Water and Environmental Research Center
Annual Technical Report
FY 2014

Introduction

The University of Alaska Fairbanks Water & Environmental Research Center (WERC) conducts basic and applied research related to water and environmental resources in Arctic and Subarctic regions.

As the water resources research branch of America's Arctic University, WERC is one of our nation's foremost centers of expertise in field based cold regions water research.

WERC research aims to help improve the quality of life for Arctic inhabitants while supporting careful and sustainable development of Alaska's bountiful natural resources, protecting fragile ecosystems, and seeking to better understand the role of the Arctic and Subarctic in the global system.

Research Program Introduction

The UAF Water and Environmental Research Center is a diverse, vibrant, and relevant research center focused on providing water resource solutions for the State of Alaska. WERC is housed in the UAF Institute of Northern Engineering, yet seeks to understand water resources in a fashion that is not limited by traditional disciplinary boundaries. Thus, 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. The FY2014 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 were broad, and included studies related to coastal erosion modeling, linkages between lake trout growth and climate on the Arctic Coastal Plain, the relative contributions of meltwater from snow and glacier sources in a glaciated subarctic watershed, improved measurement of snow inputs to glacier mass balance, and the potential use of gel-immobilized nanoparticles for treatment of water in rural Alaska communities.

Gone fishin': Reconstructing temperature and productivity in Arctic lake ecosystems using lake trout (proposal to USGS NIWR)

Basic Information

Title:	Gone fishin': Reconstructing temperature and productivity in Arctic lake ecosystems using lake trout (proposal to USGS NIWR)
Project Number:	2014AK120B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	AK
Research Category:	Not Applicable
Focus Category:	Climatological Processes, Ecology, Water Quantity
Descriptors:	None
Principal Investigators:	Christopher Douglas Arp

Publication

1. Torvinen, E.S., J.J. Falke, C.D. Arp, C.E. Zimmerman, T.M. Sutton, B.M. Jones, 2015. Lake trout (Salvelinus namaycush) otoliths as biochronological indicators of recent climate patterns in high Arctic lakes. Oral Presentation at American Fisheries Society Student Symposium. 3 April, Fairbanks, AK.

2014 Report
Gone Fishin': Lake trout (*Salvelinus namaycush*) otoliths as biochronological indicators of recent climate patterns in high Arctic lakes.

Objectives 1.) *Develop Lake Trout otolith growth-increment chronologies to be used as a tool for recent historic lake temperature reconstruction*.

During the 2014 field season a pilot study was conducted to establish where in the Fish Creek Watershed Lake Trout are present. This effort also focused on methods and timelines that would likely result in a feasible sample size. 13 adult Lake Trout where ultimately sacrificed for the purpose of this pilot study. Otoliths were processed and aged. These data and methods (described below) have been used to write a detailed study plan for the 2015 field season. These as well as the 2015 otoliths will be used to construct a growth-increment chronology that can be used as a tool to reconstruct past temperature histories. Sagittal otoliths will be removed from sacrificed individuals using the Guillotine method as described in Secor et al. (1992). Otoliths will then be rinsed with water, dried, and stored in an envelope. One otolith will be embedded in EpoThin Buehler epoxy with the sulcal groove point up and allowed to dry for 24 hours. The otolith will then be sectioned through the center using an Isomet low-speed wafering saw. It will then be attached to a microscope slide and polished using a 2000 grit wet-dry sandpaper. Final polishing will be done using 4000 grit wet-dry sandpaper. Digital images of each otolith will be taken at a magnification of 4x using a Leica camera attached to a dissection microscope (Black et al. 2012). Once photographed, cross-dating techniques described in Black et al. 2005 will be used to validate that the correct calendar year has been assigned to the correct annuli (Black et al. 2005). The Dendrochronolgy program COFECHA will be used to statistically verify crossdating and growth-increment measurements. Once crossdated, annuli widths will be measured from the margin to as close to the center as possible. Annuli will be measured from the outer edge of the dark ring to the outer edge of the next dark ring. After growth chronologies are completed a measurement time series will be constructed. An age-related growth decline is observed in all biochronology data (Cook 1985). To correct for this the measured time series will be fitted with a negative exponential function. This detrended time series will be constructed for all individuals before being averaged to produce a master growth chronology (Cook 1985). This final chronology will be compared to climate data including mean annual and mean monthly temperature as well as precipitation and lake ice phenology collected by a weather station at Inigok, AK. Comparisons will also be made using climate data from the CALON lake monitoring project (Hinkle 2013, *unpublished data*).

Objective 2.) *Describe the relationship between climate and Lake Trout growth across a diverse set of lake types located on the Arctic Coastal Plain, Alaska*.

Using the physical characteristics of the lakes where Lake Trout were detected during the 2014 field effort, a number of lakes in the Fish Creek Watershed were chosen to be sampled in 2015. This was done using lake descriptions provided by Benjamin Jones (USGS). These characteristics along with productivity data from the Fish Café project should ensure that Lake Trout will be captured from a diverse set of lake types. Once otoliths from these fish are analyzed data collected from these lakes as well as larger scale climate data will be compared to these growth chronologies. This will help us gain knowledge as to how Lake Trout respond to different conditions and how climate change may be affecting them.

Presentations:

Torvinen, E.S., J.J. Falke, C.D. Arp, C.E. Zimmerman, T.M. Sutton, B.M. Jones, 2015. Lake trout (*Salvelinus namaycush*) otoliths as biochronological indicators of recent climate patterns in high Arctic lakes. Oral Presentation at American Fisheries Society Student Symposium. 3 April, Fairbanks, AK.

Hydrograph partitioning of a glacierized watershed, Interior Alaska

Basic Information

Title:	Hydrograph partitioning of a glacierized watershed, Interior Alaska
Project Number:	2014AK121B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Hydrogeochemistry, Floods
Descriptors:	None
Principal Investigators:	Anna Liljedahl, Tom Trainor

Publications

1. Gatesman, T.A., Liljedahl, A.K., Douglas, T.A., Trainor, T.P. (2015). Hydrograph separation of a sub-arctic glacial watershed using stable water isotope variation. Poster presentation at the Alaska State AWRA Annual Conference and Workshop. 13 May 2015, Fairbanks, AK.
2. Gatesman, T.A., Liljedahl, A.K., Douglas, T.A., Trainor, T.P. (2015). Hydrograph separation of a sub-arctic glacial watershed using stable water isotope variation. Oral presentation at the Midnight Sun Science Symposium. 26 March 2015, Fairbanks, AK.
3. Gatesman, T.A., Jacobs, N., Debolskiy, M., Bailey, J., Barnard, C., Douglas, T.A., Gusmeroli, A., Hock, R., Liljedahl, A.K., Wagner, A., (2015). What role do glaciers play in terrestrial subarctic hydrology? Poster presentation at the Delta Farm Forum. 21 February 2015. Delta Junction, AK.
4. Gatesman, T.A., Liljedahl, A.K., Douglas, T.A., Trainor, T.P. (2015). Hydrograph separation of a sub-arctic glacial watershed using stable water isotope variation. Oral presentation at the Department of Chemistry and Biochemistry, UAF Seminar. 17 February 2015, Fairbanks, AK.
5. Gatesman, T.A., Liljedahl, A.K., Douglas, T.A., Trainor, T.P. (2015). Hydrograph separation of a sub-arctic glacial watershed using stable water isotope variation. Oral presentation at the Water and Environmental Research Center Symposium. 6 February 2015, Fairbanks, AK.

2015 Annual Report:
Hydrograph separation of a sub-arctic glacial watershed, Interior Alaska:
A geochemical analysis

Objective 1) *Assess the hydrologic pathways of glacier wastage within a watershed underlain by discontinuous permafrost.*
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 an Interior Alaska watershed (Jarvis Creek watershed, 634 km^2). Water samples for geochemical analysis include end-of-winter snow pack cores, rain, surface water, glacier surface water melt, glacier terminus runoff, winter baseflow and groundwater since 2011. All water samples have been analyzed for stable water isotopes ($\delta^{18}O$ and δD) and major ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, $NH4^+$, Cl^-, F^-, SO_4^{2-}, PO_4^{2-}, NO_3^-). Streamflow water samples were taken from three different locations along Jarvis Creek and two of its tributaries, McCumber Creek and Riley Creek. Synoptic snow samples were collected from the Jarvis glacier and an additional >20 locations within watershed. A majority of the 2014 and 2015 effort by the MSc student (Gatesman) have been invested into field data collection and laboratory analyses and, in particular, learning how to operate several advanced instruments including Dionex ICS-3000 ion chromatograph with an AS-19 anion column and CS-12 cation column (Dionex Corporation Sunnyvale, California), Wavelength-Scanned Cavity Ringdown Spectroscopy on a Picarro L2120i (Sunnyvale, California) and Asymmetric Flow Field-Flow Fractionation, FFF, (Postnova Anlytics) and Acoustic Doppler Current Profiler (Teledyne RD Instruments, Poway, California). Geochemical results show distinct chemical signatures of contributing sources (Figure 1) and significant seasonal $\delta^{18}O$ variability in Jarvis Creek runoff (Figure 2). Seasonal daily variations from 2011-2014 show spring snowmelt, major rain events and groundwater contribution with respect to the source chemical signatures. Stable isotopic variations show a decrease in values during spring snow melt and an increase during rain events. There is general decrease in $\delta^{18}O$ and δD toward a groundwater signature during low rainfall periods. Patterns in $\delta^{18}O$ variations coincide with daily stream discharge patterns for each year (Figure 3). The geochemical time series in 2014 presented somewhat different values that the previous years. For example, the lack of the typical snowmelt signal in early summer 2014 may be explained by the unusual snowmelt in late January that produced significant runoff. A large portion of the 2014 summer, especially mid- and late summer, presented $\delta^{18}O$ values that were closer to the "snow/ice" signature. Also, runoff during the same time period show an elevated baseflow (compared to early summer). Together they indicate the importance of glacier melt. Note that identical measurements have also been made each summer since 2011 and Gatesman will be including all 2011-2015 data into her MSc thesis. Stable isotope and dissolved ion chemical signatures will inform our end-member volumetric mixing models and allow us to quantify the contributing sources to streamflow while gaining fundamental knowledge about the regional hydrologic system.

