AK CSC

ALASKA CLIMATE SCIENCE CENTER

ANNUAL REPORT HIGHLIGHTS 2014–2015

A message from the Alaska Climate Science Center Directors

The past two years have been very busy, marked by continued growth and well deserved recognition as our research and outreach agendas mature.

In this issue, you will learn about our research efforts in the development of downscaled climate information, products, and tools. These efforts have filled a critical data gap in Alaska and are now serving both the research community's needs as well as informing the decision making process for land managers and policy makers. Alaska is undergoing some of the fastest changes to glaciers and icefields on Earth, and our sustained research efforts have also lead to new understandings of these critical landscape components.

We have likewise focused significant efforts on how to effectively communicate climate science information to our stakeholders and to facilitate dialogue between decision makers and the research community. These efforts have been demonstrated in numerous ways including prominent collaborations between the AK CSC, NOAA, and the US Forest Service. Our efforts working with stakeholders over the past four years culminated in the Climate, Conservation, and Community in Alaska and Northwest Canada conference held in November 2014.

The AK CSC has continued to support the development of our next generation of scientists through the AK CSC fellows program. These early career scientists are addressing challenging issues related to climate variability and impacts on natural resource management, and once again you will meet some of the AK CSC-funded graduate students.

We hope you enjoy learning about the AK CSC. We encourage you to visit our websites or contact us directly to learn more about our research, education, and outreach activities.

HIGHLIGHTS

- Collaborative conference addresses resource management in the face of rapid change
- Kettle works to map the web of Alaska climate research
- Featured students: Katrina Bennett, Katia Kontar
- Dynamic downscaling techniques yield new understandings and attention
- *From Icefield to Ocean* synthesis paper and figures garner widespread attention
- AK CSC prominent in President Obama's Alaska visit
- Girls on Ice continues to lead students toward careers and adventures in science
- AK CSC contributes to the new National Climate Assessment

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See more news from the Alaska Climate Science Center at **csc.alaska.edu** and **doi.gov/csc/alaska**

▲ Above: Aerial view of the Yukon River in the Yukon Delta National Wildlife Refuge. (photo: Fred Broerman)

Collaborative conference addresses resource management in the face of rapid change

In November of 2014, more than 150 scientists, resource managers, and other decision makers from across Alaska and northwest Canada discussed how the region's resources can be studied and managed during rapidly changing conditions.

Since 2011, the AK CSC and five regional Landscape Conservation Cooperatives, or LCCS (part of a nationwide network of conservation-focused partnerships founded by the U.S. Fish and Wildlife Service) have worked together to develop understanding and responses in the face of climate change in Alaska and Northwest Canada.

The conference was a chance for these groups to share their scientific progress, learning outcomes, new opportunities for capacity and effectiveness, and strategies for future work. "These days, we think it's better if science doesn't happen in a vacuum," Littell said. "We need decision-makers and managers involved in asking the important questions, and we need scientists to work in a way that responds to the needs of decision-makers."

The engagement that the CSC-LCC partnership was designed to facilitate depends on collaborative opportunities like this conference, though such events can occur only rarely. The meeting included sessions to demonstrate partnerships that are working well, promote further dialogue, identify places for synergy, and prepare the next generation of scientists to work in this manner.

The main conference was held on the first two days and was open to all participants. The program included plenary sessions, a poster session, parallel sessions, innovative "SWIRL" panels and audience discussion sessions. The event also included special events for AK CSC early career scientists, called "fellows." The third day of the conference was a LCC Joint Steering Committee Meeting, which included steering committee members and coordinators from each LCC. AK CSC personnel and fellows were also invited to participate.

Participants described how the conference provided great net-

Kettle works to map the web of Alaska climate research

Nathan Kettle, a research associate with the AK CSC and Alaska Center for Climate Assessment and Policy (ACCAP), is developing and evaluating processes to connect science and decision-making. One project is a social network analysis of climate research, applications, and services in Alaska.

Social network analysis is used to study social structures by looking at nodes (individuals or things within a network) and the ties (relationships or interactions) that connect them. Network maps (right) help visualize connections across the network.

