Witness the ARCTIC

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In this Issue

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Study of Environmental Arctic Change (SEARCH) Update

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This update on the Study of Environmental Arctic Change (SEARCH) program (http://www.arcus.org/search-program) provides an introduction to SEARCH's new Science Steering Committee (SSC) members (https://www.arcus.org/search-program/structure/ssc-committee) and cross-disciplinary working groups; discusses opportunities to connect with SEARCH activities at the upcoming SEARCH events at the Fall Meeting of American Geophysical Union (https://www.arcus.org/search-program/meetings/2016/agu); and includes a summary of a Sea Ice Action Team Knowledge Exchange workshop. A perspective on the outcomes of the recent White House Arctic Science Ministerial, by SEARCH Executive Director Brendan Kelly, is available here (https://www.arcus.org/witness-the-arctic/2016/3/article/26072).

SEARCH Welcomes Two New Science Steering Committee Members

At a SEARCH SSC meeting in August, the SSC voted to elect two new members. Dr. Amy L. Lovecraft and Ms. Raychelle Aluaq Daniel will serve three-year terms, taking over the seats recently held by Dr. Stephen Vavrus (University of Wisconsin-Madison) and Ms. Karen Pletnikoff (Aleutian Pribilof Islands Association).

Dr. Amy Lauren Lovecraft (University of Alaska Fairbanks)

Dr. Lovecraft is a Professor of Political Science at the University of Alaska Fairbanks where she has been a member of the faculty since 2001. Working to foster interdisciplinary engagement among students and faculty, she is active in the Arctic and Northern Studies program and an International Arctic Research Center Affiliate at UAF. In her research, Dr. Lovecraft explores power dynamics in social-ecological systems. In particular, how will the changes in climate affect the policy relationships among various and competing Arctic interests? She has served two terms as a member of the U.S. National Academies Polar Research Board. Currently, as the Principal Investigator on a four-year National Science Foundation grant, she leads a team working with resident experts in the Northwest Arctic and North Slope Boroughs on scenarios development asking "what is required for healthy sustainable communities in Arctic Alaska by 2040?" She received her B.A. in International Studies in 1994 from Trinity University and her Ph.D. from the University of Texas at Austin in 2001, with a concentration on American political development, public policy, and political theory.

Raychelle Aluaq Daniel (U.S. Department of the Interior)

Ms. Daniel currently works as a Policy Analyst in the U.S. Department of the Interior's Office of Policy Analysis. Previously she has served as a Senior Associate with the Pew Charitable Trusts, focusing on Pew's work in the U.S. Arctic, as well as a Conservation Scientist with The Ocean Conservancy. Ms. Daniel grew up in Tuntutuliak, Alaska where the Kuskokwim River meets the Bering Sea in a Yup'ik community inextricably linked to a subsistence way of life, where fish and marine mammals were prominent. Her background influenced her to study marine mammal ecology. She earned a B.S. in Biology at the University of Alaska Southeast in 1999 and a M.S. in Zoology from the University of British Columbia Fisheries Centre in 2003. She has worked on several major research projects on pinnipeds in the Beaufort Sea and the Gulf of Alaska and has natural resource management experience that includes ecological monitoring, marine ecology, and conservation science.

New SEARCH Working Groups Announced

In August, the SEARCH SSC approved the formation of new working groups to facilitate cross-cutting research in the following areas:

Coastal Resilience

The Coastal Resilience Working Group will convene broad-thinking experts to assess the ecological, morphological, and socioeconomic components of the Arctic's coastal resilience (as defined by the Intergovernmental Panel on Climate Change (http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=297#box6-5)) and recommend to the SEARCH SSC research areas that would benefit from greater coordination and multi-disciplinarity. This working group is being led by Dr. Betsy Baker (University of Vermont).

Methane Budget Working Group

A Methane Budget Working Group has been convened by the SSC to assist in the planning, facilitation, and reporting on an international workshop to reconcile methane budgets in the northern permafrost region, tentatively scheduled for the first quarter of 2017. This workshop will bring together researchers studying methane from terrestrial sources (primarily wetlands and lakes), coastal sources, and inferences of fluxes based on atmospheric methane concentrations. This working group effort is led by Dr. A. David McGuire (University of Alaska Fairbanks). Funding support for the upcoming workshop has been generously committed by the National Aeronautics and Space Administration (https://www.nasa.gov/), the U.S. Arctic Research Commission (https://www.arctic.gov/), and the U.S. Geological Survey (https://www.usgs.gov/).

Arctic Future Scenarios

The Arctic Future Scenarios Working Group will outline steps for SEARCH to produce synthetic Arctic scenarios as well as a successful Arctic Futures 2050 Open Science Meeting currently targeted for 2019. More details on this working group will be available soon.

SEARCH Events at the Fall Meeting of the American Geophysical Union (AGU)

SEARCH Town Hall

Date: Monday, 12 December 2016

Time: 11:15am - 12:15pm PT

Location: San Francisco Marriott Marquis, Foothills E - 780 Mission St, San Francisco, CA 94103 or online for live webinar.

At this open Town Hall, SEARCH leadership will discuss how researchers, agencies, and stakeholders can contribute to and participate in SEARCH's "Permafrost", "Sea Ice", and "Land Ice" activities; help steer the work of new cross-disciplinary working groups on coastal resilience and Arctic scenarios; and introduce SEARCH's new "Knowledge Pyramids." SEARCH is constructing Knowledge Pyramids to make scientific knowledge available on-line to decision makers, journalists, students, and scientists in diverse fields. Each knowledge pyramid answers a specific question about environmental change in the Arctic through tiers of increasing detail. The top of the pyramid provides—in accessible language—a succinct synopsis of what we know about the question in the form of a 1–2-page brief suitable for policymakers. Published reports back up the brief in lower tiers. The second tier down contains summaries more detailed than the brief; below that are published conceptual and technical syntheses; and, finally, the base of the pyramid is made of detailed technical reports focused on specific details—the scientific building blocks.

Broad participation enhances SEARCH's success and we invite everyone interested in the Arctic to learn more about becoming part of our community at this event. Light refreshments will be provided. Students and early career investigators are encouraged to participate.

In addition to the in-person event, an online webinar stream will be available for those not attending AGU. To join via an online participant, please register at: https://www.arcus.org/search-program/meetings/2016/agu/townhall.

Registration is not required for in-person attendance. For more information, please contact Brit Myers: brit@arcus.org.

Permafrost Carbon Network Annual Meeting

The 6th annual meeting of the Permafrost Carbon Network will take place on Sunday, 11 December prior to the Fall AGU meeting. Bringing together the international community of permafrost researchers, the program for the day will feature a series of presentations and speed talks to introduce break-out session topics. Meeting participants will then have the opportunity to split into smaller break-out groups to discuss the Permafrost Carbon Network's ongoing and new synthesis research products. The meeting is open to all members of the scientific community with an interest in permafrost carbon research synthesis.

To register for this event, please visit: https://www.arcus.org/search-program/meetings/2016/agu/pcn

For more information about this event, please contact Christina Schädel at 928-523-9588 or christina.schaedel@nau.edu.

Other SEARCH Events at AGU

In addition to the events above, SEARCH will be active in several oral and poster sessions; more information is available at: https://www.arcus.org/search-program/meetings/2016/agu.

Towards a Sea Ice Action Network to Support *Knowledge for Action*

The SEARCH Sea Ice Action Team (https://www.arcus.org/search-program/sea-ice/team) held its First SEARCH Knowledge Exchange Workshop on the Impacts of Arctic Sea Ice Loss (https://www.arcus.org/search-program/sea-ice/activities) in Washington, D.C., 14–15 September 2016. The goals were three-fold: 1) to begin building a new network of researchers, Arctic residents, decision-makers, and other Arctic stakeholders to exchange knowledge and experience regarding the socio-environmental implications of an ice-diminishing Arctic; 2) to identify new opportunities for relevant synthesis science; and 3) to discuss avenues for co-communicating knowledge for action to diverse audiences. A Sea Ice Action Network (SIAN) will foster collaboration and communication related to impacts of Arctic sea ice loss with the goal of making science and research more relevant to those on the frontlines of policy and practice. The Sea Ice Action Team, led by Jennifer Francis (Rutgers University) and Henry Huntington (Huntington Consulting), is in the midst of developing Knowledge Pyramids that provide timely and tiered information about the impacts of sea-ice loss,

organized across a series of high-level topics, such as the links between Arctic sea ice loss and marine ecosystems, coastal communities, and mid-latitude weather. This web resource will enable the scientific community to collaboratively disseminate important scientific knowledge, while providing a trusted and reliable resource for decision-makers, the media, and the public. Look for the "Sea Ice Matters" website and SIAN blog to be released this fall. For more information, please contact SIAN Coordinator Matthew Druckenmiller at druckenmiller@nsidc.org.

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The First Meeting of Arctic Science Ministers: A Study of Environmental Arctic Change (SEARCH) Perspective

By: Brendan Kelly, SEARCH Executive Director

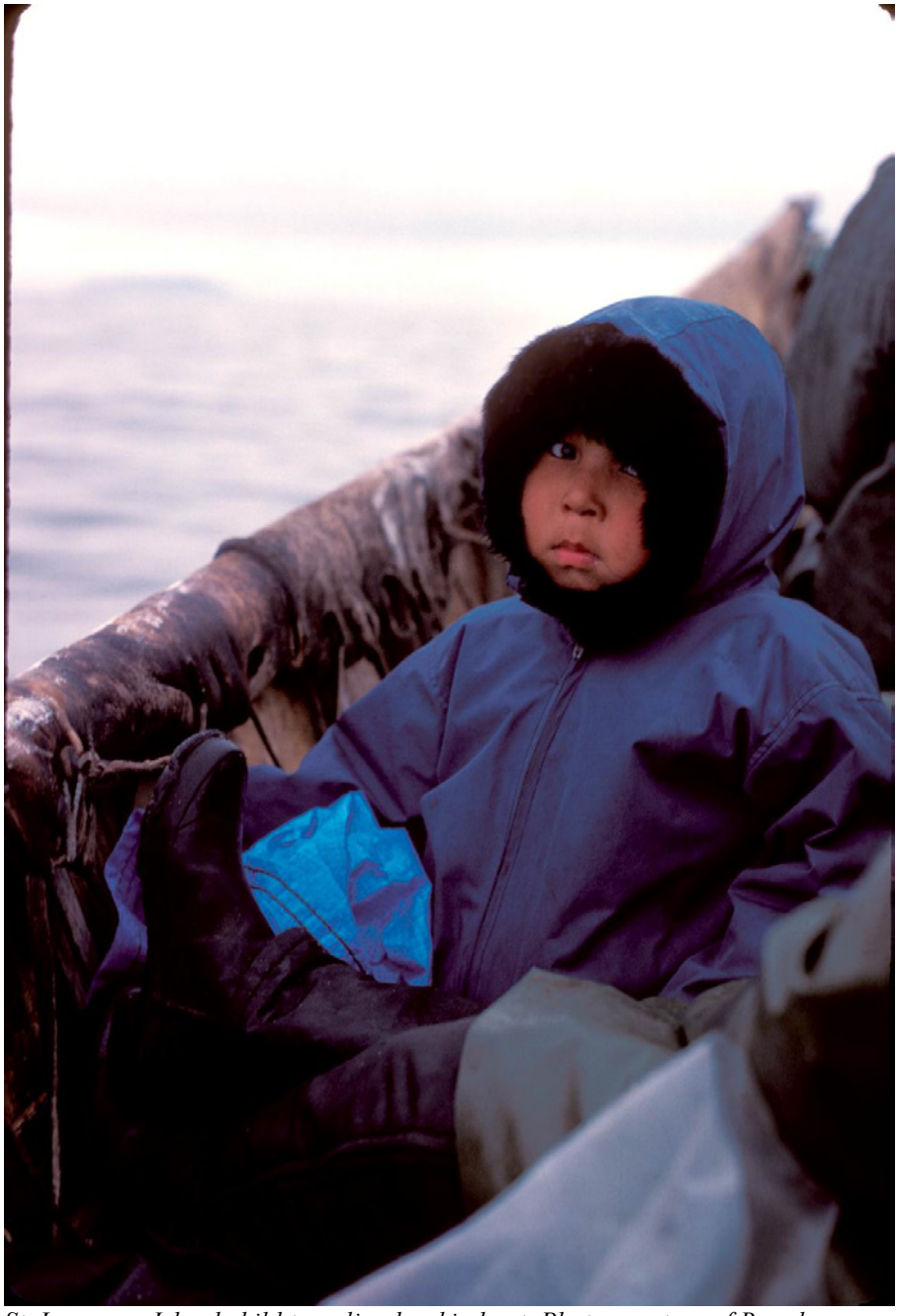
The Obama Administration advanced Arctic science and policies in many important ways, including moving the Interagency Arctic Research Policy Committee into the White House; creating collaboration teams to implement the Arctic research plan; creating and implementing the first National Strategy for the Arctic Region; creating the Arctic Executive Steering Committee in the White House; and hosting the first-ever meeting of Sciences Ministers from Arctic countries (https://www.whitehouse.gov/blog/2016/05/13/white-house-arctic-science-ministerial-september-28-2016).

If all the Ministerial accomplished was prompting briefings of Science Ministers from 25 countries on science needs in the Arctic, it would have been an important advance, but the Ministerial promises more if the effort can be sustained. Whether galvanizing the international community to invest in understanding what is happening in the Arctic and the global implications is sustained will depend not only on future administrations and their international partners, but also on the scientific community. It will depend on our continued research and communications.

SEARCH (https://www.arcus.org/search-program) and the community it represents are dedicated to the call for "knowledge to action" that emanated from the International Polar Year. Thus, we informed the U.S. Congress and the media of our current knowledge of—and concern about—the state of the Arctic through briefings to Congress, our Arctic Alerts event in July 2016 (https://www.arcus.org/search-program/meetings/2016/arctic-alerts); the development of "Knowledge Pyramids," online resources that answer a specific question about environmental change in the Arctic through tiers of increasing detail; and a keynote address at the Arctic Science Ministerial.

In 15 minutes, that keynote had to summarize science challenges and global implications of a rapidly changing Arctic, a task only possible because of the hard work of the Arctic research community and SEARCH's dedication to knowledge to action. To draw in the Ministers, I built the address around a

story many in the Arctic research community have heard about the understanding of albedo by St. Lawrence Island hunters. Readers of *Witness the Arctic* already are drawn in, so I shall not repeat the story here, but I shall summarize the remarks.



St. Lawrence Island child traveling by skin boat. Photo courtesy of Brendan Kelly.

We understand that the changing albedo of the Arctic Ocean and lands as one of the key amplifiers of global warming. The impact is especially great in the Arctic Ocean where enhanced surface warming melts sea ice, which further reduces the reflectivity: a self-perpetuating cycle. As a result, sea ice loss is contributing strongly to accelerated warming in the Arctic, where temperatures are now increasing more than two times faster than for the planet as a whole.

These changes are unprecedented in the course of civilization. Civilization evolved in the shadow or—more accurately—in the reflection of a frozen Arctic. Where we grow food, the location of population centers, and much more came about in a geophysical context dependent on a frozen Arctic. Hence, we have no precedents for dealing with the very rapid melting that is occurring. We need aggressive policies informed by science, and we need them very soon.

The scientific challenges include how people are—and will continue to be—impacted by ice melt and

permafrost thaw, the main amplifiers of the warming induced by high concentrations of greenhouse gases. The resulting unprecedented change in the Earth's energy balance calls for extraordinary research to understand the impacts on people both inside and outside of the Arctic region.

Some of the most dramatic impacts on people in the Arctic stem directly from declining sea ice. When I first visited the Arctic in 1978, the area covered by sea ice in September averaged 7 to 8 million square kilometers. Since then, the summer ice has shrunk to nearly half that size. That loss of ice has resulted in a warming signal equivalent to 25% of the warming attributed to greenhouse gas emissions.

In an underdeveloped region with minimal roads, ports, and other infrastructure, Indigenous hunters depend on sea ice as an extension of land. They travel over that ice to access their marine foods. In the past few decades, however, an area of sea ice twice the size of Alaska has been lost—diminishing essential access to important foods.

Moreover, sea ice decline is outpacing the model projections, suggesting that some key process or processes are not understood. But, even the most optimistic models forecast a dire future for Arctic sea ice. The models make clear that unless we reduce considerably the burning of fossil fuels, summer sea ice—in a few decades—will be down to 1/8th of the area it covered when I first visited the region. We obviously need to accelerate understanding and model development.

Diminishing sea ice also threatens species dependent on ice as habitat and, in turn, threatens people who have depended on those species for millennia. Walruses and a host of other species are especially adapted to living on, in, or directly below sea ice. The much-reduced ice cover of the near future may or may not provide an adequate refuge for ice-dependent species.

Many of those species will be depleted—if not driven to extinction—by diminished sea ice cover. Walrus mortalities of the sort that Alex Akeya of Savoonga and I investigated in 1979 are becoming more common as walruses are forced to coastlines by shrinking ice cover. But those coastlines themselves are under assault. Reduced sea ice cover allows waves to batter shorelines. In northern Alaska, rates of coastal erosion have doubled in the past 50 years. The average rate of loss is now 1.5 meters per year with some areas losing 20 meters per year. Homes, airports, oil wells, and ice cellars are being lost.

Nor, is infrastructure damage limited to the coasts. Permafrost underlies one quarter of Northern Hemisphere landscapes. Thawing permafrost is altering those landscapes and undermining

Young walruses on ice in the Chukchi Sea. Photo courtesy of Brendan Kelly.

infrastructure across the entire Arctic.

While diminished access to food, ecosystem changes, and collapsing infrastructure are impacting Arctic residents, people at lower latitudes increasingly will also feel the consequences of the changing Arctic.

For example, permafrost thaw will impact people outside of the Arctic by amplifying atmospheric concentrations of greenhouse gases. As permafrost thaws, organic compounds become available for decomposition by microbes, releasing greenhouse gases. At current rates of warming, an additional 150 billion tons of permafrost carbon could be released, primarily as carbon dioxide, during this century. For perspective, that is equivalent to about 22 years of carbon emissions by the United States at current rates.

Nor, are global impacts limited to permafrost thaw. Since the year 2000, the volume of water annually entering the ocean from melting glaciers and ice sheets has increased by more than 500% in Greenland and close to 200% in the Gulf of Alaska. The combined total is now contributing close to 1 mm in sea level rise annually. Projections of sea level rise in this century range from less than 1 meter to over 2 meters depending on emissions scenarios and assumptions about how ice sheets will respond. Millions of homes and hundreds of billions of dollars in infrastructure will be imperiled. Thus, the well being of hundreds of millions of people living in coastal areas will depend on accelerated research and more precise estimates of future sea level rise.

In contrast to land ice, sea ice does not contribute directly to sea level rise, but it does contribute indirectly through its amplification effect on atmospheric temperatures. And no location is immune to the changes in global weather patterns linked to the loss of sea ice in the Arctic. Increasingly persistent weather regimes are leading to longer and more severe droughts, cold outbreaks, heat waves, and wildfires.

