# **DARTMOUTH IGERT** GRADUATE STUDENT SCIENCE IN GREENLAND

### **A PRELIMINARY REPORT, 2014**



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Institute of Arctic Studies Dickey Center for International Understanding Dartmouth, Hanover New Hampshire, USA Dartmouth is a member of the Ivy League universities in the U.S. and consistently ranks among the world's best academic institutions. Dartmouth has forged a singular identity for combining its deep commitment to outstanding undergraduate and graduate education with distinguished research and scholarship in the Arts & Sciences and its three leading professional schools—the Geisel School of Medicine, Thayer School of Engineering, and the Tuck School of Business.

Since its founding in 1769, Dartmouth has had a long and distinguished history of polar exploration and research, culminating in the 1950s and '60s by the founding of a Northern and Polar Studies Program at Dartmouth by the explorer and scholar Vilhjálmur Stefansson. Today, a new generation of faculty and graduate students at Dartmouth are pursuing interdisciplinary collaboration and research as a pathway to understanding the environmental and human consequences of rapid environmental change in polar regions. The Institute of Arctic Studies at the Dickey Center for International Understanding has been Dartmouth's crossroads for interdisciplinary research and education in polar studies, and a leader in supporting graduate research on Greenland and the effects of climate change on its complex ecosystems. The Institute of Arctic Studies leads Dartmouth's IGERT (Interdisciplinary Graduate Education and Research Traineeship) Program in Polar Environmental Change, an initiative of the National Science Foundation, and is a founding member of the University of the Arctic's Institute for Applied Circumpolar Policy.

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#### Dartmouth IGERT Program in Polar Environmental Change

The National Science Foundation, Integrative Graduate Education and Research Traineeship (IGERT)

Institute of Arctic Studies at **T**he John Sloan Dickey Center for International Understanding, Dartmouth College











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### INTRODUCTION

Greenland is a hotspot for polar environmental change research due to rapidly changing physical and ecological conditions. Hundreds of international scientists visit each year to carry out research on diverse topics ranging from atmospheric chemistry to ice sheet dynamics to Arctic ecology. The strong links between science and the social and political issues of rapid environmental change in Greenland have the potential to affect environmental policies worldwide and thus are an essential part of the dialogue between scientists, policy makers, and other stakeholders.

Dartmouth (Hanover, NH, USA) has been training a new generation of scientists who understand the complex scientific and societal impacts of polar environmental change using the interdisciplinary framework of a National Science Foundation (NSF) Integrative Graduate Education and Research Traineeship (IGERT). Our program, initiated in 2008, has developed a curriculum that builds on the foundations of disciplinary training in Ecology & Evolutionary Biology, Earth Sciences, and Engineering with an interdisciplinary curriculum in Polar Environmental Change. Twenty-five Ph.D. students have completed coursework with the following objectives: The curriculum was developed through an ongoing collaborative model of exchange and education with Ilisimatusarfik (University of Greenland), the Inuit Circumpolar Council and other partners in Greenland. Since 2008, we have directly supported six students from Greenland for term study at Dartmouth. The scholarly and social participation of these students in the IGERT community has created a more meaningful dialogue about polar environmental change and its implications for residents in the Arctic, as well as fostering long-term personal relationships and networks connecting Greenland and Dartmouth.

The culminating IGERT experience is a 5-week field based course in Greenland to examine the scientific, cultural and political issues that span the circumpolar region. This course features training and field work in terrestrial and aquatic ecosystems near Kangerlussuaq, an introduction to ice and firn research on the Greenland Ice Sheet at Summit Camp, and a policy workshop in Nuuk.

The IGERT experience has inspired many students to develop independent research projects in Greenland that fulfill all or part of their graduate degree requirements

- training in the central topics of polar science and engineering
- exposure to cross-cutting technologies that allow for interdisciplinary polar science
- understanding the human dimensions of polar science
- development of skills to communicate polar science to different groups
- awareness of traditional ecological knowledge and its implications for the ethical conduct of scientific research in Native communities
- fostering a lasting community among IGERT students and with international colleagues in Greenland and other Arctic nations.

at Dartmouth. The projects are largely interdisciplinary and cover diverse topics including polar robotics, ice sheet and glacial dynamics, atmospheric science, climate impacts on physical and biological properties of ecosystems, and traditional use of plants and connections with the Greenlandic language. On the following pages of this preliminary science report, we include descriptions of the projects conducted by students trained through Dartmouth's IGERT in Polar Environmental Change, as well as lists of the peer-reviewed journal articles and a selection of presentations at scientific meetings that this work has generated. We anticipate these major contributions to the scientific literature to expand over the next several years. We also describe the numerous outreach projects developed in conjunction with this research that highlight our commitment to sharing science with diverse audiences in Greenland.

We attribute our success to the generous support from our friends and colleagues in Greenland, particularly at Kangerlussuaq International Science Support, the Inuit Circumpolar Council, Ilisimatusarfik (University of Greenland), Naalakkersuisut (the Government of Greenland), Pinngortitaleriffik (Greenland Institute of Natural Resources), and Kalaallit Nunaanni Aalisartut Piniartullu Kattuffiat (KNAPK, Greenland Hunters and Fishers Association).



Students and faculty disembark a boat at the Nuuk Basic Research Site in Kobbefjord/ Kangerluarssunguaq.