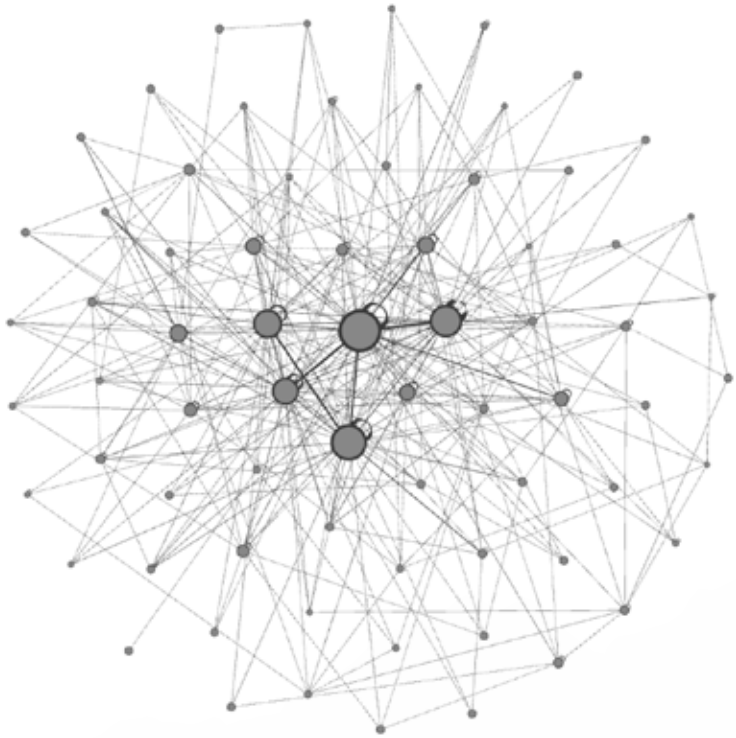
There are growing numbers of people and organizations working on climate-related research, decision making, and services in Alaska, but obstacles to fostering interaction and providing usable data and information exist. "The challenges to communicating in Alaska are unique and acute," Kettle observes. "When it comes to climate research here, individual stakeholders are separated by large geographic distances, and there are significant time and resource constraints."

These concerns gave rise to this project, which aims to understand the role of social networks in supporting climate adaptation. The project maps the structure and function of communication and information exchange among federal, state, tribal, industry, and non-profit entities engaged in climate science, services, decision making, and adaptation in Alaska.

Kettle interviewed 126 people involved in climate work across Alaska and asked them about the types of climate-related activities they were involved in, and whom they networked with.

Kettle feels that "this work will identify and map the complex network of climate research, applications, services, and adaptation in Alaska. We'll identify how our network structure relates to our adaptation, enabling us to better evaluate all of our program activities."

Kettle aims to finish the project in January 2016. Results will be posted on the ACCAP and AK CSC websites and presented as part of the ongoing ACCAP climate webinar series.



▲ Network analysis of the climate-science practice interface across Alaska. Dots represent organizations and the lines represent the network ties between organizations. Larger dots represent organizations with more network ties.

working opportunities, with one noting that they met "managers that were interested in our work and this was a good opportunity to make them aware of what's been done and future research directions."

In all, the event provided a forum for those involved in climate and conservation in the region, across agencies, research groups, and stakeholder communities, to discuss where they've been, where they wish to go, and what to do to get there. One participant said, "It was a great workshop that brought together most of the players actively involved in climate related research or dealing with resource management in the face of a changing climate."

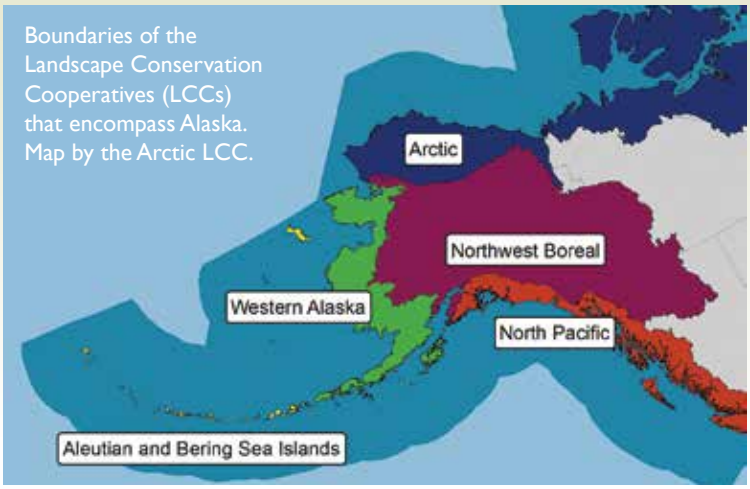
The event provided a superb atmosphere for networking and valuable new collaborations were forged. Several people spoke favorably about bringing together academic scientists and resource managers.

"The CSC-LCC relationship is an experiment in how we both identify and respond to the challenges of climate change," Littell said. "We're asking ourselves as a community how that experiment is going, and challenging ourselves to be more effective."