With larger portions of the Arctic Ocean free of ice for longer periods, ocean heat is escaping into the Arctic atmosphere. One result is a reduced differential in atmospheric temperatures between the Arctic and mid latitudes, and that reduced differential weakens the jet stream's west-to-east winds. These wavier jet streams are believed to be responsible for more frequent extreme weather events, such as stormy winters and flooding in Europe, Asia, and North America.

We urgently need to understand the complexities of the whole earth system—an unprecedented scientific challenge that no nation can meet alone. We need scientific leadership at the highest levels of governments to ensure that we expeditiously harness our collective scientific talent and resources to meet a challenge unlike any civilization has previously faced.

We in the scientific community need to sustain and amplify observations, process studies, and models to inform the global response the rapid environmental changes in the Arctic. Thus, we must shoulder much of the responsibility to make good on the Arctic promises of the Obama Administration and the Arctic Science Ministerial.

For another perspective on the Arctic Science Ministerial, see this article by Robert Rich, ARCUS Executive Director (https://www.arcus.org/witness-the-arctic/2016/3/article/26061)

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500 Predictions: Looking Back on Nine Years of the Sea Ice Outlook

By: Lawrence C. Hamilton, Carsey School of Public Policy, University of New Hampshire; and Julienne Stroeve, National Snow and Ice Data Center, University of Colorado

Summer sea ice cover on the Arctic Ocean has been declining since the 1970s, as the Arctic itself warmed. In 2007 the sea ice decline steepened abruptly to reach a new record low (Stroeve et al. 2008). Even scientists with their eyes on the Arctic were surprised by the sudden drop, which focused attention on the need for better prediction. Where was Arctic change heading, and how fast?

Responding to this need to improve prediction, the Study of Environmental Arctic Change (SEARCH) (https://www.arcus.org/search-program) organized the Sea Ice Outlook (SIO) (https://www.arcus.org/search-program/seaiceoutlook), to which any group or individual could contribute their prediction of how many square kilometers (km^2) of sea ice would remain in September. The initiative has been highly successful, drawing 39 contributions to its early June, July, and August cycles in 2008. The number rose steadily to reach 105 in 2016, with a total of 589 over the nine-year series. In 2014, the SIO was incorporated into a new project, the Sea Ice Prediction Network (SIPN) (https://www.arcus.org/sipn).

Figure 1 charts this rise, distinguishing different types of methods such as statistical, modeling, or a catch-all group termed "heuristic." Among modeling efforts, we see increasing sophistication as more contributions employ coupled models that take into account the dynamics of ice, ocean, and atmosphere.

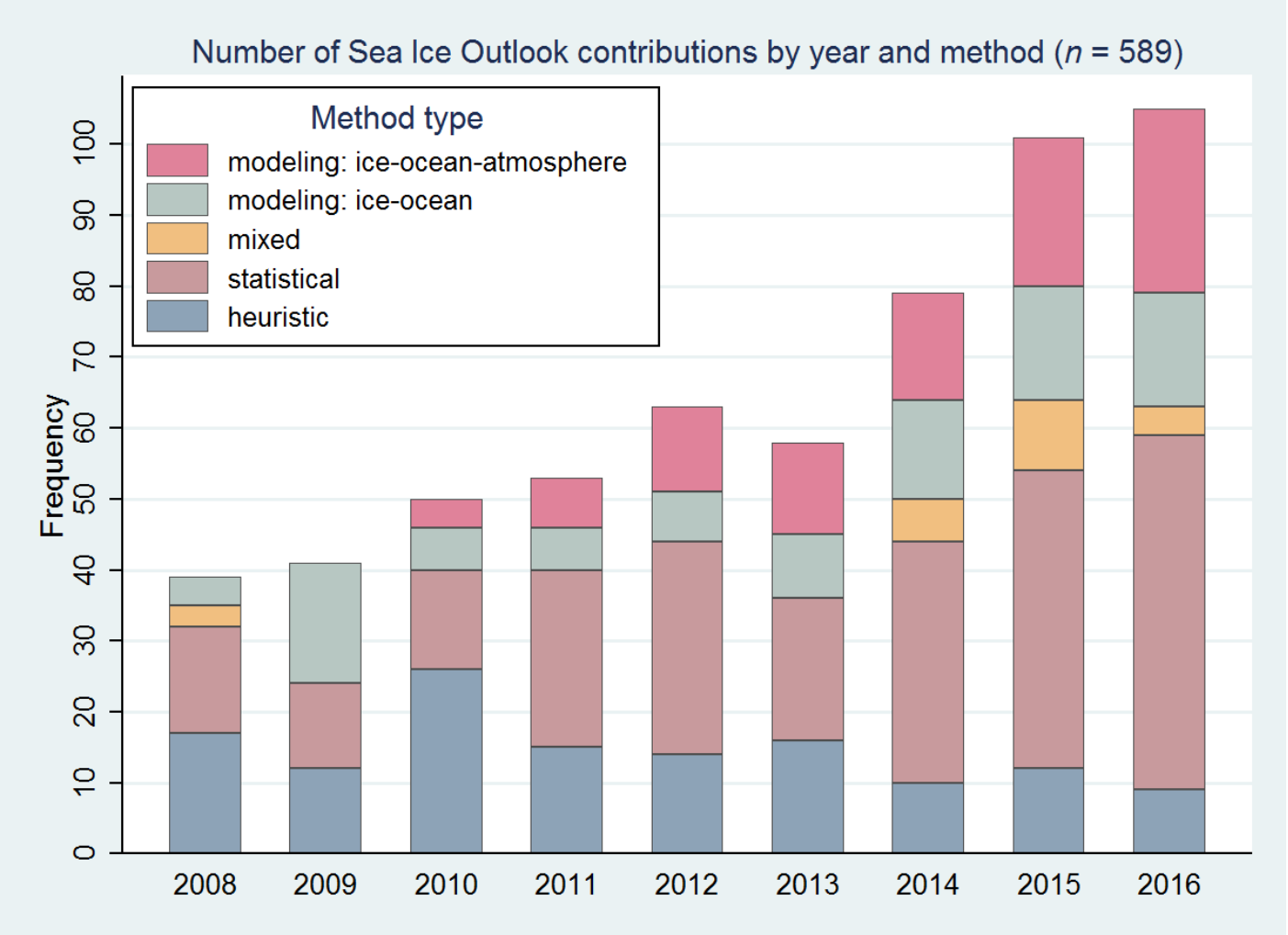

Figure 1: Number of contributions to the SEARCH/SIPN Sea Ice Outlook over 2008–2016, by type of method. Figure updated from Hamilton and Stroeve (2016).

How accurate were the predictions? Several papers have analyzed their performance, comparing individual and median SIO predictions with the actual extent of sea ice each September from 2008 through 2013 (Stroeve et al. 2014) or through 2015 (Hamilton and Stroeve 2016). Figure 2 updates these comparisons through 2016. The graph shows median SIO contributions from July each year from 2008 to 2016, along with the 1979–2016 satellite era record of September sea ice extent and its downward trend.

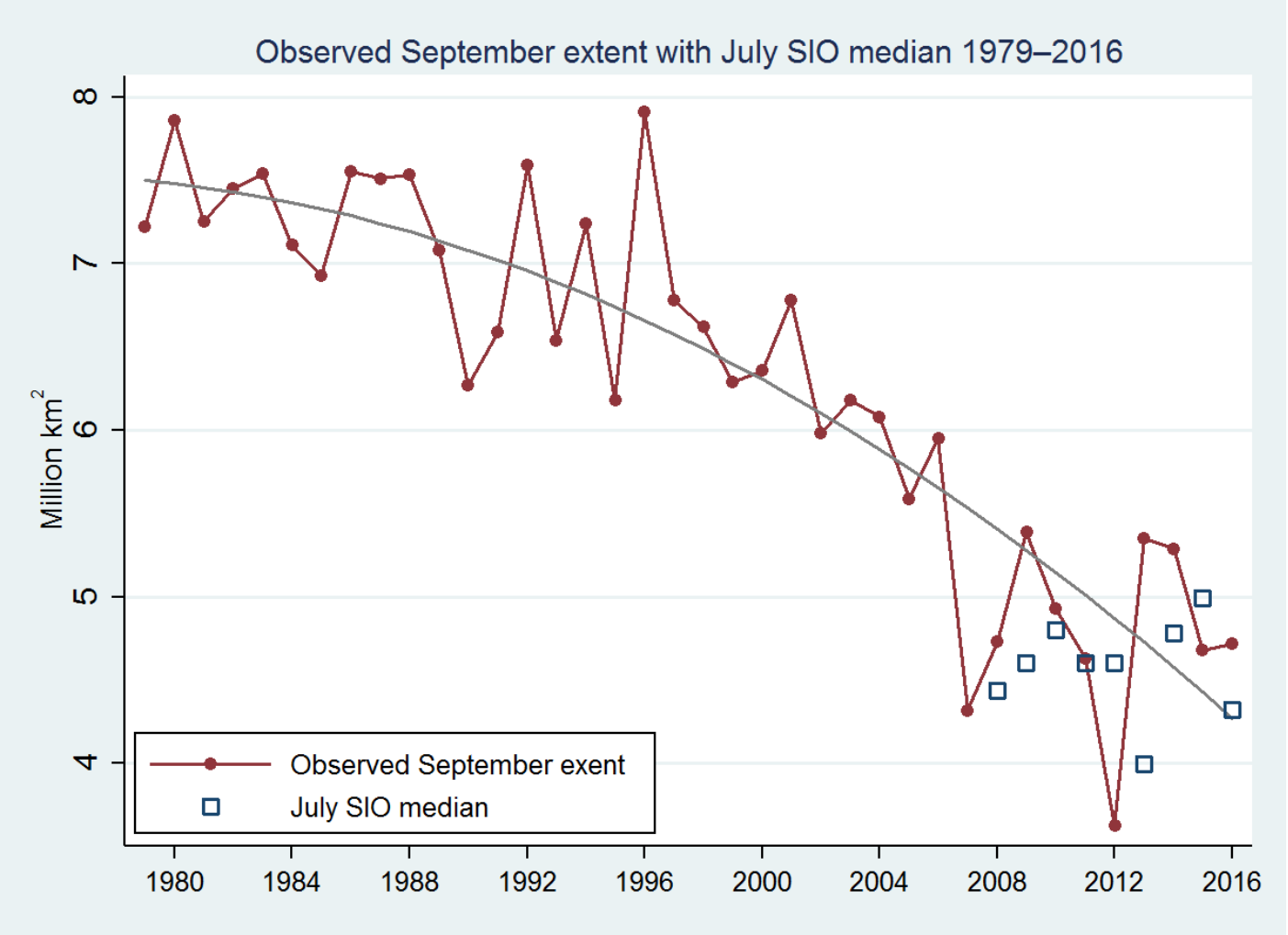

Figure 2: Observed September sea ice extent, with median SIO predictions over 2008–2016. Figure updated from Hamilton and Stroeve (2016).

Close inspection finds a pattern of "easy and difficult" prediction years, corresponding roughly to the difference between climate and weather (for a summary with additional data, see Hamilton and Stroeve 2014, Witness the Arctic, Spring 2014 (https://www.arcus.org/witness-the-arctic/2014/2/article/21066)). Easy years are those when sea ice extent is close to its long-term downward trend, which reflects Arctic warming, and is illustrated by the smooth curve in Figure 1. In difficult-to-predict years, summer wind and weather push sea ice well above or below its climatological trend, and most SIO predictions are off the mark.

In summer of 2016 for example, the Arctic ice cover was very broken up, but weaker than usual compacting effects from wind or currents left it thinly spread out. Despite the lack of compaction, ice reached its second-lowest historical extent on 10 September, but the dispersed ice pack then refroze over a wide area as temperatures cooled later than month. The monthly average ended above most of the SIO predictions (see Figure 3).

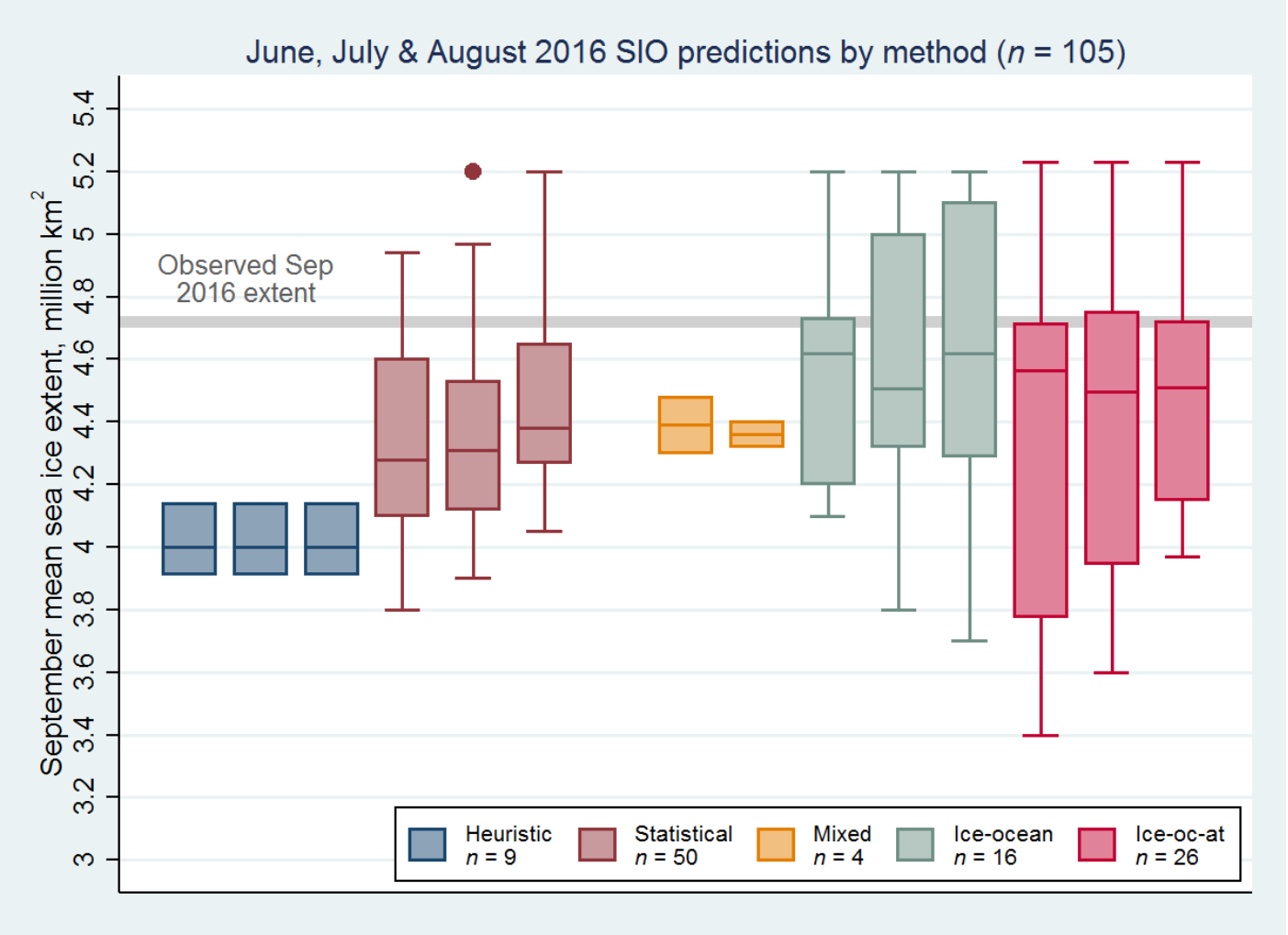

Figure 3: June, July, and August 2016 SIO contributions as box plots, broken down by type of method. Boxes show medians and interquartile ranges. Colors identify method types, and n denotes the number of contributions. Individual boxes for each method represent, from left to right, contributions to the June, July, and August SIO. A gray line shows the 2016 observed September extent. Figure updated from Hamilton and Stroeve (2016).

Although the 2016 daily minimum tied with 2007 as the second lowest, freeze-up following that minimum was faster than seen in the last ten years (nearly 1 million km^2 from 16 September through 1 October), leading to the monthly mean for September that was fifth lowest and above the long-term trend line. The median SIO prediction, on the other hand, was in line with the long-term trend (see Figure 2). Had the ice growth rate following the minimum been similar to that in 2007, the resulting September mean would have been close to the median SIO prediction.

Arctic sea ice is currently in a transitional state between a cooler past, when much thick multiyear ice survived through the summer, and a warmer future, when little of this thick ice remains. Thinner ice is sensitive to summer weather, such as how the winds blow and whether skies are sunny. Weather sensitivity makes ice extent hard to predict for any one year, although the longer-term trend is all too clear.

Acknowledgments

This research was carried out under the Sea Ice Prediction Network (SIPN) project, with support from the U.S. National Science Foundation (PLR-1303938) and the Office of Naval Research (N00014-13-1-0793). Helen Wiggins and Betsy Turner-Bogren (ARCUS) provided Sea Ice Outlook data.

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Investigating Jamming in Iceberg-choked Fjords

By: Jason Amundson, University of Alaska Southeast; Justin Burton, Emory University; and Michael Dennin, University of California Irvine

Recent and on-going retreat of many Northern hemisphere marine-terminating glaciers is contributing significantly to sea level rise. It is driven by poorly understood processes occurring at the ice-ocean interface, such as subglacial discharge into the ocean, turbulent plume dynamics, submarine melting, and iceberg calving. An interdisciplinary project, led by Jason Amundson (University of Alaska Southeast), Justin Burton (Emory University), and Michael Dennin (University of California Irvine) and supported by NSF's Physical Oceanography and Arctic Natural Sciences programs seeks to provide unique data and improved models for projecting contributions to future sea level rise.

The response of tidewater glaciers (i.e., marine-terminating glaciers) to climate change is highly complex and strongly affected by mass losses that occur at the ice-ocean interface via submarine melting and iceberg calving. These processes are poorly constrained, and thus limit our ability to predict the future evolution of tidewater glaciers. In recent years, several studies have provided compelling evidence that ice mélange (Figure 1), a granular material consisting of icebergs and brash ice found in some proglacial fjords, can provide sufficient resistance to a glacier terminus to inhibit calving activity and thereby affect glacier stability. Preliminary theoretical and laboratory work has shown that large resistive forces are not necessary to prevent even the most energetic calving events, i.e., those that involve the calving and immediate capsize of full-glacier thickness icebergs which release ~1014 joules of potential energy within a few minutes. Beyond that, however, very little is known about the physics of ice mélange or the potential stresses associated with jamming of ice mélange, a common and important phenomenon that occurs in granular materials. Consequently, we are currently unable to assess ice mélange's role within the ice-ocean system.