Objective 2) *Quantify the contribution of glacier melt, snow melt and rainfall to stream runoff.*
An end-member mixing model forced with measured stable water isotopes will be used for hydrograph separation in order to quantify the contribution of glacier melt, snow melt, groundwater and rainfall to overall streamflow. Major ion results will also support the modeling.

Gatesman has performed a literature review in the subject of end-member modeling of glaciated watersheds and has decided to first test the model presented by Taylor et al. (2002):

$$\delta^{18}O_{str} = x\delta^{18}O_{New} + (1 - \mathrm{x})\delta^{18}O_{Old} \qquad (1)$$

where $\delta^{18}O_{str}$ is stream water, $\delta^{18}O_{New}$ is rain or snowmelt, $\delta^{18}O_{Old}$ is pre-event water (ground water, soil water, pore water - can be measured by low flow (base flow)) and x is fraction of glacial input at given instant in time during event. Therefore,

$$x = \frac{\delta^{18}O_{str} - \delta^{18}O_{Old}}{\delta^{18}O_{new} - \delta^{18}O_{Old}} \qquad (2)$$

The model will be informed by measured $\delta^{18}O$ values (and possible additional geochemical signatures) from Jarvis Creek watershed.

OCCURENCES OF APPLIED RESEARCH BENEFITING ALASKA

Gatesman, T.A., Jacobs, N., Debolskiy, M., Bailey, J., Barnard, C., Douglas, T., Gusmeroli, A., Hock, R., Liljedahl, A., Wagner, A., (2015). What role do glaciers play in terrestrial subarctic hydrology? Poster presentation at the Delta Farm Forum. 21 February 2015. Delta Junction, AK.

PRESENTATIONS

Gatesman, T.A., Liljedahl, A.K., Douglas, T.A., Trainor, T.P. (2015). Hydrograph separation of a sub-arctic glacial watershed using stable water isotope variation. Poster presentation at the Alaska State AWRA Annual Conference and Workshop. 13 May 2015, Fairbanks, AK.

Gatesman, T.A., Liljedahl, A.K., Douglas, T.A., Trainor, T.P. (2015). Hydrograph separation of a sub-arctic glacial watershed using stable water isotope variation. Oral presentation at the Midnight Sun Science Symposium. 26 March 2015, Fairbanks, AK.

Gatesman, T.A., Jacobs, N., Debolskiy, M., Bailey, J., Barnard, C., Douglas, T.A., Gusmeroli, A., Hock, R., Liljedahl, A.K., Wagner, A., (2015). What role do glaciers play in terrestrial subarctic hydrology? Poster presentation at the Delta Farm Forum. 21 February 2015. Delta Junction, AK.

Gatesman, T.A., Liljedahl, A.K., Douglas, T.A., Trainor, T.P. (2015). Hydrograph separation of a sub-arctic glacial watershed using stable water isotope variation. Oral presentation at the Department of Chemistry and Biochemistry, UAF Seminar. 17 February 2015, Fairbanks, AK.

Gatesman, T.A., Liljedahl, A.K., Douglas, T.A., Trainor, T.P. (2015). Hydrograph separation of a sub-arctic glacial watershed using stable water isotope variation. Oral presentation at the Water and Environmental Research Center Symposium. 6 February 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.

SCHOLARSHIPS AND AWARDS

IARC Summer School Scholarship. "Arctic in a warming climate: Connection to vegetation, permafrost and hydrology". University of Alaska, Fairbanks, Alaska and Toolik Lake field base, Alaska. May 26 – June 9 2015.

Special Research Student Scholarship: Enrollment and travel to University of Hokkaido EES Laboratory Short Course in Stable Isotopes, Sapporo, Japan. 14-20 December 2014.

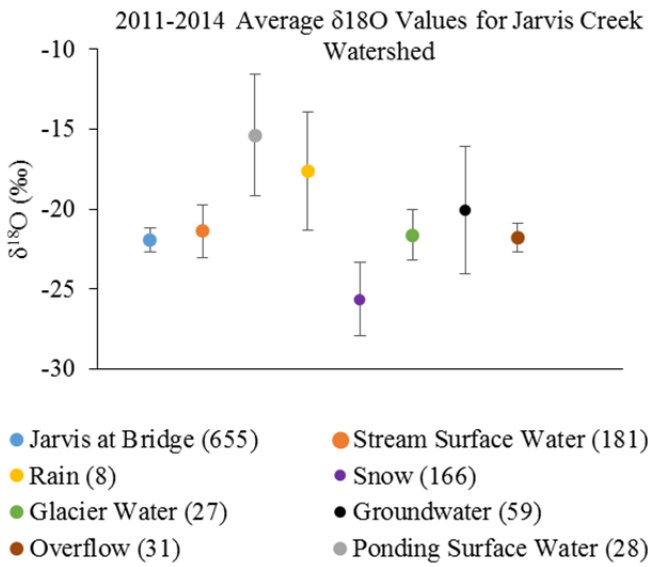


Figure 1. *Average $\delta^{18}O$ values in per mil (‰) with standard deviation recorded as error bars; number of samples are shown in parenthesis. The variation in average isotopic composition between rain and groundwater are attributed to evaporation of water before infiltration into the aquifer (Gat & Tzur, 1967). The large variation of precipitation and snow shown in the error bars in figure 2 are most likely related to the topographical and temporal variations of precipitation (Ingraham et al., 1991). Ponding surface water and groundwater most likely originated from rainfall, thus explaining the large standard deviation of these samples.*

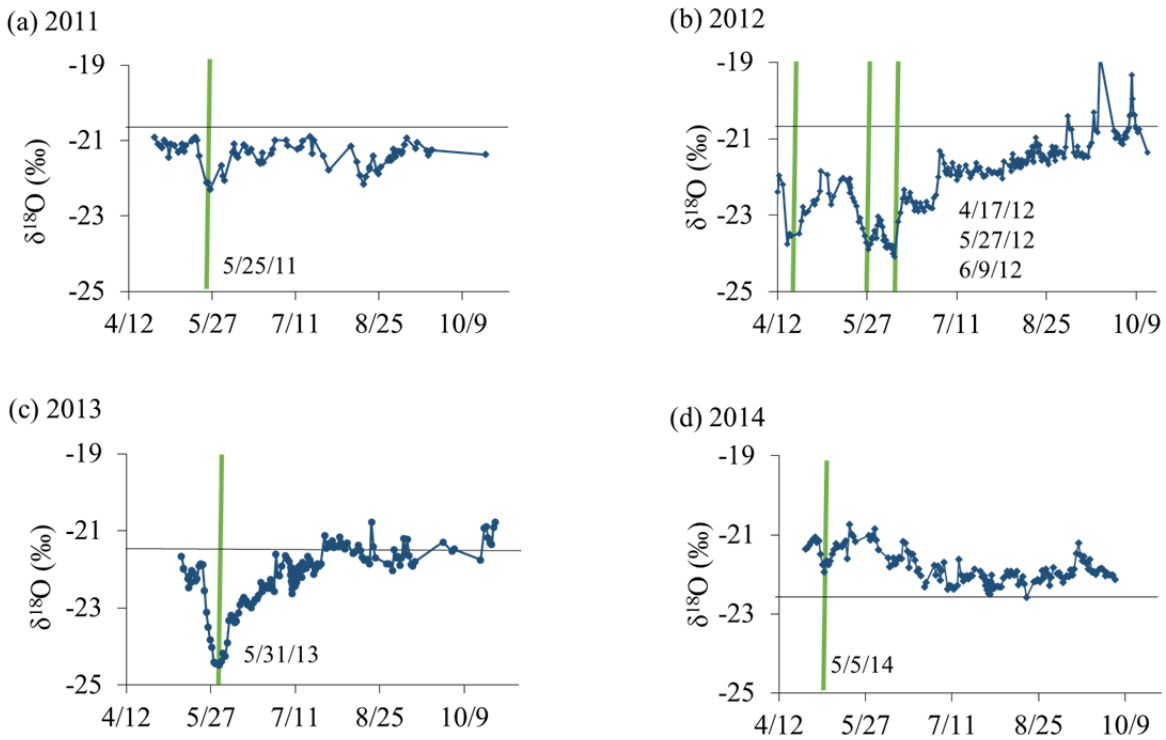


Figure 1 *Seasonal $\delta^{18}O$ variability in Jarvis Creek stream flow. Green vertical lines show decrease in $\delta^{18}O$ values that are similar to snow values suggesting an influence in spring snowmelt in stream flow. Black horizontal lines show groundwater (baseflow) $\delta^{18}O$ values for that year. If the groundwater line is above plotted values, stream is influenced more by snow and/or glacier (2011, part of 2012 & 2013). If the groundwater line is below plotted values, stream is influenced more by rainfall (2014).*