### **IGERT GRADUATE STUDENT RESEARCH IN GREENLAND**

#### ALDEN ADOLPH, PH.D. STUDENT ENGINEERING SCIENCES

Alden is studying how the Greenland Ice Sheet keeps records of historical atmospheric composition in the tiny bubbles of air trapped within the ice. She focuses on understanding how the gases in the atmosphere travel through the snow and firn (snow that is more than one year old) so that we know how long the air has been trapped within the ice. In 2007, Alden and her colleagues collected a firn core from Summit Station in Greenland and have since been studying how gas travels through the firn. The first step has been determining the best method to measure gas transport, which is important for correctly reconstructing the history of atmospheric composition and relating that to past temperature. Once Alden and her colleagues can understand the way that the earth has behaved in the past, they can hopefully improve predictions about what might happen with regards to future changes in the atmosphere, as well as the implications for the Greenland Ice Sheet, ecosystems, and people.

#### JULIA BRADLEY-COOK, PH.D. STUDENT ECOLOGY AND EVOLUTIONARY BIOLOGY

Julia is studying how climate warming is altering the biological processes that control carbon flow through natural ecosystems. She investigates microbial decomposition in tundra soils where permafrost and cold soil temperatures have allowed for the buildup of large stores of carbon. In 2011 and 2012, Julia collected samples from soil pits to measure soil carbon content across two spatial scales: the local area near Kangerlussuag and the regional area of western Greenland (Kangerlussuaq, Sisimiut, and Nuuk). She used a combination of field experiments and laboratory studies to measure how decomposition rates vary with moisture and temperature. Soil organic carbon storage varies substantially at local and regional scales and she will soon be able to describe how the "quality" of carbon varies as well. This determines the biological availability of the carbon and how sensitive it is to warming. Carbon storage by soils prevents carbon from entering the atmosphere and further contributing to climate change, a positive feedback cycle that has huge implications for society. This research is especially relevant to Greenlanders because carbon-rich soils and permafrost are unique treasures of Arctic nations, and both are rapidly responding to global climate change.



Students examining lake biology near Kangerlussuaq, Greenland.



Lauren Culler, Postdoctoral Fellow and Outreach Coordinator at the Institute of Arctic Studies, studying how changes in temperature affect mosquito emergence.

#### LEE CORBETT, PH.D. STUDENT EARTH SCIENCES

Lee studies glaciers and ice sheets, which are powerful forces in shaping the landscape. They can cause significant erosion and move massive amounts of rock and sediment. Specifically, Lee studies erosion beneath the Greenland Ice Sheet and addresses questions about how rapidly this erosion occurs and how spatially variable it is. She has participated in five trips to Greenland to study the landscape and collect samples for analysis. This work has taken place in Kangerlussuaq, Ilulissat, Upernavik, and Thule. To assess the efficiency of subglacial erosion, Lee examines rare isotopes (including beryllium-10 and aluminum-26) that build up in rocks over time. Thus far, she has learned that subglacial erosion in Greenland is highly variable over space: certain regions contain ice that is highly erosive and effectively shapes the landscape, while the ice in other landscapes is almost completely incapable of performing erosion. Lee has documented the existence of "ghost glaciers" (those that produce no erosion and leave no evidence of their presence) in Upernavik, thereby highlighting the need to rethink the assumption that all glaciers are erosive. Her work provides insight into how Greenland's landscape has developed over time, which helps understand rates of soil formation and movement of nutrients to the ocean.

#### LAUREN CULLER, PH.D. ECOLOGY & EVOLUTIONARY BIOLOGY

Climate change is causing temperatures to rise in the Arctic and Lauren is studying how these changes in temperature affect mosquito emergence from freshwater ponds. During the summers of 2011 and 2012, she counted the numbers of mosquitoes in several ponds near Kangerlussuag every few days and measured how many mosquitoes emerged from each pond. She also used lab studies at Kangerlussuag International Science Support to measure how temperature affects the number of days it takes a mosquito larva to grow into an adult. So far, she has leaned that warmer temperatures are likely to increase the numbers of mosquitoes that emerge because the larvae grow much faster when it's warmer and thus spend fewer days exposed to predators. She has also discovered that the amount of rainfall in the spring is a crucial factor because very dry weather leads to the death of mosquito larvae as their habitat dries. Mosquitoes are a concern to Arctic residents and wildlife because for one, they endlessly harass residents and potentially restrict an already limited tourism season. Secondly, they can cause health declines in caribou, which are an important subsistence resource for many Greenlanders. Dr. Culler completed her Ph.D. in 2013 but she is still engaged with research and outreach in Greenland as a postdoctoral researcher at Dartmouth's Institute of Arctic Studies.



#### RUTH HEINDEL, PH.D. STUDENT EARTH SCIENCES

**R**uth studies soils, a valuable resource for Greenland that supports natural ecosystems and also agricultural activity in South Greenland. Specifically, she studies past and present wind-driven soil erosion, a process that threatens soil resources by removing soil and disturbing vegetation. During the summers of 2012 and 2013, Ruth collected spatial data describing eroded areas in the Kangerlussuag region. Additionally, she measured lichen diameters in order to estimate past and present rates of soil erosion. In the spatial analysis lab at Dartmouth, Ruth has developed a land cover classification for the Kangerlussuaq region that identifies eroded areas from satellite imagery. She has found that eroded areas generally occur on steep south-facing slopes, and are much more common closer to the Greenland Ice Sheet. Ruth's lichenometry data show that ongoing soil erosion has the potential to remove valuable organic matter and disturb vegetation in dry regions like Kangerlussuaq. Ruth's work is crucial for understanding how soil erosion has changed during past climate fluctuations and allows for more precise predictions of what will happen to soil erosion as the climate continues to change.