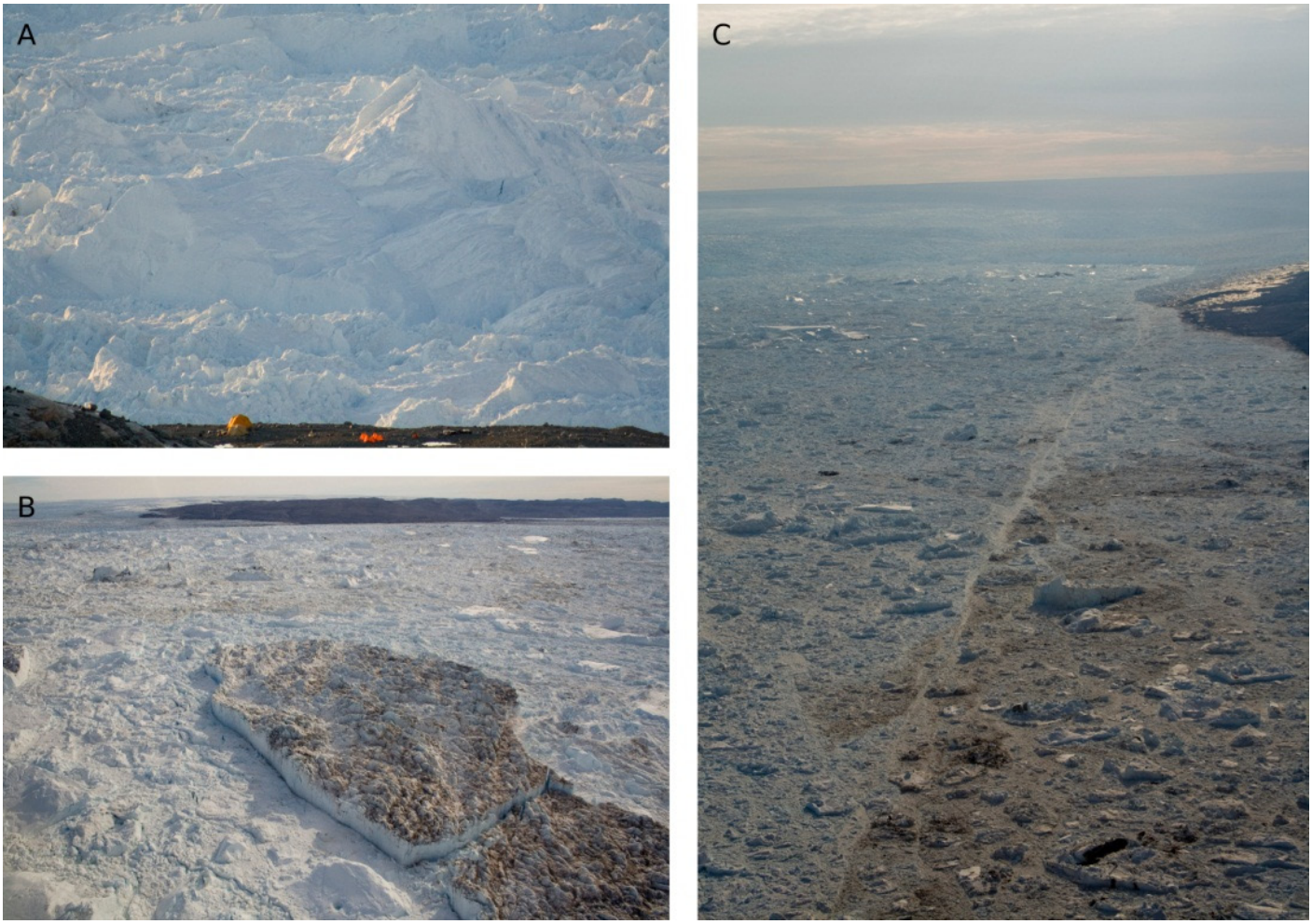


Figure 1: Photographs of ice mélange taken at Jakobshavn Isbræ, Greenland. (A) Iceberg clasts can range in size from decimeters to hundreds of meters. (B) In a dense ice mélange, no water is visible at the surface of the fjord. (C) Distinct shear bands are also visible in the ice mélange. Photo courtesy of Jason Amundson.

As a first step toward arriving at a rheological description of ice mélange, we are focusing our work on jamming that occurs as a result of iceberg-iceberg, iceberg-bedrock, and iceberg-glacier collisions. In densely-packed granular materials, force chains can develop that support stresses that are surprisingly large and focused in unexpected directions. This leads to a range of phenomena, including arching in grain silos and jammed flow in hoppers. When a material jams, particles within the material are not free to flow past each other. Jamming and unjamming of a material, which can occur intermittently, will strongly affect the bulk behavior of the system. We expect this to also be the case for ice mélange.

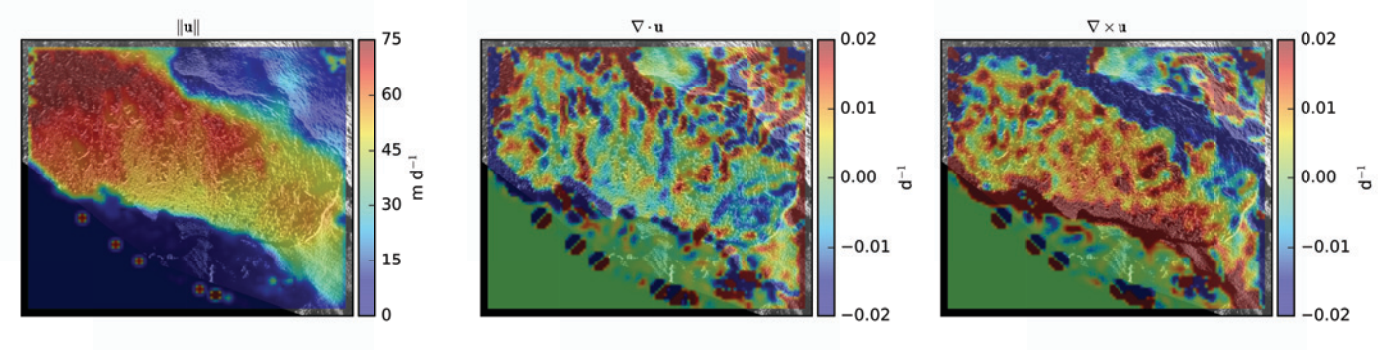


Figure 2: Ice mélange velocity field derived from terrestrial scanning radar data collected at Jakobshavn Isbræ, Greenland in August 2012. For scale, the width of the fjord is about 5 km. Shown here are the speed (left), divergence (middle), and curl (right) of the velocity field. Image produced by Jason Amundson and Ryan Cassotto.

Ice mélange is a challenging geophysical material to study in the field; it is inaccessible except by helicopter and it is unpredictable. Large calving events greatly perturb the proglacial environment and cause icebergs within the ice mélange to rapidly accelerate and capsize. Field observations are therefore primarily restricted to velocity fields (Figure 2) and iceberg size distributions derived from terrestrial radar data and satellite imagery. We are using these observations to guide development of and provide benchmarks for complementary numerical models and laboratory experiments.

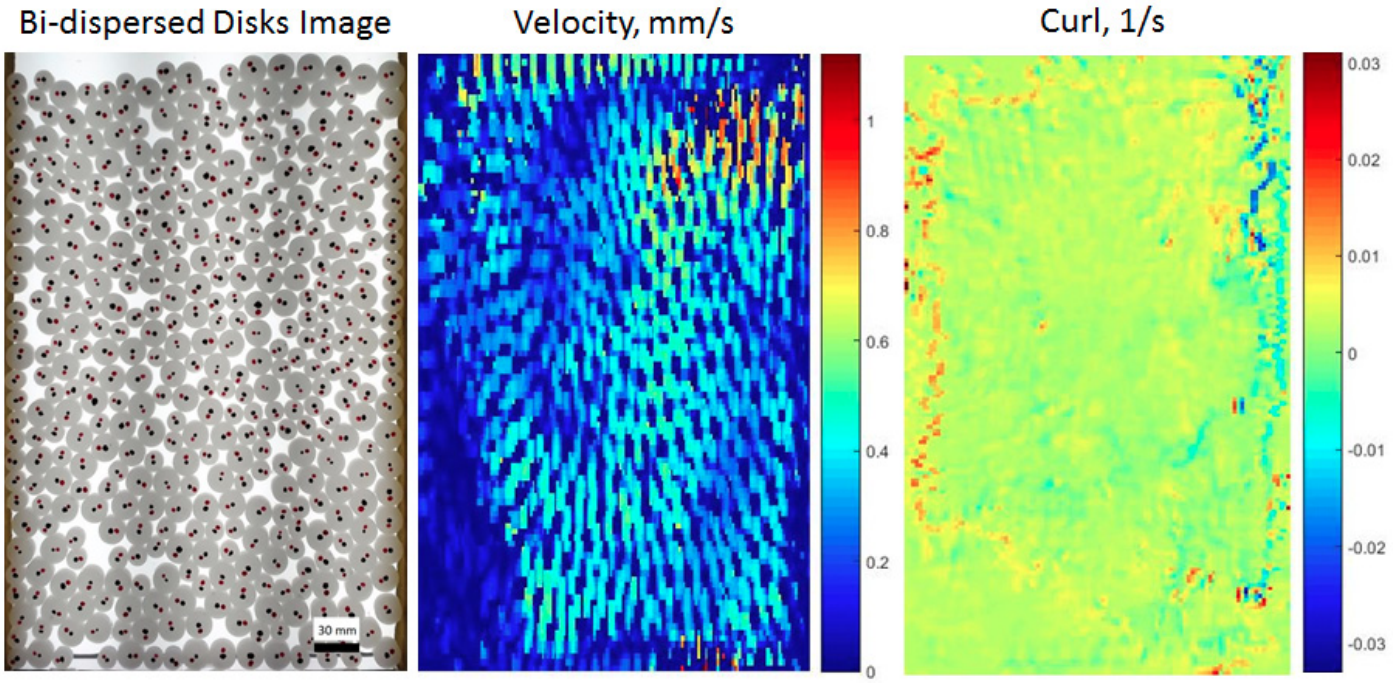
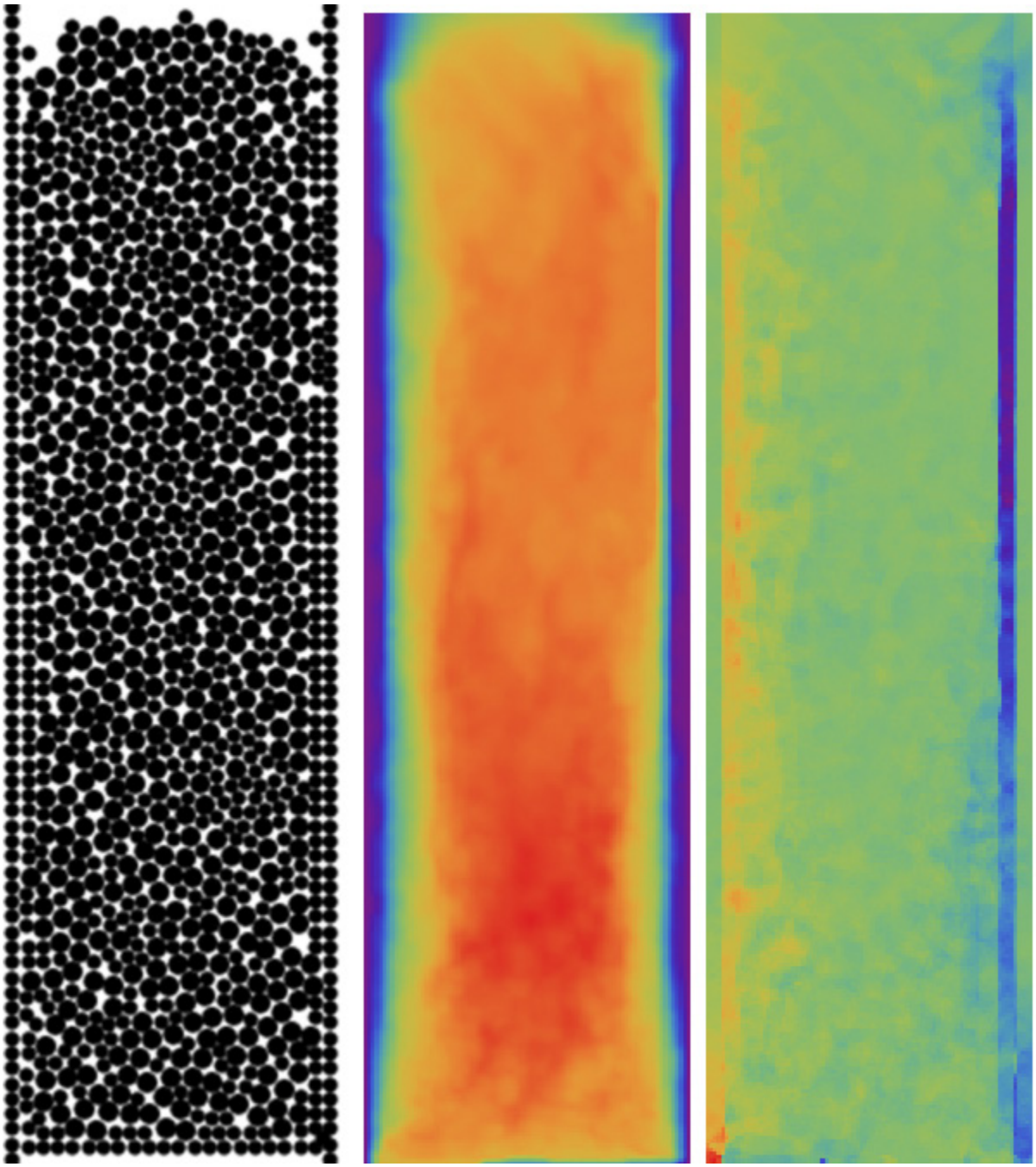


Figure 3: Laboratory experiment of floating disks being pushed down a channel (left) and snapshots of the speed (middle) and curl (right) of the velocity field. Image produced by Chin-Chang Kuo and Michael Denning.

In the laboratory experiments we push a collection of plastic blocks, which have a density close to that of ice, with a model terminus. We are able to measure the horizontal velocity field of the experiments (Figure 3), and also the force exerted against the terminus and any out-of-plane displacement of the blocks. The advantage to using laboratory experiments is that we can control and

test everything and, for example, determine the effect that iceberg shape and size distribution have on the flow of the material. At the same time, we are using numerical experiments (Figure 4) to provide a bridge between the laboratory experiments and field observations. In the experiments we are able to test simplified physical descriptions of ice mélange, with the ultimate goal of developing a model of ice mélange that can be coupled to long length- and time-scale glacier models.



Figures 4a 4b 4c: Example numerical simulation of disks getting pushed down a channel. Model set-up (4a, left), speed (4b, center), and curl of the velocity field (4c, right). Image produced by Justin Burton.

By bringing together ideas in condensed matter physics to study large-scale glaciological processes, our work will shed new light on processes affecting polar regions. This work also provides us with an opportunity to test whether theories of jamming developed at the microscale are also applicable for granular materials comprised of clasts that are 10's of 100's meters in all three spatial dimensions.

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Arctic Futures? Climate, Geopolitics, and Local Realities

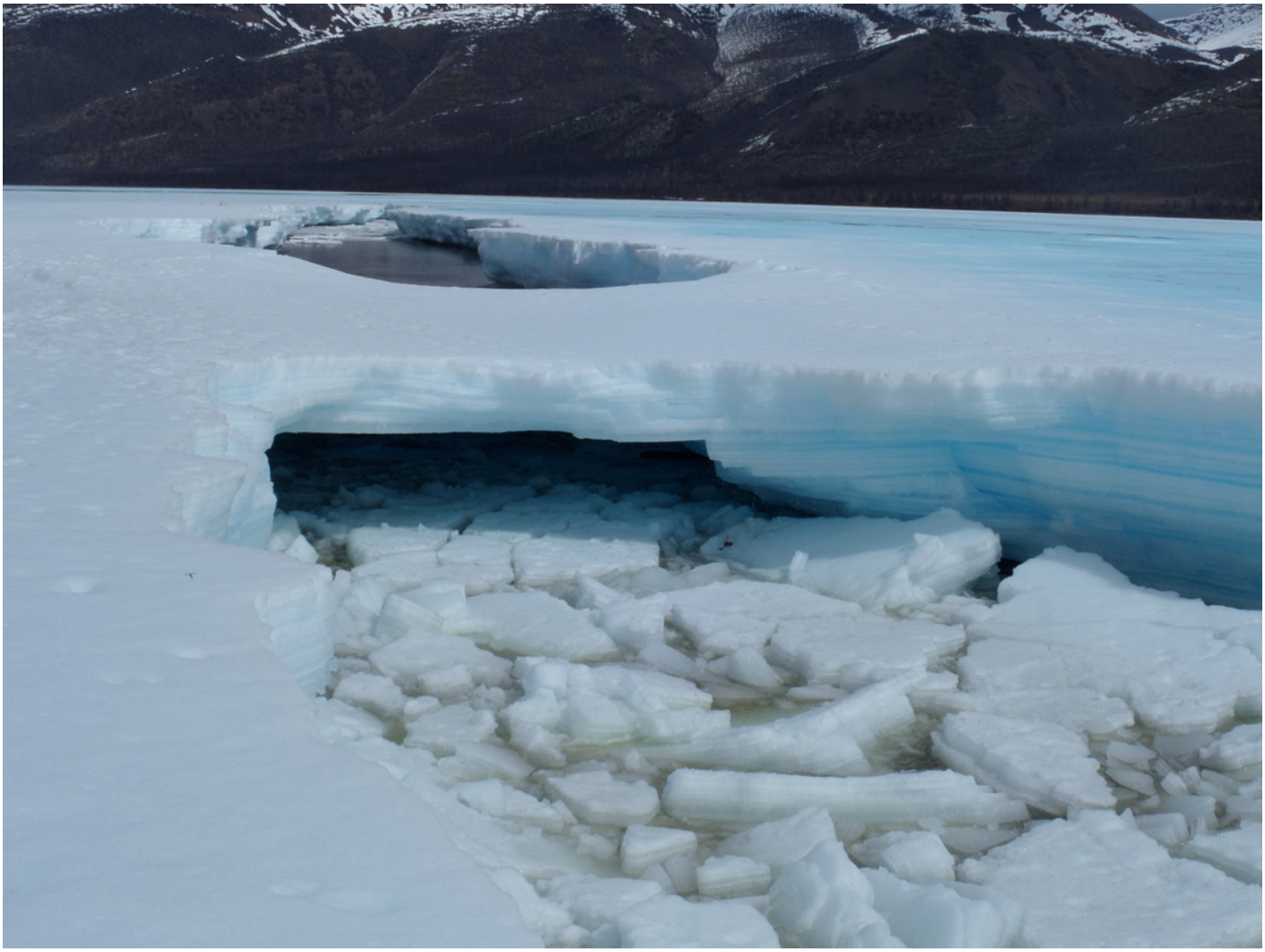
By: Olga Ulturgasheva, University of Manchester and Barbara Bodenhorn, University of Cambridge

The Anthropology, Weather and Climate Change 2016 conference (https://therai.org.uk/conferences/anthropology-weather-and-climate-change-2016) was held by the Royal Anthropological Institute, London, 27-28 May 2016. One the many conference panels was convened by Olga Ulturgasheva, University of Manchester and Barbara Bodenhorn, University of Cambridge and titled "Northern Futures? Climate, Geopolitics, and Local Realities." (http://www.nomadit.co.uk/rai/events/rai2016/panels.php5?PanelID=3804) This panel considered the intersections between environmental conditions, geopolitical tensions, and local innovative reactions characterising the Arctic in the early 21st century. Siberian and Alaskan participation was supported by the Arctic Social Sciences Program (https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13425) of the National Science Foundation. Each of the three sessions was framed by a report from places vulnerable to environmental, political, and socio-economic upheavals, given by people who live in—and whose ancestors lived in—the country about which they were talking. These were stories of calamity, but not of victimhood.