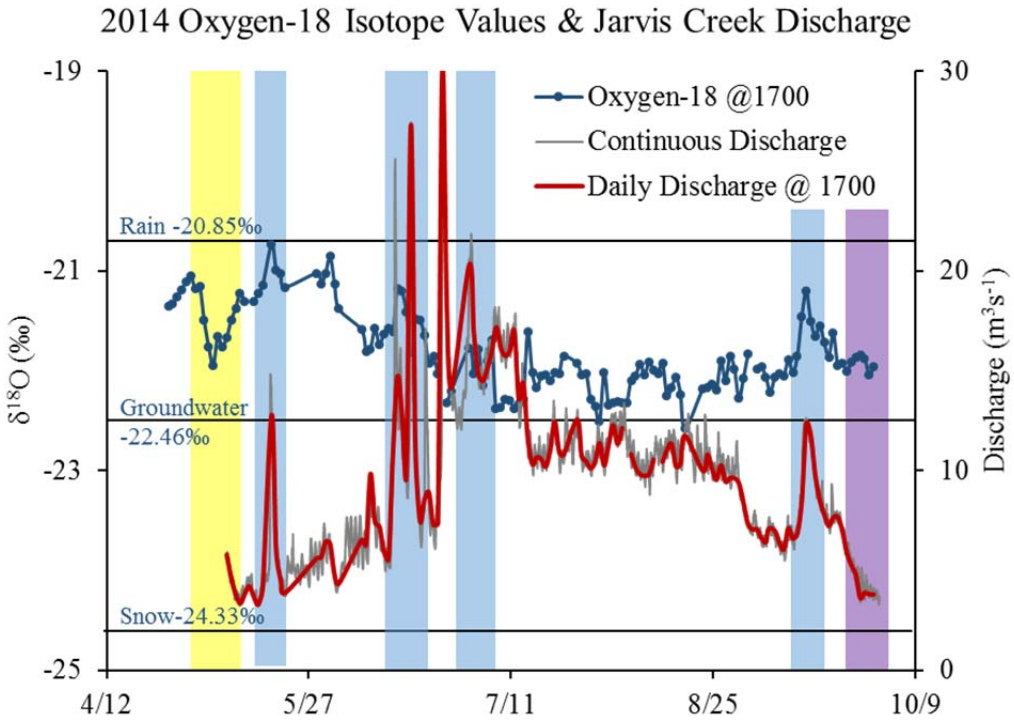


Figure 3 *Daily Jarvis Creek (bulk) stable water isotope $\delta^{18}O$ values and daily discharge measurements at Richardson Highway Bridge, 2014. Black horizontal lines show annual average isotope signatures of respected water source. Yellow regions show discharge increase due to snow melt (decrease $\delta^{18}O$); blue region show increase in discharge due to rain influence (increase $\delta^{18}O$); purple region show decrease in discharge resulting in dominant groundwater flow (base-flow, groundwater $\delta^{18}O$ values). Patterns in $\delta^{18}O$ variations coincide with daily stream discharge patterns and together they indicate the importance of glacier melt in mid to late summer. This data, as well as data from 2011-2013, will be forced into the end-member mixing model (equation 1 and 2) to find the fraction of glacial input.*

Use of Gel Encapsulated Graphene Oxide Nanoparticles for Water Treatment

Basic Information

Title:	Use of Gel Encapsulated Graphene Oxide Nanoparticles for Water Treatment
Project Number:	2014AK122B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Not Applicable
Focus Category:	Water Quality, Treatment, Toxic Substances
Descriptors:	None
Principal Investigators:	Srijan Aggarwal

Publications

There are no publications.

Progress report for "Use of Gel Encapsulated Graphene Oxide Nanoparticles for Water Treatment" (Funded by USGS NIWR program 2014-2015)

PI: Srijan Aggarwal, Water and Environmental Research Center, UAF, Alaska, Fairbanks.

Background. The objective of this project is to evaluate the potential of gel-immobilized nanoparticles as a water treatment option in batch and column experiments to be conducted in the WERC laboratories. As explained in the main proposal text, very little work has been done to explore the efficacy of novel and promising immobilized nanoparticles for use in water treatment. While having wide applicability, the on-going research could be especially useful towards developing simple and effective applications for point-of-use water treatment tools for rural Alaskan villages.

Progress made to date. A graduate student (Katie Husk, MS Environmental Engineering, UAF) has been recruited to work on this research project. Additionally an undergraduate student (Sophia Tidler, BS, Civil Engineering) has been awarded an Undergraduate Research Student Award (URSA scholarship, UAF, $2500) to work on this project with the PI. Both Katie and Sophia started work on this project in August 2014 and have made significant progress in one semester.

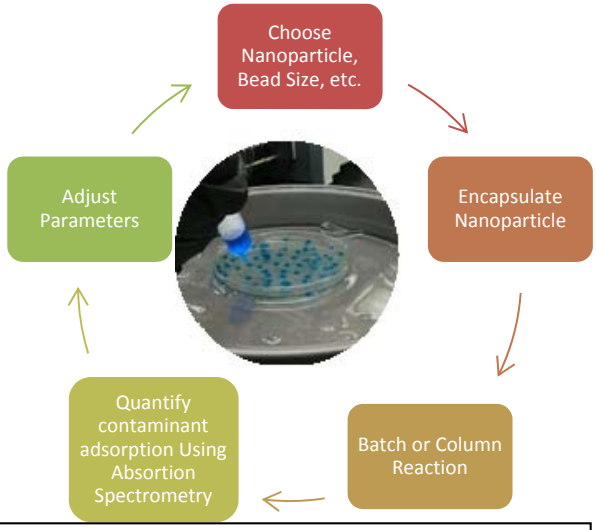


Figure 1: Schematic for Experimental Procedures

To begin with, the graduate student conducted a comprehensive literature review on the project topic and prepared a draft review article based on her findings. We plan to submit the review article to Environmental Science and Technology Letters in Spring 2015. Additionally, both the graduate and undergraduate student have been trained in laboratory techniques (specifically Atomic Absorption Spectrophotometer) and have been working towards bead production in the lab. Students also performed some initial experiments with immobilized orange-peels to reproduce prior work, thus establishing confidence in the conducting the batch experiments and have developed a general experimental protocol (Figure 1).

Future directions. As a next step, during the winter break the students plan to work on immobilizing graphene oxide and other nanoparticles to understand the adsorption characteristics of graphene oxide nanoparticles. In the spring semester students plan to build laboratory columns to conduct column studies and work with different contaminants (cadmium, lead and arsenic) to develop kinetic and adsorption models for heavy-metal removal using immobilized nanoparticles. We hope to submit a journal manuscript to Journal of Environmental Engineering during the summer 2015, based on the results obtained from the year-long work.

Summary. Significant progress has been made on the current project and the USGS NIWR funds were used to leverage university funding for an undergraduate student to assist on the research project. Students have conducted literature review and have been familiarized with the laboratory techniques

for successful completion of the project. We plan to submit a review article in the spring 2015 semester and a research article in the summer 2015 based on the project findings. Finally, based on these preliminary findings the PI envisions applying for an NSF grant (via the Environmental Engineering program), to continue further research on the topic.

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:	3/1/2014
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.

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 DGGS, 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 DGGS 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.