#### KAITLIN KEEGAN, PH.D. ENGINEERING SCIENCES

Kaitlin studies firn, the top 100 meters of an ice sheet that contains snow layers that are compacting are undergoing the process of becoming glacial ice. Firn is where climate information gets recorded into the ice sheet. If we understand how climate information gets recorded then we can understand how climate has changed naturally in the past. In 2009, Kaitlin and colleagues drilled an 80-meter deep core of firn layers at NEEM camp, in Northern Greenland. The core was shipped to a lab in the U.S. where they've studied the various layers and their properties. One significant finding was a layer in the firn that formed in 1889 and indicated a widespread melt event over the entire surface of the Greenland Ice Sheet. In 2012, after a visit to Summit Station, Kaitlin discovered that most of the surface of the ice sheet melted in 2012 as well. Kaitlin's results show that these melting events are caused by warm summers where large wildfires take place in North America and Siberia. The wildfires produce ash that reaches the ice sheet, darkens the surface, increases sunlight absorption, and speeds up melting. Kaitlin's research highlights the importance of the Greenland Ice Sheet to the global climate and helps to predict how future changes will affect the rest of the world. Dr. Keegan recently moved to Denmark to begin a postdoctoral position at the Center for Ice and Climate at the University of Copenhagen where she continues her work on Greenland Ice Sheet dynamics.

#### BENJAMIN KOPEC, PH.D. STUDENT EARTH SCIENCES

Ben studies the current state of the hydrologic cycle across Greenland and surrounding regions and how it might change with a warming climate. In 2011 and 2012, Ben traveled to Kangerlussuag, Greenland, to measure water chemistry in lakes and water vapor concentrations in the air. Together with his colleagues, they ultimately found that many of the lakes are declining in size as a result of very high evaporation rates and low precipitation. He also found that a strong interaction in the coastal regions between glacial air masses over the ice sheet and marine air masses is an important feature of the local climate. Ben also collected samples of precipitation from all around Greenland with the help of collaborators, including a teacher and students in Ikerasaarsuk and scientists at Danmarkshavn and Summit Station. Analysis of these samples showed a significant relationship between the amount of sea ice and the source and amount of precipitation. Less sea ice increases evaporation from water bodies in the Arctic and thus increases precipitation. For Greenland, this means that as sea ice continues to decline, precipitation is likely going to increase. Changes to the amount of rain and snow will impact the lifestyles of people around Greenland, along with the ecosystems and even the ice sheet.

#### LAURA LEVY, PH.D. EARTH SCIENCES

The future of the Greenland Ice Sheet is uncertain due to modern day climate change. Laura looks at how the Greenland Ice Sheet and glaciers in Greenland have responded to climate changes during the past 11,500 years in order to help understand how it will change in the future. She uses detailed mapping and surface exposure dating of glacier deposits and analyses of glacial lake sediments. Her research shows that the western margin of the Greenland Ice Sheet, near Kangerlussuag, was behind its present limit from 6,500 years ago to the mid 19th century. Laura has also developed a climate record along the margin of the ice sheet near Scoresby Sund, in eastern Greenland, which shows that over the last 10,000 years, glaciers responded to long-term (for example, changes in the intensity of incoming solar radiation) and also to short-term climate changes that have occurred over the past few thousand years. Laura's research helps determine a baseline for future ice sheet and glacier fluctuations and can also be used by climate scientists for calibrating ice sheet models that forecast how the ice sheet will change in the future. Dr. Levy graduated in 2014 and is continuing her research in Greenland as a postdoctoral researcher at Arhus University in Denmark.



(top) Kangerlussuaq International Airport. (bottom) IGERT students and faculty across disciplines share knowledge in the field.

#### THOMAS OVERLY, PH.D. STUDENT EARTH SCIENCES

Combining a background in remote-sensing, glaciology, and cultural geography, Thomas examines how people can integrate knowledge to best understand and prepare for polar environmental change. Thomas is interested in the future of the Greenland Ice Sheet (GIS) by understanding rates of snow accumulation and loss to determine rates of mass balance change through time. He uses methods from satellite remote sensing and the direct measurement of snow accumulation on the ice sheet made during ground traverse expeditions from the northwest coast of Greenland to Summit Station in the deep interior. Prior to IGERT he was a Fulbright Grantee traveling throughout coastal Greenland with hunters and fishers examining the potential for interweaving local Greenlandic environmental knowledge and the current scientific understanding of climate change. Environmental knowledge generated by living in Greenland and relying upon its resources for survival interwoven with environmental knowledge formed from remote sensors provides a richer understanding of the reality of global climate change. Measurements of the mass balance of the GIS are central to predicting future sea level rise and in providing policy makers with critical information on the size and rate of sea level rise. Coastal communities in Greenland and throughout the Arctic need this information to anticipate and adapt to environmental change.