In session one, Rachel Edwardson, Iñupiaq film-maker, examined the destructive impact of "silo thinking" at the community level, where questions about how to protect the future of whaling—and subsistence more generally—and the future(s) of non-renewable resource development are bitterly contested within families and across local institutions. These questions simultaneously reflect local politics, national and international economics, and global processes. Edwardson began with a description of a public hearing that Federal officials held on new proposals to open up areas of the Arctic Ocean to exploration, only weeks after Shell had withdrawn their intentions to launch such an endeavour. "Why were only three Iñupiat there?'" she asked about the hearings. The timing of these unannounced public hearings coincided with the day that all whaling captains and their crews attended a blessing ceremony for the up-coming spring whaling season. An innocent miscalculation? Perhaps not.

Edwardson noted that if the spirits of both whales and humans reincarnate, then her grandchildren may well eat of the same whale as her own grandparents. Such an awareness and explicit valuing of intergenerational sharing poses a different kind of understanding of responsible action than what underpins institutions organized to realize profit in the short term. Edwardson herself recognized the extent to which local Alaska Native Claims Settlement Act (ANCSA) (http://www.akhistorycourse.org/modern-alaska/alaska-native-claims-settlement-act) corporations have often used the funds they gain through their participation in global economic ventures for the benefit of their Iñupiaq shareholders: education, medical services, and general infrastructure. She appreciated this without accepting them as justification to pursue policies that seem to threaten the core of Iñupiaq lifeways. "Our children, and our children's children, need to have the chance to make choices about their lives," she asserted. "We do not have the right to take that from them." Ending on a hopeful note, Edwardson emphasised the success of whaling this spring, despite thinning ice, and of the arrival of new Iñupiaq babies—reminding us that there is a cycle and that we have faced much harder challenges than those that confront us today.

Two further presentations offered alternative ways of considering voice and representation. By exploring the coverage of the terms "Arctic", "oil", "climate", and "Indigenous" as journalistic categories, Candis Callison analyzed environmental news coverage in international, national, and regional press from 2013-14 with a brief nod to tweets as they circulated through the international climate change summit COP21 (http://www.cop21.gouv.fr/en/what-was-cop21/). Not surprisingly, the more global the view, the less we find local voices, perspectives, and disparate forms of knowledge included in the analysis. More surprisingly, given the extent to which the Arctic is considered a planetary driver, it often fades from analytical view. Tweets connecting "The Arctic" to environmental changes decreased as the international climate change summit COP21 progressed, she noted, and did not figure at all in the final Paris agreement. The Arctic may be a planetary driver of environmental process, but the nation-states that encircle the Arctic are heavily interested in the non-renewable resources to be had in the present, and in an ice-free future.



Melting glacier in Upper Verkhoyanie mountains, Northeast Siberia. Image courtesy of Olga Ulturgasheva.

Marie-Jeanne Royer discussed a community-based monitoring initiative conducted by a collaborative network of scientists and Cree trappers in Eastern Canada. They identified challenges for local biodiversity brought about by climate change and anthropogenic factors as mining activity and hydro-electric power stations. The conditions they detailed included thinning ice, shifting precipitation patterns that affect the load-bearing capacity of that ice along the lakes and rivers used by the trappers, changing patterns of animal behaviors, and the impact of hydro-electric developments on what Royer calls the "fragility of space". Cree explicitly connect these shifts in ice and animal behavior to climate change. Cree are keen for their knowledge to be recognized. They also want to know what the geographers are learning, and they are consciously combining their knowledge sources to generate strategies for coping with an increasingly unfamiliar present and an unpredictable future.

Eveny reindeer herder with their domestic reindeer. Image courtesy of Olga Ulturgasheva.

Siberian Eveny reindeer herders' safety are threatened by increased likelihood of snow avalanches. Image courtesy of Olga Ulturgasheva.

The second session produced accounts of the impacts of changing conditions in the natural environment, contextualised through an examination of local reactions. Taisiia Keimetinova and Vasilii Keimetinov are Siberian Eveny reindeer herders who follow their animals on migratory routes that shift between high mountains, where glaciers provide refuge from the summer heat, and lower altitudes during the winter where life is easier for both humans and reindeer. Their video illustrated collapsing mountains; sudden, all-engulfing floods; intense temperature rises that threaten reindeer

because they can no longer retreat to glacial ice for refuge from heat and mosquitoes; and erratic behavior of animals. Virtually, every aspect of daily life has been rendered unpredictable. As the need for fast response times becomes ever more urgent, the pace of their lives has increased. Building on their already mobile lifestyle, they are making lighter infrastructure in order to pack up camp and move within minutes, shifting routes for moving across the landscape, and using every possible predictive method available to them. It is an exemplary account of resilience without trivialising the enormity of the events confronting residents of the Siberian boreal forests.

Reindeer pastures in Upper Verkhoyanie mountains, Northeast Siberia. Image courtesy of Olga Ulturgasheva.

Astrid Ogilvie and Niels Einarsson noted that Iceland is experiencing familiar environmental changes: diminishing sea ice cover, warming temperatures, and changes in fish stocks. Einarsson examined the "perfect storm" on Grímsey Island of economic collapse associated with global events of 2008, environmental changes, and especially the local side effects of a neoliberal fisheries governance system that treats what were formerly common property rights as privately owned and

transferable commodities. Quota-holding fishermen conducted what Einarsson called "an irreversible experiment" of selling their fishing rights. This generated not only the monetization of value—fishing rights may now be treated as financial assets—but also monetization of risk, resulting in new forms of unsustainable debt and social inequities. Global capitalist regimes, as well as the neoliberal ideologies that currently underpin them, are assumed to be relentlessly expansive. These accounts provide a nuanced view of the social consequences of such processes and open up the possibility of considering complex ways in which social actors respond to them.

Glenn Juday described the climate shifts in Alaska's interior from his perspective as a boreal ecologist, but focused primarily on the ethical dimensions of these shifts as understood by the Alaskan diocese of the Catholic Church in the aftermath of the papal encyclical of 2015. Resonating with Ogilvie and Royer, his scientific accounts—which combined data documenting changes in climatological, geological, and biological conditions—showed the extent to which the Arctic is warming faster than any other inhabited place on Earth. This in turn leads to species collapse as well as species transformations. He noted the mismatch between inflexible institutions and rapidly shifting environmental conditions and considered spiritual strength as an adaptive factor.

The final presentations invited us to broaden our perspective again. As with the Iñupiaq and Eveny papers, Diemberger suggested that thinking about ice at high altitudes might be usefully joined with thinking about ice at high latitudes—in her words, the cryosphere. This connects accounts of changes in the Arctic latitudes that characterise Iñupiaq homelands, of the Eveny reindeer herders who reside at both high latitudes and the high altitudes of the Upper Verkhoyanie mountains in Siberia, and the Tibetan she interviewed, for whom ice and snow are a constant and powerful presence. Her work emphasizes the importance of understanding ice and glaciers as powerful in themselves in both of these kinds of areas.

Diemberger's paper resonated with Rasmus and Nation's account. In both cases, we hear how youth often experience environmental change without the needed skills for knowing how to cope. According to the presenter, Yup'ik and Athabaskan elders make an explicit connection between changes in the physical climate and changes in the social climate brought about by colonialism, the spread of industrial capital, and challenges to local ways of knowing. As young people have become more village bound, the potential balancing out of human emotional relations through balanced human/animals relations has become curtailed. The authors argued that physical and social environmental change can intensify feelings of uncertainty which, when coupled with other forms of stresses associated with devalued cultural practices, can generate a sense of a closed-down future that

may lead to suicide.

Themes of risk and resilience, of giving voice and being silenced, of unfamiliarity and uncertainty, of gathering together, and of reaching out were threaded through the entire day. The panel discussion highlighted the idea that the major plan for dealing with uncertainty is building up a "stash" of strategies combined in different ways depending on circumstances.

For more information, please contact Barbara Bodenhorn, University of Cambridge (bb106@cam.ac.uk) and Olga Ulturgasheva, University of Manchester (olga.ulturgasheva@manchester.ac.uk).

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R/V Sikuliaq Readiness Tested in Arctic Ice Trials

By: Lauren Frisch, Public Information Officer, Sikuliaq *Science Liaison, College of Fisheries and Ocean Sciences, University of Alaska Fairbanks*

The research vessel (R/V) *Sikuliaq* (https://www.*sikuliaq*.alaska.edu/) is owned by the National Science Foundation and operated by the University of Alaska Fairbanks College of Fisheries and Ocean Sciences (https://www.uaf.edu/sfos/) as part of the U.S. academic research fleet. The global-class research vessel is used by scientists in the U.S. and international oceanographic community through the University-National Oceanographic Laboratory System (UNOLS) (https://www.unols.org/). Ice trials conducted during the spring of 2015 for the R/V *Sikuliaq* helped researchers and crew understand the opportunities and limitations posed by operating an ice-capable vessel in icy Arctic waters.

The Sikuliaq travels through icy water during a past science mission. Photo courtesy of Mark Teckenbrock.

Sikuliaq means "young sea ice" in Inupiaq (https://www.uaf.edu/anlc/languages/i/), a name that

properly reflects the designed function of the research vessel. The 261-foot R/V *Sikuliaq* was built to occupy a specific niche for Arctic researchers who are interested in conducting research in moderate ice conditions. The ice-capable research vessel was not designed with technology to cut ice in the most extreme situations. The ship is a smaller and more economical option than more serious icebreakers like the USCGC *Healy* (https://www.uscg.mil/pacarea/cgcHealy/). But given its capacity to work and maneuver in ice that might be newer or thinner, the vessel is more versatile for icy Arctic research than a non-icebreaker.

During March and April of 2015, researchers and crew set out to investigate the limitations of the *Sikuliaq* to understand the full ice-capability of the vessel. This includes the ability to maneuver and conduct day-to-day activities, as well as the feasibility of completing various scientific tasks in ice. The ice trials were conducted south of St. Matthew's Island in the Bering Sea; they occurred between 19 March and 7 April, which is typically when ice cover is the greatest in the Arctic.

From left to right: Sikuliaq crew members Paul St. Onge (bosun), John Hamill (second mate), and Ethan Roth (marine science technician) test an ice floe for safety. Photo courtesy of Kimberly Kenny.

Researchers onboard tested the ability of the *Sikuliaq* to operate different scientific equipment in the ice, such as the conductivity temperature and depth (CTD) (http://www.whoi.edu/instruments/viewInstrument.do?id=1003) instrument, which is commonly used to collect a breadth of oceanography samples. Researchers also practiced tasks such as remaining in place in the ice to collect data at a particular station, towing plankton nets through ice, and sampling sea ice properties.

The Sikuliaq crew uses small boat missions to test if ice is safe for scientific research. Photo courtesy of Mark Teckenbrock.

The *Sikuliaq* crew used the ice trials as an opportunity to test operational procedures related to

regular day-to-day ship operations, including the ability to turn within sea ice and ram through new ice while sailing on a path. The experience also served as an opportunity to train ship personnel. Ensuring the researchers and crew were safe during all operations was critical during the process.

The first few days of the ice trials were halted due to water intake issues. When a faulty valve was diagnosed, the crew and researchers were able to continue on with their original mission. Variable ice conditions throughout the trials made it tricky to find ice that was suitable for testing. For example, much of the ice in the study path was not attached to land, or was not level enough for researchers to utilize. But the variability in thickness helped reveal the limitations of the *Sikuliaq* to cut through ice: in one case, ice was extremely compacted and not possible to cut through.

The ice trials confirmed that the *Sikuliaq* could operate during heavy ice months in March and April, and cut through ice up to three feet. But the research vessel had difficulty traveling through thicker ice, as well as ice that was highly compacted. The trials also confirmed that the ship can transit through thin ice floes when need be.

Video of the *Sikuliaq* breaking ice is available here (https://www.youtube.com /watch?v=YQh1o8FZyEs).

Further information about the *Sikuliaq* is available on the University of Alaska Fairbanks College of Fisheries and Ocean Sciences website (https://www.*sikuliaq*.alaska.edu/ops/?q=node/172).

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National Centers for Environmental Information Arctic Data Integration with the NSF Arctic Data Center

By: Sheekela Baker-Yeboah, University of Maryland, Co-Principal Investigator Arctic Data Center; Krisa Arzayus, Deputy Director, NOAA/NESDIS/National Centers for Environmental Information (NCEI), Center for Coasts, Oceans, and Geophysics; Kenneth S. Casey, Deputy Director, NOAA/NESDIS/NCEI, Data Stewardship Division; and Matthew B. Jones, National Center for Ecological Analysis and Synthesis (NCEAS), Principal Investigator Arctic Data Center

The National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) (https://www.nesdis.noaa.gov/content/about) National Centers for Environmental Information (NCEI) (https://www.ncei.noaa.gov/)[1] serves as the Nation's archive for oceanographic, atmospheric, climatic, geophysical, and space-weather data. NCEI archives data from national and international partners, and its holdings of over 14 petabytes include a wide range of data types from the bottom of the ocean to the surface of the sun and from around the world.

NCEI is part of an Arctic-focused project partnership: the National Science Foundation (NSF) Arctic Data Center (https://arcticdata.io/) (Budden, Jones, and Schildhauer, 2016) (see also: Witness the Arctic, Spring 2016 (https://www.arcus.org/witness-the-arctic/2016/2/article/25687)), which encompasses the National Center for Ecological Analysis and Synthesis (NCEAS) (https://www.nceas.ucsb.edu/) at U.C. Santa Barbara, DataONE (https://www.dataone.org/) at the University of New Mexico, and NCEI at NOAA. This joint collaboration provides long-term data archive, distribution, integration, and public access services for Arctic data within the purview of NSF and NOAA and will provide more organized and discoverable Arctic data to user communities. As such, NCEI, which currently participates in the DataONE Federation as a Tier 1 member[2] node providing read-only access to data, will elevate its status to Tier 4 to support upload and replication of data from the Arctic Data Center to NCEI and provide supporting data storage, curation, and discovery services. This partnership will leverage existing NCEI scientific data stewardship infrastructure, products, and expertise.

[1] NCEI, formerly the National Oceanographic Data Center (NODC), National Climatic Data Center (NCDC), and National Geophysical Data Center (NGDC).

[2] More information about Tier levels in the context of DataONE is available on the DataONE website (http://jenkins-1.dataone.org/jenkins/job/DataONE-Operations-Manual/ws/operations/_build/html/member_node_deployment/mn_checklist.html).

NCEI Levels of Scientific Stewardship

NCEI provides long-term scientific stewardship of environmental data collected from a variety of data providers. Data are routinely archived and made discoverable and accessible for current as well as future use by NOAA and the Nation. In particular, these data support NOAA's efforts in environmental intelligence in monitoring climate stressors on marine ecosystems and supporting the resilience of connected communities, including the Arctic. NCEI organizes its data stewardship into six conceptual levels (see Figure 1). At the most fundamental level, NCEI works to provide long-term preservation and access to data and metadata; create standards-compliant metadata to describe it; and support its discovery and use. At the second level of stewardship, NCEI provides enhanced access to data, supporting functions such as on-line visualization; slicing or subsampling; more thorough, detailed, or complete metadata; and automated quantitative characterizations of data quality and extent. At the third level of stewardship, NCEI works to improve data with scientific quality assessments and control, flagging, and corrections. At the fourth level, NCEI generates products such as running means, aggregates, composites, or climatologies. At the fifth level of stewardship, NCEI works to create data records that are recognized and utilized by the community as authoritative sources of information, including products such as climate data records and multi-platform intercalibration. Finally, at the highest level of scientific stewardship, NCEI acts as a recognized authority, leading the community in the development of standards or in the practice of scientific stewardship of ocean data.

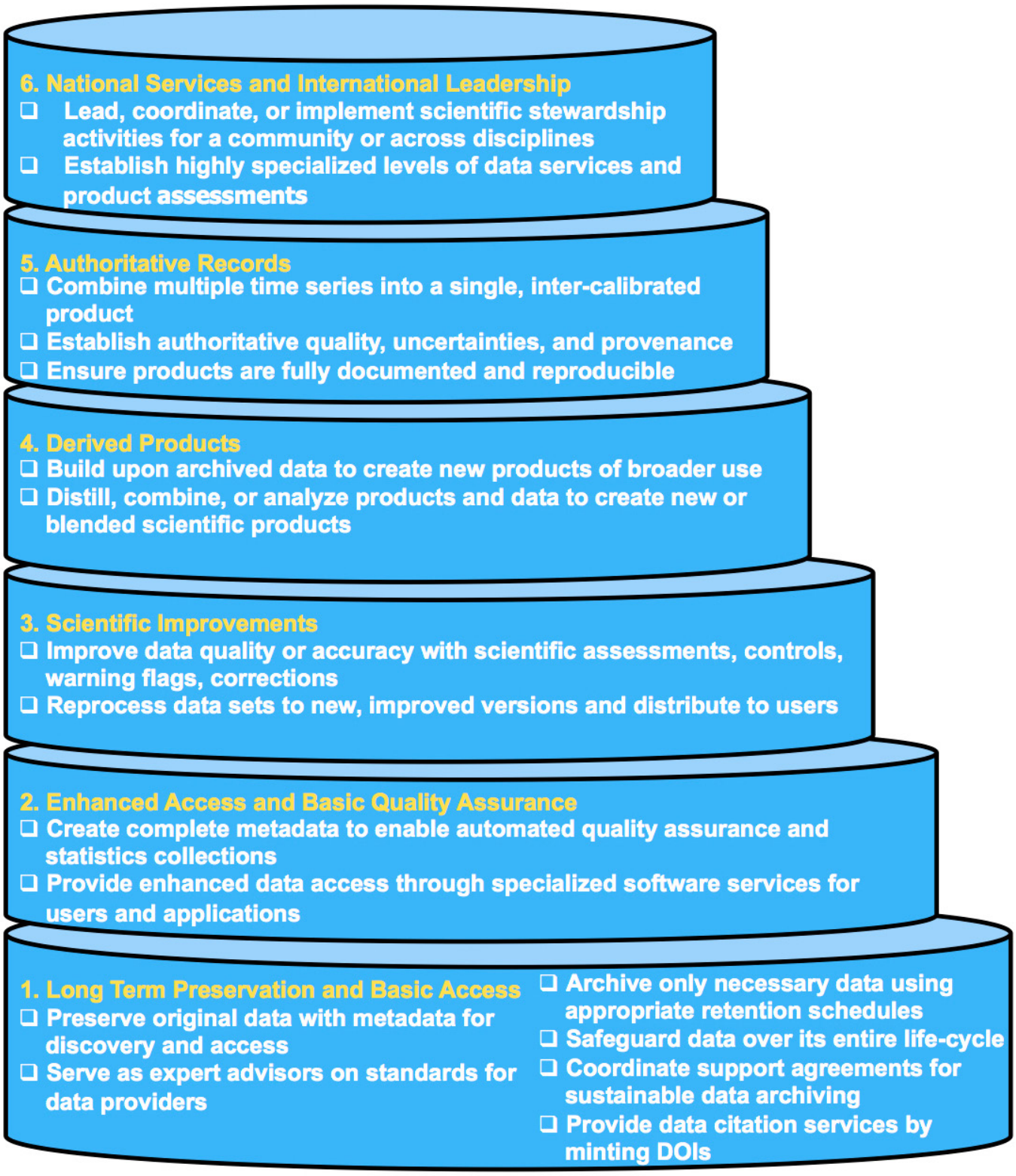

Figure 1: NCEI levels of scientific stewardship of data holdings for long-term preservation to national services and international leadership. Figure courtesy of S. Baker-Yeboah, K. Saha, Y. Zhang, K. S. Casey, Y. Li., NOAA/NESDIS/NCEI.