Visit the conference website
tinyurl.com/gpb9rmn

CONFERENCE VIDEOS
vimeo.com/channels/889350

"This event wasn't just about the science … It's about how the whole community has to work harder and faster — together — to get answers and apply them to making better decisions."
— *JEREMY LITTELL, CSC LEAD SCIENTIST AND CONFERENCE ORGANIZER*



Boundaries of the Landscape Conservation Cooperatives (LCCs) that encompass Alaska. Map by the Arctic LCC.

Student profile: Katia Kontar

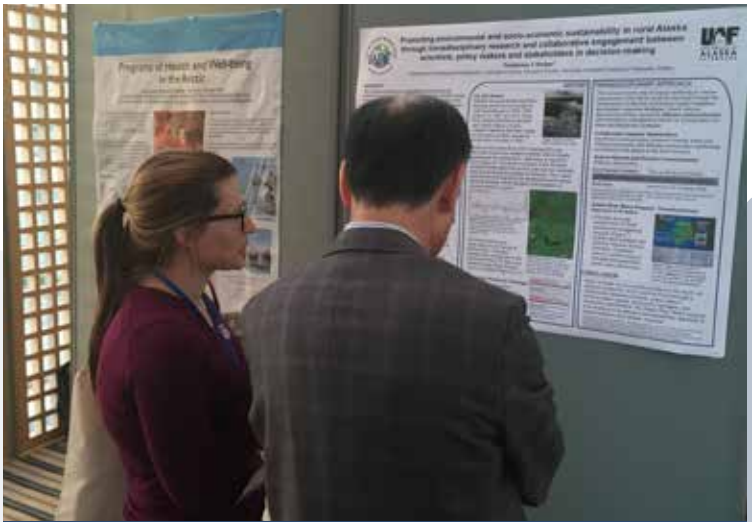
PhD student Katia Kontar's research has focused on mitigating and adjusting to the risks that natural disasters pose to Arctic and Subarctic communities. She has been recognized widely for her graduate work and potential as an early career scientist, including her selection to the international Arctic Frontiers Emerging Leaders Program in early 2015.

Kontar is currently analyzing communities in Subarctic Alaska and Russia — including the flood-ravaged village of Galena, Alaska — that are prone to flooding caused by down-river ice jams. In Galena, this risk is typified by the disastrous flooding and evacuation that occurred there in 2013. While there is a great deal of physical damage that comes with such a disaster, Kontar says she has learned the costs are often more widespread than property, in some cases threatening the continued existence of the community itself.

To prepare for and mitigate such risks, Kontar's project is designed to evaluate past and present responses to similar situations. She notes that ice jams are notoriously difficult to predict, and that most strategies have focused on responding quickly to jams as they develop, using tools such as explosives and ice breaker ships to disrupt waterway blockage. Many of these approaches have proven dangerous and costly, however, and cannot be relied on long term. In the case of Galena, she believes it is important to communicate with community leaders about alternatives, including possible relocation.

"As a social scientist," says Kontar, "I am focused on methods for bridging the gaps between local, traditional knowledges and leadership and those of our scientific researchers. The only ways for such a project to succeed is for all stakeholders to recognize the shared interest and expertise that exists across our distinct perspectives."

Though her work includes a focus on physical and climate science, Kontar comes from a background in strategic communication and social understanding. From there, she has been intrigued by the unique challenges of extreme climates, first through her work with the Antarctic Drilling Project (ANDRILL) in Antarctica and then studying with advisor John Eichelberger in Alaska. Kontar observes that Northern communities' remoteness, limited infrastructure, harsh winters, complicated history, and constrained communication systems make them both demanding and fascinating to study.


▲ Katia presented her research at the Arctic Science Summit Week in Toyama, Japan.

Dynamic downscaling techniques yield new understandings

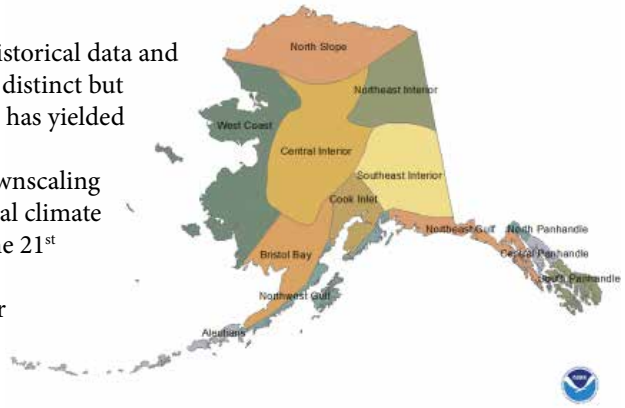
AK CSC researchers have achieved important successes in efforts to downscale past climate profiles in Alaska using a variety of coarse-resolution historical data.