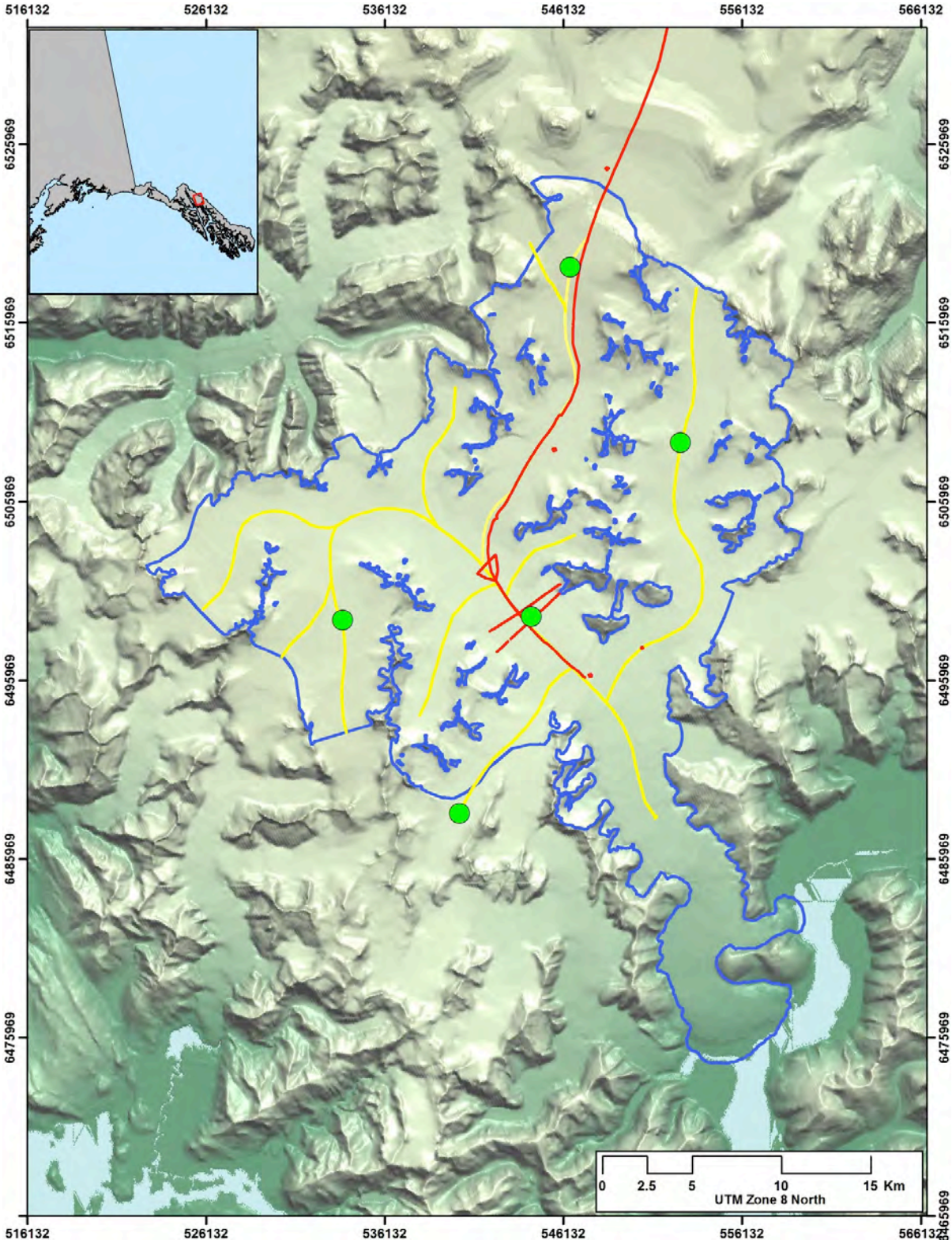


Figure 1. Taku Glacier. 2013 glacier boundary is outlined in blue. Existing (red) and proposed (yellow) radar lines are shown, along with ongoing mass balance measurement sites (green dots). Inset shows location of detailed map in southeast Alaska.

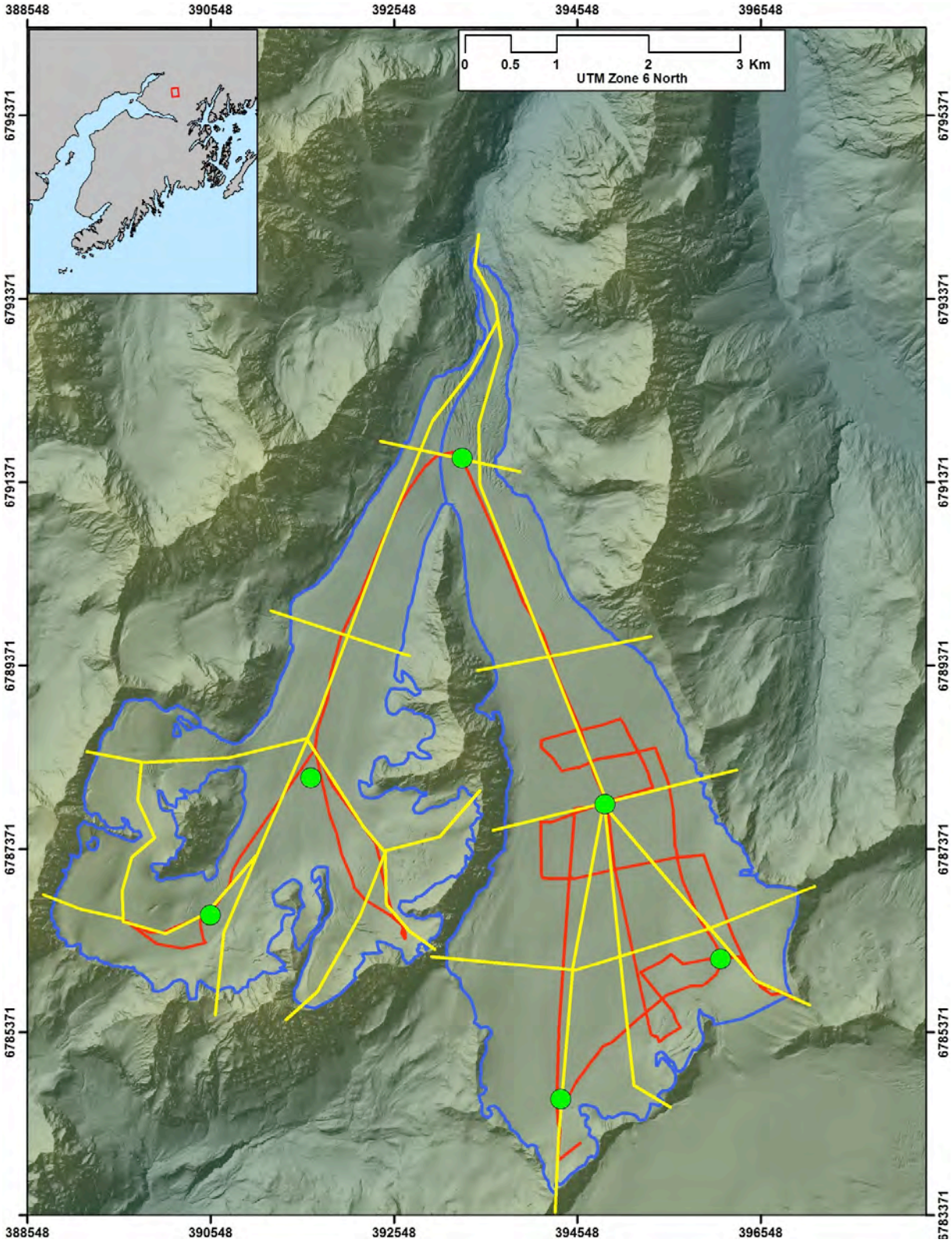


Figure 2. Eklutna Glacier. 2012 glacier boundary is outlined in blue. Existing (red) and proposed (yellow) radar lines are shown, along with ongoing mass balance measurement sites (green dots). Inset shows location of detailed map in southcentral Alaska.