NCEI New and Upcoming Features

During the upcoming year, NCEI discovery and access capabilities (see Figure 2) will be expanded in collaboration with the NSF Arctic Data Center to develop new capabilities and features supporting Arctic researchers and general users. NCEI is in the process of elevating its DataONE Member Node status by setting up replication to repositories in DataONE. Prototype development and testing of DataONE Tier 4 replication capabilities are expected to be completed over the next two years for the NCEI repository.

Figure 2: NCEI datasets can be discovered and accessed at the collection level and granule level using HTTP, FTP, Live Access Server, THREDDS, OPeNDAP server, and other services. Figure courtesy of S. Baker-Yeboah, K. Saha, Y. Zhang, K. S. Casey, Y. Li., NOAA/NESDIS/NCEI.

Part of the NCEI Arctic mission connects to advances being made through the NSF Arctic Sciences Section. Shared datasets specific to the NSF Arctic Data Center program and NCEI will have

combined data management plans and unified access to products in an effort to provide a replica of the NSF holding within the scope of NOAA's mission. These will include support infrastructure, client tools, an extended web submission system to support rich data entities and attributes, and advanced submission features for full replication status. The NCEI Arctic program continues to grow and product development efforts are ongoing. The upcoming NCEI Arctic Data Viewer (see Figure 3) will link to the NSF Arctic Data Center Discovery Portal and Upload Tool to facilitate a more organized and discoverable approach for user communities to Arctic datasets.

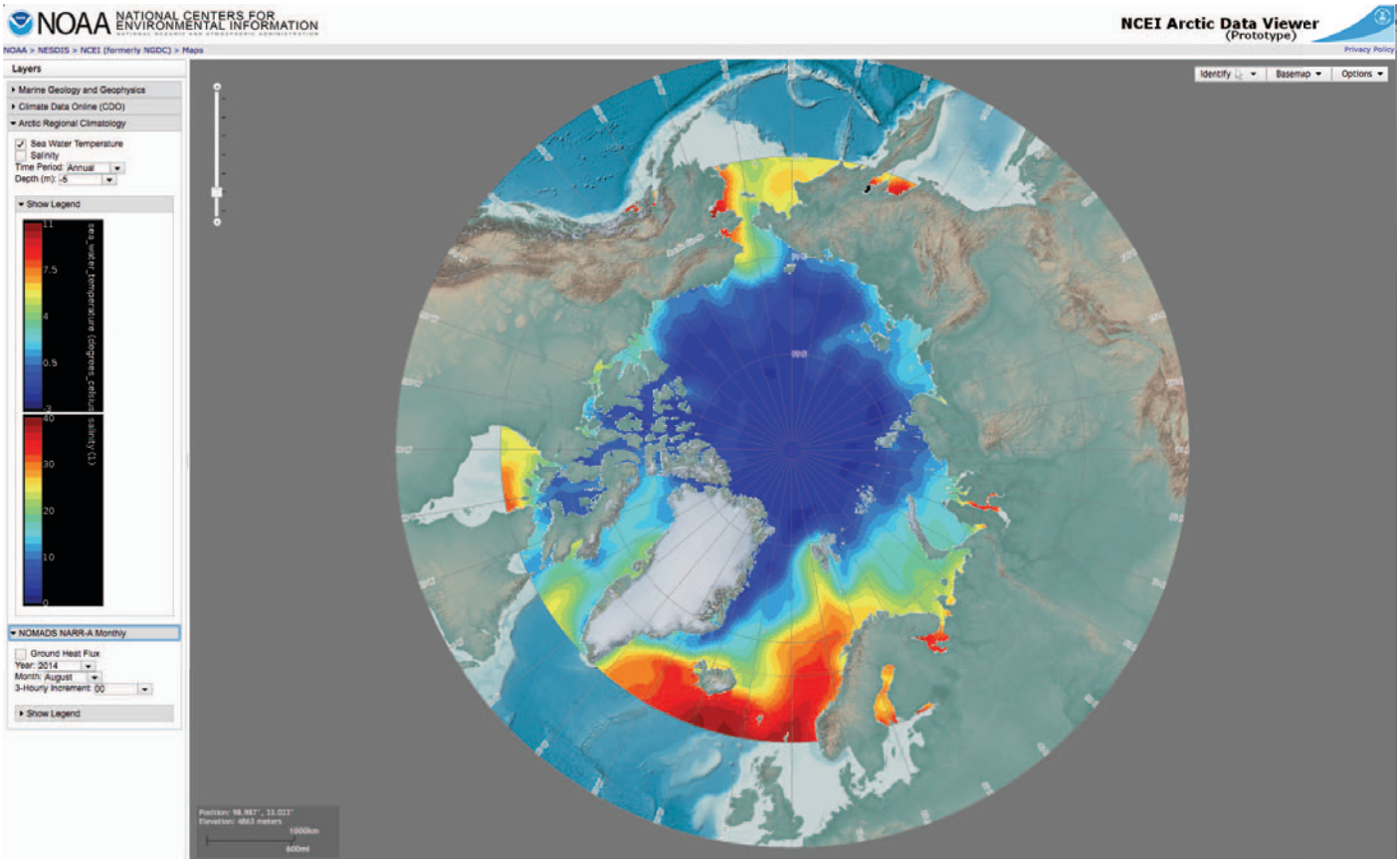

Figure 3: An NCEI Arctic Data Viewer of product holdings is under development and will be published for user access in 2017 by the NCEI Arctic Team. Image courtesy of NOAA/NESDIS/NCEI Arctic Team: H. Garcia, J. Jencks, M. Zweng, S. Baker-Yeboah, H. Diamond, F. Fetter, G. Peng, K. Rose, S. Helfrich, P. Groisman, M. Palecki, and J. Partain.

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There's Something in the Air: Release of Volatiles from Arctic Vegetation Increasing

By: Riikka Rinnan and Magnus Kramshøj, Department of Biology and Center for Permafrost, University of Copenhagen, Denmark

Volatile organic compounds (VOCs) are gaseous chemicals originating from a range of man-made sources like traffic and paint fumes, and natural sources such as plants that emit VOCs to deter pests, attract pollinators, or to protect their leaves from heat. In the atmosphere, VOCs rapidly undergo reactions influencing the concentrations of greenhouse gases like methane and ozone. Furthermore, atmospheric VOCs contribute to the formation of particles that scatter radiation and can even condense to form clouds, which may actually cool the climate.

A research team, including Riikka Rinnan and Magnus Kramshøj from the Center for Permafrost (http://cenperm.ku.dk/) at the University of Copehagen, Denmark recently conducted studies to assess the VOC emission response of vegetation to warming temperatures in the Arctic. The team's results, discussed below, showed that warming caused a significant increase in emission rates for plants that is considerably higher than what is observed at more southern latitudes, emphasizing the high temperature sensitivity of ecosystem processes in the changing Arctic (M. Kramshøj 2016).

Until recently, the Arctic was considered an insignificant area for research into natural VOCs. It was thought to be too cold, have too few plants, and too short growing seasons. Not fully appreciated was how efficiently the dark soil and vegetation surface on the tundra heats up in the sunlight, that the tiny plants are extremely efficient during the short Arctic summers, and that the Arctic climate is experiencing drastic increases in temperature. The temperature is increasing twice as fast as the global average temperature. As a matter of fact, tundra heaths even in far north Greenland release measurable amounts of VOCs.

Knowing that the release of volatiles from plants is highly temperature-dependent, the team set out to study how the predicted climate warming will affect VOC emissions from the Arctic tundra. A field experiment was set up near Nuuk, Greenland to monitor changes in ecosystems caused by climate changes. Small open-top greenhouses were used around plots of vegetation to create areas a few

degrees warmer than the surrounding plants. These plots, created to mimic future climate conditions, were compared to plots of vegetation without the extra warming (see Figure 1). Similar experiments have also been conducted on Disko Island and Zackenberg, Greenland and in Abisko, Swedish Lapland.

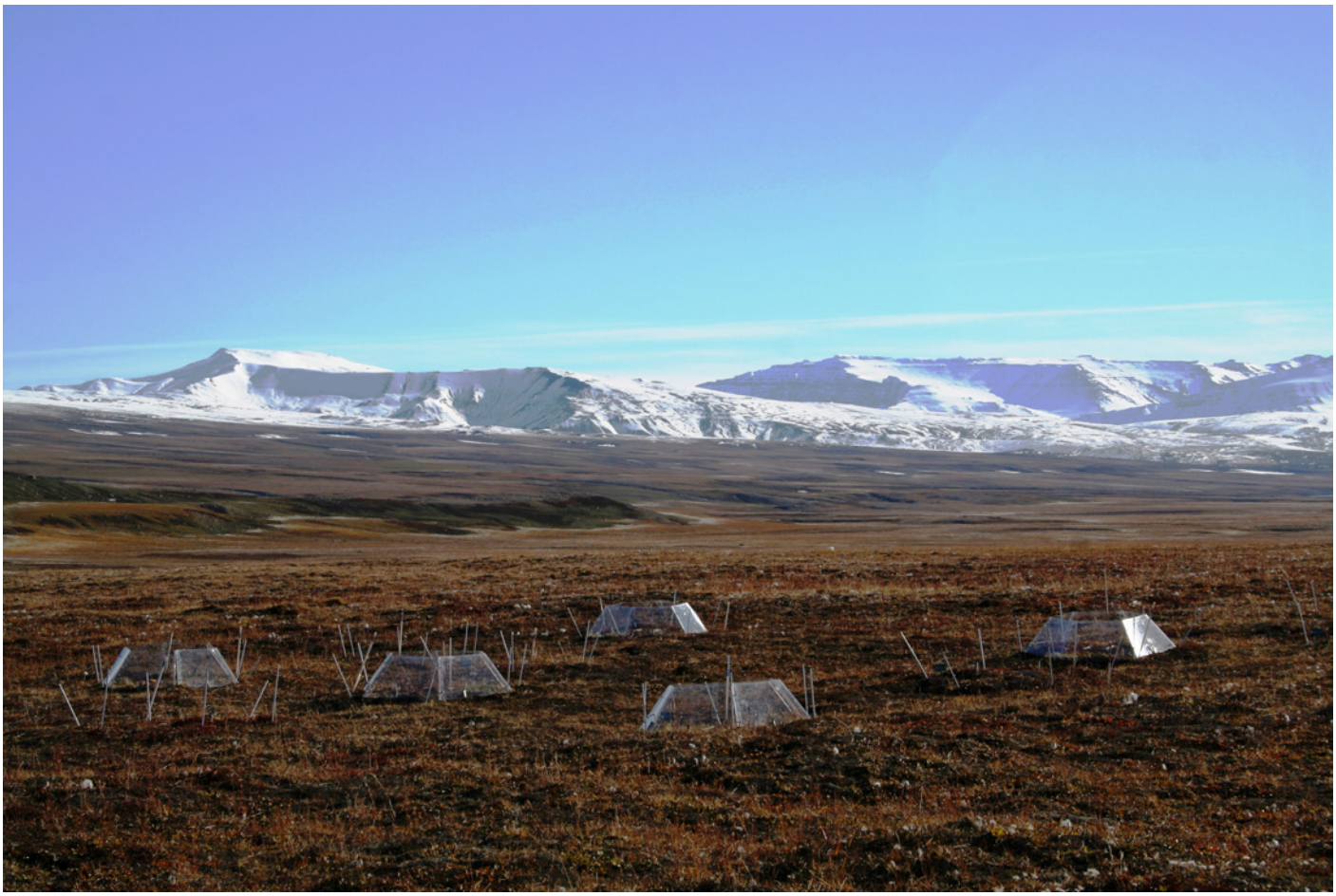

Figure 1: Open-top hexagon-shaped greenhouses have been used across the Arctic to create warmer micro-climate on plots of tundra without the use of electricity. The photo illustrates an experiment from Zackenberg, Greenland in fall colors. Image courtesy of Riikka Rinnan.

In Nuuk, the team measured consistently higher volatile emissions in the warmed plots, even though the vegetation cover in the open top greenhouses had decreased over years of warming. Despite fewer plants per ground area, the vegetation grown in the open top greenhouses released three to four times more VOCs than the plots without this warming (see Figure 2). To locate the origin of the effect, we measured separately on each of the dominant plants—an Arctic willow and an evergreen crowberry—while also surveying the effect on the bare soil. We could see that warming stimulated the release of volatiles from each of the two dominant plants and the whole ecosystem, while having no impacts on release from soil. This result points towards an extreme temperature sensitivity in Arctic plants. They might be tiny, but they are also adapted to make use of all the available warmth and sunlight during the short summer. It might also be that the response is a combination of the

elevated temperature and drought. Lack of water may have stressed the warmed plants, and plant stress is known to increase VOC emissions.

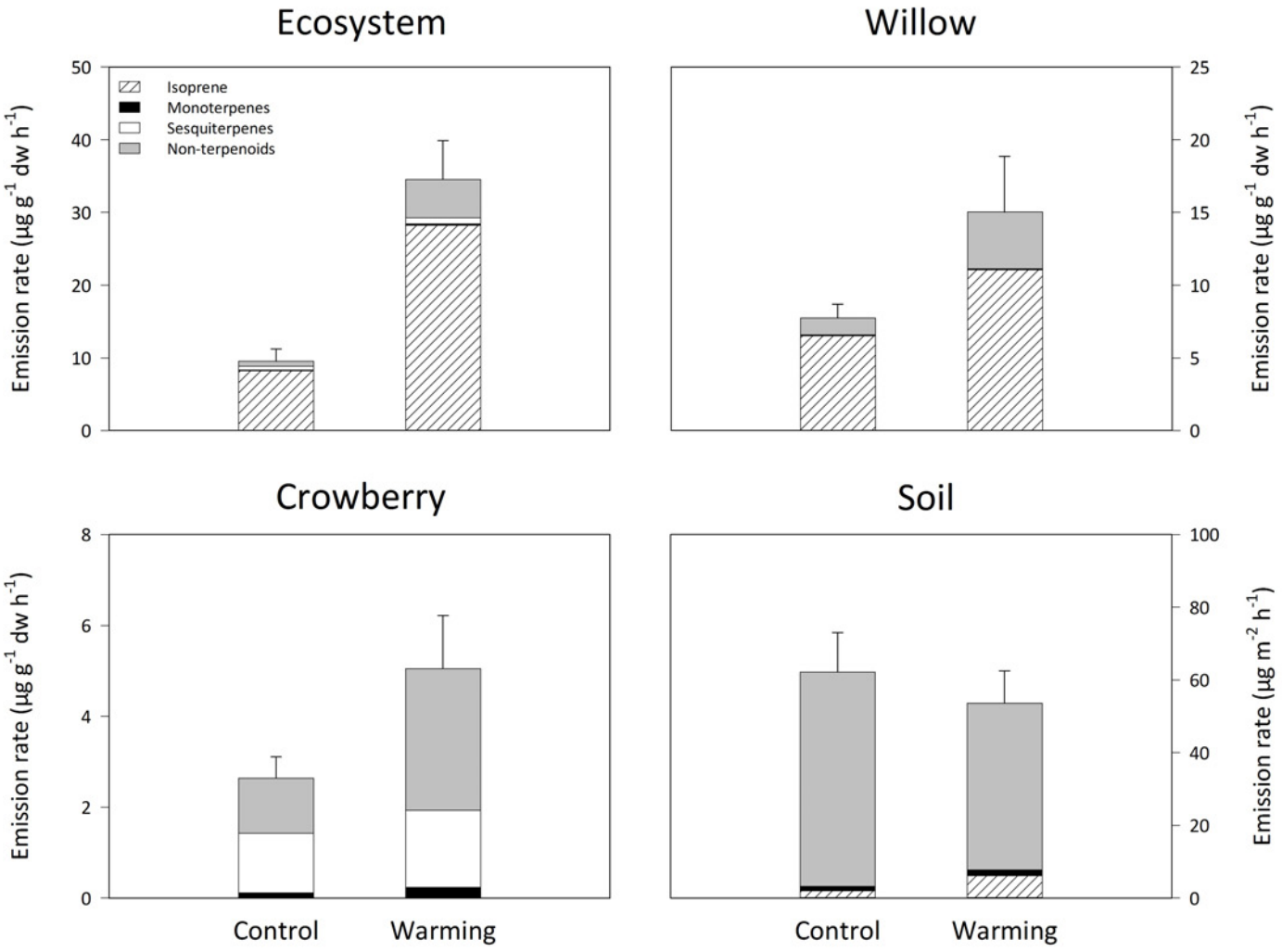

Figure 2: Release of VOCs from the control and warmed plots in the Nuuk experiment averaged over one summer of measurements. The graph shows release of VOCs in the two treatments for the whole tundra ecosystem (calculated per gram plant biomass), the two dominant plant species, and for bare soil. The bars also show the contribution by different types of VOCs: Isoprene accounts for about 50% of VOCs from nature. Monoterpenes and sesquiterpenes typically have a strong odor. The rest of the compounds cannot be categorized as terpenoid compounds. Image is modified from Kramshøj et al.

The results across our experimental sites are surprisingly similar: warming by a few degrees causes several-fold higher emission of VOCs from the tundra. This is a drastic response compared to more southern areas. The typical expectation is for about one third more plant volatiles in response to this kind of rise in temperature. It is also a tremendous response compared to how much other biological processes change upon warming.

In the Greenlandic sites, the large increase in the release of volatiles has appeared without a vegetation expansion and seems like a direct plant physiological response. In Abisko, where water

availability is not limiting plant growth, we have observed shifts in vegetation, with some species boosted and others declining under elevated temperature. In general, with climate change we are expecting more plant growth in the Arctic. And clearly, if the plant species cover changes, the volatile blends will also change as different plants produce different VOCs. If the vegetation grows denser, higher, or expands to new areas, more volatiles will be released as a result of more VOC producing leaf mass per ground area. The team concludes that an increasing load of volatiles from nature in the Arctic can therefore be expected.