Downscaling — a class of research methods that adds greater precision and detail to historical data and future projections — has long held potential for Alaska and the Arctic, a region with a distinct but sparse climatic record. Work by researchers Uma Bhatt, Peter Bieniek, and John Walsh has yielded important validations — and revelations — regarding our climate.

Bhatt worked with the AK CSC and ACCAP to extend a model-based, dynamic downscaling project to all of Alaska. This project uses the Weather Research and Forecasting regional climate model and reveals greater complexity for Alaska climate simulations from 1979 into the 21st century.

Bieniek found that the climatic conditions of Interior Alaska actually extend further south than assumed, and that southeast Alaska has many more distinct climate zones (see climate divisions map at right) than had been previously identified.

Walsh, whose work has long focused on Arctic sea ice, used downscaling to establish a long-term sea ice database. In conjunction with NOAA, Walsh's group determined ow much sea ice loss is due to warming water temperatures, establishing a common-format background for sea ice levels back to the 1920s. This work provides important new data relevant to offshore and coastal locations impacted by variations in surface temperature, winds, and sea ice.



▲ Alaska has 13 climate divisions. Knowing these divisions will help scientists better understand the various climates in Alaska, as well as how they are changing over time.

Walsh's group has also developed web-based, searchable data tools for accessing downscaled data. Users can select climate variables for plots of frequency of occurrence over time, as well as search the historical Sea Ice Atlas for visual mapping of how Arctic sea ice off the coast of Alaska has changed over the last 90+ years. Find these tools and others at **snap.uaf.edu/tools-and-data/all-analysis-tools.**

Student profile: Katrina Bennett

For her PhD work, Katrina Bennett studied changes to the hydroclimate caused by extreme weather and surveyed historical climate model data. Her work has been published in leading journals such as Hydrological Processes and Journal of Climate.

Bennett notes that the Arctic and the world are experiencing more extreme weather events more often, and it is important to examine the effects of these changes across the wide array of features that make up a climate and an ecosystem. Bennett has been primarily interested in changes to Subarctic watersheds, especially the river basins of interior boreal ecosystems. She has also surveyed lake systems in the boreal forests of Alberta for varying isotopes and acidity levels. Because of the shifts that extreme weather events and newer extraction methods can cause in ecosystems over time, it is important to observe hydrological factors such as drainage, thawing, and streamflow patterns, which can also change drastically.

"By working to understand the scope of these changes today," Bennett says, "our climate science community can also present a fuller picture of the hydrology of the past and the future. This is why I have been working to build more complete hydrology models from extensive historical data." By developing models with broader and more diverse detail, Bennett says we can use important factors like temperature and precipitation for more confident, specific, and accurate forecasting.

Since January 2015, Bennett has relocated to the high mountain deserts of Los Alamos, New Mexico to work as a Postdoctoral Researcher at the Los Alamos National Lab. She is working on a project focused on analysis of climate change and vegetation disturbance impacts to hydrology in the Colorado River basin. Her work will focus on identifying and characterizing changes associated with thresholds, tipping points and extreme events.

◀ Katrina Bennett pauses while retrieving isotope samples from Mendenhall Glacier near Juneau. *(Photo: Eran Hood)*

Bennett feels strongly that scientists' work should provide direct benefits and connections to the public, and her long-term goals include an emphasis on communication pathways between scientists and their larger communities. She hopes to lead an interdisciplinary research lab to address frustrations and misunderstandings she believes can result from particular scientific conventions and practices.

From Icefield to Ocean synthesis paper and figures garner widespread attention

Representing the culmination of a two-year project featuring input from dozens from across the Alaska climate science and resource management communities, the AK CSC's "From Icefield to Ocean" work was prominent in 2015.

"Alaska's icefields are closely linked to downstream rivers and estuaries … we need interdisciplinary research that allows us to study this icefield-to-ocean system in a holistic manner. This work highlights the pressing need to increase our understanding of the role that glaciers play in Gulf of Alaska coastal ecosystems."

– ERAN HOOD, SECOND AUTHOR, UNIVERSITY OF ALASKA SOUTHEAST

Beginning in March 2013 as part of an interdisciplinary glacier study workshop, the "Icefield to Ocean" project has created informational products that cross multiple genres and audiences, including peer reviewed synthesis research, mainstream briefing publications, and graphic figures recognized with an international award.