#### CHRIS POLASHENSKI, PH.D. ENGINEERING SCIENCES

Chris studies the Greenland Ice Sheet (GIS), which is the second largest ice cap in the world and contains 10% of Earth's glacial ice. In the past several years, melt on the GIS has been increasing and contributing to sea level rise, but understanding how rapidly the ice sheet will melt in the future remains fairly limited. Chris has executed two long traverses on the GIS to determine what controls the amount of sunlight absorption, and thus melt, on the surface of the ice. In 2012, a number of major wildfires in the Northern Hemisphere during late spring and early summer resulted in large depositions of black carbon onto the GIS, darkening the ice in a way that may have increased sunlight absorption and thus the amount of melt. The possibility that increased fire activity in places like Siberia, which is predicted in a warming climate, could be linked to increased melt on the GIS shows the interconnectedness of our world. With global sea level potentially threatening the homes of hundreds of millions of people and billions of dollars of coastal infrastructure, understanding future melt on the GIS of great importance. This research has informed people around the world on the importance of climate change and sea level rise, and has had a profound impact on the international dialogue about climate change mitigation and adaptation strategies. Dr. Polashenski continues his research in Greenland as a Research Geophysicist at the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory.

#### KRISTIN SCHILD, PH.D. STUDENT EARTH SCIENCES

Kristin is studying specific environmental controls, such as warming temperatures, that are driving an increase in ice mass loss through Greenland's tidewater glaciers. She uses remote sensing (satellite imagery and time lapse cameras taking pictures of the glacier terminus) to determine how much of the glacier is experiencing melt and when meltwater exits the glacier and enters the fjord. The timing between melt onset and when the meltwater emerges gives her an idea as to how the meltwater travels through and below the glacier. Kristin and her colleagues have found that the fastest flowing glaciers episodically release meltwater rather than constantly discharging water through efficient subglacial networks. A buildup of water beneath the glacier creates pressure and causes these glaciers to move faster. Greenland has the potential to contribute 6-7 meters of global sea level rise predominantly through ice mass lost out of large tidewater glaciers. Currently, these glaciers have discharged enough ice and meltwater to alter the fjord stratification. This change around the Greenland coast can influence the fish and animal populations that are important subsistence resources for local communities.

#### JESSICA TROUT-HANEY, PH.D. STUDENT ECOLOGY AND EVOLUTIONARY BIOLOGY

Jess studies how climate change affects high latitude aquatic ecosystems, specifically their physical, biochemical, and biological properties. She studies how differences in lake chemistry and morphometry of low-nutrient Arctic lakes affect the abundance of cyanobacteria and cyanotoxins in southwestern Greenland. In the summer of 2013, Jess surveyed 19 lakes of varying size and depth between Kangerlussuag and the Greenland Ice Sheet in southwestern Greenland. She ran sonar transects across each lake in order to generate maps of lake basins. Additionally, she collected lake water, phytoplankton, and zooplankton samples in order to examine how nutrients, species composition and cyanobacterial toxins vary among lakes. Her preliminary results demonstrate that high-latitude lakes have the potential to support toxigenic cyanobacteria, and that activity in the benthos may be a significant contributor to both lake productivity and toxicity. Cyanobacterial blooms are of increasing ecological and economic concern worldwide, because they threaten the health of aquatic food webs and the safe use of freshwater for recreation and drinking water supply.



(top) Jessica Trout-Haney collected samples from 19 lakes in Greenland to determine how climate change affects high latitude aquatic ecosystems. (bottom, L to R) Julia Bradley-Cook, Marcus Welker, and Sam Fey measure the release of greenhouse gases from tundra soil in Kangerlussuaq, Greenland.

#### CHRISTINE URBANOWICZ, PH.D. STUDENT ECOLOGY AND EVOLUTIONARY BIOLOGY

Christine studies the pollinators and plant-pollinator interactions that are beneficial for flowing plants in Greenland's tundra ecosystem. She is interested in how variation in plant density and temperature influence the number of pollinators that visit flowers and the number of fruits a plant produces. She is also collecting data on parasites of bumblebees in Greenland. In 2013, she counted the numbers of insects visiting flowers in six sites around Kangerlussuaq that were subjected to different wind conditions. She collected and identified insects at these sites, and collected and identified pollen off their bodies to determine the plants that each insect visits. In the summer of 2014, Christine will determine how variation in temperature in Kangerlussuaq affects the pollination and fruit set of blueberry as well as a few other plants. Climate change is expected to cause drastic changes in vegetation in Greenland, and many of these changes will be mediated by the availability and composition of pollinators.

#### CHELSEA VARIO PETRENKO, PH.D. STUDENT ECOLOGY AND EVOLUTIONARY BIOLOGY

Arctic soils contain more than half of the soil carbon that is stored worldwide. Because microorganisms are more active at higher temperatures, warming temperatures in the Arctic could cause a significant release of carbon from soils to the atmosphere, creating a positive feedback to climate change. Chelsea is measuring the sensitivity of Greenlandic soils to warming temperatures and determining if and how vegetative cover (shrub versus grass-dominated) influences belowground soil carbon dynamics. During the summer of 2012, Chelsea and her colleagues collected 20 deep soil cores from two locations near Kangerlussuag, Greenland, a near-ice zone and a zone further away from the ice sheet. They are measuring soil texture, pH, carbon and nitrogen content, and doing sequential carbon extractions. So far, her results indicate significant differences in the amount of carbon in grass versus shrub-vegetated areas that persist to 60 cm deep in the mineral soil profile. As shrubs continue to expand in a warming Arctic, measuring the consequent changes in belowground carbon dynamics improves our understanding of how soils may contribute to further climate warming.