Why is this relevant? VOCs are not greenhouse gases, but because of their high reactivity in the atmosphere they have many impacts in the air close to their source. Perhaps the most relevant are the impacts on tiny particles in the atmosphere known as aerosols. These aerosol particles can grow big enough to form clouds. What is exciting is that aerosols and clouds can actually cool the climate and thus mitigate the warming impact of greenhouse gases. There are still many uncertainties in the formation of aerosols and clouds from VOCs, but one thing is certain: If the Arctic continues to warm as expected, much more VOCs will be released from the vegetation in these areas. As the man-made sources of VOC pollution are rare in the Arctic, the plant volatiles are the most important player in this region.

Figure 3: Field work in the Nuuk area, Greenland. Researchers collect ongoing gas exchange measurement. Photo courtesy of Magnus Kramshøj.

Figure 4: Field work in the Nuuk area, Greenland. Researchers perform detailed vegetation analyses. Images courtesy of Magnus Kramshøj.

More information about this project and field stations is available on the Cnter for Permafrost website (http://cenperm.ku.dk/).

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70 Years of Science and Education on the Juneau Icefield: History, Reflections, and New Directions

By: Matt Beedle, Juneau Icefield Research Program (JIRP) Director of Academics and Research, and Erin Whitney, JIRP Executive Director

The 2016 summer field season of the Juneau Icefield Research Program (JIRP) (http://juneauicefield.com/) marked the 70-year anniversary of continuous study of the Juneau Icefield. As the program looks toward the next 70 years with new ideas and directions, this anniversary provides a timely opportunity to reflect on a rich history and fabric of participant experiences.

JIRP's largest camp (Camp 10) sits above the main branch of Taku Glacier with the Taku Range in the distance. Permanent camps serve as bases from which to study outlying areas of the Juneau Icefield as a venue for in-camp lessons in inclement weather. Photo courtesy of Matt Beedle.

Initial aerial surveys began in 1946, followed by the first on-ice reconnaissance in 1948. Focused field research continued annually through the International Geophysical Year (http://www.nas.edu/history/igy/) with leadership from notable individuals such as William O. Field (https://www.nps.gov/glba/learn/nature/upload/Brown_2007_LegacyOfWOField.pdf), Maynard Miller (http://juneauicefield.com/blog/2014/2/5/maynard-m-miller-1921-2014), Ed LaChapelle (http://www.lachapellelegacy.org/Ed.html), Calvin Heusser (http://juneauicefield.com/history/), and Melvin Marcus (http://www.aag.org/cs/membership/tributes_memorials/mr/marcus_melvin_g). This

earliest decade was primarily research focused, but also included budding scientists and explorers and helped launch the careers of many, including a young AustinPost (http://www.legacy.com /obituaries/nytimes/obituary.aspx?pid=161311627).

In the early 1960s, Maynard Miller and his wife Joan assumed leadership of JIRP, and the program began to shift towards the training of young scientists through the annual expedition, its research objectives, and resident faculty. The longevity of JIRP is a credit to the vision of Maynard, the monumental support of Joan, and the hundreds of volunteers and donors that have helped the Program continue. Early funding partners included the American Geographical Society, Office of Naval Research, National Geographic Society, National Science Foundation and the National Aeronautics and Space Administration (NASA). In recent decades, JIRP restructured itself as a non-profit funded primarily through tuition fees and alumni donations. This continuity has made possible the two longest glacier mass-balance records in North America, scores of Masters and PhD theses and, most importantly, inspiration for many hundreds of young scientists.

This cadre of JIRP alums is noteworthy, and the wooden rafters of the permanent field stations read like a who's who of glacial, earth systems, and planetary science. Dr. Steven Squyres, Principal Investigator of the Mars Exploration Rover Project writes:

"My JIRP experience strengthened in me a love of exploration that ultimately led to my participation in the space program, including the Mars Exploration Rovers Spirit and Opportunity. JIRP was fundamental to my growth as a scientist and as a person."

As in previous seasons, the 2016 JIRP curriculum was shaped by the traverse from Juneau, Alaska to Atlin, British Columbia, and a focus on six core research areas: 1) Glacier Mass Balance, 2) Geodetic Surveying, 3) Glacial Geophysics, 4) Biogeochemistry, 5) Isotope Geochemistry, and 6) Nunatak Ecology. In addition to foundational teachings in these six core areas, the curriculum included exposure to remote sensing and GIS, nunatak geology, and meteorology, all with a spatial focus on the northern Coast Mountains of Alaska and British Columbia. The program maintains a close relationship with the University of Alaska Southeast to offer field course credit to students each summer.

An additional focus of JIRP in recent years, and of increasing importance within the JIRP curriculum, is science communication. In addition to making public presentations in Atlin and Juneau, as well as presenting their work at the annual fall American Geophysical Union meeting, JIRP students blog from the field, telling the scientific and expeditionary story in near real time.

Molly Peek (Smith College) in her post "From Different to Dynamic, Thanks to a Glacier" (http://juneauicefield.com/blog/2016/7/23/jirpers-from-different-to-dynamic-thanks-to-a-glacier) writes of how the challenges and camaraderie of the expedition brings the team together, and can serve as a model elsewhere:

"The glacier links us . . . The trail conversations we strike up connect us . . . These stories also connect us as scientists, as we come out of our own small worlds to see how our own relationships to glaciers are completely different from those of others. These realizations are becoming increasingly important as our world changes . . . If we are to investigate changes in the environment with an aim to make society better, we must work with people from a variety of locations and experiences and integrate the struggles and opportunities from all parts of the world."

JIRP faculty member Dr. Natalie Kehrwald (USGS) and student Chris Miele measure and sample a snow core for biogeochemical analysis. Photo courtesy of Shad O'Neel.

JIRP faculty members Drs. Catharine White (Northwest Community College) and Jeremy Littell (USGS), ascend Blackerby Ridge towards camp after a day-long outing to explore alpine ecology, and dendrochronology with a team of JIRP students. Photo courtesy of Matt Beedle

In "Dendrochonology – Stories Told by Tree" (http://juneauicefield.com/blog/2016/7/23/dendrochronology-stories-told-by-tree), Alexandra Kessler (University of Zurich) writes of the science behind a method to reconstruct Juneau Icefield mass balance:

"Trees and glaciers do actually respond similarly to the climate. When there is a year with a lot of snow and is cold, a glacier is happy. A tree however will be freezing and sad, creating only a small ring. Therefore, a glacier's mass balance and the tree's growth patterns, represented in the thickness of the tree ring, correspond. This means, that we can reconstruct a glacier's mass balance in a time when there was no JIRP around to measure it."

And Riley Wall (Occidental College), in his blog "Communication and Toads" (http://juneauicefield.com/blog/2016/9/26/communication-and-toads) reflects on the difficulty of how to capture in words the look, sounds, smell, feel and taste of a remote field setting:

"So my only remaining recourse is a plea to those truly interested in JIRP, glaciers, climate change, and the greater natural world: to embark on your own adventures, for you learn from your own

personal experiences best, to foster any feelings of inspired motivation you find on those adventures, and to be a champion of the change you want to see."

More from these blogs and others is available on the JIRP website (http://juneauicefield.com/blog/).

JIRP is forging forward into its next 70 years, with plans for the 71st field season in 2017 well underway that will further advance research on the Juneau Icefield with new partners and community partnerships and continue immersive scientific expeditions to inspire participants.

For more information, contact Matt Beedle, JIRP Director of Academics and Research (matt.jirp@gmail.com) or Erin Whitney, JIRP Executive Director (edubbs.jirp@gmail.com). Or, see the JIRP home page (http://juneauicefield.com/).

JIRP students head out on the Ptarmigan Glacier for more ski practice before the two-day ski traverse to Camp 10. Photo courtesy of Samuel Hepner.

NSF Arctic Sciences Section Welcomes New Program Directors

Arctic Sciences Section at NSF welcomes four new Program Directors and looks forward to working with them to advance Arctic science.

Dr. Cynthia Suchman is now serving as a Program Director for Arctic Natural Sciences (ANS). Dr. Suchman comes to the Arctic Sciences Section from the Biological Oceanography Program in the Division of Ocean Sciences where she served as a NSF Program Director since 2014 and during 2007-2011. Her expertise is in zooplankton ecology. She has also worked for state and regional marine science funding programs in Virginia and Alaska.

ANS will also soon be welcoming the addition of Dr. Anjuli Bamzai as a new Program Director for the Section. Dr. Bamzai is joining us from the Climate and Large-Scale Dynamics Program in the Division of Atmospheric and Geospace Sciences where she has been serving as an NSF Program Director since 2010. At NSF, Dr. Bamzai has served on cross-directorate program management teams for the Science Engineering, and Education for Sustainability (SEES) (https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504707) initiative for the competitions on Earth System Modeling at Decadal and Regional Scales, and Sustainability Energy Pathways. She has also been active on the interagency U.S. Climate Variability and Predictability program (CLIVAR) (http://www.clivar.org/), and U.S. Global Change Research Program (USGCRP) (http://www.globalchange.gov/).

Dr. Jennifer Mercer is joining the section as Program Manager for Arctic Research Support and Logistics (RSL). Dr. Mercer comes to this position from her role as a contracted project manager with the RSL program over the past four years and prior to that as a polar engineering program manager at the U.S. Army Cold Regions Research and Engineering Lab (CRREL) (http://www.erdc.usace.army.mil/Locations/CRREL/). She previously served on detail as RSL Program Manager in 2010 and 2012. Dr. Mercer has a broad scientific background with extensive field experience and logistics management in both the Arctic and Antarctica as well as at other

extreme and austere locations around the globe.

Dr. Frank Rack is now serving as a Program Manager for Arctic Research Support and Logistics (RSL) with a focus on marine operations and Alaska projects. Dr. Rack joins the section from the University of Nebraska-Lincoln (UNL) (http://www.unl.edu/) where he was the Executive Director of the Antarctic geological Drilling (ANDRILL) (http://www.andrill.org/static/index.html) Science Management Office since 2006. At UNL Dr. Rack helped to implement U.S. activities within the ANDRILL Program, as well as provided support for various subglacial access projects in Antarctica, including the Whillans Ice Stream Subglacial Access Research Drilling (WISSARD) (http://www.wissard.org/), Sub-Ice Investigation of Marine and Planetary-analog Ecosystems (SIMPLE) (https://nobusinesslikesnowbusiness.wordpress.com/2014/10/01/about-simple/), and Subglacial Antarctic Lakes Scientific Access (SALSA) (http://www.communicationofscience.org /salsa) projects, as well as project management for the Lake El'gygytgyn drilling project in northeast Russia. He formerly worked for Joint Oceanographic Institutions as a Program Director for the Ocean Drilling Program, U.S. Science Support Program, and Integrated Ocean Drilling Program from 1998 through 2006.

The Arctic Sciences Section will hold **two town hall meetings** during the 2016 Fall Meeting of the American Geophysical Union (AGU) (https://fallmeeting.agu.org/2016/) in San Francisco, California. Both meetings will be held in the ARCUS Arctic Community Meeting Room (https://www.arcus.org/communitymeetings/agu/2016), Foothill E, located on the second floor of the San Francisco Marriott Marquis (http://www.marriott.com/hotels/travel/sfodt-san-francisco-marriott-marquis) at 780 Mission Street.

Arctic Research Support and Logistics Town Hall is scheduled for Thursday, 15 December from 8:00 to 9:00 a.m.

Arctic Natural Sciences Section Town Hall is scheduled for Thursday, 15 December from 7:30 to 9:00 p.m.

All interested community members are welcome to attend.

The Distributed Biological Observatory (DBO) Collaboration Team of the Interagency Arctic Research Policy Committee (IARPC) Completes a Long-term Implementation Plan

By: Sue E. Moore, National Oceanic and Atmospheric Administration (NOAA)/Fisheries ST7 and Jacqueline M. Grebmeier, University of Maryland, Center for Environmental Science (UMCES)

The IARPC Distributed Biological Observatory (DBO) Collaboration Team (http://www.iarpccollaborations.org/teams/Distributed-Biological-Observatory), led by Sue Moore (NOAA) (http://www.noaa.gov/) and Jacqueline Grebmeier (UMCES) (http://www.umces.edu/), has completed a decadal DBO Implementation Plan (http://www.iarpccollaborations.org/uploads/cms/documents/iarpc-dbo-ct-_-dbo-10-year-implementationplan-version1.pdf). The Plan focuses on the period 2015 - 2024 and provides a framework for the preparation of Periodic Assessments of the State of Pacific Arctic Marine Environment (PARMA) at three-year intervals starting in 2018. The PARMA will be based on analyses and modeling using DBO-generated data and data from projects supported by the National Oceanic and Atmospheric Administration (NOAA) (http://www.noaa.gov/), National Science Foundation (NSF) (https://www.nsf.gov/), Bureau of Ocean Energy Management (BOEM) (http://www.boem.gov/), National Aeronautics and Space Administration (NASA) (http://www.nasa.gov/), North Pacific Research Board (NPRB) (http://www.nprb.org/), and other sources. Internationally, linkages to pan-Arctic DBO-type sampling programs will be fostered, including transects identified by the Arctic Council CAFF (http://www.caff.is/)/Circumpolar Biodiversity Monitoring Program and the Protection of the Arctic Marine Environment (PAME) (http://www.pame.is/)/Implementation of Ecosystem Approach (EA) to Management Program. Regionally, the DBO Implementation Plan identifies specific strategies to foster connections with existing community-based observation programs in an effort to link offshore observations of biological change to local observations and Indigenous knowledge.

Other achievements in 2016 include the completion of year-seven of sampling in DBO/Chukchi regions 1-5, and opportunistic sampling in DBO/Beaufort regions 6-8 in the Pacific Arctic sector

(http://www.arctic.noaa.gov/dbo/) (see Figure 1). Field-sampling was contributed by colleagues from 11 projects representing 5 countries. Since 2010, the DBO has provided a framework to focus and coordinate sampling and analytical efforts that link biological changes to physical drivers in a rapidly changing Arctic. A key science achievement of this framework has been the ability to track shifts in benthic community biomass and structure concomitant with measures of annual sea ice persistence in five DBO regions[1,2,3,4]. An important physical oceanographic achievement, through occupation of the DBO-5 (Barrow Canyon) line, has been the observation of the seasonal freshening and warming of sea water transiting northward on the eastern and surface layers of the Chukchi Sea, with the maximum temperature observed in Septembersup[5].

Internationally, the DBO continues to benefit from organizational support from the Pacific Arctic Group (PAG) (http://pag.arcticportal.org/), including integrated collaborations with the Pacific Arctic Climate Ecosystem Observatory (PACEO). These achievements in international cooperation lay the groundwork for a truly pan-Arctic biological observatory, as envisioned at the PAME EA International Conference (http://www.pame.is/index.php/projects/ecosystem-approach/ea-conference).

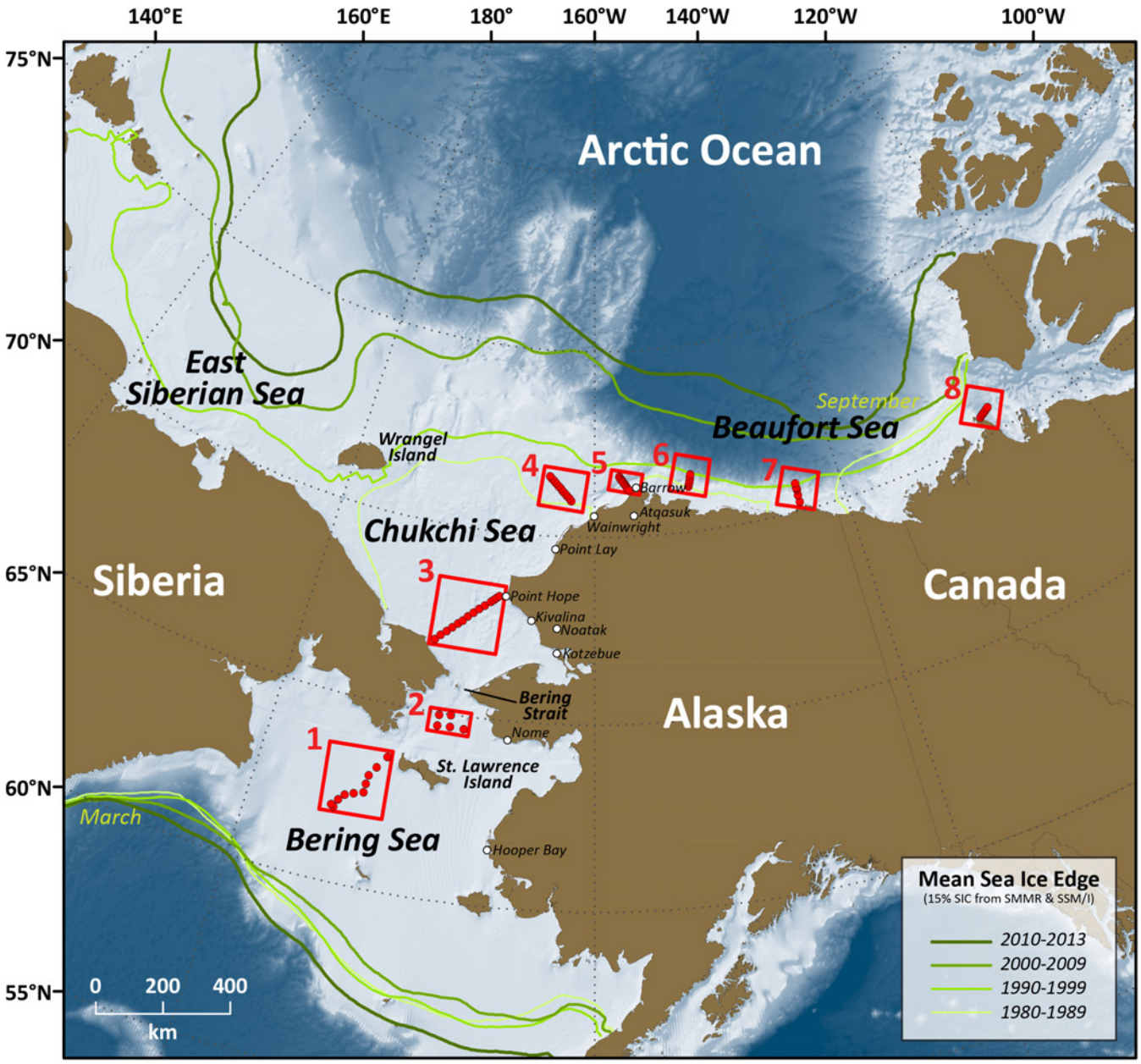

Figure 1: The Distributed Biological Observatory (DBO) extends from the northern Bering Sea to the Beaufort Sea, with eight sampling regions centered on "hotspots" of marine productivity and biodiversity. The DBO serves as a change detection array for the identification and consistent monitoring of biophysical responses to rapid physical changes in the Pacific Arctic sector. Decadal maximum and minimum median ice extent based on Scanning Multichannel Microwave Radiometer (SMMR) and Special Sensor Microwave/Imager (SSM/I) Satellite-Derived Sea Ice Concentrations (1979-2012); map courtesy Karen Frey, Clark University.