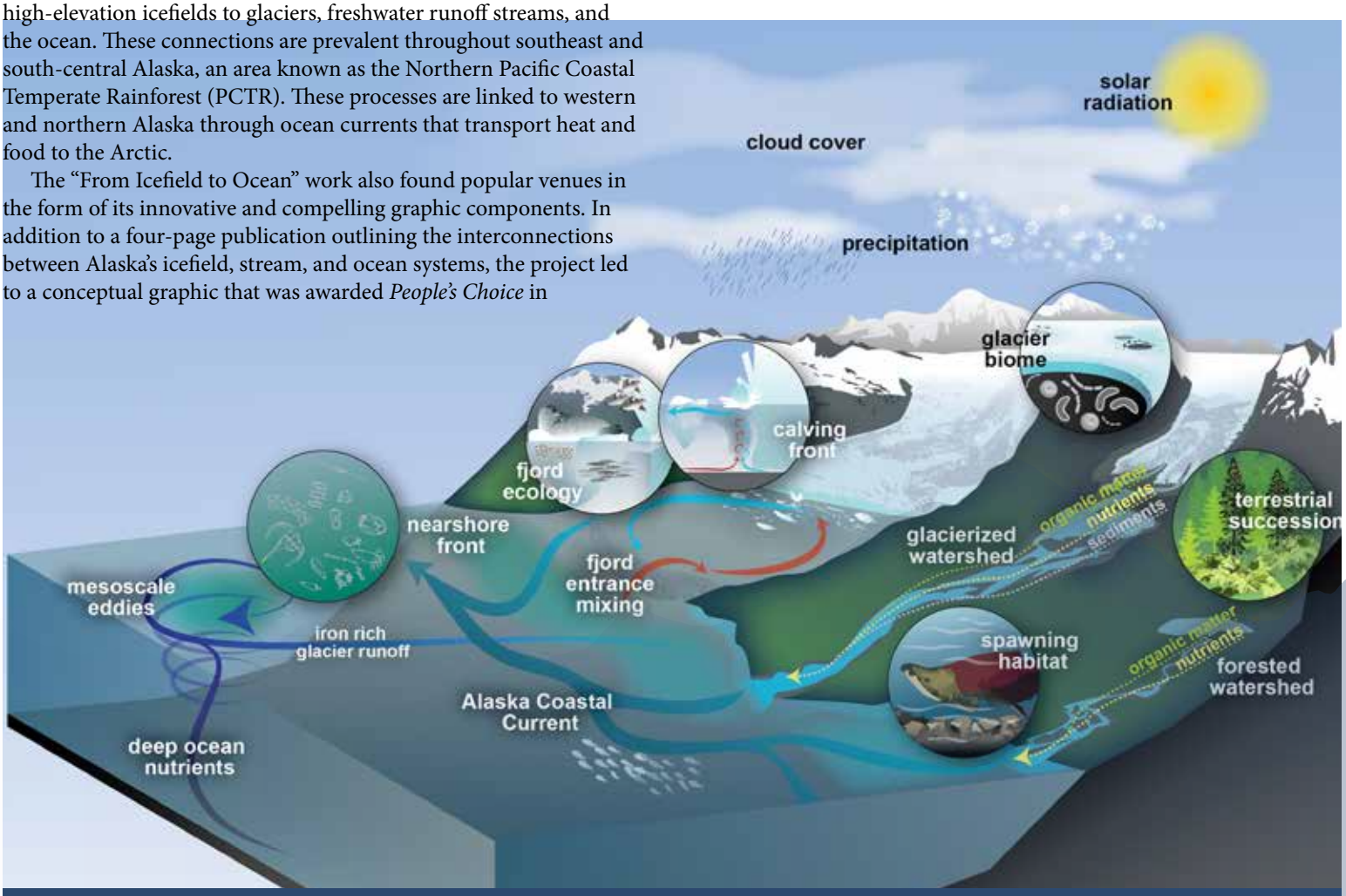
Shad O'Neel (USGS Alaska Science Center) led a team of authors in publishing the synthesis paper *Icefield-to-Ocean Linkages across the Northern Pacific Coastal Temperate Rainforest Ecosystem* in the journal Bioscience. It presents an ecosystem-wide understanding of Alaska glacier systems, including implications of ongoing glacier change for scientists, resource managers, and policy makers in coastal Alaska.

As the paper notes, Alaska and British Columbia glaciers are among the fastest changing glaciers on Earth, and glaciers are central to many natural processes and economic activities in this region. Changes in coastal icefields and glaciers can ripple through the watershed all the way to the ocean.