#### BENJAMIN WALKER, PH.D. STUDENT ENGINEERING SCIENCES

Ben studies ways in which to conduct safe crevasse detection for supply traverse personnel through robotics research. Each year a heavy equipment resupply is conducted between Thule, NEEM and Summit Camp, and this resupply must traverse heavily crevassed sections of the Greenland Ice Sheet to complete the job. Ben's research is developing a robot and instrument combination that will automatically collect and interpret this data. During his fieldwork season at Summit Camp in June of 2013, Ben increased the reliability of the solar power system of a robot the "Cool Robot." This robot tows the Ground Penetration Radar, which is used to detect crevasses. Ben and his colleagues performed multiple long-distance runs in order to determine the solar power available and the daily range of the system. This project is in support of the Supply Traverse, which decreases energy use in keeping NEEM and Summit Camp supplied for research operations by ground-hauling supplies rather than flying them in. This upgrade in Crevasse Detection is useful because the robot can be implemented in order to scout ahead, and perform the scans for the team, thereby decreasing risk for personnel.

#### SIMONE WHITECLOUD, PH.D. STUDENT ECOLOGY AND EVOLUTIONARY BIOLOGY

Simone documents plant names and uses in order to preserve traditional knowledge. Plant ranges are changing in response to a changing climate, and her data will preserve knowledge that would otherwise be lost as plant ranges shift and practitioners lose access to the same plants. During the summer of 2011, Simone worked with her collaborator, Lenore Grenoble, to document plant uses in southern Greenland (Qassiarsuk and Nanortalik) by interviewing community-recognized plant experts. She used fresh and dry plant samples, as well as photos, to speak via an interpreter with nine women and one man about names, uses, and to document pronunciation. Interviews were recorded and are archived at the University of Chicago. Simone's research demonstrates that people are using both traditional knowledge about plants, most often handed down from elders, and also contemporary knowledge, including Anne Sophie Hardenberg's cookbook of Greenlandic cuisine. Although medicinal uses account for the largest amount (~27%), the combination of the food, beverage, and spice/condiment categories make up nearly half of all uses.



Simone Whitecloud studies plant names and their uses. She has shown that people use both traditional and contemporary plant knowledge in Greenland.

#### GIFFORD WONG, PH.D. STUDENT EARTH SCIENCES

Gifford looks at the effect of climate change on the growth and decay of the Greenland Ice Sheet (GIS). He studies how changes in temperature affect our ability to assess the health of the GIS. During the summers of 2010 and 2011, Gifford collected snow samples from pits (~2 m depth) and cores (~10-100 m depth) in the northwest GIS along a traverse route that roughly connects Thule Air Base with NEEM camp and Summit Station. He took these samples back to the labs at Dartmouth College where he prepared them for chemical analyses. So far, Gifford has characterized how snow pit chemistry in the dry snow zone of the GIS is affected by percolating melt water. He also observed how the rate of change in snow accumulation is different between more coastal sites than it is in the interior of the GIS. This observation may improve our ability to model glacier mass changes with our changing climate. The mass balance of the GIS is a particular concern to Arctic residents, but also to any global citizen living in coastal regions because of the ice sheet's impact on sea level rise. Gifford's work will enable scientists to better inform policymakers on how to effectively steward for the Arctic and, in particular, Greenland.

Stratigraphy of a snow pit near Summit Station.



# OUTREACH

**A** core goal of the IGERT curriculum is developing skills to communicate our science and its links to the social and political issues of rapid environmental change in Greenland. We have presented at various outreach and education events in Greenland, on Dartmouth's campus, with the local community in Hanover, New Hampshire, and as far away as Antarctica.

In Greenland, graduate and undergraduate student researchers have participated in the Joint Committee's Joint Science Education Project (JSEP) by sharing their science with high school students and teachers from Greenland, Denmark, and the U.S. at the Kangerlussuaq Science Field School and the Arctic Science Education Week at Summit Station, Greenland. We have also made and distributed tri-lingual education materials, given presentations about our research at Katuaq in Nuuk, been interviewed for a radio program on Kalaallit Nunaata Radioa (KNR), and visited and led field trips for Greenlandic schools.

Back in the U.S., we've shared the results and implications of our projects in Greenland at several campus events, including the Graduate Women in Science and Engineering's "Science Day" for local elementary and middle school students, seminars for local residents in Dartmouth's Lifelong Learning Institute, undergraduate students involved with Dartmouth's Coalition on Climate Change, and first-year students in Dartmouth's Great Issues Scholars Program. Our efforts extend to the local community as well, with students presenting their research from Greenland in local elementary, middle, and high school classrooms and at a science pub held at a local restaurant.

