student Travel Award to attend and present at AWRA National Spring Specialty Conference, Anchorage, AK. April 25-27, 2016.

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