The paper combines what many scientists currently know about the physical, chemical, and biological connections that link high-elevation icefields to glaciers, freshwater runoff streams, and the ocean. These connections are prevalent throughout southeast and south-central Alaska, an area known as the Northern Pacific Coastal Temperate Rainforest (PCTR). These processes are linked to western and northern Alaska through ocean currents that transport heat and food to the Arctic.

The "From Icefield to Ocean" work also found popular venues in the form of its innovative and compelling graphic components. In addition to a four-page publication outlining the interconnections between Alaska's icefield, stream, and ocean systems, the project led to a conceptual graphic that was awarded *People's Choice* in the 2015 Visualization Challenge (Vizzie) awards sponsored by Popular Science and the National Science Foundation.

Kristin Timm (AK CSC and SNAP) led the team that created the graphic, which also included O'Neel, Eran Hood, and Allison Bidlack (Alaska Coastal Rainforest Center). The figure they developed depicts the important linkages between glaciers and the ocean. The team felt that it was important to find a compelling way to communicate these research findings to Alaskans, as glacial runoff will likely influence the state's marine habitats and ocean currents — and thus its economic activities. Find "From Icefield to Ocean" products at **csc.alaska.edu/resource/icefield-ocean.**



▲ The Icefield to Ocean figure shows important linkages between glaciers and the ocean.

▲ Scott Rupp was one of several AK CSC scientists who presented to national media at the Climate Expo preceding the GLACIER conference.

▲ Eran Hood (fourth from left) was one of several AK CSC scientists who met with John Holdren during his visit to Alaska. *(Photo: L. Craig)*

AK CSC prominent in President Obama's Alaska visit

Government officials, diplomats from around the world, and the President of the United States visited Alaska in late August and early September 2015 to discuss climate change in Alaska and the Arctic. Several AK CSC administrators, scientists, fellows, and research projects were prominent throughout special activities and events held around the state.

AK CSC University Director Scott Rupp and scientists Vladimir Romanovsky and Brad Griffith spoke about their research during the Science Expo — a press conference and networking event preceding the Conference on Global Leadership in the Arctic: Cooperation, Innovation, Engagement and Resilience, or GLACIER, conference. Coordinated by the Alaska Ocean Observing System and chaired by the Hon. Fran Ulmer, Chair of the US Arctic Research Commission, more than 75 people attended. Resulting news stories from major outlets were published in the Alaska Dispatch News and Mashable.

Rupp, along with scientists John Walsh and Vladimir Romanovsky, and AK CSC Fellows Rick Lader, Simon Filhol, and Katia Kontar, met with John Holdren, Director of the White House Office of Science and Technology Policy, in Fairbanks. The participants of the roundtable, including AK CSC fellows, shared information about their AK CSC research. Holdren also visited AK CSC scientist Eran Hood at the University of Alaska Southeast to discuss links between glaciers and ocean systems.

NOAA Administrator Kathryn Sullivan met with AK CSC scientist Uma Bhatt and fellow Peter Bienieck during her visit to the University of Alaska Fairbanks. The meeting included discussions about the partnerships between wildfire management, climate, and weather in Alaska. Director Rupp was also invited by the White House to join a roundtable discussion and to attend President Obama's closing remarks at the conference.

Girls on Ice continues to lead students toward careers and adventures in science

Marking its seventh year of expeditions, Girls on Ice led summer mountaineering courses again in 2015, hosting girls on twelve-day trips to Gulkana Glacier in eastern Alaska and Mount Baker in the North Cascades of Washington.

▲ AK CSC Communications Lead Kristin Timm and UAF PhD student Aurora Roth spent a day with Girls on Ice as guest instructors. They talked about how glaciers are connected to the watershed and how to use storytelling techniques to talk about scientific processes. *(Photo: K. Maisch)*

The program, a unique and free wilderness science education program for high school girls, assembles two teams of nine teenage girls and three instructors to spend twelve days exploring and learning about mountain glaciers and the alpine landscape through scientific field studies with professional glaciologists, ecologists, artists, and mountaineers.

This year, in June and July, participants in Alaska visited Gulkana and its surrounding alpine landscape. There they hiked alpine meadows, witnessed noisy icefall, spotted a caribou herd across the slopes, and traversed snow-covered glacier ice, all under the sunshine of Alaska's long summer days.

And in Washington, the team once again explored the Cascade Mountains' 6000-ft Mount Baker, an active volcano, while learning scientific experimentation skills, wilderness and natural ethics, and basic mountaineering techniques.