We have also developed a variety of web-based outreach resources including a regularly updated blog (dartmouthigert.wordpress.com) that has over 280 posts and has received over 62,000 views. Students contribute various observations, descriptions, and stories about their experiences doing research in Greenland and other related activities. We've also created a series of educational videos based on our work in Greenland that can be accessed on YouTube (youtube.com/DartmouthIGERT). One of our videos, "Science in Greenland: It's a Girl Thing", received over 12,000 views and national press attention (see Press and News). In addition, students have developed profile videos that describe their interest and research in the polar regions, as well as a series of videos about various topics related to rapid environmental change.

We remain fully committed to our outreach and education initiatives around science in Greenland and thank the Joint Committee and our Greenlandic exchange students and colleagues for helping us develop creative and collaborative approaches to science outreach.





(top) Henriette Rassmussen from Greenland Radio interviews Chris Polashenski about his sea ice research. (bottom) IGERT fellows have created short videos on science topics for use in Greenlandic classrooms.

### **PRESS AND NEWS**

**R**esults from research and outreach conducted by students in the IGERT program have made it into the local and national news. Simone Whitecloud's ethnobotany work has been featured in Dartmouth's Graduate Forum and in Dartmouth's campus newspaper. Dr. Lauren Culler's research results showing that a warming Arctic could lead to greater numbers of mosquitoes were featured in *Nunatsiaq News*, Nunavut's leading newspaper. The Yeti robot that Ben Walker helps design and engineer has been featured in *Popular Mechanics* and *Wired*. Dr. Kaitlin Keegan's work on the Greenland Ice Sheet's widespread melt event in 2012 was reported by the *Washington Post, Science News*, Fox News, and the Environmental News Service. Most recently, her work linking this melt to wildfires has again launched her into the press, with the *Anchorage Daily News*, Reuters, Climate Central, and other prominent news sources reporting on her work. *The Boston Globe, Huffington Post*, and *The New York Times* all featured content related to our viral video, "Science in Greenland: It's a Girl Thing."



# **PEER-REVIEWED PUBLICATIONS**

**B**elow is an early and growing list of peer-reviewed scientific publications of research conducted in Greenland by IGERT fellows while students at Dartmouth. Dartmouth papers on Greenland by faculty and non-IGERT students are not included on this list, but can be found on the Institute of Arctic Studies website (dickey.dartmouth.edu).

Adolph A, Albert MR (2013) An improved technique to measure firn diffusivity. Int. J. Heat Mass Tran. 61:598-604

Adolph A, Albert MR (2014) Gas diffusivity and permeability through the firn column at Summit, Greenland: measurements and comparison to microstructural properties. The Cryosphere 8:319-328

**Keegan K, Albert MR, Baker I (2014)** The impact of ice layers on gas transport through firn. The Cryosphere Discussions 8:1095-1110

**Keegan K, Albert MR, McConnell J, Baker I (2014)** Climate change and forest fires synergistically drive widespread melt of the Greenland Ice Sheet. Proceedings of the National Academy of Sciences doi:10.1073/ pnas.1405397111

Nghiem SV, Hall DK, Mote TL, Tedesco M, Albert MR, Keegan K, Shuman CA, DiGirolamo NE, Neumann G (2012) The extreme melt across the Greenland ice sheet in 2012. Geophys. Res. Lett. 39: L20502, doi:10.1029/2012GL053611

**Levy LB, Kelly MA, Howley JA, Virginia RA (2012)** Age of the Ørkendalen moraines, Kangerlussuaq, Greenland: Constraints on the extent of the southwestern margin of the Greenland Ice Sheet during the Holocene: Quaternary Science Reviews 52:1-5

Levy LB, Kelly MA, Lowell TV, Hall BH, Hempel LA, Honsaker WM, Lusas AR, Howley JA, Axford YL (2013) Holocene fluctuations of Bregne ice cap, Scoresby Sund, east Greenland: a proxy for climate along the Greenland Ice Sheet margin. Quaternary Science Reviews 92:357-368

Lowell TV, Hall BL, Kelly MA, Bennike O, Lusas AR, Honsaker W, Smith CA, Levy LB, Travis S, Denton G (2013) Late Holocene expansion of Istorvet ice cap, Liverpool Land, east Greenland. Quaternary Science Reviews: 63:128-140

Polashenski C, Courville ZR, Benson C, Wagner A, Chen J, Wong GJ, Hawley RL, Hall D (In Press) Observations of Pronounced Greenland Ice Sheet Firn Warming and Implications for Runoff Production. Geophys. Res. Lett.

Whitecloud SS, Grenoble LA (2014) An interdisciplinary approach to documenting knowledge: plants & their uses in Greenland. Arctic 67:57-70

Grenoble LA, Whitecloud SS (2014) Conflicting goals, ideologies and beliefs in the field. In Austin PK and Sallabank J (eds) Endangered languages: Ideologies and beliefs. Oxford: Oxford University Press

Wong GJ, Hawley RL, Lutz ER, Osterberg EC (2013) Trace-element and physical response to melt percolation in Summit (Greenland) snow. Annals of Glaciology 54:52-62

Hawley RL, Courville Z, Kehrl LM, Lutz ER, Osterberg EC, Overly TB, Wong GJ (2014) Recent Accumulation Variability in Northwest Greenland from GPR and Shallow Cores Along the Greenland Inland Traverse. Journal of Glaciology 60:375-382

# SCIENTIFIC PRESENTATIONS

We have shared our research with the scientific community at various and diverse conferences, workshops, and meetings around the world. Below is a selection of first-authored talks and posters by IGERT student researchers.