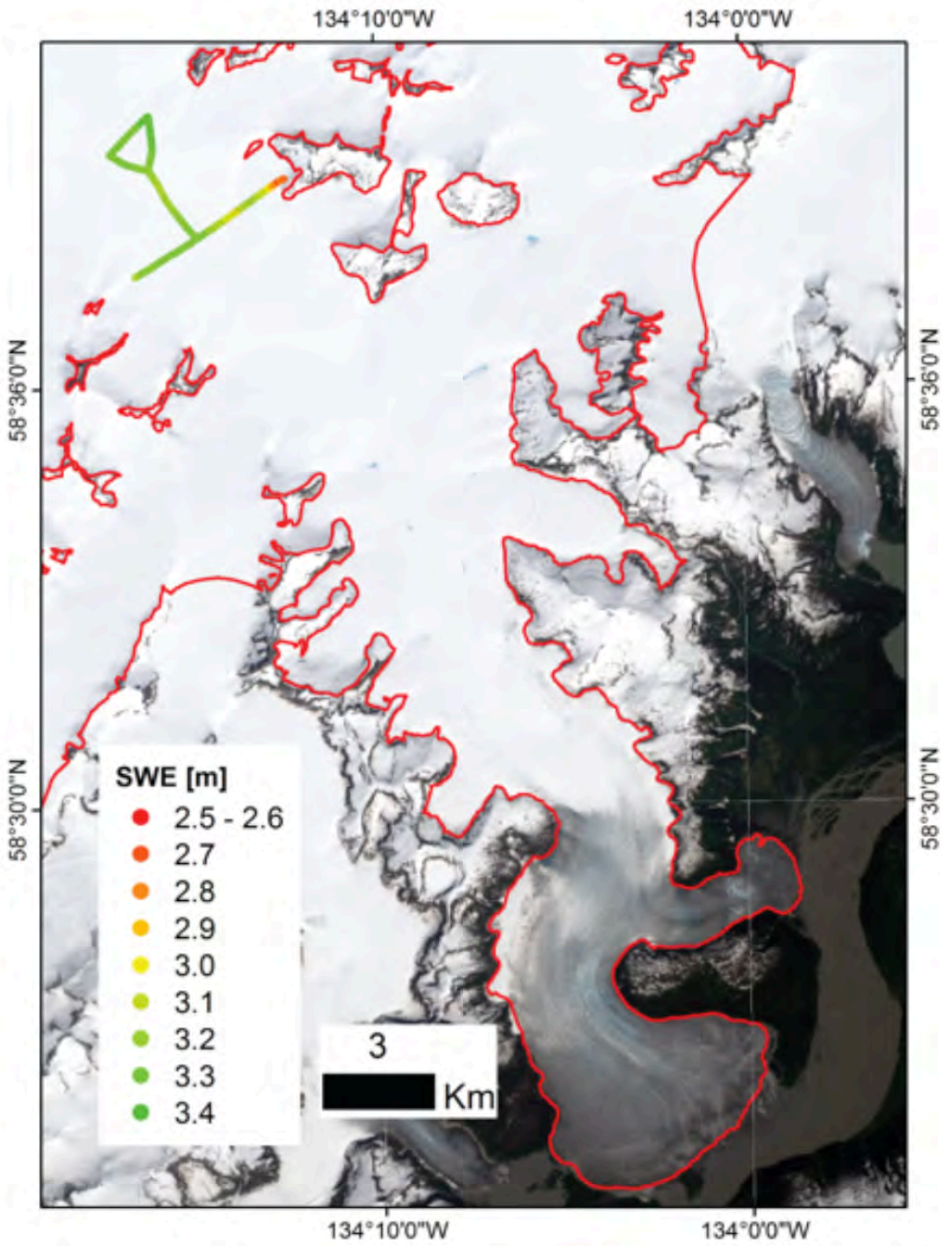


Figure 3. Inferred snow depths (in SWE: meters of water equivalent) for Taku Glacier in 2013.

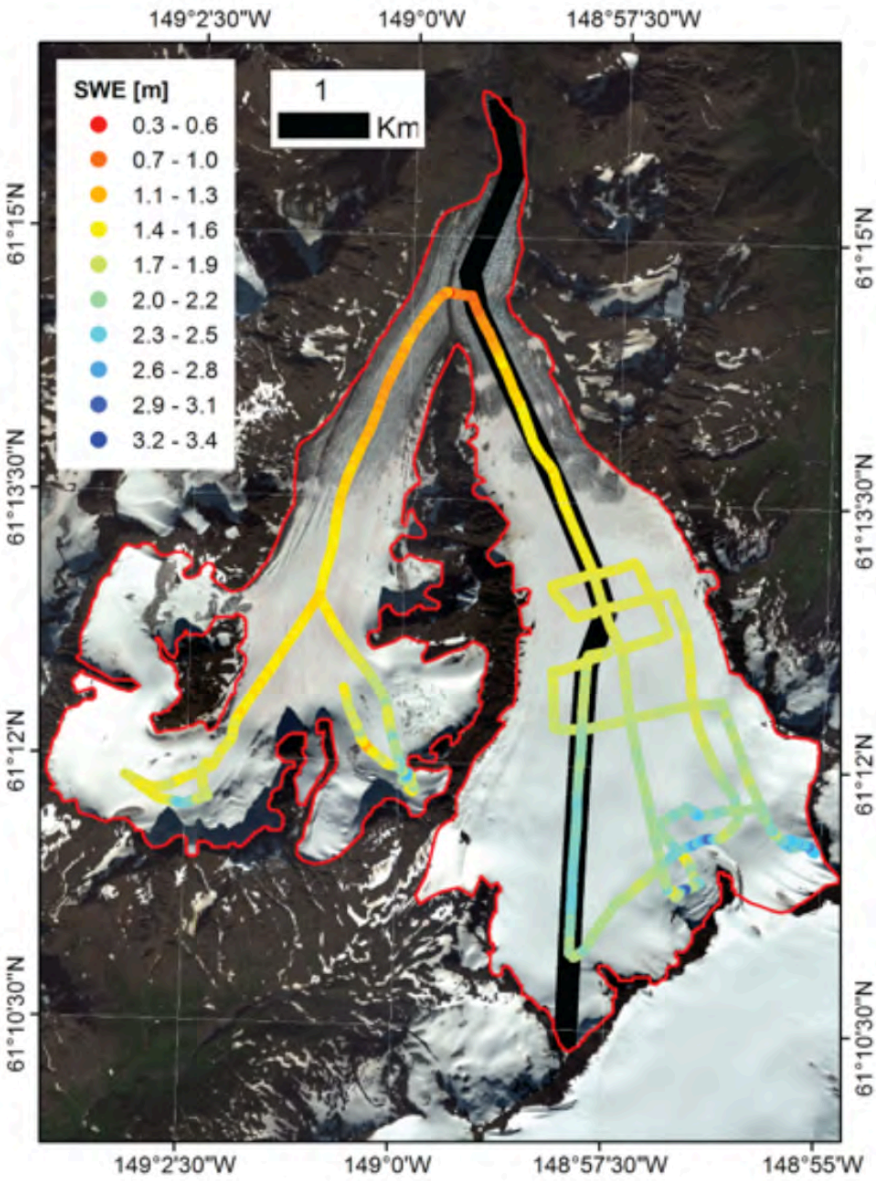


Figure 4. Inferred snow depths (in SWE: meters of water equivalent) for Eklutna Glacier in 2013.

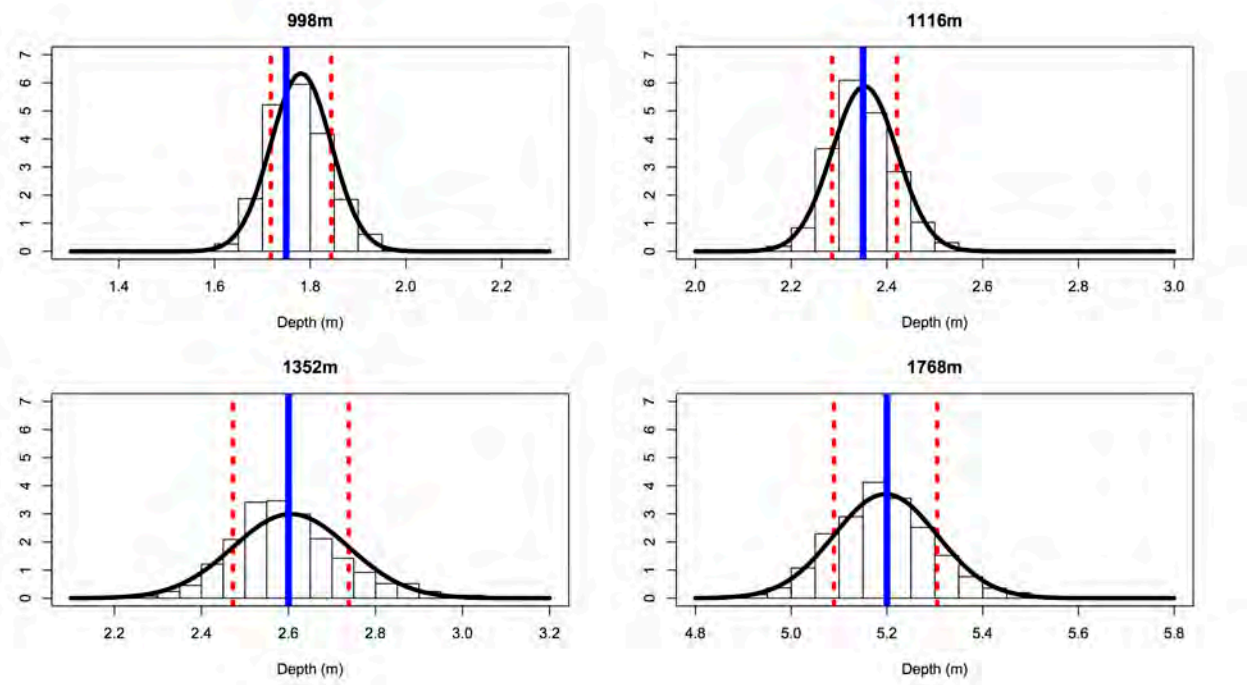


Figure 5. Comparison of radar and ground-truth based snow depths at four sites on Taku Glacier in 2013. Distributions of radar-inferred snow depths from grids surrounding single snowpits are shown by the histogram bars, and approximated by the normal distributions shown in bold black. Vertical blue bars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