As a program, Girls on Ice aims to provide its girls a feeling for the natural processes that create the alpine world and provide an environment that fosters the critical thinking integral to scientific inquiry. "Girls on Ice provides a unique confidence building and experiential learning experience for girls who are interested in science," field instructor Casey Brown says.

Girls are encouraged to observe and think like scientists by making observations and inferences. They develop their own experiments to test ideas and answer questions. "This program also gives early career scientists and artists an opportunity to develop classes and hone their teaching skills," says Brown.

Major CSC research projects receive new funding support

In 2014–2015, the AK CSC added three new climate studies to its growing series of funded projects. Since 2011, AK CSC has been committed to innovative approaches to climate change research in Alaska, including emphasis on cross-disciplinary study and collaboration across academic, government, and tribal organizations. These new projects are the most recent examples of AK CSC's platform of high-level climate science priorities with relevance and practical response to management needs.

▲ In his new AK CSC project, Brad Griffith and his team will study how landscape level changes influence the ranges of caribou and moose. *(Photo: Jay Elhard, Denali National Park)*

Climate change and impacts on large ungulates

A study of climate change impacts on moose and caribou habitats began in April 2015. Led by Brad Griffith, a researcher at the USGS Alaska Cooperative Fish & Wildlife Research Unit and at UAF, this project aims to identify effects of climate change on the amount of food available to moose and caribou throughout most of Alaska and parts of northwest Canada, 1970–2100.

Project personnel will use simulation results from the Integrated Ecosystem Model (IEM), designed to integrate expected effects of climate change on lichen and shrub production, wildfire, and resulting plant community change, together with restrictions to food availability caused by deep snow and ground icing. Since caribou and moose diets during winter differ greatly — caribou feed on snow-covered lichens while moose eat mostly the twigs of deciduous shrubs, above the snow — changing winter climates have complex and even contrasting consequences for these species.

This project also considers how these changes may affect subsistence and sport hunters. Simulation results will be mapped according to land ownership and physical landscape characteristics. These maps will represent a directly usable product for natural resource managers in planning strategies for a changing climate.

▲ In his new AK CSC project, Vladimir Romanovsky and his team will study the impacts of changing permafrost on existing and future infrastructure in the Arctic of northern Alaska. *(Photo: Todd Paris, UAF)*

Permafrost, climate change, and infrastructure

Another new project is led by UAF Geophysical Institute scientist Vladimir Romanovsky, and focuses on the impacts of changing permafrost on existing and future infrastructure in Alaska's Arctic. Using the permafrost component of the IEM, this research is constructing highly detailed representations of climate and infrastructure-induced changes to Arctic permafrost. From these scenarios, researchers will evaluate further feedback impacts from permafrost changes on existing and future ecosystem and infrastructure conditions, producing regional maps for planning and assessment purposes.

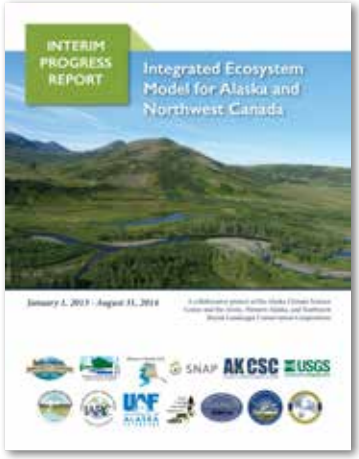
▲ Rupp and D'Amore's new AK CSC project aims to develop a spatially explicit groundwater prediction model for Southeast Alaska. *(Photo: Kristin Timm)*

Modeling rainforest watersheds

A third project seeks to develop a model for watershed behavior in Alaska's rainforests, and is being led by Scott Rupp (Scenarios Network for Alaska and Arctic Planning) and David D'Amore (US Forest Service). This modeling work targets the perhumid coastal temperate rainforest (PCTR) of southeast Alaska. It is based on the priority of water flow in land management planning and assessments, as well as on identification of reduced snowfall and snowpack, earlier spring runoff, increased winter streamflow and flooding, and decreased summer streamflow as potential impacts due to climate change.

The goal is to develop a spatially explicit groundwater prediction model that will focus on forest plant distributions, soil moisture, and snowpack — all of which play important roles in ecosystem planning in the face of climate change. Researchers will use remote sensing, digital elevation models, GIS, and spatial analysis techniques. Outcomes will include a "wetness index" based on extensive soil water measurement records. This index will be used to identify areas of moisture accumulation and water flow networks, features critical to improving and evaluating the IEM.