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Alaska Fire Science Consortium: Improving Science Information for Response Management

By: Alison York, Alaska Fire Science Consortium

Wildland fire is the dominant ecological disturbance in boreal forests. Wildland fire also affects tundra environments, as evidenced by the record Anaktuvuk River Fire of 2007. In Alaska, the number of acres burned each season varies dramatically (see Figure 1), but accumulating evidence indicates that climate change is increasing the extent of fire and contributing to extreme events such as the 2015 Alaska fire season, when over 5.1 million acres burned (more than half of all acres burned in the U.S.) or the 2016 conflagration in Ft McMurray, Alberta.

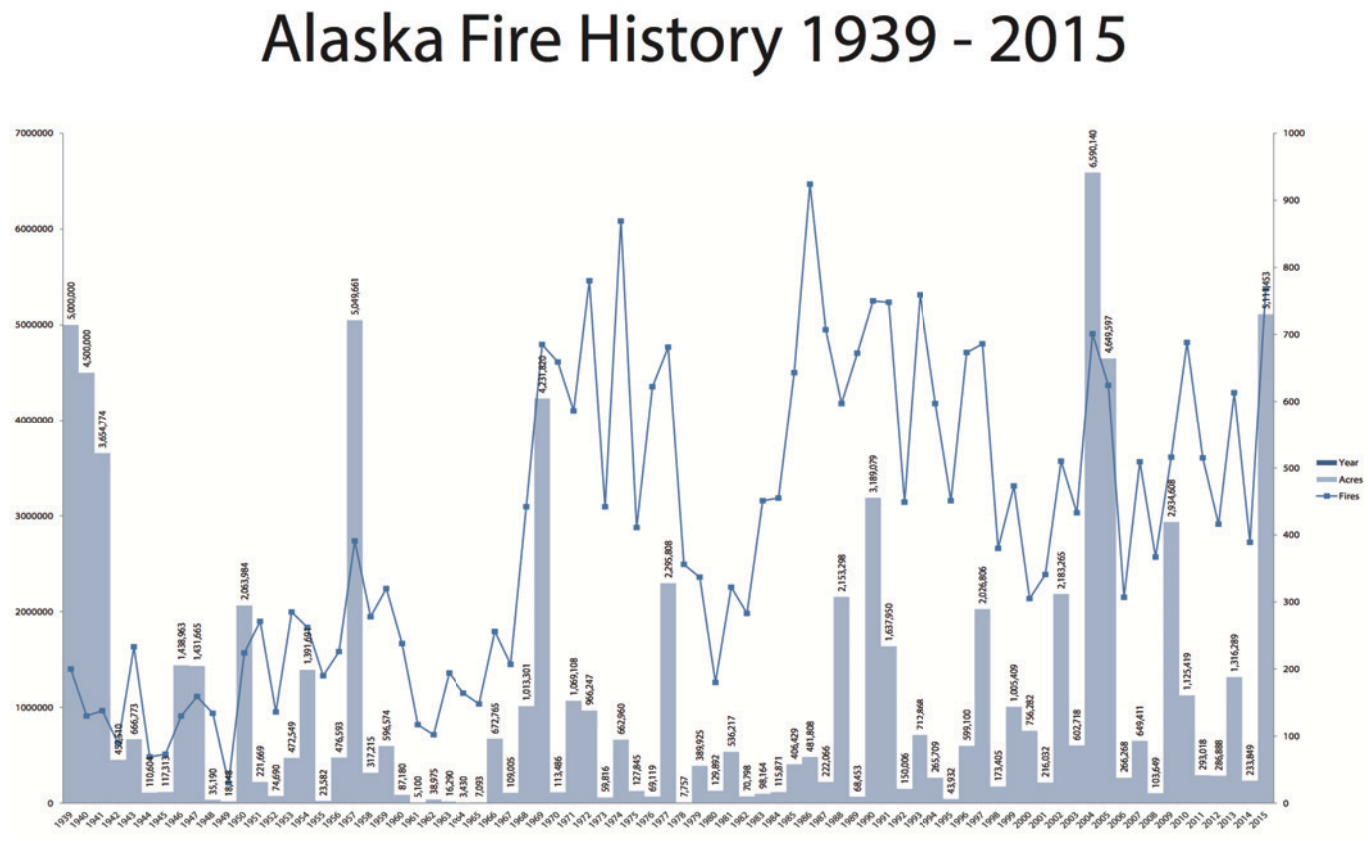

Figure 1: Number of wildland fires and acres burned in Alaska annually since 1939. Courtesy of the Alaska Interagency Coordination Center.

The Alaska Fire Science Consortium (AFSC) (https://www.frames.gov/partner-sites/afsc/home/) is one of 15 regional fire science exchanges supported by the federal Joint Fire Science Program

(http://www.firescience.gov/) to accelerate the awareness, understanding, and adoption of wildland fire science information by stakeholders within ecologically similar regions. Housed at the International Arctic Research Center (http://www.iarc.uaf.edu/) at the University of Alaska Fairbanks, AFSC works with both academic researchers and Alaska's interagency fire management community to improve the scientific basis of managers' decision-making.

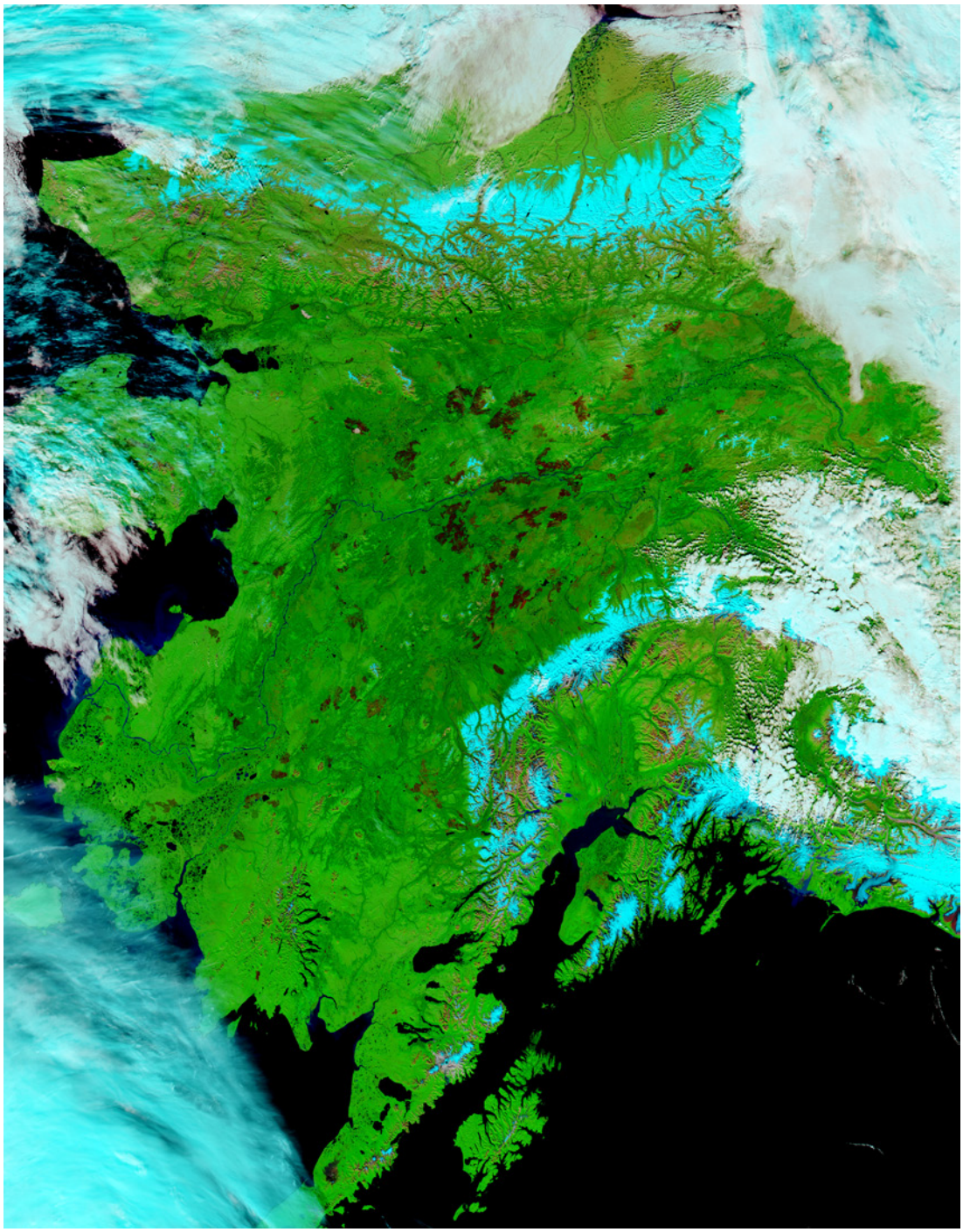

Figure 2: MODIS image of Alaska, taken 1 September 2015, shows more than five million acres of burn scars from the 2015 season as dark red patches. NASA image courtesy of Jeff Schmaltz, MODIS Rapid Response Team.

AFSC has actively collaborated with the Interagency Arctic Research Policy Committee (IARPC) (http://www.iarpccollaborations.org/index.html) Wildfire Collaboration Team (WCT) (http://www.iarpccollaborations.org/teams/Wildfires). This body was chartered to address research gaps and areas for improvement in knowledge relating to wildfire activity, succession, and effects on local communities in the Arctic, specifically focusing on the tundra environment.

Figure 3: AFSC fire ecologist Randi Jandt examining fire effects on tundra one year after the 2007 Anaktuvuk River fire. Photo courtesy of Randi Jandt.

With support from the NASA Applied Sciences Program (http://appliedsciences.nasa.gov/), AFSC and WCT are collaborating to organize Opportunities to Apply Remote Sensing in Boreal/Arctic Wildfire Management and Science (https://www.frames.gov/partner-sites/afsc/events/previous-events/workshops/2017-rs-workshop), an international workshop that will convene in Fairbanks 4-6 April 2017.

The workshop seeks to advance remote sensing tools and data for operational and scientific applications by high northern latitude fire ecology and management communities. Participants will

include interagency fire managers as well as scientists with an interest in remote sensing and a variety of disciplines, including those active in the NASA Arctic-Boreal Vulnerability Experiment (ABoVE) (http://above.nasa.gov/).

Topics of interest include:

- Potential fire risk: Can remotely sensed data (e.g., daily snow extent, others) estimate spring soil moisture and surface and subsurface fuel moisture and fuel conditions, and thus provide critical inputs for fuel moisture indices used to predict fire danger and risk?
- Near real-time fire behavior: Which remotely sensed data are best and most timely for fire detection, plume tracking of fire emissions, fire behavior modeling, mapping of flaming fronts, fire intensity, active fire perimeters, and response for ongoing fires?
- Post-fire effects: Can we improve analytical methods for remotely sensed data to assess fire severity, consumption/carbon dioxid balance, active-layer changes, and successional trajectories of high latitude vegetation communities?

The outcomes of this workshop will advance co-developed investigations into new management and scientific uses of remote sensing data, including

- Increasing the scientific foundation and operational efficiency of northern fire management.
- Improving understanding of climate-induced changes in northern fire regimes and ecosystem components and potential feedbacks to the global climate system.
- Leading to expanded application and use of remotely sensed data for fire management and fire science in high latitudes.

AFSC will publish workshop proceedings, including presentation abstracts, results, and consensus recommendations.

Limited funding is available to offset selected presenters' travel expenses, with priority given to students and other young investigators. The deadline to submit abstracts or apply for travel support is 15 November 2016. Submission instructions are on the AFSC website (https://www.frames.gov/partner-sites/afsc/home).

For more information, contact Alison York, by email (ayork@alaska.edu) or by phone: 907-474-6964.

A New Era for the High-frequency Active Auroral Research Program

By: Ned Rozell, writer, Geophysical Institute, University of Alaska Fairbanks

The High-frequency Active Auroral Research Program (HAARP) (http://www.gi.alaska.edu/haarp-0), is the world's most capable high-power, high-frequency transmitter for study of the ionosphere. Operation of the research facility was transferred from the United States Air Force to the University of Alaska Fairbanks (UAF) (https://www.uaf.edu/) in August of 2015, allowing HAARP to continue with exploration of ionospheric phenomenology via a land-use cooperative research and development agreement.

The 33-acre HAARP antenna array near Gakona, Alaska. Photo courtesy of Todd Paris of UAF.

The HAARP program is committed to developing a world-class ionospheric research facility consisting of:

- The Ionospheric Research Instrument (IRI), a high power transmitter facility operating in the High Frequency range. The IRI can be used to temporarily excite a limited area of the ionosphere for scientific study.
- A sophisticated suite of scientific or diagnostic instruments that can be used to observe the physical processes that occur in the excited region.

Scientific instruments installed at the HAARP Observatory can also be used for a variety of continuing research efforts that do not involve the use of the IRI but are strictly passive. These include ionospheric characterization using satellite beacons, telescopic observation of the fine structure in the aurora, and documentation of long-term variations in the ozone layer.

HAARP will soon host its first campaigns under university ownership. Technicians are preparing the site for two science missions in February 2017. UAF scientists will run one experiment and researchers from Los Alamos National Laboratory in New Mexico the other.

Geophysical Institute (http://www.gi.alaska.edu/) scientists at UAF will fire the transmitters as part of a three-year experiment involving a few elements of complicated space physics. The Los Alamos researchers will use HAARP to generate irregularities in the ionosphere to test satellite-to-ground communications under conditions similar to solar storms. Large solar storms can disrupt communications and sometimes take out power grids.

Since it opened 13 years ago HAARP hosted many scientists doing applied research for the military. One such study was using the antenna array to heat a part of the ionosphere, which in turn acted as a low-frequency antenna that could send an ocean-penetrating signal to a submarine.

The military experiments and the complex nature of studying a region people cannot see or easily understand have fed a controversy about HAARP. Despite the facility being a magnet for conspiracy theorists, Geophysical Institute Director Bob McCoy thought HAARP was too valuable to fall to the dozer blade and hopes the February experiments will help attract customers to HAARP by showcasing UAF's ability to run it. As technicians at the site replace vacuum tubes and lubricate moving capacitor plates that make up the powerful radio-frequency transmitters, HAARP is readying for its first customers of a new era.

More information is available on the HAARP website (http://www.gi.alaska.edu/haarp-0).

Update from the U.S. Arctic Research Commission

By: John Farrell, U.S. Arctic Research Commission (USARC) Executive Director and Cheryl Rosa, USARC Commission Deputy Director

Obama Appoints New Commissioner

On 8 August 2016, President Obama appointed engineer Ms. Jacqueline A. Richter-Menge, research civil engineer at the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL) (http://www.erdc.usace.army.mil/Locations/CRREL.aspx) in Hanover, NH, to a four-year term on the U.S. Arctic Research Commission (USARC) (https://www.arctic.gov/), an independent federal agency that advises the President and Congress.

Richter-Menge replaced Charles Vörösmarty, Director, City University of New York Environmental Cross-Roads Initiative at the City College of New York, who served on the commission for eight years (more information about current Commissioners is available here (https://www.arctic.gov/commissioners.html)).

Fran Ulmer, the Chair of the USARC, endorsed Richter-Menge's selection, saying, "I am grateful that President Obama has appointed an outstanding scientist to join USARC. She has many years of experience doing research in the Arctic focused on solving problems with innovative solutions, which will be a great benefit to our work."

Commissioner Richter-Menge. Photo courtesy of Andrew Roberts, U.S. Naval Post Graduate School)

Richter-Menge, an expert in Arctic sea ice, has made fundamental contributions to the understanding of the mechanical and physical properties of ice, from both laboratory and field experiments. She has led or participated in over 15 field programs to the Arctic, and formerly served as Chief of the Snow and Ice Branch at CRREL. Her work improves projections of sea ice in support of near-real-time operations and on longer timescales.

Richter-Menge has been instrumental in the SCience ICe EXercise (SCICEX) (https://nsidc.org/scicex) program, a collaboration between the U.S. Navy and the marine research community to use nuclear-powered submarines to study the Arctic Ocean. She chairs the program's Science Advisory Committee that met at the Navy's Arctic Submarine Laboratory on 25 October 2016.

For many years, Richter-Menge was either a lead author or a co-author of the annual "The State of the Arctic Report" (now titled "Arctic Report Card" (http://www.arctic.noaa.gov/reportcard/index.html)) for NOAA that summarizes and presents the most recent observations collected by the

international community on the Arctic environment. The 2016 Arctic Report Card will be presented during the Fall Meeting (https://fallmeeting.agu.org/2016/) of the American Geophysical Union, 12-16 December in San Francisco.

About her appointment, Richter-Menge said, "I am excited to join this impressive group in developing, promoting, and supporting the U.S. Arctic research plan."

USARC and the White House Arctic Science Ministerial

The Commission played a significant role in preparing for, supporting, and conducting the first-ever White House Arctic Science Ministerial that was held in Washington, D.C. on 28 September 2016. The U.S. delegation to this meeting included USARC Chair Fran Ulmer and NSF Director Dr. France Cordova, who served as Vice-Chairs of the meeting, and Dr. John Holdren, the President's Science Advisor, who served as Chair. Representatives from 25 countries participated in the day-long event that also included representatives from Indigenous organizations.

White House Arctic Science Ministerial, with Chair Dr. John Holdren, Vice-Chair Fran Ulmer, and Mark Brzezinski. Photo courtesy of U.S. Coast Guard Petty Officer 2nd Class Connie Terrell.

USARC compiled, edited, and published a booklet about the ministerial meeting to serve as a record of the event and its outcomes. Notably, this booklet contains a compilation of two-page descriptions of Arctic science support from each of the 25 countries. This compilation served as background and reference for the meeting and is of interest to the broader Arctic research community. This booklet is available under "publications" at the USARC website (https://www.arctic.gov/).

USARC's 2017-2018 Goals Report

The Commission will soon release its next biennial goals report, which recommends key goals and objectives for the U.S. Arctic Research Program Plan. As the Interagency Arctic Research Policy Committee is also releasing its next five-year Arctic Research Program Plan for 2017-2021, the USARC report will include a focus on achievements.

New USARC Working Group Websites and the Conference on Water Innovations for Healthy Arctic Homes (WIHAH)

Because one of the primary duties of the USARC is to interact with Arctic residents, local institutions, and regional governments, USARC coordinates Alaska-based working groups (https://www.arctic.gov/working_groups.html) to examine and develop research needs for specific topics. USARC staff in Anchorage are currently coordinating three such groups that are addressing "real-world issues" facing Arctic residents. These are the "Alaska Rural Water and Sanitation Working Group," (https://www.arctic.gov/water-san/index.html) the "Arctic Renewable Energy Working Group," (https://www.arctic.gov/arewg/index.html) and the "Arctic Mental Health Working Group." (https://www.arctic.gov/ambhwg/index.html) Descriptions of each working group, information on member organizations, and affiliated publications are available online. The group focusing on water and sanitation played a significant role in the recently-completed conference on Water Innovations for Healthy Arctic Homes (http://wihah2016.com/) that was held in Anchorage, 18-21 September 2016. This Arctic Council-endorsed conference brought together U.S. and international engineers, health experts, researchers, community members, policymakers, and innovators to discuss the challenges and opportunities associated with making running water and sewer services in remote northern communities safe, affordable, and sustainable. A conference-related publication is expected in early 2017.