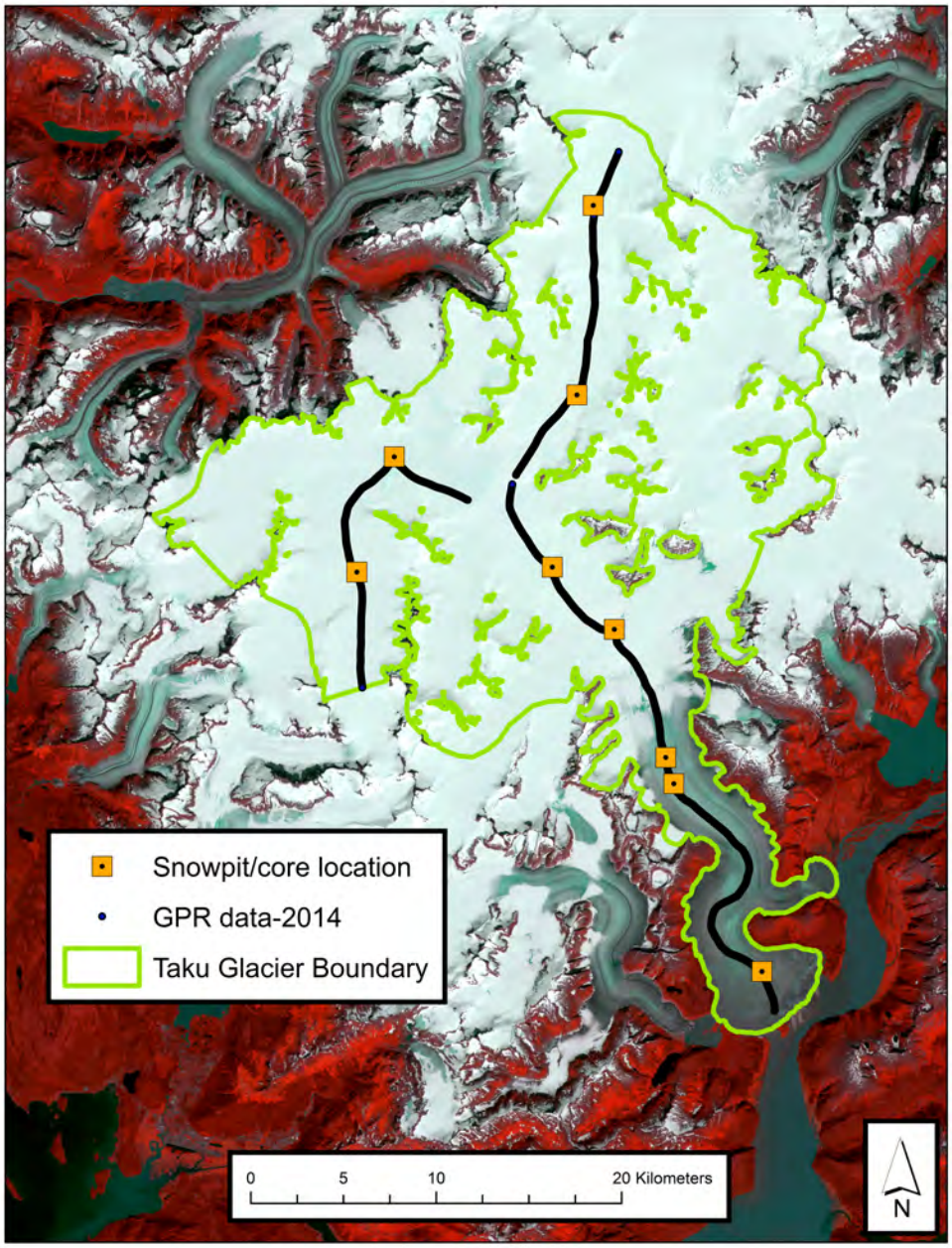
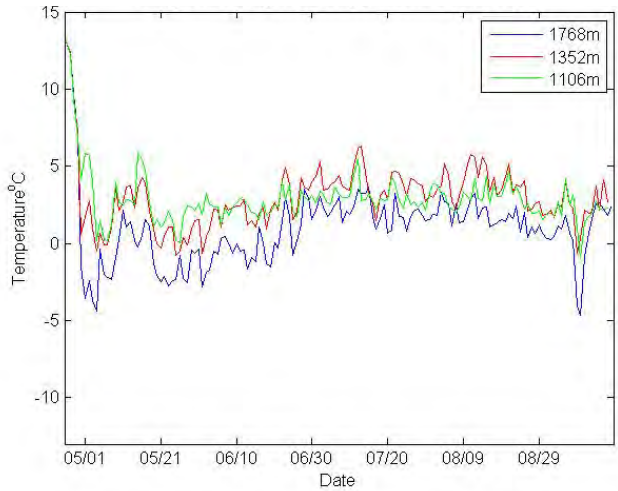


Figure 6. Taku Glacier. Collected 2014 (year 2) radar data is shown in black. Snowpits used for ground-truthing are shown with yellow squares. Measured temperatures are shown in the inset at right.



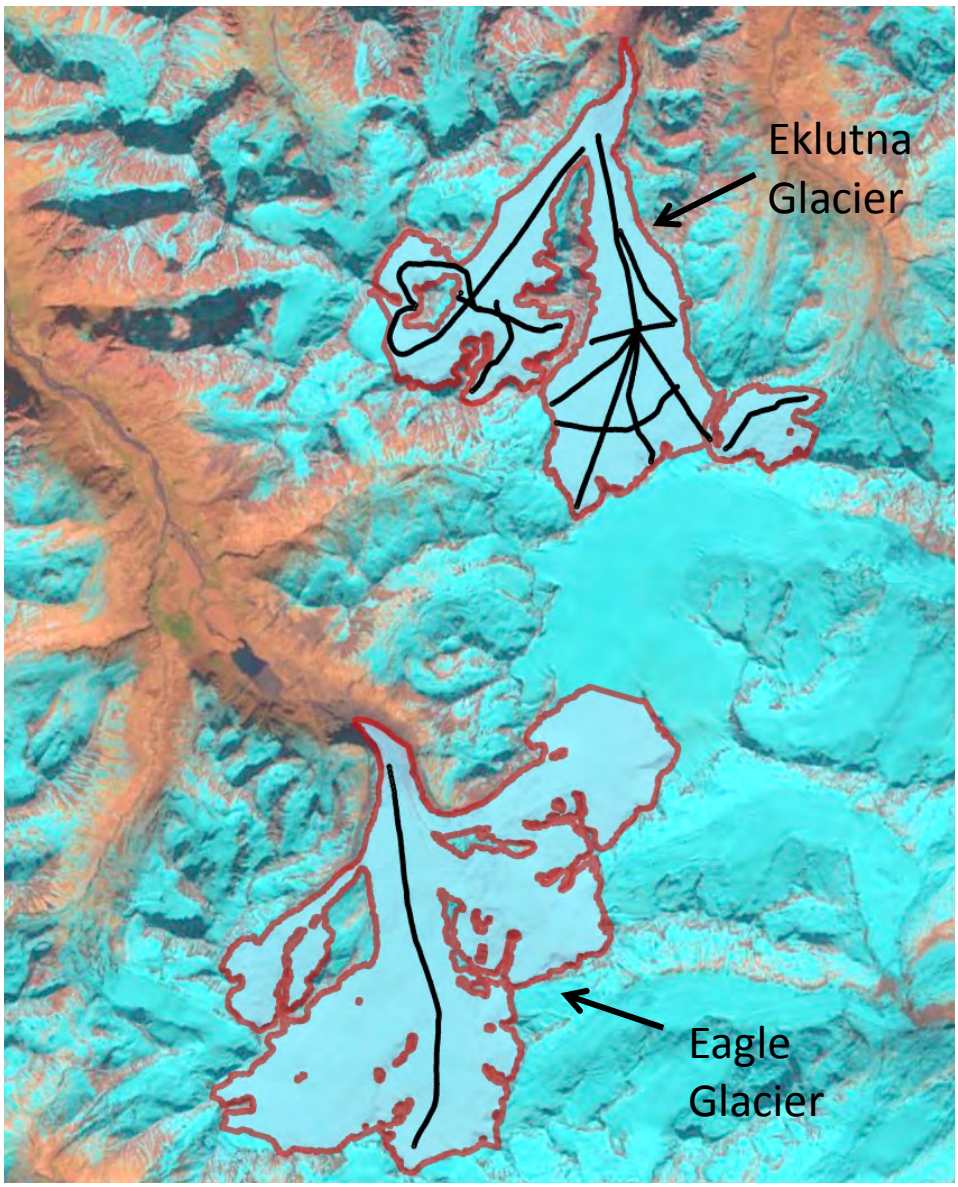


Figure 7. Eklutna and Eagle Glaciers. Collected 2014 (year 2) radar data is shown in black.