Adolph A, Albert MR (2013) Gas Diffusivity and Permeability of Polar Firn at Summit, Greenland. PIRE Workshop on Firn Processes. La Jolla, California, United States

Adolph A, Albert MR (2012) Gas Diffusion and Physical Property Investigations for Polar Firn. American Geophysical Union Fall Meeting. San Francisco, California, United States

Adolph A, Albert MR (2012) Physical and microstructural properties of firn and their effects on interstitial gas diffusion. International Partnerships in Ice Core Science Open Science Conference, Giens, France

Adolph A, Albert MR (2011) Gas Diffusivity of Polar Firn. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Bradley-Cook JI, Hammond-Wagner CR, Racine P, Virginia RA (2013)** Soil carbon storage and respiration potential across a climate gradient in western Greenland. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Bradley-Cook JI, Hammond-Wagner CR, Virginia RA (2012)** Molecules in a living landscape: soil carbon and vegetation cover in a Greenland mosaic. Video and poster at NSF IGERT National Conference. Washington D.C., United States

**Bradley-Cook JI, Virginia RA (2012)** Associations between land cover and soil carbon in a west Greenland tundra landscape. Poster presented at International Polar Year Conference: From Knowledge to Action. Montreal, Quebec, Canada

**Bradley-Cook JI, Burzynski AM, Hammond-Wagner CR, Virginia RA (2011)** Land cover heterogeneity and temperature sensitive soil carbon dynamics in an Arctic landscape. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Corbett LB, Kelly MA, Osterberg EC, Lasher GE, Axford Y (2014)** Glacial sediments and landscape chronology in Thule, northwestern Greenland. Northeastern Geological Society of America Meeting. Lancaster Pennsylvania, United States

**Corbett LB, Kelly MA, Osterberg EC, Axford Y, Bigl M, Roy EP, Thompson JT (2013)** Holocene history of North Ice Cap, northwest Greenland. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Corbett LB, Osterberg EC, Kelly MA, Axford Y (2012)** Holocene paleolimnological records from Thule, northwestern Greenland. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Culler LE, Trout-Haney JV, Bradley-Cook JI, Cottingham KL, Ayres MP, Virginia RA (2014)** Freshwater ecosystems in Greenland's rapidly changing tundra: interdisciplinary research at the Institute of Arctic Studies, Dartmouth College. Thermokarst Aquatic ecosystems Workshop (THAW): Freshwater ecosystems in changing permafrost landscapes. Quebec City, Canada

**Culler LE, Albert MR, Ayres MP, Grenoble LA, Virginia RA (2013)** Building sustained partnerships in Greenland through shared science. Global Human Ecodynamics Alliance Conference, College Park, Maryland and American Geophysical Union Annual Meeting, San Francisco, California, United States

**Culler LE, Ayres MP (2012)** Aquatic insects in a warming Arctic: Effects of temperature on interactions between Arctic mosquitoes (*Aedes nigripes*) and predaceous diving beetles (*Colymbetes dolabratus*) in West Greenland. Entomological Society of America Annual Meeting, Knoxville, Tennessee, United States **Culler LE (2012)** Temperature alters interactions between Arctic Mosquitoes and their predators in snowmelt ponds in West Greenland. International Polar Year meeting. Montreal, Quebec, Canada

**Heindel R, Kelly MA, Virginia RA (2013)** Dynamics of Soil Deflation Features in Kangerlussuaq, Greenland Revealed by Variations in Lichen Diameters on Exposed Surfaces. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Keegan K, Baker I, Albert MR (2013)** The Effect of Impurities on Firn Layering at NEEM, Greenland. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Keegan K, Albert MR, Baker I (2012)** NEEM Firn Physical Properties. Partnerships in International Research and Education-International Collaboration and Education in Ice Core Science Workshop. Giens, France

**Keegan K, Albert MR, Baker I (2012)** Progress on NEEM Firn Structure Studies. Center for Ice and Climate. Copenhagen, Denmark

**Keegan K, Albert MR, Baker I (2012)** Relationship Between NEEM Firn Permeability and Diffusivity. American Geophysical Union Fall Meeting. San Francisco, California, United States

Kopec B, Lauder A, Posmentier E, Michel F, Feng X (2013) Effects of sea ice extent on Arctic precipitation through deuterium excess. American Geophysical Union Fall Meeting. San Francisco, California, United States

Kopec B, Lauder A, Feng X, Faiia A, Posmentier E, Chipman J, Tracy B (2012) Lake Water Balance near Kangerlussuaq, Greenland and their Interannual Variability. International Polar Year meeting. Montreal, Canada

**Kopec B, Lauder A, Posmentier E, Feng X (2012)** Variations of the glacio-marine air mass front in West Greenland through water vapor isotopes. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Kopec B, Lauder A, Faiia A, Posmentier E, Feng X (2011)** Lake water balance near Kangerlussuaq, Greenland and their potential response to future climate change. American Geophysical Union Fall Meeting. San Francisco, California, United States

Levy LB, Kelly MA, Lowell TV Hall BL, Applegate PJ, Howley JA, Axford YL (2013) A comparison of Holocene fluctuations of the eastern and western margins of the Greenland Ice Sheet. American Geophysical Union Fall Meeting. San Francisco, California, United States