AK CSC scientists produce report highlighting IEM

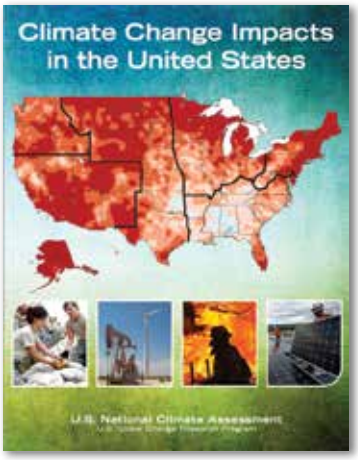


From climate to land cover, soil properties (including permafrost), fire disturbance, treeline and vegetation dynamics, plant productivity, and carbon storage, the Integrated Ecosystem Model (IEM) includes variables essential to the understanding of natural science and natural resources in Alaska and Northwest Canada.

Now, thanks to UAF's David McGuire and his 2015 report, the climate research community has more information about the state of the ongoing IEM project and the data for some of the most important variables in the model.

Produced by McGuire and other members of the IEM team, this report details the progress of the IEM project between January 1, 2013 and August 31, 2014. The review also includes information about new data products developed during this time, and provides updates on the thermokarst disturbance model and models that use IEM outputs to estimate how landscape and ecological change will affect natural resources. Find a copy of the report at csc.alaska.edu/resource/interim-progress-report-IEM.

AK CSC contributes to National Climate Assessment



The Third National Climate Assessment (NCA) summarizes climate change impacts on the U.S., including observed trends and projected future conditions of climate change as well as information on climate change mitigation and adaptation.

The AK CSC provided input and support for the Alaska Region — one of ten regional chapters — as well as the technical report section of the NCA. AK CSC Directors Steve Gray and Scott Rupp authored portions of the technical input, while partner scientists contributed in a variety of ways.

The AK CSC anticipates that its stakeholders will use the 2014 NCA national report and the Alaska regional report as a definitive source of baseline information on observed changes and anticipated trends in climate and ecosystems. The AK CSC looks forward to continuing its involvement in the NCA process, and to incorporating recommendations from the report into our Center's Science Strategy. Find the Third National Climate Assessment at nca2014.globalchange.gov.

Congratulations to AK CSC recent graduates

MSc, Winslow Hansen (Dec 2013)
Pursuing a PhD at the University of Wisconsin.

MSc, Carson Baughman (Dec 2013)
Working at the USGS Alaska Science Center.

PhD, Katrina Bennett (Aug 2014)
Working as a post doctoral fellow at Los Alamos National Laboratory, NM.

MSc, Rick Lader (May 2014)
Pursuing a PhD at the University of Alaska Fairbanks.

MSc, Kristin Timm (Aug 2014)
Working as Science Communications Lead for the Scenarios Network for Alaska and Arctic Planning (SNAP) and the AK CSC.

Featured publications

Bieniek, P., J. W. Walsh, R. L. Thoman, and U. S. Bhatt. 2014. *Using climate divisions to analyze variations and trends in Alaska temperature and precipitation.* J. Climate 27, 2800–2818. http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-13-00342.1 (April 2014)

O'Neel, S., E. Hood, A. Arendt, and L. Sass. 2014. *Assessing streamflow sensitivity to variations in glacier mass balance.* Climatic Change 123(2), 329-341. link.springer.com/article/10.1007%2Fs10584-013-1042-7#page-1 (March 2014)

Gusmeroli, A., G. J. Wolken, A. Arendt. 2014. *Helicopter-borne radar imaging of snow cover on and around glaciers in Alaska.* Annals of Glaciology 55(67): 78-88. doi: 10.3189/2014AoG67A029. ingentaconnect.com/content/igsoc/agl/2014/00000055/00000067/art00010 (July 2014)

Euskirchen, E.S., T.B. Carman, and A.D. McGuire, 2014. *Changes in the structure and function of northern Alaskan ecosystems when considering variable leaf-out times across groupings of species in a dynamic vegetation model.* Global Change Biology. doi: 10.1111/gcb.12392. (January 2014)

Browse all AK CSC publications at csc.alaska.edu/publications

Visit the Alaska Climate Science Center online at **csc.alaska.edu** or **doi.gov/csc/alaska.**

The project described in this publication is supported by Grant/Cooperative Agreement Number GIOAC00588 from the United States Geological Survey. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USGS. Conference icon (page 2) created by Cedric Cummings from the Noun Project. UAF is an affirmative action / equal opportunity employer and educational institution. December 2015