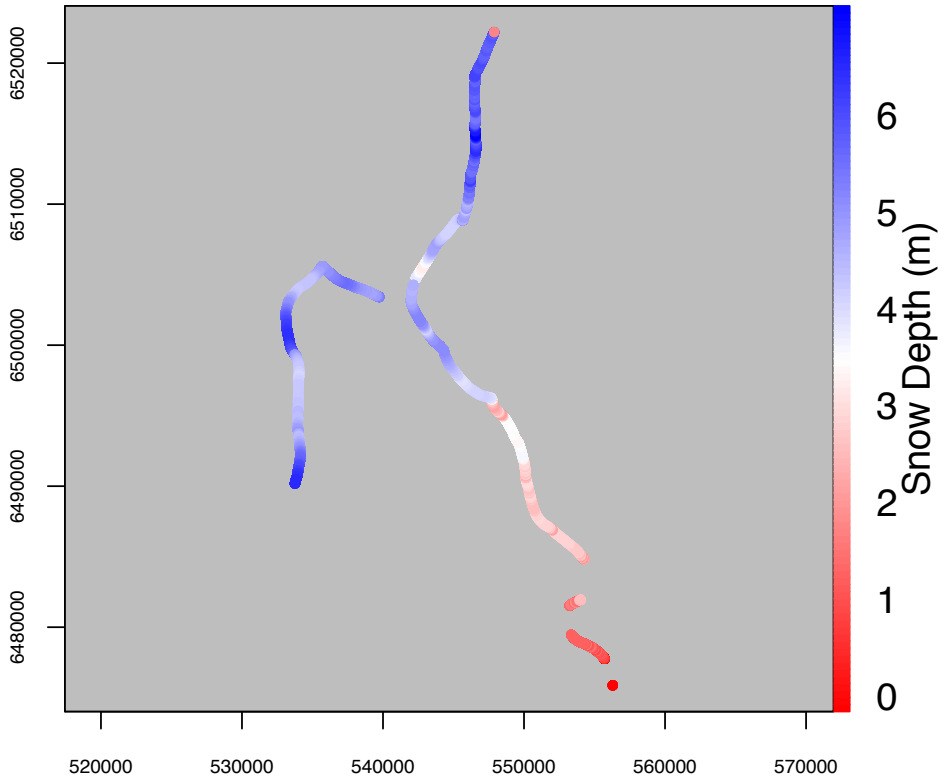


Figure 8. Inferred snow depths for Taku Glacier in 2014.

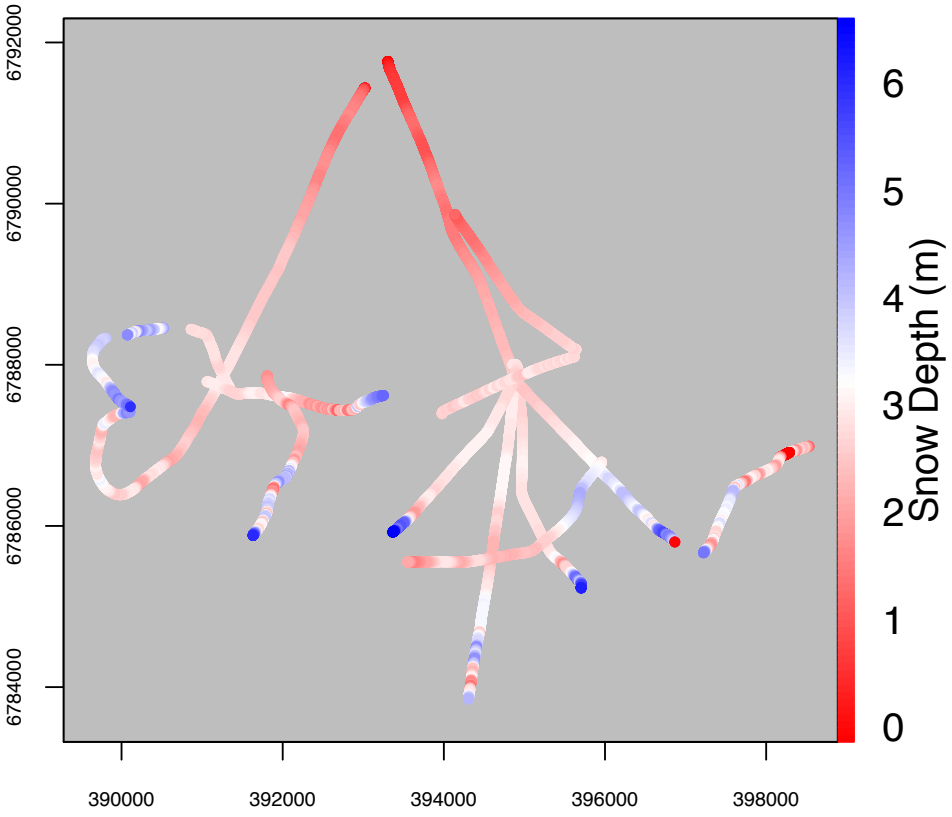


Figure 9. Inferred snow depths for Eklutna Glacier in 2014.

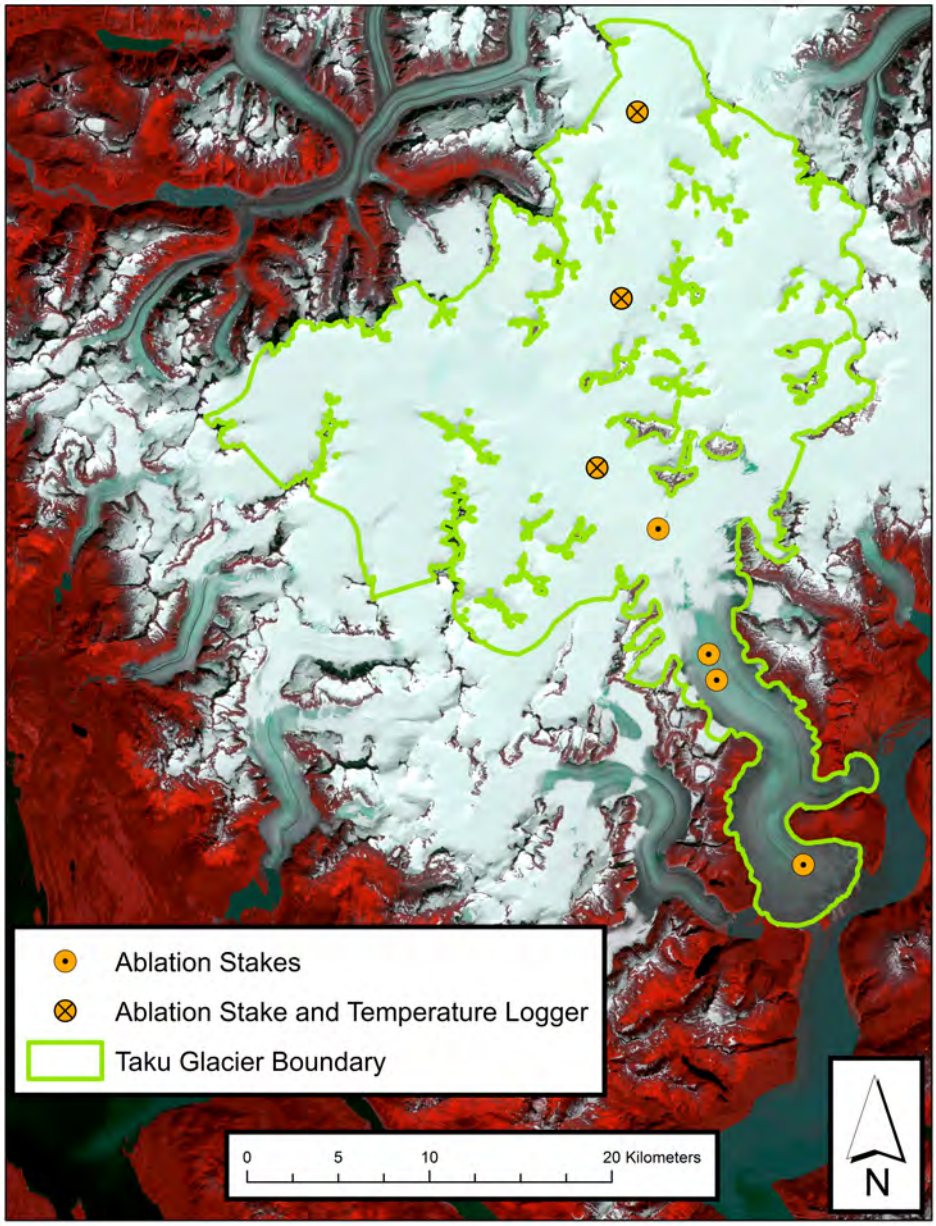


Figure 10. Locations of ablation stakes and temperature loggers placed on Taku Glacier in summer 2014.