Levy LB, Kelly MA, Applegate PJ, Arthur C, Virginia RA, Howley JA (2013) How small was the Greenland Ice Sheet during the Holocene Thermal Maximum? A rare snapshot of the Holocene extents of the southwestern margin of the Greenland Ice Sheet, Kangerlussuaq, Greenland. PALeo constraints on SEA level rise 2 meeting. Rome, Italy

Levy LB, Hempel LA, Kelly MA, Lowell TV, Hall BL (2012) Holocene glacier fluctuations, Scoresby Sund, eastern Greenland. International Polar Year meeting. Montreal, Canada

Levy LB, Kelly MA, Lowell TV, Hall BL (2011) Holocene fluctuations of Bregne ice cap, Scoresby Sund, eastern Greenland. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Overly TB, Hawley RL, Lutz ER (2013)** CryoSat-2 Waveform Shape and Signal Penetration along the 2011 Greenland Inland Traverse. European Space Agency's 3rd CryoSat-2 Users Workshop. Dresden, Germany

**Overly TB, Hawley RL, Wong GL, Osterberg EC, Courville Z (2013)** Surface conditions and error contribution to CryoSat-2 Low Rate Mode signal penetration across the Greenland Ice Sheet. American Geophysical Union Fall Meeting. San Francisco, California, United States

#### SCIENTIFIC PRESENTATIONS CONT.

**Overly TB, Hawley RL, Lutz ER (2012)** Dartmouth Team Calibration and Validation: Greenland Inland Traverse. European Space Agency's Calibration/Validation Retrieval Team Meeting. Frascati, Italy

**Overly TB, Hawley RL, Wong GJ, Osterberg EC, Courville Z, Lutz ER (2012)** Validation of CryoSat-2 Elevation Measurements along the Greenland Inland Traverse. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Polashenski C, Courville Z, Benson C, Wong GJ, Hawley R, Hall D (2013)** Pronounced warming of Greenland Ice Sheet Firn. American Geophysical Union Fall Meeting. San Francisco, California, United States

Schild KM, Hawley RL, Morriss BF (2013) What sediment plumes can tell us about the subglacial hydrology of a Greenland Tidewater Outlet Glacier. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Schild KM (2013)** Understanding the Subglacial Hydrological Environment of a Greenland Tidewater Glacier. US Climate and Variability (CLIVAR)-sponsored International Workshop (Understanding the Response of Greenland's Marine-Terminating Glaciers to Oceanic and Atmospheric Forcing). Beverly, Massachusetts, United States

Schild KM, Hawley RL, Morriss BF, Catania G, Hoffman M, Neumann T (2012) Seasonal subglacial hydrological evolution of a Greenland tidewater glacier. American Geophysical Union Fall Meeting. San Francisco, California, United States

**Trout-Haney JV, Wood ZT, Cottingham KL (2014)** Benthic colonial cyanobacteria (Genus: *Nostoc*) and the occurrence of cyanotoxins in low-nutrient arctic lakes of southwestern Greenland. Joint Aquatic Sciences Meeting. Portland, Oregon, United States

**Urbanowicz C (2013)** How does flower density affect pollination in Greenland? Third Conference for Sustainability IGERTs: Ecosystem Services for Sustainability. Portland, Oregon, United States

Whitecloud SS, Grenoble LA (2012) An interdisciplinary approach to documenting knowledge: plants and their uses in Greenland. 35th Annual Conference, Society of Ethnobiology. Denver, Colorado, United States

Whitecloud SS, Grenoble LA (2012) An interdisciplinary approach to documenting knowledge: plants and their uses in Greenland. 18th Inuit Studies Conference, Smithsonian Institute. Washington, D.C., United States

Whitecloud SS, Grenoble LA (2011) An interdisciplinary approach to documenting knowledge: plants and their uses in Greenland. International Conference on Language Documentation and Conservation. University of Manoa, Hawaii, United States

Whitecloud SS, Grenoble LA (2011) Arctic Migration, Plants and People. Dartmouth Graduate Arts and Sciences Poster Session. Dartmouth College, Hanover, New Hampshire, United States

**Wong GJ, Osterberg EC, Courville ZR, Hawley RL, Lutz ER, Overly TB (2012)** Geochemical cycling and depositional patterns across the northwest region of the Greenland Ice Sheet as determined from trace element chemistry. American Geophysical Union Annual Meeting. San Francisco, California, United States

**Wong GJ, Osterberg EC, Hawley RL, Courville ZR (2010)** Artificially induced melt in firn at Summit, Greenland. American Geophysical Union Annual Meeting. San Francisco, California, United States

**Wong GJ, Osterberg EC, Hawley RL, Caughey SK, Courville ZR, Howley J, Lutz ER, Overly TB (2013)** Coast-to-interior gradients and recent trends in physical and chemical properties of near-surface snow and firn in northwest Greenland. American Geophysical Union Annual Meeting. San Francisco, California, United States

**Wong GJ, Overly TB, Courville ZR, Hawley RL, Lutz ER, Osterberg EC (2011)** Thule to Summit: Using the physical and chemical properties of shallow firn to describe glacier faces, accumulation, and 55 years of change. American Geophysical Union Annual Meeting. San Francisco, California, United States

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