Further information is available on the USARC website (https://www.arctic.gov/).

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Science Priorities for a Changing Arctic: The National Academies' Public Forum in Honor of the White House Arctic Science Ministerial

By: Riya Anandwala and Laurie Geller, National Academies of Sciences, Engineering, and Medicine

On 28 September 2016, science ministers and advisers from 25 nations came together at the first-ever Arctic Science Ministerial (https://www.whitehouse.gov/blog/2016/05/13/white-house-arctic-science-ministerial-september-28-2016) hosted by the White House, to discuss collaboration and commitment to address the dramatic environmental changes facing the Arctic. This cadre of international leaders gathered to increase understanding of these environmental changes and to identify priorities for international scientific cooperation. Some of the major themes the group focused on were: solidifying and integrating data and observations on the region, building resilience and response mechanisms, and empowering citizens with Science, Technology, Engineering, and Mathematics (STEM) education.

Figure 1: Fran Ulmer, chair of the U.S. Arctic Research Commission, discusses Arctic science at the forum. Photo courtesy of the Polar Research Board.

The following day, the National Academies of Science'(NAS) (http://www.nasonline.org/) Polar Research Board (PRB) (http://dels.nas.edu/prb) invited several of the representatives from the Ministerial and other speakers to continue the conversation, in a public event hosted at the National Academy of Sciences NAS building. Panelists at the Academies' forum were **Nikolai Toivonen**, Director for International Cooperation, Ministry of Education and Science of Russia (http://government.ru/en/department/33/events/); **Hyoung Chul Shin**, Head of International Cooperation at the Korean Polar Research Institute (http://eng.kopri.re.kr/home_e/contents/e_1100000/view.cms); **Andrea Tilche**, Head, Climate Action and Earth Observation Unit and Directorate General for Research and Innovation, European Commission (http://ec.europa.eu/research/environment/index.cfm); and **Satu Paasilehto**, Senior Adviser, Finland Ministry of Education, Science, and Culture (http://www.minedu.fi/OPM/?lang=en)—each of whom fielded questions from the moderator, **Julie Brigham-Grette**, chair of the Academies' PRB (http://dels.nas.edu/prb), and members of the audience. In addition, Ambassador **Mark Brzezinski**, Executive Director of the Arctic Executive Steering Committee (https://www.arctic.gov/aesc/) and

former U.S. Ambassador to Sweden, **Fran Ulmer**, chair of U.S. Arctic Research Commission (USARC) (https://www.arctic.gov/), and **Kelly Falkner**, Director of National Science Foundation's (NSF) Division of Polar Programs (https://www.nsf.gov/div/index.jsp?div=PLR) also spoke at the forum.

Figure 2: Panelists discuss the Arctic Science Ministerial Meeting with PRB chair, Julie Brigham-Grette. Photo by Mark Finkenstaedt, courtesy of NAS.

The ambition to contribute to Arctic science is different for each nation. Shrinking glaciers, receding sea ice, and coastal erosion are directly impacting the eight Arctic nations, but countries far away from the region are also feeling the consequences of a changing Arctic. For example, a warmer Arctic may be contributing to more extreme weather outbreaks around the mid-latitudes of the northern hemisphere.

"It's a delicate region, environmentally and also strategically, and no one country can dictate to everyone else what is needed," said Mark Brzezinski (AESC) at the National Academies forum. "Following President Obama's visit to the Arctic, we decided to convene this international gathering of science ministers to engage a process of cooperative setting of priorities in Arctic science. That

resulted in a process that will continue beyond this administration about a problem that is increasing globally—hence the participation of a lot of non-Arctic countries."

The biggest takeaway from the ministerial, said Fran Ulmer (USARC), was identifying the need to create a more robust observation system with an international governance regime and long-term financing. Observation is crucial in building the research infrastructure going forward and is also needed for improving weather, water, and sea-ice forecasting; understanding how changes in the Arctic will affect conditions around the world; and the evolution of the Arctic under different global-emissions scenarios.

A number of efforts are underway to strengthen observation practices and improve data policies that promote sharing through full and open access. The work has already started moving in that direction with the European Union's five-year project to develop an Integrated Arctic Observing System (INTAROS) (http://web.gfi.uib.no/polarnettverk/polardag_sept_2016/Polardagen_2016_Sagen.pdf) that will take shape starting this year. In 2017, the U.S. Office of Naval Research will start a five-year Arctic Mobile Observing System (AMOS) (http://www.onr.navy.mil/en/Science-Technology/Departments/Code-32/All-Programs/Atmosphere-Research-322/Arctic-Global-Prediction/AMOS-DRI.aspx) project that will develop new sensors, platforms, and techniques for a science platform that will drift with the moving sea-ice cover or operate autonomously in the ocean below the ice.

The Arctic can also serve as a real-time laboratory to educate and train the next generation of scientists and engineers in a variety of disciplines. Incorporating more Arctic science into STEM education will help to develop experts who can contribute to addressing some of these regional and global challenges.

For Nikolai Toivonen (Ministry of Education and Science of Russia), improving education for Arctic populations is an important issue, and he also favors a working group to combine knowledge and competencies with other countries and build concrete research for data-sharing. "We care about the training and education of Indigenous people, to help them stay in their native areas and develop their businesses for sustainable development of the Arctic region," said Toivonen.

The current challenges, and the potential to build unique solutions to address them, exemplify this Arctic effort as a model of sustainable development goals for the rest of the world, said panelists at the forum. Repeating the sentiments of one of the science representatives at the ministerial, Kelly Falkner (NSF Division of Polar Programs) said, "If we don't succeed in the Arctic, then we will have

trouble succeeding in the world."

The Academies event ended with a special preview showing of a new 3D film about Greenland, along with a discussion about the use of storytelling to enhance public communication about the Arctic (the film was produced by Peter Chang and directed by Todd Jones). The event also included Arctic science exhibits: the National Aeronautics and Space Administration (NASA) (http://www.nasa.gov/) "PufferSphere", a 360° interactive system that highlight's NASA's Earth science data; and "ArcticDEM" (https://www.nsf.gov/news/news_summ.jsp?cntn_id=136108), a demonstration of the NSF, National Geospatial-Intelligence Agency, and the Environmental Systems Research Institute (ESRI) (http://www.esri.com/) project to produce a high-resolution digital elevation model of the entire Arctic.

Video recordings of the event can be viewed here (http://dels.nas.edu/Upcoming-Event/Science-Priorities-Changing-Arctic/AUTO-7-89-17-G?bname=prb).

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Report from the ARCUS Executive Director

By Robert H. Rich, Ph.D., CAE

September was a watershed in Arctic research, with the first-ever White House Arctic Science Ministerial (https://www.whitehouse.gov/blog/2016/05/13/white-house-arctic-science-ministerial-september-28-2016) (see my more in-depth article in this issue) (https://www.arcus.org/witness-the-arctic/2016/3/article/26061) taking place in Washington, D.C. Associated with this meeting of high-level government officials from 25 countries, ARCUS provided the primary public forum for the broader Arctic research community to engage with the Ministerial's themes. We worked with the Arctic Portal (http://arcticportal.org/), the Woods Hole Research Center (http://whrc.org/), Arctic 21 (an ad hoc coalition of non-governmental organizations concerned with climate change in the Arctic), the Consortium for Ocean Leadership (http://oceanleadership.org/), and Columbia University's PoLAR Partnership (http://thepolarhub.org/) to hold a day-long event focused on Science, Technology, Engineering, and Math (STEM) education as it relates to Arctic research. Following a keynote presentation by the Executive Director of the U.S. Arctic Executive Steering Committee (https://www.arctic.gov/aesc), Ambassador Mark Brzezinski, we held panels of international experts and officials on how Arctic research can inspire STEM education around the world and on how to improve STEM education and citizen empowerment within the Arctic. A recording of the presentations and discussions is online (https://www.arcus.org/meetings/2016/arctic-science-ministerial). Following the panels, our D.C. office also hosted a wide range of hands-on activities, opportunities for educational resources, and other outreach tools that engaged local and national educators, officials, and other stakeholders.

We also have continued to host leading researchers who are traveling to D.C. in our D.C. Arctic Research Seminar/Webinar Series (https://www.arcus.org/research-seminar-series). These events serve both the researchers, policymakers, funders, and thought leaders in D.C. and a global online audience (live and recorded). In September, Dr. Henry Huntington (Pew) shared some key Arctic social science priorities for improved understanding of the complex human dimensions within the

region. On 26 October we hosted the seventh of the Seminars featuring Dr. George Divoky who talked about his interesting studies of #Arctic seabirds and what they can tell us about the changing environment. We are always on the lookout for excellent speakers and researchers who will be in D.C. and can present on a timely research topic. Please email me at bob@arcus.org if you or someone you know would like to be considered as a future speaker.

In October, I traveled to Akureyri, Iceland and to the Arctic Circle Assembly (http://www.arcticcircle.org/) in Reykjavik, Iceland. Akureyri is a major international Arctic research hub, serving as home to the Arctic Council's working groups on Conservation of Arctic Flora and Fauna (CAFF) (http://www.caff.is/) and the Preservation of the Arctic Marine Environment (PAME) (http://www.pame.is/), the Northern Forum (http://www.northernforum.org/en/the-northern-forum/about-the-northern-forum), the Arctic Portal (http://arcticportal.org/), the Icelandic Arctic Cooperation Network (http://arcticiceland.net/en/um-nordhurslodhanetidh), the Steffanson Institute (http://www.svs.is/en), the University of Akureyri (http://english.unak.is/), and (soon) the International Arctic Science Committee (IASC) (http://iasc.info/) Secretariat among others. We are delighted to strengthen ARCUS connections with all of these partners and I was honored to be able to speak with the European Polar Board (http://www.europeanpolarboard.org/) about possible connections and attend the Polar Law Symposium (http://www.polarlaw.is/en/previous-symposiums). The Arctic Circle Assembly is the largest meeting on the Arctic each year, with about 2,000 participants. ARCUS organized two breakout sessions there, including a panel on "Essential Science for Informed Decision-Making in the Changing Arctic" and one on "How to Connect with Arctic Research across Boundaries." Both went very well, and more information is available here (https://www.arcus.org/meetings/2016/arctic-circle-assembly). It is important for the U.S. Arctic research community to engage with international partners through communication, coordination, and collaboration. The Arctic is a region that cuts across national boundaries, and ARCUS participates in the important conversations to help you to connect.

I'm pleased to report that we are well underway in updating this publication, in order to increase its value to you. We conducted a comprehensive readership survey this summer, which has helped to inform the changes. We expect to roll out the new version of Witness in early 2017, with all of the useful news you've counted on us for about NSF Polar Programs, ARCUS, research results, and efforts of the broader Arctic research and education communities.

As I hope you know, ARCUS is a member-driven organization. Since last fall, all types of organizations and individuals are eligible to become ARCUS members. If you are reading this and

share our passion for connecting Arctic research across boundaries, we invite you to become a member at https://www.arcus.org/arcus/member-information.

Finally, please mark your calendars for the ARCUS Arctic research community reception (https://www.arcus.org/annual-meetings) at the American Geophysical Union Fall Meeting. This year, we will be holding the open reception on Wednesday, 14 December from 7:00–8:30 p.m. in the Arctic Community Meeting Room (Foothill E at the Marriott Marquis). You are also invited to observe the ARCUS Annual Meeting from 6:00–7:00 p.m. immediately preceding the reception.

Welcome New ARCUS Members (Since January 2016)

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A Historic Week for Arctic Research in Washington, D.C., 27-29 September 2016

By: Robert H. Rich, Ph.D., CAE, ARCUS Executive Director

The Obama administration has demonstrated strong interest in the Arctic through development of a pioneering National Strategy for the Arctic Region (https://www.whitehouse.gov/blog/2015/03/27/white-house-releases-implementation-report-national-strategy-arctic), establishment of an Arctic Executive Steering Committee (https://www.arctic.gov/aesc/), convening of the international GLACIER Conference (http://www.state.gov/e/oes/glacier/index.htm) in Alaska last summer, and the President's trip (https://www.whitehouse.gov/2015-alaska-trip) above the Arctic Circle, the first time ever by a sitting President.

This series of actions reached a culminating point when the White House invited nations engaged in Arctic research to the first-ever Arctic Science Ministerial (https://www.whitehouse.gov/blog/2016/05/13/white-house-arctic-science-ministerial-september-28-2016) meeting on 28 September in the Indian Treaty Room in the Eisenhower Executive Office. This historic event brought together leaders from the eight Arctic nations and many others, 25 in all, along with circumpolar indigenous groups and top U.S. Arctic officials. It was chaired by Presidential Science Advisor Dr. John Holdren and co-chaired by Fran Ulmer, Chair of the U.S. Arctic Research Commission. The meeting focused on four key themes, to which the organizers asked U.S. agencies and participating governments to suggest possible areas for cooperation. These included science; Arctic observing; community resilience; and Science, Technology, Engineering and Math (STEM) education.

Each minister participating gave a presentation in one of the four theme areas and then discussion to identify additional areas of cooperation took place. The ministers agreed to a Joint Statement (https://www.whitehouse.gov/the-press-office/2016/09/28/joint-statement-ministers) and released a Fact Sheet (https://www.whitehouse.gov/the-press-office/2016/09/28/fact-sheet-united-states-hosts-first-ever-arctic-science-ministerial) of new initiatives, some cooperative, to which they are committed. We also expect a summary of existing Arctic research initiatives by each participating country to be released soon on the U.S. Arctic Research Commission (USARC) website (https://www.arctic.gov/).

The afternoon before the Ministerial, Presidential Science Advisor Dr. John Holdren hosted Alaska Native and circumpolar Indigenous leaders at the White House for a listening session to inform the ministerial discussions. That evening, 340 key Arctic research stakeholders attended a kickoff reception at the Smithsonian Museum of Natural History, where I was able to attend and represent ARCUS. In addition to Dr. Holdren, speakers included Ann Bancroft (who is the first woman to trek to the North Pole), Admiral Robert Papp (U.S. Special Representative to the Arctic), and Alaska Lt. Governor Byron Mallott (who provided an Alaska Native invocation).

On 27 September, ARCUS hosted an international side event (https://www.arcus.org/events/arctic-calendar/25701) focused on STEM education and citizen empowerment at our D.C. office. Co-organizers with us included the Arctic Portal (http://arcticportal.org/), the Woods Hole Research Center (http://whrc.org/), Arctic 21 (an ad hoc coalition of NGOs concerned with climate change in the Arctic), and the Consortium for Ocean Leadership (http://oceanleadership.org/). Our speakers included Ambassador Mark Brzezinski (Executive Director of the Arctic Executive Steering Committee), who provided a briefing on the Ministerial plans. We held two panels: one focused on using Arctic science as a vehicle to encourage interest in STEM education, and the other focused on empowering Arctic communities through research and STEM education. A recording of the event and other resource materials are available online here (https://www.arcus.org/meetings/2016/arctic-science-ministerial).

Following the panels, we hosted many hands-on activities and displays that use the Arctic to inspire STEM education, and we also featured the influential ARCUS PolarTREC program (https://www.polartrec.com/). The displays were organized by the PoLAR Partnership (http://thepolarhub.org/) at Columbia University.

On 29 September, the U.S. Arctic Research Commission (https://www.arctic.gov/) met and considered the results of the Ministerial. Generally, Commissioners were excited and optimistic about how the Ministerial had brought high-level interest and support to the key needs of Arctic research. Outside reaction from the research community was guardedly optimistic, as described in an Eos article (https://eos.org/articles/first-arctic-science-ministers-confab-yields-cooperation-pledge). I mentioned that getting top science advisors to say that Arctic research is a priority for their country will go a long way, but the next crucial step is to follow up with real action and real implementation and real investment.

Further reactions that I've since heard from Arctic research stakeholders in the U.S. and worldwide

suggested that more social science should have been considered, since human factors are integral to fully understanding Arctic change. Also, there is some concern that initiatives resulting from the Ministerial may be lost in the Presidential transition in January. It is clear, however, that this event raised awareness of the importance of Arctic research among the participating ministers and to some extent among the U.S. and global public. It also allowed for the visible endorsement by many nations of a number of cooperative projects intended to advance each of the four themes.

The organizers of the Ministerial will be holding an implementation conversation among the countries involved in October, according to Ambassador Brzezinski. Many of the projects proposed still need quite a bit of development. ARCUS will be monitoring these and attempting to bring in perspectives from the broader Arctic research community as appropriate. The European Union has agreed to hold a second Arctic Science Ministerial meeting in 2018.

Please feel free to email me at bob@arcus.org if you have ideas for how ARCUS might best support connections across national boundaries to advance Arctic research in collaboration with our government and other partners.

See also *The First Meeting of the Arctic Science Ministers: A SEARCH Perspective* (https://www.arcus.org/witness-the-arctic/2016/3/article/26072).

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Meet Carolina Behe

Carolina Behe serves on the ARCUS Executive Committee as Member-at-Large. She joined the Board of Directors in 2015 and her term ends 2018.

Behe is the Indigenous Knowledge/Science advisor for the Inuit Circumpolar Council Alaska (http://iccalaska.org/). She received an MA in Biodiversity and Conservation from Scripps Institution of Oceanography in 2011 and began her current position that same year.

Carolina's work within the Inuit Circumpolar Council Alaska is diverse and ranges from topics within climate change to management and policy. Internationally, Carolina acts as the Inuit Circumpolar Council (ICC) Head of Delegation on the Conservation of Arctic Flora and Fauna (http://www.caff.is/) working group under the Arctic Council. Much of ICC's work within this group is focused on ensuring an Inuit perspective and interest are at the table. Additionally, a high amount of focus is placed on the involvement of Indigenous Knowledge—promoting the involvement of Indigenous Knowledge and promoting the use of a co-production of knowledge to utilize both Indigenous Knowledge and science in the work conducted within the Arctic Council.

Carolina was drawn to work in the Arctic through an awareness of the many rapid changes occurring within our world today; she hoped to be able to work within the Arctic to aid in adjusting and increasing our understanding of the world. She was also drawn to the Arctic and this position because it allows for her to work within two knowledge systems, Indigenous Knowledge and science. Indigenous Knowledge takes a holistic view and sees how many pieces fit together. Working with this understanding and way of knowing, combined with science, will aid in making adaptive ecosystem-based decisions in the face of climate change.

A key role for ARCUS to play is bringing together people of different knowledge systems, such as scientists of different disciplines and Indigenous Knowledge holders. This is what has encouraged Carolina to engage with ARCUS as a board member. Building a strong platform for sharing and exchanging information from different knowledge systems will move us in a direction of understanding the Arctic through a more holistic view.

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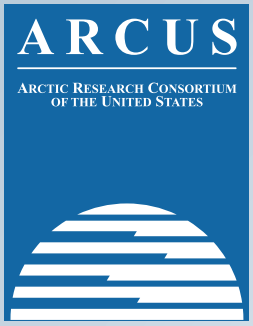

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