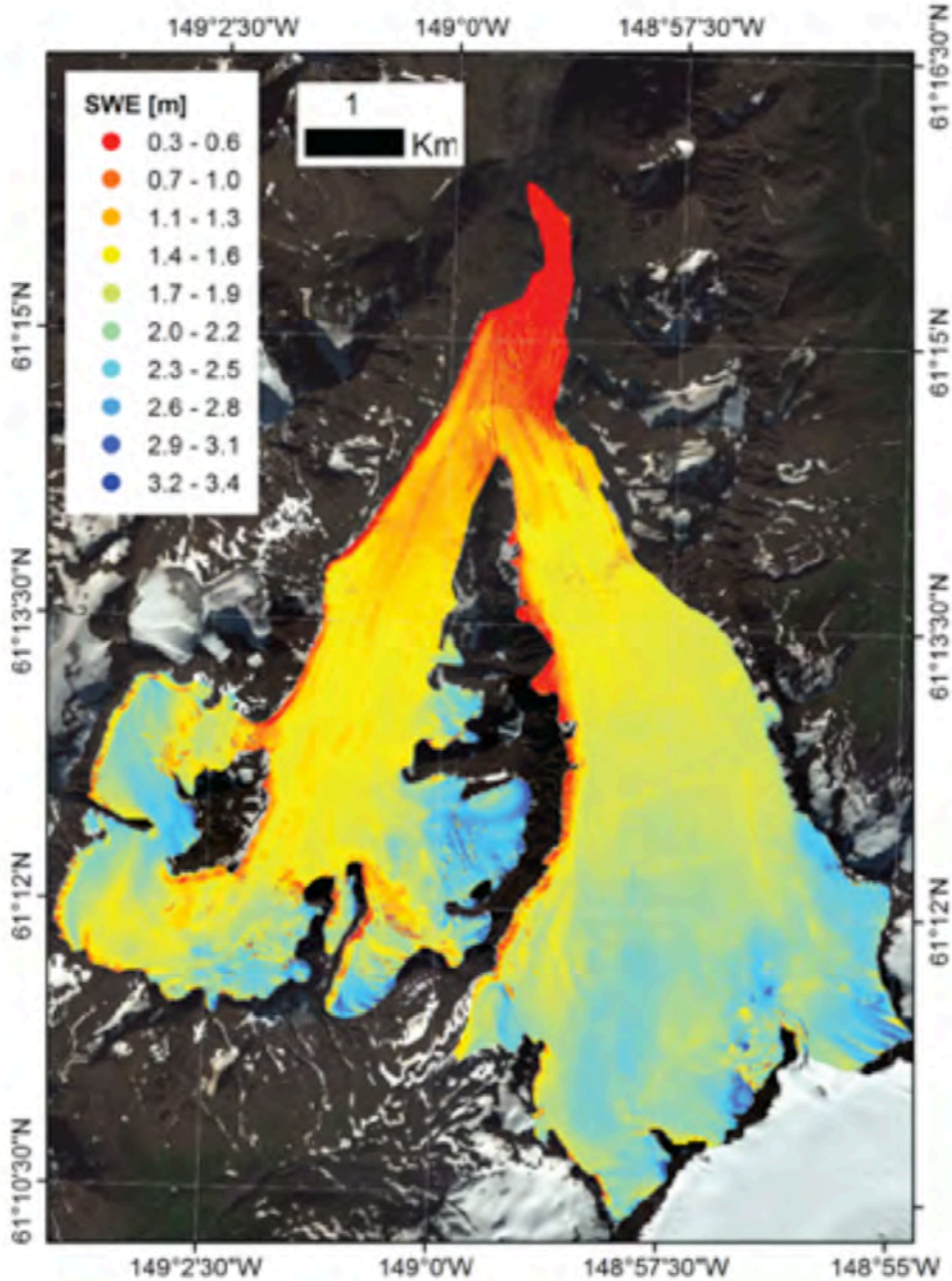


Figure 11. Distributed snow depth (in SWE: meters of water equivalent) in spring 2013 at Eklutna Glacier.

Accounting for Thermal Processes in Alaska Coastal Erosion

Basic Information

Title:	Accounting for Thermal Processes in Alaska Coastal Erosion
Project Number:	2014AK124B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	AK-1
Research Category:	Climate and Hydrologic Processes
Focus Category:	Sediments, Models, Surface Water
Descriptors:	None
Principal Investigators:	Tom M Ravens

Publications

There are no publications.

2015 Report:
Accounting for Thermal Processes in Alaska Coastal Erosion

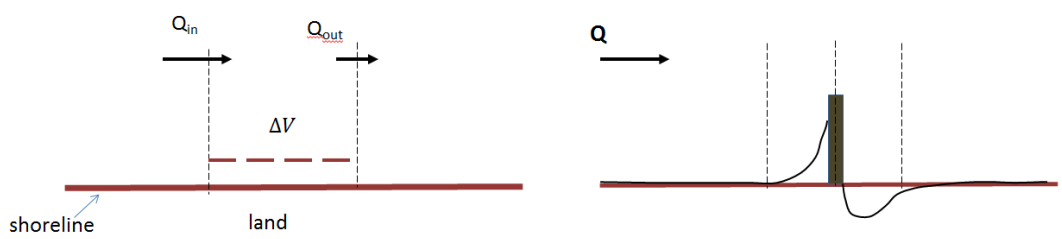
Objective: *Develop a new approach to arctic Alaska coastal erosion modeling that accounts for both thermal and mechanical processes.*

We have developed a conceptual approach to the next generation of arctic coastal erosion models. The arctic coastal erosion models that have been recently developed for the Arctic have focused on process-based (Ravens et al. 2011, Ravens et al. 2012, Barnhart et al. 2014) or empirical approaches (Ravens et al 2008). The approaches to arctic coastal erosion referred to above all focused on the cross-shore sediment transport. They neglect the alongshore sediment transport contribution to coastal erosion (e.g., Ravens and Sitanggang, 2007). Existing arctic coastal erosion models can be improved by including longshore sediment transport. For example, when coastal erosion results in the delivery of large blocks of coastal soil into the nearshore zone, that material can be transported along the coast where it may build up in certain areas (Figure 1).

Figure 1a. Photo of niche erosion/block collapse erosion mechanism. 1b. Photo of emergent offshore sand bar likely constructed from the recycling of previously eroded material.

In the sub-arctic, coastal erosion mainly occurs due to longshore variation in the alongshore sediment transport (Q). However, large storms that transport material out of the littoral system can also be important. Figure 2 illustrates the concept of the sediment budget, and it explains how longshore

$$Q = C\, H_b^{5/2} \sin(2\alpha_b)$$



$$\Delta V = Q_{in} - Q_{out}$$

Figure 2. Sediment budget used to understand coastal erosion in sub-arctic settings.

variation in alongshore sediment transport can contribute to coastal erosion. The alongshore transport rate (Q) is readily calculated based on the wave height and direction of the waves at the breaking point (H_b,α_b) as indicated by the formula in Figure 2. The nearshore zone is divided into a number of cells. If the flowrate of sediment into a given cell (Q_{in}) is greater than the flow rate out (Q_{out}), then that cell will be acretional and the shoreline will move seaward. The schematic on the right side shows how this sediment budget concept can explain shoreline change in the vicinity of a shore-perpendicular groin.

Our new arctic erosion modeling approach would integrate cross-shore and alongshore sediment transport. Figure 3 below illustrates the new approach.

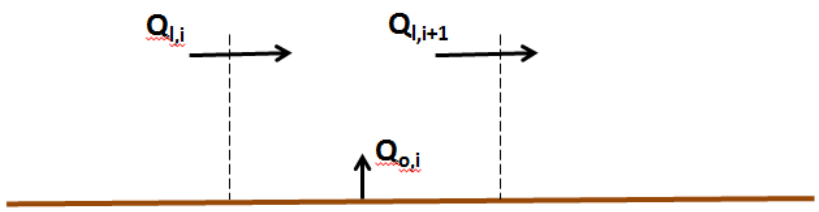


Figure 3. Sediment budget including offshore and alongshore sediment transport.

Outreach:

The proposed new approach to arctic coastal erosion modeling was recently presented at a workshop organized by the Arctic Landscape Conservation Cooperative (ALLC). It is hoped that ALLC will provide funding to demonstrate the new approach on the north coast of Alaska.

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Ravens, T. M., and K. I. Sitanggang. 2007. Numerical modeling and analysis of shoreline change on Galveston Island. *J. of Coastal Research,* 23(3): 699-710.

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Ravens, T. Kartezhnikova, M, Ulmgren, M., Yager, G., Jones, B., Erikson, L., Gibbs, A. Richmond, B., Zhang, J., Tweedie, C., and Aguirre, A. 2011. Arctic coastal erosion modeling. Presented at the AGU Fall Meeting, San Francisco, CA, Dec. 2011.

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Barnhart, K. R., Anderson, R. S., Overeem, I., Wobus, C., Clow, G. D., and Urban, F. E. 2014. Modeling erosion of ice-rich permafrost bluffs along the Alaska Beaufort Sea coast. *Journal of Geophysical Research*. Doi: 10.1002/2013JF002845.

Information Transfer Program Introduction

None.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	5	0	0	0	5
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	7	0	0	0	7

Notable Awards and Achievements